April 2023

EVALUATION OF ADDITIONAL STORAGE IN THE DELAWARE RIVER BASIN

Technical Report No. 2023-2

Prepared by Mott MacDonald in association with GEI Consultants

Managing, Protecting and Improving the Water Resources of the Delaware River Basin since 1961

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

Evaluation of Additional Storage in the Delaware River Basin

Prepared by Mott MacDonald in association with GEI Consultants.

Authorizations and Disclaimers

This work is being conducted in accordance with Article 3 Section 3.6 c and Article 4 Section 4.1 of the Delaware River Basin Compact (PL-87-328, 75 Stat. 688). This specific work was approved in the FY2023-2025 DRBC Water Resources Program.

This report contains information and data that are the result of analyses conducted by the Delaware River Basin Commission (DRBC) staff and its consultants for the purposes set forth in this document. These data and information have been compiled from publicly available sources and interviews with facility owners and operators. No express or implied warranty is made regarding the accuracy or utility of the data for other purposes, nor does the act of distribution constitute any such warranty.

Acknowledgements

All work performed by Mott MacDonald and GEI Consultants was funded by the Commission's Water Supply Storage Fund.

A portion of Commission staff time on this project was funded by the U.S. Fish and Wildlife Service (FWS) through the National Fish and Wildlife Foundation's (NFWF) Delaware Watershed Conservation Fund (DWCF), grant number 75117. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U.S. Government or the National Fish and Wildlife Foundation and its funding sources. Mention of trade names or commercial products does not constitute their endorsement by the U.S. Government, or the National Fish and Wildlife Foundation or its funding sources.

Suggested Citation

DRBC (2023). *Evaluation of Additional Storage in the Delaware River Basin: Technical Report No. 2023-2*. Prepared by Mott MacDonald in association with GEI Consultants. West Trenton, New Jersey. Delaware River Basin Commission.

MOTT MACDONALD

in association with

GEI Consultants

Evaluation of Additional Storage in the Delaware River Basin

Prepared for the Delaware River Basin Commission

Delaware River Basin Commission

DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

April 2023

This page left intentionally blank for pagination.

Cover photo of Prompton Lake. Credit to US Army Corps of Engineers, Philadelphia District

Mott MacDonald
111 Wood Avenue South
Iselin, NJ 08830-4112

United States of America

T +1 (800) 832 3272
mottmac.com

Delaware River Basin
Commision
25 Cosey Road
P.O. Box 7360
West Trenton, NJ 08628-9522

Delaware River Basin Commission

Evaluation of Additional Storage in the Delaware River Basin

April 2023

This page left intentionally blank for pagination.

Contents

Appendices

Appendix A – Storage Project Summaries

NEW DAMS

N1 Red Creek
N2 Milanville
N3 Little Martins Creek
N4 Rattling Run
N5 Equinunk
N6 Hawley
N7 Silver/Big Creek

EXISTING DAMS -- STORAGE INCREASE

E1 Wild Creek
E2 Cannonsville
E3 Blue Marsh
E4 Prompton

EXISTING DAMS – TRANSFERABLE STORAGE

T1 Merrill Creek
T2 Rio
T3 Penn Forest/Wild Creek
T4 Lake Ontelaunee

QUARRIES

Q01 Wadesville Mine Pit
Q02 Glasgow McCoy
Q03 Plymouth Meeting
Q04 Penns Park
Q05 Lehigh Nazareth
Q06 Imperial
Q07D Stockertown (Delaware River option)
Q07B Stockertown (Bushkill Creek option)
Q08 Evansville
Q12 Solebury
Q14 Telford
Q16 Temple
Q19 Rush Valley
Q21 Ormrod
Q22 Whitehall
Q23 Perkiomenville
Q25 Oxford
Q27 NESL Nazareth

DEEP MINES

M05 Silver Creek
M10 Wadesville
M19 Phoenix Park
M20 Otto
M32 Morea Basin

Appendix B Technical Memorandum – Estimate of Cost of Transferable Storage from Existing Reservoirs in the Delaware River Basin

Appendix C Technical Memorandum – Representative Pattern of Monthly Flow in Streams in the Delaware River Basin

Appendix D Summary of Screened-Out Potential Projects

Appendix E Detailed Table of All Potential Project Scores

Appendix F Pumping Station Schematic Drawings and Supporting Data

Appendix G Manufacturer’s brochure for typical pump for quarry discharge

Appendix H Relevant Permit Program Summary

Appendix I One-page Descriptions of Top Ten Recommended Projects

List of Tables and Figures

Acronyms

AACE	American Association of Cost Engineers
ACRNP	Anthracite Coal Region of Northeastern Pennsylvania
AMD	acid mine drainage
AML	abandoned mined lands
BG	billion gallons
cfs	cubic feet per second
CWF	cold water fishes
DNREC	Delaware Department of Natural Resources and Environmental Control
DRBC	Delaware River Basin Commission
EPCAMR	Eastern Pennsylvania Coalition for Abandoned Mine Reclamation
EVW	exceptional value waters
GIS	geographic information system
HQW	high quality waters
MF	migratory fishes
mgd	million gallons per day
MCOG	Merrill Creek Owner's Group
MRWS	maximum reservoir water surface
NDI	National Inventory of Dams
NJDE	New Jersey Department of Environmental Protection
NPDES	National Pollution Discharge Elimination System
NRCS	Natural Resource Conservation Service
NRWS	normal reservoir water surface
NWI	National Wetland Inventory
NYCDEP	New York City Department of Environmental Protection
NYSDEC	New York State Department of Environmental Conservation
PADEP	Pennsylvania Department of Environmental Protection
PASDA	Pennsylvania Spatial Data Access
PDCNR	Pennsylvania Department of Conservation and Natural Resources
PFABC	Pennsylvania Fish and Boat Commission
PMF	probable maximum flood
PMP	probable maximum precipitation
PV	present value
ROW	right of way
SPS	storage project summary
TDS	total dissolved solids
TS	trout stocking
TSS	total suspended solids
USACE	US Army Corps of Engineers
USFWS	US Fish and Wildlife Service
WWF	warm water fishes
7Q10	lowest 7-day average flow that occurs (on average) once every 10 years

Section 1
Executive Summary

1 Executive summary

1.1 Background

In 1961, the United States and the states of Delaware, New Jersey, and New York, and the Commonwealth of Pennsylvania enacted concurrent legislation creating the Delaware River Basin Commission (DRBC or Commission) to manage the water resources of the Basin. The Compact recognized "the water and related resources of the Delaware River Basin as regional assets" and established the Commission as an agency through which these vital shared resources could be jointly managed.

Section 3.6 of the Compact authorizes the Commission to conduct and sponsor research on water resources, their planning, use, conservation, management, development, control and protection, and the capacity, adaptability and best utility of each facility thereof, and collect, compile, correlate, analyze, report and interpret data on water resources and uses in the Basin, including without limitation thereto the relation of water to other resources, industrial water technology, ground water movement, relation between water price and water demand, and general hydrological conditions.

The most comprehensive evaluation of storage options in the Delaware River Basin was performed by the United States Army Corps of Engineers (USACE or "Corps") at the direction of Congress in the late 1950s, through 1961, which culminated in the publication of the Corps' Comprehensive Survey of the Water Resources of the Delaware River Basin (House Document 522) (Revised, May 1961). A number of smaller initiatives by the Delaware River Basin Electric Utilities Group (DRBEUG) evaluated additional storage options in the Basin throughout the early 1970s. The Delaware River Basin Comprehensive Level B Study was published in 1983 and the Commission worked with partners to do a large update to its Comprehensive Plan in 2001.

Since it had been approximately 40 years since a thorough review of storage options was evaluated within the Basin, the Commission deemed the development of a comprehensive updated inventory of potential storage options to be prudent. Subsequently, in late 2019 the Commission initiated a procurement process for engineering services to inventory and evaluate options for additional storage to meet potential water supply and flow management needs in the Basin.

The evaluation of additional storage options is part of a broader project termed "Water Supply Planning for a Sustainable Water Future 2060", which has been approved in annual DRBC Water Resources Programs. This study is likely the most comprehensive, basin-wide evaluation of potential storage options in the DRB since House Document 522.

1.2 Goals and Objectives

The goal of this study was to inventory and evaluate potential projects to provide additional storage to meet potential water supply and flow management needs in the Delaware River Basin. This planning-level study is intended to provide the Commission with a prioritized list of storage projects to further evaluate if the Commission determines that additional storage is necessary. To date, the Commission has not determined that additional storage is necessary.

Specifically, the goals of the project were to identify, characterize and evaluate potential projects to provide additional storage comprising a minimum of 1, 5, 10 or 20 billion gallons. To meet these goals, the effort involved a specific scope of work with discrete objectives in evaluating both previously identified and new storage opportunities. The project team worked collaboratively in an effort to achieve these goals and objectives.

1.3 General Approach and Limitations

In general, the approach involved the following steps

- defining potential water storage categories,
- identifying the universe of potential projects,
- screening out potential projects that would not meet study objectives or have major obstacles to implementation,
- characterizing and cost estimating of remaining potential projects, and
- evaluating relative to specific criteria and scoring/ranking to define those potential projects that are most feasible to meet the project goals.

Certain projects were excluded from consideration in this study by the DRBC, including any dam on the mainstem. These projects are listed in Section 2.4.

Existing databases were used to identify the universe of potential storage projects, which may have excluded some projects. Increasing levels of focused criteria were used to reduce the multitude of potential projects to a manageable subset of high-potential projects for more detailed analysis. The development of the storage project concepts and cost estimates required some preliminary engineering, but a detailed analysis and design would be required to implement any project. The storage project summaries in Appendix A describe each potential storage project, major governing criteria, assumptions, and level of concept development.

Four categories of potential projects were considered:

- construction of new dams/reservoirs,
- two subcategories in existing reservoirs:
  - transfer of control of a certain volume of existing storage in an existing reservoir to DRBC through purchase or lease,
  - increasing storage in an existing reservoir through raising a dam or inlet,
- repurposing quarries, and
- repurposing abandoned mines.

The study involved identifying the universe of potential project and three stages of screening out projects because they did not meet the study goals or were infeasible to implement or to characterize due to insufficient information. The remaining potential projects were evaluated in some detail. The number of potential projects involved in each stage is presented in Table 1.3-1.

Table 1.3-1: Number of Potential Projects Involved at Different Stages in the Study

	Potential Storage Project Category				
Project Stage	**New reservoirs**	**Existing reservoirs**	**Quarries**	**Abandoned mines**	**Total**
Identifying potential projects	22	1,041	1,421	29	2,513
Passing pre-screening	22	34	66	5	127
Passing initial screening	7	16	33	5	61
Passing supplemental screening (evaluated projects)	7	8	18	5	38
Recommended projects	0	2	12	0	14

The study relied on readily available data to screen the potential projects. Primary data sources were the previous studies of locations for new dams provided by DRBC, the National Inventory of Dams, state permit databases on quarries, and Pennsylvania databases on abandoned mined lands and anthracite coal mine permits. Altogether, over 2,500 potential projects were screened, with quarries comprising the bulk.

The first screening stage was prescreening on feasibility to meet study goals, embodied by these criteria:

- Must feed the Delaware River's mainstem above its confluence with the Christina River to suppress the salt line
- New dams/reservoirs must provide >1 BG storage
- Existing dams/reservoirs must provide >2 BG of storage currently
- Quarries must have area of >25 acres and depth >50 feet (giving a minimum volume of approximately 0.5 BG)
- Deep mines must provide >1 BG of storage and should have a surface expression of water

The 127 potential projects that passed the prescreening were then further screened on several criteria related to feasibility and assigned ratings of poor, fair or good. Initial screening criteria are identified in Table 3.1.2-1, and the rubrics used to assign a rating for each criterion are listed in Table 3.1.2-2. The focus was on the number and importance of the "poor" ratings, which would indicate major drawbacks that would make a potential project less feasible. Low-rated potential projects were screened from further study. Higher-rated potential projects (61 in total) passed the initial screening. Twenty-three potential projects were eliminated in a supplemental screen for reasons listed in Appendix D, leaving 38 potential projects which were characterized in detail and evaluated as explained below.

New reservoir potential projects
Twenty sites for new reservoirs were identified in previous reports provided by the DRBC, providing volumes up to 140 BG. Five passed the screening and were fully evaluated:

- Red Creek, Schuylkill Co., PA
- Milanville, Wayne Co., PA
- Little Martins Creek, Northampton Co., PA
- Equinunk, Wayne Co., PA
- Hawley, Wayne Co., PA

In addition, two additional potential projects not previously studied were characterized and evaluated: Rattling Run, Berks Co., PA and Silver Creek/Big Creek, Schuylkill Co., PA.

Existing reservoir potential projects
Thirty-four existing dam/reservoirs passed prescreening, which are mapped in Figure 3.3-1 and listed in Table 3.3-1. Fourteen reservoirs passed the initial screening based on a "good" rating regarding feasibility for a dam raise including five public water utility dams (Green Lane, Lake Ontelaunee, Penn Forest/Wild Creek, Peace Valley, Still Creek), four hydropower dams (Wallenpaupack, Swinging Bridge, Toronto, Rio), three owned by Pennsylvania (Nockamixon, Shohala Marsh and Marsh Creek), and two USACE dams (Blue Marsh and Beltzville). Three additional reservoirs passed based on good feasibility for a transfer of control of some storage (Merrill Creek and the USACE's Prompton and Jadwin flood control dams). Crystal Lake and Jadwin were proposed to pass the initial screening but were eliminated during discussions with DRBC. This gave 16 potential projects that passed the initial screening. In supplemental screening, nine projects were eliminated and NYCDEP's Cannonsville Reservoir was added based on a previous study of adding moveable gates on the spillway to raise the water level. Eight existing reservoir potential projects were characterized and evaluated.

Quarry potential projects
The state quarry databases contained many entries in the Basin above the Christina River: 796 in PA, 351 in NJ, and 274 in NY. The data fields, except location, did not address important criteria for this study, such as area, depth, volume or end date of operation. Accordingly, the location of each entry in the database was examined using satellite photos and topographic data. No quarry was observed in the satellite photos at many locations specified in the databases. If a quarry was identified, its area was delineated, and the depth and volume were approximated when possible. Sixty-six quarries passed the prescreening criteria, as presented in Table 3.4-1 and Figure 3.4-1, with several providing over 5 BG. Thirty-three were rated "good" regarding feasibility and passed the initial screen; supplemental screening reduced this to 18 evaluated potential projects.

Mine pool potential projects
Twenty-nine mine pools were identified (Table 3.5-1), with five passing the prescreen with volumes near or greater than one BG. All five were passed on to the evaluation (Figure 5.5.1-1 and Table 5.5.1-2).

Evaluation criteria
Criteria by which the 38 potential projects were evaluated were developed, as explained in Section 4. There were six primary criteria:

1. Water quantity and quality
2. Infrastructure design, construction, and operation
3. Environmental impacts
4. Social and economic impacts
5. Project costs and schedule
6. Ancillary benefits.

Each primary criterion was refined with subcriteria and a rubric for scoring each subcriterion on a scale of 1 (least preferable) to 5 (most preferable) was developed (Table 4.2-1). For example, under the "water quantity and quality" criteria, volume provided was a subcriterion with the scoring rubric >20 BG=5, >10 BG=4, >5 BG=3, >1 BG=2. Scores on subcriteria were averaged to obtain the score for each primary criterion. Weightings were then developed and applied to the primary criteria (Table 4.2-1) to obtain an overall weighted score between 1 and 5 for each project.

Project characterization
Project characterization (e.g., investigating site details, developing designs) is described in Section 5 for each project category. Project characterization included a "Level 4" cost-estimate, which is appropriate for feasibility studies and with an uncertainty of +50% (AACE, 2005). Capital cost estimates are in 2022 dollars and include construction, and land acquisition. Annual operation costs were also estimated, and added to capital costs assuming 3% annual rate for 30 years to express total cost as present value (PV).

Project Evaluation
Section 6 explains how the 38 potential projects were evaluated according to the criteria. The overall weighted score, the scores on the six primary criteria and various key metrics are summarized in Table 6.1-1, grouped by storage project type. The scores of all 38 potential projects for all primary and subcriteria are presented in a single comprehensive table in Appendix E. All projects were evaluated based on gross volume.

1.4 Summary of Findings

The overall weighted score, the scores on the six primary criteria and key metrics are summarized in Table 6.1-1, grouped by storage project type, and then sorted by overall weighted score.

The potential project characteristics and scores vary widely. For example, storage volume ranges from 1 BG to 42 BG, while estimated costs range about $25M for several of the quarries to about $1B for each of the two new large dams/reservoirs (Milanville and Equinunk). Given the large range in volume and costs, a key metric to compare potential projects is the cost effectiveness, defined herein as cost (M$) per BG, which ranged from $5-$6M/BG for three quarry projects (Q1-Wadesville Mine Pit, Q2-McCoy and Q7-Stockertown Delaware River Source) and the Cannonsville dam raise to over $100M/BG for two new, small reservoirs (Hawley and Rattling Run) and one dam raise (Wild Creek).

The overall weighted scores range from 2.8 to 4.1. Scores are dependent on both the scores for individual subcriteria and the weightings of the six primary criteria. Because there are many subcriteria, a very low (unfavorable) score on one subcriteria has a minor effect on the overall weighted score, even though it could possibly represent a "fatal flaw" (see Table 6.1-1). Therefore, there is uncertainty in the scores on individual criteria and in the effect of these scores on a project's feasibility; further investigation will be required to reduce this uncertainty.

Each of the 38 evaluated potential projects is described in detail in a "Storage Project Summary" (SPS); these are presented in Appendix A. The SPSs are organized to correspond to the primary evaluation criteria. The cost estimate for each potential project is presented in the SPS along with the detailed score sheet with comments explaining the scores. For new reservoirs, the SPSs contain conceptual drawings.

1.5 Recommendations and Conclusions

The project team identified a subset of high-ranking potential projects, 14 out of 38, which are recommended as the most feasible, presented in Table 1.4-1, ranked by overall score. The 14 potential projects are comprised of 12 repurposed quarries and 2 existing reservoirs with increased storage. Cumulatively, these 14 potential projects represent about 50 BG in additional potential storage volume in the Basin. One-page project descriptions for the top ten recommended projects are provided in Appendix I.

Some key findings regarding these 14 projects include the following.

- The Cannonsville dam raise provides the largest volume by far, 13 BG; it is also the most expensive, estimated at $77M.
- Four quarries provide large volumes (Q01, Q02, Q04, Q07-Delaware), ranging from 3.3 to 6.9 BG, although the entire volume is likely not usable.
- Several quarries have estimated costs under $30M.
- Prompton dam modification, which involves raising only the inlet, is the least expensive and most cost-effective project at $2M and $1M/BG, respectively, but provides only 2 BG as envisioned.
- Cannonsville and three quarries (Q01, Q02, Q07) have the next best cost effectiveness of about $6M/BG.

Although the transferable storage projects generally scored high, the project team is reluctant to provide any recommendation on them because owners were unable to commit to a specific volume of storage for transfer and the cost of such storage. As such, the estimates of both are highly uncertain. Volume and cost terms are likely to be revealed only in serious negotiations. The Penn Forest/Wild Creek system of Bethlehem is most promising, with an assumed 3 BG available, but it might be more.

All new reservoirs scored poorly (none ranked above 30), primarily because of their high cost and high environmental and social/economic impacts. Therefore, none are on the recommended list.

The Morea and Otto mine pools scored moderately, but not high enough to make the recommended list. Morea appears most feasible of the mines because contract or shared treatment of withdrawn water may be possible using existing facilities of the adjacent landowner.

Table 1.4-1: Most Feasible Potential Projects, Sorted by Overall Score

Rank	Project Name	Project ID	County/ State	Overall Weighted Score	Volume, BG	Cost, M$	Cost Effectiveness, M$/BG
1	Rush Valley	Q19	Bucks, PA	4.07	1.7	24	14.1
2	McCoy	Q02	Montgomery, PA	4.06	6.2	30	4.9
3	Prompton	E4	Wayne, PA	4.04	2.0	2	1.0
4	Penns Park	Q04	Bucks, PA	4.04	3.3	31	9.5
5	Solebury	Q12	Bucks, PA	4.03	2.3	38	16.3
6	Tilcon Oxford	Q25	Warren, NJ	4.02	1.2	28	23.3
7	Stockertown (Delaware River source)	Q07D	Northampton, PA	4.01	4.6	26	5.7
8	Cannonsville	E2	Delaware, NY	3.99	13.0	77	5.9
9	Whitehall	Q22	Lehigh, PA	3.96	1.2	34	28.0
10	Ormrod	Q21	Lehigh, PA	3.92	1.3	45	34.6
11	Wadesville Mine Pit	Q01	Schuylkill, PA	3.91	6.9	39	4.8
12	Evansville	Q08	Berks, PA	3.91	3.1	44	14.3
13	Perkiomenville	Q23	Montgomery, PA	3.91	1.0	26	26.0
14	NESL Nazareth	Q27	Northampton, PA	3.86	1.0	25	25.0

The project team believes this study meets the project objective to evaluate the feasibility of potential projects to create additional water storage in the Basin. This was achieved through assembling a large list of potential storage projects covering different types throughout the Basin, screening out infeasible projects until a manageable set of potential projects was obtained. The surviving 38 potential projects were evaluated in a level of detail consistent with the objectives, including conceptual design, cost estimates and considering various potential impacts and ancillary benefits. The potential projects were scored with a consistent set of criteria related to feasibility. The potential projects were ranked, with the most feasible projects listed in Table 1.4-1. Caveats regarding the results are presented in Section 7.7

On behalf of the project team, Mott MacDonald expresses our appreciation for the opportunity to provide professional services to support DRBC's goal to define additional storage and satisfy long-term water-supply planning objectives.

Section 2
Introduction

2 Introduction

Water demands in the Delaware River Basin are everchanging. Changes that may be associated with climate change such as precipitation intensity/frequency, temperature increases, and sea level rise will have an impact on water supply in the Basin.

The DRBC has limited storage they can directly manage and the opportunity to further manage storage and supply under approaching drought conditions. Identifying and understanding the feasibility of additional future storage will aid in Basin water resources planning, especially considering the potential for impacts of climate change.

2.1 DRBC and Water Supply

In 1961, President Kennedy and the four Basin state (DE, NJ, NY and PA) governors signed the Delaware River Basin Compact, creating the Delaware River Basin Commission (DRBC), marking the first time in U.S. history that the federal government and a group of states joined together as equal operating partners in a river basin planning, development, and regulatory agency. Through coordinated resource management efforts, substantial improvements have been made in water supply and water quality of the shared Basin waters.

Per the annual report (DRBC, 2021), the Delaware River Basin ("Basin", Figure 2.2-1) drains 13,539 square miles of watershed in four states and contains the main stem river that is 330 miles long. Water supply in the Basin is managed by the DRBC in conjunction with the four Basin states and the federal government. The Basin satisfies the water needs of approximately 13.3 million people (about 4% of the U.S. population) and supplies an average of 6.6 billion gallons a day to a variety of users in the Basin, predominately power, public water, industry, and agriculture. Basin water use also includes significant exports to New York City (up to 800 mgd) and New Jersey (up to 100 mgd). Based on a study by the University of Delaware, the Basin contributes over $21B in economic value to the region.

In order to meet the needs of present and future populations and ensure that ecosystems are protected, the DRBC understands, per the DRBC water supply/planning web page (https://www.nj.gov/drbc/programs/supply/), that:

- Water resources must be properly managed, efficiently utilized and responsibly conserved.
- Water efficiency should always be practiced.
- Reducing water use not only provides significant economic and environmental benefits but can help avoid or delay the imposition of drought declarations.

The DRBC employs a comprehensive water conservation program, which has become an integral component of its broader strategy to manage water supplies and plan for future water needs throughout the Basin. Key components of DRBC's water supply planning and water conservation programs include the following:

- Basin Water Use – The agency performs key sector trend analyses (e.g., public water supply, power generation, industry) to ensure that there is enough water to meet current and future demand, as well as during extreme conditions (e.g., drought).

- Water Conservation Program - Over the years, the DRBC has passed numerous resolutions focused on water efficiency. This includes a Water Audit Program, which requires water purveyors to identify and control water loss in their systems.
- Water Storage – DRBC owns and maintains storage in two U.S. Army Corps reservoirs in Pennsylvania (Beltzville and Blue Marsh). The agency is also involved in management of Basin storage owned by others and actively seeks to optimize and/or expand storage in the Basin.
- Water Supply Charges Program - DRBC charges certain entities for water they use to help support water supply storage in the Basin.

2.2 Available Storage and Need

The Delaware River and its tributaries provide water for many different purposes, including drinking and industrial water supply, power generation, irrigation, water quality maintenance, in-stream flow needs for aquatic life, fishing, boating, and recreation. DRBC's water supply and flow management programs work to balance supply/storage with water use demands for these competing purposes during normal conditions and in times of drought. Because there is no dam on the mainstem Delaware River, the reservoirs on its tributaries provide storage for the variety of purposes mentioned above as well as for flood mitigation. In fact, many of the reservoirs in the Basin are designed for multiple purposes.

Section 3.6 (a) of the Delaware River Basin Compact authorizes the Commission to:

Plan, design, acquire, construct, reconstruct, complete, own, improve, extend, develop, operate, and maintain any and all projects, facilities, properties, activities and services, determined by the commission to be necessary, convenient or useful for the purposes of this compact.

In terms of water management, water is stored in reservoirs and can be released during dry periods to augment streamflow levels and/or help repel salinity in the Delaware Estuary to protect drinking water supplies. DRBC's Drought Operating Plans are based upon available storage in several Basin reservoirs and DRBC works closely with multiple stakeholders on flow management in the Basin.

Reservoirs in the Delaware River Basin are all located on tributaries and play a key role in flow management. The map (Figure 2.2-1) shows the locations of major reservoirs in the Delaware River Basin.

Figure 2.2-1: Delaware River Basin and Major Reservoirs (source: DRBC)

Major Basin Reservoirs: New York City

The New York City Delaware River Basin reservoirs are Cannonsville, Pepacton, and Neversink. These reservoirs, owned/operated by New York City, are in the Basin's headwaters in New York State. Through the Delaware River Master (a USGS position), releases from these reservoirs are made to meet the Montague, N.J. flow target of 1,750 cfs. Storage levels in these reservoirs drive the DRBC's Basin-wide drought management plan.

Major Basin Reservoirs: U.S. Army Corps

The reservoirs/dams owned by the U.S. Army Corps of Engineers (USACE) are F. E. Walter Reservoir, Blue Marsh Reservoir, Beltzville Reservoir, Prompton Lake, and Jadwin Dam. DRBC owns water supply storage in two Army Corps reservoirs, Beltzville and Blue Marsh, which are in the Lehigh and Schuylkill sub-basins respectively; this storage is primarily utilized to meet the Trenton, N.J. flow target of 3,000 cfs. Storage levels in these reservoirs drive the DRBC’s lower Basin drought operating plan.

Other Major Basin Reservoirs

Merrill Creek Reservoir, in NJ, was built by a consortium of power companies to provide water releases to make up for their consumptive use. Storage in the Marsh Creek Reservoir, in PA, is used to support in-stream flow management in Brandywine Creek. In times of drought emergency, DRBC can call for an additional water release for flow augmentation from several other Basin reservoirs: Mongaup System in NY, Lake Wallenpaupack in PA, F.E. Walter Reservoir in PA, and Lake Nockamixon in PA.

2.3 Goals and Objectives

The goal of this study was to inventory and evaluate potential storage projects to provide additional storage to meet potential water supply and flow management needs in the Delaware River Basin. Specifically, the goals of the project were to identify, characterize and evaluate potential projects to provide additional storage comprising a minimum of 1, 5, 10 or 20 billion gallons. This planning-level study is intended to provide the Commission with a prioritized list of storage projects to further evaluate if the Commission determines that additional storage is necessary, which, to date, the Commission has not so determined.

2.4 Projects Disconsidered by the Request for Proposals

The Commission’s RFP excluded the following projects from consideration in this study:

- Tocks Island Reservoir or any other main stem Delaware River dam.
- Maiden Creek Reservoir (Maiden Creek upstream of Lake Ontelaunee, Berks County).
- Trexler Reservoir (Jordan Creek, Lehigh County).
- Hawk Mountain (East Branch Delaware River below Pepacton).
- F.E. Walter Reservoir in the Lehigh River Basin because there are ongoing studies by the Commission and other partners.

- Optimization of existing storage volumes in the New York City Reservoirs in the Delaware River Basin or the calculation, or re-calculation, of the Excess Release Quantity (ERQ) as defined in the 2017 Flexible Flow Management Plan. Evaluation of flow management requirements, diversions and releases under the US Supreme Court Decree of 1954 and subsequent jurisdiction was not the subject of this study, being considered by others. (However, increasing storage of these reservoirs was considered).

2.5 Potential Projects Considered

The original study scope included several storage project categories or types:

- construction of new reservoirs;
- two subcategories in existing reservoirs:
  - transfer of control of a certain volume of existing storage in an existing reservoir to DRBC through purchase or lease;
  - increasing storage in existing reservoirs through raising dam or inlet crest;
- repurposing quarries;
- repurposing abandoned mines;
- aquifer storage/recovery (ASR);
- dredging to increase storage volume;
- tunnels.

After initial research and discussion, ASR, tunnels and dredging were eliminated. ASR is a proven technology and can provide some significant storage. However, the location in the Basin where conditions are most conducive to ASR (i.e., the Coastal Plain) is not advantageous regarding storage for water supply and flow augmentation. Furthermore, water delivery at the rates needed to meet the goals of this study would be difficult to obtain using ASR. Tunnels are also a proven storage option but can be prohibitively expensive, and also offer water delivery challenges in this application. Dredging reservoirs can be appropriate in certain situations but does not deliver significant increases in volume and can present environmental challenges.

Thus, the identification, screening and characterization focused on four major categories:

- constructing new reservoirs;
- transferring control of existing storage or increasing storage through raising dam or inlet crest in existing reservoirs;
- repurposing quarries;
- repurposing subsurface pools in abandoned mines.

Potential projects in these four categories were identified and screened for feasibility, as will be described in Section 3. The 38 potential projects that passed the screen were more fully characterized, evaluated and ranked as described in Sections 5, 6 and 7.

2.6 Project Screening, Development, Scoring and Ranking

The research, data development and initial screening included over 2,500 potential projects in the four storage categories. The screening process, described in Section 3, reduced the number of potential projects in two stages based on high-level screening criteria. As noted, this was required to reduce the dataset to a manageable level and allow for detailed characterization of each project and later scoring/ranking. The project characterization stage required collection of the more detailed data necessary to support later evaluation. Data collection varied among the four categories and in some cases varied between potential projects within a category, depending on data availability and facility owner cooperation.

Specifically, the data gathering focused on data needed for characterizing the storage and control elements. Collected data enabled development of storage projects, such that infrastructure requirements and related construction/operation issues could be identified. This and related project information was sought to provide specific data suitable for comparing the projects to project scoring criteria. Uniformly developed potential projects that were consistently scored allowed the various project types to be compared and ranked.

2.7 Organization of Report

This report is organized into 10 sections and attached appendices. The individual sections are listed and briefly described below.

- Section 1 Executive Summary – Concise overview and summary of findings.
- Section 2 Introduction – Description of major project elements.
- Section 3 Identification and Screening of Potential Storage Projects – Identification of potential projects and screening out infeasible ones.
- Section 4 Evaluation Criteria – Description of criteria used and application.
- Section 5 Project Characterization – Details of the characterization process and summaries of storage projects.
- Section 6 Project Evaluation – Comparison of characterized storage projects and the scoring of the projects.
- Section 7 Recommendations – Ranking of the scored storage projects and combinations or variants to meet the project goals, as well as recommendations.
- Section 8 Conclusion – Brief conclusion.
- Section 9 Acknowledgements - Credit to major project contributors.
- Section 10 References - Major sources of information.
- Appendices – Supporting details, including the individual Storage Project Summaries (SPSs) for the developed storage projects and other supporting information.

In reviewing the report, the following key points should be considered:

1. Storage project details are provided in the respective Storage Project Summary (SPS) located in Appendix A. Key parameters of the SPS are brought forward and summarized in the body of the report.
2. The report presents potential storage projects grouped in the four main categories (new reservoirs, existing reservoirs, quarries and mines). This is to allow ease in comparison within the category as well as to explain elements that are common among storage types in a category (i.e., pumping systems common to all quarries), as opposed to repeating that information in the SPSs.
3. Descriptions of the particular storage project in the SPS and in the body of the report are consistent with the review criteria to aid comparable scoring among the various storage projects.

4. While potential projects are presented in categories, the approach and report are organized to compare, score and rank all storage projects consistently.
5. Finally, as related to scoring and ranking projects, efforts were made to objectively score and rank projects based on criteria. Because of the limits of specific data available for this level of study, some scoring may be partially subjective and based on professional judgement. Scoring and ranking rationale are documented.

Section 3
Identification and Screening of Potential Storage Projects

3 Identification and Screening of Potential Storage Projects

Screening of available datasets allowed for logical and defensible elimination of potential projects based on high-level criteria. Reducing the number of potential projects to a practical dataset size enabled more efficient project characterization.

3.1 General Approach

Potential storage projects were identified in each of the four categories. Screening occurred in three stages: prescreen, initial screen and supplemental screen. The number of potential projects involved in each stage is presented in Table 3.1-1. The projects that passed the prescreen but were screened before evaluation are listed in Appendix D, including a brief reason for screening.

The screening approach used online public-domain databases and data management approaches to filter available data. Data was exported from the databases into ArcGIS Online, shareable geographical information systems (GIS) software for data comparison and filtering. Google Earth and other common tools were used to augment the data analysis. In general, the large number potential storage projects contained in many data sets were filtered through key high-level screening criteria to quickly eliminate projects. The approach varied slightly among the four storage categories based on their unique and different properties. The below sections further elaborate on the data review and the screening of the categories.

Table 3.1-1: Number of Potential Projects Involved at Different Stages in the Project

	Project Category				
Project Stage	New reservoirs	Existing reservoirs	Quarries	Abandoned mines	Total
Identifying Potential projects	22	1,041	1,421	29	2,513
Passing pre-screening	22	34	66	5	127
Passing initial screening	7	16	33	5	61
Passing supplemental screening (evaluated projects)	7	8	18	5	38
Recommended storage projects	0	2	12	0	14

3.1.1 Data Collection

Data collection regarding potential new dam/reservoirs included reports as listed below, dating back to the 1960s, involving twenty previously studied reservoir sites. Characteristics such as location, maximum proposed storage, pool elevation and pool area were extracted from the reports when available, but the amount of detail varied considerably by site. The location of each dam/reservoir was plotted in GIS or estimated when necessary. The Request for Proposal (RFP) issued by the DRBC specifically excluded several projects from consideration: Tocks Island, Maiden Creek, Trexler, and Hawk Mountain. Table 3.1.1-1 lists the initial reports that were reviewed related to the previously studied projects for new dams/reservoirs. Twenty projects were identified as explained below.

Table 3.1.1-1: New Dam/Reservoir Studies

A.	Initial Comprehensive Plan	
	a.	House Document (HD) 522: prepared in 1961 by US Army Corps of Engineers and published by the US House of Representatives in 1962. (Seminal document setting the stage for identification of potential reservoir storage locations.)
	b.	DRBC Comprehensive Plan 1962, follows HD 522
B.	Water Resources Programs 1965-1976	
	a.	Resolutions 64-15, 65-4, etc.
	b.	A-List and B-List Projects
C.	DRB Electric Utilities Group (DRBEUG) Studies: 1972, 1975, 1976	
D.	Subsequent studies	
	a.	1975 URS study of Tocks Island and Alternatives
	b.	1983 Level B study
	c.	2001 Comprehensive Plan
	d.	2008 USACE Multijurisdictional study
E.	2009 DRBC Staff reservoir evaluation	

Regarding newly identified sites for reservoirs, the large study area precluded a comprehensive investigation of all possible sites for new reservoirs, especially because off-line reservoirs (i.e., pumped in from a nearby source) were also of interest. Therefore, only projects that were already known as high potential (but not necessarily studied) were considered for further evaluation. DRBC requested two newly identified new-reservoir sites be evaluated: Rattling Run near Port Clinton, PA and Silver Lake near New Philadelphia, PA.

Regarding existing dams/reservoirs, the primary data source was the National Inventory of Dams, which is maintained by the US Army Corps of Engineers. The database is comprehensive (all dams impounding more than 50 acre-feet) and records many important parameters useful to this evaluation, foremost including coordinates, river name, owner, purpose (water supply, flood control, hydropower, recreation, habitat), drainage area, maximum volume, pool elevation and pool area. The Inventory listed 1,041 dams within the Basin: 501 in PA, 335 in NJ, 199 in NY, 6 in DE.

For quarries, state databases were initially used (web links provided):

- PA Industrial Mineral Mining Operations
- NJ Quarries (Sand and Gravel)
- NY Mining Database

While the databases had many entries (over 1400 in the Basin with about 800 in Pennsylvania), the data fields (except location) did not address important criteria for this study such as volume. Furthermore, no quarry was observed on satellite photos at many locations listed in the databases.

For deep mines, only the coal mines in the Anthracite Coal Region of Northeastern Pennsylvania (ACRNP) are geographically relevant. Most of this region falls outside of the Basin and into the Susquehanna River Basin. GIS data on abandoned and operating mines were downloaded from the Pennsylvania Spatial Data Access site:

- Abandoned Mine Land Inventory
- Anthracite Coal Mine Permits

The layers showed only the footprint of mines. Details on void depth and volume were not available. Additional reports listed in Table 3.1.1-2 were referenced to estimate these important parameters.

Table 3.1.1-2: Key Reviewed Mine Pool Documents

Source	Title	Primary Author	Description
USBM TP#727-1949	Water Pools in Pennsylvania Anthracite Mines	S. H. Ash, et.al.	Signature study that compiled available mining data and estimated mine pool volumes based on then current water level information.
USGS SIR 2010-5261	Water Budgets and Groundwater Volumes for Abandoned Underground Mines in the Western Middle Anthracite Coalfield	D. J. Goode, et al.	Estimates of water budgets and groundwater volumes stored in abandoned underground mines in the Western Middle Anthracite Coalfield
USGS WRI Report 95-4243	Water Quality of Large Discharges from Mines in the Anthracite Region of Eastern Pennsylvania	Charles R. Wood, et.al.	Compilation of key water quality information in many of the major mine pools in the four anthracite regions.
EPCAMR	Mine Water Resources of the Anthracite Coal Fields of Eastern Pennsylvania	R.E. Hughes, et.al.	This document draws from prior mining information and initial mine pool estimates and uses current data mapping technology to update mine water resources estimates and opportunities.

3.1.2 Prescreening

Each identified potential project was prescreened based on its ability to meet essential criteria listed in Table 3.1.2-1. The number of projects in each category that passed prescreening is presented in Table 3.1-1. They included all 20 previously identified projects for new reservoirs, 2 new sites for new reservoirs, 34 existing reservoirs, 66 quarries and 5 deep mine pools, which will be discussed below.

Table 3.1.2-1: Prescreening Criteria

Must feed the Delaware River's mainstem above its confluence with the Christina River (near Wilmington, DE) to suppress the salt line
New reservoirs must provide >1 BG storage
Existing reservoirs must provide >2 BG of storage currently
Quarries must have area of >25 acres and depth >50 feet (giving a minimum volume of approximately 0.5 BG)
Deep mines must provide >1 BG of storage and should have a surface expression of water

3.1.3 Initial screening -- methods

Potential projects passing the prescreening went through an initial screen based on several criteria and were assigned a rating level for each criterion based on the feasibility of the potential storage project, namely poor (1), fair (2) or good (3). Initial screening criteria are identified in Table 3.1.3-1 and the rubrics used to assign a rating level for each criterion are listed in Table 3.1.3-2. Given limited data availability for some criteria, the rating level's delineation was often subjective or relative to other projects, as explained below. Criteria were qualitatively weighted in relative importance as shown in Table 3.1.3-1 below. The individual criteria were integrated based on professional judgement to provide an overall feasibility rating for each project on the same three-level scale. The focus was on the number and importance of the "poor" ratings, which indicate that a project is undesirable or infeasible. Potential projects were ranked within each category by their overall feasibility rating level. Low-rated projects were screened from further study because of their poor feasibility. Higher-rated projects were carried to be investigated further.

Table 3.1.3-1: Initial Screening Criteria

Criteria	Relative Importance (high, med., low)	Rationale
Volume of storage	high	More volume provides greater and/or longer (in time) flow augmentation
Sufficiency of water supply	high	Reliable and sufficient supply is desirable for filling/refilling storage
Environmental resource impact	high	Inundation of high-value resources (e.g., presence or habitat for endangered species, trout streams, wetlands) is undesirable
Infrastructure and social impact	high	Inundation of roads, pipelines, electrical lines, buildings or recreational/cultural facilities is undesirable
Position in Basin	med	High in the Basin benefits more stream miles
Owner cooperativeness	med	Certain reservoir owners are not likely to support certain projects, or obtaining approval may be very cumbersome
Water retention	med	Applicable to quarries only --- leaky is undesirable
Proximity to mainstem	low	Close to the mainstem delivers water quicker when needed; the reason importance is low is that travel time from all points to the mainstem is only a few days

Table 3.1.3-2: Rubrics for Rating Each Initial Screening Criterion

Criteria	Reservoirs	Quarries	Deep Mines
Volume of storage	existing/estimated new storage >10 BG = 3 >5 BG = 2 <5 BG = 1	estimated storage volume >2 BG = 3 >1 BG = 2 <1 BG = 1 water filled = 2	All 3; > 2 BG
Sufficiency of water supply	based on drainage area: >100 sq. mi. = 3 > 20 = 2 < 20 = 1	distance to DRBC-mapped stream <1 mi = 3 < 2 mi = 2 > 2 mi = 1	All assumed 3
Environmental resource impact	relative area/length of wetlands/high-quality streams inundated low =3 medium = 2 high = 1	all 3 (low impact)	
Infrastructure and social impact	relative number of buildings and length and importance of roads inundated low =3 medium = 2 high = 1	surrounding land use completely rural = 3 mostly rural = 2 suburban/urban = 1	all 3 (low impact)
Position in Basin	Enters mainstem above Trenton = 3 Schuylkill to Trenton = 2 Below Schuylkill = 1		All 2 (in upper Schuylkill)
Owner cooperativeness	Dam raise water or power = 3 NYC/USACE/state = 2 private = 1 Operational change power co. = 3 USACE/state = 2 water utilities/ private = 1	all 2	all 2
Water retention	Not applicable	Ponded area >5 ac = 3 >2 ac = 2 <2 ac = 1	Not applicable
Proximity to mainstem	< 10 stream miles = 3 < 50 stream miles = 2 > 50 stream miles = 1		All Schuylkill

3.2 Initial Screening Results – New Reservoirs

The twenty previously studied projects found in historical reports are shown in Table 3.2-1. Sixteen of the sites were in PA, three in NJ and one in DE. All reservoirs would provide large volumes, ranging from 5 BG to 140 BG.

Table 3.2-1: Previously Studied Sties for New Dams/Reservoirs (20 total)

Project Name	**2009 DRBC Internal**	**2008 Enhancing Water Resources**	**2001 Comprehensive**	**1981 Level B Study**	**1976 Study for a Water Supply Reservoir**	**1975 Alternative Water Supply Reservoirs**	**State**	**New Capacity (BG)**
Aquashicola	•			•			PA	8
Blacks Creek					•	•	NJ	7
Cherry Creek				•	•		PA	140
Equinunk				•	•	•	PA	43
Evansburg	•	•					PA	8
Flat Brook				•			NJ	81
French Creek	•	•					PA	8
Girard				•			PA	14
Hackettstown				•			NJ	10
Hawley				•			PA	19
Icedale				•			PA	5
Irish Creek					•	•	PA	23
Little Martins Creek				•	•	•	PA	29
McMichael				•			PA	15
Milanville				•	•	•	PA	43
Mill Creek				•	•	•	PA	21
Newark				•			DE	10
Pidcock Creek				•			PA	49
Red Creek				•	•	•	PA	26
Tobyhanna				•			PA	28

The ratings for each initial screening criterion and overall ratings are shown in Table 3.2-2. The projects and their overall ratings are mapped in Figure 3.2-1. Given likely impacts from any large reservoir, no project received the highest (i.e., good or 3) overall rating, but five projects received overall ratings of fair (2). These five projects were passed through to the next screening phase.

Two of these potential projects have small drainage areas (Little Martin's Creek and Red Creek at 6.8 and 5.3 square miles, respectively) so promptly filling/refilling the reservoir could be a significant problem. However, both are adjacent to larger streams, so the reservoirs could conceivably be fed by pumping.

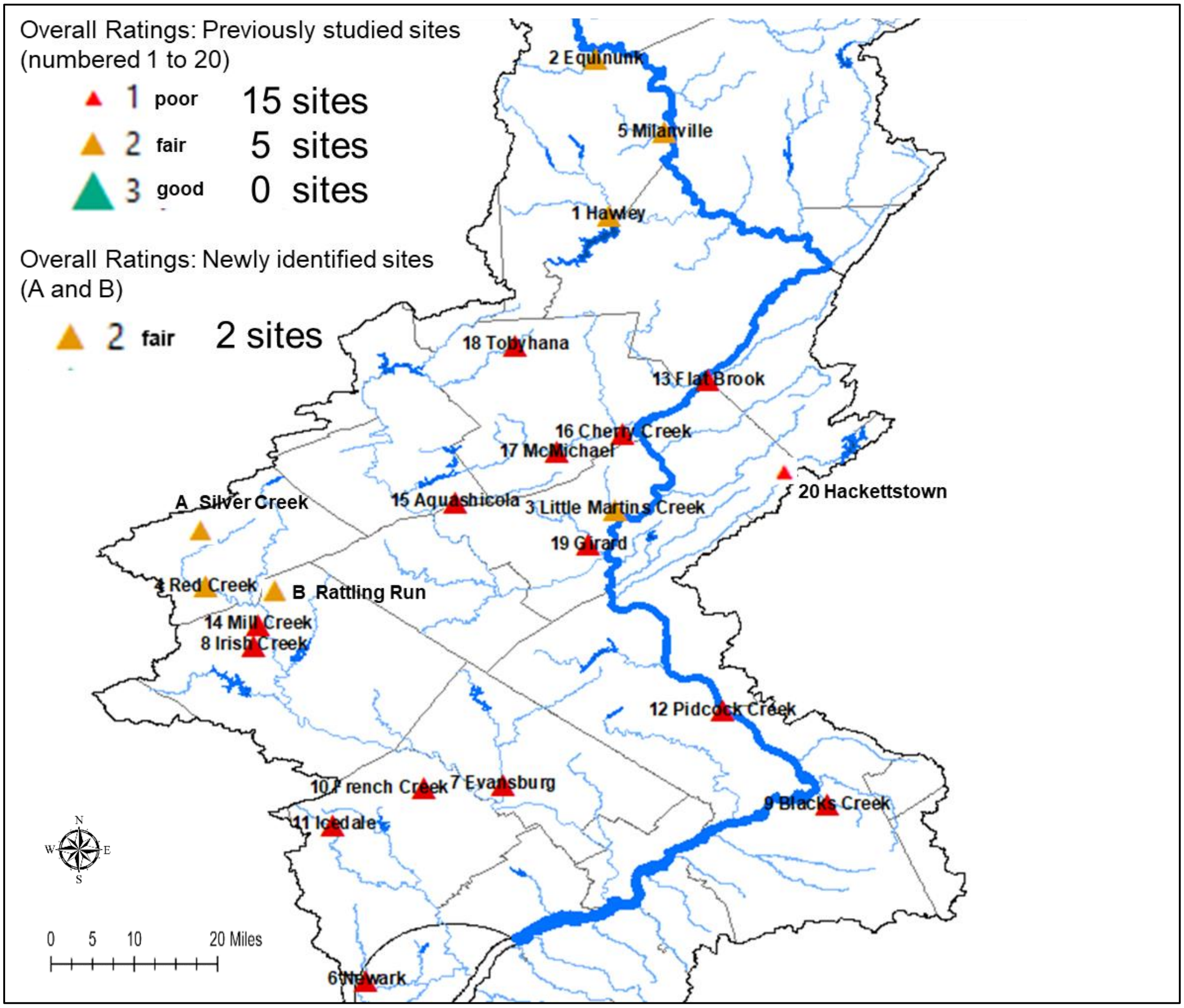
The other fifteen projects were rated low (poor or 1), usually due to impacts to infrastructure or to preserved areas as indicated in the rating and comments in Table 3.2-2. These projects were not evaluated further.

The two newly identified new-reservoir projects mentioned above (Rattling Run and Silver Lake) are also presented in Table 3.2-2 and Figure 3.2-1. Both have very small drainage areas so they rated poor regarding supply sufficiency, but both could conceivably be filled by pumping. Other disadvantages include, for the former, impacting a Class A stream and, for the latter, a large distance from the Delaware River. The five previously studied projects that were rated fair plus the two new projects were advanced to the next stage.

Table 3.2-2: Screening Ratings for Previously Studied and Newly Identified New Reservoirs

											Rating (1= poor, 2=fair, 3=good, NR = not rated)										
Map key	**Project Name**	**State**	**County**	**Sub watershed**	**Stream**	**New Capacity, BG**	**Pool Elevation, ft**	**Dam volume, Mcy**	**Flooded Area, ac**	**Drainage Area, sq mi**	**Road Flooding**	**Building Flooding**	**Utility Conflicts**	**Recreational**	**Wetland Impacts**	**Stream Impacts**	**Position in Basin**	**Distance from Del. River**	**Supply Sufficiency**	**Overall Rating**	**Comments**
1	Hawley	PA	Wayne	Lackawaxen	Middle/Wangum Creek	5	1040		394	82.6	3	3	3	2	1	2	3	2	2	2	Exact location and elevation not identified; heavily forested, very few residential properties.
2	Equinunk (large)	PA	Wayne	Upper DR	Equinunk Creek	42	1160	11.8	1358	56.9	3	3	2	2	3	2	3	3	2	2	Mostly forested. Floods several residential properties.
3	L. Martins Creek	PA	Northampton	Middle DR	Little Martins Creek	7.1	500	7.6	400	6.8	3	2	3	2	2	2	3	3	1	2	Mostly farmland with some forest. Flood several rural residential properties. Very Small drainage area but could be augmented by pumping from Martins Creek.
4	Red Creek	PA	Schuylkill	Schuylkill	Red Creek	26	693	6.5	1282	5.3	3	2	3	3	2	2	2	1	1	2	Mostly farmland. Floods a few residential properties and the road serving them. Very small drainage area; possible pump-in from Schuylkill.
5	Milanville	PA	Wayne	Lackawaxen	Calkins Creek	43	995	10.4	1979	43.7	2	2	2	2	3	2	3	3	2	2	Power line conflict. Floods several residential properties and local roads. Mostly forested with some farmland.
6	Newark	DE	New Castle	Brandywine	White Clay Creek	10	156		1060		3	3	3	1	1	2	1	2	NR	1	Floods White Clay Creek State Park.
7	Evansburg	PA	Montgomery	Schuylkill	Skippack Creek	8	166		1120		2	3	2	1	1	2	2	2	NR	1	Floods Evansburg State Park.
8	Irish Creek	PA	Berks	Schuylkill	Schuylkill River	23	420				2	1	2	1	2	2	2	1	NR	1	Floods several housing subdivisions.
9	Blacks Creek	NJ	Burlington	Crosswicks	Blacks Creek	7	70		1790		2	1	2	2	1	2	2	3	NR	1	Major commercial facility would be flooded.
10	French Creek	PA	Berks	Schuylkill	French Creek	8	289		1250		1	1	2	2	2	2	2	2	NR	1	Floods dozens of residential properties. French Creek is a PA scenic river here.
11	Icedale	PA	Chester	Brandywine	W. Br. Brandywine	5					2	2	2	2	1	2	1	2	NR	1	Low in Basin. Pool elevation not identified but could have major infrastructure impacts.
12	Pidcock Creek	PA	Bucks	Middle DR	Pidcock Creek	49			4160			1	3	1	1	2	3	3	NR	1	Could flood Washington Crossing State Park and Bowman's Hill.
13	Flat Brook	NJ	Sussex	Middle DR	Flat Brook	81			2940		2	1	3	1	1	1	3	3	NR	1	Would flood trout stream and protected land within the Delaware Water Gap National Recreation Area.
14	Mill Creek	PA	Bucks	Schuylkill	Mill Creek	21	470		1810		1	1	2	3	1	2	2	1	NR	1	Mostly farmland but would flood dozens of residential properties.
15	Aquashicola	PA	Carbon	Lehigh	Aquashicola Creek	8	503		1230		1	1	1	2	2	2	3	2	NR	1	Floods about 20 buildings in Little Gap, PA and Blue Mountain Ski Resort.
16	Cherry Creek	PA	Monroe	Middle DR	Cherry Creek	140	590		3750		1	1	1	2	1	2	3	3	NR	1	Per 1976 report, "Cherry Creek appears to have very serious environmental problems…It is recommended that Cherry Creek be dropped from consideration." Would flood dozens of residential properties
17	McMichael	PA	Monroe	Middle DR	McMichael Creek	15	?		?		1	1	1	2	1	2	3	3	NR	1	Flood several rural residential properties and a highway.
18	Tobyhanna	PA	Monroe	Lehigh	Tobyhanna Creek	28	?		?		1	1	1	2	2	2	3	1	NR	1	Flat area. Will flood much infrastructure. Upstream of FE Walter Dam.
19	Girard	PA	Northampton	Middle DR	Bushkill Creek	14	?		?		1	1	1	NR	NR	2	3	3	NR	1	Highly developed.
20	Hackettstown	NJ	Warren	Musconetcong	Musconetcong River	10	?		?		NR	NR	NR	NR	NR	1	NR	NR	NR	1	Several dams have been/will be removed on Musconetcong River; installing new dam not feasible.
Newly identified projects																					
A	Rattling Run	PA	Berks	Schuylkill River	Rattling Run	1.0	700		209	4.2	3	3	3	3	2	1	2	1	1	2	Rattling Run is a Class A Stream; small drainage area but possible pumping from Schuylkill.
B	Silver Creek/Big Creek	PA	Schuylkill	Schuylkill River	Silver Creek	11	1540		270		3	3	3	3	3	3	2	1	1	2	Small drainage area. Possible pumping from or combining with Big Creek impoundment.

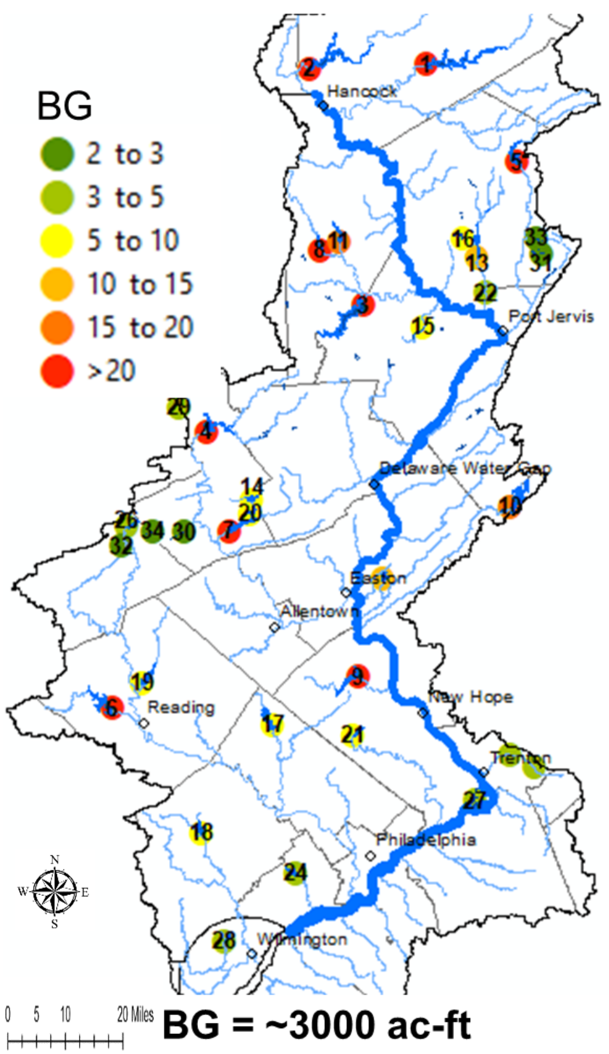
Figure 3.2-1: Locations and Overall Ratings for Potential New Reservoirs



3.3 Initial Screening Results – Existing Reservoirs

According to the National Inventory of Dams, there are 34 dams/reservoirs providing a maximum of >2 BG of storage in the Basin, which are mapped and listed in Figure 3.3-1. Maximum storage may be significantly greater than active storage as, for example, in Blue Marsh (42 BG vs 15.1 BG) and Prompton (24 BG vs. 17.8 BG).

Figure 3.3-1: Existing Reservoirs Providing a Maximum of more than 2 Billion Gallons



Ranked by volume

Map ID	Name	Max storage, BG
1	PEPACTON	199
2	CANNONSVILLE	142
3	WALLENPAUPACK	88
4	FE WALTER	52
5	NEVERSINK	46
6	BLUE MARSH	42
7	BELTZVILLE	34
8	PROMPTON	24
9	NOCKAMIXON	23
10	HOPATCONG	16
11	MERRILL CREEK	15
12	JADWIN	15
13	SWINGING BRIDGE	12
14	PENN FOREST	9
15	SHOHOLA MARSH	9
16	TORONTO	8
17	GREEN LANE	8
18	MARSH CREEK	8
19	LAKE ONTELAUNEE	7
20	WILD CREEK	6
21	PEACE VALLEY (GALENA)	6
22	RIO	5
23	LAKE MERCER	5
24	GEIST (SPRINGTON)	4
25	ASSUNPINK LAKE	4
26	STILL CREEK	4
27	VAN SCIVER LAKE	4
28	HOOPES	4
29	CRYSTAL LAKE	3
30	MAUCH CHUNK	3
31	YANKEE LAKE	2
32	LOCUST CREEK (TUSCARORA)	2
33	WANAKSINK (LORDS)	2
34	LAKE HAUTO	2

The ratings are presented in Table 3.3-1 and Figure 3.3-2. Each potential storage project received a separate overall rating for a dam raise and for any operational change, the latter including transfer of control of existing storage through purchase/lease and conversion of a flood-control-only reservoir to a reservoir with a larger permanent storage (i.e., Jadwin and Prompton). The more feasible projects are presented in Figure 3.3-3 (i.e., rated good for either dam raise or operational change).

Fourteen reservoirs were rated having good feasibility for a dam raise, including the five public water utility dams, all four power dams, three owned by Pennsylvania (Nockamixon, Shohala Marsh and Marsh Creek) and two USACE dam (Blue Marsh and Beltzville). Three reservoirs were rated with good feasibility for an operational change, namely Merrill Creek and the USACE's Prompton and Jadwin flood control dams.

While Beltzville, Jadwin and Crystal Lake were proposed to pass the initial screening, they were eliminated during discussions with DRBC (see Appendix D for reasons). Therefore, they are shown with strike-through in Table 3.3-1 and crossed out in Figure 3.3-2. The FE Walter reservoir (#34) is also struck-through because it was excluded within the RFP because it is part of a different active study. This yielded 16 potential projects that passed the initial screening.

Existing reservoirs were rated poor on overall feasibility for various reasons, such as

- recreational reservoirs that have densely populated shorelines or are providing other high-value uses incompatible with increasing and/or releasing storage,
- NYCDEP reservoirs because of the expected difficulty reaching an agreement with the owner (although a raise at Cannonsville was an exception),
- others because their small surface area would require a very large elevation increase to provide sufficient extra storage or a small drainage area that makes capture of additional inflow unreliable.

Table 3.3-1: Screening Ratings for Existing Reservoirs

							USES							Ratings on specific criteria								Overall Ratings		
Map ID	Name	STATE	COUNTY	River	Owner	Owner Type	Water Supply	Flood control	Recreation	Hydropower	Max storage, BG	Surface area, ac	Drainage Area, sq mi	Storage Volume	Sufficiency of Inflow	Proximity to Delaware River	Position in Basin	Land Use Setting	Institutional Ease -- raise	Institutional Ease—operational change		Dam Raise	Operational Change or Purchase/Lease	Notes
1	WALLENPAUPACK	PA	PIKE	Wallenpaupack Cr	Brookfield	Pwr Co			X	X	88	5,700	228	3	2	2	3	2	3	3		3	3	Not regulated by DRBC
2	SWINGING BRIDGE	NY	SULLIVAN	Mongaup River	Eagle Creek	Pwr Co			X	X	12	1,000	118	3	3	1	3	3	3	3		3	1	Two reservoirs downstream
3	TORONTO	NY	SULLIVAN	Mongaup River	Eagle Creek	Pwr Co				X	8	860	23	3	3	2	3	3	3	3		3	1	Three reservoirs down stream
4	RIO	NY	SULLIVAN	Mongaup River	Eagle Creek	Pwr Co			X	X	5	460	195	2	2	1	3	3	3	3		3	1	Terminal Mongaup reservoir
5	BLUE MARSH	PA	BERKS	Tuplehocken Creek	USACE	Fed	X	X	X		42	1,147	175	1	3	1	2	3	2	2		3	1	Surrounded by farm fields
~~6~~	~~BELTZVILLE~~	~~PA~~	~~CARBON~~	~~Pohopoco Creek~~	~~USACE~~	~~Fed~~	~~X~~	~~X~~	~~X~~		~~34~~	~~947~~	~~96~~	~~3~~	~~3~~	~~2~~	~~3~~	~~3~~	~~2~~	~~2~~	-	~~3~~	~~1~~	~~Just downstream of the two Bethlehem reservoirs~~
7	NOCKAMIXON	PA	BUCKS	Tohickon Creek	PADCNR	State		X	X		23	1,450	73	3	2	1	3	3	2	2		3	1	Requires use change from state
8	PENN FOREST	PA	CARBON	Wild Creek	Bethlehem	Pub Util	X				9	462	17	3	2	3	3	3	3	1		3	1	Beltzville and Wild Creek are downstream
9	SHOHOLA MARSH	PA	PIKE	Shohola Creek	PA GAME	State			X		9	1,130	54	2	1	1	3	3	2	2		3	1	May require raising I84 bridge
10	GREEN LANE RES	PA	MONTGOMERY	Perkiomen Creek	Aqua PA	Priv Wtr	X		X		8	814	71	2	2	2	2	2	3	1		3	1	Some development along upper reaches
11	LAKE ONTELAUNEE	PA	BERKS	Maiden Creek	Reading	Pub Util	X				7	1,037	192	2	2	1	2	3	3	1		3	1	Many farm fields
12	WILD CREEK	PA	CARBON	Wild Creek	Bethlehem	Pub Util	X				6	304	22	2	3	2	3	3	3	1		3	1	Beltzville Reservoir is downstream
13	PEACE VALLEY (GALENA)	PA	BUCKS	Neshaminy Creek	Bucks County	Pub Util	X	X	X		6	365	16	2	2	2	2	3	3	1		3	1	Mix of farms and forest
14	STILL CREEK	PA	SCHUYLKILL	Still Creek	Tamaqua Water	Pub Util	X				4	332	7	2	1	3	2	2	3	1		3	1	Mixed farms/forest; raise 20-30 for 2-3 BG; high in Schuylkill Basin
~~15~~	~~CRYSTAL LAKE~~	~~PA~~	~~LUZERNE~~	~~Wapwallopen Cr~~	~~PA Am Water~~	~~Priv Wtr~~	~~X~~				~~3~~	~~494~~	~~3~~	~~1~~	~~1~~	~~1~~	~~3~~	~~3~~	~~3~~	~~1~~	-	~~3~~	~~1~~	~~Sits just outside of the Basin; could be connected by pipeline~~
16	MERRILL CREEK	NJ	WARREN	Merrill Creek	Merrill Creek	Pwr/Priv Wtr					15	690	2	1	1	1	3	2	2	2		2	3	Purchase/lease is promising
17	PROMPTON	PA	WAYNE	Lackawaxen River	USACE	Fed		X	X		24	290	60	3	2	2	3	3	1	1		1	3	Flood control dam, with small permanent pool; would require use change from federal government
~~18~~	~~JADWIN~~	~~PA~~	~~WAYNE~~	~~Dyberry Creek~~	~~USACE~~	~~Fed~~		~~X~~			~~15~~	~~1~~	~~65~~	~~3~~	~~1~~	~~2~~	~~3~~	~~3~~	~~1~~	~~1~~	-	~~1~~	~~3~~	~~Flood control dam, with no permanent pool; would require use change from federal government~~
19	MARSH CREEK RES	PA	CHESTER	Marsh Creek	PADCNR	State	X	X	X		8	535	20	2	1	2	1	3	2	2		2	1	Many farm fields; small drainage area; low in Basin
20	PEPACTON	NY	DELAWARE	E Br Delaware R	NYCDEP	Pub Util	X				199	5,763	372	3	3	2	3	3	2	1		2	1	operation change not considered at NYC Reservoirs per RFP
21	CANNONSVILLE	NY	DELAWARE	W Br Delaware R	NYCDEP	Pub Util	X			X	142	4,800	456	3	3	3	3	3	3	1		2	1	Institutional ease rated high because dam raise already studied operation change not considered at NYC Reservoirs;
22	NEVERSINK	NY	SULLIVAN	Neversink River	NYCDEP	Pub Util	X				46	1,472	90	3	2	1	3	3	2	1		2	1	operation change not considered at NYC Reservoirs per RFP
23	GEIST (SPRINGTON)	PA	DELAWARE	Crum Creek	Aqua Pa	Priv Wtr	X				4	391	22	1	1	3	1	1	3	3		1	1	Heavily developed shoreline
24	VAN SCIVER LAKE	PA	BUCKS	Scotts Creek	Warner Co	Private			X		4	700	2	1	1	3	2	1	1	1		1	1	Not really a dam here. More like a levee/polder
25	HOOPES	DE	NEW CASTLE	Red Clay Creek	Wilmington	Pub Util	X				4	194	2	1	1	3	1	2	2	1		1	1	Small surface area; would have to raise by >20 ft
26	MAUCH CHUNK	PA	CARBON	Mauch Chunk Cr	PA Fish & Boat	State	X	X	X		3	320	6	1	2	1	3	3	2	2		1	1	Small drainage area
27	LOCUST CREEK (TUSCARORA)	PA	SCHUYLKILL	Locust Creek	PADCNR	State		X	X		2	96	13	1	1	1	2	3	3	3		1	1	Small area and steep sides; requires 30' raise to get 1 BG; very far from Delaware River
28	YANKEE LAKE	NY	SULLIVAN	Pine Kill	Yankee L Assoc.	Private			X		2	415	4	3	2	2	3	1	1	1		1	1	Houses around private lake
29	WANAKSINK (LORDS)	NY	SULLIVAN	Fowlwood Brook	Wanaksink L Club	Private			X		2	325	2	1	2	2	3	1	1	1		1	1	Houses around private lake
30	LAKE HAUTO	PA	CARBON	Nesquehoning Cr	Lake Hauto Club	Private			X		2	290	9	1	2	1	3	1	1	1		1	1	Houses around private lake
31	HOPATCONG	NJ	MORRIS	Musconetcong R	NJDEP	State		X			16	2,474	25	1	1	1	3	1	1	1		1	1	Heavily developed shoreline; another dam before Delaware R
32	LAKE MERCER	NJ	MERCER	Assunpink Creek	Mercer County	County		X	X		5	275	30	1	1	3	3	1	2	1		1	1	Small surface area; would flood active recreation
33	ASSUNPINK LAKE	NJ	MERCER	Assunpink Creek	NJDEP	State		X			4	66	22	1	1	2	3	3	2	2		1	1	Small surface area; would have to raise by a lot
~~34~~	~~FE WALTER~~	~~PA~~	~~LUZERNE~~	~~Lehigh River~~	~~USACE~~	~~Fed~~		~~X~~	~~X~~		~~52~~	~~80~~	~~288~~	~~3~~	~~3~~	-	-	-	-	-	-	~~1~~	~~1~~	~~Ruled out in RFP; part of another study~~

Figure 3.3-2: Feasibility of Existing Reservoirs

Feasibility ratings based on dam raise change **Feasibility ratings based on operational or purchase/lease**

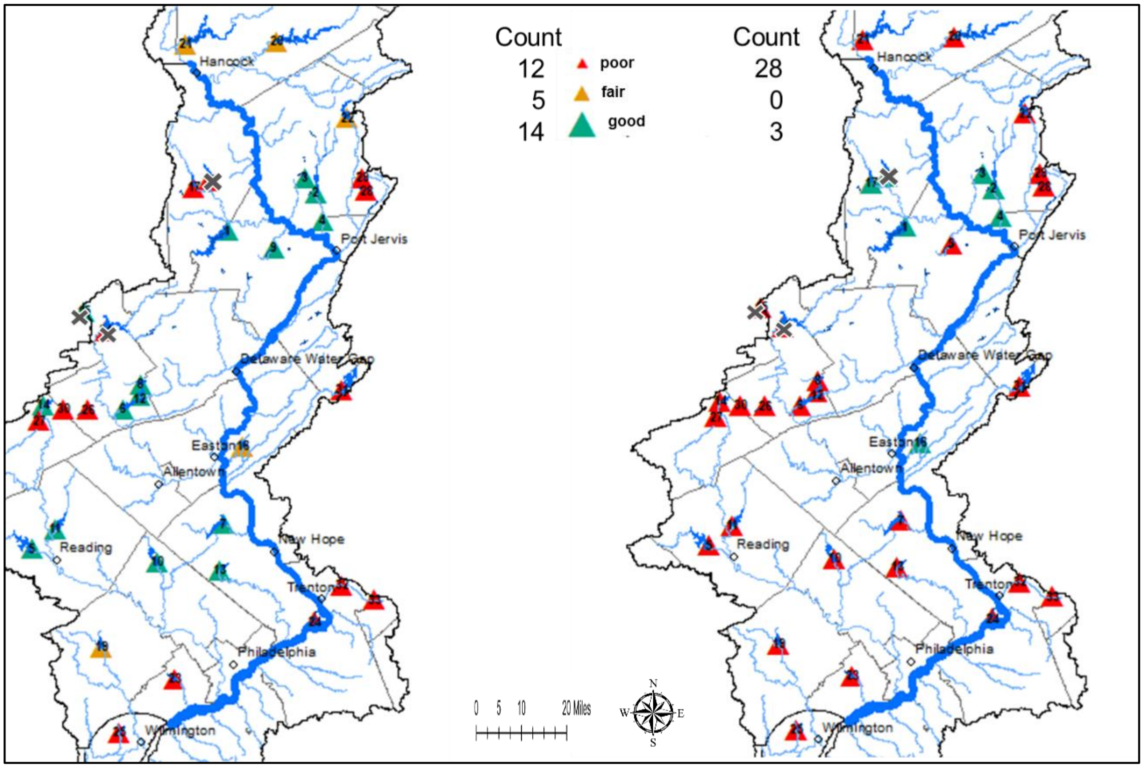
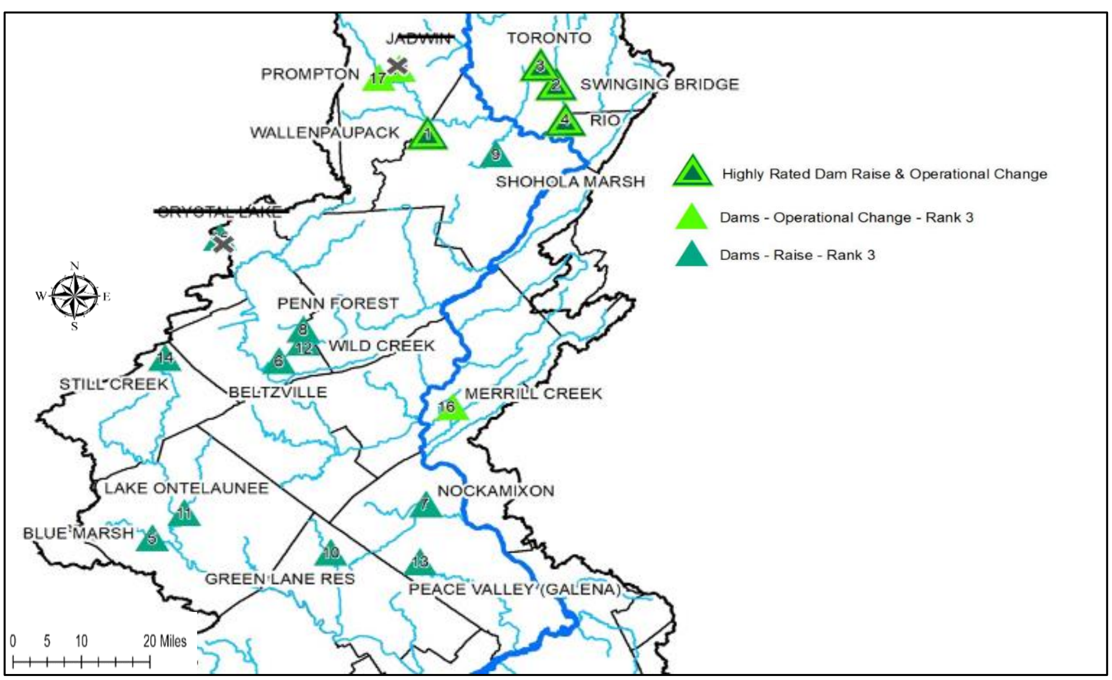


Figure 3.3-3: Existing Reservoirs Rated Good for Feasibility of a Dam Raise or Operation Change



3.4 Initial Screening Results – Quarries

The state databases contained many entries in the Basin above the Christina River: 796 in PA, 351 in NJ, and 274 in NY. The data fields, except location, did not address important criteria for this study, such as area, depth, volume or connectivity with groundwater. Accordingly, each location was examined by an analyst using satellite photos and topographic data. The area was delineated and the depth and volume were approximated when possible. Many entries listed in the databases were not observed as quarries via aerial imagery, presumably because the entry did not refer to a quarry, the quarry had been reclaimed after closing, was very shallow, was input incorrectly in the database, or never constructed.

Sixty-six quarries passed the prescreening criteria of area >25 acres, as presented in Table 3.4-1 and Figure 3.4-1. While some quarries had a distinct, continuous rim (which made their area easy to delineate) others had widely varying topography, requiring an approximation of the boundary area for feasible water storage. Furthermore, many quarries had complicated topography, with one side much lower or with high points inside the quarry. This made it difficult to quickly assess the feasibility and approximate volume. In addition, if a quarry was full of water, neither depth nor volume could be estimated. Another complication included the several cases where a cluster of quarries was too small to be feasible alone, but big enough in combination and close enough to possibly share some of the same pumping and piping infrastructure.

After applying the screening criteria, 33 quarries (30 in PA, 2 in NJ and 1 in NY) were rated good and were passed forward for further evaluation. These are shown in Table 3.4-1 and have an overall rating of 3. Several quarries (including the largest) are not close to a major stream, so accessing adequate supply to fill/refill promptly could be problematic. Six quarries were full of water so volume could not be estimated; these quarries are evidently inactive (some for decades), so they are likely readily available, unless already employed for alternative use. Their volume was presumed to exceed 0.5 BG, so they were passed through.

Many quarries had no or very small pools, which may indicate low permeability native intact rock or active dewatering. A large pool may be evidence of good water retention or complete quarry recharge from surrounding groundwater. The natural permeability and extent of dewatering needs to be further understood.

Figure 3.4-1: Quarries Passing Prescreening and Overall Ratings (those rated "good" numbered 1-33 with green circles)

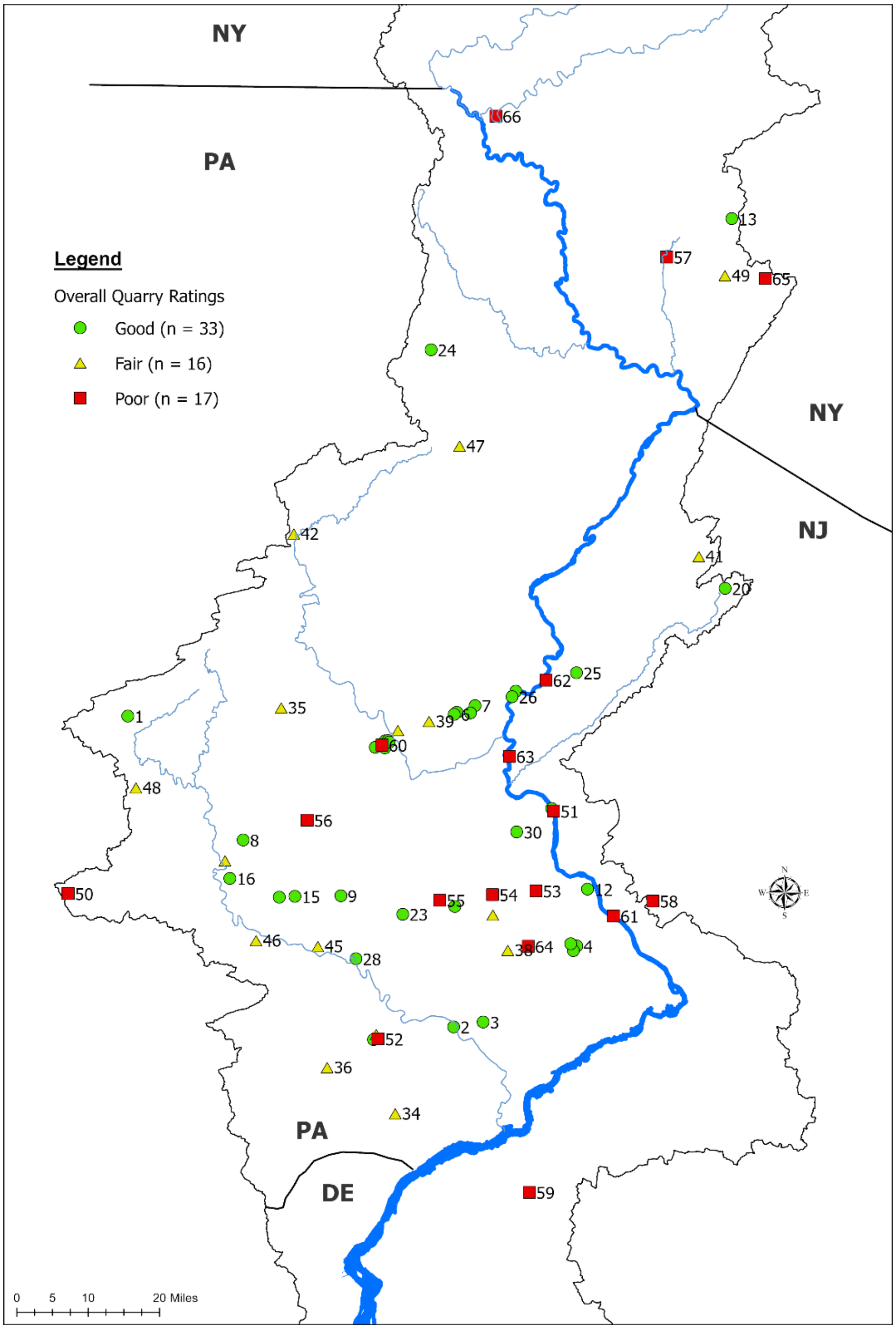


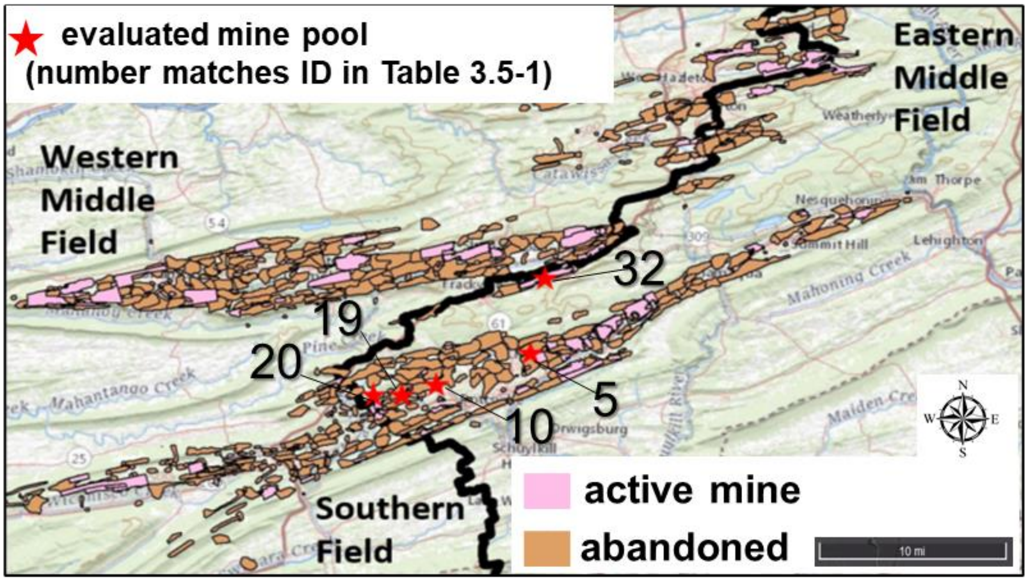
Table 3.4-1: Quarries Passing Prescreening, Sorted by Overall Screening Rating (33 bold entries passed to next stage)

												Ratings (3=good; 1= poor)							
Project	Quarry Owner and/or Name	State	County	SubBasin (HUC8)	Dist. to closest stream (ft)	Closest stream	Nominal Area, ac	Nominal Rim Elev (ft)	Nominal Bottom Elev (ft)	Nominal Depth (ft)	Est. Vol, BG	Pool Area, ac	Storage Volume	Access to Water	Water Retention	Proximity to Del R	Position In Basin	Land Use Setting	Overall	
1	**WADESVILLE MINE PIT**	PA	Schuylkill	Schuylkill	7,000	Mill Cr	182	780	380	400	11.8	0	3	2	1	1	2	3	3	Mill Creek is small but easy right-of-way (ROW); could take very long to fill; big lift to quarry
2	**GLASGOW MCCOY**	PA	Montgomery	Schuylkill	1,278	Schuylkill River	123	70	-280	350	7.0	1	3	3	1	3	2	3	3	very close to river. Probably fill by gravity.
3	**HIGHWAY MAT. PLYMOUTH MTG**	PA	Montgomery	Schuylkill	5,000	Wissahickon Cr	122	160	-100	260	5.2	8	3	1	3	2	2	3	3	existing pool, feed by gravity.
4	**HANSON AGGREGATES PENNS PARK**	PA	Bucks	Crosswicks-Neshaminy	3,447	Neshaminy Cr	87	180	-160	340	4.8	1	3	3	1	2	2	3	3	
5	**LEHIGH CEMENT NAZARETH**	PA	Northampton	Lehigh	1,625	Coplay Cr	102	450	220	230	3.8	8	3	1	3	3	3	3	3	3 mi to Bushkill Creek
6	**LEHIGH CEMENT IMPERIAL**	PA	Northampton	Lehigh	50	Monocacy Cr	71	440	120	320	3.7	0	3	1	1	3	3	3	3	
7	**BUZZI UNICEM STOCKERTOWN**	PA	Northampton	Middle Del	209	Bushkill Cr	120	300	110	190	3.7	18	3	1	3	3	3	3	3	fill by gravity; 6 stream miles to Del River.
8	**LEHIGH CEMENT EVANSVILLE**	PA	Berks	Schuylkill	10	Maiden Cr	88	320	80	240	3.4	0	3	3	1	2	2	3	3	adjacent to Ontelaunee Lake.
9	**MARTIN STONE BECHTELSVILLE**	PA	Berks	Schuylkill River	1,500	Swamp Creek	130	395	242	153	3.2	0	3	2	1	2	2	3	3	near a medium creek. Far from major stream.
10	**GLASGOW CATANACH**	PA	Chester	Schuylkill	9,600	Valley Cr	92	307	122	185	2.8	0	3	1	1	2	2	2	3	large but not near major stream; no pool but adjacent former quarry (259938) is full.
11	**NEW ENTERPRISE STONE & LIME**	PA	Berks	Schuylkill	1,415	Limekiln Cr	52	380	60	320	2.7	50	3	2	3	2	2	3	3	rural; near minor stream.
12	**NEW HOPE -- SOLEBURY**	PA	Bucks	Middle Del	4,461	Delaware River	82	100	-100	200	2.7	5	3	3	3	3	3	3	3	very close to Delaware River; ~30' elevation change.
13	**WOODBOURNE FLATS**	NY	Sullivan	Middle Del	100	Neversink River	57	1155	?	?	?	55	2	3	3	2	3	2	3	full of water.
14	**M & M STONE TELFORD**	PA	Bucks	Schuylkill	690	E Br Perkiomen Cr	30	300	?	?	?	20	2	3	3	2	2	2	3	filled since 2010; looks deep in 2002 photo.
15	**LEHIGH CEMENT**	PA	Berks	Schuylkill	6,600	Manatawny Creek	56	304	?	?	?	56	2	2	3	1	2	3	3	two filled quarries separated by a road; both full since 1990s.
16	**BERKS PROD TEMPLE**	PA	Bucks	Schuylkill	6,800	Laurel Run	29	280	?	?	?	29	2	2	3	1	2	2	3	water filled since 1990s; 2.5 miles to Schuylkill.
17	**NEW ENTERPRISE STONE & LIME**	PA	Northampton	Middle Del	50	Delaware River	29	215	?	?	?	29	2	3	3	3	3	3	3	water filled since 1990s; adjacent to Delaware River
18	**DELAWARE VALLEY LANDSCAPE**	PA	Bucks	Middle Del	500	Delaware River	35	115	?	?	?	35	2	3	3	3	3	3	3	water filled; next to but separate from Giving Pond; not part of park.
19	**EUREKA RUSH VALLEY I**	PA	Bucks	Crosswicks-Neshaminy	100	Neshaminy Cr	97	160	40	120	1.9	0	2	3	1	2	2	3	3	feed by gravity; another large, very deep quarry adjacent.
20	**WELDON QUARRY**	NJ	Sussex	Middle Del	2,256	Lubbers Run	200	990	932	58	1.9	0	2	3	1	1	3	2	3	next to Lake Hopatcong
21	**NEW ENT STONE & LIME ORMROD**	PA	Lehigh	Lehigh	480	Coplay Cr	87	390	290	100	1.4	0	2	3	2	3	3	3	3	5.1 to Lehigh River with easy ROW; adjacent to Ranger Lake
22	**NEW ENT STONE & LIME WHITEHALL**	PA	Lehigh	Lehigh	2,700	Coplay Cr	62	360	240	120	1.2	32	2	2	3	3	3	3	3	3.3 mi to Lehigh River w easy ROW.
23	**HIGHWAY MAT PERKIOMENVILLE**	PA	Montgomery	Schuylkill	447	Unami Cr	33	200	-20	220	1.2	0	2	3	1	2	2	3	3	near Perkiomen Creek; could feed by gravity from Unami Creek.
24	**HANSON AGGREGATES PA**	PA	Wayne	Lackawaxen	2,300	Middle Cr	36	1480	1300	180	1.0	4	2	1	3	2	3	3	3	<1 mi to Wangum Creek; high in watershed.
25	**TILCON NEW JERSEY/OXFORD**	NJ	Warren	Middle Del	2,800	Pequest River	64	530	370	100	1.0	0	2	3	1	3	3	3	3	3 mi to Delaware River
26	**H & K GROUP**	PA	Northampton	Middle Del	1,100	Delaware River	62	320	245	100	1.0	0	2	3	1	3	3	3	3	very close to Delaware River; rim ~200 ft above river; no pool.
27	**NEW ENT STONE & LIME NAZARETH**	PA	Northampton	Middle Del	2,400	Schoeneck Cr	151	360	320	40	1.0	98	2	2	3	3	3	3	3	large pool.
28	**H & K GROUP**	PA	Montgomery	Schuylkill River	500	Schuylkill River	25	130	10.0	120	.5	0	2	3	1	2	2	3	3	adjacent to Schuylkill River
29	**NEW ENTERPRISE STONE & LIME**	PA	Lehigh	Lehigh	97	Coplay Cr	39	470	350	120	.8	12	1	3	3	3	3	3	3	2.5 mi to Lehigh River with easy ROW; near Ranger Lake.
30	**HANSON AGGREGATES PA**	PA	Bucks	Middle Del	120	Rapp Cr	50	360	280	80	.7	2	1	3	2	3	3	3	3	could be filled from Lake Nockamixon.
31	**HOLCIM (US)**	PA	Lehigh	Lehigh	1,176	Coplay Cr	34	400	290	110	.6	6	1	3	3	3	3	3	3	1.5 mi to Lehigh River w easy ROW.
32	**NACEVILLE MATERIALS**	PA	Bucks	Crosswicks-Neshaminy	417	Mill Cr	24	160	40	120	.5	1	1	3	1	2	2	3	3	
33	**COPLAY AGGREGATES**	PA	Lehigh	Lehigh	3,197	Lehigh River	33	380	300	80	.4	20	1	3	3	3	3	3	3	1.5 mi to Lehigh River w easy ROW.
34	LEHIGH CEMENT HANSON GLEN MILLS	PA	Delaware	Lower Del	300	Chester Cr	86	200	-180	380	5.3	2	3	1	2	3	1	3	2	Chester Creek is small; 4.1 miles from Geist reservoir on Crum Creek.
35	LEHIGH ASPHALT PAVING & CONST	PA	Schuylkill	Lehigh	1,267	Lizard Cr	179	760	600	160	4.7	0	3	1	1	2	3	3	2	rural; Lizard Creek is small; 4 mi from Jordan Cr but have to pump over big hill
36	HANSON AGGREGATES PA	PA	Chester	Brandywine-Christina	754	Valley Cr	104	260	20	240	4.1	23	3	2	3	1	1	2	2	large pool; 1.5 mi to Brandywine Cr; very low in Basin.
37	HOLCIM (US)	PA	Northampton	Lehigh	248	Hokendauqua Cr	53	330	20	310	2.7	6	3	2	3	1	3	3	2	1.6 mil from Lehigh; closer if pumping from Lehigh into adjacent minor creek.
38	EUREKA STONE	PA	Bucks	Crosswicks-Neshaminy	150	Mill Cr	135	260	160	100	2.2	24	3	1	3	3	2	2	2	rural by quarry but suburban surroundings; small stream.
39	KEYSTONE CEMENT	PA	Northampton	Lehigh	3,800	Monocacy Cr	96	430	290	140	2.2	25	3	1	3	3	3	3	2	close streams are small; no major stream nearby
40	ALLAN MYERS	PA	Chester	Schuylkill	5,307	Pickering Cr	49	350	120	230	1.8	0	2	1	1	3	2	3	2	rural; adjacent creek very small.
41	LIMECREST QUARRY DEVELOPER	NJ	Sussex	Middle Del	12,500	Paulins Kill	130	670	600	70	1.5	24	2	2	3	2	3	3	2	25 miles to Delaware River; close to lakes.
42	HANSON AGGREGATES PA	PA	Luzerne	Lehigh	765	Lehigh River	67	1360	1260	100	1.1	0	2	3	1	1	3	3	2	50 mi to Delaware River
43	BERKS PROD	PA	Berks	Schuylkill	1,300	Schuylkill River	54	260	140	120	1.0	28	2	3	3	1	2	3	2	at confluence of Maiden Creek and Schuylkill River
44	H & K GROUP	PA	Bucks	Crosswicks-Neshaminy	5,947	N Br Neshaminy Cr	51	520	420	100	.8	1	1	2	1	2	2	3	2	very rural; small stream; 3 mi from Peace Valley Res. with easy ROW.
45	H & K GROUP	PA	Berks	Schuylkill	4,700	not named	38	200	80	120	.8	1	1	2	1	2	2	2	2	housing nearby; 1 mi from Schuylkill River
46	DYER	PA	Berks	Schuylkill	758	Seidel Cr	93	310	265	45	.7	0	1	2	1	2	2	3	2	.8 mi from Schuylkill with easy ROW except road and railroad crossing.
47	GF EDWARDS	PA	Wayne	Lackawaxen	384	Wallenpaupack Cr	57	1460	1400	60	.6	10	1	2	3	1	3	3	2	flows thru Wallenpaupack reservoir.
48	PENNSY SUPPLY	PA	Schuylkill	Schuylkill	200	Bear Cr	17	660	520	140	.4	7	1	1	3	1	2	3	2	between 2 small streams; 8 mi to Schuylkill River; steep sides.
49	CALLANAN IND BRIDGEVILLE	NY	Sullivan	Middle Del	500	Neversink	43	1187	1140	47	.3	30	1	3	3	2	3	3	2	pool covers entire bottom; bottom depth uncertain.
50	PENNSY SUPPLY	PA	Lebanon	Schuylkill	2,363	Tulpehocken Cr	96	480	280	200	3.1	0	3	1	1	1	2	3	1	poor water availability; at edge of Basin.
51	DELAWARE VALLEY CONCRETE	PA	Bucks	Middle Del	1,400	Delaware River	59	113	?	?	?	59	2	3	3	3	3	1	1	now Giving Pond, part of Delaware Canal State Park; Owned by Fish and Game
52	WARNER	PA	Chester	Schuylkill	1,000	Valley Cr	52	NA	?	?	?	52	2	1	3	2	2	1	1	full pond by office building; owner not likely to cooperate; not near major stream.
53	NACEVILLE MATERIALS	PA	Bucks	Crosswicks-Neshaminy	157	N Br Neshaminy Cr	70	420	300	120	1.4	0	2	1	1	1	2	3	1	poor water availability; long distance to Delaware River.
54	H & K GROUP	PA	Bucks	Schuylkill	2,121	Morris Run	32	460	300	160	.8	1	1	1	1	1	2	3	1	small stream; 2.1 mi to E. Branch of Perkiomen; 50 stream miles to Delaware River.
55	NACEVILLE MATERIALS	PA	Montgomery	Schuylkill	3,100	Ridge Valley Cr	50	480	380	100	.8	0	1	1	1	2	2	3	1	2.4 mi to E. Branch Perkiomen Cr.
56	NEW ENTERPRISE STONE & LIME	PA	Berks	Schuylkill	4,000	Sacony Cr	92	440	390	50	.8	0	1	1	1	2	2	2	1	very poor water availability
57	E TETZ MONGAUP VALLEY	NY	Sullivan	Middle Del	3,100	Mongaup	100	1300	1250	50	.8	1	1	3	1	2	3	3	1	many interior hills; low on one side; not too deep.
58	TRAP ROCK INDUSTRIES	NJ	Mercer	Middle Del	26,000	Jacobs Cr	48	260	200	60	.5	0	1	1	2	3	3	3	1	.5 mi out of Basin; no stream nearby; 5 mi to Del. River.
59	INVERSAND COMPANY	NJ	Gloucester	Lower Del	1,758	Mantua Cr	251	150	140	10	.4	0	1	2	3	2	1	3	1	not deep; not far from Mantua Creek
60	HOLCIM (US)	PA	Lehigh	Lehigh	1,903	Coplay Cr	29	420	370	50	.2	0	1	3	1	3	3	3	1	4.4 to Lehigh River with easy ROW.
61	TRAP ROCK INDUSTRIES	NJ	Mercer	Middle Del	846	Delaware River	31	60	20	40	.2	0	1	3	1	3	3	3	1	good option but slated to become a park.
62	HARMONY SAND AND GRAVEL	NJ	Warren	Middle Del	1,005	Delaware River	13	290	250	40	.1	0	1	3	1	3	3	3	1	adjacent to Delaware River; low on one side and not deep; very little volume.
63	BAER RIVERLINE AGG	NJ	Warren	Middle Del	1,485	Delaware River	18	180	160	20	.1	1	1	2	3	3	3	3	1	adjacent to Delaware River; low on one side and not deep; very little volume.
64	EUREKA STONE	PA	Bucks	Crosswicks-Neshaminy	3,728	Neshaminy Cr	32	240	220	20	.1	0	0	2	1	3	2	2	1	too shallow; low volume.
65	JML QUARRIES MASTEN LAKE	NY	Sullivan	Middle Del	800	South Brook	15	1190	1188	2	.0	9	0	3	3	2	3	3	1	very low on one side; very low storage.
66	COBLESKILL STONE HANCOCK	NY	Delaware	East Branch Delaware	1,000	E Br Delaware R	26	1225	1220	NA	.0	0	0	3	0	3	3	3	1	low but narrow opening on one side; could be dammed; up 300' from river.

3.5 Initial Screening Results – Deep Mine Pools

Only about 20% of the Anthracite Coal Region of Northeastern Pennsylvania (ACRNP) is within the Basin (Figure 3.5-1), but the area of mines is considerable: about 50,000 acres of abandoned mines and about 13,000 acres of active mines.

Figure 3.5-1: Anthracite Coal Mines in the Delaware River Basin (source: PASDA)
(thick black line is Basin boundary)



Data sources (Table 3.1.1-2) were researched to identify 29 deep mine pools in the Delaware River Basin portion of the ACRNP (21 in the Southern Field; 7 in the Eastern Middle Field; 1 in the Western Field). Five mines (all abandoned) passed the prescreen criteria of providing approximately >1 BG of total storage volume, ranging in estimated volume from 1.8 to 3.6 BG. Table 3.5-1 below lists the potential mine pools and those five that passed the initial screen to project characterization, indicated with an "x" in the table and a red star in Figure 3.5-1.

Table 3.5-1: Screened Basin Mine Pools (x indicates passed screen)

South Anthracite Field			
ID	Pool	Vol. (BG)	
1	Tamaqua Lands (S)	0.80	
2	Tamaqua Lands (N)	0.31	
3	Mary D	0.40	
4	Kaska	0.60	
5	Silver Creek	1.77	X
6	Eagle Hill	0.73	
7	Palmer Vein	0.40	
8	Bear Ridge	0.04	
9	Pine Fores	0.42	
10	Wadesville	3.58	X
11	Pottsville East	0.13	
12	Pine Knot #1	0.60	
13	Thomaston	0.78	
14	Richardson	0.63	
15	Glendower	0.40	
16	Buck Run (old)	0.48	
17	Buck Run (dam basin)	0.05	
18	Lytle	0.80	
19	Phoenix Park	2.05	X
20	Otto	2.27	X
21	Middle Creek	0.70	
	Total	17.94	

Eastern Middle Anthracite Field			
ID	Pool	Vol. (BG)	
24	Audenreid	0.24	
25	Spring Brook	0.01	
26	Tresckow	0.02	
27	Tresckow #21	0.08	
29	Coleraine	0.07	
29	Evans	0.02	
31	Silver Brook	0.68	
	Total	**1.12**	

Western Middle Anthracite Field			
ID	Pool	Vol. (gal)	
32	Morea	2.68 #	X
	Total	**2.68 #**	

Note: Volumes taken from USBM TP #727-1949; # denotes value from USGS SIR 2010-5261.

3.6 Supplemental Screening

The results of the initial screening of potential storage projects yielded 61 projects to be characterized and evaluated (Table 3.1-1). This number exceeded the originally proposed number of 35 projects that would be carried into the more labor-intensive process. Therefore, the project team performed a supplemental screening by gathering additional key data to further reduce the number of projects. See Appendix D for the list of screened-out projects, including a brief reason for screening. This process reduced the number to 38 projects that were fully characterized and evaluated.

Generally, the intent was to perform some of the early project characterization tasks for each project to see if additional project information would identify any major flaws for a storage project that would eliminate it from the screened project group.

No new reservoir projects were screened at this stage, leaving seven for characterization and evaluation. For existing reservoirs, the team focused on contacts with the owner/operator and gaging their initial willingness to consider some future transfer of excess water or allow a modification of their facilities to increase storage and some future shared use. Nine reservoirs were screened out: Lake Wallenpaupack, Beltzville, Mongaup--Swinging Bridge, Mongaup—Toronto, Nockamixon, Shohala Marsh, Peace Valley (Galena), Still Creek, and Green Lane. NYCDEP's Cannonsville Reservoir was added based on a previous study of adding moveable gates on the spillway to raise the water level. This left eight existing reservoir projects for characterization and evaluation: four storage-increase projects (Wild creek, Cannonsville, Blue Marsh and Prompton) and four transferrable-storage projects (Merrill Creek, Mongaup-Rio, Lake Ontelaunee, and Penn Forest/Wild Creek) that were characterized and evaluated as explained in Section 5.3.

In the case of quarries, the team performed a cursory review of nearby stream sources and water availability. This reduced the number from 33 to 18 projects (with one quarry, Q7 Stockertown, having two source options) for characterization and evaluation as discussed in Section 5.4 and listed in Table 5.4.2-1. Lastly, no additional mines were screened.

The additional data allowed the project team to further eliminate projects and to selectively reduce the potential projects from 61 to 38. These 38 projects were characterized and evaluated, including the development of cost estimates.

Section 4
Evaluation Criteria

4 Evaluation Criteria

The criteria development and application are important to understand how they influenced the scoring and eventual ranking of a potential storage project. Further, the criteria in some ways governed the data gathering as the project team collected data to perform quantitative evaluations, as much as possible, on the scored potential projects. The criteria development is explained and the application is introduced. The detail and examples of the application will be further explained and become evident in later sections of the report and in the individual SPSs located in Appendix A.

4.1 Criteria Development

The criteria were initially developed based on four main pillars including importance to DRBC and stakeholders; ability to evaluate with available information; clearly defined; and non-overlapping or synergistic. Emphasized criteria included technical feasibility and cost. Potential impacts on the environment, stakeholders, residents and business were deemed important. Minor criteria included a measurement of the potential to have ancillary benefits, including the ability to leverage other programs to possibly realize these leveraged benefits.

Criteria were developed by the project team based on experience in previous assessment and ranking projects including ones involving standardized criteria lists and assessment methods, such as the Alternatives Evaluation and Recommended Outcome (AERO) Report (Philadelphia Water Department, 2019) and, specifically for wetlands and waterbodies, the Clean Water Act Section 404(b)(1) guidelines. Criteria were evaluated for relevance to this project and a list of proposed criteria was reviewed with DRBC staff. This process led to the list of primary criteria and subcriteria in Table 4.1-1.

4.2 Criteria Application

The evaluation of the subcriteria provided the metrics to evaluate storage projects and therefore also guided the collection of data. As mentioned, some criteria could be evaluated using quantitative data, while others have only limited data. To apply the criteria more consistently, a rubric was developed for all subcriteria. The rubric established five levels for scoring an individual criterion with a number from one (least preferable) to five (most preferable). Rubrics were based on a quantified variable (e. g., billions of gallons) where possible. In the absence of a quantifiable variable, the project team defined qualitative rubrics. All projects were evaluated based on gross volume.

Regarding scoring negative impacts on habitat, both the quantity of the impact (e.g., acres of land flooded) and the quality of impacted habitat (e. g., mature forest vs. row crops) are important, so the project team adapted the scoring to include both a quantity and quality rubric and score. To maintain that a score of five is most preferable, the quality score was framed as "reproducibility". For example, row crops have lower ecological quality that is easier to reproduce, so its loss is more preferable, scoring five. In contrast, mature forest is very difficult to reproduce, so its destruction is least preferable, scoring one.

The scoring system also includes weights assigned to the six major criteria to emphasize one criterion relative to another. These were developed by the project team and reviewed with DRBC. Total scores are dependent on the weights assigned and this sensitivity will be examined further in Section 6.

The evaluation criteria matrix and associated rubrics are illustrated in Table 4.2-1. This table and format were used to score each of the 38 evaluated potential projects and can be found attached to each SPS in Appendix A.

This approach encouraged consistency in scoring between various projects and various reviewers, as much as practical. The evaluation of the criteria and storage project scoring is further explained in the following Section 5 as part of the detailed project characterization process.

Table 4.1-1: Primary Criteria and Subcriteria used for Evaluation

1. Water quantity and quality
- Volume of storage provided (BG)
- Hydrologic reliability of supply (months to fill)
- Release rate (cfs)
- Promptness of delivery to mainstem (days)
- Geographic benefit
- Quality of stored water

2. Infrastructure design, construction and operation
- Site/civil, land and easements
- Subsurface conditions
- Infrastructure complexity
- Construction complexity
- Operational complexity

3. Environmental impacts
- Protected species
- Water quality degradation of downstream waters
- Obstruction to passage of aquatic animals
- Hydromodification
- Wetlands inundated or filled (ac)
- Stream length inundated (mi)
- Uplands inundated or developed (ac)

4. Social and Economic Impacts
- Disruption/displacement
- Safety and health
- Social equity/environmental justice
- Recreational loss
- Cultural/historical resources
- Aesthetic
- Loss of tax revenue
- Loss of production (farmland, timberland, quarries)
- Emissions of greenhouse gasses

5. Project Costs and Schedule
- Land acquisition cost ($)
- Construction cost ($)
- Operating Cost ($/year)
- Overall Cost Present Value ($)
- Cost effectiveness ($/BG)
- Schedule (Time to make Operational, years)

6. Ancillary Benefits
- Flood control
- Recreation/tourism
- Habitat/fishery enhancement
- Water quality improvement/environmental remediation (i.e., acid mine discharge; quarry reclamation)
- Ability to leverage funding from other programs

Table 4.2-1: Applied Evaluation Criteria, Rubrics and Weightings

Six primary criteria	Quantitative Evaluation Metric (where appropriate; enter values only in ungreyed cells)	Score (5=best, 1 = worst)			Weight	Weighted score	RUBRIC
1. Water quantity and quality		#			30%	#	
o Volume of storage provided (BG)	#	#					>20BG=5, >10=4, >5=3, >1=2
o Hydrologic reliability of supply (months to fill)	#	#					<6months=5, <12=4,<24=3,<36=2, >36=1
o Release rate (cfs)	#	#					>200 cfs=5, >100=4, >50=3, >25 =2, <25= 1
o Promptness of delivery to mainstem (days)	#	#					<1 day = 5, <2 = 4, <3 = 3, <4=2, >5 = 1
o Geographic benefit		#					Enters mainstem above Montague = 4; Above Trenton = 5; Above Schuylkill = 4, at Schuylkill=3, below Schuylkill=2
o Quality of stored water		#					excellent=5; satisfactory=3, unsatisfactory=1
2. Infrastructure design, construction and operation		#			10%	#	
o Site/Civil, Land & Easements							simple=5; typical=3; complex=1
o Subsurface conditions							No geo issues=5; typical issues & some geo data =3; complex or problematic=1
o Infrastructure Complexity							straight forward & proven =5 typical complexity=3 unproven,
o Construction complexity							risky or complex=1
o Operational complexity							simple=5; typical=3; complex with potential for significant operation upsets=1
3. Environmental impacts		#			15%	#	
o protected species		#					No impacts=5; harm to habitats of USFWS species of concern=4; harm to habitat of USFWS endangered or threatened species=3; harm to habitat with known occurrence of listed species=2; harm to critical habitat with know
o Water quality degradation of downstream waters		#					minimal = 5, minor = 4, moderate = 3, major=2, extreme = 1
o obstruction to passage of aquatic animals		#					No obstruction=5; obstruction to minor resource=3; obstruction to important resource=1
o hydromodification		#					No or minimal modification=5, minor change during cold season=4; significant change in cold season only=3; minor change during warm season = 2; major change year round=1
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o wetlands inundated or filled (ac)	#	#	#	#			Replaceability: none or open water = 5, aquatic bed=4, marsh=3, scrub/shrub =2, forested=1
o stream length inundated (mi)	#	#	#	#			Replaceability: Warm water fishery without migratory fish=5, WWF supporting migration =4, cold water fishery=3, High quality=2; exception value or naturally reproducing trout=1 Quantity: 0 mi=5, <.25=4, <.5=3, <.75=2, >.75=1
o uplands inundated or developed (ac)	#	#	#	#			Replaceability: Upland habitat types displaced: 80% or more cropped/developed=5; 50% cropped/developed=4; 10% or less cropped with reverting farmfields=3; 10% or less cropped with mixed second growth and mature woodlands=2; 100% woodlands=1 Quantity: <1 ac = 5, <10=4, <50=3, <100=4, >100= 1
4. Social and Economic Impacts		#			10%	#	
o Disruption/displacement		#					no displacement, minimal disruption = 5; significant disruption, minor displacement = 3, permanent displacement of numerous entities= 1
o Safety and health		#					No or minimal risk to safety to public=5; minor safety risk of limited scope=3; major risk with large scope=1
o Social equity/environmental justice		#					
o Recreational loss		#					
o Cultural/historical resources		#					
o Aesthetic		#					No or minimal impacts=5; minor or temporary impact=3; major and permanent impact=1
o Loss of tax revenue		#					
o Loss of production from farmland, timberland, quarries		#					
o Emissions of greenhouse gasses		#					
5. Project Costs & Schedule		#			30%	#	
o Land acquisition cost ($)	#						
o Construction Cost ($)	#						
o Operating Cost ($/yr)	#						Converted to present value based on 30 years of costs with
o Overall Cost ($)	#	#					Sum on present value basis: <25M$=5, <50M$=4, <100M$=3,
o Cost effectiveness ($/BG)	#	#					$ per BG: <5M$=5, <10M$=4, <25M$=3, <50M$=2, >100M$=1
o Schedule (Time to make Operational, years)	#	#					<5 years = 5, <15 = 3, >15 =1
6. Ancillary Benefits		#			5%	#	
o Flood control		#					
o Recreation/tourism		#					
o Habitat/fishery enhancement		#					major = 5, moderate = 3, minor=1
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		#					
o Ability to leverage funding from other programs		#					5=identified opportunity to leverage programs; 3- possible opportunity; 1-no foreseeable opportunity or conflicts with related programs or objectives
OVERALL		#			100%	#	

Section 5
Project Characterization

5 Project Characterization

Project characterization involved the research, concepting and calculations for the 38 potential storage projects that passed the screening such that they could be evaluated against established criteria for subsequent ranking.

5.1 Concept and Approach

The following sections discuss project characterization of new reservoirs, existing reservoirs, quarries and deep mines, generally following evaluation criteria. In most categories, there are common elements of project characterization that were more efficient to describe for the entire category rather than in the individual SPS. The SPSs provide further project-specific details.

5.2 New Reservoirs

5.2.1 Project Research and Overview

Of the seven potential new reservoir projects passing the initial screening (Figure 5.2-1; all in Pennsylvania), five were investigated previously in reports provided by the DRBC. Regarding the additional two potential projects, the Silver Creek site was previously investigated as reported by Skelly and Loy (2004). The final potential project, Rattling Run near Port Clinton, PA, was investigated for the first time herein at the request of DRBC. Where design parameters such as the location and elevation of the dam were available in a previous report, they were reused, with adjustments as appropriate. It is important to keep in mind that the locations and heights of the dams could be adjusted to reduce their cost and impacts but also reduce the associated reservoir's volume. This is particularly relevant to the two very large dams/reservoirs (Milanville and Equinunk), each providing 42 BG but at tremendous cost and with large potential impacts.

Figure 5.2-1: Sites of Potential New Reservoirs

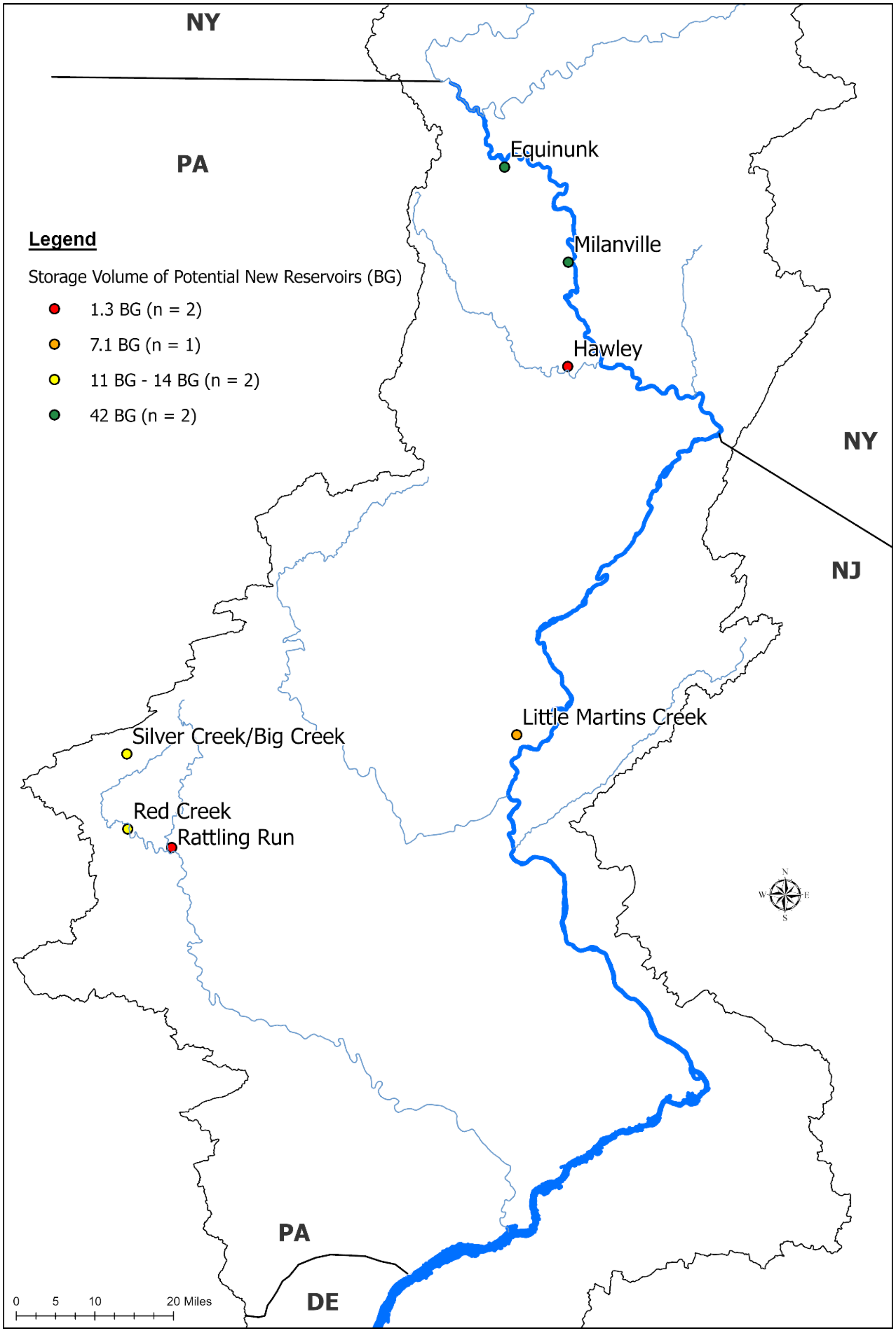


Table 5.2-1: Parameters of Potential New Reservoirs

ID	Project Name	County	Subwater-shed	Stream	Fill Method	Volume at NRWS, BG	Dam Height, ft	Dam Length, ft	Area at NRWS, ac	Drainage Area, sq mi	Mean Annual Flow, cfs	Time to Fill, months (without pump-in)	Days of Augmentation at 100 cfs
N1	Red Creek	Schuylkill	Schuylkill	Red Creek	pump in	13.3	185	2050	830	5.3	10	69	205
N2	Milanville	Wayne	Lackawaxen	Calkins Creek	gravity	42.2	286	2600	1797	43.7	77	28	651
N3	L. Martins Creek	North-ampton	Middle Del. River	Little Martins Creek	pump in	7.1	212	1400	400	6.8	12	29	110
N4	Equinunk	Wayne	Upper Del. River	Equinunk Creek	gravity	41.6	298	2550	1392	56.9	113	19	642
N5	Hawley	Wayne	Lackawaxen	Middle/ Wangum Creek	gravity	1.3	118	1400	273	82.6	145	0.5	20
N6	Rattling Run	Berks	Schuylkill River	Rattling Run	gravity	1.3	153	680	90	4.2	9	8	20
N7	Silver Creek/Big Creek (main dam)	Schuylkill	Schuylkill River	Silver Creek/ Big Creek	pump in	11.2	260	3330	473	2.6	7	81	173

5.2.2 Water Quantity and Quality

The storage volume provided by each potential reservoir at the normal reservoir water surface elevation (NRWS, assuming the reservoirs will be kept full to the spillway elevation) is presented in Table 5.2.1. The volumes range from modest (about 1 BG for Rattling Run and Hawley) to very large (about 42 BG for Milanville and Equinunk).

Regarding water quality, in this context, it pertains to the suitability of the water quality in a reservoir to support the project goal of flow augmentation. The environmental impacts of reservoir releases on downstream waters are considered in the environmental section (5.2.4). The most likely water quality problem would be eutrophication, which is common in reservoirs (Wagner and Erickson, 2017). A good reference is Blue Marsh Reservoir, which is assessed as eutrophic by its owner, the US Army Corp of Engineers (USACE, 2021). Although it is eutrophic, the DRBC currently directs release of storage that it controls for flow augmentation. Therefore, presumably, even if a new reservoir is eutrophic, its water quality is likely to be sufficient for flow augmentation.

5.2.3 Infrastructure Design, Construction and Operation

5.2.3.1 Dam Design

Conceptual dam designs presented for a project in their SPS are in general accordance with the Pennsylvania Code Title 25, Chapter 105, Dam Safety and Water Management. Conceptual drawings were produced for each project and are attached to the corresponding SPS located in

Appendix A. Such drawings were key in checking the feasibility of the dam location and necessary to compute quantities on which the cost estimates were based.

At this conceptual stage, all seven dams were designed to have a similar earthen embankment. A dam would consist of a low permeable clay core, with granular drainage filters on the downstream side of the core to minimize the potential for fines migration through the dam. The dam is comprised of an outer shell on both the upstream and downstream side.

The same design criteria and design assumptions were applied to all dam projects as follows:

- All main dams are assumed to be “Category 1 Hazard Potential” dams as described in the Pennsylvania Code Title 25, Chapter 105. Dam Safety and Water Management.
- All dams were designed for the Probable Maximum Flood (PMF) as required for Category 1 Hazard by the Pennsylvania Code.
- Freeboard was assumed to be 2 feet above the MRWS (maximum reservoir water surface) elevation. Wind seiche was not included in the freeboard estimate.
- Material for the embankment dam (core, filters, and shell) is assumed to be available from nearby sources. The dam construction excavation could also be used as potential embankment material.
- A 20-foot excavation was assumed across the dam foundation, and a 10-foot excavation for the remaining footprint to found the dam on suitable foundation materials. This excavation depth may decrease or increase based on subsurface investigations at the site.
- A grout curtain was also included in the design to minimize seepage underneath the dam and reduce uplift pressures at the dam foundation. The curtain has been estimated to stretch along the dam foundation and up each abutment, with a depth of half the maximum height of the dam. Dam upstream and downstream slopes were sketched at 2.5H:1V inclination. Steeper slopes may be achievable once more information about the potential nearby shell materials is acquired.
- A 25-foot-wide crest was assumed for maintenance vehicles to access the dam crest.
- Saddle dams were required to contain the NRWS at Silver Creek and to contain the MRWS at Little Martins Creek and Red Creek.
- Site access roads to key dam facilities were not developed at this stage. Instead, an estimated allowance has been included in the cost estimate for roads.

5.2.3.2 Hydrologic Design

Regarding hydrologic design, the Pennsylvania Department of Environmental Protection (PADEP) provides a Probable Maximum Precipitation Tool (PMP Tool, Applied Weather Associates, LLC. 2019) for all drainage basins within Pennsylvania. The PMP Tool, which runs inside of ArcGIS, provides estimates of the probable maximum rainfall depths and durations applicable to a specified watershed.

For this study, the PMP Tool was used to calculate the PMP for six of the new-reservoir projects. The seventh (Silver Creek) used an alternate method because of limited site data. The process includes the following main steps which were carried out for all potential projects.

- Determining the watershed area for each reservoir location (see Figure 5.2-1) and developing this as a shapefile for GIS import. This was developed through the use of the USGS StreamStats web service.
- Import the shapefile into ArcGIS and calculate the PMP depths and durations for the watershed using the PMP Tool.
- The results from the PMP Tool were then used in the PMP distribution spreadsheet which was part of a supplement developed by PADEP Dam Safety to develop a hyetograph (rainfall intensity over time) for each catchment.
- The PMP hyetograph was used with a range of watershed characteristic assumptions to generate reservoir inflow flood using HEC-HMS 4.3. Additional inputs included calculated inputs such as the time of concentration calculated from the watershed length and slope. This modelling resulted in a PMF hydrograph for each location.
- Finally, the peak inflow developed through this process was compared with a “ballpark PMF” estimate according to the method published by Harrison and Paxson (2003). The results between the modelling and the ballpark were found to be within ±10%.

Because of limited site data, the ballpark PMF was used in design of the Silver Creek reservoir; the close agreement between the two methods is well within the expected uncertainty. The estimated PMF for the seven evaluated new dams is provided in Table 5.2.3-1

Table 5.2.3-1: Inflow Probable Maximum Flood (PMFs)

New Reservoir	PMF Modelling (cfs)	Ballpark PMF (cfs)
Equinunk	112,722	112,639
Hawley	142,410	139,666
Little Martins Creek	27,573	28,741
Milanville	101,695	96,447
Rattling River	20,488	23,180
Red Creek	25,157	26,828
Silver Creek	NA	17,900

5.2.3.3 Spillway Design

The spillway for each of the new dams is an ungated, reinforced concrete structure with an ogee crest. The spillway chute and side walls are sized to contain and safely pass the design flood, as prescribed in the Pennsylvania Code Title 25, Chapter 105.94 Spillways.

For this analysis, the PMF previously described above was used as the design flood. The reservoir stage-storage curve was developed and the inflow PMF was routed through the reservoir using a standard time-step method with standard ogee crest discharge parameters. The outputs of this assessment were the expected flood rise in the reservoir and the attenuated maximum PMF outflow, which was used as the spillway design flow. The length of spillway was balanced against the height of the dam needed to contain the flood rise with sufficient freeboard. Given the topography, this typically led to side channel spillways extending upstream of the dam centerline.

The conceptual spillways are embedded in either the left or right abutment and are to be anchored into suitable foundation materials with appropriate drainage beneath the spillway slabs. Excavation for the spillway is estimated to have stable slopes at 1.5H:1V. The spillway is designed to discharge into a stilling basin to reduce the amount of energy as water cascades down the chute before entering the existing waterway.

5.2.3.4 Outlet Design

All reservoirs would be drained by gravity through an intake tower and low-level outlet conduit. According to the Pennsylvania Code Title 25, Chapter 105.96, the outlet works is designed to pass a minimum of 70% of the highest mean monthly inflow plus the capacity to drain the top 2 feet of reservoir storage below the normal pool in 24 hours. The project team has conceptually developed an intake tower with associated controls, piping, and valves housed within the tower. A concrete-encased steel conduit pipe travels through the dam connecting the intake tower to an outlet structure where water releases are to be made. Steel conduits are sized at 42 inches in diameter to accommodate the hydrologic conditions of the reservoir basin. Conduits shown are placed at generally the same elevation through the dam to minimize excavation and discharge into the existing waterway. In all cases, these outlet works could deliver over 400 cfs at NRWS, well in excess of the target minimum rate for flow augmentation of 100 cfs.

5.2.3.5 Pump-in Design

Three projects have very small drainage areas relative to their volume: Red Creek, Silver Creek, and Little Martins Creek. These reservoirs would take several years to fill or refill under natural drainage. Therefore, they require pump-in, increasing the construction and operating cost and complexity. The pump station and pipeline were designed according to procedures detailed for quarries in Sections 5.4.3.

5.2.4 Environmental and Permitting Considerations

Relevant permitting programs are identified in Appendix H. Although the sections below focus on environmental permitting for new dams/reservoirs, much of the discussion applies to other storage project categories as well, so the reader is referred here in those sections.

5.2.4.1 Watershed Context

The current land cover and water resources within the footprint of a reservoir were key factors in assessing its environmental impacts. For example, if the watershed was heavily farmed or a pipeline passed through an urban area, this was not considered to have as heavy an impact as if the watershed was undeveloped.

Each new or expanded reservoir was evaluated according to the watershed physiography and geological setting and how the hydrology of the watershed could impact resources or affect a new water body. This general environmental approach described below in Sections 5.2.4.2 to 5.2.4.4 was also used for quarry and mine storage, presented later in Section 5.4 and 5.5, respectively.

Watershed setting considerations also included development pressure, current and past land use, current and past vegetative cover, existence of special designations, public lands and current water management efforts. A notation of a waterway as “Wild and Scenic” or currently providing public recreational use was noted and considered in each evaluation.

5.2.4.2 Wetlands and Aquatic Habitat

Each potential project was assessed for its potential impact on wetlands and aquatic habitat caused by both construction and operation of the new water source. Evaluation criteria for the environmental aspects of all potential projects are described in Section 4, the Evaluation Criteria.

Generally, new inundation of natural features causes permanent destruction of them, lowers diversity of aquatic organisms and decreases water quality through eutrophication (Power, 1996). If wetlands are present in the proposed impoundment pool area, these wetlands would be a complete loss even though open water would replace them. Stream habitat would be so drastically changed; inundation of the stream would also be considered a loss.

Raising the elevation of an existing impounded waterbody would set back habitat that was relatively recently recreated by the impoundment present within the pool area. These shoreline zones are already disturbed and an additional disturbance will not affect them as much as a pristine ecosystem. Some impoundment shorelines can provide significant aquatic habitat especially if there is an expanded littoral zone, submerged aquatic vegetation or other habitat enhancements. Water pipelines can be installed with trenchless methods across (below) a water body and therefore would have limited effect on the environment.

The evaluation process to understand present wetlands and aquatic habitat included the use of the U.S. Department of the Interior Fish and Wildlife Service (USFWS) National Wetland Inventory (NWI) maps for the area and understanding and comparing the wetland classes to what was photointerpreted on aerial photos. In addition, because NWI maps frequently underestimate wetland acreage, the project team also evaluated USDA Natural Resource Conservation Service SSURGO soils maps for hydric soils or soils that were somewhat poorly drained or alluvial (often these soils make up wetlands), compared them to NWI maps and also photointerpreted obvious wetland and stream signatures. These acreages were included to get closer to the actual areas of potential impacts.

In addition to measuring the length of inundated streams, the project team consulted databases that identified stream classification categories based on either water quality or utilization by and/or reproduction of native trout. It is very difficult or impossible to obtain permits to lower water quality or impact wetlands and streams in the very high-quality categories (i.e., Exceptional Value) watersheds within the Commonwealth of Pennsylvania. The USEPA’s 303(d) list of impaired waters and the trout categories for streams in Pennsylvania, New Jersey and New York were also consulted.

In Pennsylvania, the PADEP develops water quality standards for all surface waters of the state. These standards consist of both use designations and the criteria necessary to protect those uses. Changes in the hydrology of streams will have an impact on the biota that inhabits those streams. Hydroperiod modification includes increased or decreased flow during a particular season, which could affect feeding or reproduction. Determining detailed changes was beyond the scope of this effort.

As part of the water quality standards program, PADEP conducts stream use designation evaluations on an ongoing basis. Evaluations may be conducted on streams or stream segments that are found to be missing from the Chapter 93 water quality standards. All State waters are protected for a designated aquatic-life use as well as water supply and recreational uses. The use designation shown in the water quality standards is the aquatic-life use. These uses include Warm Water Fishes (WWF), Trout Stocking (TSF), Cold Water Fishes (CWF) and Migratory Fishes (MF).

In addition, streams with excellent water quality may be designated High Quality Waters (HQ) or Exceptional Value Waters (EV). The water quality in a HQ stream can be lowered only if a discharge is the result of necessary social or economic development, the water quality criteria are met, and all existing uses of the stream are protected. EV waters are to be protected at their existing quality; water quality shall not be lowered.

In addition to Chapter 93, The Pennsylvania Fish and Boat Commission (PAFBC) designates stream quality based on the incremental quality of that stream for trout. The PAFBC categorizes trout streams as Keystone Select, Special Regulation, Class A, Stocked, and Natural Reproduction. Class A Wild Trout Streams support a population of wild (natural reproduction) trout of sufficient size and abundance to support a long-term and rewarding sport fishery. Wild Trout Waters are designated in sections that support naturally reproducing populations of trout. A wild trout stream section is a biological designation rather than a water quality designation like those in Chapter 93.

Wilderness Trout Streams are categorized somewhat subjectively upon the provision of a wild trout fishing experience in a remote, natural and unspoiled environment where human-disrupting activities are minimized. The streams occur in watersheds of "superior" quality and are considered an important part of the overall experience for anglers. All stream sections that are designated as wilderness trout streams also qualify for the Chapter 93 Exceptional Value (EV) special protected water use classification, which represents the highest protection status provided by the PADEP. It is very difficult or impossible to obtain permits to lower water quality or impact wetlands and streams in the Exceptional Value category.

5.2.4.3 Threatened and Endangered Species

The USFWS Endangered Species Act is the main federal policy that protects endangered species from being in jeopardy of becoming extinct. To evaluate the potential for a site to support endangered species, the following efforts were made:

- USFWS or state databases were queried.
- The habitat within the area of impact was generally evaluated using aerial photographs and public domain data.

The project team consulted the USFWS "Information for Planning and Consultation" database (iPaC, https://ipac.ecosphere.fws.gov/) to identify potential presence of endangered species within the potential impact areas, but did not query the Commonwealth of Pennsylvania website (Pennsylvania Natural Diversity Inventory or PNDI) for state-listed species because of the large number of potential projects and cost of the query. The State of New York Environmental Resource Mapper and the State of New Jersey's GeoWeb were consulted.

Generally, if the site photointerpretation included observation of habitat for a species, the project team included the presence of habitat as a component to seriously consider, e.g., a hit for Northern Long-eared Bats (NLEB) and extensive, unbroken forest was considered a positive indicator for presence of the bats within the area of inundation and destruction of forest habitat the bats utilize in the spring, summer and fall. However, the "hit" for NLEB without the presence of mature, unbroken forest was not considered to be as serious as the former example.

5.2.4.4 Regulatory Context

A new or expanded reservoir footprint (all located in PA or NY) would require:

- Placement of fill within a water of the US as the primary impact, and/or
- Secondary impacts caused by placement of fill resulting in impounding water.

These filling activities require a permit from the US Army Corps of Engineers under the Clean Water Act. Section 404 of the Act regulates placement of dredged or fill material in waters of the US, which includes navigable waters, perennial and intermittent streams, their connected wetlands and wetlands adjacent to them. All of the new/raised reservoirs considered would require a Section 404 permit under the Clean Water Act. In addition, the Commonwealth of Pennsylvania requires a Chapter 105 Dam Safety and Encroachments Act permit for a dam that is 15 feet high or higher at the upstream face, or one that has a watershed of at least 100 acres.

Obtaining these permits involves other federal Acts like the Endangered Species Act, the National Historic Preservation Act, and the Migratory Bird Treaty Act. The Section 404 permit is evaluated according to the Section 404(b)(1) guidelines that also takes into account national parks, wilderness areas, special aquatic sites, and social issues associated with the action. Permitting encumbrances associated with each potential project were not analyzed in detail. Instead, the major complicating features for obtaining a Section 404 permit were evaluated, including regulated wetlands, high-quality streams, public parks and recreation areas, and endangered species.

Withdrawal of water is an activity regulated by the state to account for the impacts on aquatic biota, especially during drought conditions. No interbasin transfers are proposed by the potential storage projects but discharge of water from one waterbody to another would require demonstration of antidegradation of the water quality of receiving water. Because time of year may result in change to water quality parameters and habitat needs of a particular stream, limits to withdrawal or discharge or even pretreatment may be imposed by the regulatory authorities, greatly increasing complexity and cost. Because the detailed regulatory evaluation was not included, only those effects of water sources that could potentially affect the feasibility of a project were evaluated. For example, withdrawal rates may be so severely limited that a potential project is ineffective in meeting project goals. Withdrawal limit was estimated as explained in Appendix C, but it could be more severe.

5.2.5 Social and Economic Impacts

The social and economic impacts that were considered are listed in the criteria section (Section 4). For new reservoirs, the primary impact is displacement of residential buildings, other buildings and infrastructure, which was considered serious for all new reservoirs except for Silver Creek and Rattling Run, which are located in completely undeveloped watersheds. The number of structures that would be inundated were counted via aerial photo and is listed in the evaluation sheet attached to each SPS.

With modern construction and monitoring techniques, a new dam was considered a minor health and safety impact. In general, social equity/environmental justice was not a major impact because the areas where new reservoirs are considered are not overburdened based on the low incidence of industrial facilities near the potential reservoir sites. Loss of recreational and cultural/historic resources was also not expected to be a major impact; however, detailed studies of each site would be required to confirm these presumptions. Similarly, given the small footprint of a reservoir relative to total area in the vicinity, loss of production or tax revenue from the inundated land was considered minor in all cases. Emission of greenhouse gases could be significant given the earth-moving required to construct a large dam.

5.2.6 Project Cost and Schedule

Conceptual capital cost estimates were developed for each potential project in 2022 dollars covering construction and land costs. Estimates for all projects are approximate – American Association of Cost Engineers (AACE) Level 4 with uncertainty of +50%, which the AACE recommends for feasibility studies (AACE, 2005). Annual operation costs were also estimated and added to capital costs assuming 3% annual rate for 30 years to express total cost as present value (PV).

Cost estimates were based on quantities taken from the concept design drawings and calculations. Construction activities were identified for each key project component and summarized below. Contractor allowances include environmental, materials testing, contractor indirect costs, and profit were applied as a function of the subtotal of the key project components. Design and construction contingencies were applied to the key project components and contractor allowances. The conceptual cost estimate total is the sum of the key project components, contractor allowances, and contingencies. The cost estimate total is rounded up to the nearest $1,000. Construction line items and associated unit costs can be found in the SPS located in Appendix A. The unit rates developed are conservative based upon recent completed reservoir projects, cost estimates for projects currently under design, available cost estimating literature (RS Means publications), project reports (Altoona Water Authority, 2010) and experience on prior projects (confidential clients). The estimate cost categories and rates are summarized in the following Table 5.2.9-1.

Table 5.2.9-1: Construction Cost Category and Unit Rates

Description	Unit	Rate	Comments/Typcial values
1.0 Dam			
1.1 Excavation	CY	$ 20.00	Main Dam + Saddle Dam
1.2 Grout Curtain	SF	$ 110.00	
1.3 Core Material	CY	$ 25.00	Core borrow area near dam site
1.4 Filter Material	CY	$ 90.00	Imported material
1.5 Dam Shell Material	CY	$ 30.00	Shell borrow area near dam site, Main Dam + Saddle Dam
1.6 Riprap	CY	$ 200.00	Improted Material, Main Dam + Saddle Dam
1.7 Hydroseed	SF	$ 0.50	Main Dam + Saddle Dam
2.0 Spillway			
2.1 Excavation	CY	$ 30.00	
2.2 Spillway Slab	CY	$ 850.00	
2.3 Spillway Walls	CY	$ 1,100.00	
2.4 Anchors	EA	$ 2,500.00	Approx 10' spacing
2.5 Drainage Layer	CY	$ 90.00	Slot trench every 50' of spillway chute
2.6 Drainage Pipes	LF	$ 100.00	
2.7 Stilling Basin	CY	$ 1,000.00	200' long x with 20' additional wall height
3.0 Outlet Works			
3.1 Outlet Pipeline and Installation	LF	$ 2,000.00	
3.2 Outlet Tower and Installation	10' Segment	$ 250,000.00	
4.0 Access Roads			
4.1 New Roads	Mile	$ 600,000.00	Estimated from nearby existing road to key project components
5.0 Key Project Components Subtotal			
5.1 Sum 1.0 thru 4.0	Subtotal		
6.0 Contractor Allowances			
6.1 Environmental Allowance: Rate x 5.0	Rate	2%	
6.2 Materials Testing (QA/QC): Rate x 5.0	Rate	2%	
6.3 Contractor Indirect Costs: Rate x 5.0	Rate	25%	
6.4 Profit: Rate x (5.0 + 6.1 + 6.2 + 6.3)	Rate	10%	
7.0 Contingencies			
8.1 Design Contingency: Rate x (5.0 + 6.0)	Rate	25%	
8.2 Construction Contingency: Rate x (5.0 + 6.0)	Rate	20%	
8.0 Conceptual Cost Estimate Total			
8.1 Sum 5.0 thru 7.0	Total		

In developing the above costs, the following general assumptions were made:

- Unit rates developed are the same for each reservoir location for consistency.
- Fill for the dam embankment core and shells would be sourced from borrow sites on-site near the dam location.
- Core material was estimated to be less than shell material due to the core material being easier to excavate than shell material, which may require more atypical excavation methods, such as blasting.
- The grout curtain was estimated to have a depth of ½ the height of the dam along the dam foundation and abutments.
- Spillway excavation was estimated to have a higher unit rate due to excavation occurring on steeper slopes than the dam foundation.
- Spillway walls were estimated to have higher unit rates than spillway slabs due to the additional reinforcement and form work required for construction.
- Spillway anchors were estimated to extend 20 feet into competent bedrock materials and generally at 10-foot spacing.
- The cost of the outlet tower was estimated and scaled based on a 2010 report on the Mill Run Dam in Blair County PA (Altoona Water Authority, 2010) which specifies a cost of $2 million for a 92-foot tower.

- The cost of the outlet conduit includes encasing the pipe in concrete through the dam.
- Road unit costs may vary based on the amount of cut and fill required to develop associated roads. The unit cost used is an estimate for roads requiring limited cut and fill.

Land costs were estimated based on the measured footprint of the NRWS. Two classes of costs were considered: residential buildings and land (commercial buildings were very rare on all projects). The potential projects were divided into three regions: Upper Schuylkill (comprising Red Creek, Silver Creek and Ratting Run), Upper Basin (Equinunk, Milanville and Hawley) and Little Martins Creek. The representative costs for the three regions are presented in Table 5.2.9-2. The number of residential buildings to be inundated at the NRWS was counted on an aerial photo for each potential project. This number was multiplied by a representative cost for a house in the region, estimated as the median list price of houses for sale (with lot size < 2 ac) in the region according to zillow.com. Similarly, the cost estimate for land was computed based on the median cost per acre of undeveloped rural land > 5 ac as listed on zillow.com. While these estimates are approximate, in all cases, the estimated land costs were very small relative to dam construction costs, so inaccuracy of land costs would not greatly affect overall costs.

Table 5.2.9-2: Land Acquisition Cost Parameters

	Residential House			Land	
Region	**Num. listings**	**Median cost**		**Num. listings**	**Median cost/ac**
Schuylkill (Red Cr, Silver Cr., Rattling Run)	106	$ 212,200		53	$ 11,246
Upper Basin (Hawley/Equinunk/Milanville)	52	$ 282,500		53	$ 8,000
L. Martins Creek	64	$ 489,450		14	$ 17,877

The estimated schedule for potential new reservoirs is also very rough. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition. Fifteen years was the typical estimate for a new dam:

- Funding acquisition 5 years
- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup 2 years
- Total 15 years

5.2.7 Potential Ancillary Benefits

For these new reservoirs, the primary ancillary benefits relate to recreation/tourism and fish habitat. In some locales, the new reservoir would be the only such facility in the vicinity. Such an amenity may support development of tourist and recreation-oriented businesses, providing jobs and increased tax revenue. The reservoir could also raise the value of surrounding property.

A reservoir would create a large lake habitat, albeit at the expense of replacing stream habitat. The likelihood of eutrophication threatens to degrade the lake's habitat quality. Plus, when a long-term release is necessary, the reservoir level could remain low for months, reducing habitat.

As conceived, these reservoirs would not offer significant benefits regarding flood control because they would normally be kept full and because they all have relatively small drainage areas (83 sq. mi. maximum).

5.3 Existing Reservoirs

Eight existing reservoir projects passed through the initial screening (refer to Figure 5.3.1-1 and Tables 5.3.1-1 and 5.3.1-2). These reservoirs were considered for two types of storage projects: increasing the amount of storage by raising normal water level and transfer of control or ownership of existing storage. Four fell into the former type and four into the latter (one reservoir, Wild Creek, is in both). In both storage project types, the increased or reallocated storage would be controlled by the DRBC and released upon request to augment flow. Re-allocation or transferred storage should not be considered new storage, unlike other presented storage project types. However, it does present accessible storage under different controls than currently available to DRBC.

5.3.1 Project Research and Overview

Previous reports, owner interviews, topographic maps and aerial photos were used to develop the projects. The information readily available from the owners or public reports varied considerably, as detailed in each SPS. For example, excellent detail was available from publicly available USACE Operations Manuals for Blue Marsh and Prompton dams/reservoirs. Where engineering drawings of dams were not obtainable (e.g., Mongaup system and Lake Ontelaunee), concept designing/costing a dam raise was not feasible, so only transfer of control was considered.

Regarding transfer of control of existing storage, an important variable is the cost associated with storage reallocation, which was challenging to estimate based on available data. This was further complicated because water allocation arrangements are typically for delivery on a regular basis, rather than continuous storage of water for an irregular and infrequent release. The project team investigated several existing arrangements to try to estimate costs for this transferrable storage. This effort is described in a separate Technical Memorandum (refer to Appendix B).

Figure 5.3.1-1: Evaluated Projects in Existing Reservoirs: Storage-Increase (E) and Transferable Storage (T)

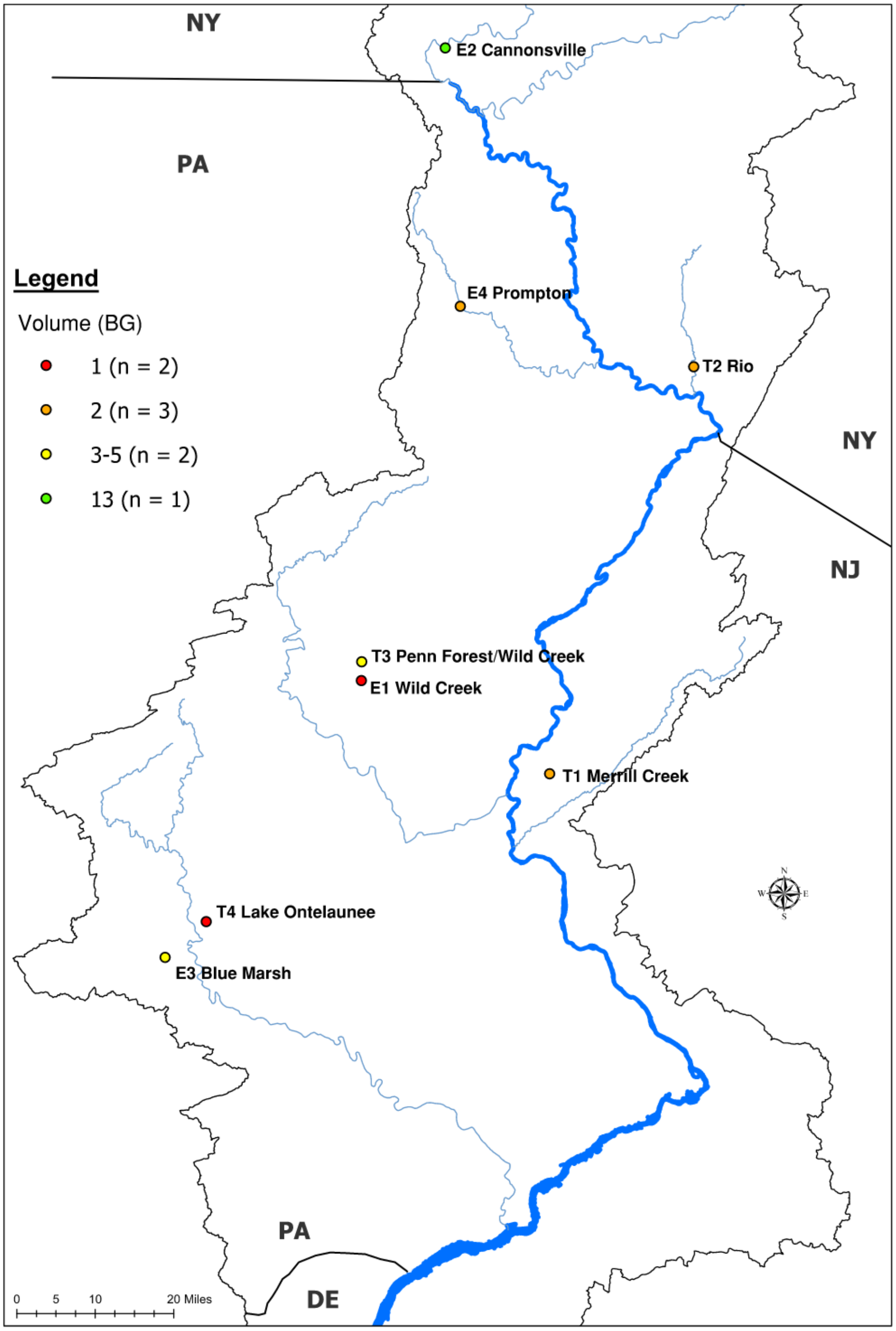


Table 5.3.1-1: Parameters of Storage-Increase Projects in Existing Reservoirs

ID	Project Name	Owner/ Manager	State	County	Sub-watershed	Stream	Volume Increase, BG	Days of Augment at 100 cfs	Water Level Increase, ft	Flooded Area Increase NRWS, ac	Drainage Area, sq mi	Mean Annual Flow, cfs	Time to Fill, months (gravity)
E1	Wild creek	Bethlehem Authority/ City	PA	Carbon	Lehigh	Wild Creek	1	15	10	45	22	51	1.0
E2	Cannonsville	NYC /NYCDEP	NY	Delaware	Upper Delaware	West Branch, Delaware River	13	201	8	450	456	486	1.4
E3	Blue Marsh	USACE	PA	Berks	Schuylkill	Tulpehocken Creek	5	77	12	580	44	77	3
E4	Prompton	USACE	PA	Wayne	Lacka-waxen	West Branch Lackawaxen River	2	31	15	115	57	112	0.9

Table 5.3.1-2: Parameters of Transferable-Storage Projects in Existing Reservoirs

ID	Project Name	Owner/ Manager	State	County	Sub-watershed	Stream	Estimated Available Volume (BG)	Days of augmentation at 100 cfs
T1	Merrill Creek	Merrill Creek Owners Group	NJ	Warren	Mid Delaware	Merrill Creek	2	31
T2	Rio	Eagle Creek	NY	Sullivan	Mongaup	Mongaup River	2	31
T4	Lake Ontelaunee	Reading Area Water Authority	PA	Berks	Schuylkill	Maiden Creek	1	15
T3	Penn Forest/Wild creek	Bethlehem Authority/ City	PA	Carbon	Lehigh	Wild Creek	3	46

5.3.2 Water Quantity and Quality

The storage volume provided by the potential projects in this storage category was modest in most cases (3 BG or less), with the exception of the Blue Marsh raise (5 BG) and Cannonsville raise (13 BG). In the transferable-storage projects, owners were hesitant to specify a volume that would be available and the cost thereof, so the project team estimated conservatively and assigned an estimated value for transferrable storage. As with the new reservoirs, water quality was expected to be satisfactory to support flow-augmentation in all cases.

5.3.3 Infrastructure Design, Construction and Operation

The four transfer projects were assumed to require no new infrastructure nor incur any additional costs for operation. The type and extent of infrastructure of projects involving a storage increase was particular to each project. For example, Blue Marsh would require raising the main dam and spillway plus four auxiliary dikes by twelve feet and reconstruction of many bridges and roads, while Cannonsville was mostly limited to installation of movable gates on top of the existing spillway, plus a short parapet wall atop the existing dam. This infrastructure is discussed and costed in detail in each SPS. The existing outlet works were assumed adequate in all cases. No pump-in facilities would be required.

5.3.4 Environmental and Permitting Considerations

The environmental impacts of the transferable-storage projects were judged to be negligible because the inundated area would not change and no permits would likely be required. For the storage-increase potential projects, the types of environmental impacts are similar to those of new reservoirs discussed above, but the area affected would typically be much less. However, because they would inundate existing ecological resources like streams and forests, impacts would still be significant and, in some cases, would affect up to 480 acres.

5.3.5 Social and Economic Impacts

The impacts of transfer projects were negligible because the inundated area would not change. As for storage increase, in most cases the land around the existing reservoir is mostly undeveloped, so impacts for all projects were minor, except for Blue Marsh.

5.3.6 Project Cost and Schedule

Cost estimates for modifications were developed as described in section 5.2.6. Cost and cost effectiveness varied widely. While the construction and land acquisition costs for the transfer projects were zero, the estimated costs demanded by owners to reallocate and hold the water were substantial, hindering the cost-effectiveness of projects. While the schedule to complete was favorable for most projects, the complications of federal regulations worked against the two projects owned by USACE.

The typical estimated schedule is 10 years for dam raise projects, compared to 15 years on the new dam projects as shown below. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, legal complications, or political opposition.

- Funding acquisition — 3 years
- Design, permitting and land acquisition — 2 years

- Construction 3 years
- Startup 2 years
- Total 10 years

The schedule for transfer projects could be much shorter but is difficult to estimate because it depends on the owner's situation. One year was assumed.

5.3.7 Potential Ancillary Benefits

The potential ancillary benefits were low overall for all potential projects in the category. The increased reservoir area associated with a dam raise would be minor relative to the existing area, so recreational or habitat expansion are not significant. The Cannonsville project may have an important flood control benefit if it could be strategically operated to respond to forecasts of large storms.

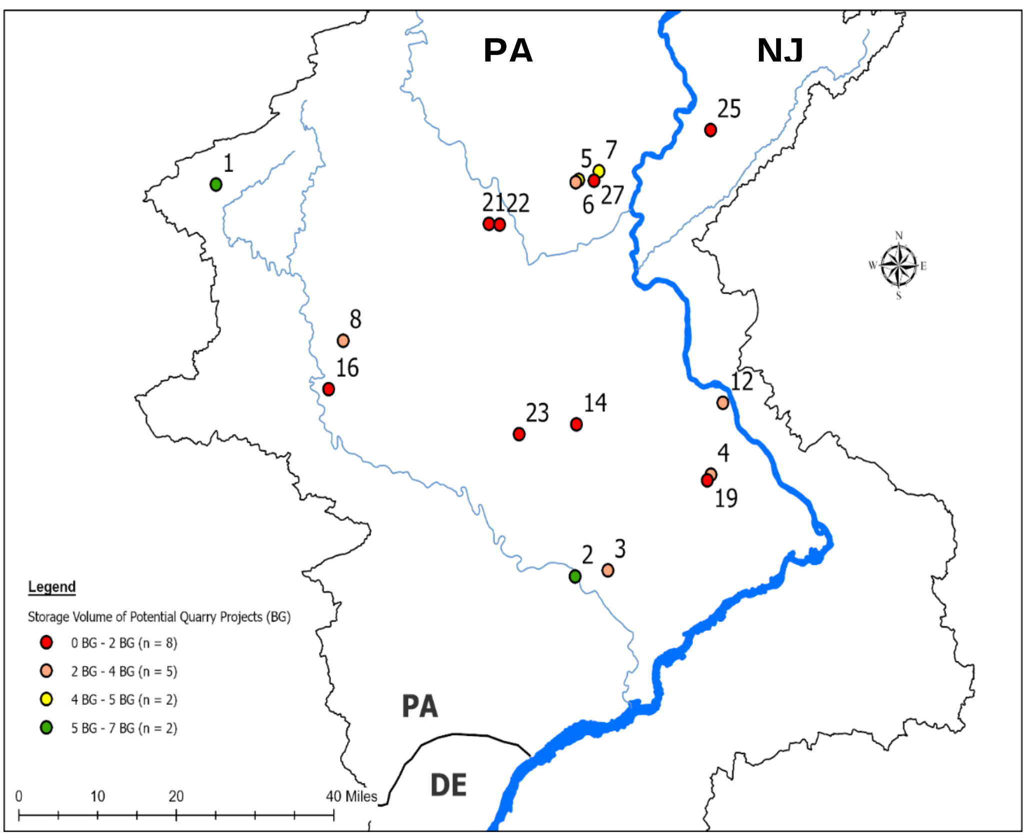
5.4 Quarries

Quarry water supply envisioned an available volume in the quarry and supply from a nearby stream. This required additional research, volume estimates and determining available sources of water supply to fill and replenish the quarry as needed.

5.4.1 Project Research and Overview

The initial screening and supplemental screening of quarry projects reduced the dataset for project characterization to 18 potential projects. These locations are shown in Figure 5.4-1.

Figure 5.4-1: Eighteen Potential Quarry Projects selected for Project Characterization and Evaluation (See Table 5.4.2-1 for names and details)



Each potential project was further researched to collect available data for the project characterization phase. This included additional on-line research, further review of permitting databases, contacts with one facility owner/operator and a PADEP file review. Further, the nature of the potential quarry inflow and subsequent discharge required a detailed understanding of sources of supply and the configuration of any pumping or gravity systems.

Research was also performed to determine where similar quarry storage facilities were in operation or planned outside the Basin to support developing the quarry storage concepts. This research included some notable examples below:

- Billmeyer Quarry – This quarry is currently undergoing study and development by the Susquehanna River Basin Commission. It is a 500 MG quarry adjacent to the Susquehanna River. Work to date has involved hydraulic studies, environmental studies and concepts for pumping. Additional quarry storage assessments have been performed by PADEP (PADEP, 2005).
- Travilah Quarry – This quarry was evaluated for raw water storage to augment Potomac River water supply. Quarry volume is approximately 6 BG and involves some complex water transfer systems (Black & Veatch, 2014).
- Vulcan Quarry – This quarry is an effort by Fairfax Water to provide future water storage and supply in the growing Northern Virginia region. The first phase is planned for 1.8 BG with an eventual buildout of up to 15 BG (Fairfax Water, 2016).

The following section describes the project characterization for quarries as a potential storage project. The 18 developed projects are described in detail in the SPSs located in Appendix A. The following subsections describe the common approach to the projects and summarize the general findings, as detailed further in the SPSs.

5.4.2 Water Quantity and Quality

Water quantity and quality covers storage in the quarry (Section 5.4.2.1), withdrawal from the supply stream (Section 5.4.2.2), and discharge back to the receiving stream (Section 5.4.2.3). Details are discussed in the following sections.

5.4.2.1 Storage

Quarry storage volume was based on the existing quarry topography, as determined from available data, and generally assumed no modification to the facility to increase the volume. Such modifications could include future mining to deepen the facility or modifications to the low areas of the existing rim to further impound water.

The total storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access (PASDA) or other state GIS data sources. AutoCAD Civil 3D 2020 was utilized to create surfaces and calculate the available volume in the quarry. In regions where the topographic data appeared to be outdated, point elevations from Google Earth were used to refine volumes within the quarry. The top elevation of full storage was assumed to be the stated rim elevation with an approximate freeboard of 10ft. The maximum operational volume available for useable storage was assumed to extend from the assigned stored water level to approximately 20% of the available total depth or approximately 80% of the maximum volume. This was to consider declining water quality with depth, concerns for quarry stability with drawdown, and potential interaction with the surrounding groundwater. The interaction with the surrounding groundwater needs to be further understood. However, the project team believes the stated assumptions for this level of planning study are sufficient. Key parameters associated with each quarry are presented in Table 5.4.2-1.

Table 5.4.2-1: 18 Potential Quarry Projects that were Evaluated

Project #	Project Owner and/or Name	County	State	Area (acres)	Rim Elev. (feet)	Bottom Elev. (feet)	Depth (feet)	Total Vol. (ac-ft)	Total Vol (BG)
Q1	Wadesville Mine Pit	Schuylkill	PA	182	780	380	400	36,337	6.9
Q2	Glasgow Mccoy	Montgomery	PA	123	70	-237	307	18,885	6.2
Q3	Highway Materials Plymouth Mtg	Montgomery	PA	122	160	-107	267	16,242	3.5
Q4	Hanson Aggregates Penns Park	Bucks	PA	87	180	-138	318	13,792	3.3
Q5	Lehigh Cement Nazareth	Northampton	PA	102	450	220	230	11,755	4.2
Q6	Lehigh Cement Imperial	Northampton	PA	71	400	114	286	10,202	3.8
Q7B&D	Buzzi Unicem Stockertown	Northampton	PA	120	300	65	235	14,101	4.6
Q8	Lehigh Cement Evansville	Berks	PA	88	320	86	234	10,318	3.1
Q12	New Hope Solebury	Bucks	PA	82	100	-100	200	8,161	2.3
Q14	M & M Stone Telford	Bucks	PA	20	300	50	250	2,500	1.0
Q16	Berks Prod Temple	Bucks	PA	42	280	130.0	150	3,150	1.0
Q19	Eureka Rush Valley	Bucks	PA	97	160	50	110	5,325	1.7
Q21	New Enterprise Stone & Lime Ormrod	Lehigh	PA	87	350	240	110	4,792	1.3
Q22	New Enterprise Stone & Lime Whitehall	Lehigh	PA	62	360	240	120	3,724	1.2
Q23	Highway Materials Perkiomenville	Montgomery	PA	33	200	-20	220	3,580	1.0
Q25	Tilcon New Jersey/Oxford	Warren	NJ	64	530	370	160	5,120	1.2
Q27	New Enterprise Stone & Lime Nazareth	Northampton	PA	151	380	320	60	4,541	1.5

5.4.2.2 Supply

Unlike most other storage projects with natural inflow, the quarries require a source of water supply to fill the quarry storage. In some cases, multiple stream sources were available. The team reviewed projects using USGS StreamStats at all locations to determine stream flow and available source water. Supply streams were selected and further analyzed for suitability. Table 5.4.2-2 provides detailed information about the supply streams.

Table 5.4.2-2 Key Source Stream Information

Project ID	Project Name	County	State	SubBasin HUC8	Closest Stream	Drainage Area (sq. mi.)	Mean Annual Flow (cfs)	7Q10 Flow (cfs)	Bank Full Flow (cfs)
Q1	Wadesville Mine Pit	Schuylkill	PA	182	Mill Cr	20	44	4	801
Q2	Glasgow Mccoy	Montgomery	PA	123	Schuylkill River	1770	2,910	360	29800
Q3	Highway Materials Plymouth Mtg	Montgomery	PA	122	Wissahickon Cr	48	72	3	2540
Q4	Hanson Aggregates Penns Park	Bucks	PA	87	Neshaminy Cr	156	228	1	6520
Q5	Lehigh Cement Nazareth	Northampton	PA	102	Coplay Cr	31	49	2	999
Q6	Lehigh Cement Imperial	Northampton	PA	71	Monocacy Cr	31	49	2	999
Q7B	Buzzi Unicem Stockertown (Bushkill Cr)	Northampton	PA	120	Bushkill Cr	31	48	2	42
Q7D	Buzzi Unicem Stockertown (Delaware R)	Northampton	PA	120	Delaware River	6670	12,400	1560	167000
Q8	Lehigh Cement Evansville	Berks	PA	88	Maiden Cr	182	292	26	4030
Q12	New Hope -- Solebury	Bucks	PA	82	Delaware River	6670	12,400	1560	167000
Q14	M & M Stone Telford	Bucks	PA	20	E. Perkiomen Cr	36	53	1	2830
Q16	Berks Prod Temple	Bucks	PA	42	Laurel Run	648	1,190	153	12000
Q19	Eureka Rush Valley	Bucks	PA	97	Neshaminy Cr	156	228	5	6520
Q21	New Enterprise Stone & Lime Ormrod	Lehigh	PA	87	Coplay Cr	940	1,880	194	18300
Q22	New Enterprise Stone & Lime Whitehall	Lehigh	PA	62	Coplay Cr	985	1,950	208	18600
Q23	Highway Materials Perkiomenville	Montgomery	PA	33	Unami Cr	49	75	3	3470
Q25	Tilcon New Jersey/Oxford	Warren	NJ	64	Pequest River	115	198	65	2610
Q27	New Enterprise Stone & Lime Nazareth	Northampton	PA	151	Schoeneck Cr	31	49	2	999

The project team established two key design parameters for quarry supply, storage and subsequent discharge. The first criteria established 50 cfs (~32 mgd) to be the target flow rate when discharging from storage back to the source stream. This was based on other similar releases elsewhere and a practical flow rate of a pumping station. The second criterion was to fill the periodically depleted storage within a 6-month target period. The quarry was assumed to be periodically filled during the wetter winter months, after being drawn down from release. The need to fill the depleted storage within the 6-month period was balanced with the ability of the lower flow streams to yield sufficient supply.

As shown in Table 5.4.2-2 most of the source streams have high flows and will not restrict withdrawal. This allows the storage to be completely replenished during the winter months or withdrawn continuously at a constant rate. In contrast, small flow streams present a challenge and can limit withdrawal to times of high flow and require variable withdrawal rates. To estimate an average allowable withdrawal rate at each project, the team analyzed stream flow patterns in gaged streams in the region. The team determined the average of the median of the monthly flows and expressed that as a percentage of the mean flow throughout the year. The average of the wetter month’s values provided a percentage of the mean flow that, on average, could be safely withdrawn from the source stream during the wetter months and still maintain adequate pass-by flow. Technical Memorandum - *Representative Pattern of Monthly Flow in Streams in the Delaware River Basin,* located in Appendix C, describes in more detail this approach used to estimate the withdrawal rate and the limiting criteria for low-flow streams.

Subsequent sections will address how pumping rates were established relative to available stream flow.

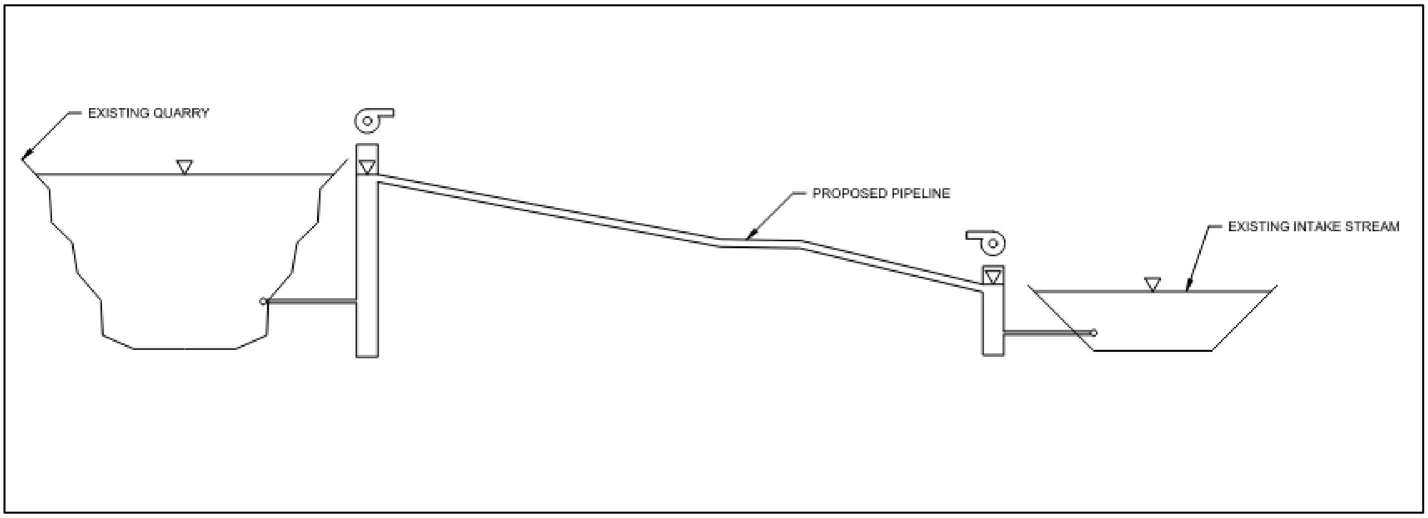
5.4.2.3 Water Quality

Water quality of quarry storage discharge back to the receiving stream was assumed to be similar to the withdrawn water quality when the storage was originally filled. Water quality may change while withdrawn water remains in storage (i. e., settling of solids, temperature changes, stratification, mixing with ground water, oxidation/reduction, eutrophication), but, because other impounded waters (which are subject to the same processes) are currently used for flow augmentation, water quality in quarries is expected to be acceptable for discharge to the source stream when needed. Water quality for all supply sources was compared to the 303D listing as well as the Chapter 93 designation to get an overall estimate of source water quality. This information is noted for the individual potential projects in their SPS.

5.4.3 Infrastructure Design, Construction and Operation

The project team considered several infrastructure alternatives to withdraw water from the source stream and subsequently discharge from storage back to the receiving stream. Figure 5.4.3-1 presents a concept schematic of the typical system components.

Figure 5.4.3-1: Source Withdrawal and Discharge Schematic

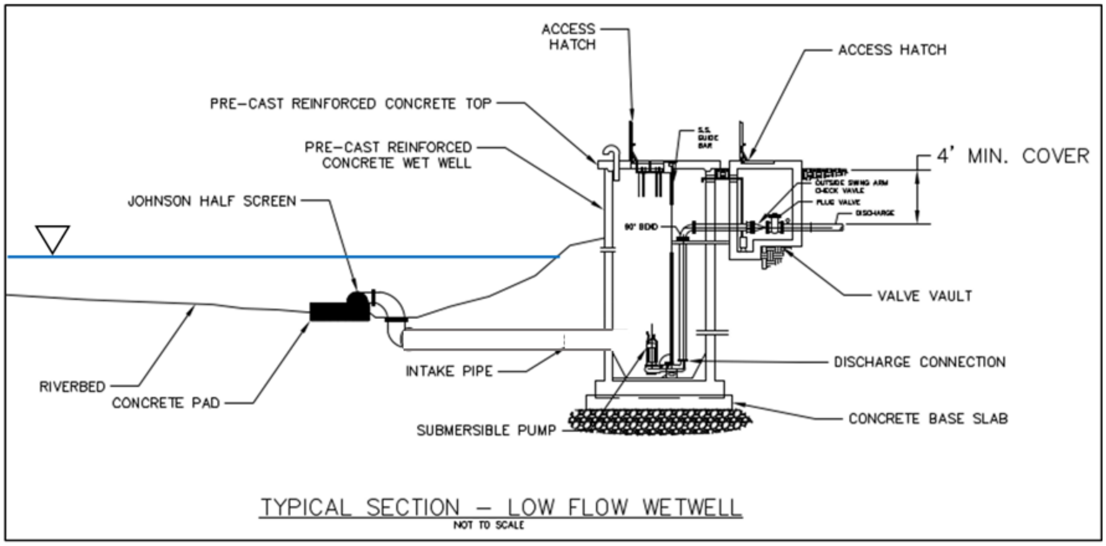


While all quarry projects were different, there were several key similarities in pumping when considering the infrastructure needs. The project team evaluated several water intake and pumping system types. It was concluded that a comparable system of intake screens, wetwells and submersible pumps would be a suitable alternative and could be applied uniformly to all projects with some scalable adjustments based on site conditions, principally in units and quantities. The following sections and accompanying graphics present these common system elements.

5.4.3.1 Stream Supply

Stream supply infrastructure can be separated into a screened intake in the stream, the high-lift withdrawal pumps and associated facilities. Figure 5.4.3-2 below shows a schematic of the stream withdrawal infrastructure. Additional detailed drawings are provided in Appendix F.

Figure 5.4.3-2: Source Withdrawal Design Concept

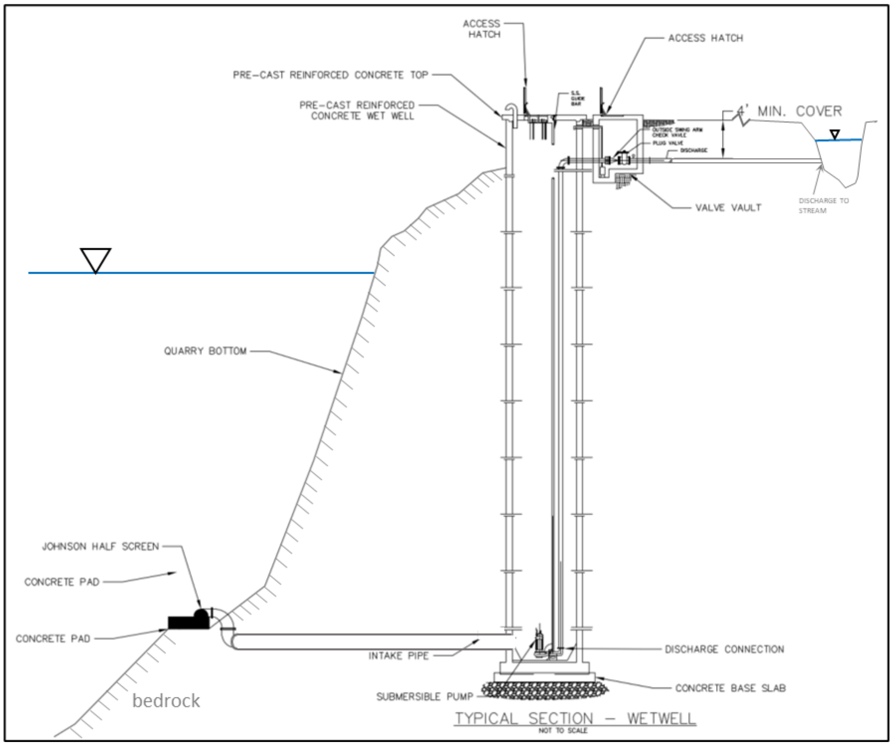


The stream intake consists of wedgewire half screens fixed to the stream bottom. Screens would be designed to limit impingement velocity (<0.5fps) and have sufficient submergence. This is a typical installation and modular for accommodating larger facilities. Intake screens would be equipped with means to minimize clogging (air backpulse systems). As shown, an intake pipe connects the screens to the precast
concrete wetwell that will house the high-lift pumps. The wetwell will contain supported (rails/cables) pumps with requisite electrical and discharge piping. The number of pumps will vary based on the flow needs and specific head conditions. Valving and piping would be as typical. Electrical, mechanical, instrumentation and controls would be housed in a small adjacent structure. Systems would allow for un-manned operation.

5.4.3.2 Quarry Discharge

The quarry discharge pumping system creates some specific challenges in that the pumping head conditions change as the water level in the quarry is drawn down. The discharge heads to overcome can be significant. The project team considered several pumping system types (centrifugal pumps, multi-stage canned pumps, floating pump platforms, mine pumps, etc.). The team converged on a wetwell/submersible system approach similar to the intake, albeit with more involved construction and more complex components. Refer to Figure 5.4.3-3 for a schematic of the discharge pumping system configuration. Additional detailed drawings are provided in Appendix F.

Figure 5.4.3-3: Quarry Discharge Design Concept



The quarry discharge system includes a deep shaft for the wetwell, connecting conveyance to the quarry source water, pumps and associated above grade facilities. The shaft would be mined in rock to an elevation below the quarry low-water level, and sized in diameter to accommodate the needed pumping components. Several shaft construction methods could be used, but conventional drill and blast excavation with structural support is envisioned. A conveyance conduit would connect the shaft/wetwell to the quarry water source. This is assumed to be installed before quarry filling and would likely be installed with trenchless technology. Only minor screening of the quarry intake line is envisioned.

The shaft/wetwell would be fitted with high-head submersible pumps able to operate at the varying quarry water levels. A manufacturer's brochure for a typical pump is provided in Appendix G. Multiple pumps, sized based on flow requirements, would be installed. The balance of mechanical, electrical and instrumentation equipment would be installed and protected in a weatherproof structure at the quarry rim. The pumping stations would be connected by the requisite pipeline. Table 5.4.3-4 below provides a summary of the hydraulic parameters for the quarry storage projects.

Table 5.4.3-4: Source Withdrawal and Quarry Discharge Design Concept

Project ID	Name	Withdrawal Flow Rate (mgd)	Withdrawal Pump Configuration (X# by Y mgd)	Discharge Flow Rate (mgd)	Discharge Pump Configuration (X# by Y mgd)
Q1	Wadesville Mine Pit	11.4	3 x 6	32	11 x 2.9
Q2	Glasgow Mccoy	31.0	3 x 10.4	36	5 x 7.4
Q3	Highway Materials Plymouth Mtg	18.7	3 x 9	32	5 x 7.2
Q4	Hanson Aggregates Penns Park	31.0	3 x 9.6	32	5 x 7.2
Q5	Lehigh Cement Nazareth	12.5	3 x 6	31	4 x 8.6
Q6	Lehigh Cement Imperial	19	3 x 6	32	5 x 7.2
Q7B	Buzzi Unicem Stockertown (Bushkill Cr)	18	3 x 6	32	4 x 8.6
Q7D	Buzzi Unicem Stockertown (Delaware R)	31.0	3 x 10	32	4 x 8.6
Q8	Lehigh Cement Evansville	31.0	3 x 10	32	4 x 8.6
Q12	New Hope -- Solebury	31.0	3 x 10	32	4 x 8.6
Q14	M & M Stone Telford	13.7	3 x 7	31	4 x 10.1
Q16	Berks Prod Temple	31.0	3 x 10	32	4 x 10.1
Q19	Eureka Rush Valley	31.0	3 x 10	31	4 x 8.6
Q21	New Enterprise Stone & Lime Ormrod	31.0	3 x 10	32	4 x 8.6
Q22	New Enterprise Stone & Lime Whitehall	31.0	3 x 10	32	4 x 8.6
Q23	Highway Materials Perkiomenville	19.4	3 x 10	32	4 x 8.6
Q25	Tilcon New Jersey/Oxford	31.0	4 x 9	32	4 x 8.6
Q27	New Enterprise Stone & Lime Nazareth	12.5	3 x 6	32	3 x 11.5

5.4.3.3 Connecting Pipeline

The pipeline connects the stream withdrawal pumping facilities and the quarry discharge pumping facilities and can vary in diameter and length based on the specific site. Pipe diameter was selected based on flow and limiting velocities, as typical. In most cases, the same pipe would be used for fill and discharge. Ductile Iron Pipe (DIP) was selected for consistency and ease of estimating. Other pipe types (HDPE, PVC, etc.) may be more economical. Typical open-cut installation is assumed. Ancillary pipeline facilities such as isolation valves were also considered and included in project cost estimates.

5.4.3.4 Construction and Operations

Construction of the envisioned facilities was discussed in the previous sections. Standard construction methods are assumed. Site-specific construction method variations, particularly in instances where gravity feed/withdrawal and trenchless pipe installation methods are considered, are described in more detail in the individual SPSs.

Operation of the facilities is anticipated to be “un-manned” through remote monitoring and control, similar to typical potable water supply facilities. Unlike potable water facilities, these pumping systems only run intermittently and could be shut down for many months. Maintenance and periodic startup would need to be considered for such intermittent facilities.

The periodic operations of both fill and discharge facilities suggests that temporary pumping facilities or contracted operations may be worthwhile. The team briefly reviewed temporary pumping. High-flow, high-head temporary systems are a challenge, but should be considered if quarry storage is further advanced. Similarly, contract operations may be a cost-effective alternative and should also be further considered.

5.4.4 Environmental and Permitting Considerations

The quarries, like other storage categories, were reviewed for potential environmental impacts and permitting concerns. The potential environmental impacts considered wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. The projects, including any pipeline route, were reviewed at a cursory level against available databases as described in Section 5.2.4 and potential issues noted for subsequent scoring.

The quarries are a somewhat different storage category when compared to reservoirs and other types in terms of potential environmental issues and permitting consideration. The potential for environmental impacts is generally less than other categories since the previously mined void is proposed to be filled with water and environmental impacts are less likely. Interaction with the groundwater table needs to be understood and potential for surface water quality changes exists, albeit minor. In addition to potential impacts identified from project review and comparison with available databases, the review also considered the potential for hydromodification or stream impacts, particularly related to projects with low-flow streams for source water and accepting subsequent discharge from the quarry. Other potential environmental impacts were considered when evaluating quarries and used the standard approach outlined in Section 5.2.4 and the scoring matrix as described earlier in Section 4. Again, in general, the quarries scored favorably relative to the other storage categories. Permit issues were described in Section 5.2.4 and Appendix H. While an involved permitting process is anticipated, permits are expected to be attainable, and also expected to be less involved than permitting for a new reservoir or major dam/reservoir modification.

5.4.5 Social and Economic Considerations

The social and economic impacts that were considered are listed in the criteria section (Section 4). The quarry storage category scored favorably on this criterion. However, in most cases of active quarrying, there could be a negative economic impact if operations were to cease.

5.4.6 Project Cost and Schedule

Project cost and schedule were developed similarly to other storage types. However, the quarries have proportionately more and varied mechanical infrastructure that must be considered. Also, operations of these quarry facilities are an important component of present value. Consequently, the quarry storage cost estimates required some additional detail. Table 5.4.6-1 provides a summary of the principal construction cost categories and a brief description of each.

Table 5.4.6-1: Quarry Construction Cost Categories

Item	Unit
FILL PUMPING STATION	
Intake	
Screens	This lump sum (LS) is for wedgewire intake screens; quantities based on flow requirements
Structure	This vertical foot (VF) cost approximates the materials and labor for wetwell construction
Other	This lump sum (LS) covers ancillary costs
Pumping Station	
Pumps	Number of pumps in the wetwell and cost per pump
MEP	This lump sum (LS) approximates cost for mechanical, electrical and plumbing
Structure	This per square foot (SF) approximates the cost for enclosures
Other	This lump sum (LS) assigns other costs as mentioned in the SPS
Dissipation	This lump sum (LS) assigns other costs for dissipation protection back at the stream
PIPELINE	
Pipeline	This per lineal foot (LF) cost estimates all cost for pipe installation
Valves	This cost estimates ancillary facilities for the pipeline, particularly values
DISCHARGE PUMPING SYSTEM	
Intake Structure	This vertical foot (VF) cost approximates the materials and labor for wetwell construction
Pumping Station	This estimates the facility cost of the pumping station
Pumps	Number of pumps in the wetwell and cost per pump
MEP	This lump sum (LS) approximates cost for mechanical, electrical and plumbing
Structure	This per square foot (SF) approximates the cost for enclosures
Electrical Service	This lump sum (LS) approximates electrical service requirements
Other	This lump sum (LS) approximates other required items as mentioned in the SPS
Treatment	This lump sum (LS) approximates any treatment cost
ACCESS ROADS	
New roads	This per-mile cost approximates needs for roads and site work
LAND ACQUISITION	
Inundation Area	Note-land acquisitions is site dependent and addressed separately in the SPS
SUBTOTALS	
Construction Costs Subtotal	Represents construction cost only
Contingency	50% contingency based on the level of concept design in this study
CONST. COST + CONTINGENCY	Total and Contingency amount

Several other cost items required additional explanation. The total construction cost includes a +50% contingency commensurate with the concept level or schematic design detail (AACE Level 4). Land costs were estimated for the quarry projects based on available information in county tax assessment databases. In some cases, no information was available, so an approximate market value was used based on comparable quarry sites in the area. The quarry storage projects typically require active pumping to fill the quarry and to later discharge back to the stream. It was difficult to assess this operation and maintenance cost. Facilities would only pump a portion of the year, and while automated, some manual intervention would be required.

The project team assumed an annual cost of $375,000 for each project and assumed an operating period of 30 years for comparison to other storage categories.

Regarding project schedule in this storage category, the team assigned estimated periods for land acquisitions/permitting, design, construction and eventual startup/operations. The infrastructure design/construction and startup are relatively straightforward and typical. Land acquisition, easements, and permit approvals are approximate. Among the 18 projects evaluated, the project duration from inception to startup is expected to be about 9-12 years.

5.4.7 Potential Ancillary Benefits

This category considered such items as recreation/tourism, environmental enhancements, reclamation-related improvements and the ability to leverage complementary funding to achieve a greater level of overall improvement. Quarries generally scored favorably here. If the mined void was converted to storage and a recreational or environmental amenity created, the social impact could be favorable. Former quarries have been converted for recreational use, mostly fishing and boating. Examples in the Basin are Ranger Lake in North Whitehall Township, PA and Moores Station Quarry redevelopment project in Mercer County, NJ. Refer to SPSs for project-specific data.

5.5 Deep Mines

This potential project type envisioned an available volume in the void space of deep coal mines in the Basin and withdrawal as needed to supply an adjacent stream and in turn, the Basin water supply. This effort required research into general anthracite mining and extent of deep mine pools. It also required additional research into specific sites in the Delaware River Basin that met preliminary screening criteria, approaches to withdrawal/treatment and examples of projects that have accomplished similar storage/supply. The following sections describe the general approach envisioned for deep mine storage and withdrawal. Storage project information is also summarized with more specific detail in the deep mine Storage Project Summaries (SPSs) located in Appendix A.

5.5.1 Project Research and Overview

An extensive network of deep mines exists in the Anthracite Coal Region of Northeastern Pennsylvania (ACRNP). Deep coal mining has existed in the region for more than 100 years with the greatest production in the early 1900s. The project team reviewed select documents (see Table 3.1.1-2) to explore the feasibility of this type of potential storage project. The effort is by no means an exhaustive review of the publicly available information but assesses feasibility of each storage project.

5.5.1.1 Project Research

Meticulous records were kept by the mining companies over the years that captured information about geology, extent of mining (shafts, gangways, chutes, etc.), barrier pillars, water elevation and dewatering. Coordination between the mining companies became important, especially as mining density increased and impacts by adjacent mining (stability/water inflow) became critical. Mine safety regulations and related requirements forced reporting and documentation. Regulatory bodies collected large quantities of useful data, albeit not initially well organized. Some of this information has been accessed by the project team and used to explore the extent of deep mine water resources.

Several key reports were referenced to support this cursory evaluation of deep mine storage as listed in Section 3.

5.5.1.2 Regions and Size

The Basin contains parts of the Eastern Middle, Western Middle and Southern Fields of the ACRNP as shown in Figure 5.5.1-1. The project team restricted efforts to the Basin mine pools primarily in the Southern Field and limited areas of the Eastern Middle and Western Middle fields. As summarized in Section 3 (Initial Screening), the mine pools in the Basin were screened by size and limited to those exceeding approximately 2 BG. This led to five potential projects for further study. Approximate locations are shown with a red star in Figure 5.5.1-1 and key parameters are summarized in Table 5.5.1-2.

Figure 5.5.1-1: Mines in the ACRNP within the Delaware River Basin (source: PASDA) (thick black line is basin boundary)

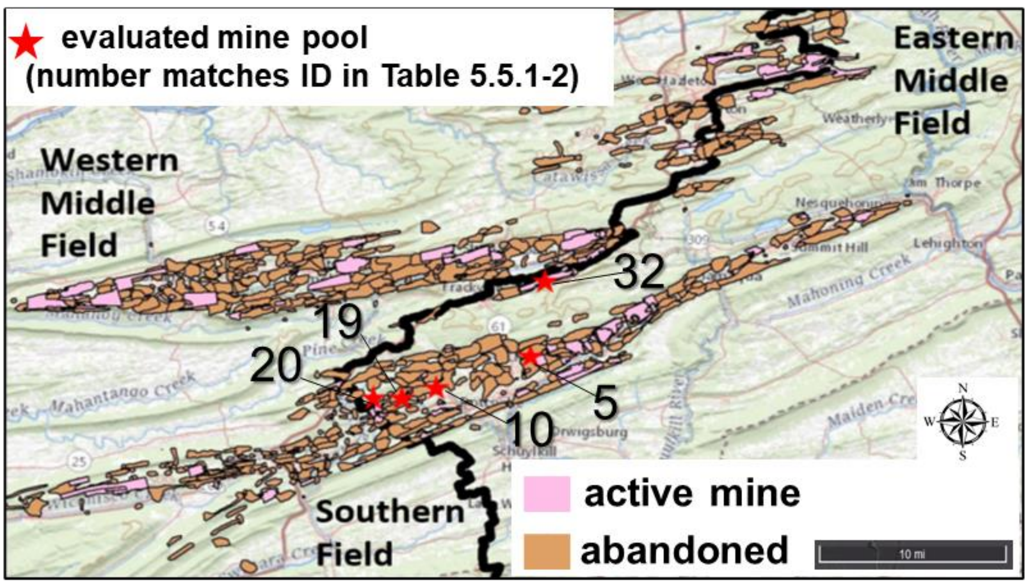


Table 5.5.1-2: Summary of Deep-Mine Potential Projects

No. (M#)	Region/Field	Mine	Volume (BG)	Elevation–Surface (FT-MSL)	Elevation - Low Level (FT-MSL)	Elevation - Water Level (FT-MSL)
5	Southern	Silver Creek	1.77	951	68.4	814.5
10	Southern	Wadesville	3.58	821.2	65	732
19	Southern	Phoenix Park	2.054	1035	375	871
20	Southern	Otto	2.265	963.2	-194.5	830
32	Western Middle	Morea Basin	2.67	1475	NA	1400

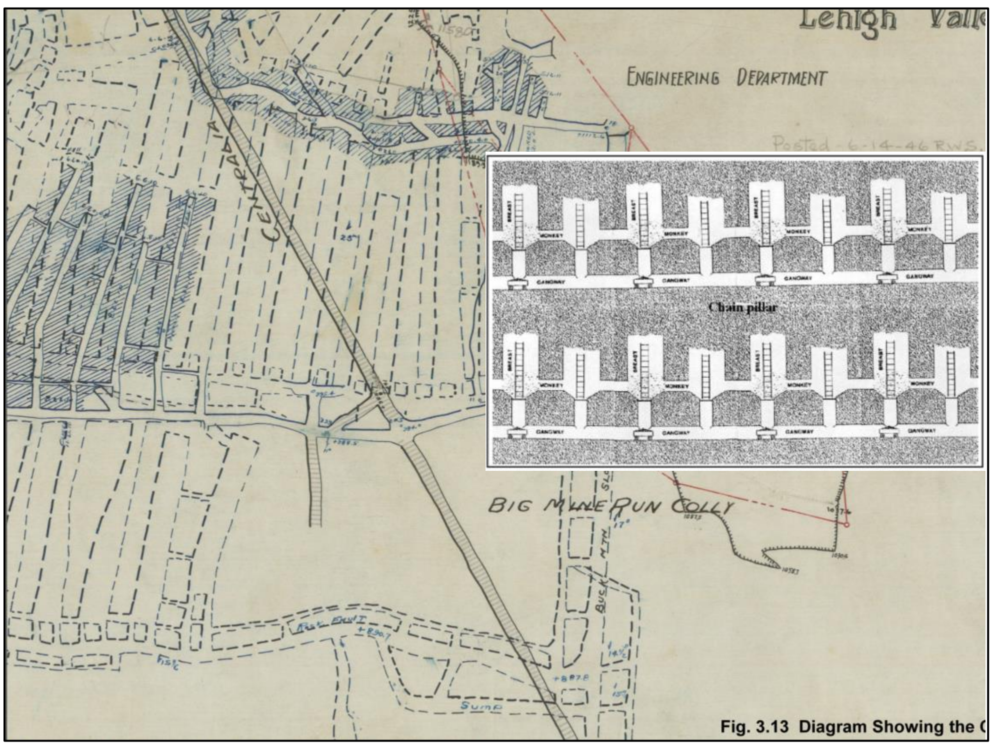
5.5.2 Water Quantity and Quality

The deep mine storage projects present quantity and quality challenges relative to the other studied storage projects. Quantity is an approximation from historical mining information, recently updated by others. Water quality is variable and treatment, or at least rigorous monitoring, may be required to allow for use as a water resource in the Basin. The following subsections elaborate on quantity/volume and quality in the studied projects.

5.5.2.1 Mining Development and Storage Creation

Void space potentially suitable for water storage and recovery has been created by historical deep mining of anthracite coal. The typical mining process is shown schematically in Figure 5.5.2-1.

Figure 5.5.2-1: Anthracite Mining Process Voids



Mines were entered from various surface access points, as generally shown in Figure 5.5.2-1 in the plan view and inset section view. Areas were mined and coal dropped through chutes to gangways to extract the coal. Veins were mined, removing as much coal as possible while maintaining intermediate pillars for rock support and also barrier pillars separating water-filled zones or adjacent mines (active or inactive). In so doing, large voids were created and dewatering the voids was a constant struggle for continued mining and mine safety. As mining decreased and dewatering ceased, water accumulated in the mine voids forming mine pools. This was accelerated in 1966 when the Clean Streams Law became applicable to mining and many of the then-active mines stopped pumping rather than treating their mine dewatering discharge.

Work by the US Bureau of Mines in the late 1940s (Ash, 1949) estimated the extent of mine pools based on mine mapping/geometry available at the time and water level monitoring data at the time. Details of the approach are available in the referenced paper and furthered by work more recently performed by the Eastern Pennsylvania Coalition for Abandoned Mine Reclamation (EPCAMR) documented, foremost by Hughes et al. (2011). EPCAMR, working with the USGS, PADEP and others, have undertaken an extensive effort to digitize old mining information for use in GIS and 3D modeling systems. This updated mine geometry and new water level information has led to updated estimates of mine pools in the ACRNP. The focus of the EPCAMR work has been in the Susquehanna River Basin, while the southern field and western field work in the Delaware River Basin is still developing. That said, the project team decided to use the mine pool location/volume estimates in Ash (1949) for this storage assessment. The volumes in Ash (1949) were conservative when first calculated. Further filling of the mine voids, reflected in more current water level data, and increased storage resolution from EPCAMR's work will likely make the project assumptions in this storage study even more conservative.

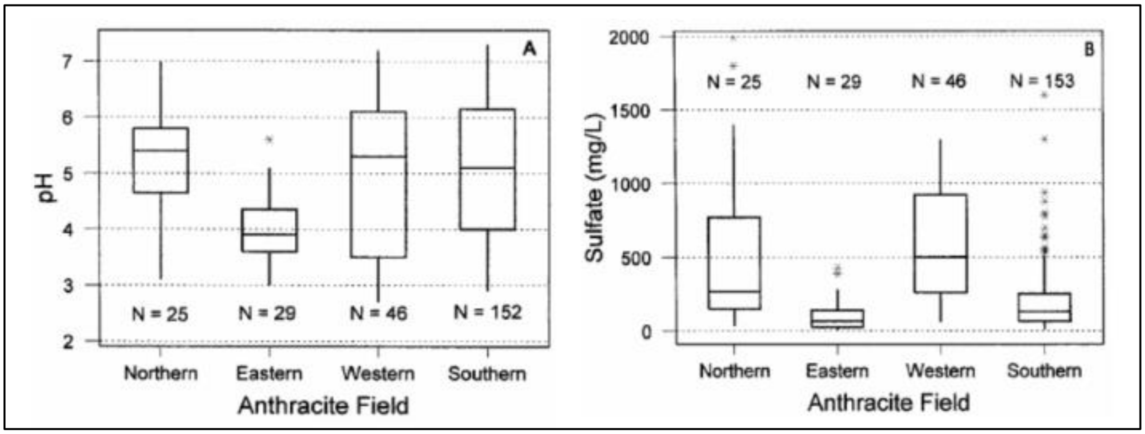
5.5.2.2 Supply

Water supply in the mine "storage volume" is difficult to estimate. Static volume can be estimated with geometry and water level information. However, the contributory area and water balance are more difficult to determine. The water inflow occurs from groundwater or surface infiltration of precipitation or through seepage from overlying water courses. Generally, water reaches some equilibrium with inflow and some feature allowing outflow or seepage/drainage (shaft, adit, overflow, etc.). The recharge dynamics of the mine pool, if partially dewatered, are not completely clear. However, Exelon's Wadesville mine pool project (Veil and Puder, 2006; Hughes et al., 2011; DRBC, 2015) suggests recharge is relatively rapid and it is assumed for this study that the available volume would be replenished within the assumed annual withdrawal/recharge period.

5.5.2.3 Water Quality

Source water quality could be a challenge, or at least a risk consideration, in developing the mine pool storage projects. The water quality is highly variable from location to location. This can be attributed to such items as mineralogy, residence time, water mixing, oxidation/reduction and more. Waters typically are acidic with high concentrations of iron, aluminum, manganese and sulfates. Generally, the waters can be acidic from the oxidation of associated iron sulfide minerals (i.e., pyrite). They can also be buffered by calcareous minerals present in other areas. This and site-specific conditions can make for highly varying water quality. Figure 5.5.2-2 (modified from Brady, 1998) shows the general pH range and sulfate range in the four major coal fields.

Figure 5.5.2-2: Summary of pH and Sulfate in Anthracite Mine Pools



Recent sampling and analysis of key constituents by Cravotta (2008) is discussed in the Otto Mine Pool SPS in Appendix A. However, sampling may not reflect the quality of the entire pool, horizontally and vertically. According to other reports (Brady, 1998), a stratification can occur in the pool creating "top water" and "bottom water" of varying quality. Again, there is inherent project risk in that potentially poor "bottom water" might require additional treatment. If deemed uneconomical to treat, this could restrict water use to the better quality "top water", thereby reducing the useable volume.

Generally, the water in the Delaware River Basin section of the ACRNP has lower sulfates and more neutral pH as shown above. More site-specific water quality information will be discussed by project in the SPSs. Further, the receiving water body for a particular deep mine site and the ability for it to assimilate water quality differences will be very important for feasibility of a particular project.

Based on the limited site data in this planning level study and the potential for poor water quality, the project team decided to include some limited treatment in the infrastructure requirements of the deep mine storage projects. This will be addressed further in Section 5.5.3 and in the individual SPSs.

5.5.3 Infrastructure Design, Construction and Operation

The infrastructure requirements of a deep mine pool storage project have some parallels to a quarry storage project in that pump-out/discharge facilities and transmission piping to a discharge receiving stream are required. However, the unique nature of each mine makes it difficult to provide uniformity in the infrastructure approach without sweeping assumptions.

5.5.3.1 Storage and Supply Facilities

The storage volume (i. e., mine void) is assumed to not be modified in any way. It may be possible to remove separating barrier pillars, modify overflow points or join mine pools together to increase overall storage. However, this is not considered at this point in this storage project characterization.

Pumping facilities need to be located at/near or below the mine pool water surface. Submersible pumps, as proposed for quarry water removal, may be applicable provided the submersible pumps extend to the deepest "low water" withdrawal level of the mine pool. Suction or centrifugal pumps would likely not be appropriate given the deepening pool water level with continued withdrawal. Vertical turbine pumps have been used in another known application (Wadesville Mine Pool), but again require submergence of the turbine intake and may be impossible to concept design at this stage of the study without site-specific details. Therefore, the project team chose to approach mine water removal similar to quarry water removal using submersible pumps that are located in a new shaft adjacent to the surface pool of a deep mine or installed directly in the deep mine.

The discharge pipeline from the mine site to the receiving stream is assumed to be similar to that used in the quarry storage projects.

5.5.3.2 Treatment Facilities

Treatment may be required prior to permitted discharge of mine water to a receiving stream to supplement Basin flow. Of course, many deep mines are currently discharging to ACRNP streams as acid mine drainage. Some passive treatment systems exist that provide crude pH control (buffering) and some solids settling for the low-flow discharges at some sites. The envisioned infrastructure for this storage concept would require active treatment rather than passive to handle the planned higher flow rates (15 - 30 mgd).

Any treatment train design would require a complete understanding of the range of raw water qualities as well as the PADEP discharge water quality criteria. Neither is explicitly known at this time. Therefore, typical project water qualities and standard NPDES discharge requirements were assumed. Based on experience and knowledge of comparable projects, such as deep mine water use for power plant cooling water (Veil and Puder, 2006), this was assumed to involve primary treatment only. Primary treatment could include chemical feed for pH control and to assist coagulation and flocculation, as well as some form of gravity settling (plates, tubes, open basin, etc.). The treatment goals would be iron and metals removal, as well as TSS/TDS reduction with pH balance to meet permit discharge criteria.

5.5.3.3 Construction and Operations

Construction of the proposed infrastructure would generally be similar to typical pumping and piping installation as described in Section 5.4 for quarry storage. However, construction and operation of treatment facilities for deep mine water will be more involved. While not complex, this adds construction, operation and maintenance costs. It also makes unmanned remote operation less feasible. These complications will add to the project complexity and overall cost, as will be discussed in the SPSs.

5.5.4 Environmental and Permitting Considerations

The deep mines, like other storage categories, were reviewed for potential environmental impacts to sensitive natural resources and permitting concerns. The potential environmental impacts considered included wetlands, protected species, high-quality water bodies, hydromodification, and other impacts to flora/fauna/habitat. The sites and pipeline route were reviewed using available databases (e.g., National Wetlands Inventory) and potential issues were noted for subsequent scoring.

The mines are somewhat similar to quarries in terms of potential environmental issues and permitting consideration. Generally, only minor disruption or impact is created by the connection of pumping/conveyance facilities for the existing mine pool. However, a potential environmental impact could be associated with the discharge of mine pool water to a receiving stream. This risk can be managed by treatment, at additional cost.

The Wadesville Mine pool is a notable reference demonstration project (Veil and Puder, 2006; Hughes et al., 2011), approved by DRBC (DRBC, 2015). This facility benefits from good quality source water that did not require any treatment. However, complex water quality and environmental monitoring was and continues to be required to prove there are no impacts under the various operating conditions.

In terms of permits, the major permits anticipated for regulatory approval of a mine project may be similar to a quarry storage project, with the relevant permit programs listed in Appendix H and discussed in some detail in Section 5.2.4. However, this is not typical and is assumed to be difficult and time consuming. Impacts on quality and quantity of water discharges to rivers/streams will be of concern to natural resource agencies and environmental non-profits. These impacts must be better assessed with water quality monitoring and modeling. Site-specific conditions may also influence these permits and may be discussed further in the SPSs.

5.5.5 Social and Economic Impacts

The social and economic impacts that were considered are listed in the criteria section (Section 4). The deep mine storage projects generally scored favorably in this category. In all cases, these are remote and abandoned facilities that should have no negative impact if operated properly. Moreover, the treatment of mine pool water and use as a resource helps solve a water supply problem and may reduce AMD discharges. Refer to SPSs for site-specific data.

5.5.6 Project Cost and Schedule

Project cost and schedule were developed similarly to other storage types, particularly the quarries. However, relative to quarries, the mines have some reduced pumping (no filling), but the added complication of probable treatment. Also, operations of these mine pool storage projects are more complex/costly and are a significant component of present value cost. Consequently, the mine storage cost estimates require some additional detail.

5.5.7 Potential Ancillary Benefits

This category considered such items as possible flood control, recreation/tourism, environmental enhancements, reclamation-related improvements and the ability to leverage complementary funding to achieve a greater level of overall improvement. Deep mines generally scored favorably here because of the potential for reduction in acid mine drainage and the possibility to leverage related funding sources. Refer to SPSs for site-specific data.

Section 6
Project Evaluation

6 Project Evaluation

6.1 Project Scores

Each potential project was evaluated according to criteria, rubrics and weightings described in Section 4, which are common to all storage categories. Each project's detailed scoresheet is appended to its SPS, located in Appendix A.

The rationale for each score is included in the score sheet and discussed in the corresponding section of the SPS.

The scores of all projects on all subcriteria are presented in a single comprehensive table in Appendix E. The overall weighted score, the scores on the six primary criteria and key metrics are summarized in Table 6.1-1, grouped by storage project type and then sorted by volume.

The project characteristics and scores vary widely. For example, storage volumes range from 1 BG to 42 BG, while estimated costs range from about $25M for several of the quarries to about $1,000M for the two new large dams/reservoirs (Milanville and Equinunk). Given the large range in volume and costs, a key metric to compare projects is the cost effectiveness, defined herein as cost (M$) per BG, with a lower value indicating better cost effectiveness. In the evaluated projects, cost effectiveness ranged from $1M/BG for the Prompton dam modification (but provides only 2 BG) to $5-$6M/BG for three quarry projects (Q1, Q2 and Q7-Delaware) and the Cannonsville dam raise to over $100M/BG for two new, small reservoirs (Hawley and Rattling Run) and one dam raise (Wild Creek).

The overall weighted scores range from 2.8 to 4.1 on a scale of 1 (least preferable or "worst") to 5 (most preferable or "best"). These scores are dependent on both the scores on individual criteria and on the weightings on the six primary criteria. For example, if the weighting of the "water quantity and quality" criteria group was increased dramatically from the current 30% to 50%, then the large volume projects (i.e., new reservoirs) would score higher. The project team provided the score sheets as Excel files so that DRBC staff can examine different weighting schemes. The impact of weighting on ranked outcomes is discussed in a later section.

Furthermore, because there are many subcriteria, a very low (bad) score on one subcriteria has a minor effect on the overall weighted score, even though it could represent a "fatal flaw". Therefore, there is uncertainty in the scores on individual criteria and in the effect of these scores on a project's feasibility; further investigation will be required to reduce this uncertainty. Potential fatal flaws identified by the project team are listed for each evaluated project (Table 6.1-1).

Table 6.1-1: Criteria Scores and Key Metrics for all Projects (grouped by project type, then sorted by weighted score)

ID	Project Name	County (PA unless indicated)	Vol-ume (BG)	Total Cost (PV M$)	Cost effec-tiveness (M$/BG)	Pump in or Gravity	**OVERALL WEIGHTED SCORE**	1. Water quantity and quality	2. Infra. design, const. & ops.	3. Environ. impacts	4. Social & Economic Impacts	5. Project Costs & Schedule	6. Ancillary Benefits	Potential fatal flaw(s)
NEW RESERVOIRS														
N4	Rattling Run	Berks	1.3	293	225	G	**3.05**	3.83	3.40	3.36	4.22	1.83	1.60	Very high cost, poor cost effectiveness; low volume; floods Class A/EV stream
N5	Equinunk	Wayne	42.0	1150	27	G	**3.03**	4.50	2.60	2.00	3.00	2.33	2.40	Extremely high cost; high environmental and social impacts
N2	Milanville	Wayne	42.0	950	23	G	**2.95**	4.17	2.60	2.16	3.00	2.33	2.40	Extremely high cost; high environmental and social impacts
N1	Red Creek	Schuylkill	13.3	366	28	P	**2.90**	3.67	2.20	2.93	3.22	2.33	2.40	Very high cost; high social impacts
N6	Hawley	Wayne	1.3	182	140	G	**2.87**	4.17	2.80	2.18	3.33	2.00	1.60	High cost, poor cost effectiveness; low volume
N3	Little Martins Creek	Northampton	7.1	353	50	P	**2.87**	4.17	2.20	1.96	3.44	2.17	2.20	Very high cost; poor cost effectiveness; high social impacts
N7	Silver/Big Creek	Schuylkill	11.3	921	81	P	**2.77**	3.50	1.80	2.68	4.33	1.83	3.00	Very High cost, poor cost effectiveness; poor source water availability
EXISTING RESERVOIRS – STORAGE INCREASE														
E4	Prompton	Wayne	2.0	2	1	G	**4.04**	4.17	3.80	3.25	4.78	4.50	1.80	Complicated permitting on Corps projects; low volume
E2	Cannonsville	Delaware, NY	13.0	77	6	G	**3.99**	4.67	3.60	3.21	4.89	4.00	1.20	Complicated working with NYC; possible resident opposition
E1	Wild Creek	Carbon & Monroe	1.0	135	135	G	**3.29**	4.00	2.80	3.50	4.89	2.50	1.00	Low volume; poor cost effectiveness
E3	Blue Marsh	Berks	5.0	65	13	G	**3.19**	3.83	2.20	3.43	4.11	2.67	1.80	Complicated permitting on Corps projects; disruptive construction; complicated land acquisition
EXISTING RESERVOIRS – TRANSFERABLE STORAGE														
T2	Rio	Sullivan, NY	2.0	27	14	NA	**4.16**	4.17	4.60	5.00	5.00	3.83	1.00	Probable low volume available; possible poor cost effectiveness
T4	Lake Ontelaunee	Berks	1.0	27	27	NA	**4.01**	3.33	4.60	5.00	5.00	4.17	1.00	
T1	Merrill Creek	Warren, NJ	2.0	110	55	NA	**3.91**	4.50	4.60	5.00	5.00	2.67	1.00	
T3	Penn Forest/Wild Creek	Carbon/ Monroe	3.0	162	54	NA	**3.87**	3.83	4.60	5.00	5.00	3.17	1.20	
QUARRIES														Possible geologic instability from filling/draining applies to all quarries
Q19	Rush Valley	Bucks	1.7	26	15		**4.07**	3.75	3.60	4.79	4.88	4.00	3.60	
Q02	Mccoy	Montgomery	6.2	30	5	P or G	**4.06**	3.50	3.10	4.61	4.75	4.50	3.60	
Q04	Penns Park	Bucks	3.3	31	10	P	**4.04**	3.58	3.60	4.57	4.88	4.17	3.60	
Q12	Solebury	Bucks	2.3	38	16	P	**4.03**	3.75	3.20	4.57	5.00	4.00	4.00	Legal issues regarding ownership
Q25	Oxford	Warren, NJ	1.2	28	23	P	**4.02**	4.00	3.60	4.57	4.88	3.83	2.80	
Q07D	Stockertown(Delaware)	Northampton	4.6	26	6	P	**4.01**	4.08	3.70	4.93	4.25	3.67	3.00	
Q22	Whitehall	Lehigh	1.2	34	28	P	**3.96**	3.83	3.00	4.86	4.69	3.67	4.20	
Q21	Ormrod	Lehigh	1.3	45	35	P	**3.92**	3.83	3.10	4.93	4.63	3.50	4.20	
Q23	Lehigh Perkiomenville	Montgomery	1.0	26	26	P	**3.91**	3.58	3.80	4.79	4.88	3.67	3.00	
Q01	Wadesville Mine Pit	Schuylkill	6.9	39	5	P or G	**3.91**	3.42	3.40	4.21	4.63	4.17	4.00	Small source stream; connection to Wadesville deep mine pool
Q08	Evansville	Berks	3.1	44	14	P or G	**3.91**	3.75	3.20	4.79	4.00	3.83	3.90	
Q27	NESL Nazareth	Northampton	1.0	25	25	P	**3.86**	3.67	3.40	4.21	5.00	3.83	2.80	Small source stream
Q03	Plymouth Meeting	Montgomery	3.5	39	11	P	**3.76**	3.50	3.10	3.89	4.75	3.83	3.80	Small source stream
Q14	Telford	Bucks	1.0	25	25	P	**3.50**	3.17	2.90	4.07	4.75	3.67	1.40	
Q07B	Stockertown (Bushkill)	Northampton	4.6	26	6	P	**3.47**	3.42	2.50	3.43	4.50	3.67	2.60	Small source stream
Q16	Temple	Berks	1.0	30	30	P	**3.42**	3.25	2.20	4.64	3.25	3.67	2.00	
Q05	Lehigh Nazareth	Northampton	4.2	48	12	P	**3.37**	3.25	2.30	3.00	4.38	3.83	2.60	Small source stream
Q06	Imperial	Northampton	3.8	51	13	P	**3.34**	3.25	2.30	3.14	4.38	3.67	2.60	Small source stream
DEEP MINES														
M32	Morea Basin	Schuylkill	2.7	65	24	P	**3.58**	3.08	3.20	4.43	5.00	3.50	2.40	Possible poor water quality; possibly slow to refill
M20	Otto	Schuylkill	2.3	65	28	P	**3.53**	3.17	3.00	4.43	5.00	3.33	2.40	
M5	Silver Creek	Schuylkill	1.7	65	38	P	**3.12**	3.00	3.20	4.50	5.00	2.00	2.40	
M19	Phoenix Park	Schuylkill	2.1	65	31	P	**2.99**	2.83	2.90	4.21	5.00	2.00	2.40	
M10	Wadesville	Schuylkill	3.6	65	18	P	**0.00**	NA	NA	NA	NA	NA	NA	Possible low volume available

6.2 Cost and Volume Comparison Among All Projects

Figure 6.2-1 plots the cost versus new storage volume provided for all evaluated projects. It illustrates the wide range of volumes and costs mentioned above, with the new dams/reservoirs providing the largest volume and incurring the largest costs including two projects of nearly $1,000M, which may make them infeasible. The quarry projects are all clustered in the lower left quadrant of the plot, indicating smaller volume and smaller cost. Figure 6.2-2 enlarges that region of the figure to better illustrate the smaller cost projects. No new reservoirs fall into this region. The highest volume project costing less than $100M is the Cannonsville dam raise, providing 13 BG at an estimated cost of $77M. There are seven quarry projects that provide significant volume (> 3 BG) for under $50M. The cost effectiveness of various projects is further revealed by Figure 6.2-3. Again, the Cannonsville project stands out as providing large volume with good cost effectiveness, as do three quarry projects, namely Q1, Q2 and Q7-Delaware in the table above. The Prompton inlet raise also stands out as the lowest cost and most cost-effective project, albeit providing only 2 BG.

Figure 6.2-1: Cost vs. New Storage Volume for all Projects

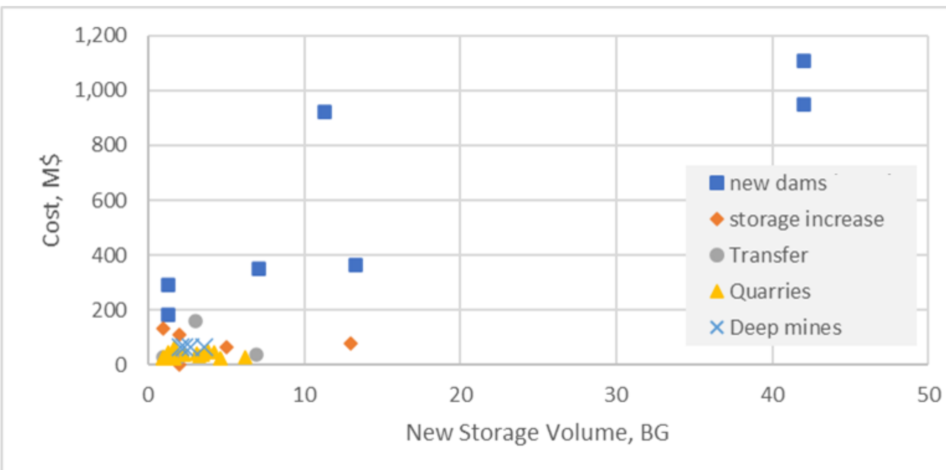


Figure 6.2-2: Storage Volume Provided by less Expensive (<$100M) Projects

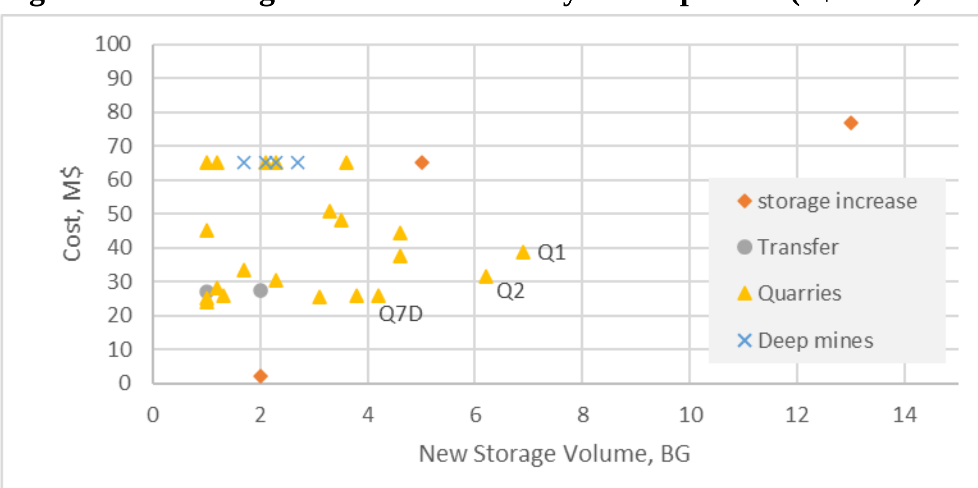
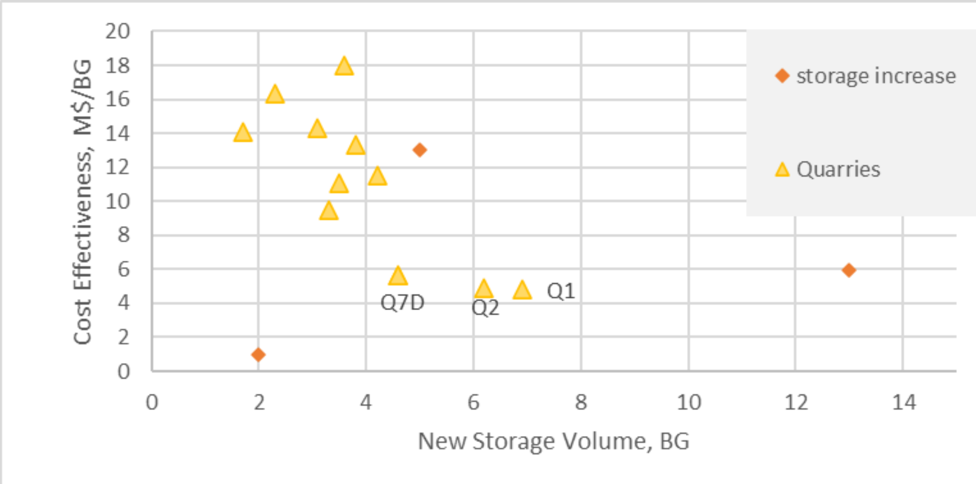


Figure 6.2-3: Storage Volume Provided by more Cost-Effective Projects



6.3 Comparison by Categories

This section compares potential projects in the four categories: new reservoirs; existing reservoirs (with two subcategories of increasing storage or reallocating/transferring control of existing storage), quarries and deep mines.

6.3.1 New Reservoirs

The primary advantage of the projects in this category is that five projects would provide large volume, with two projects (Milanville and Equinunk) providing 42 BG each and three others providing 7 to 13 BG, larger than all other projects except for one (Cannonsville dam raise at 13 BG). On the downside, they are the most expensive projects by far, with the largest estimated at nearly $1B. Even the least expensive reservoirs (Hawley and Rattling Run, which provide only about 1 BG each) would cost over $180M, which is much more expensive than any project in the other storage categories. The height of a dam could be reduced, reducing both cost and volume, but probably not improving the cost effectiveness metric significantly. The cost effectiveness of new reservoirs (M$/BG) was fair to poor: $23M/BG for the largest reservoirs to >$100M/BG for the smallest reservoirs. The new reservoirs also had low scores on environmental, social and economic impacts compared to quarries, except the two reservoirs in undeveloped areas (Hawley and Rattling Run) had good social/economic impact scores. Another disadvantage of all new reservoirs is their long time-to-operation estimated at more than 15 years, assuming no major difficulties.

In addition, three reservoirs (Red Creek, Little Martins Creek and Silver Creek) have small drainage areas relative to their volume and, therefore, would likely require pump-in to fill the reservoir, which increases costs and operational complexity. The first two sites have a large river nearby that can serve as a reliable source, the Schuylkill and Delaware Rivers respectively, while Silver Creek Reservoir sits near the Basin boundary with no large water source nearby.

Unless a very large volume in a specific location is an overriding priority and high construction cost can be reasonably financed/funded, none of the new reservoirs appear attractive.

6.3.2 Storage Increase in Existing Reservoirs

The Wild Creek and Blue Marsh projects are not attractive. Both provide low or moderate volume (1 and 5 BG respectively) at poor or moderate cost effectiveness ($105M/BG and $13M/BG respectively). Blue Marsh scored poorly on social/economic impacts because of the many roads and bridges that would need to be raised or re-routed, as well as the raising and/or extension of the Bernville Dike, which would cause great disruption to the community.

Cannonsville Reservoir, on the other hand, provides large volume (13 BG) with good cost effectiveness of $6M/BG, close to the best of all projects by this metric. The time lag to operation is also favorable relative to new reservoirs. The Prompton project provides modest volume at 2 BG, but its cost is low and has excellent cost effectiveness. Both projects have low social/economic impacts. The environmental impacts are presumed moderate but may be serious if impacting endangered species. A downside to the Prompton project is that modifying the dam requires compliance with USACE regulations which could be very lengthy and problematic.

6.3.3 Transfer of Control of Existing Storage in Existing Reservoirs

The primary advantages of the four storage-transfer projects are the near zero environmental, social and economic impacts (because there is no new construction or flooded land) and short time to operation. While owners were reluctant to specify, the potential volumes available are believed to be modest (≤ 3 to 5 BG). Surprisingly, the cost effectiveness is relatively poor, ranging widely from $14M to $55 M/BG, but also highly uncertain because of reluctance among the owners to provide cost in any detail at this early stage. True available storage volume and cost terms are likely to be revealed only during negotiations with a serious buyer and water provider.

6.3.4 Quarries

The quarry category provides several attractive potential projects. Three provide sizable volume, ranging from 4.6 to 6.9 BG, while also providing favorable cost effectiveness of $6 M/BG or less (Q1, Q2 and Q7-Delaware). Five others provide over 3 BG each with moderate cost effectiveness of less than $15M/BG. Most of these projects score high regarding environmental, social and economic impacts. The fact that there are several attractive projects with moderate cost ($25M to $50M) means that they could be accomplished sequentially.

The primary drawback of the quarries is the filling process, with pumping rates and durations limited by allowable withdrawal, particularly in the cases of low-flow source streams. Another drawback is that quarries must also be pumped out, which means the discharge rate is considerably less than dammed reservoirs and less than the stated desired rate of 100 cfs, with a practical limit of 50 cfs assumed. The pump-in and pump-out increase both construction and operating costs, but if draining and refilling occurs in response to infrequent drought as expected, then operating costs may be more acceptable.

6.3.5 Deep Mines

Of the five deep mines evaluated, none scored high. Treatment of withdrawn water makes all of these projects more difficult and costly. Of the five projects, Morea Basin (M32) appears most feasible in that contract or shared treatment may be possible using existing facilities of the adjacent landowner.

6.4 Project Combinations

The project team considered project combinations that may be advantageous in meeting project goals. Within the quarry category, there are three clusters where adjacent quarries might be combined for larger volume and greater cost effectiveness (Q5, Q6, Q7, and Q27; Q21 and Q22; Q4 and Q19, see mapping in Figure 5.4-1). These are described in the specific quarry SPSs. In addition, some combination of storage projects from different categories were considered. Two examples are discussed further below.

6.4.1 Combination 1 - Lake Ontelaunee and Evansville Quarry

The Evansville Quarry (Q8) provides a large volume at 3.1 BG and sits on the edge of Lake Ontelaunee (T4). The lake could provide a reliable, large, gravity-fed water source for the quarry, which is unique in this study and beneficial by avoiding the cost of a building and operating a pump-in station and avoiding severe restrictions on timing and rate of source withdrawal that hamper many of the quarry projects. See the respective SPS for further details.

6.4.2 Combination 2 – Silver Creek Reservoir and Silver Creek Mine

A disadvantage of the new Silver Creek dam and reservoir is the lack of a close, reliable water source for pumping to fill the reservoir, which is needed because of its very small drainage area. If Silver Creek Mine could serve as the source, it may reduce or alleviate the source reliability problem. However, the mine water would still need to be pumped in and presumably treated, so the cost savings may be minor. In any case, the cost of the dam was estimated at $819M versus $51M for the pump station and pipeline, so even if the cost savings of combining projects was considerable, the resulting cost would still be very high, and the cost effectiveness would still be poor at $73M/BG.

Section 7
Recommendations

7 Recommendations

Table 7-1 lists the criteria scores and key metrics for all evaluated projects, including the overall weighted criteria score, and the recommendation class. There are three recommendation classes: projects with no recommendation, projects that are not recommended, and projects recommended as most feasible, as will be discussed further in Sections 7.1, 7.2 and 7.3. The recommendation is based on the weighted scores on the evaluation criteria, except that the high uncertainty in the volume and cost for the transferable-storage projects lead to "no recommendation" for those projects.

While higher scores indicate more advantageous projects, the overall weighted score may not completely capture a project's feasibility. First, these scores are dependent on the scores of individual criteria and on the subjective weightings on the six primary criteria. Furthermore, because there are many subcriteria, a very low (bad) score on one subcriteria has a minor effect on the overall weighted score, even though it could potentially represent a "fatal flaw" in the project. Potential fatal flaws identified for each evaluated project are listed in Table 6.1-1. Other fatal flaws may emerge as projects are further developed.

Table 7-1: All Evaluated Projects Sorted by Weighted Score (recommended projects in bold)

ID	Recommendation (1=No Recommendation, 2=Not Recommended, 3= Recommended)	Project Name	Location	Project type	Vol. (BG)	Total Cost (PV M$)	Cost effective-ness (M$/BG)	Pump in or Gravity	Years to complete	**OVERALL WEIGHTED SCORE**	1. Water quantity & quality	2. Infra. design, const. & ops.	3. Environ. impacts	4. Social & Economic Impacts	5. Project Costs & Schedule	6. Ancil. Benefits
T2	1	Rio	Sullivan, NY	Transfer	2.0	27	14	NA	1	**4.16**	4.17	4.60	5.00	5.00	3.83	1.00
Q19	**3**	**Rush Valley**	**Bucks**	**Quarry**	**1.7**	**24**	**14**	**P**	9	**4.07**	**3.75**	**3.60**	**4.79**	**4.88**	**4.00**	**3.60**
Q02	**3**	**Mccoy**	**Montgomery**	**Quarry**	**6.2**	**30**	**5**	**P**	7	**4.06**	**3.50**	**3.10**	**4.61**	**4.75**	**4.50**	**3.60**
E4	**3**	**Prompton**	**Wayne**	**Dam mod**	**2.0**	**2**	**1**	**G**	10	**4.04**	**4.17**	**3.80**	**3.25**	**4.78**	**4.50**	**1.80**
Q04	**3**	**Penns Park**	**Bucks**	**Quarry**	**3.3**	**31**	**10**	**P**	10	**4.04**	**3.58**	**3.60**	**4.57**	**4.88**	**4.17**	**3.60**
Q12	**3**	**Solebury**	**Bucks**	**Quarry**	**2.3**	**38**	**16**	**P**	11	**4.03**	**3.75**	**3.20**	**4.57**	**5.00**	**4.00**	**4.00**
Q25	**3**	**Oxford**	**Warren, NJ**	**Quarry**	**1.2**	**28**	**23**	**P**	9	**4.02**	**4.00**	**3.60**	**4.57**	**4.88**	**3.83**	**2.80**
T4	1	Lake Ontelaunee	Berks	Transfer	1.0	27	27	NA	5	**4.01**	3.33	4.60	5.00	5.00	4.17	1.00
Q07D	**3**	**Stockertown (Delaware)**	**Northampton**	**Quarry**	**4.6**	**26**	**6**	**P**	9	**4.01**	**4.08**	**3.70**	**4.93**	**4.25**	**3.67**	**3.00**
E2	**3**	**Cannonsville**	**Delaware, NY**	**Dam mod**	**13.0**	**77**	**6**	**G**	10	**3.99**	**4.67**	**3.60**	**3.21**	**4.89**	**4.00**	**1.20**
Q22	**3**	**Whitehall**	**Lehigh**	**Quarry**	**1.2**	**34**	**28**	**P**	11	**3.96**	**3.83**	**3.00**	**4.86**	**4.69**	**3.67**	**4.20**
Q21	**3**	**Ormrod**	**Lehigh**	**Quarry**	**1.3**	**45**	**35**	**P**	9	**3.92**	**3.83**	**3.10**	**4.93**	**4.63**	**3.50**	**4.20**
T1	1	Merrill Creek	Warren, NJ	Transfer	2.0	110	55	NA	10	3.91	4.50	4.60	5.00	5.00	2.67	1.00
Q23	**3**	**Perkiomenville**	**Montgomery**	**Quarry**	**1.0**	**26**	**26**	**P**	1	**3.91**	**3.58**	**3.80**	**4.79**	**4.88**	**3.67**	**3.00**
Q01	**3**	**Wadesville Mine Pit**	**Schuylkill**	**Quarry**	**6.9**	**39**	**5**	**P**	8	**3.91**	**3.42**	**3.40**	**4.21**	**4.63**	**4.17**	**4.00**
Q08	**3**	**Evansville**	**Berks**	**Quarry**	**3.1**	**44**	**14**	**P**	10	**3.91**	**3.75**	**3.20**	**4.79**	**4.00**	**3.83**	**3.90**
T3	1	Penn Forest/Wild Creek	Carbon/ Monroe	Transfer	3.0	162	54	NA	5	**3.87**	3.83	4.60	5.00	5.00	3.17	1.20
Q27	**3**	**NESL Nazareth**	**Northampton**	**Quarry**	**1.0**	**25**	**25**	**P**	10	**3.86**	**3.67**	**3.40**	**4.21**	**5.00**	**3.83**	**2.80**
Q03	2	Plymouth Meeting	Montgomery	Quarry	3.5	39	11	P	8	**3.76**	3.50	3.10	3.89	4.75	3.83	3.80
M32	2	Morea Basin	Schuylkill	Mine Pool	2.7	65	24	P	12	**3.58**	3.08	3.20	4.43	5.00	3.50	2.40
M20	2	Otto	Schuylkill	Mine Pool	2.3	65	28	P	13	**3.53**	3.17	3.00	4.43	5.00	3.33	2.40
Q14	2	Telford	Bucks	Quarry	1.0	25	25	P	10	**3.50**	3.17	2.90	4.07	4.75	3.67	1.40
Q07B	2	Stockertown (Bushkill)	Northampton	Quarry	4.6	26	6	P	8	**3.47**	3.42	2.50	3.43	4.50	3.67	2.60
Q16	2	Temple	Berks	Quarry	1.0	30	30	P	9	**3.42**	3.25	2.20	4.64	3.25	3.67	2.00
Q05	2	Lehigh Nazareth	Northampton	Quarry	4.2	48	12	P	8	**3.37**	3.25	2.30	3.00	4.38	3.83	2.60
Q06	2	Imperial	Northampton	Quarry	3.8	51	13	P	8	**3.34**	3.25	2.30	3.14	4.38	3.67	2.60
E1	2	Wild Creek	Carbon/ Monroe	Dam mod	1.0	135	135	G	10	**3.29**	4.00	2.80	3.50	4.89	2.50	1.00
E3	2	Blue Marsh	Berks	Dam mod	5.0	65	13	G	20	**3.19**	3.83	2.20	3.43	4.11	2.67	1.80
M5	2	Silver Creek	Schuylkill	Mine Pool	1.7	65	38	P	12	**3.12**	3.00	3.20	4.50	5.00	2.00	2.40
N4	2	Rattling Run	Berks	New dam	1.3	293	225	G	15	**3.05**	3.83	3.40	3.36	4.22	1.83	1.60
N5	2	Equinunk	Wayne	New dam	42.0	1150	27	G	15	**3.03**	4.50	2.60	2.00	3.00	2.33	2.40
M19	2	Phoenix Park	Schuylkill	Mine Pool	2.1	65	31	P	13	**2.99**	2.83	2.90	4.21	5.00	2.00	2.40
N2	2	Milanville	Wayne	New dam	42.0	950	23	G	15	**2.95**	4.17	2.60	2.16	3.00	2.33	2.40
N1	2	Red Creek	Schuylkill	New dam	13.3	366	28	P	15	**2.90**	3.67	2.20	2.93	3.22	2.33	2.40
N6	2	Hawley	Wayne	New dam	1.3	182	140	G	20	**2.87**	4.17	2.80	2.18	3.33	2.00	1.60
N3	2	Little Martins Creek	Northampton	New dam	7.1	353	50	P	15	**2.87**	4.17	2.20	1.96	3.44	2.17	2.20
N7	2	Silver/Big Creek	Schuylkill	New dam	11.3	921	81	P	15	**2.77**	3.50	1.80	2.68	4.33	1.83	3.00
M10	2	Wadesville	Schuylkill	Mine Pool	3.6	65	18	P		**NA**	NA	NA	NA	NA	NA	NA

7.1 Projects with No Recommendation

The project team is reluctant to provide any recommendation on the transferable-storage projects because, while some owners expressed interest, all owners were unable to commit to a specific volume of storage for transfer and the cost of such storage. Volume and cost terms are likely to be revealed only in negotiation with a serious buyer and willing supplier.

If there is a near-term need, these projects may be worth pursuing because of the potential for quick implementation and near-zero impacts. It is understood that this is not “new water” but would provide new contracted access to stored water. In any case, the volume to be gained is not likely to be very large (less than 5 BG). The Penn Forest/Wild Creek system of Bethlehem is most promising, with 3 BG assumed available, but it might be more.

7.2 Projects that are Not Recommended

Numerous projects are not recommended because another project or combination of projects can provide similar benefits at lower cost, lower impacts and/or in a shorter time frame. All new dam/reservoir projects have very high costs and fair to poor cost effectiveness. Plus, they have serious negative environmental and/or socioeconomic impacts and long time-horizons. The primary advantage of projects in this category is the very large volume provided (>7 BG, except Rattling Run and Hawley). Therefore, unless a very large volume in a specific location is an overriding priority and high cost and long delay are not major impediments, no new reservoir is recommended as feasible.

The Wild Creek and Blue Marsh dam raises are not recommended. For Wild Creek, the cost is high and volume is low. For Blue Marsh, while the volume is substantial (5 BG) and the cost is moderate, the amount of disruption of raising many bridges and roads, three saddle dams and the Bernville Dike (besides the main dam and spillway), as well as the long duration of acquiring permission to do so and acquiring necessary property makes the project unattractive relative to other projects providing equivalent volume.

Four quarry projects (Q14, Q16, Q6 and Q7-Bushkill) are not recommended as feasible because of their small volume (< 1 BG for Q14 and Q16) and low cost-effectiveness or concerns over the adequacy of the source stream. Other quarries can provide more volume at similar or, sometimes, even lower cost.

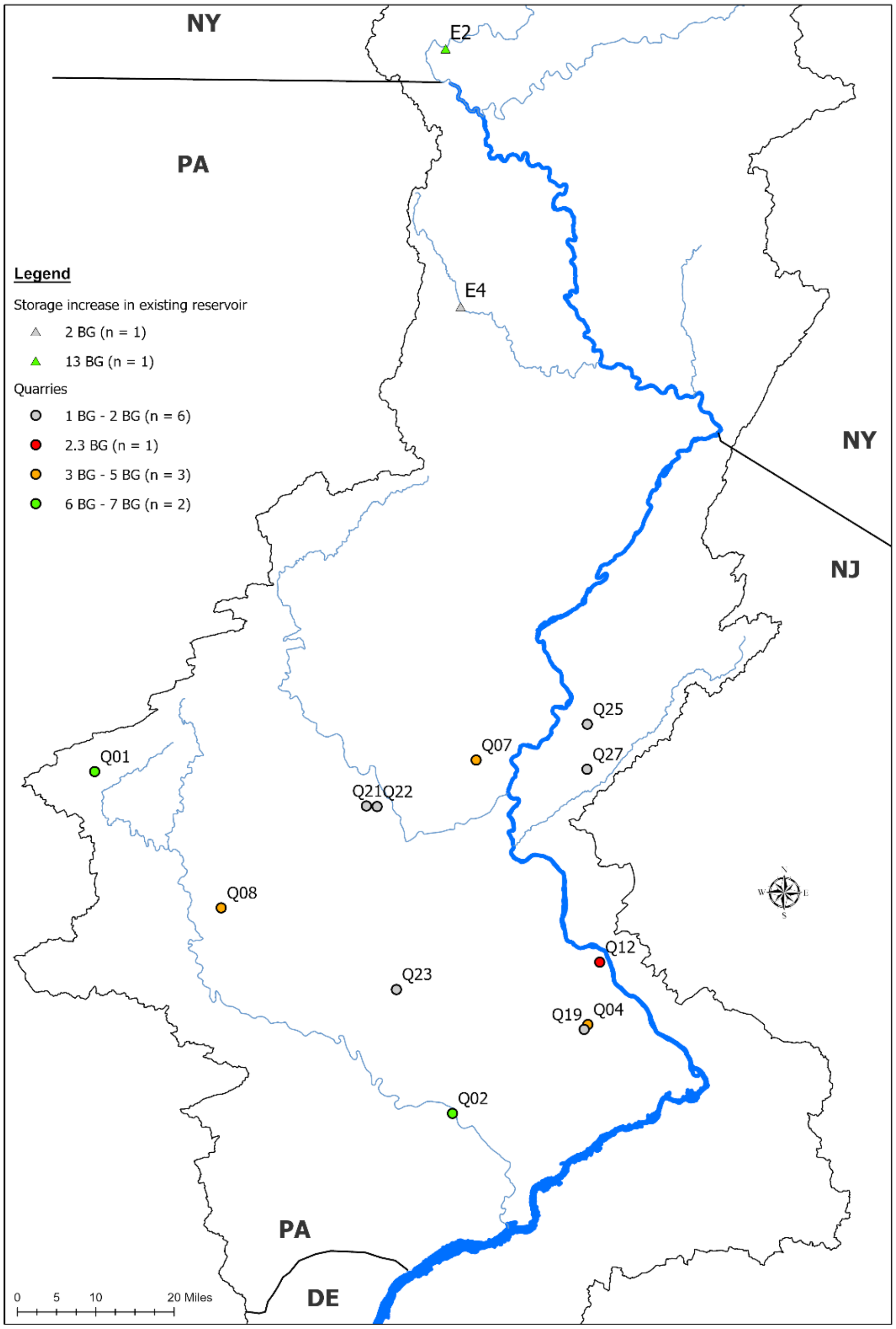
7.3 Recommended Projects

The project team recommends 14 higher-ranked potential projects as most feasible, listed in Table 7.3-1 and mapped in Figure 7.3-1.

Table 7.3-1: Project Recommended as Most Feasible, Sorted by Overall Score

Rank	Project Name	Project ID	County/ State	Overall Weighted Score	Volume (BG)	Cost, (PV M$)	Cost Effectiveness, M$/BG
1	Rush Valley	Q19	Bucks, PA	4.07	1.7	24	14.1
2	McCoy	Q02	Montgomery, PA	4.06	6.2	30	4.9
3	Prompton	E4	Wayne, PA	4.04	2.0	2	1.0
4	Penns Park	Q04	Bucks, PA	4.04	3.3	31	9.5
5	Solebury	Q12	Bucks, PA	4.03	2.3	38	16.3
6	Tilcon Oxford	Q25	Warren, NJ	4.02	1.2	28	23.3
7	Stockertown (Delaware River)	Q07D	Northampton, PA	4.01	4.6	26	5.7
8	Cannonsville	E2	Delaware, NY	3.99	13.0	77	5.9
9	Whitehall	Q22	Lehigh, PA	3.96	1.2	34	28.0
10	Ormrod	Q21	Lehigh, PA	3.92	1.3	45	34.6
11	Wadesville Mine Pit	Q01	Schuylkill, PA	3.91	6.9	39	4.8
12	Evansville	Q08	Berks, PA	3.91	3.1	44	14.3
13	Perkiomenville	Q23	Montgomery, PA	3.91	1.0	26	26.0
14	NESL Nazareth	Q27	Northampton, PA	3.86	1.0	25	25.0

Figure 7.3-1: Recommended Feasible Projects (12 quarries; 2 storage increase in existing reservoirs; see Table 7.3-1 for project names and details)



7.4 Sensitivity Analysis

The project team performed a sensitivity analysis on the weighting factors used in the scoring process, specifically the impact of decreased and increased weighting on two key criteria, Water Quantity/Quality and Project Cost/Schedule. The sensitivity analysis modified the weightings as shown below in Table 7.4-1. In the default weighting scheme, these two criteria had the largest weightings at 30% each. Scheme modification #1 was more balanced: the weighting was reduced greatly for the latter criteria (to 15%) and reduced only slightly for the former (25%) in recognition that large storage volume is a key advantage. These reductions required modest increases in other criteria to maintain the sum at 100%. Scheme modification #2 heavily emphasized Project Cost and Schedule, weighted at 40%, with corresponding reductions from the default scheme in two other criteria to maintain 100%.

Table 7.4-1: Sensitivity Analysis Weightings

Primary Criteria	Weighting Modification 1	Default Weighting	Weighting Modification 2
Water Quantity and Quality	25	30	30
Infrastructure Des. and Const.	20	10	10
Environmental	20	15	10
Social and Economic	10	10	5
Project Cost and Schedule	15	30	40
Ancillary Benefits	10	5	5

The results of the weighting changes on overall scores are shown in Table 7.4-2 and 7.4-3. Generally, projects in categories did not change appreciably relative to one another. However, projects overall ranked differently; specifically, projects with medium to large volume and good cost effectiveness moved higher in the rankings.

Table 7.4-2 shows the scores for the different weighting schemes for each project with the projects listed based on rank in the default scheme, while table 7.4-3 shows the projects in rank order for each scheme. The cluster of the top projects listed are very similar in the three categories. However, project E2 (Cannonsville Dam raise) and E4 (Prompton Dam modification) moved higher with more emphasis on quantity and cost effectiveness. Some projects moved into (e. g. Plymouth Meeting, Q23) or out of the top 18 based on the different weightings.

The transferrable storage projects appear in the top-ranked projects for all weightings. However, as mentioned above, there is great uncertainty in the volume available and its respective cost, which can be resolved only by serious negotiation with the owners.

Table 7.4-2: Scores for Sensitivity Analysis on Weightings (ranked by score in default weighting)

Project Name	Project ID	Weight Modification 1	Default Weighting	Weight Modification 2
Rio	T2	4.14	4.16	4.04
Rush Valley	Q19	4.06	4.07	3.99
McCoy	Q02	3.93	4.06	4.04
Prompton	E4	3.78	4.04	4.08
Penns Park	Q04	4.00	4.04	3.98
Solebury	Q12	3.99	4.03	3.95
Oxford	Q25	3.98	4.02	3.93
Ontelaunee	T4	3.98	4.01	3.93
Stockertown (Del River)	Q07D	4.02	4.01	3.92
Cannonsville	E2	3.74	3.99	3.99
Whitehall	Q22	3.97	3.96	3.85
Ormrod	Q21	3.97	3.92	3.79
Perkiomenville	Q23	3.95	3.91	3.79
Merrill Creek	T1	4.05	3.91	3.68
Wadesville Mine Pit	Q01	3.86	3.91	3.88
Evansville	Q08	3.90	3.91	3.85
Penn Forest/Wild Creek	T3	3.97	3.87	3.69
NESL Nazareth	Q27	3.79	3.86	3.78

Table 7.4-3: Rankings for Sensitivity Analysis on Weightings

Rank	Weight Modification 1	Default Weighting	Weight Modification 2
1	Rio (T2)	Rio (T2)	Prompton(E4)
2	Rush Valley(Q19)	Rush Valley(Q19)	Rio (T2)
3	Merrill Creek(T1)	McCoy(Q02)	McCoy(Q02)
4	Stockertown DR(Q07)	Prompton(E4)	Rush Valley(Q19)
5	Penns Park(Q04)	Penns Park(Q04)	Cannonsville(E2)
6	Solebury (Q12)	Solebury (Q12)	Penns Park(Q04)
7	Ontelaunee(T4)	Oxford(Q25)	Solebury (Q12)
8	Oxford(Q25)	Ontelaunee(T4)	Oxford(Q25)
9	Penn Forest(T3)	Stockertown DR(Q07)	Ontelaunee(T4)
10	Ormrod(Q21)	Cannonsville(E2)	Stockertown DR(Q07)
11	Whitehall(Q22)	Whitehall(Q22)	Wadesville (Q01)
12	Perkiomenville(Q23)	Ormrod(Q21)	Evansville(Q08)
13	McCoy(Q02)	Perkiomenville(Q23)	Whitehall(Q22)
14	Evansville(Q08)	Merrill Creek(T1)	Ormrod(Q21)
15	Wadesville (Q01)	Wadesville (Q01)	Perkiomenville(Q23)
16	NESL Nazareth(Q27)	Evansville(Q08)	NESL Nazareth(Q27)
17	Prompton(E4)	Penn Forest(T3)	Plymouth Mtg(Q03)
18	Cannonsville(E2)	NESL Nazareth(Q27)	Penn Forest(T3)

Evaluating potential projects depends not only on feasibility but on projects most effectively meeting the specific needs of DRBC. As needs become more defined, the scores and/or weightings can be changed.

It is difficult to rank the recommended projects because they would rank differently depending on the priority (e.g., large volume, low cost, low impacts, preferred geographic location or short time horizon). The weightings on the different criteria are designed to capture the relative priorities, but these may differ based on specific storage needs as will be defined by DRBC. Further, different individuals and organizations/stakeholders may have different priorities, and all of these may also change over time. Therefore, these recommendations are solely based on the described criteria and approach, as well as the stated limitations of this study. DRBC is encouraged to further modify the weightings to prioritize different criteria and note the changes to the scores and rankings. The information provided herein, scoring/sensitivity analysis and preferred project listing should provide useful tools to support DRBC's long-range planning efforts.

7.5 Project Summaries

Storage Project Summaries (SPSs) are provided in Appendix A for all 38 evaluated projects. One-page project descriptions for the top ten recommended projects are provided in Appendix I.

7.6 Combinations to achieve desired storage thresholds

A goal of this storage evaluation project was to present potential projects for providing additional storage that exceeded 1, 5, 10 and 20 BG through either a single project or multiple projects. Considering the 14 recommended projects, each exceeds 1 BG. Theoretically, they could be constructed independently to reach any volume desired up to the combined volume of about 50 BG.

The 20 BG threshold could be reached in the most cost-effective way by combining the Cannonsville dam raise (13 BG) with one or more of the large, cost-effective quarries. Alternatively, multiple quarries could be combined, such as Wadesville Mine Pit (Q1 at 6.9 BG) and the two other highly cost-effective large quarry projects, McCoy (Q2 at 6.2 BG) and/or Stockertown-Delaware River source (Q7D at 4.6 BG). This could provide almost 18 BG, and could be supplemented with one or more of the smaller projects to reach 20 BG.

The Cannonsville project exceeds the 10 BG and 5 BG thresholds. Two quarries (Q1 and Q2) each exceed the 5 BG threshold; they and/or other quarries could be combined to exceed the 10 BG or the 5 BG thresholds.

The variation in storage type and size allows for many different combinations of projects to achieve the goal of delivering 1, 5, 10 and 20 BG of storage in the Basin. Again, the optimum combination will depend on specific long-term goals and/or short- term priorities that might develop in reaction to another more immediate Basin supply need. The project team recommends that the Commission work with the greater project team and possibly with other key stakeholders to consider a variety of project combinations to meet future needs. Similar to the individual scoring/ranking process, a sensitivity analysis can be performed with a combination of projects to explore combinations that may best meet specific DRBC needs.

7.7 Caveats

This storage study was an evaluation of the feasibility of creating additional storage in the Basin. As such, the developed concepts and cost estimates are approximate. In some cases, data limitations precluded precise criteria scoring, forcing some of the scores assigned to some criteria to be subjective. Furthermore, only particular configurations of potential projects were evaluated where many other possible configurations may better suit the specific needs of DRBC's long-term plans. For example, the heights and locations of new dams could be varied, providing much different volumes, costs and impacts. Some assumptions were necessary regarding the likelihood of environmental and socioeconomic impacts of projects.

Scores for a particular project are dependent on the scores on individual criteria and on the weightings on the six primary criteria. Because there are many subcriteria, a very low (bad) score on one subcriteria has only a minor effect on the overall weighted score, even though it might potentially represent a "fatal flaw". These potential fatal flaws need to be explored further with DRBC in context of the long-term plan.

Section 8
Conclusion

8 Conclusion

The project team believes this study meets the project objective to evaluate the feasibility of potential projects to create additional water storage in the Delaware River Basin. This was achieved through assembling a large list of potential storage projects covering different types of projects throughout the Basin and screening out infeasible projects until a manageable data set was obtained. These 38 potential projects were evaluated in a level of detail consistent with the objectives, including conceptual design, cost estimates and considering various potential project impacts and ancillary benefits. These 38 projects were all scored with a consistent set of criteria, then ranked using these scores to determine relative feasibility. The projects that rated as most feasible were determined as listed in Table 7.3-1. Caveats regarding the results are presented in Section 7.7.

The project team appreciates the opportunity to provide our professional services in support of DRBC's need to define additional storage projects and satisfy long-term water supply planning needs.

Section 9
Acknowledgements

9 Acknowledgments

The contracted project team would like to acknowledge the following individuals and entities for their contributions to this study.

- Staff of DRBC including Steve Tambini, Kristen Bowman Kavanagh, Michael Thompson, and Amy Shallcross with special recognition of the Project Manager, Chad Pindar
- Richard Tallman, Dan Koury, Michael Kutney and staff of PADEP Bureau of Mines, Pottsville Office
- Dan Caprioli of the USACE Philadelphia District
- Staff of the Bethlehem Water Authority, with special recognition of Edward Boscala and Stephen Pallone
- Arlene McCoy, Merrill Creek Reservoir
- Paul DiRenzo
- Matt Ocwieja and Joyce Foster, Eagle Creek Renewable Energy
- Katie Lester and Dustin Droege, Brookfield Renewable
- Staff of EPCAMR
- Staff of Susquehanna River Basin Commission
- Fellow contracted project team members including:
    - GEI, LLC, especially Katie Laird and Roger Putty
    - Normandeau Associates
    - Technical Advisory Team
        - Anthony Bonasera (East Latitude, LLC)
        - Tony Fernandes (ALF Consulting)
        - Frank Falcone

Section 10
References

1 References

AACE (American Association of Cost Engineers). 2005. AACE International Recommended Practice No. 18R-97. Cost Estimate Classification System – as Applied in Engineering, Procurement, And Construction for the Process Industries.

Applied Weather Associates, LLC. 2019. Probable Maximum Precipitation Study for Pennsylvania. Pennsylvania Department of Environmental Protection. https://www.dep.pa.gov/Business/Water/Waterways/DamSafety/Pages/Probable-Maximum-Precipitation-Study-.aspx

Ash SH, Eaton WL, Hughes K, Romisher WM and Westfield J, Water Pools in Pennsylvania Anthracite Mines, 1949. US Department of the Interior Technical Paper 727.

Bethlehem Municipal Water Authority. 1939."Drawings for Construction of Reservoir Dam and Miscellaneous Appurtenances. Bethlehem Municipal Water Authority.

Black & Veatch. 2014. Phase 1 – Evolution the Tavilah Quarry for Water Supply Storage. Interstate Commission on the Potomac River Basin.

Brady KBC, Hornberger RJ and Fleeger G, 1998, Influence of Geology on Post Mining. PADEP.

Cravotta III, C.A., 2008. Dissolved metals and associated constituents in abandoned coal-mine discharges, Pennsylvania, USA. Part 1: Constituent quantities and correlations. Applied Geochemistry, 23(2), pp.166-202.

DRBC. 2015. Docket no. D-1969-210 CP-14. Exelon Generation Company, LLC Limerick Generating Station and Surface Water Augmentation. DRBC.

DRBC. 2018. Docket No. D-1977-110 CP-19. Merrill Creek Owners Group Merrill Creek Reservoir. DRBC.

DRBC. 2021. Docket NO. D-2000-059 CP-3. Reading Area Water Authority Surface Water Withdrawal. DRBC.

DRBC. 2022. Docket No. D-1995-019 CP-3. City of Bethlehem Surface Water Withdrawal and Impoundments. DRBC.

DRBC. 2021. 2021 Annual Report. DRBC. https://www.nj.gov/drbc/library/documents/2021AR.pdf

Eagle Creek Renewable Energy. 2020. Final License Application. Mongaup River Hydroelectric Projects: Swinging Bridge Hydroelectric Project (No. 10482), Mongaup Falls Hydroelectric Project (No. 10481), Rio Hydroelectric Project (No. 9690). Submitted to the Federal Energy Regulatory Commission.

Ebasco Services Inc. 1986. Cannonsville Reservoir Enlargement Feasibility Study. New York Department of Environmental Conservation.

Fairfax Water. 2016. Vulcan Quarry Water Supply Reservoir – Quick Facts, Fairfax Water. https://www.fairfaxwater.org/sites/default/files/newsletters/Vulcan%20Fact%20Sheet.pdf

Gannett Fleming Inc. 1978. Silver Creek Dam, Phase I Inspection Report.

Gannett Fleming Inc. 1995. Raw Water Supply Study: Safe Yield and Reservoir Storage Condition Curves. Bethlehem Authority.

Goode, D. J. 2011. Water Budgets and Groundwater Volumes for Abandoned Underground Mines in the Western Middle Anthracite Coalfield, Schuylkill, Columbia, and Northumberland Counties, Pennsylvania. USGS. SIR 2010-5261.

Harrison JP and GS Paxson. 2003. Ballpark PMFs. in 2003 Northeast Regional Conference Proceedings. Association of State Dam Safety Officials

Hornberger, RJ et al. 2011. Coal Ash Beneficial Use (Conventional Ash Placement) On Anthracite Mine Sites. in Hughes, RE, et al. Mine Water Resources of the Anthracite Coal Fields of Eastern Pennsylvania. EPCAMR (Eastern Pennsylvania Coalition of Abandoned Mine Reclamation).

Hughes, RE, et al. 2011. Mine Water Resources of the Anthracite Coal Fields of Eastern Pennsylvania. EPCAMR (Eastern Pennsylvania Coalition of Abandoned Mine Reclamation).

Lancaster County Solid Waste Municipal Authority. 2016. Preliminary Assessment of Consumptive Use Mitigation Potential Billmeyer Quarry, Convo Township, Lancaster County, Pennsylvania, DRBC, March 14, 2016.

MCOG (Merrill Creek Owner's Group). 2018. Plan of Operation for the Merrill Creek Reservoir. MCOG

MMA (Muhlenberg Municipal Authority). 2003. Comprehensive Plan. Muhlenberg Municipal Authority. https://www.muhlenbergtwp.com/227/Muhlenberg-Township-Comprehensive-Plan

Mott MacDonald. 2020. Proposal for Feasibility Evaluation of Additional Storage Options for Meeting Water Demands and Managing Flows in the Delaware River Basin, Mott MacDonald, March 27, 2020 (Amended 11/30/20).

NYCDEP (New York City Department of Environmental Protection. 2021. Before the Federal Energy Regulatory Commission Application for License for Major Project – Existing Dam -- Cannonsville Hydroelectric Project. VOLUME 1 Verification Statement Initial Statement Exhibits A – E. NYCDEP. FERC Project No. 13287

PADFW (PA Dept. of Forest and Waters). 1968. Bulletin #3. Water Resources of the Schuylkill River Basin. PADFW

PADEP. 2005. Pennsylvania Agricultural Consumptive Use Study, PADEP.

PADEP Bureau of Waterways Engineering, Division of Dam Safety. 2021. Penn Forest Dam Inspection Report. PADEP.

PADEP Bureau of Waterways Engineering, Division of Dam Safety. 2021. Wild Creek Dam Inspection Report. PADEP.

Petheram, C. and McMahon, T.A., 2019. Dams, dam costs and damnable cost overruns. Journal of Hydrology X, 3, p.100026.

Philadelphia Water Department. 2019. Alternatives Evaluation and Recommended Outcome (AERO) Report. Philadelphia Water Department.

Power, M. E., W. E. Dietrich and J. C. Finlay. 1996. Dams and Downstream Aquatic Biodiversity: Potential Food Web Consequences of Hydrologic and Geomorphic Change. Environmental Management. Vol. 20, No. 6, pp. 887-895. doi:10.1007/BF01205969

Skelly & Loy, Inc. 2004. Report of Findings, Evaluation of a Proposal to Increase Water Storage in the Delaware River Basin. DiRenzo Coal Company, Pottsville, PA.

SSM (Spotts, Stevens and McCoy Engineering and Environmental Services). 2019. Source Water Protection Program. Reading Area Water Authority.

Thompson, M. Y. and Pindar, C. E. (2021). Water Withdrawal and Consumptive Use Estimates for the Delaware River Basin (1990-2017) With Projections Through 2060. DRBC Report No: 2021-4. Delaware River Basin Commission.

USACE (U.S. Army Corps of Engineers). 2018 Water Control Manual (Revised) Prompton Reservoir Lackawaxen River Basin Pennsylvania. U.S. Army Corps of Engineers, Philadelphia District.

USACE (U.S. Army Corps of Engineers). 2018. Water Control Manual, Blue Marsh Lake And Dam, Schuylkill Basin, Pennsylvania. U.S. Army Corps of Engineers, Philadelphia District.

USACE (U.S. Army Corps of Engineers). 2021. 2021 Water Quality Monitoring, Beltzville Reservoir, Lehighton, Pennsylvania. U.S. Army Corps of Engineers, Philadelphia District, Environmental Resources Branch.

USACE (U.S. Army Corps of Engineers). 2021. 2020 Water Quality Monitoring, Blue Marsh Reservoir, Leesport, Pennsylvania. U.S. Army Corps of Engineers, Philadelphia District, Environmental Resources Branch.

Ullery, C. 2021. Rockhill quarry neighbors urge DEP to mining permit lapse this year. Bucks County Courier Times. Dec. 27. 2021.

Veil JA and Puder MG. 2006. Update on Use of Mine Pool Water for Power Generation. US Department of Energy, Argonne National Lab. ANL/EVS/R-06/6.

Wagner, T. and Erickson, L. 2017. Sustainable Management of Eutrophic Lakes and Reservoirs. Journal of Environmental Protection, 8, 436-463. doi: 10.4236/jep.2017.84032.

Wood CR, Water Quality of Large Discharges from Mines in the Anthracite Region of Eastern Pennsylvania. 1996. US Geological Survey Water Resources Investigation Report 95-4243.

Section 10
Appendices

Appendices

Appendix A – Storage Project Summaries

NEW DAMS

N1	Red Creek
N2	Milanville
N3	Little Martins Creek
N4	Rattling Run
N5	Equinunk
N6	Hawley
N7	Silver/Big Creek

EXISTING DAMS -- STORAGE INCREASE

E1	Wild Creek
E2	Cannonsville
E3	Blue Marsh
E4	Prompton

EXISTING DAMS – TRANSFERABLE STORAGE

T1	Merrill Creek
T2	Rio
T3	Penn Forest/Wild Creek
T4	Lake Ontelaunee

QUARRIES

Q01	Wadesville Mine Pit
Q02	McCoy
Q03	Plymouth Meeting
Q04	Penns Park
Q05	Lehigh Nazareth
Q06	Imperial
Q07D	Stockertown (Delaware River option)
Q07B	Stockertown (Bushkill Creek option)
Q08	Evansville
Q12	Solebury
Q14	Telford
Q16	Temple
Q19	Rush Valley
Q21	Ormrod
Q22	Whitehall
Q23	Perkiomenville
Q25	Tilcon Oxford
Q27	NESL Nazareth

DEEP MINES

M05	Silver Creek
M10	Wadesville
M19	Phoenix Park
M20	Otto
M32	Morea Basin

Appendix B – Technical Memorandum – *Estimate of Cost of Transferable Storage Existing Reservoirs in the Delaware River Basin*

Appendix C - Technical Memorandum – *Representative Pattern of Monthly Flow in Stream in the Delaware River Basin*

Appendix D - Summary of Screened-Out Potential Projects

Appendix E – Detailed Table of All Potential Projects Scores

Appendix F - Pumping Station Schematic Drawings and Supporting Data

Appendix G – Manufacturer’s brochure for typical pump for quarry discharge

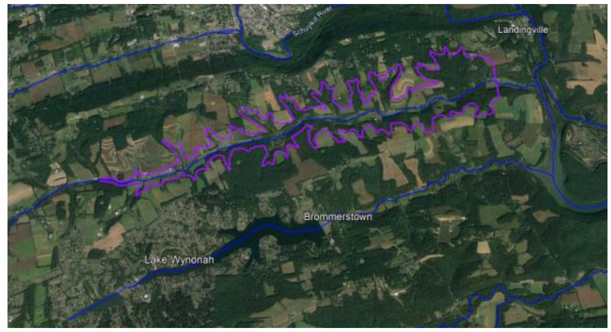
Appendix H – Relevant Permit Program Summary

Appendix I – One-page Descriptions of Top Ten Recommended Projects

MOTT MACDONALD

Storage Project Summary

Project:	Red Creek Reservoir (N1)	
Location:	Schuylkill County, PA, near Schuylkill Haven	
Storage Type:	New reservoir	
Est. Volume:	13.3 BG	
Score:	2.90	



1 Project Overview

The location of the potential dam and pump storage reservoir is on Red Creek, near Schuylkill Haven, PA (Figure 1.1). The dam would be located about ¼ mile from the confluence with the Schuylkill River (Figures 1.2 through 1.4). Red Creek's watershed is small at just over 5 sq mi, extending to the western boundary of the Schuylkill River watershed. The area is a mixture of cropped lands and forest (Figure 1.3).

The dam would be a conventional earthen embankment dam as described in the section 5.2 of the main report. At a height of 185 ft and length of 2,050 ft, this dam would create a reservoir of about 830 acres at normal pool, providing 13.3 BG of storage (Figure 1.4). The reservoir would flood approximately 70 rural residential properties and about 7.5 miles of roads, foremost, Deilberts Valley Road (which runs along the Creek and provides access to these properties) and Berne Rd, which is the only road that crosses the reservoir footprint. The dam's location or height could be adjusted to reduce these impacts.

The reservoir would discharge to the Schuylkill River. The Au burn Desilting Basin is on the River just downstream of the confluence with Red Creek and could make a convenient location for discharge because no stilling basin would be required.

Because the drainage area is small, the reservoir would need to be filled by pumping from the Schuylkill River; the Auburn Desilting Basin is a convenient point for withdrawal. The Schuylkill watershed is fairly large at this point at 144 sq mi with a mean flow of 303 cfs and so provides an adequate source to fill/refill the reservoir.

A Red Creek dam was investigated in previous reports, most thoroughly in 1976. The 1981 Level B report stated that this site would not be included in the comprehensive plan; however, no reasons were given. It was rated as having moderate environmental and social impact. The project was selected for detailed evaluation due to its large volume and limited impact (relative to its volume) on forests, roads, buildings, wetlands, and high-quality streams.

Figure 1.1: Project location

Figure 1.2: Topographic map: Drainage area in red (5.3 sq miles). Reservoir outline in purple.

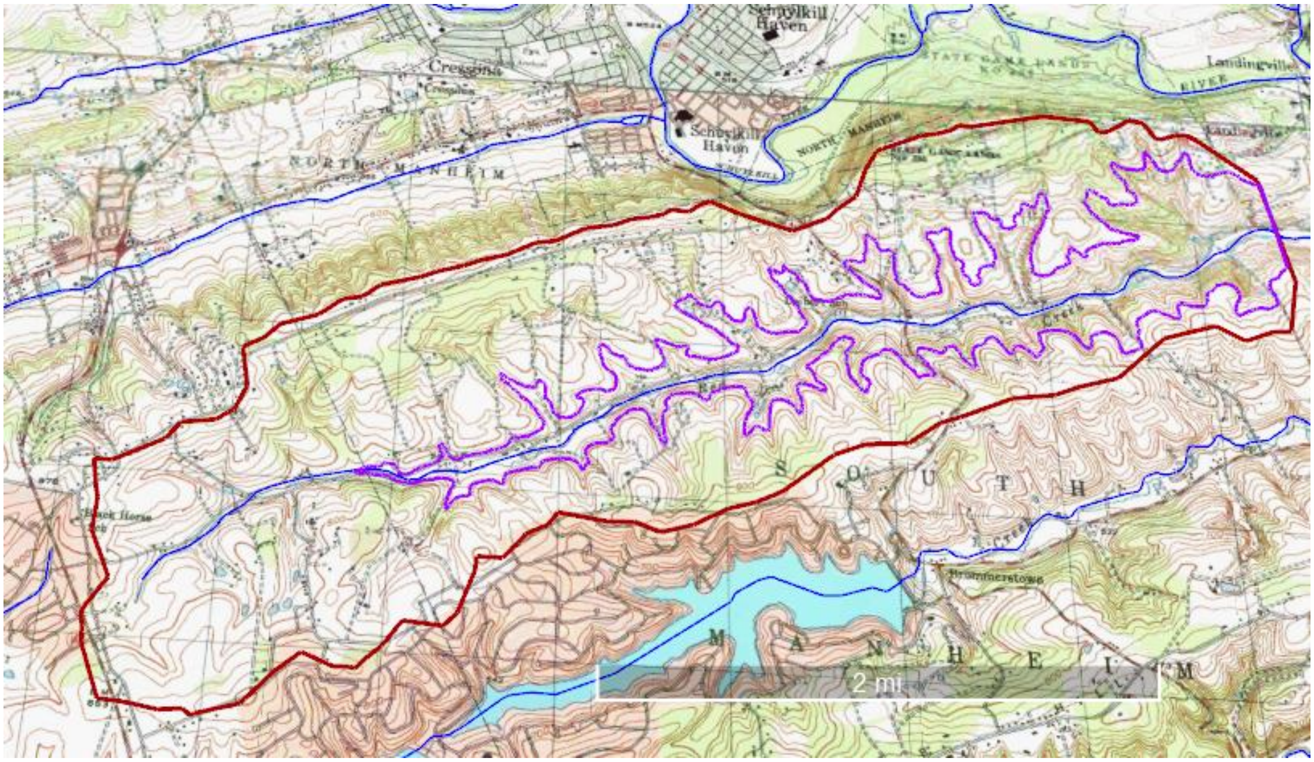


Figure 1.3: Aerial photo: Drainage area in red (5.3 sq miles). Reservoir outline in purple.

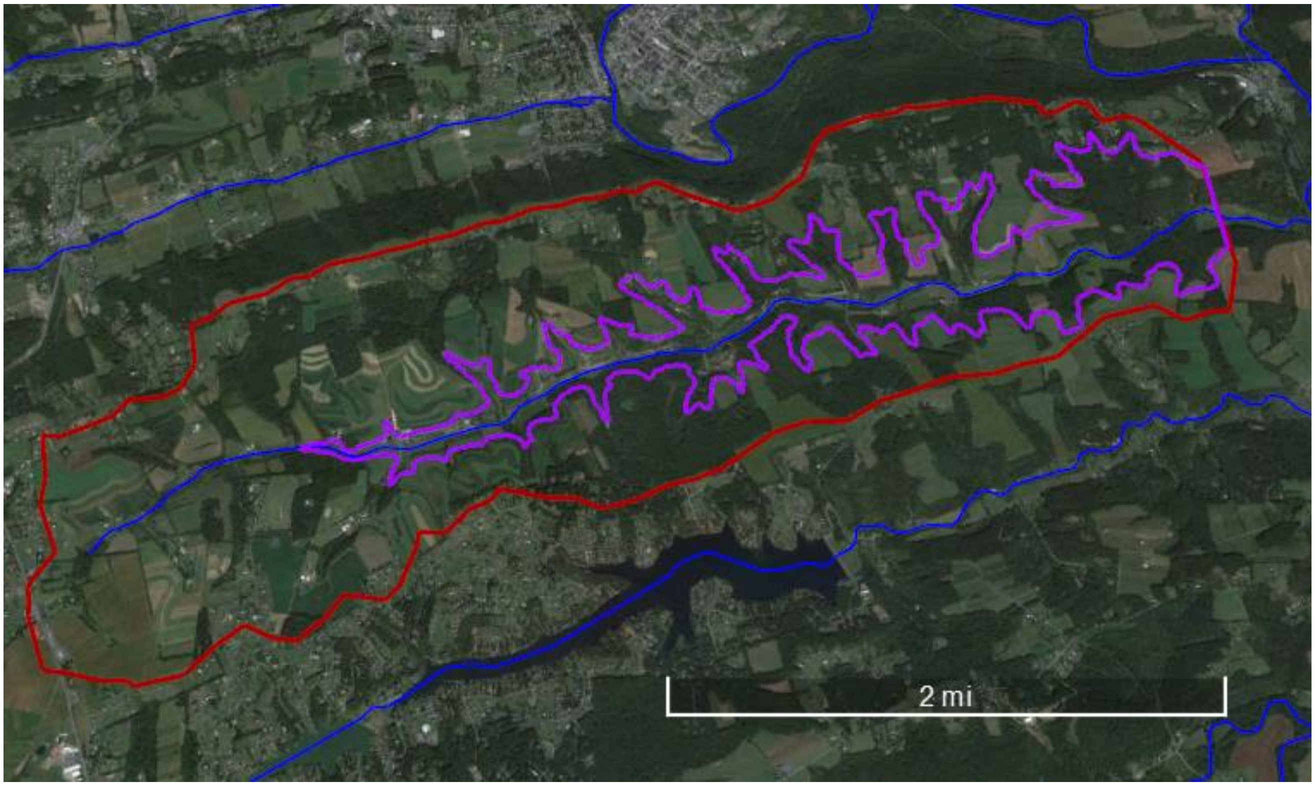
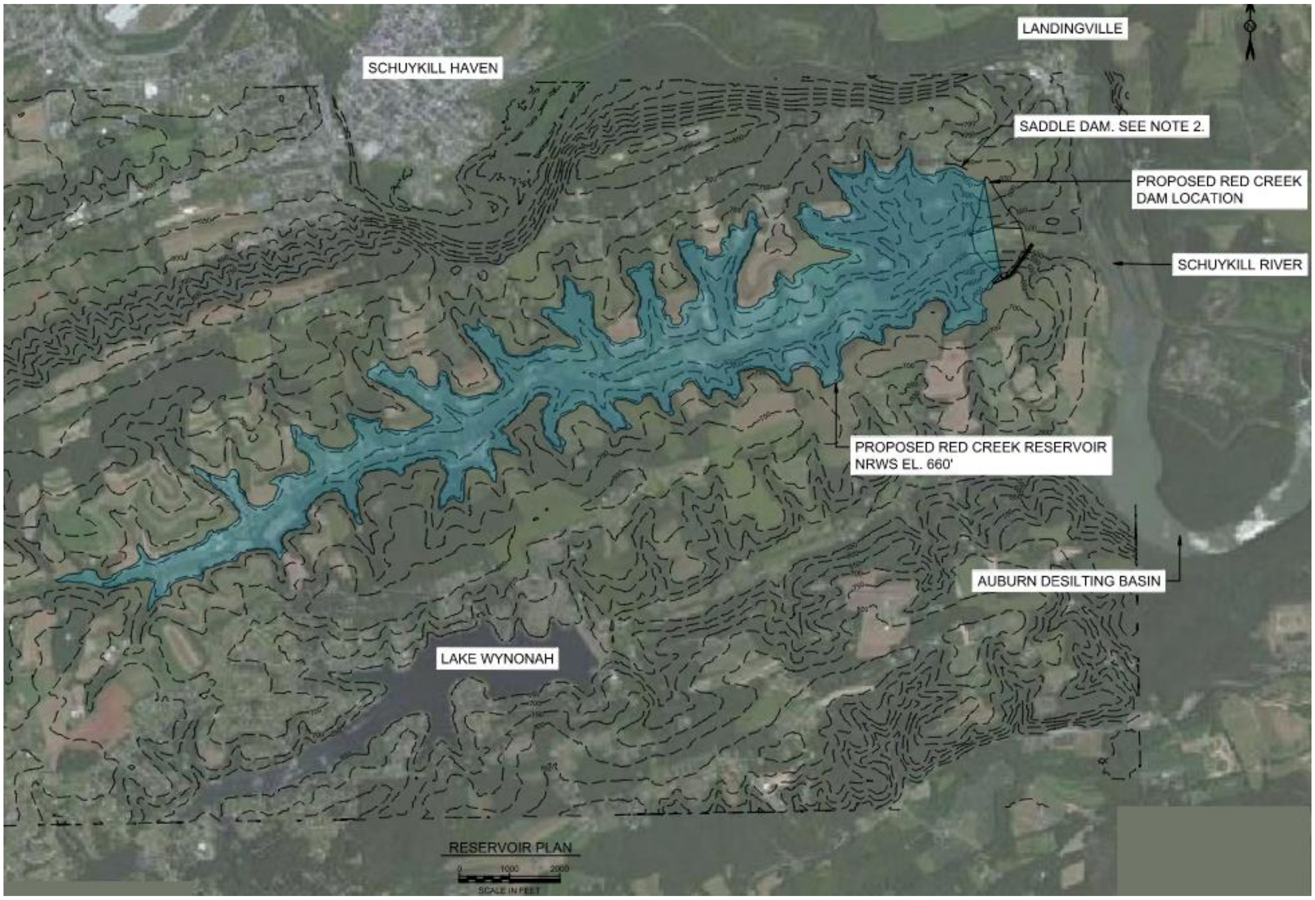


Figure 1.4: Project Schematic



2 Water Quantity & Quality

Key parameters of the potential dams and reservoir are listed in Table 2.1 below. Detailed drawings are presented in the Appendix. The project would provide large storage volume (13.3 BG) to support flow augmentation downstream. A significant drawback is the small drainage area. To provide reliable water supply, this reservoir would require pumping from the Schuylkill River for filling, thereby increasing capital and operating costs as detailed below.

Table 2.1: Dam, Reservoir and Spillway Parameters

DAM	
Lat/Long	40.6178, -76.1243
Size Category per PADEP Code	A – Equal or greater than 100 feet; Equal to or greater than 50,000 ac-ft
Hazard Potential per PADEP Code	1 – Substantial (Numerous homes or small businesses or a large business or school)
Dam Type	Earthen Dam with Clay Core
Dam Crest El	668 ft
Dam Height	185 ft
Dam Crest Length	2,050 ft
Dam Crest Width	25 ft
Dam Slope Inclination	2.5h:1v Upstream 2.5h:1v Downstream
Saddle Dam	6 ft height, 455 ft length, 2.5h:1v slopes to contain MRWS
RESERVOIR	
Normal Reservoir Water Surface (NRWS)	660 ft
Maximum Reservoir Water Surface at PMF (MRWS)	666 ft
Storage Capacity at NRWS	13.3 BG / 47,520 ac-ft
Reservoir Area at NRWS	830 ac
Reservoir Area at MRWS	840 ac
Reservoir Area Footprint (50 ft Buffer)	901 ac
Freeboard at NRWS	8 ft
Freeboard at MRWS	2 ft
Drainage Area of Dam	5.3 sq mi
SPILLWAY	
Spillway Type	Concrete lined, ungated, ogee crest, “L” shaped side-channel
Spillway Crest El	660 ft
Peak Discharge	12,870 cfs
OUTLET	
Outlet Works Type	Outlet Tower
Outlet Works Conduit	42-inch steel pipe
Outlet Elevation	484 ft
Conduit Length	970 ft
Required Capacity	36 cfs
Outlet capacity at NRWS	418 cfs

2.1 Fill and Discharge

Because the drainage area is small (5.3 sq. mi.) relative to the impoundment, the reservoir would need to be filled by pumping from the Schuylkill River. The Auburn Desilting Basin could be a convenient point for withdrawal. As explained in the main report, design capacity of a pump station was set at 30 mgd or 50 cfs with pumping planned for 6 months per year (November through April) at an average rate equal to the lesser of the pumping station capacity or 40% of the mean flow. With a large watershed providing a mean flow of 300 cfs in the Schuylkill River, the design capacity of 50 cfs was assumed as a constant pumping rate. Operating continuously over six months, the pump could provide about 5 billion gallons. At this rate, it would take about 11 months of pumping to fill the reservoir, including the natural mean flow of about 10 cfs in Red Creek. However, in reality, the pump will not be able to operate at that flow rate when the flow rate in the River is very low. A more detailed analyses would more accurately determine the time to fill under different conditions.

The water would be released by gravity, so a large release could be readily achieved through the 42-inch low-level outlet pipe, 418 cfs at the NRWS. If such a large release were discharged to Red Creek, a stilling basin would be required. However, if discharge was directed to the Auburn Desilting Basin, one may not be required; more investigation would be needed. The 13 BG reservoir could provide about 200 days of flow augmentation at the desired rate of 100 cfs.

The project sits high in the Schuylkill watershed, which is both an advantage (the released water would benefit a long reach of the Schuylkill River) and a disadvantage – with about 100 stream miles to travel, the release will take a few days to reach to the Delaware River. With the Schuylkill River entering the mainstem at Philadelphia low in the Basin, the upper/middle Delaware will not benefit from the project, but the flow will help repel the salt front.

2.2 Water Quality

Red Creek was assessed by the PADEP in the 2022 integrated report as supporting aquatic life use, while impaired by pathogens (source unknown) for recreational use. Red Creek was not assessed for fish consumption or potable water use. The source of pathogens could be livestock operations upstream. If the reservoir were built, it would displace some of these operations and reforestation of forested buffers could reduce pathogen loads.

The large majority of the water in the reservoir would be pumped in from the Schuylkill River. Schuylkill River water is assessed (Table 2.2) as impaired for aquatic life due to hydrologic alteration from urban runoff and due to siltation and iron from acid mine drainage. It is impaired for recreation due to pathogens (source unknown) and for fish consumption due to PCBs. Pumping PCB-containing water into the reservoir could be problematic. However, the PCBs are likely sediment bound and so may be very low concentration in pumped water – this would need to be investigated. Pumping from the Stilling Basin may also reduce sediment in the pumpage.

In any case, water that would be pumped into the reservoir would, in its absence, be headed downstream in the Schuylkill River. Schuylkill water is already withdrawn for drinking water treatment at multiple locations, most notably in Philadelphia. Therefore, the water quality in a Red Creek reservoir should be adequate for augmenting flow and resisting the salt front.

One concern is eutrophication in the reservoir, because residence time will be long and little mixing will occur. A useful comparator is Lake Wynonah, which sits just south of Red Creek. Its discharge, Plum Creek, has the same usage/impairment status as Red Creek does now. Another relevant comparator is Blue Marsh reservoir, which discharges into the Schuylkill River at Reading. It was determined eutrophic by the US Army Corps of Engineers. The DRBC owns storage in Blue Marsh, which is released to augment flow. Therefore, water quality of Red Creek reservoir is expected to be suitable for the same purpose.

Table 2.2: Impairment status reported in the 2022 integrated report

	Aquatic Life Use	Recreational	Fish Consumption	Potable water
Red Creek	Supported	Impaired: Pathogens (source unknown)	NA	NA
Schuylkill River	Impaired: hydrologic alteration from urban runoff, and siltation and iron from acid mine drainage	Impaired: pathogens (source unknown)	Impaired - PCBs (source unknown)	NA

3 Infrastructure Design, Construction & Operation

3.1 Dam

As detailed in the main report, conceptual designs were developed in general accordance with the Pennsylvania Code Title 25, Chapter 105, Dam Safety and Water Management. Detailed parameters are given in Table 2.1. The dam and spillway were designed to pass the “probable maximum flood” (PMF), which was estimated as described in Section 5.2 of the main report. A small saddle dam is needed as shown in Figure 1.4 Freeboard was assumed to be 2 feet above the MRWS elevation. Detailed drawings are presented in the Appendix.

An intake tower was conceptually designed with associated controls, piping, and valves housed within the tower. A 42”, concrete-encased, steel pipe travels through the dam connecting the intake tower to an outlet structure where water releases are to be made. The outlet capacity at NRWS greatly exceeds the required capacity.

Site access consisting of roads to key dam facilities has not been developed into the designs. An estimated allowance has been included in the cost estimate for project roads.

3.2 Pumping Facilities and Pipeline

Water would be pumped from the Schuylkill River about 2,600 feet away. Pumping and pipeline parameters are detailed in Table 3.1. As mentioned above, design capacity of the pump station was set at 30 mgd or 50 cfs. Anticipating that the reservoir might be drained about once every ten years, the operating costs would be a small portion of overall costs. The standard configuration of the pump station is described in the main report: submerged wedgewire screen on the river bottom connected to a wetwell on the adjacent bank that will house submersible pumps for lifting and transferring river water. The proposed configuration has 3 x 10 mgd pumps in the wetwell. Components and quantities of the envisioned facilities are detailed further in Section 6, Project Cost & Schedule. The system will function as others and be automated and monitored for remote operation.

The intake is envisioned as located at the head of the Auburn Stilling Basin, about 2,600 ft from the dam. The pump would have to work against 190 ft of static head at NRWS.

Table 3.1: Pump and Pipeline Parameters

Parameter	Value
Pump Design Flow	30 mgd (50 cfs)
Pump Capacity (3 x 10 mgd)	30 mgd (50 cfs)
Pipeline Distance	2600 ft
Elevation at Withdrawal Point	470 ft
Elevation at NRWS	660 ft
Elevation difference	190 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

4 Environmental Impacts

Under 25 Pennsylvania Code Chapter 93 Water Quality Standards (Chapter 93), Red Creek is classified as a cold-water fishery (CWF) which may include migratory fish; however, the PA Fish and Game Commission does not rate this stream for trout. Red Creek's watershed produces a mean flow of less than 10 cfs. During late summer and early autumn months, the flow may be lower, especially during drought.

The watershed vegetated cover appears to be about an even mixture of cropped lands and forest (Figure 1.3). Mature forest dominates about 60% of the inundated area which equates to about 500 acres. The value or condition of the forest was not assessed in detail, but from aerial photos the forest appears to be dense, but fragmented and interspersed with farm fields.

The potential dam would result in inundating about four miles of Red Creek, covering about 830 acres of the 3,400-acre watershed, or about 24% of the land area. Though maps of the area do not indicate tributaries, aerial photo interpretation and topographic relief indicate numerous permanent or intermittent tributaries to Red Creek. These would be also partially or fully inundated. Construction of a reservoir in Red Creek would replace these lotic or flowing creeks with a large lentic aquatic system.

Construction of a dam across Red Creek would eliminate its seasonal hydroperiod, including spring pulses and releases to the floodplain and downstream areas. Because the Red Creek watershed is relatively small, the change would not be expected to result in significant downstream effects. If the free-flowing stream would be retained behind a dam, the water would become warmer and, as happens in most reservoirs, nutrient retention would increase, resulting in eutrophication.

About five acres of riverine wetlands would be inundated, which, compared to other sites examined for new dams, is relatively low.

Two endangered/threatened species are reported by the USFWS iPaC as being "potentially affected" by activities in this location: Indiana Bat (Myotis sodalis) and Northern Long-eared Bat (Myotis septentrionalis). The dam site is at least 60 miles from a known bat maternity colony and at least 50 miles from a known hibernaculum, so though expected severe impact on bats would not be anticipated, a better understanding of the local bat population is needed before definitively understanding potential impacts.

5 Social and Economic Impacts

The reservoir site is currently rural, comprised mainly of farmland and forest with some rural residences. The reservoir would flood about 70 residential properties. Many of the properties within the reservoir footprint are very large – over 25 acres. Presumably, these large properties are farms with one or two residences. Most of these properties have a significant portion outside the reservoir footprint, meaning some inundated residences could possibly be relocated or reconstructed at a different location on the same property. Given the abundance of undeveloped land, other displaced residences could possibly be reconstructed near their current location.

Two businesses are identified on maps, which are likely relocatable. Farming is the main commercial activity. Much farmland would remain after reservoir construction. In fact, in some instances, an owner may be able to continue to farm currently owned land that is outside of the reservoir footprint.

About 7.5 miles of roads would be inundated, foremost Deilberts Valley Road, which runs along the Creek and provides access to most of the properties that would be flooded, and Berne Rd, which is the only road crossing the footprint of the reservoir. Alternative through routes are available within one-half to three miles.

Regarding risk to safety of downstream residents, with modern construction technologies and monitoring, the risk of a dam failure would be low. There are no housing areas between the dam and the Auburn Stilling Basin, nor around the Basin. The Basin is U-shaped, contained by a hundred-foot bluff, which could deflect and attenuate a flood wave. The town of Auburn, about three river miles downstream of the Red Creek dam and one mile downstream of the Stilling Basin dam, sits mostly on a bluff above the river. Scattered houses on lower ground along Rt 895 east of Auburn would be most vulnerable.

The demographics of South Manheim Township (which would encompass the reservoir) as reported in the 2000 census are not dominated by historically oppressed groups. Nor is there any indication that this area has been highly burdened in the past with undesirable facilities. Therefore, social equity concerns seem minor.

Maps do not indicate any public recreation or fishing sites within the reservoir footprint, so impacts on same are presumed minor. A public reservoir could create many such opportunities.

Similarly, loss of tax revenue from inundated properties would be minor because most of the land is tax-advantaged farmland or undeveloped forest. The possibility of tourist facilities oriented to reservoir recreation could provide opportunities for economic development, jobs and increased tax revenue. The loss of production of some 400 acres of farmland would not be expected to burden the community.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level (level 4) cost estimate for construction costs are presented in Table 6.1 for the dam and Table 6.2 for the pump station and pipeline. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) are reported in Table 6.3. Methods are described in the main report in Section 5.2.6. Costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail.

Table 6.3 shows the cost estimate (present value) of this potential project is high at $366M; its cost effectiveness is $28M/BG, which is among the best for new dams, but significantly larger than several other projects per Section 6.2 of the main report.

Table 6.1: Dam Construction Cost Summary

Description	Unit	Quanity	Rate	Total	Comments
1.0 Dam				**$ 137,434,200**	
1.1 Excavation	CY	467,300	$ 20.00	$ 9,346,000	Main Dam + Saddle Dam
1.2 Grout Curtain	SF	197,400	$ 110.00	$ 21,714,000	
1.3 Core Material	CY	407,900	$ 25.00	$ 10,197,500	Core borrow area near dam site
1.4 Filter Material	CY	42,700	$ 90.00	$ 3,843,000	Imported material
1.5 Dam Shell Material	CY	2,912,200	$ 30.00	$ 87,366,000	Shell borrow area near dam site, Main Dam + Saddle Dam
1.6 Riprap	CY	23,200	$ 200.00	$ 4,640,000	Improted Material, Main Dam + Saddle Dam
1.7 Hydroseed	SF	655,400	$ 0.50	$ 327,700	Main Dam + Saddle Dam
2.0 Spillway				**$ 9,092,800**	
2.1 Excavation	CY	19,800	$ 30.00	$ 594,000	
2.2 Spillway Slab	CY	2,600	$ 850.00	$ 2,210,000	
2.3 Spillway Walls	CY	1,600	$ 1,100.00	$ 1,760,000	
2.4 Anchors	EA	1,060	$ 2,500.00	$ 2,650,000	Approx 10' spacing
2.5 Drainage Layer	CY	120	$ 90.00	$ 10,800	Slot trench every 50' of spillway chute
2.6 Drainage Pipes	LF	680	$ 100.00	$ 68,000	
2.7 Stilling Basin	CY	1,800	$ 1,000.00	$ 1,800,000	200' long x with 20' additional wall height
3.0 Outlet Works				**$ 6,710,000**	
3.1 Outlet Pipeline and Installation	LF	980	$ 2,000.00	$ 1,960,000	
3.2 Outlet Tower and Installation	10' Segment	19	$ 250,000.00	$ 4,750,000	
4.0 Access Roads				**$ 900,000**	
4.1 New Roads	Mile	1.5	$ 600,000.00	$ 900,000	Estimated from nearby existing road to key project components
5.0 Key Project Components Subtotal				**$ 154,137,000**	
5.1 Sum 1.0 thru 4.0	Subtotal			$ 154,137,000	
6.0 Contractor Allowances				**$ 64,583,403**	
6.1 Environmental Allowance: Rate x 5.0	Rate		2%	$ 3,082,740	
6.2 Materials Testing (QA/QC): Rate x 5.0	Rate		2%	$ 3,082,740	
6.3 Contractor Indirect Costs: Rate x 5.0	Rate		25%	$ 38,534,250	
6.4 Profit: Rate x (5.0 + 6.1 + 6.2 + 6.3)	Rate		10%	$ 19,883,673	
7.0 Contingencies				**$ 98,424,181**	
8.1 Design Contingency: Rate x (5.0 + 6.0)	Rate		25%	$ 54,680,101	
8.2 Construction Contingency: Rate x (5.0 + 6.0)	Rate		20%	$ 43,744,081	
8.0 Conceptual Cost Estimate Total				**$ 317,145,000**	
8.1 Sum 5.0 thru 7.0	Total			$ 317,144,584	

Table 6.2: Pump Station and Pipeline Cost

Item	Unit	Quantity	Cost/Unit	Extended
Pump Station			**Subtotal**	**$ 3,465,500**
Intake				
Screens	LS	3	$ 80,000	$ 240,000
Structure	VF	12	$ 50,000	$ 600,000
Other	LS	1	$ 90,000	$ 90,000
Pumping Station				
Pumps	#	3	$ 450,000	$ 1,350,000
MEP	LS	1	$ 265,500	$ 265,500
Structure	SF	1200	$ 350	$ 420,000
Other	LS	1	$ 500,000	$ 500,000
Dissipation	LS		$ 500,000	$ -
Pipeline			**Subtotal**	**$ 2,362,000**
Pipeline	LF	2640	$ 800	$ 2,112,000
Valves	#	5	$ 50,000	$ 250,000
Access Roads				**$ 250,000**
New roads	Mile	0.5	$ 500,000	$ 250,000
Land Acquisition				**$ 22,492**
Inundation Area	ACRE	2	$ 11,246	$ 22,492
Subtotals				
Construction Costs Subtotal				$ 6,099,992
Contingency			$ 0	$ 1,829,997
Construction Estimate + Contingency				**$ 7,929,989**

Table 6.3: Overall Cost Summary

Land acquisition cost ($)	21M
Construction Cost ($)	325M
Operating Cost ($/yr)	1.M
Overall Cost (Present value, $)	366M
Cost effectiveness ($/BG)	28M

The schedule for the project is also very rough. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition. Fifteen years was the typical estimate for a new dam.

- Funding acquisition 5 years
- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup 2 years
- Total 15 years

7 Potential Ancillary Benefits

A major benefit would be a large, public-accessible reservoir suitable for multiple types of recreation, similar to Blue Marsh. This would be the only such public facility close to residents of the Schuylkill Haven/Pottsville area. Such an amenity may support development of tourist and recreation-oriented businesses, providing jobs and increased tax revenue. The reservoir could also raise the value of surrounding property.

The reservoir would create a large lake habitat, which is scarce in the vicinity, while replacing about 5 miles of small-stream habitat. However, the likelihood of eutrophication threatens to degrade the lake's habitat quality. Plus, if a long-term release is necessary, the reservoir level could remain low for months, reducing habitat.

Regarding flood control, this reservoir would not provide significant benefit because the drainage area is small. The pump station would not be capable of significantly reducing high flows in the Schuylkill River.

8 Storage Project Score

This site was scored as determined and described in the main report and summarized in Table 8.1 below for the six primary criteria. Each primary criterion contained subcriteria which were scored on a 1 (worst) to 5 (best) scale and averaged. Scores on the primary criteria were weighted as shown in Table 8.1 and summed to obtain an overall weighted average score. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

Table 8.1: Storage Project Score

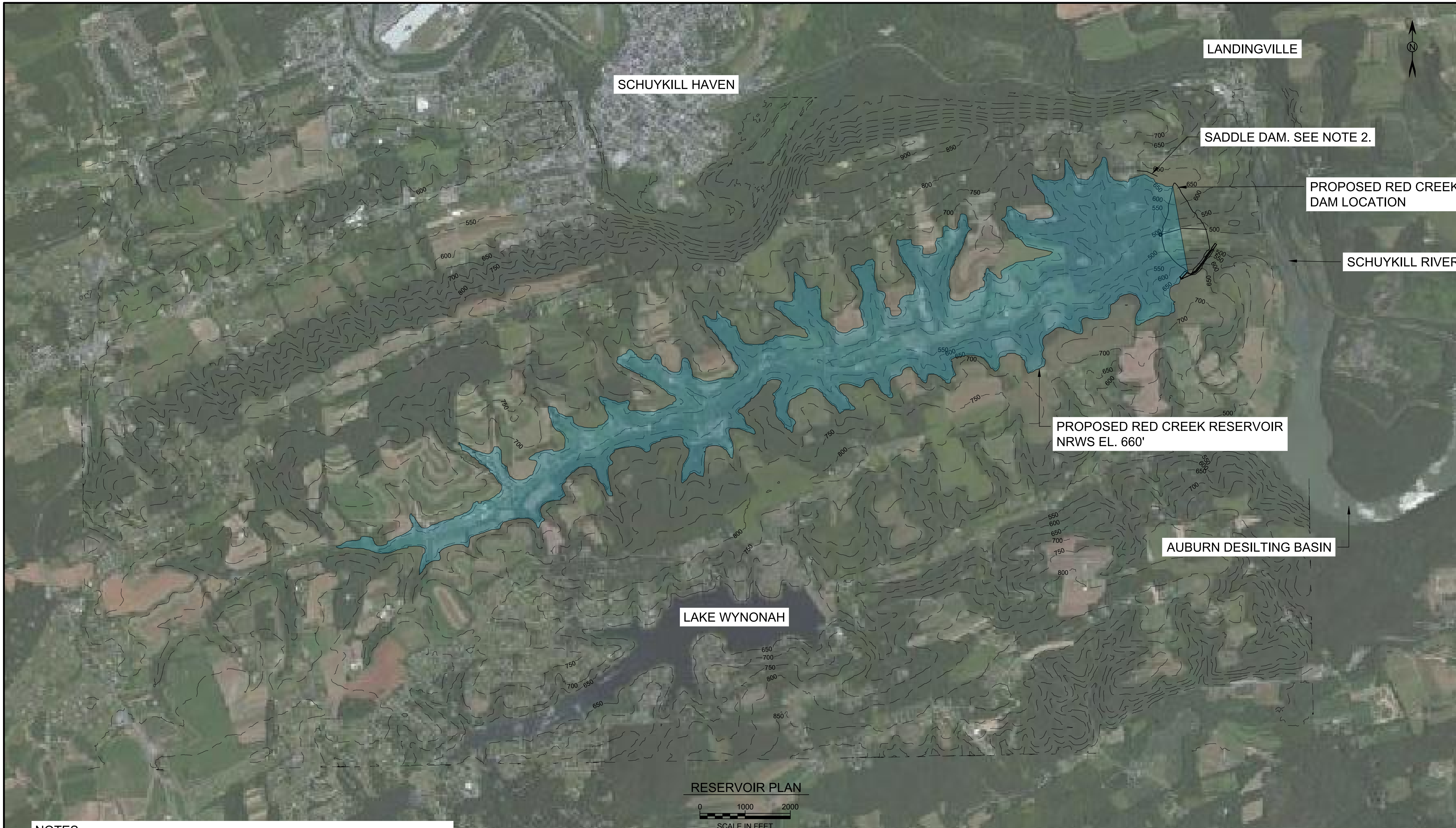
Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.67	30%	1.10
Infrastructure Design, Construction & Operation	2.20	10%	0.22
Environmental Impacts	2.93	15%	0.44
Social & Economic Impacts	3.22	10%	0.32
Project Cost & Schedule	2.33	30%	0.70
Ancillary Benefits	2.40	5%	0.12
AVERAGE	**2.79**		**2.90**

APPENDIX

Score Sheet

Drawings

Six primary criteria	Quantitative Evaluation Metric (when appropriate) (enter values only in ungreyed cells)	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
1. Water quantity and quality		3.67			30%	1.10	
o Volume of storage provided (BG)	13.3	4					
o Hydrologic reliability of supply (months to fill)	11	4					
o Release rate (cfs)	410	5					
o Promptness of delivery to mainstem (days)	>2	3					
o Geographic benefit		3					Enters at Schuylkill
o Quality of stored water		3					
2. Infrastructure design, construction and operation		2.20			10%	0.22	
o Site/Civil, Land & Easements		1					Many private properties to aquire
o Subsurface conditions		3					
o Infrastructure Complexity		2					Needs pump station and pipeline from Schuylkill River
o Construction complexity		3					
o Operational complexity		2					Need to carefully monitor/adjust pumping rate
3. Environmental impacts		2.93			15%	0.44	
o protected species		3					60 miles from known bat maternity colony; 50 miles from known hibernaculum
o Water quality degradation of downstream waters		3					Could be eutrophication but likely small effect on downstream
o obstruction to passage of aquatic animals		3					At edge of watershed, so little opportunity for passage
o hydromodification		3					Pump-in rate will be restricted to reduce impacts
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted 5=small, 1=large)			
o wetlands inundated or filled (ac)	5 ac	3.5	3	4			
o stream length inundated (mi)	4 mi	2	3	1			
o uplands inundated or developed (ac)	825 ac	3	5	1			
4. Social and Economic Impacts		3.22			10%	0.32	
o Disruption/displacement		1					Floods about 70 houses
o Safety and health		3					
o Social equity		4					
o Recreational loss		4					
o Cultural/historical resources		4					
o Aesthetic		4					
o Loss of tax revenue		3					
o Loss of production from farmland, timberland, quarries		3					
o Emissions of greenhouse gasses		3					Small operational emissions from infrequent pumping
5. Project Costs & Schedule		2.33			30%	0.70	
o Land acquisition cost ($)	21M						
o Construction Cost ($)	325M						317M$ for dam + 8M$ for pump station and pipeline
o Operating Cost ($/yr)	1.M						
o Overall Cost (Present value, $)	366M	1.5					
o Cost effectiveness ($/BG)	28M	2.5					
o Schedule (Time to make Operational, years)	15	3					
6. Ancillary Benefits		2.40			5%	0.12	
o Flood control		2					Small basin provides little benefit
o Recreation/tourism		5					Large reservoir provides significant beneft
o Habitat/fishery enhancement		3					Large reservoir provides significant habitat but likely eutrophic and floods streams
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		2.79			100%	2.90	



RESERVOIR PLAN

0 1000 2000
SCALE IN FEET

NOTES:
1. TOPO REFERENCE: ONE THIRD ARC SECOND PUBLISHED ON 2022-04-29 (USGS NATIONAL MAP)
2. SADDLE DAM: HEIGHT = 6FT, LENGTH = 455FT. DETAILS NOT PROVIDED.

Project Number: 507101042	Date: 31 MAY 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 01

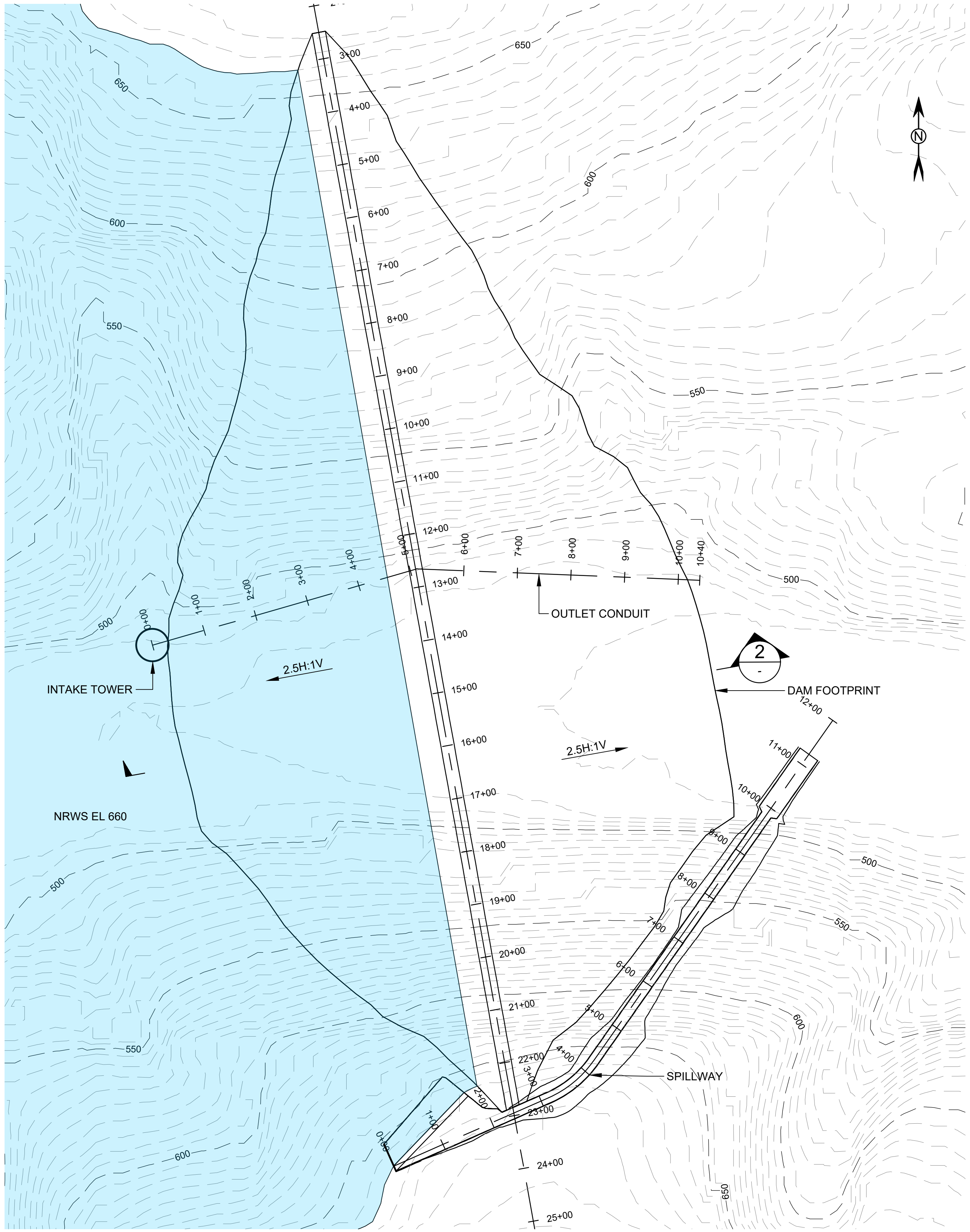
MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

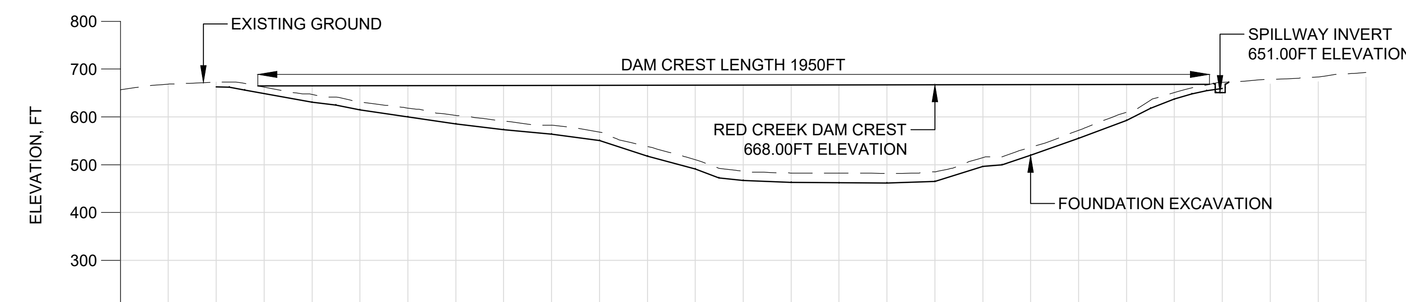
RED CREEK DAM
FIGURE 01 - GENERAL SITE PLAN

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D RC_DAM V2.DWG



PLAN VIEW - RED CREEK DAM

0 125 250
SCALE IN FEET



STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00
EXISTING GROUND ELEVATION (ft)	656.8	668.6	672.6	662.5	646.9	631.7	618.6	603.3	591.4	582.9	568.0	538.2	510.4	486.4
CORE TRENCH ELEVATION (ft)			662.6	648.6	630.6	614.7	600.0	585.3	573.3	564.0	550.3	518.2	491.5	467.0

STATION (ft)	14+00	15+00	16+00	17+00	18+00	19+00	20+00	21+00	22+00	23+00	24+00	25+00	26+00
EXISTING GROUND ELEVATION (ft)	482.7	482.4	481.7	485.3	515.1	536.2	572.1	609.7	650.7	672.4	678.6	683.5	693.1
CORE TRENCH ELEVATION (ft)	462.8	462.3	461.8	465.3	496.6	520.0	555.5	592.8	637.4	659.2			

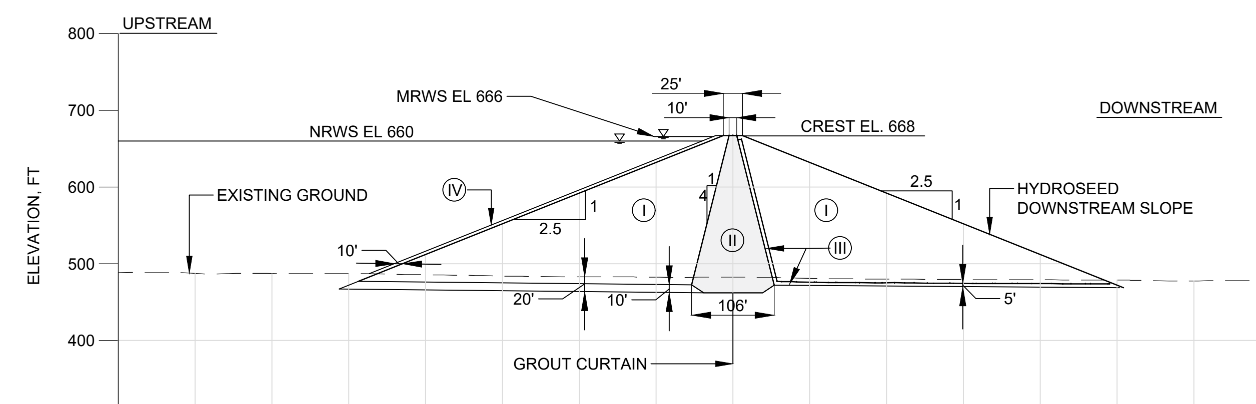
1 - SECTION ALONG DAM AXIS

RED CREEK DAM CENTERLINE

DAM TYPE	MATERIALS
I. SHELL	GENERALL FILL FROM LOCAL BORROW AREA
II. CORE	LOW PERMEABLE CLAY
III. FILTER	HIGH PERMEABLE GRANULAR
IV. RIPRAP EROSION PROTECTION	ROCKFILL BOULDERS

NOTES:

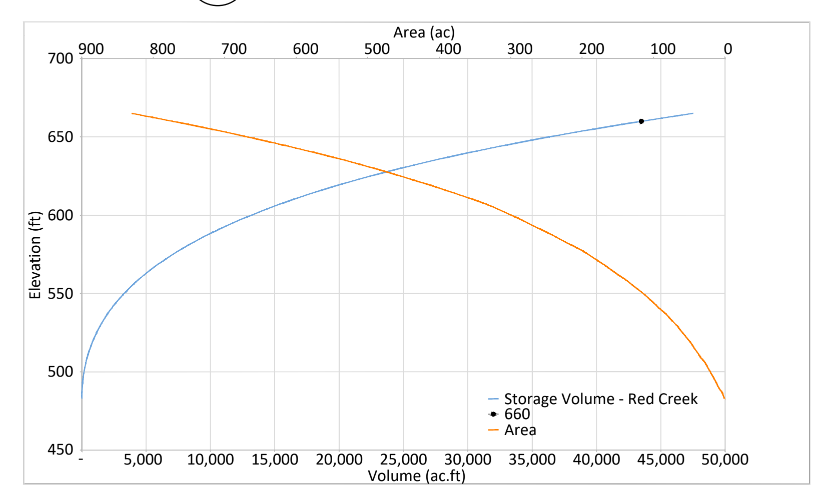
1. MAXIMUM RESERVOIR WATER SURFACE (MRWS)
2. NORMAL RESERVOIR WATER SURFACE (NRWS)



OFFSET (ft)	-8+00	-7+00	-6+00	-5+00	-4+00	-3+00	-2+00	-1+00	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00
EXISTING GROUND ELEVATION (ft)	488.4	487.4	487.2	487.0	485.6	483.7	483.0	482.4	482.5	481.1	480.2	479.4	479.0	478.7	477.6	477.5	478.8

2 - MAXIMUM DAM SECTION (STA 15+50)

RED CREEK DAM CROSS SECTION



3 - STAGE STORAGE AND AREA-STORAGE CURVE

RED CREEK DAM STORAGE AREA VOLUME

Project Number: 507101042	Date: 31 MAY 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 02

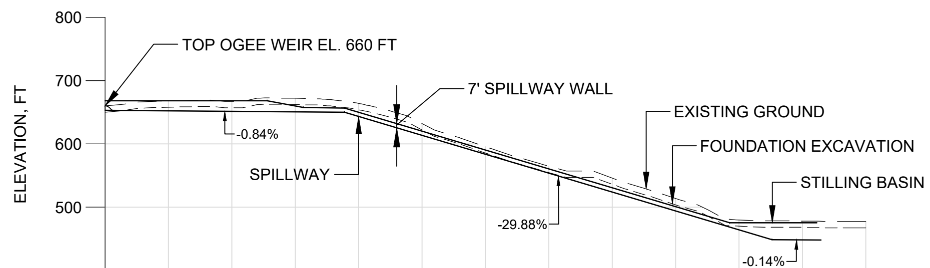
MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

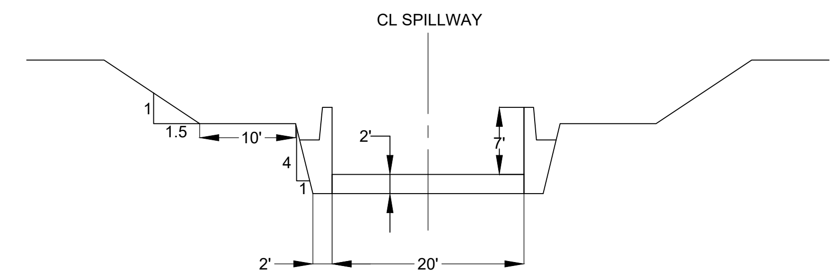
RED CREEK DAM
FIGURE 02 - PROFILE VIEWS

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D RC_DAM V2.DWG

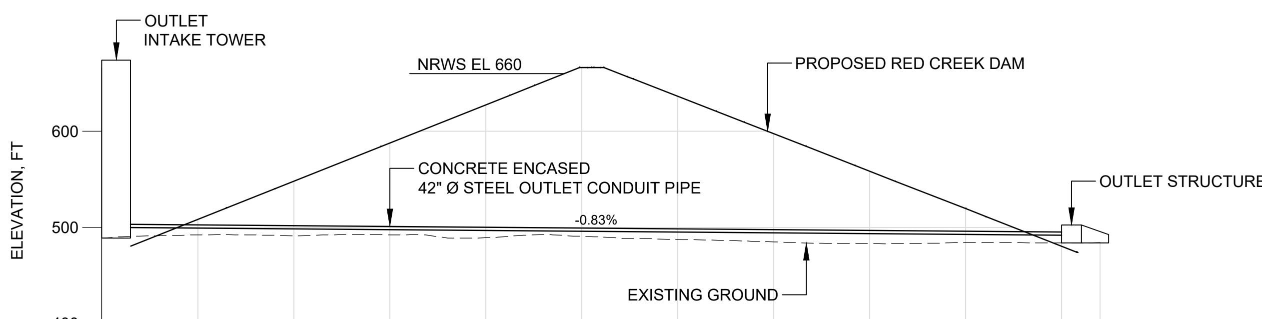


STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00
SPILLWAY INVERT ELEVATION (ft)	653.0	652.2	651.3	650.5	643.2	613.3	583.4	553.5	523.7	493.8	463.9	448.3	

4 SPILLWAY PROFILE
RED CREEK DAM SPILLWAY



5 SPILLWAY SECTION PROFILE
RED CREEK DAM SPILLWAY SECTION



STATION (ft)		1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	
EXISTING GROUND ELEVATION (ft)	488.9	492.2	491.1	492.2	489.3	490.7	487.3	484.8	483.1	484.2	483.9	484.2

6 OUTLET CONDUIT PROFILE
RED CREEK DAM OUTLET CONDUIT

Project Number: 507101042	Date: 31 MAY 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 03

MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

RED CREEK DAM
FIGURE 03 - OUTLET STRUCTURE

MOTT MACDONALD

Storage Project Summary

Project:	**Milanville Reservoir (N2)**
Location:	Milanville, Wayne County, PA
Storage Type:	New reservoir
Est. Volume:	42 BG
Score:	2.95

1 Project Overview

The location of this potential dam and reservoir is near Milanville, a village in Damascus Township, Wayne County PA, close to the Delaware River (Figure 1.1). The dam would be located on Calkins Creek just downstream of the confluence of the North Branch and South Branch (Figures 1.2 and 1.3), which would form two arms of the reservoir. The 44 square mile watershed is mostly forested (Figure 1.3) with a few farms and residential properties.

The dam would be a conventional embankment dam as described in the section 5.2 of the main report. At a height of 286 ft and length of 2,600 ft, this large dam (Figure 1.4) would create a reservoir of about 1800 acres providing about 42 BG of storage. The exact position of the dam analyzed here was chosen as the deepest point in the valley to represent maximum water storage. The dam site could be readily moved upstream to reduce impacts to roads and buildings, with the height and volume also reduced.

The reservoir would flood about 110 residential buildings and a few businesses concentrated near the dam in the village of Milanville; moving the dam upstream by 0.25 would reduce these impacts considerably. The reservoir would also flood about 12 miles of roads.

The reservoir would be filled by gravity; no pumps are needed. With the feeder streams combining for a mean annual flow of 77 cfs, the dam would take 28 months to fill/refill. The outflow would enter the Delaware River 1.5 miles downstream of the dam about 50 miles above the Montague gauge.

The dam was investigated in the 1976 and 1981 reports, with the 1976 report recommending that this dam location be disconsidered due to the environmental issues, low yield, and insignificant cost advantage. The 1981 report investigated this project further but noted it would “not be offered for inclusion in the Comprehensive Plan”. The project was selected for detailed evaluation here due to its limited impact on roads, buildings, and wetlands, plus it provides a desirable location near the Delaware River and high in the Basin, providing flow augmentation to many stream miles.

This river reach is part of the Upper Delaware Scenic and Recreational River, regulated by the Wild and Scenic River Act. The Act prevents the federal government from approving or funding projects on tributaries that would “invade or unreasonably diminish” fish, wildlife, scenic, or recreational resources of the River, with the determination made by the National Park Service. The federally endangered Dwarf Wedge Mussel may occupy this area. These factors complicate permitting for this potential project.

Figure 1.1: Project location

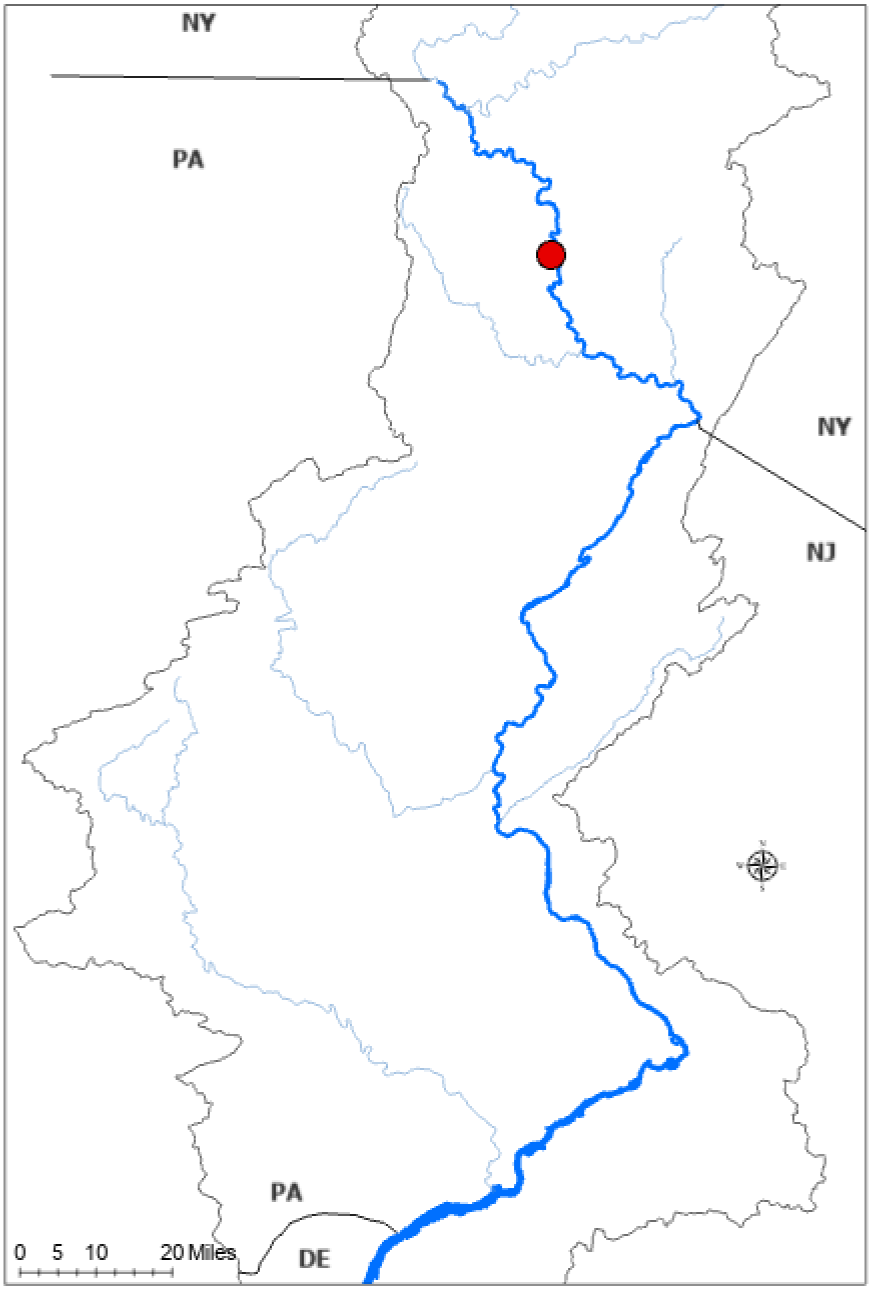


Figure 1.2: Topographic map: Drainage area in red (44 sq miles). Reservoir outline in purple.

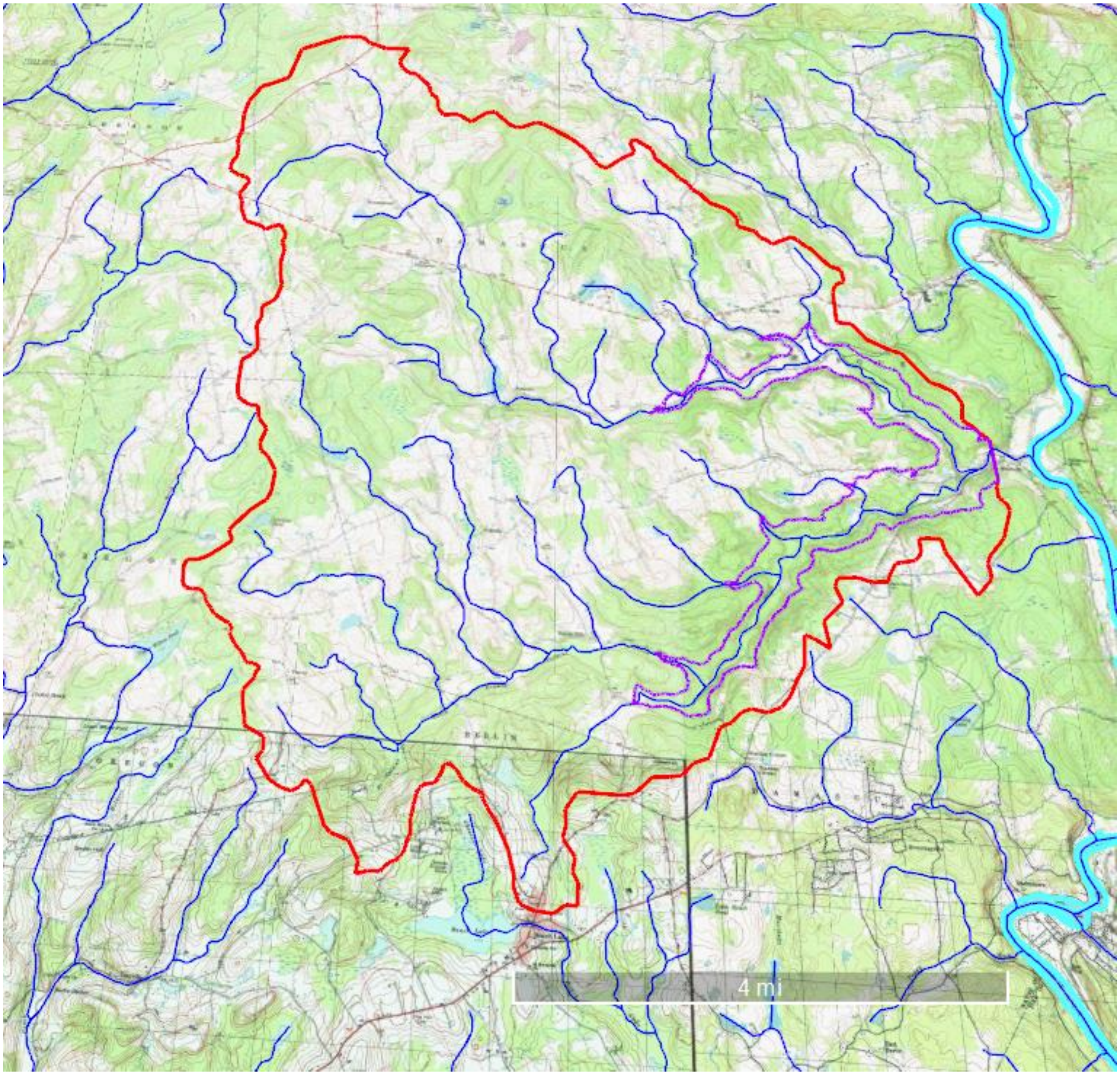


Figure 1.3: Aerial photo: Drainage area in red (44 sq miles). Reservoir outline in purple.

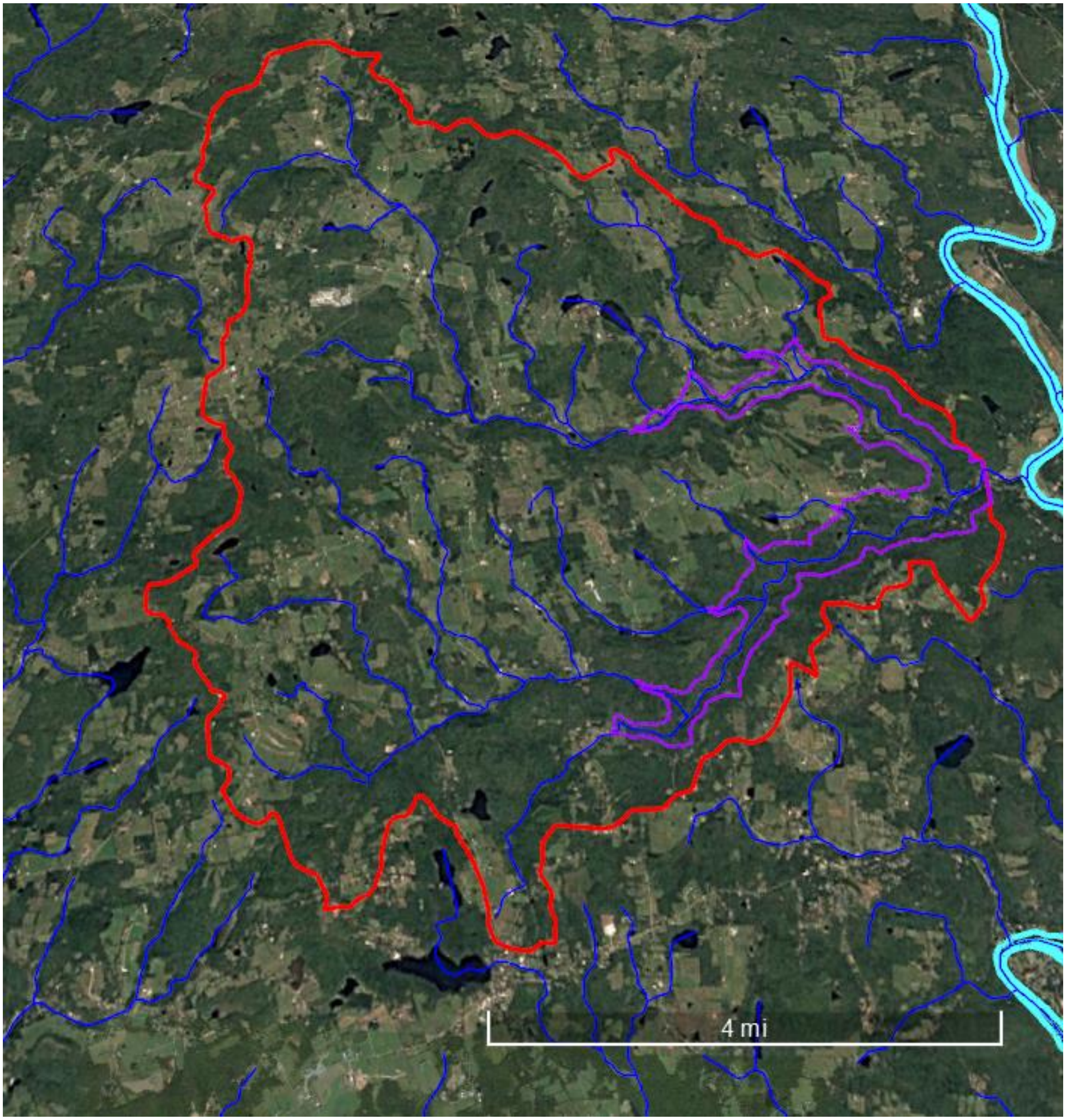
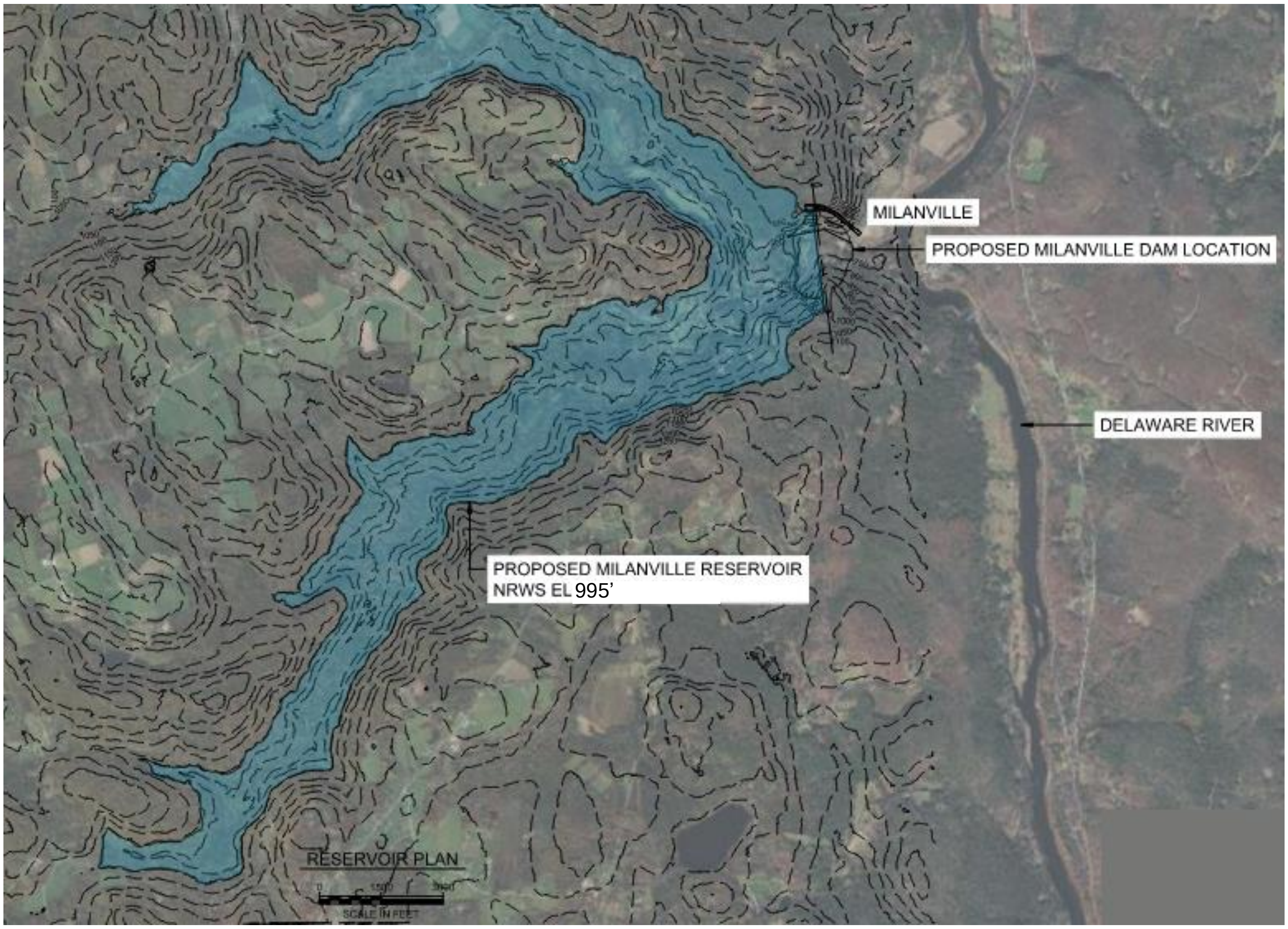


Figure 1.4: Project Schematic



2 Water Quantity & Quality

Key parameters of the potential dams and reservoir are listed in Table 2.1 below. Detailed drawings are presented in the Appendix. The footprint of the dam, reservoir and spillway is shown in Figure 1.4.

Table 2.1: Dam, Reservoir and Spillway Parameters

DAM	
Lat/Long	41.6715, -75.0669
Size Category per PADEP Code	A – Equal or greater than 100 feet; Equal to or greater than 50,000 ac-ft
Hazard Potential per PADEP Code	1 – Substantial (Numerous homes or small businesses or a large business or school)
Dam Type	Earthen Dam with Clay Core
Dam Crest El	1011 ft
Dam Height	286 ft
Dam Crest Length	2,600 ft
Dam Crest Width	25 ft
Dam Slope Inclination	2.5h:1v Upstream 2.5h:1v Downstream
Saddle Dam	None
RESERVOIR	
Normal Reservoir Water Surface (NRWS)	995 ft
Maximum Reservoir Water Surface at PMF (MRWS)	1009 ft
Storage Capacity at NRWS	42.2 BG / 150,790 ac-ft
Reservoir Area at NRWS	1,797 ac
Reservoir Area at MRWS	1,989 ac
Reservoir Area Footprint (50 ft Buffer)	2,076 ac
Freeboard at NRWS	16 ft
Freeboard at MRWS	2 ft
Drainage Area of Dam	43.7 sq mi
SPILLWAY	
Spillway Type	Concrete lined, ungated, ogee crest, “L” shaped side channel
Spillway Crest El	995 ft
Peak Discharge	86,820 cfs
OUTLET	
Outlet Works Type	Outlet Tower
Outlet Works Conduit	42-inch steel pipe
Outlet Elevation	717 ft
Conduit Length	1,580 ft
Required Capacity	151 cfs
Outlet capacity at NRWS	428 cfs

2.1 Fill and Discharge

With a drainage area of about 44 sq. mi. and mean flow of 77 cfs, Calkins Creek would fill/refill the reservoir in about 28 months. Pump-in is not necessary.

The chief advantage of this project is its large volume (42 BG), which could provide the desired 100 cfs of augmentation for 642 days, or a larger flow for a shorter period. Water would be released by gravity, so a large release could be readily achieved through the 42-inch low-level outlet pipe, 428 cfs at the NRWS. If the water can be released directly into the Delaware River, then it is likely that a stilling basin would not be required. The outflow would enter the Delaware River 1.5 miles downstream of the dam about 50 miles above the Montague gauge.

2.2 Water Quality

Calkins Creek was assessed by the PADEP in the 2022 integrated report as supporting aquatic life use while other uses were unassessed. The reservoir's watershed is a mixture of forest and farmland so water quality could be impacted. However, other reservoirs in the Basin, like Blue Marsh, have even more farmland. While Blue Marsh is eutrophic, the DRBC uses it for flow augmentation. Therefore, water quality in the Milanville Reservoir is expected to be suitable for the same purpose.

3 Infrastructure Design, Construction & Operation

As detailed in the main report, conceptual designs were developed in general accordance with the Pennsylvania Code Title 25, Chapter 105, Dam Safety and Water Management. Detailed parameters are given in Table 2.1. The dam and spillway were designed to pass the "probable maximum flood" (PMF), which was estimated as described in Section 5.2 of the main report. No saddle dam or pumps are needed here. Freeboard was assumed to be 2 feet above the MRWS elevation.

An intake tower was conceptually designed with associated controls, piping, and valves housed within the tower. A 42", concrete-encased, steel pipe travels through the dam connecting the intake tower to an outlet structure where water releases are to be made. The outlet capacity at NRWS greatly exceeds the required capacity.

Site access consisting of roads to key dam facilities has not been developed into the designs. An estimated allowance has been included in the cost estimate for project roads.

4 Environmental Impacts

The reservoir footprint (1800 ac at NRWS) is primarily forested, with about 10% agricultural. Recent (2020) aerial photography reveals the South Branch flooded riparian area is primarily forested. The North Branch of Calkins Creek impoundment footprint would encompass about 800 acres and contains more farmland.

Chapter 93 designation for both the North and South Branch of Calkins Creek indicates that its categorized use is as a High Quality, Cold water Fishery (HQ-CWF); about 15 miles of stream will be inundated The PA Fish and Boat Commission does not include these streams at any level as trout fisheries in their online data source but a 2016 document proposed to include the South Branch of Calkins Creek as a wild trout stream (https://www.fishandboat.com/Regulations/Documents/noticesDocs/2016_04_26wild.pdf).

The dam would restrict discharge of high quality, cold water to the Delaware River thereby potentially changing the habitat in the River at the discharge point and for an unknown distance downstream. Construction of the dam would eliminate the seasonal hydroperiod, including releases to the floodplain in the reservoir footprint and would affect spring pulses throughout the season and alter discharge into the Delaware River from the entire watershed. If the free-flowing stream is retained behind a dam, the water will become warmer, it will retain nutrients and subsequently become more eutrophic. At this point, the Delaware's watershed is about 1900 sq. mi., which is very large relative to the proposed reservoir's watershed of 44 sq. mi., so impacts would be expected to be minor.

The most significant environmental impact of the constructed dam is likely the restriction of movement of aquatic organisms from the Delaware River into the 44 sq. mi. watershed. The watershed consists of many miles of high-quality, cold-water streams. It would be difficult to obtain a permit to construct an impoundment in the Calkins Creek Watershed.

The dam would sit just outside the boundary of the Upper Delaware Scenic and Recreational River. Section 7(a) of the Wild and Scenic River Act regulates projects on a tributary that would invade or unreasonably diminish the segment's fish, wildlife, scenic, or recreational resources, with the determination made by the National Park Service (https://www.nps.gov/upde/learn/management/lawsandpolicies.htm). Because scenic effects are considered, the permitting of this dam could be problematic.

The USFWS iPac included a hit for the Dwarf Wedge Mussel-DWM *(Alismadonta heterodon)*. All freshwater mussels are globally critically imperiled, but the DWM is on the USFWS endangered species list and the only listed freshwater mussel species in the Northeast. Freshwater mussels have complex life cycles where they depend heavily on clear water and firm substrate, but also on the existence and well-being of fish species on which they depend for their life cycle. According to the USFWS, areas around the Calkins Creek watershed and especially the Delaware River in Northeastern PA are occupied Critical Habitat for the DWM. If DWM are found in the Calkins Creek Watershed, construction of an impoundment could jeopardize the existence of the species in this location, thereby resulting in a project that may not be permittable.

Other endangered/threatened species are reported by the USFWS iPaC as being potentially affected by activities in this location, including Indiana Bat (IB), Northern Long-eared Bat (NLEB), and Monarch Butterfly. It appears the preferred habitat for both is located within the Calkins Creek Watershed. No information was found about known maternity colonies or hibernacula in the area of this potential reservoir site. A better understanding of all protected species must be obtained before understanding final impacts.

The National Wetland Inventory (NWI) does not identify many wetlands within the impoundment area of either branch of Calkins Creek, not surprising because the area has high topographic relief. The NWI aerial photo interpretation in general often misses forested wetlands in many locations because hydrology is difficult to see through dense woods. However, the USDA Natural Resource Conservation Service does identify a number of poorly and somewhat poorly drained soils within the impoundment area. Wetland area is estimated at about 162 acres based on both NWI wetlands and anticipated hydric (very poorly, poorly or somewhat poorly drained) and fluvaquentic soils outside of the NWI wetland areas. A significantly sized riverine wetland is located at the mouth of Calkins Creek at the Delaware River, which could be impacted depending on the exact location of a dam and the release rates. Field inspection is needed to provide clearer information regarding non-persistent/aquatic vegetation or submerged aquatic vegetation in this location.

5 Social and Economic Impacts

The reservoir footprint is rural, with residences more densely clustered near the dam site. Under the configuration here, the reservoir would flood about 125 residences and one mapped business; the residential properties flooded could be reduced by about 25 if the dam was moved about 0.4 miles upstream. Given the abundance of undeveloped land, displaced residences could possibly be reconstructed near their current location.

Farming is the main commercial activity. Most of the land to be flooded is wooded; about 200 acres of farmland would be lost, almost all along the North Branch.

About 11 miles of roads would be flooded. Alternative through routes are available nearby, except for the area between the two arms of the reservoir.

Regarding risk to safety of downstream residents, with modern construction technologies and monitoring, the risk of a dam failure would be low. If the dam was moved upstream, about 50 homes would reside directly downstream of the dam. No other housing areas are in the vicinity.

The demographics of the area as reported in the 2000 census are not dominated by historically oppressed groups. Nor is there any indication that this area been highly burdened in the past with undesirable facilities. Therefore, social equity concerns seem minor.

Maps do not indicate any public recreation or fishing sites within the reservoir footprint, so impacts on same are minor.

Similarly, loss of tax revenue from inundated properties would be minor because most of the land is tax-advantaged farmland or undeveloped forest. The possibility of tourist facilities oriented to reservoir recreation could provide opportunities for economic development, jobs and increased tax revenue. The loss of production of some 200 acres of farmland would not be expected to burden the community.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level (level 4) cost estimate for construction costs, as detailed in Table 6.1. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) are reported in Table 6.2. This potential project does not require any pumping. Methods are described in the main report Section 5.2.6. Costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail.

The feasibility-level cost estimate of the present value of this project is very high, $950M, because of the large size of the dam; land acquisition costs comprise only about 5% at about $46M and operation and maintenance costs would be about $2M/year. The cost effectiveness is $23M/BG, which is the best for a new reservoir, but significantly larger than for several quarries and two dam raises.

Table 6.1: Construction Cost Summary

Description	Unit	Quanity	Rate	Total	Comments
1.0 Dam				**$ 384,214,250**	
1.1 Excavation	CY	939,500	$ 20.00	$ 18,790,000	
1.2 Grout Curtain	SF	399,000	$ 110.00	$ 43,890,000	
1.3 Core Material	CY	1,125,900	$ 25.00	$ 28,147,500	Core borrow area near dam site
1.4 Filter Material	CY	77,700	$ 90.00	$ 6,993,000	Imported material
1.5 Dam Shell Material	CY	9,203,500	$ 30.00	$ 276,105,000	Shell borrow area near dam site
1.6 Riprap	CY	48,500	$ 200.00	$ 9,700,000	Improted Material
1.7 Hydroseed	SF	1,177,500	$ 0.50	$ 588,750	
2.0 Spillway				**$ 26,753,200**	
2.1 Excavation	CY	81,600	$ 30.00	$ 2,448,000	
2.2 Spillway Slab	CY	7,600	$ 850.00	$ 6,460,000	
2.3 Spillway Walls	CY	7,600	$ 1,100.00	$ 8,360,000	
2.4 Anchors	EA	2,420	$ 2,500.00	$ 6,050,000	Approx 10' spacing
2.5 Drainage Layer	CY	480	$ 90.00	$ 43,200	Slot trench every 50' of spillway chute
2.6 Drainage Pipes	LF	1,920	$ 100.00	$ 192,000	
2.7 Stilling Basin	CY	3,200	$ 1,000.00	$ 3,200,000	200' long x with 20' additional wall height
3.0 Outlet Works				**$ 10,410,000**	
3.1 Outlet Pipeline and Installation	LF	1,580	$ 2,000.00	$ 3,160,000	
3.2 Outlet Tower and Installation	10' Segment	29	$ 250,000.00	$ 7,250,000	
4.0 Access Roads				**$ 1,500,000**	
4.1 New Roads	Mile	2.5	$ 600,000.00	$ 1,500,000	Estimated from nearby existing road to key project components
5.0 Key Project Components Subtotal				**$ 422,877,450**	
5.1 Sum 1.0 thru 4.0	Subtotal			$ 422,877,450	
6.0 Contractor Allowances				**$ 177,185,652**	
6.1 Environmental Allowance: Rate x 5.0	Rate		2%	$ 8,457,549	
6.2 Materials Testing (QA/QC): Rate x 5.0	Rate		2%	$ 8,457,549	
6.3 Contractor Indirect Costs: Rate x 5.0	Rate		25%	$ 105,719,363	
6.4 Profit: Rate x (5.0 + 6.1 + 6.2 + 6.3)	Rate		10%	$ 54,551,191	
7.0 Contingencies				**$ 270,028,396**	
8.1 Design Contingency: Rate x (5.0 + 6.0)	Rate		25%	$ 150,015,775	
8.2 Construction Contingency: Rate x (5.0 + 6.0)	Rate		20%	$ 120,012,620	
8.0 Conceptual Cost Estimate Total				**$ 870,092,000**	
8.1 Sum 5.0 thru 7.0	Total			$ 870,091,497	

Table 6.2: Overall Cost Summary

Land acquisition cost ($)	46M
Construction Cost ($)	870M
Operating Cost ($/yr)	1.7M
Overall Cost (Present value, $)	950M
Cost effectiveness ($/BG)	23M

The schedule for the project is also very rough. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition. Fifteen years was the typical estimate for a new dam.

- Funding acquisition 5 years
- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup 2 years
- Total 15 years

7 Potential Ancillary Benefits

The major benefit would be a large, public-accessible reservoir suitable for multiple types of recreation, although Lake Wallenpaupack is nearby and provides similar opportunities. The reservoir would create a large lake habitat, while replacing stream habitat. However, the possibility of eutrophication threatens to degrade the lake's habitat quality.

Regarding flood control, this dam would provide flood protection to the Village of Milanville relative to Calkins Creek, but current risk would remain regarding the Delaware River. The dam would not provide significant flood control benefit beyond the Village because its drainage area is small compared to the Delaware's at this point.

8 Storage Project Score

This site was scored as described in the main report and summarized in Table 8.1 below for the six primary criteria. Each primary criterion contained subcriteria which were scored on a 1 (worst) to 5 (best) scale and averaged. Scores on the primary criteria were weighted as shown in Table 8.1 and summed to obtain an overall weighted average score. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

Table 8.1: Storage Project Score

Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.17	30%	1.25
Infrastructure Design, Construction & Operation	2.60	10%	0.26
Environmental Impacts	2.16	15%	0.32
Social & Economic Impacts	3.00	10%	0.30
Project Cost & Schedule	2.33	30%	0.70
Ancillary Benefits	2.40	5%	0.12
AVERAGE	**2.78**		**2.95**

APPENDIX

Score Sheet

Drawings

Six primary criteria	Quantitative Evaluation Metric (when appropriate) (enter values only in ungreyed cells)	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
1. Water quantity and quality		4.17			30%	1.25	
o Volume of storage provided (BG)	42	5					
o Hydrologic reliability of supply (months to fill)	28	2					
o Release rate (cfs)	430	5					
o Promptness of delivery to mainstem (days)	<1	5					
o Geographic benefit		4					Above Montague
o Quality of stored water		4					
2. Infrastructure design, construction and operation		2.60			10%	0.26	
o Site/Civil, Land & Easements		1					
o Subsurface conditions		3					
o Infrastructure Complexity		3					
o Construction complexity		3					
o Operational complexity		3					
3. Environmental impacts		2.16			15%	0.32	
o protected species		2					Bats, Dwarf Wedge Mussel occupied critical habitat
o Water quality degradation of downstream waters		4					Discharges directly to Delware River; little impact likely to a large
o obstruction to passage of aquatic animals		1					Cuts off access to alrge watershed
o hydromodification		4					Discharges directly to Delware River, so little impact likely
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted 5=small, 1=large)			
o wetlands inundated or filled (ac)	160	1.25	1.5	1			NWI shows small ponds within impoundment area; NRCS soils map shows somewhat poorly and poorly drained soils.
o stream length inundated (mi)	15	1.5	2	1			classified as high quality, cold-water fishery
o uplands inundated or developed (ac)	1500	1.375	1.75	1			~50% mature, ~20% 2nd growth, ~30% cropped
4. Social and Economic Impacts		3.00			10%	0.30	
o Disruption/displacement		1					About 125 residences; could be reduced by ~25 by moving dam upstream slightly
o Safety and health		3					Small housing area lies directly downstream
o Social equity		4					
o Recreational loss		4					
o Cultural/historical resources		4					
o Aesthetic		4					
o Loss of tax revenue		3					
o Loss of production from farmland, timberland, quarries		3					
o Emissions of greenhouse gasses		1					Construction of very large dam
5. Project Costs & Schedule		2.33			30%	0.70	
o Land acquisition cost ($)	46.M						
o Construction Cost ($)	870M						
o Operating Cost ($/yr)	1.7M						
o Overall Cost (Present value, $)	950M	1					
o Cost effectiveness ($/BG)	23M	3					
o Schedule (Time to make Operational, years)	15	3					
6. Ancillary Benefits		2.40			5%	0.12	
o Flood control		3					
o Recreation/tourism		4					
o Habitat/fishery enhancement		3					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		2.78			100%	2.95	

NOTES:

1. TOPO REFERENCE: ONE THIRD ARC SECOND PUBLISHED ON 2022-04-29 (USGS NATIONAL MAP)

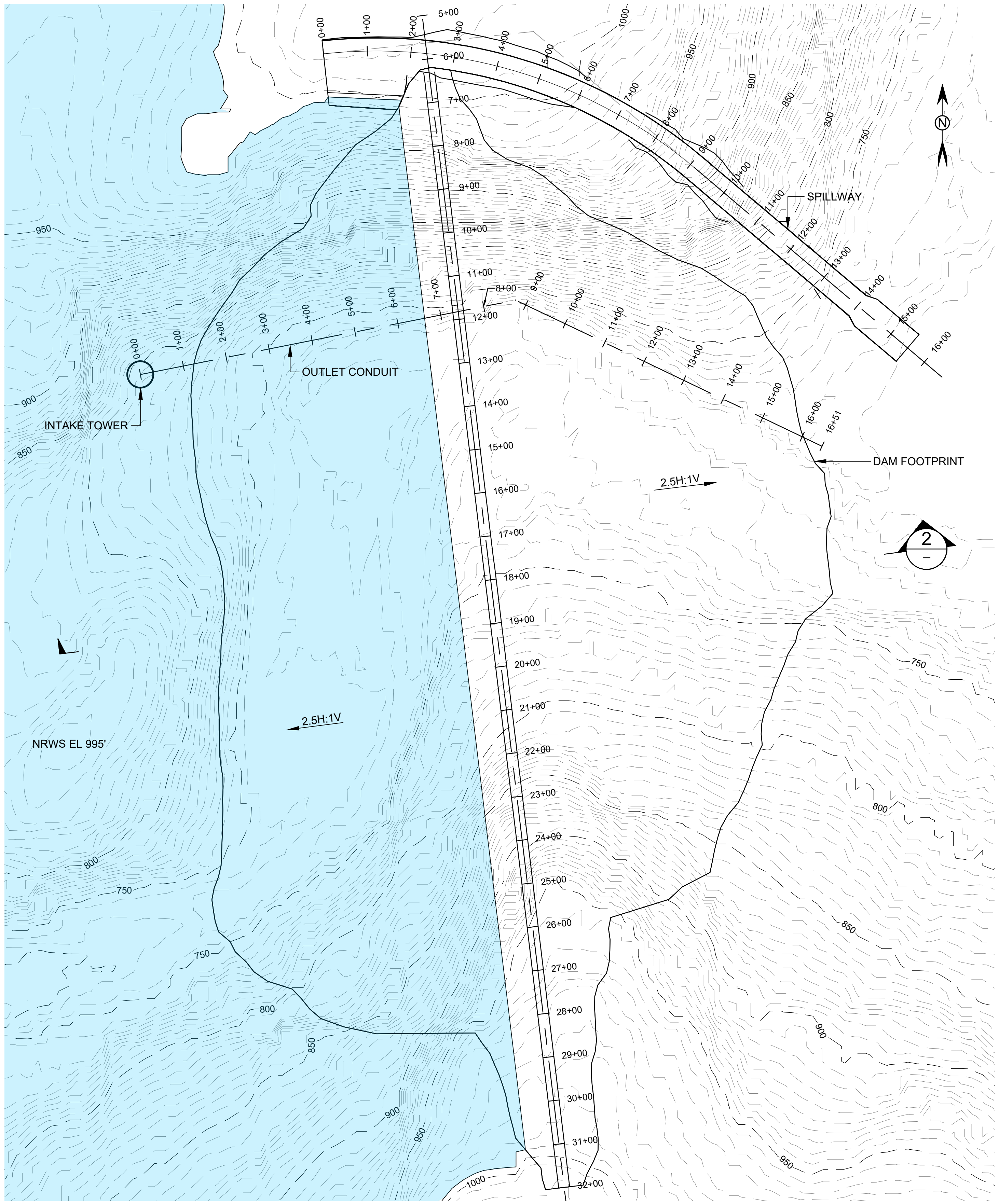
Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 01

MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

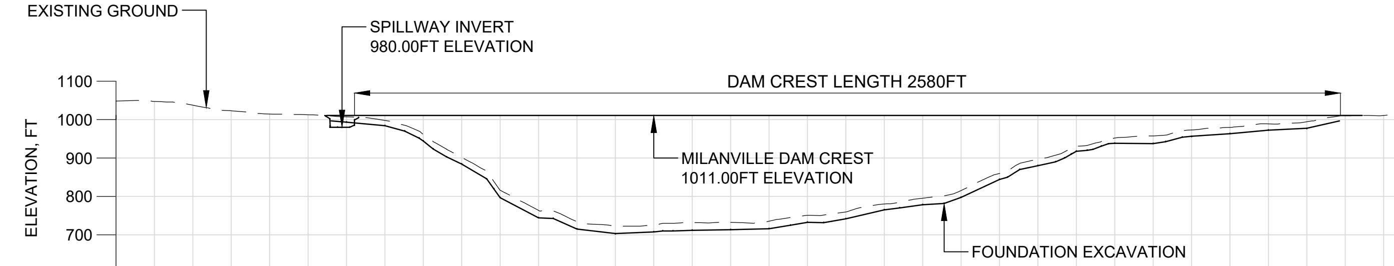
DELAWARE RIVER BASIN STORAGE STUDY

MILANVILLE DAM
FIGURE 01 - GENERAL SITE PLAN



PLAN VIEW - MILANVILLE DAM

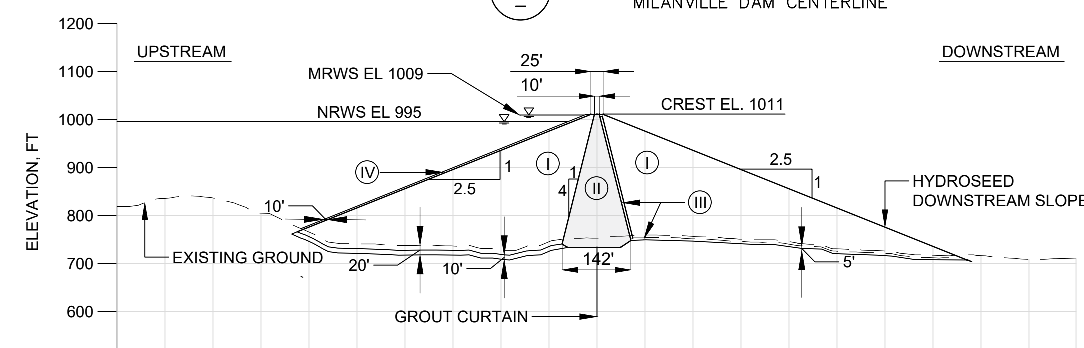
0 150 300
SCALE IN FEET



STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00	14+00	15+00	16+00	17+00
EXISTING GROUND ELEVATION (ft)	1048.9	1048.0	1037.7	1023.3	1015.1	1012.7	1007.5	998.2	961.5	902.0	817.0	764.4	734.2	723.3	725.8	732.3	732.6	736.1
CORE TRENCH ELEVATION (ft)							993.7	984.5	944.5	884.2	797.0	744.4	715.2	703.3	708.0	712.3	713.9	716.1

STATION (ft)	18+00	19+00	20+00	21+00	22+00	23+00	24+00	25+00	26+00	27+00	28+00	29+00	30+00	31+00	32+00	33+00	34+00
EXISTING GROUND ELEVATION (ft)	751.1	759.7	780.6	795.3	815.3	860.3	897.8	930.3	952.1	958.1	973.6	980.2	989.5	994.7	1010.4	1011.3	1018.5
CORE TRENCH ELEVATION (ft)	733.0	742.0	765.6	778.6	797.6	844.8	880.0	917.9	939.0	938.1	956.6	963.6	972.9	977.4			

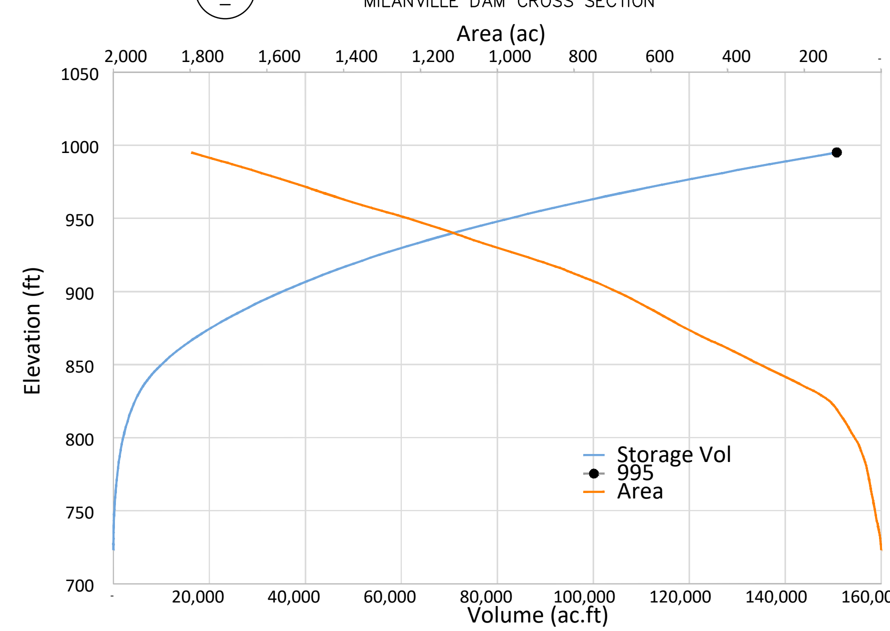
1 SECTION ALONG DAM AXIS
MILANVILLE DAM CENTERLINE



OFFSET (ft)	-10+00	-9+00	-8+00	-7+00	-6+00	-5+00	-4+00	-3+00	-2+00	-1+00	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	9+98
EXISTING GROUND ELEVATION (ft)					775.9	815.9	855.9	895.9	935.9	975.9	1010.9	975.9	935.9	895.9	855.9	815.9	775.9	735.9			

2 MAXIMUM DAM SECTION (STA 18+50)
MILANVILLE DAM CROSS SECTION

DAM TYPE	MATERIALS
I. SHELL	GENERALL FILL FROM LOCAL BORROW AREA
II. CORE	LOW PERMEABLE CLAY
III. FILTER	HIGH PERMEABLE GRANULAR
IV. RIPRAP EROSION PROTECTION	ROCKFILL BOULDERS



3 STAGE STORAGE AND AREA-STORAGE CURVE
MILIANVILLE DAM STORAGE AREA VOLUME

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 02

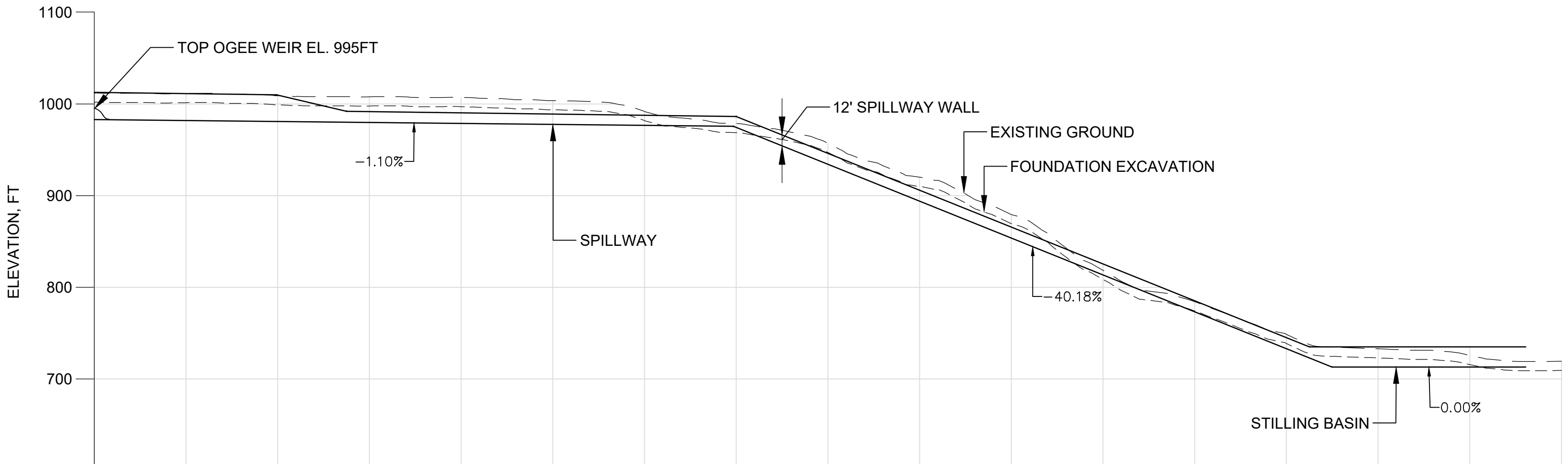
MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

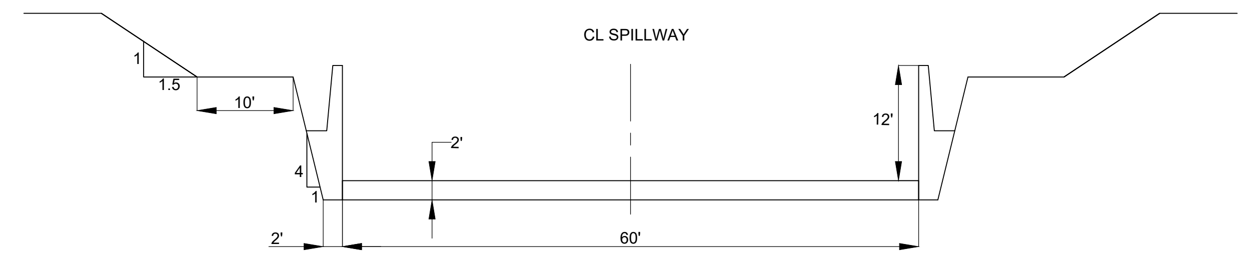
MILANVILLE DAM
FIGURE 02 - PROFILE VIEWS

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D MV_DAM.DWG

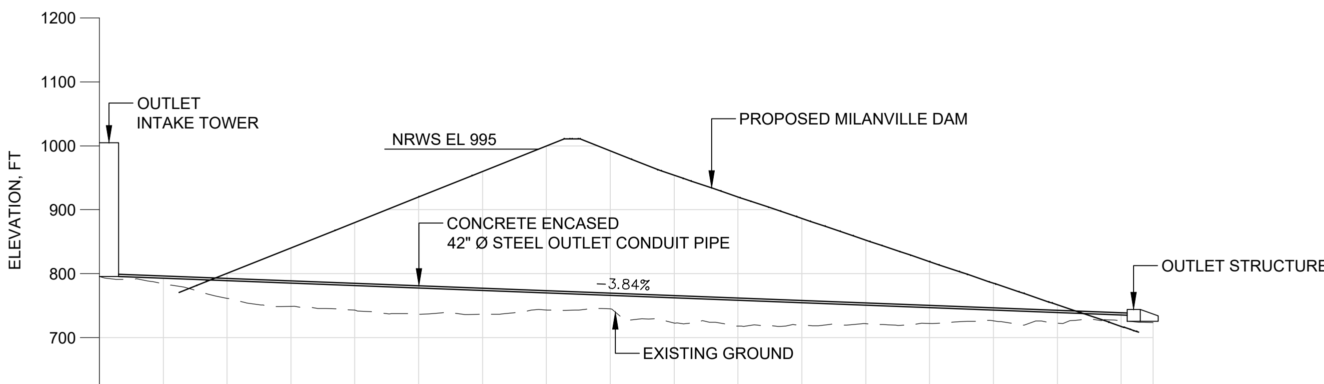


STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00	14+00	15+00	16+00
SPILLWAY INVERT ELEVATION (ft)	983.0	981.9	980.8	979.7	978.6	977.5	976.4	974.2	934.0	893.8	853.6	813.4	773.3	733.1	713.1	713.1	

4 – SPILLWAY PROFILE
MILANVILLE DAM SPILLWAY



5 – SPILLWAY SECTION PROFILE
MILIANVILLE DAM SPILLWAY SECTION



STATION (ft)		1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00	14+00	15+00	16+00	
EXISTING GROUND ELEVATION (ft)	795.4	784.5	761.1	748.8	742.9	736.7	736.4	743.2	744.8	722.9	718.1	719.5	721.7	722.0	726.3	722.6	726.5	723.6

6 – OUTLET CONDUIT PROFILE
MILANVILLE DAM OUTLET STRUCTURE

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 03

MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

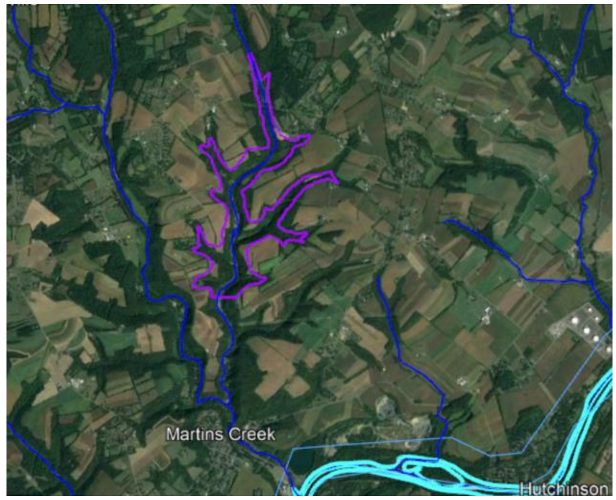
DELAWARE RIVER BASIN STORAGE STUDY

MILANVILLE DAM
FIGURE 03 - OUTLET STRUCTURE

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D MV_DAM.DWG

Storage Project Summary

Project:	**Little Martins Creek Reservoir (N3)**	
Location:	Martins Creek, Northampton County, PA	
Storage Type:	New reservoir	
Est. Volume:	7.1 BG	
Score:	2.87	



1 Project Overview

The location of the potential dam and pump storage reservoir is on Little Martins Creek in Martins Creek, Northampton County, PA (Figure 1.1). The dam would be located about 2 stream miles from Delaware River (Figures 1.2 and 1.3). The area is a mixture of forest in the steep valley and cropped lands above (Figure 1.3). Most of the land within the reservoir footprint is forested.

The dam would be a conventional earthen embankment dam as described in the section 5.2 of the main report. At a height of 212 ft and length of 1400 ft, this dam would create a reservoir of about 400 acres at normal pool, providing 7.1 BG of storage (Figure 1.4).

The reservoir would flood approximately 70 residential properties and about 6.5 miles of roads, foremost, Little Creek Road, which runs along the Creek and provides access to these properties.

The reservoir would discharge to Little Martins Creek, which meets Martins Creek just upstream of the Delaware River. Because the drainage area is small (6.1 sq. mi.), the reservoir would need to be filled by pumping from the Delaware River. The Delaware River watershed is very large at this point (4500 sq. mi.) with a mean flow of over 8000 cfs and so provides an adequate source to fill/refill the reservoir in 6 months at a feasible pump-in rate of 50 cfs.

A dam at Little Martins Creek was investigated in previous reports, including the 1981 Level B report, which rated it as having moderate environmental and adverse social impact. The project was selected for detailed evaluation here due to its substantial volume, moderate impacts and desirable location close to the mainstem and between Trenton and Montague.

Figure 1.1: Project location

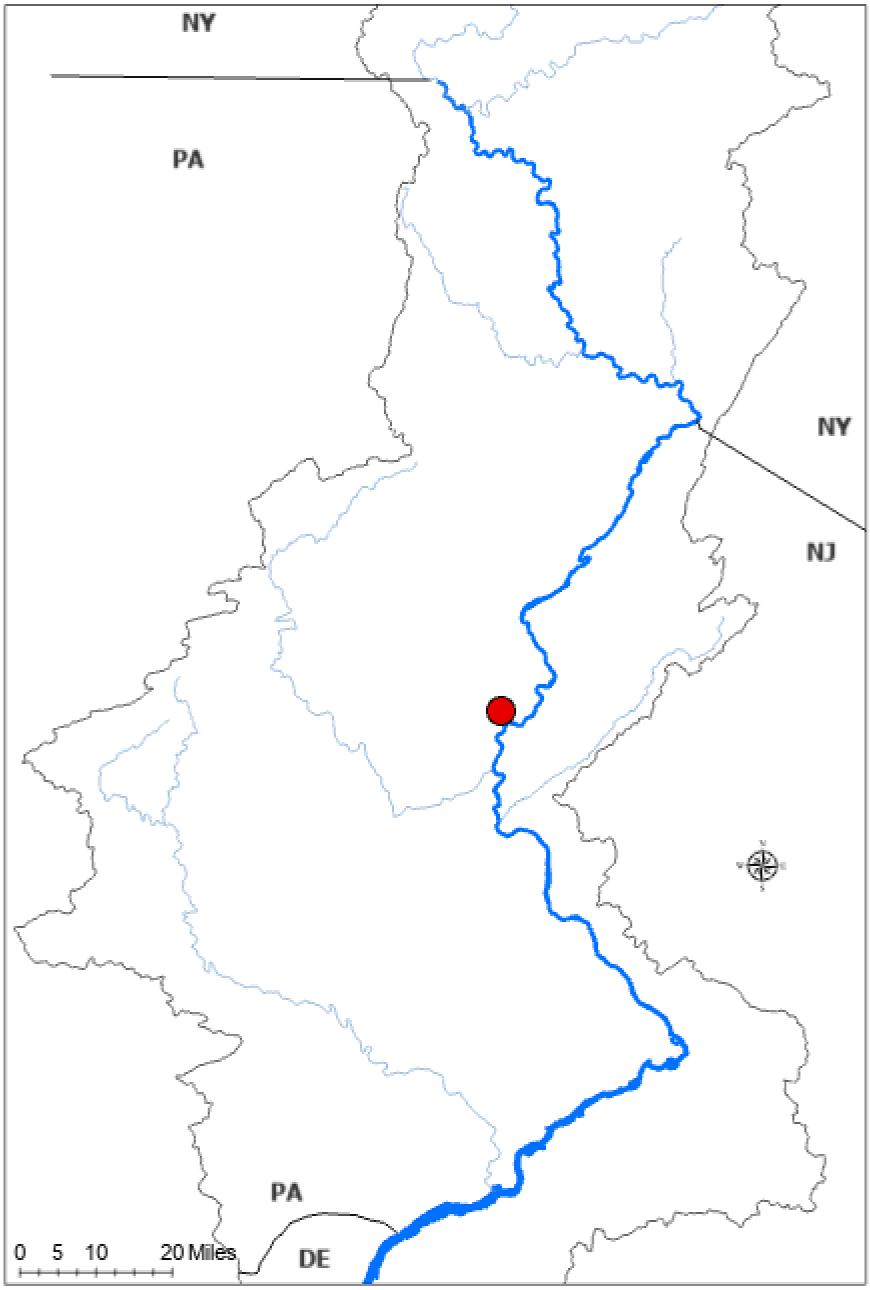


Figure1.2: Aerial Photo: Drainage area in red (6.1 sq miles). Reservoir outline in purple.

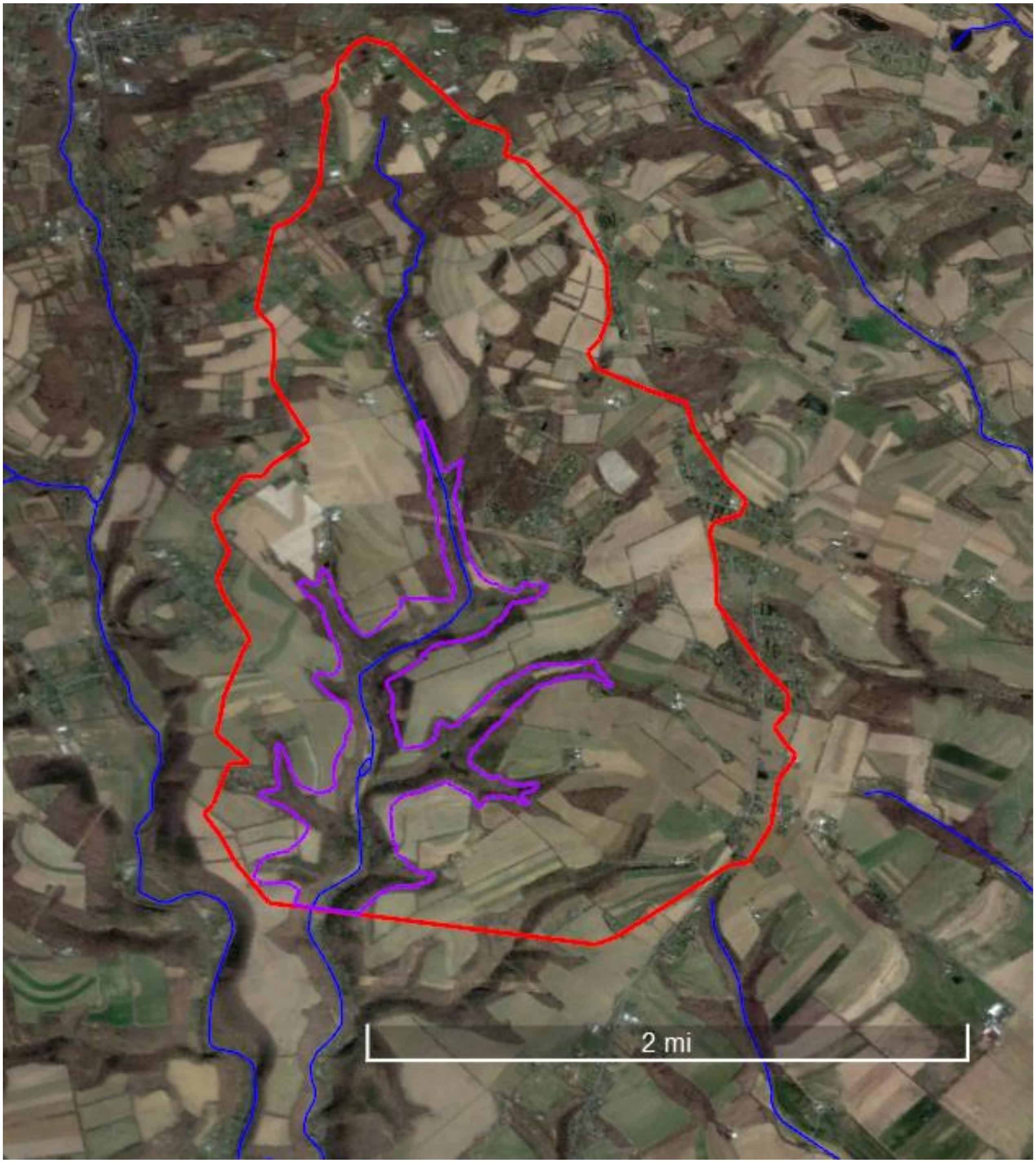


Figure 1.3: Topographic map: Drainage area in red (6.1 sq miles). Reservoir outline in purple.

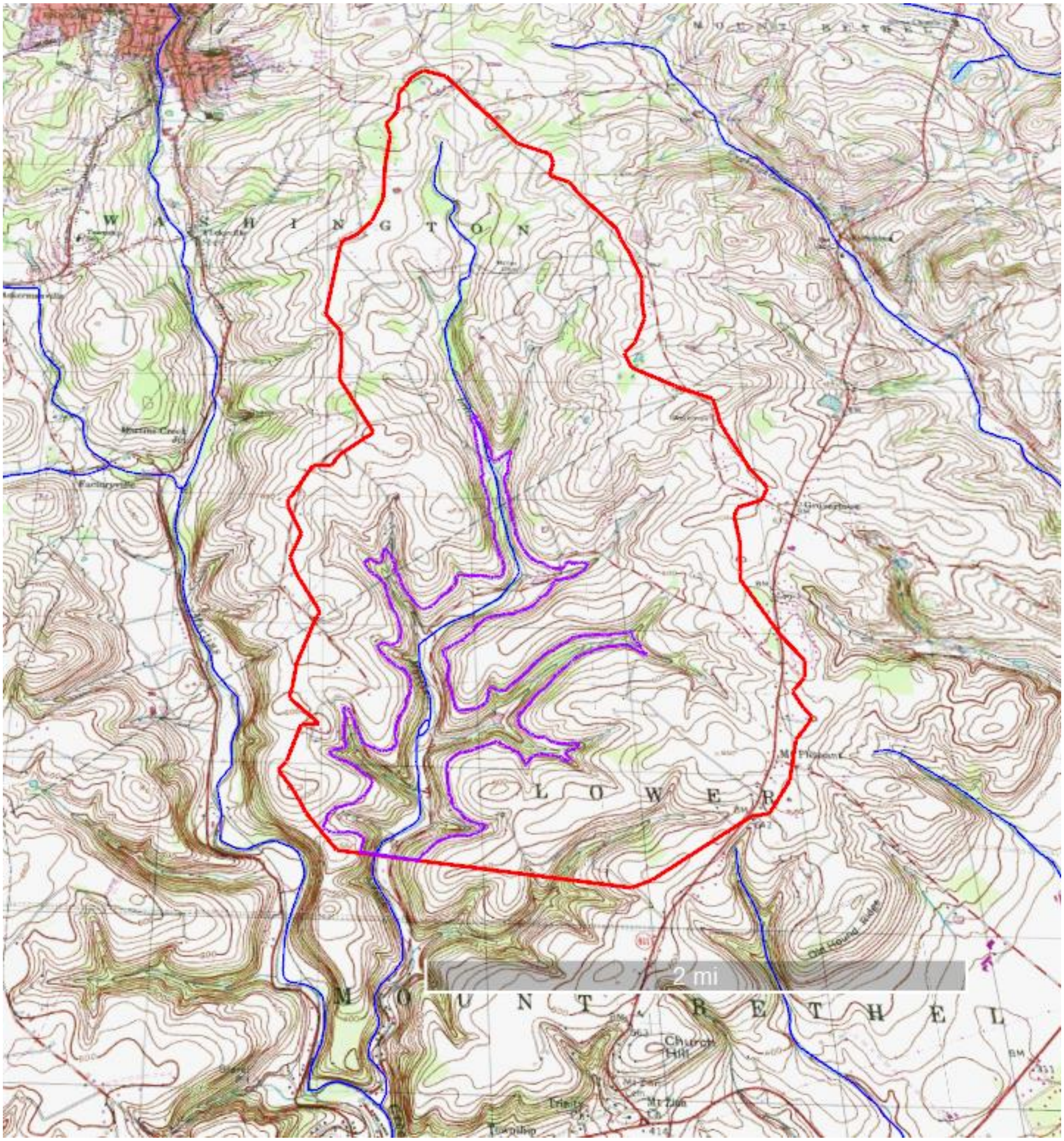
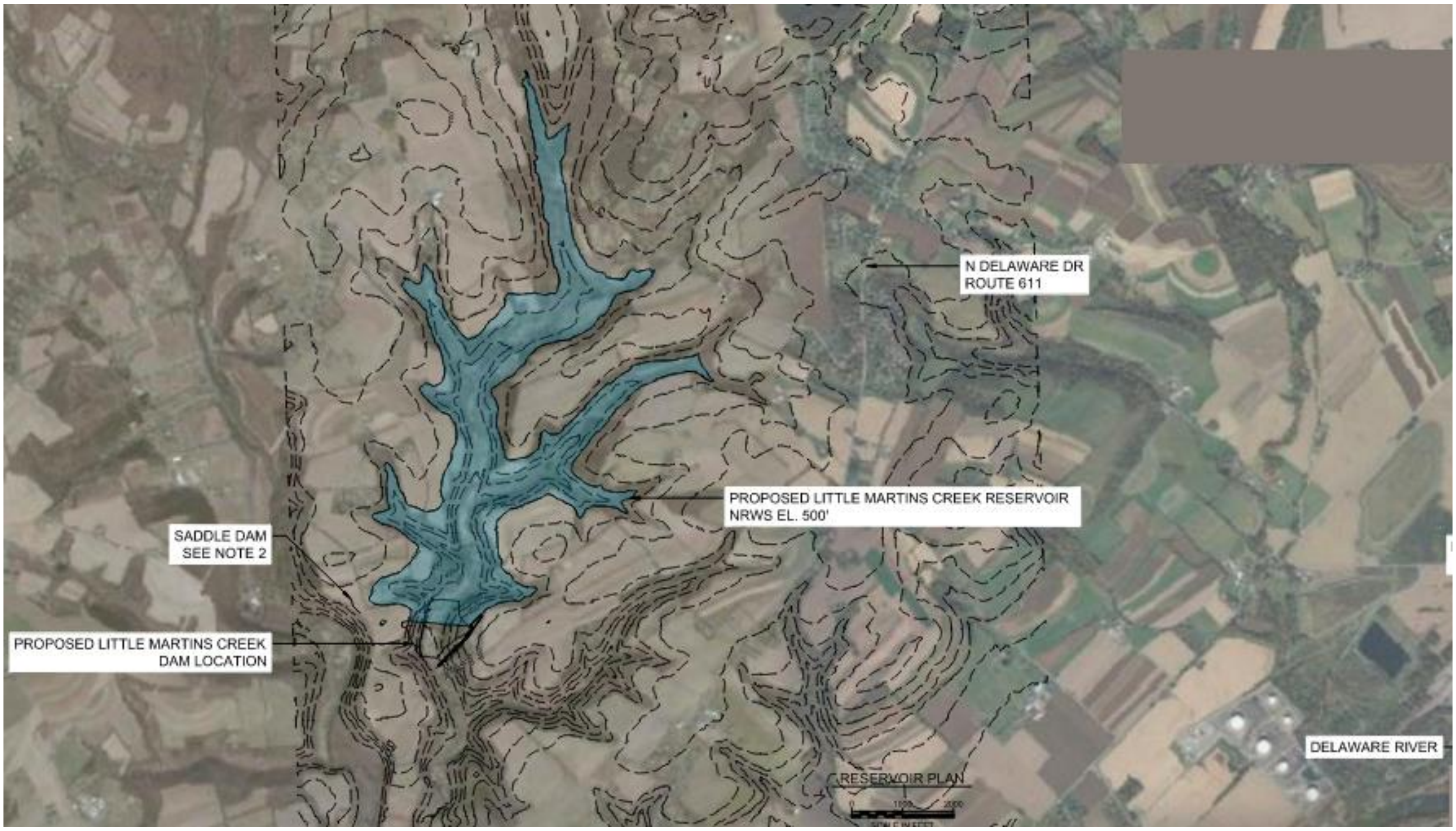


Figure 1.4: Project Schematic



2 Water Quantity & Quality

Key parameters of the potential dams and reservoir are listed in Table 2.1 below. Detailed drawings are presented in the Appendix. The project would provide about 7 BG to support flow augmentation downstream. The project sits between Montague and Trenton, which the DRBC has identified as the most impactful location for flow augmentation. A significant drawback is the small drainage area. To provide reliable water supply, this reservoir would require pumping from a nearby waterbody (namely, the Delaware River) for filling, thereby increasing capital and operating costs as detailed below.

Table 2.1: Dam, Reservoir and Spillway Parameters

DAM	
Lat/Long	40.8005., -75.1845
Size Category per PADEP Code	A – Equal or greater than 100 feet; Equal to or greater than 50,000 ac-ft
Hazard Potential per PADEP Code	1 – Substantial (Numerous homes or small businesses or a large business or school)
Dam Type	Earthen Dam with Clay Core
Dam Crest El	516 ft
Dam Height	212 ft
Dam Crest Length	1,400 ft
Dam Crest Width	25 ft
Dam Slope Inclination	2.5h:1v Upstream 2.5h:1v Downstream
Saddle Dam	6 ft height, 330-foot length, 2.5h:1v slopes to contain MRWS
RESERVOIR	
Normal Reservoir Water Surface (NRWS)	500 ft
Maximum Reservoir Water Surface at PMF (MRWS)	514 ft
Storage Capacity at NRWS	7.1 BG / 25,370 ac-ft
Reservoir Area at NRWS	400 ac
Reservoir Area at MRWS	480 ac
Reservoir Area Footprint (MRWS + 50 ft Buffer)	543 ac
Freeboard at NRWS	16 ft
Freeboard at MRWS	2 ft
Drainage Area	5.8 sq mi
SPILLWAY	
Spillway Type	Concrete lined, ungated, ogee crest, “L” shaped side-channel
Spillway Crest El	500 ft
Peak Discharge	22,150 cfs
OUTLET	
Outlet Works Type	Outlet Tower
Outlet Works Conduit	42-inch ID steel pipe
Outlet Elevation	292 ft
Conduit Length	1,145 ft
Required Capacity	24 cfs
Outlet capacity at NRWS	420 cfs

2.1 Fill and Discharge

Because the drainage area is small (about 6 sq. mi.) and the impoundment is large, the reservoir would need to be filled by pumping. Fortunately, the Delaware River is only 2 miles away, with a drainage area over 4500 sq. mi. and mean flow rate over 8000 cfs. The River provides adequate flow to fill the reservoir within 6 months with a 50 cfs pump station operating continuously over that period. The need for pumping increases capital and operating costs as detailed below.

Return flow to the Delaware will be provided via gravity meaning a high flow can be provided, about 420 cfs at normal pool. This flow rate can be controlled via partial closure of a valve. Such a large release would likely destabilize the Creek, so a stilling basin to prevent this was included in the design and cost estimate. If the outlet pipe extended to the Delaware River, then perhaps this stilling basin would not be needed.

2.2 Water Quality

Little Martins Creek was assessed by the PADEP in the 2022 integrated report as supporting aquatic life use while impaired by pathogens (source unknown) for recreational use. Little Martins Creek was not assessed for fish consumption or potable water use. The source of pathogens could be livestock operations upstream. If the reservoir were built, it would displace some of these operations and reforestation of forested buffers could reduce pathogen loads.

Regardless, the large majority of the water in the reservoir would be pumped in from the Delaware River. Delaware River water is assessed as supporting aquatic life, recreation and fish consumption. While not assessed by Pennsylvania for potable water supply at this location, it supports this use downstream at Trenton. Therefore, the water quality in a Little Martins Creek reservoir should be adequate for augmenting flow and resisting the salt front.

One concern is eutrophication in the reservoir, because residence time will be long and little mixing will occur. Here, a useful comparator is Merrill Creek Reservoir, to which water from the Delaware River is pumped and is released only when flow augmentation is required. The NJDEP sampled the Reservoir in 2020 and found no harmful algal blooms. Merrill Creek Reservoir reportedly supports a year-round population of lake trout, which requires oxygen-rich waters. Given this condition, extreme eutrophication is not expected to be a problem.

3 Infrastructure Design, Construction & Operation

3.1 Dam

As detailed in the main report, conceptual designs were developed in general accordance with the Pennsylvania Code Title 25, Chapter 105, Dam Safety and Water Management. Detailed parameters are given in Table 2.1. The dam and spillway were designed to pass the “probable maximum flood” (PMF), which was estimated as described in Section 5.2 of the main report. No saddle dam is needed here. Freeboard was assumed to be 2 feet above the MRWS elevation.

An intake tower was conceptually designed with associated controls, piping, and valves housed within the tower. A 42”, concrete-encased, steel pipe travels through the dam connecting the intake tower to an outlet structure where water releases are to be made. The outlet capacity at NRWS greatly exceeds the required capacity.

Site access consisting of roads to key dam facilities has not been developed into the designs. An estimated allowance has been included in the cost estimate for project roads.

3.2 Pumping Facilities

Pumping and pipeline parameters are detailed in Table 3.1. As mentioned above, design capacity of the pump station was set at 30 mgd or 50 cfs. The standard configuration of the pump station is described in the main report: submerged wedgewire screen on the river bottom connected to a wetwell on the adjacent bank that will house submersible pumps for lifting and transferring river water. The proposed configuration has 3 x 10 mgd pumps in the wetwell. Components and quantities of the envisioned facilities are detailed further in Section 6, Project Cost & Schedule. The system will function as others and be automated and monitored for remote operation.

3.3 Pipeline

The intake is envisioned on the Delaware River near the mouth of Martin's Creek, about 1.9 miles from the dam. The pump would have to work against 282 ft of static head at NRWS.

Table 3.1: Pump and Pipeline Parameters

Parameter	Value
Pump Design Flow	30 mgd (50 cfs)
Pump Capacity (3 x 10 mgd)	30 mgd (50 cfs)
Pipeline Distance	1.9 mi
Elevation at Withdrawal Point	218 ft
Elevation at NRWS	500 ft
Elevation difference	282 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

4 Environmental Impacts

Chapter 93 classifies Little Martins Creek as a cold-water fishery (CWF); PFBC rates it as a natural-reproduction trout stream. The confluence of Little Martin's Creek with Martin's Creek is about one mile from the dam location. Martins Creek is a Chapter 93 High Quality Stream and a PA FBC Class A Stream. The potential of the dam to degrade water quality in Martins Creek is a concern.

The watershed vegetative cover is about an even mixture of cropped lands and forest (Figure 1.2), but the flooded area, which conforms to the steep creek valley, is almost completely forested. The reservoir would cover about 400 acres. Mature forest comprises about 60% of the inundated area which equates to about 240 acres. The condition of the forest was not assessed in detail, but, from aerial photos, the forest appears to be dense.

The dam would result in inundating nearly four miles of Little Martin's Creek. Maps of the area indicate at least eight tributaries of unknown permanence entering Little Martins Creek. These tributaries would also be mostly inundated. Construction of a reservoir in Little Martin's Creek would replace these lotic or flowing creeks with a large lentic aquatic system.

Construction of a dam across Little Martin's Creek would eliminate the seasonal hydroperiod, including spring pulses and releases to the floodplain and downstream areas. Because the Little Martins Creek watershed is relatively small, the change would not be expected to result in large downstream effects. If the free-flowing stream is retained behind a dam the water will become warmer and, as happens in most reservoirs, nutrient retention will increase, resulting in eutrophication. Again, the small watershed indicates small effects downstream in the Delaware River.

Up to 100 acres of riverine and palustrine wetlands would be inundated. Some potentially inundated wetlands are already open water palustrine systems and some are forested wetlands that line either side of the Creek.

It is possible that more wetlands are present than what can be detected using NWI mapping and NRCS Soils maps on this site.

Three protected species are reported by the USFWS iPaC as being “potentially affected” by activities in this location: Indiana Bat (*Myotis sodalis*) and Northern Long-eared Bat (*Myotis septentrionalis*), and Bog Turtle. Preferred habitat for both bat species may be located within this watershed although presence or existence of hibernacula are not known. There is no available information about maternity colonies or hibernacula in the area of this potential dam site. The Bog Turtle (*Glyptemmys muhlenbergii)* hits were obtained for this location although few habitat areas appear to be present. A better understanding of all protected species must be obtained before a final understanding of impacts can be obtained.

5 Social and Economic Impacts

The reservoir site is currently rural, comprised mainly of farmland and forest with some rural residences. The reservoir would flood about 70 residential properties. Given the abundance of undeveloped land, other displaced residences could possibly be reconstructed near their current location.

Two businesses are identified on maps, which are likely relocatable. Farming is the main commercial activity in the area. Little farmland would be flooded; much would remain after reservoir construction. In some instances, an owner may be able to continue to farm currently owned land that is outside of the reservoir footprint.

The reservoir would flood about 6.5 miles of roads, foremost, Little Creek Road, which runs along the Creek and provides access to the properties along the creek. Alternative through-routes are available within one mile. Two power lines cut across the reservoir.

Regarding risk to safety of downstream residents, with modern construction technologies and monitoring, the risk of a dam failure would be low. The village of Martins Creek (population 631 in 2010) lies just downstream. A small housing area and a large flour mill lie just downstream on the Delaware River. No other settlements are in the vicinity.

The demographics of the area as reported in the census are not dominated by historically oppressed groups. The area has been subject to impactful industrial operations. Two quarries are active. A large cement plant closed in 1964.

Maps do not indicate any public recreation or fishing sites within the reservoir footprint, so impacts on same are presumed minor.

Similarly, loss of tax revenue from inundated properties would be minor because most of the land is tax-advantaged farmland or undeveloped forest. The possibility of tourist facilities oriented to reservoir recreation could provide opportunities for economic development, jobs and increased tax revenue. The loss of production of some 400 acres of farmland would not be expected to burden the community.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level (level 4) cost estimate for construction costs, as detailed in Table 6.1 for the dam and Table 6.2 for the pump station and pipeline. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) are reported in Table 6.3. Methods are described in the main report. Costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail.

Table 6.3 shows the feasibility-level cost estimate (present value) is high at $353M; with only moderate volume, the cost effectiveness is poor at $50M/BG.

Table 6.1: Dam Construction Cost Summary

Description	Unit	Quanity	Rate	Total	Comments
1.0 Dam				**$ 121,746,100**	
1.1 Excavation	CY	371,800	$ 20.00	$ 7,436,000	Main Dam + Saddle Dam
1.2 Grout Curtain	SF	165,600	$ 110.00	$ 18,216,000	
1.3 Core Material	CY	372,500	$ 25.00	$ 9,312,500	Core borrow area near dam site
1.4 Filter Material	CY	33,900	$ 90.00	$ 3,051,000	Imported material
1.5 Dam Shell Material	CY	2,660,100	$ 30.00	$ 79,803,000	Shell borrow area near dam site, Main Dam + Saddle Dam
1.6 Riprap	CY	18,400	$ 200.00	$ 3,680,000	Improted Material, Main Dam + Saddle Dam
1.7 Hydroseed	SF	495,200	$ 0.50	$ 247,600	Main Dam + Saddle Dam
2.0 Spillway				**$ 12,740,700**	
2.1 Excavation	CY	38,600	$ 30.00	$ 1,158,000	
2.2 Spillway Slab	CY	3,000	$ 850.00	$ 2,550,000	
2.3 Spillway Walls	CY	3,700	$ 1,100.00	$ 4,070,000	
2.4 Anchors	EA	1,230	$ 2,500.00	$ 3,075,000	Approx 10' spacing
2.5 Drainage Layer	CY	130	$ 90.00	$ 11,700	Slot trench every 50' of spillway chute
2.6 Drainage Pipes	LF	760	$ 100.00	$ 76,000	
2.7 Stilling Basin	CY	1,800	$ 1,000.00	$ 1,800,000	200' long x with 20' additional wall height
3.0 Outlet Works				**$ 7,800,000**	
3.1 Outlet Pipeline and Installation	LF	1,150	$ 2,000.00	$ 2,300,000	
3.2 Outlet Tower and Installation	10' Segment	22	$ 250,000.00	$ 5,500,000	
4.0 Access Roads				**$ 900,000**	
4.1 New Roads	Mile	1.5	$ 600,000.00	$ 900,000	Estimated from nearby existing road to key project components
5.0 Key Project Components Subtotal				**$ 143,186,800**	
5.1 Sum 1.0 thru 4.0	Subtotal			$ 143,186,800	
6.0 Contractor Allowances				**$ 59,995,269**	
6.1 Environmental Allowance: Rate x 5.0	Rate		2%	$ 2,863,736	
6.2 Materials Testing (QA/QC): Rate x 5.0	Rate		2%	$ 2,863,736	
6.3 Contractor Indirect Costs: Rate x 5.0	Rate		25%	$ 35,796,700	
6.4 Profit: Rate x (5.0 + 6.1 + 6.2 + 6.3)	Rate		10%	$ 18,471,097	
7.0 Contingencies				**$ 91,431,931**	
8.1 Design Contingency: Rate x (5.0 + 6.0)	Rate		25%	$ 50,795,517	
8.2 Construction Contingency: Rate x (5.0 + 6.0)	Rate		20%	$ 40,636,414	
8.0 Conceptual Cost Estimate Total				**$ 294,615,000**	
8.1 Sum 5.0 thru 7.0	Total			$ 294,614,000	

Table 6.2: Pump Station and Pipeline Cost

Item	Unit	Quantity	Cost/Unit	Extended	Remarks
Pump Station			**Subtotal**	**$ 3,465,500**	
Intake					
Screens	LS	3	$ 80,000	$ 240,000	Costs for screens
Structure	VF	12	$ 50,000	$ 600,000	Cost for wetwell/tunnel/pool/shaft that water will draw from
Other	LS	1	$ 90,000	$ 90,000	Additional costs associated with other disciplines (15% of Struture Costs
Pumping Station					
Pumps	#	3	$ 450,000	$ 1,350,000	al sized pumps, 1 running at min allowed withdrawl, 3 for max flow of 31
MEP	LS	1	$ 265,500	$ 265,500	15% of total costs (pumps & structure)
Structure	SF	1200	$ 350	$ 420,000	Based on rough $/sf buildout
Other	LS	1	$ 500,000	$ 500,000	Other pipe and site work
Dissipation	LS		$ 500,000	$ -	Spillway or channel design
Pipeline			**Subtotal**	**$ 2,362,000**	
Pipeline	LF	2640	$ 800	$ 2,112,000	30" Pipe - All in installed price
Valves	#	5	$ 50,000	$ 250,000	All in installed price (2 valves at each PS and one every 1000 ft.)
Access Roads				**$ 250,000**	
New roads	Mile	0.5	$ 500,000	$ 250,000	
Land Acquisition				**$ 22,492**	
Inundation Area	ACRE	2	$ 11,246	$ 22,492	
Subtotals					
Construction Costs Subtotal				$ 6,099,992	
Contingency			$ 0	$ 1,829,997	
Construction Estimate + Contingency				**$ 7,929,989**	

Table 6.3: Overall Cost Summary

Land acquisition cost ($)	21.M
Construction Cost ($)	312M
Operating Cost ($/yr)	1.M
Overall Cost (Present value, $)	353M
Cost effectiveness ($/BG)	50M

The schedule for the project is also very rough. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition. Fifteen years was the typical estimate for a new dam.

- Funding acquisition 5 years
- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup 2 years
- Total 15 years

7 Potential Ancillary Benefits

The major benefit would be a large, public-accessible reservoir suitable for multiple types of recreation. While the Delaware River is a valuable recreational resource, there are no large lakes or reservoirs in the vicinity. Such an amenity may support development of tourist and recreation-oriented businesses, providing jobs and increased tax revenue. The reservoir could also raise the value of surrounding property.

The reservoir would create a large lake habitat, which is scarce in the vicinity, while replacing about 5 miles of small-stream habitat. However, the likelihood of eutrophication threatens to degrade the lake's habitat quality. Plus, if a long-term release is necessary, the reservoir level could remain low for months, reducing habitat.

Regarding flood control, this reservoir would not provide significant benefit because the drainage area is small. The pump station would not be capable of significantly reducing high flows in the Delaware River.

8 Storage Project Score

This site was scored as described in the main report and summarized in Table 8.1 below for the six primary criteria. Each primary criterion contained subcriteria which were scored on a 1 (worst) to 5 (best) scale and averaged. Scores on the primary criteria were weighted as shown in Table 8.1 and summed to obtain an overall weighted average score. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

Table 8.1: Storage Project Score

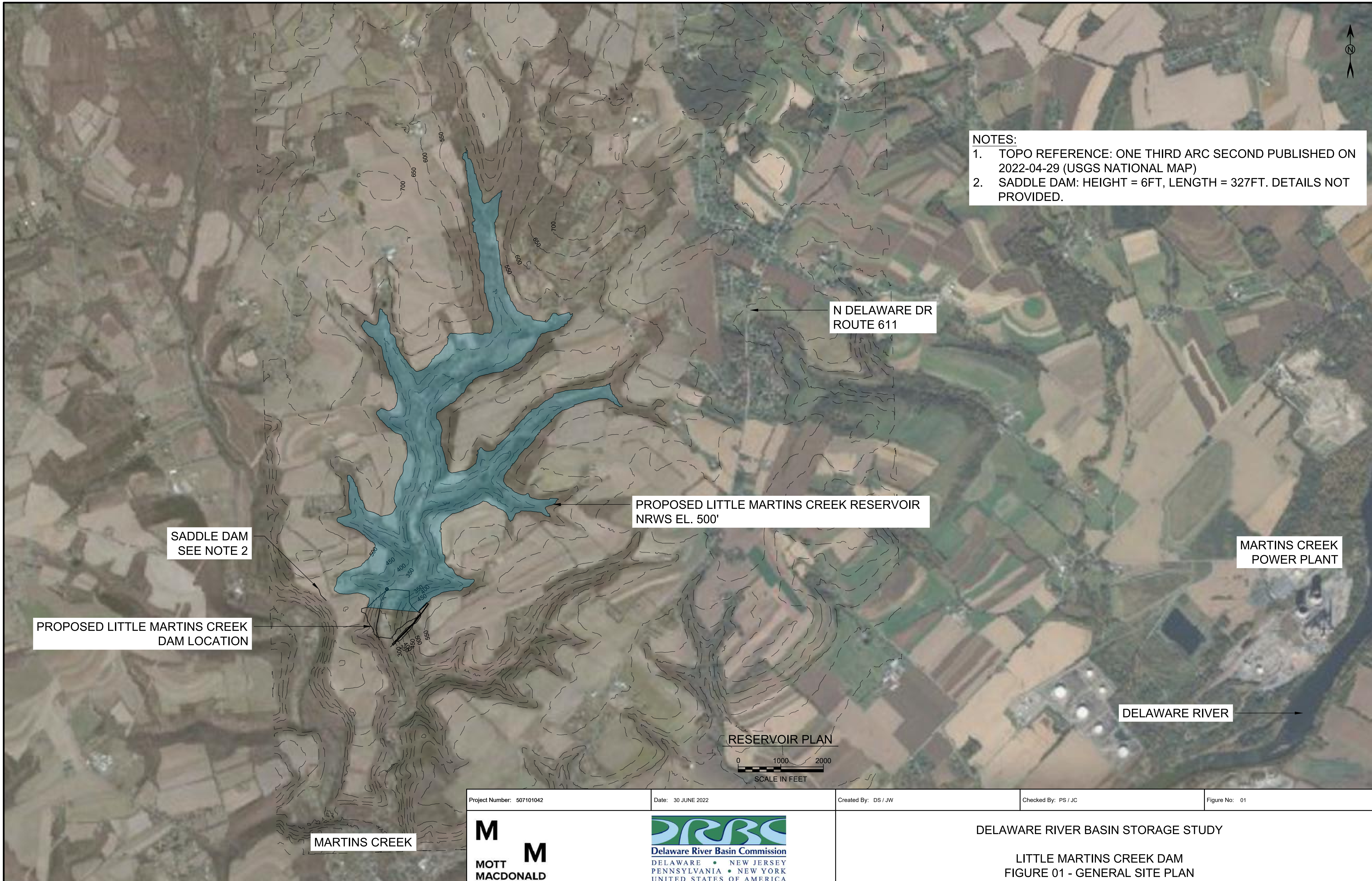
Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.17	30%	1.25
Infrastructure Design, Construction & Operation	2.20	10%	0.22
Environmental Impacts	1.96	15%	0.29
Social & Economic Impacts	3.44	10%	0.34
Project Cost & Schedule	2.17	30%	0.65
Ancillary Benefits	2.20	5%	0.11
AVERAGE	**2.69**		**2.87**

APPENDIX

Score Sheet

Drawings

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only in ungreyed cells)	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
1. Water quantity and quality		4.17			30%	1.25	
o Volume of storage provided (BG)	7.1	3					
o Hydrologic reliability of supply (months to fill)	6	4					
o Release rate (cfs)	535	5					
o Promptness of delivery to mainstem (days)	<1	5					
o Geographic benefit		5					
o Quality of stored water		3					
2. Infrastructure design, construction and operation		2.20			10%	0.22	
o Site/Civil, Land & Easements		1					Many properties to acquire
o Subsurface conditions		3					
o Infrastructure Complexity		2					Needs pump station on Delaware River
o Construction complexity		3					Needs pump station on Delaware River
o Operational complexity		2					Needs pump station on Delaware River
3. Environmental impacts		1.96			15%	0.29	
o protected species		3					Bat habitat; possible bog turtle habitat
o Water quality degradation of downstream waters		2					Martins Creek, one mile downstream, is class A; likely little effect on Delaware River
o obstruction to passage of aquatic animals		1					Little Martins Creek is rated natural-reproduction for trout
o hydromodification		3					Dam on small watershed close to Delaware River will have little effect
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted 5=small, 1=large)			
o wetlands inundated or filled (ac)	90	1.75	2.5	1			some wetlands suspected in historical farmlands
o stream length inundated (mi)	6	1	1	1			natural-production trout stream
o uplands inundated or developed (ac)	310	2	3	1			Mostly woods
4. Social and Economic Impacts		3.44			10%	0.34	
o Disruption/displacement		1					about 70 houses
o Safety and health		3					Town of Martins Creek 1 mile downstream
o Social equity		4					
o Recreational loss		4					
o Cultural/historical resources		4					
o Aesthetic		4					
o Loss of tax revenue		4					
o Loss of production from farmland, timberland, quarries		4					
o Emissions of greenhouse gasses		3					Small operational emissions from infrequent pumping
5. Project Costs & Schedule		2.17			30%	0.65	
o Land acquisition cost ($)	21.M						
o Construction Cost ($)	312M						295M$ for dam + 17M for pump station and 2 mile pipeline
o Operating Cost ($/yr)	1.M						Includes pumping cost
o Overall Cost (Present value, $)	353M	1.5					
o Cost effectiveness ($/BG)	50M	2					
o Schedule (Time to make Operational, years)	15	3					
6. Ancillary Benefits		2.20			5%	0.11	
o Flood control		2					small watershed
o Recreation/tourism		4					
o Habitat/fishery enhancement		3					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		2.69			100%	2.87	



Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 01

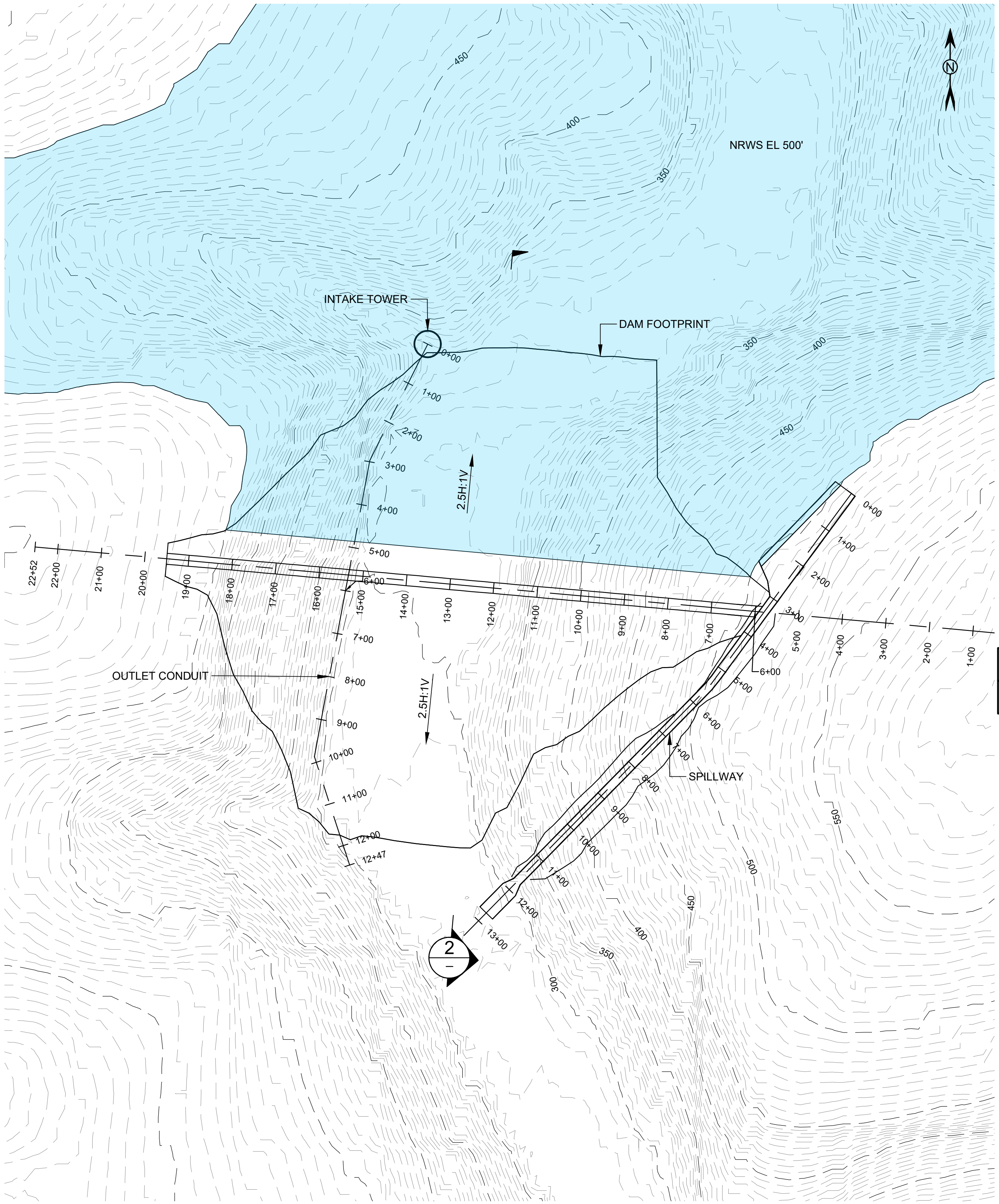
MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

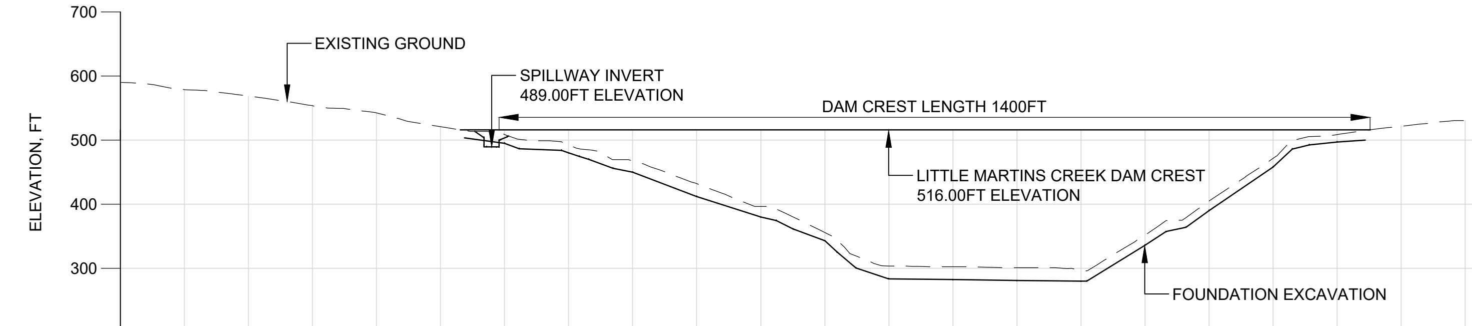
LITTLE MARTINS CREEK DAM
FIGURE 01 - GENERAL SITE PLAN

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D LMC_DAM.DWG



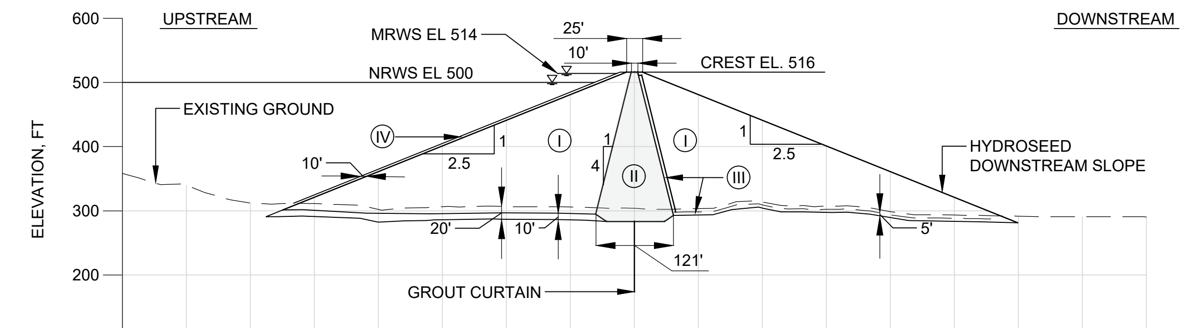
PLAN VIEW - LITTLE MARTINS CREEK DAM

0 150 300
SCALE IN FEET



STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00	14+00	15+00	16+00	17+00	18+00	19+00	20+00	21+00
EXISTING GROUND ELEVATION (ft)	590.1	578.5	568.6	553.6	542.4	520.9	508.7	492.7	467.7	432.3	396.6	356.1	303.6	302.5	301.2	297.3	351.8	404.7	471.5	508.6	521.8	530.3
CORE TRENCH ELEVATION (ft)							495.3	480.0	450.0	412.3	380.0	342.9	283.6	282.5	281.2	280.0	336.0	390.0	457.9	496.8		

1 SECTION ALONG DAM AXIS
LITTLE MARTINS CREEK DAM CENTERLINE

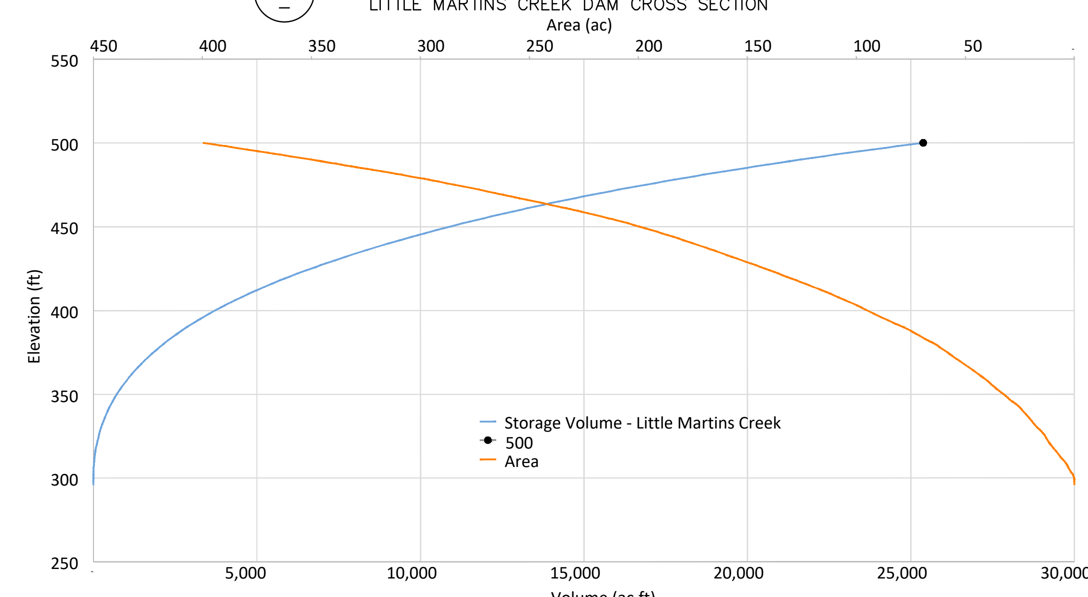


OFFSET (ft)	-8+00	-7+00	-6+00	-5+00	-4+00	-3+00	-2+00	-1+00	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00
EXISTING GROUND ELEVATION (ft)	358.2	339.7	312.3	311.2	302.3	306.3	306.7	305.7	303.6	303.4	314.0	307.3	298.7	293.4	291.5	290.8	290.2

2 MAXIMUM DAM SECTION (STA 12+25)
LITTLE MARTINS CREEK DAM CROSS SECTION

DAM TYPE	MATERIALS
I. SHELL	GENERALL FILL FROM LOCAL BORROW AREA
II. CORE	LOW PERMEABLE CLAY
III. FILTER	HIGH PERMEABLE GRANULAR
IV. RIPRAP EROSION PROTECTION	ROCKFILL BOULDERS

NOTES:
1. MAXIMUM RESERVOIR WATER SURFACE (MRWS)
2. NORMAL RESERVOIR WATER SURFACE (NRWS)



3 STAGE STORAGE AND AREA-STORAGE CURVE
LITTLE MARTINS CREEK DAM STORAGE AREA VOLUME

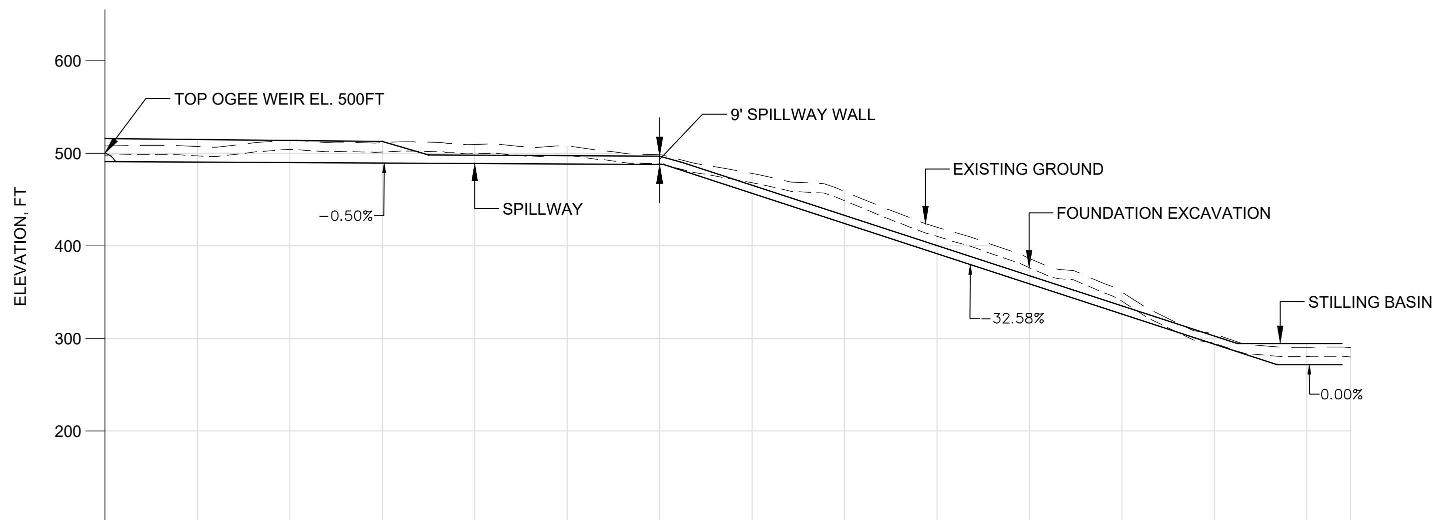
Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 02

MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

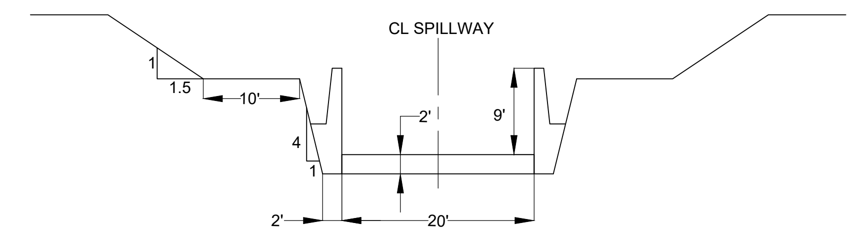
DELAWARE RIVER BASIN STORAGE STUDY

LITTLE MARTINS CREEK DAM
FIGURE 02 - PROFILE VIEWS

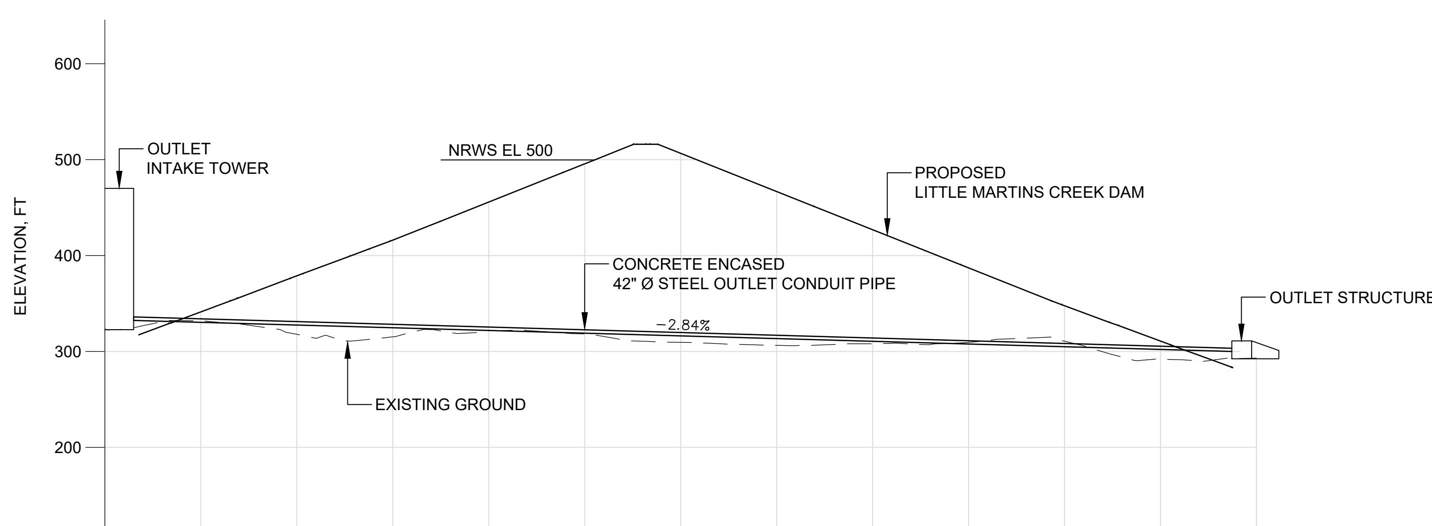


STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00	13+47.44
SPILLWAY INVERT ELEVATION (ft)	491.0	490.5	490.0	489.5	489.0	488.5	488.0	456.8	424.2	391.7	359.1	326.5	293.9	271.8	

4 – SPILLWAY PROFILE
LITTLE MARTINS CREEK DAM SPILLWAY



5 – SPILLWAY SECTION PROFILE
LITTLE MARTINS CREEK DAM SPILLWAY SECTION



STATION (ft)		1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	
EXISTING GROUND ELEVATION (ft)	323.5	331.8	317.9	315.3	321.4	318.2	309.5	306.4	308.2	309.6	310.8	292.1	293.2

6 – OUTLET CONDUIT PROFILE
LITTLE MARTINS CREEK DAM OUTLET CONDUIT

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 03

MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

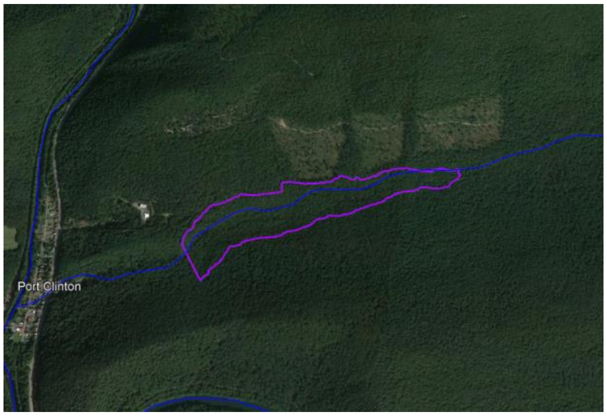
DELAWARE RIVER BASIN STORAGE STUDY

LITTLE MARTINS CREEK DAM
FIGURE 03 - OUTLET STRUCTURE

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D LMC_DAM.DWG

Storage Project Summary

Project:	**Rattling Run Reservoir (N4)**	
Location:	Port Clinton, PA	
Storage Type:	New reservoir	
Est. Volume:	1.3 BG	
Score:	3.05	



1 Project Overview

This potential reservoir and dam would be located on Rattling Run, about ½ mile from where it enters the Little Schuylkill River at Port Clinton, PA (Figure 1.1), just above the confluence with the Schuylkill River. Rattling Run's watershed is small at under 5 sq. mi. It is completely forested (Figure 1.2 and 1.3).

The dam would be a conventional embankment dam as described in the Section 5.2 of the main report. At a height of about 150 ft and length of 680 ft, this dam (Figure 1.4) would create a smaller reservoir of about 90 acres at normal pool, providing 1.3 BG of storage, which is the lowest of the new reservoirs considered. The dam's location could be moved downstream slightly to increase the volume, but would begin to approach some private residences.

Because the volume is small, the reservoir would fill in about 8 months, despite the small drainage area. However, this small volume means it could provide the desired 100 cfs of augmentation for only 20 days.

Rattling Run is rated a Class A stream by the PA Fish and Boat Commission and an Exceptional Value stream by PA Chapter 93, which makes its inundation problematic and permittability very difficult, perhaps impossible.

This dam was not studied previously; it was included for analysis at the request of the DRBC.

Figure 1.1: Project location

Figure 1.2: Topographic map: Drainage area in red (4.2 sq miles). Reservoir outline in purple.

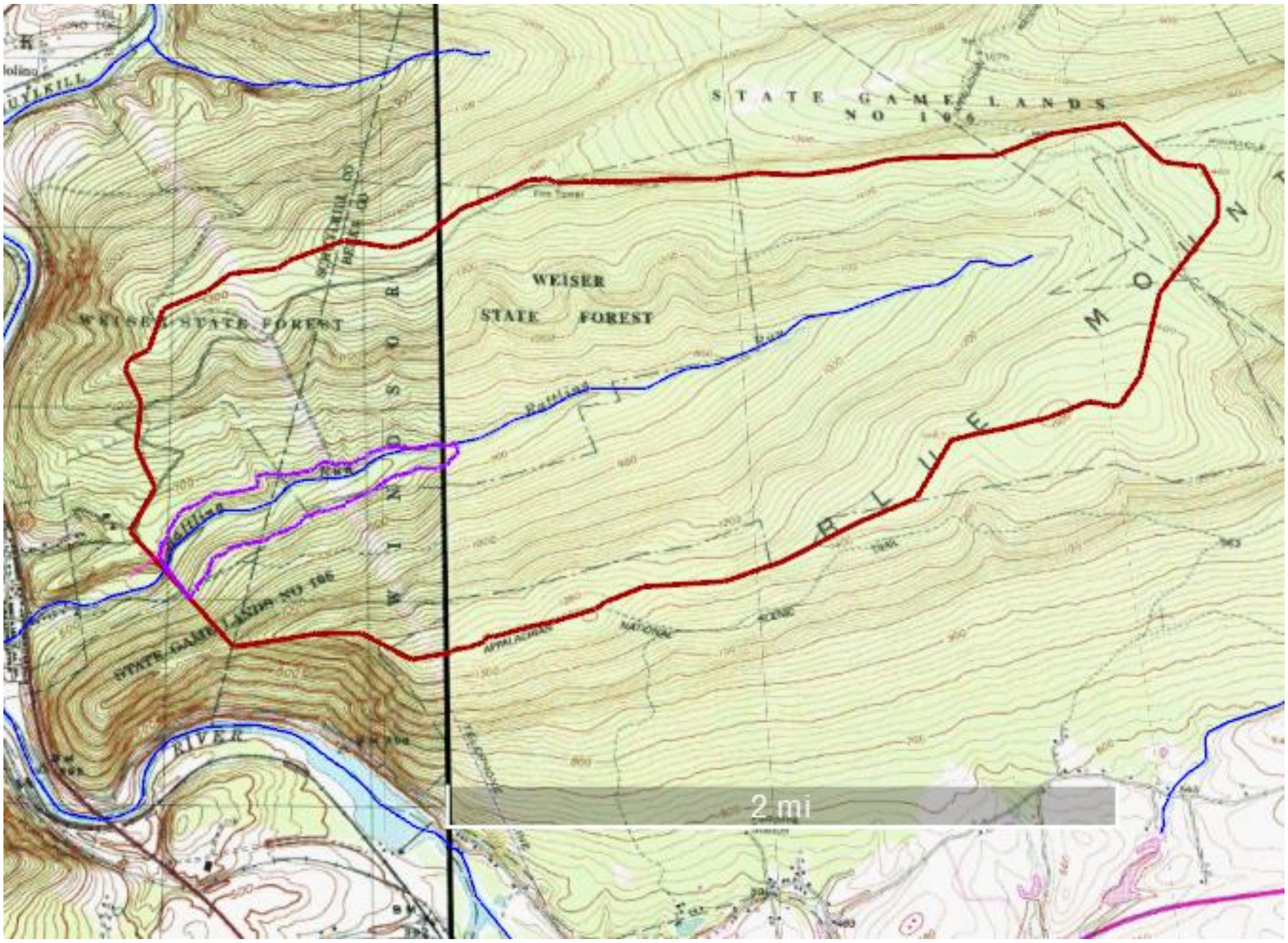


Figure 1.3: Aerial photo: Drainage area in red (4.2 sq miles). Reservoir outline in purple.

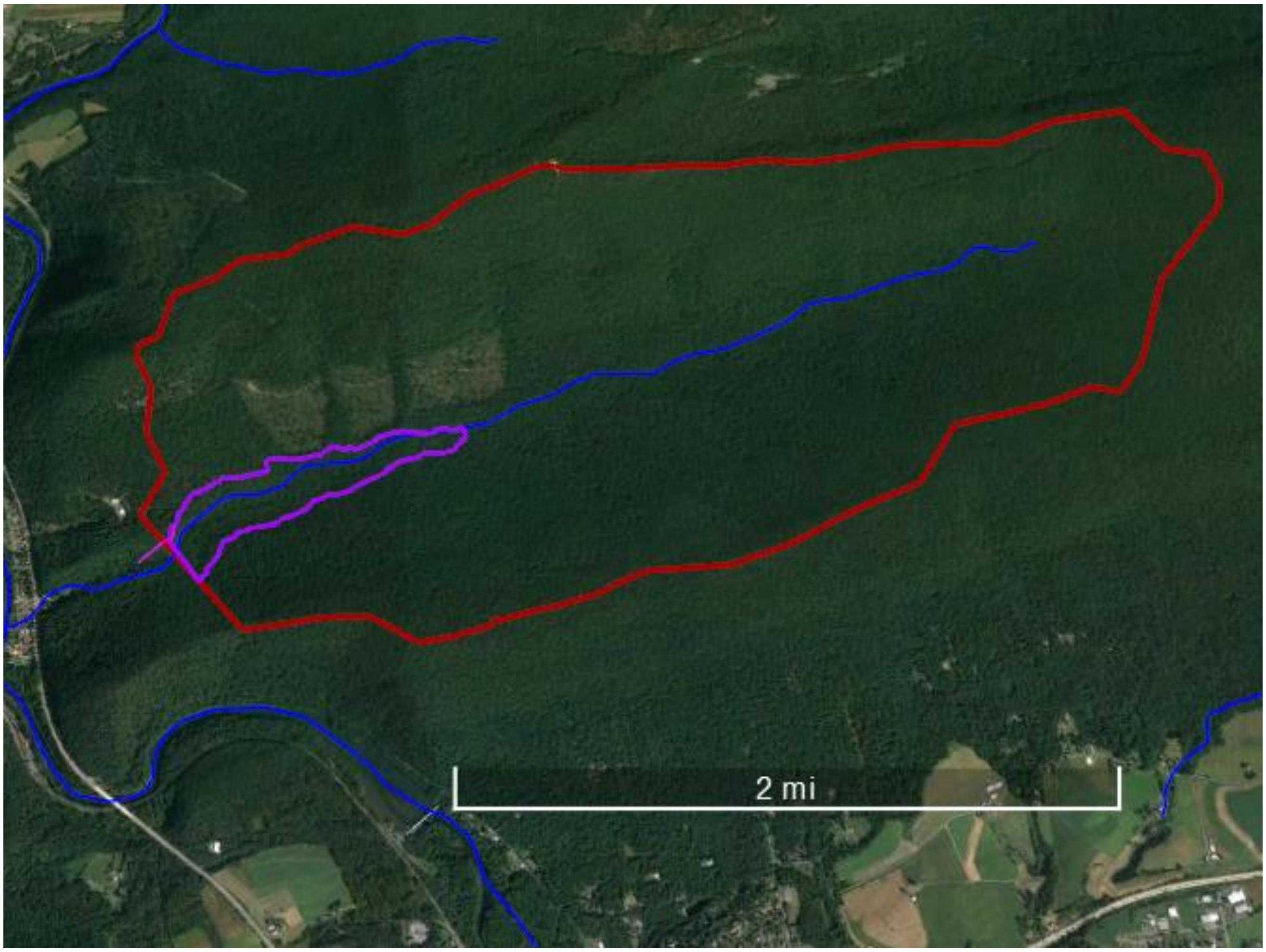
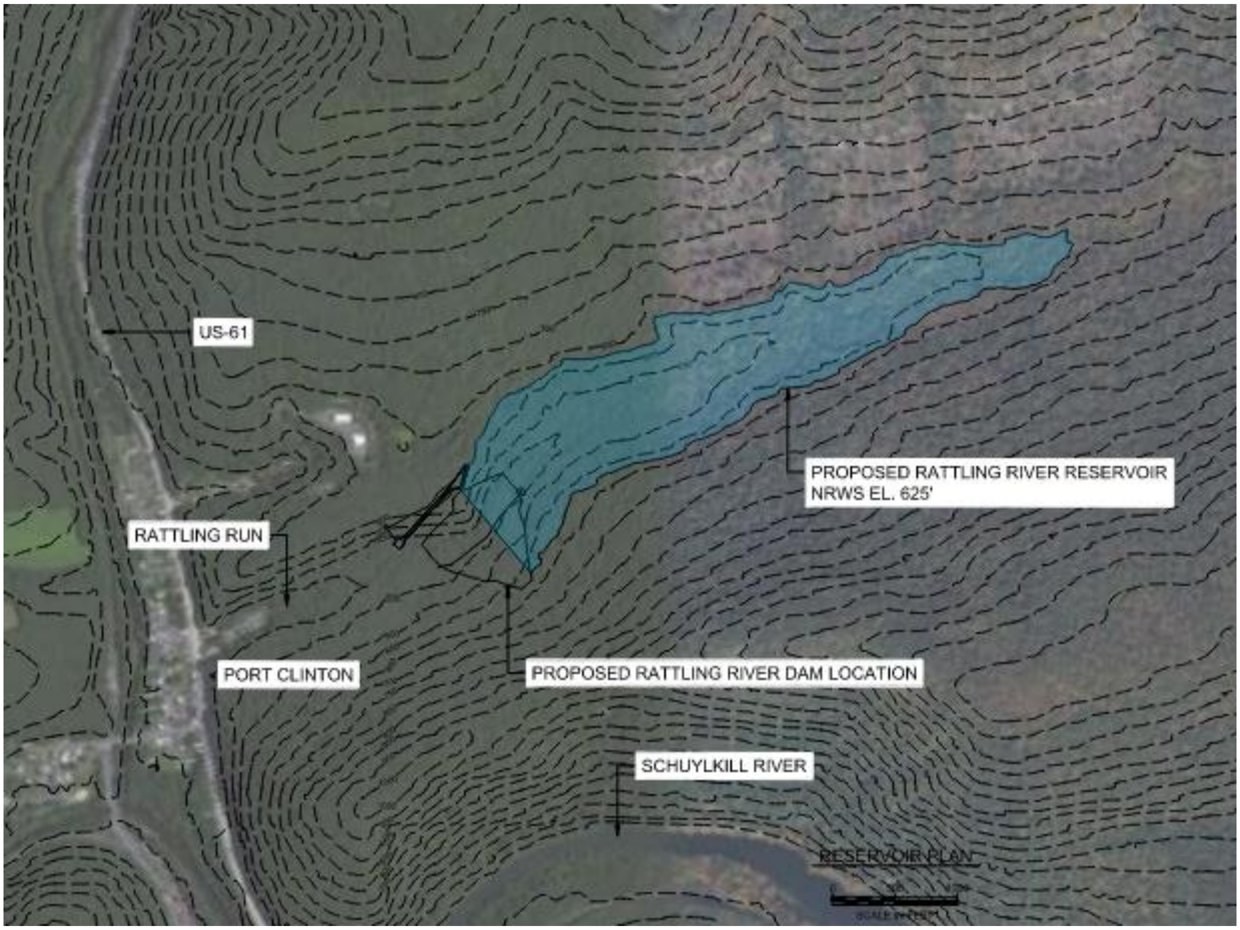


Figure 1.4: Project Schematic



2 Water Quantity & Quality

Key parameters of the potential dam and reservoir are listed in the Table 2.1 below. Detailed drawings are presented in the Appendix. The footprint of the dam, reservoir and spillway is shown in Figure 1.4.

The volume of this reservoir is modest at 1.3 BG. The dam could be moved downstream about ¼ mile to increase the volume without inundating any houses.

Table 2.1: Dam, Reservoir and Spillway Parameters

DAM	
Lat/Long	40.5850, -76.0171
Size Category per PADEP Code	A – Equal or greater than 100 feet; Equal to or greater than 50,000 ac-ft
Hazard Potential per PADEP Code	1 – Substantial (Numerous homes or small businesses or a large business or school)
Dam Type	Earthen Dam with Clay Core
Dam Crest El	636 ft
Dam Height	153 ft
Dam Crest Length	680 ft
Dam Crest Width	25 ft
Dam Slope Inclination	2.5h:1v Upstream 2.5h:1v Downstream
Saddle Dam	None
RESERVOIR	
Normal Reservoir Water Surface (NRWS)	625 ft
Maximum Reservoir Water Surface at PMF (MRWS)	634 ft
Storage Capacity at NRWS	1.3 BG / 4,720 ac-ft
Reservoir Area at NRWS	90 ac
Reservoir Area at MRWS	99 ac
Reservoir Area Footprint (50 ft Buffer)	116 ac
Freeboard at NRWS	11 ft
Freeboard at MRWS	2 ft
Drainage Area of Dam	4.1 sq mi
SPILLWAY	
Spillway Type	Concrete lined, ungated, ogee crest, “L” shaped side-channel
Spillway Crest El	625 ft
Peak Discharge	20,600 cfs
OUTLET	
Outlet Works Type	Outlet Tower
Outlet Works Conduit	42-inch steel pipe
Outlet Elevation	471 ft
Conduit Length	875 ft
Required Capacity	12 cfs
Outlet capacity at NRWS	410 cfs

2.1 Fill and Discharge

Because the volume is small, the mean flow of about 9 cfs would fill the reservoir in about 8 months, despite the small drainage area.

The water would be released by gravity, so a large release could be readily achieved through the 42-inch low-level outlet pipe, 410 cfs at the NRWS. A stilling basin would be constructed to avoid destabilizing Rattling Run.

The project would provide a modest volume of 1.3 BG to support flow augmentation. At the flow rate desired for augmentation (100 cfs), this volume would last only 20 days.

The project sits in the upper Schuylkill River watershed. With about 95 stream miles to travel, the release will take a couple of days to reach to the Delaware River. With the Schuylkill River entering the mainstem at Philadelphia low in the Basin, the upper/middle Delaware would not benefit from the project, but the flow would help repel the salt front.

2.2 Water Quality

Rattling Run is supporting aquatic life, recreation and fish consumption uses. It was not assessed for water supply. With a completely forested watershed, excellent water quality is expected.

3 Infrastructure Design, Construction & Operation

As detailed in the main report, conceptual designs were developed in general accordance with the Pennsylvania Code Title 25, Chapter 105, Dam Safety and Water Management. Detailed parameters are given in Table 2.1. The dam and spillway were designed to pass the “probable maximum flood” (PMF), which was estimated as described in Section 5.2 of the main report. No saddle dam or pumps are needed here. Freeboard was assumed to be 2 feet above the MRWS elevation.

An intake tower was conceptually designed with associated controls, piping, and valves housed within the tower. A 42”, concrete-encased, steel pipe travels through the dam connecting the intake tower to an outlet structure where water releases are to be made. The outlet capacity at NRWS greatly exceeds the required capacity.

Site access consisting of roads to key dam facilities has not been developed into the designs. An estimated allowance has been included in the cost estimate for project roads.

4 Environmental Impacts

The reservoir would inundate about 90 acres of dense mostly coniferous (likely Eastern Hemlock but possibly Eastern White Pine) forest and some deciduous forest and about a mile of Rattling Run. Rattling Run has no obvious perennial tributaries, but likely at least 1-2 intermittent tributaries are present, which would also be inundated for short lengths.

Rattling Run is rated a Class A stream by the PA Fish and Boat Commission, defined as supporting “a population of naturally produced trout of sufficient size and abundance to support a long-term and rewarding sport fishery.” Rattling Run’s existing use is defined by Chapter 93 as an Exceptional Value (EV) stream. Mitigating for the inundation of an Exceptional Value/Class A stream would be very difficult or maybe impossible to permit.

The Little Schuylkill River, to which Rattling Run discharges just north of its confluence with the Schuylkill River, is part of the State of Pennsylvania scenic river system. The PDCNR states that “construction projects in the vicinity of a designated Scenic River are required to undergo a more rigorous permitting process and may be required to adjust the project design and/or construction practices to ensure that the natural and aesthetic values of the waterway are maintained." It is unclear how this would affect permitting for this reservoir on a tributary of the Little Schuylkill River.

The dam across Rattling Run would eliminate the regular seasonal hydroperiod, but since the watershed is small, this change is expected to have little effect downstream. With a forested watershed, the water in the reservoir should remain of high quality and may benefit downstream, stressed waters during low-flows.

At the desired release rate of 100 cfs, the flow would drain the reservoir in only 20 days. The reservoir would take about 8 months to refill under average flow and could remain very low for many months during drought, stressing any animals that had come to rely on it.

The iPaC database lists three federally endangered/threatened species potentially occurring near this site, including, Indiana Bat (IB) (*Myotis sodalis*), Northern long-eared Bat (NLEB) (*Myotis septentrionalis*) and Bog Turtle (BT) (*Glyptemys muhlenbergii*). The dense forested area may be adequate habitat for the NLEB, while suboptimal for IB. However, no bog turtle habitat appears to be present within the impoundment site or the watershed.

5 Social and Economic Impacts

The reservoir site is currently 100% forested. There are no private residences, roads or businesses within the footprint of the reservoir. While the reservoir site is mostly within Weiser State Forest, access to the stream is poor with no roads leading to Rattling Run. The closest road runs atop the mountain, about 500 feet above the Run, with no mapped trail to the Run. As such, the recreational use of Rattling Run is expected to be low.

Regarding risk to safety of downstream residents from a dam failure, with modern construction and monitoring technologies, the risk to downstream residents from a dam failure would be low. About 6 private residences sit within ¼ mile of the dam within the Borough of Port Clinton, comprising about 300 people, between the dam and the Little Schuylkill River.

The demographics near the reservoir are not dominated by historically oppressed groups. Nor has this area been highly burdened in the past with undesirable facilities. Therefore, social equity concerns seem minor.

Loss of tax revenue or production from inundated properties would be minor. The possibility of tourist facilities oriented to reservoir recreation presents opportunities for economic development, jobs and increased tax revenue.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level (level 4) cost estimate for construction costs, as detailed in Table 6.1. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) are reported in Table 6.2. This potential project does not require any pumping. Costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail.

The feasibility-level cost estimate of the present value of this project is high at $293M despite the reservoir's small volume of 1.3 BG and low land costs of $1M. Consequently, the project has a very poor cost effectiveness of $225M/BG, the highest of all new dams.

Table 6.1: Construction Cost Summary

Description	Unit	Quanity	Rate	Total	Comments
1.0 Dam				**$ 120,970,550**	
1.1 Excavation	CY	467,300	$ 20.00	$ 9,346,000	
1.2 Grout Curtain	SF	84,000	$ 110.00	$ 9,240,000	
1.3 Core Material	CY	407,900	$ 25.00	$ 10,197,500	Core borrow area near dam site
1.4 Filter Material	CY	42,700	$ 90.00	$ 3,843,000	Imported material
1.5 Dam Shell Material	CY	2,908,100	$ 30.00	$ 87,243,000	Shell borrow area near dam site
1.6 Riprap	CY	5,100	$ 200.00	$ 1,020,000	Improted Material
1.7 Hydroseed	SF	162,100	$ 0.50	$ 81,050	
2.0 Spillway				**$ 8,947,100**	
2.1 Excavation	CY	25,900	$ 30.00	$ 777,000	
2.2 Spillway Slab	CY	1,500	$ 850.00	$ 1,275,000	
2.3 Spillway Walls	CY	2,600	$ 1,100.00	$ 2,860,000	
2.4 Anchors	EA	830	$ 2,500.00	$ 2,075,000	Approx 10' spacing
2.5 Drainage Layer	CY	90	$ 90.00	$ 8,100	Slot trench every 50' of spillway chute
2.6 Drainage Pipes	LF	520	$ 100.00	$ 52,000	
2.7 Stilling Basin	CY	1,900	$ 1,000.00	$ 1,900,000	200' long x with 20' additional wall height
3.0 Outlet Works				**$ 5,760,000**	
3.1 Outlet Pipeline and Installation	LF	880	$ 2,000.00	$ 1,760,000	
3.2 Outlet Tower and Installation	10' Segment	16	$ 250,000.00	$ 4,000,000	
4.0 Access Roads				**$ 1,200,000**	
4.1 New Roads	Mile	2.0	$ 600,000.00	$ 1,200,000	Estimated from nearby existing road to key project components
5.0 Key Project Components Subtotal				**$ 136,877,650**	
5.1 Sum 1.0 thru 4.0	Subtotal			$ 136,877,650	
6.0 Contractor Allowances				**$ 57,351,735**	
6.1 Environmental Allowance: Rate x 5.0	Rate		2%	$ 2,737,553	
6.2 Materials Testing (QA/QC): Rate x 5.0	Rate		2%	$ 2,737,553	
6.3 Contractor Indirect Costs: Rate x 5.0	Rate		25%	$ 34,219,413	
6.4 Profit: Rate x (5.0 + 6.1 + 6.2 + 6.3)	Rate		10%	$ 17,657,217	
7.0 Contingencies				**$ 87,403,223**	
8.1 Design Contingency: Rate x (5.0 + 6.0)	Rate		25%	$ 48,557,346	
8.2 Construction Contingency: Rate x (5.0 + 6.0)	Rate		20%	$ 38,845,877	
8.0 Conceptual Cost Estimate Total				**$ 281,633,000**	
8.1 Sum 5.0 thru 7.0	Total			$ 281,632,609	

Table 6.2: Overall Cost Summary

Land acquisition cost ($)	1M
Construction Cost ($)	281M
Operating Cost ($/yr)	0.6M
Overall Cost (Present value, $)	293M
Cost effectiveness ($/BG)	225M

The schedule for the project is also very rough. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition. Fifteen years was the typical estimate to develop a new dam.

- Funding acquisition 5 years
- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup 2 years
- Total 15 years

7 Potential Ancillary Benefits

A major benefit would be a 90 ac, public-accessible reservoir suitable for multiple types of recreation. This would be the only such facility readily accessible to residents of the immediate vicinity. Such an amenity may support development of tourist and recreation-oriented businesses, providing jobs and increased tax revenue. The reservoir would expand the area of aquatic habitat, albeit by inundating an exceptional value stream. Regarding flood control, this reservoir would not provide significant benefit because the basin is small and flooding is not likely a current problem.

8 Storage Project Score

This site was scored as described in the main report and summarized in Table 8.1 below for the six primary criteria. Each primary criterion contained subcriteria which were scored on a 1 (worst) to 5 (best) scale and averaged. Scores on the primary criteria were weighted as shown in Table 8.1 and summed to obtain an overall weighted average score. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

The project scored relatively high compared to other new reservoirs despite its low score on project cost and stream impacts because the social economic impacts are low, its water quality is excellent, and it does not impact any wetlands.

Table 8.1: Storage Project Score

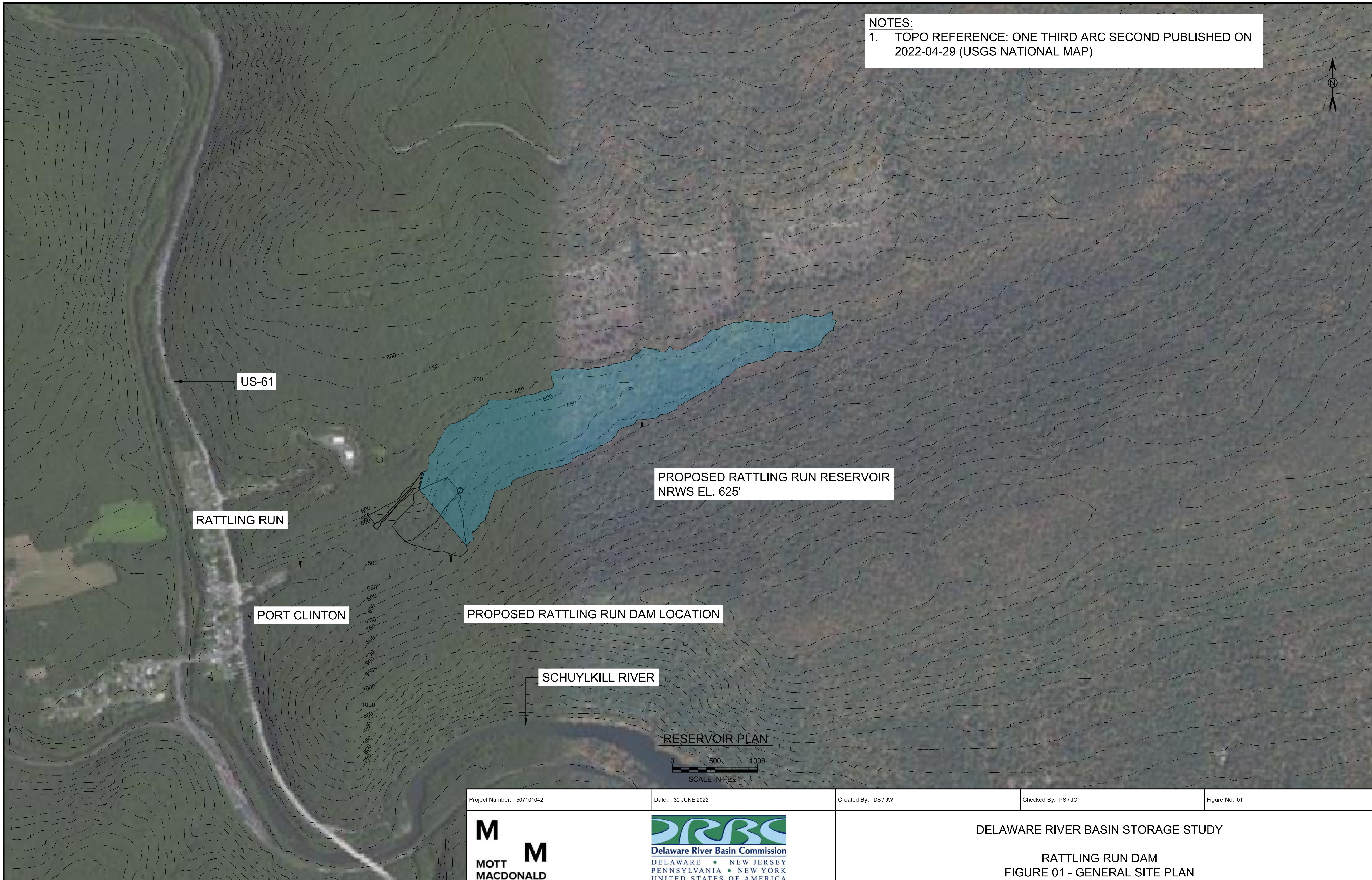
Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.83	30%	1.15
Infrastructure Design, Construction & Operation	3.40	10%	0.34
Environmental Impacts	3.36	15%	0.50
Social & Economic Impacts	4.22	10%	0.42
Project Cost & Schedule	1.83	30%	0.55
Ancillary Benefits	1.60	5%	0.08
AVERAGE	**3.04**		**3.05**

APPENDIX

Score Sheet

Drawings

Six primary criteria	Quantitative Evaluation Metric (when appropriate) (enter values only in ungreyed cells)	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
1. Water quantity and quality		3.83			30%	1.15	
o Volume of storage provided (BG)	1.3	2					
o Hydrologic reliability of supply (months to fill)	8	4					
o Release rate (cfs)	400	5					
o Promptness of delivery to mainstem (days)	2	4					
o Geographic benefit		3					Schuylkill basin
o Quality of stored water		5					
2. Infrastructure design, construction and operation		3.40			10%	0.34	
o Site/Civil, Land & Easements		5					
o Subsurface conditions		3					
o Infrastructure Complexity		3					
o Construction complexity		3					
o Operational complexity		3					
3. Environmental impacts		3.36			15%	0.50	
o protected species		3					Habitat for bats
o Water quality degradation of downstream waters		5					Expect excellent water quality in the reservoir
o obstruction to passage of aquatic animals		3					Little connectivity to upstream areas
o hydromodification		4					Small watershed will have little effect downstream
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted 5=small, 1=large)			
o wetlands inundated or filled (ac)		5	NA	5			no wetlands suspected; all soils well drained and no NWI wetlands
o stream length inundated (mi)		1	1	1			Class A stream
o uplands inundated or developed (ac)	90	2.5	1	4			Dense forest
4. Social and Economic Impacts		4.22			10%	0.42	
o Disruption/displacement		5					uninhabited
o Safety and health		3					Town of Port Clinton downstream
o Social equity		5					
o Recreational loss		3					Loss of 1 mile of Class A fishing stream
o Cultural/historical resources		5					
o Aesthetic		4					
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		3					
5. Project Costs & Schedule		1.83			30%	0.55	
o Land acquisition cost ($)	1M						All forested; no buildings
o Construction Cost ($)	281M						
o Operating Cost ($/yr)	0.6M						
o Overall Cost (Present value, $)	293M	1.5					
o Cost effectiveness ($/BG)	225M	1					
o Schedule (Time to make Operational, years)	15	3					
6. Ancillary Benefits		1.60			5%	0.08	
o Flood control		1					Small basin; little benefit
o Recreation/tourism		3					Creates large lake
o Habitat/fishery enhancement		2					Creates large lake but floods EV stream
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		3.04			100%	3.05	



Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 01

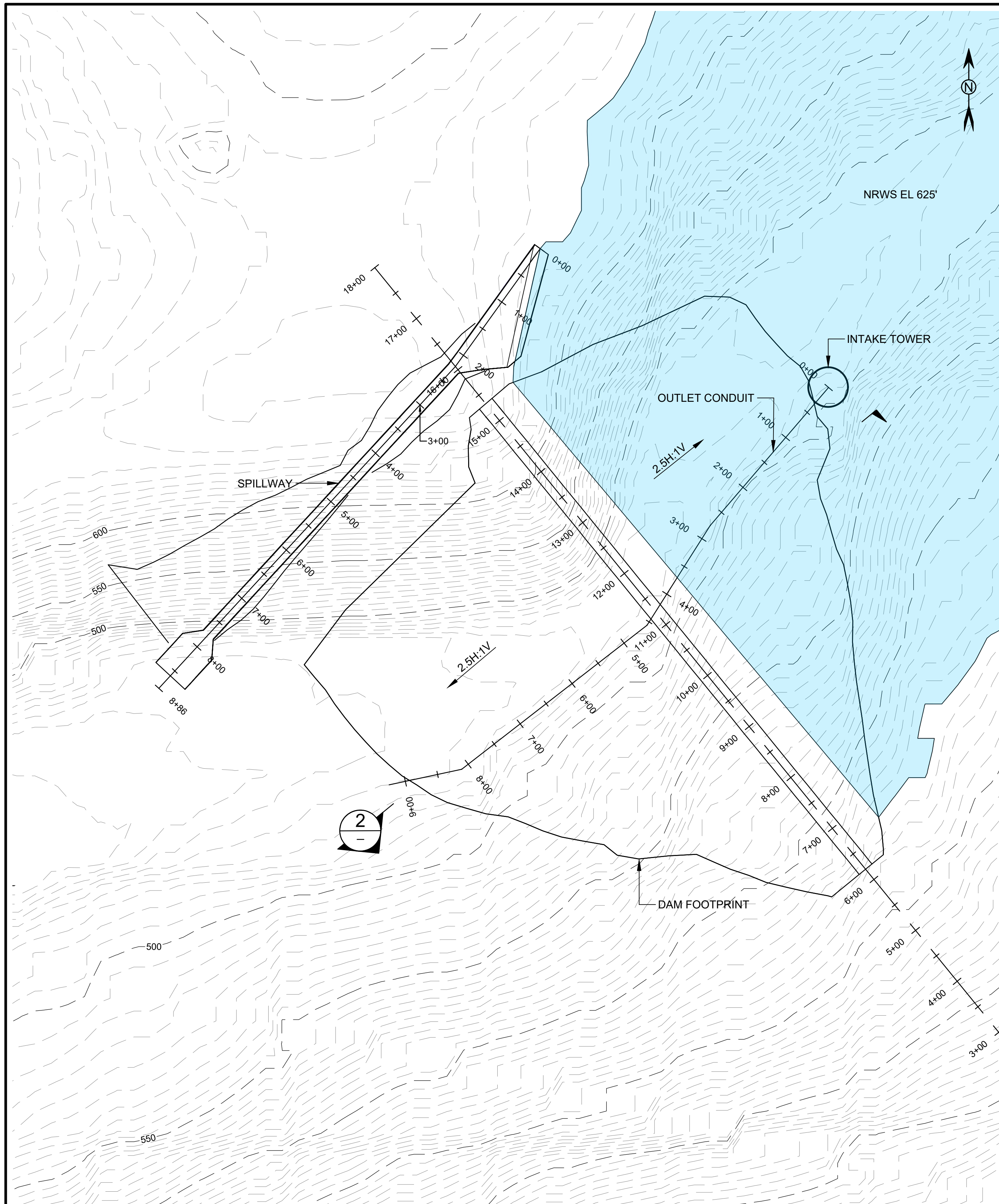
MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

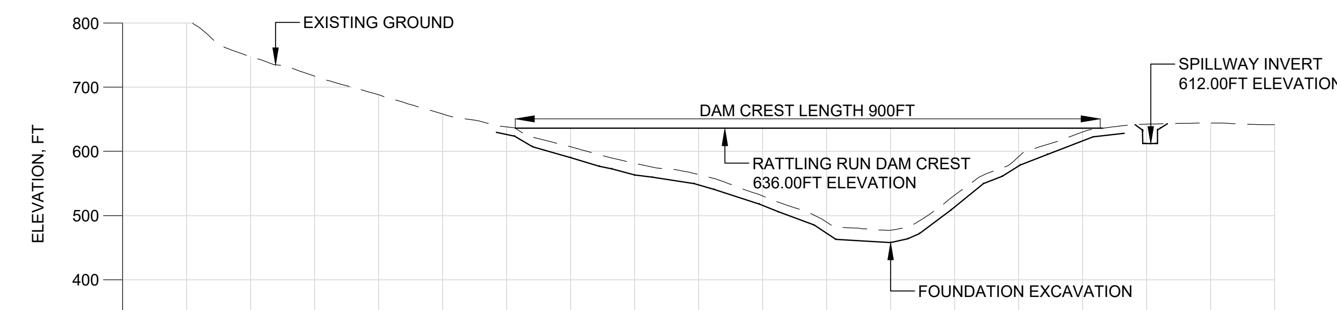
RATTLING RUN DAM
FIGURE 01 - GENERAL SITE PLAN

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D RR_DAM.DWG



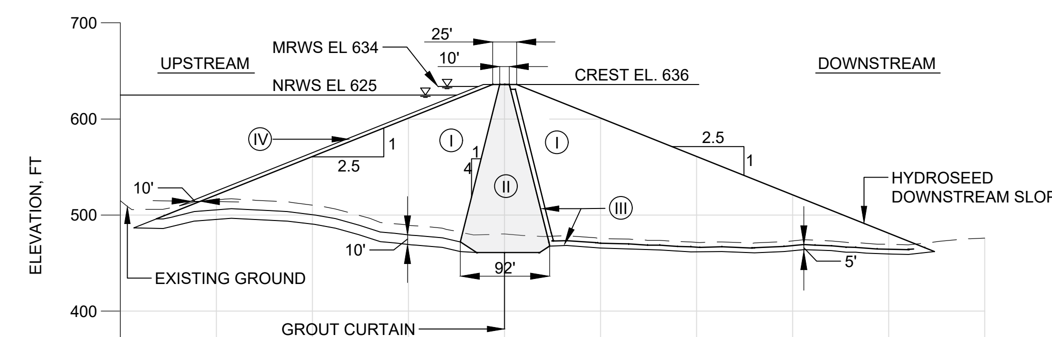
PLAN VIEW - RATTLING RUN DAM

0 75 150
SCALE IN FEET



STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00	14+00	15+00	16+00	17+00	18+00
EXISTING GROUND ELEVATION (ft)	850.7	806.4	747.6	717.3	688.1	658.3	638.1	607.1	581.5	564.1	530.4	489.7	477.1	531.8	591.8	630.2	642.4	644.0	641.8
CORE TRENCH ELEVATION (ft)							626.3	590.4	563.0	547.9	515.9	472.3	458.0	513.3	577.0	616.4			

1 SECTION ALONG DAM AXIS
RATTLING RUN DAM CENTERLINE

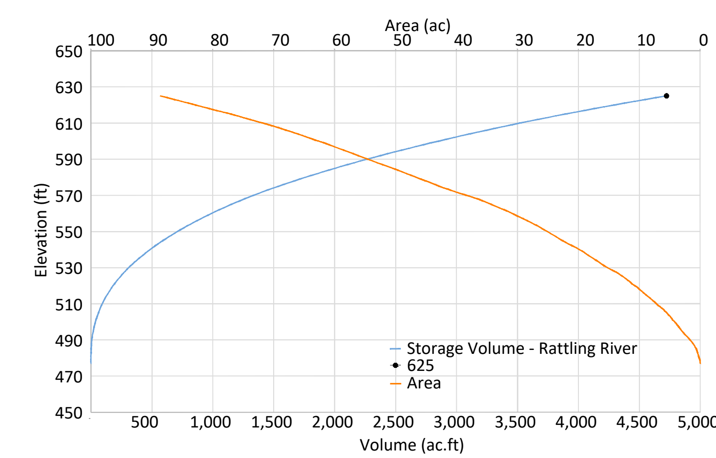


OFFSET (ft)	-4+00	-3+00	-2+00	-1+00	0+00	1+00	2+00	3+00	4+00	5+00
EXISTING GROUND ELEVATION (ft)	514.7	515.6	510.4	489.4	480.2	475.7	471.6	473.0	469.4	475.7

2 MAXIMUM DAM SECTION (STA 11+50)
RATTLING RUN DAM CROSS SECTION

DAM TYPE	MATERIALS
I. SHELL	GENERALL FILL FROM LOCAL BORROW AREA
II. CORE	LOW PERMEABLE CLAY
III. FILTER	HIGH PERMEABLE GRANULAR
IV. RIPRAP EROSION PROTECTION	ROCKFILL BOULDERS

NOTES:
1. MAXIMUM RESERVOIR WATER SURFACE (MRWS)
2. NORMAL RESERVOIR WATER SURFACE (NRWS)



3 STAGE STORAGE AND AREA-STORAGE CURVE
RATTLING RUN DAM STORAGE AREA VOLUME

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 02

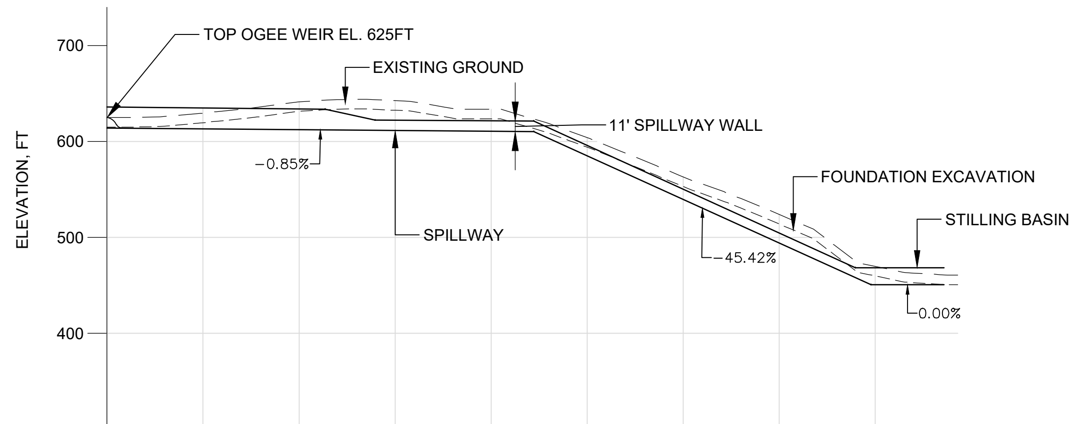
MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

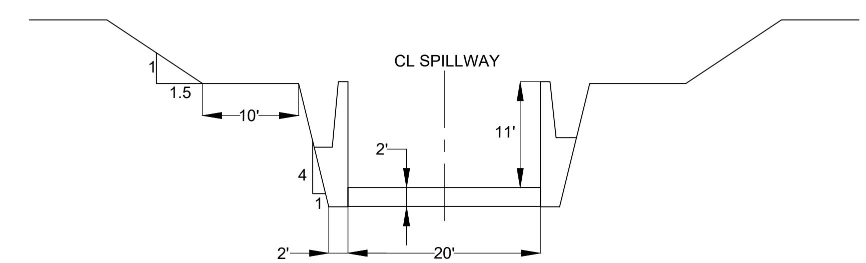
RATTLING RUN DAM
FIGURE 02 - PROFILE VIEWS

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D RR_DAM.DWG

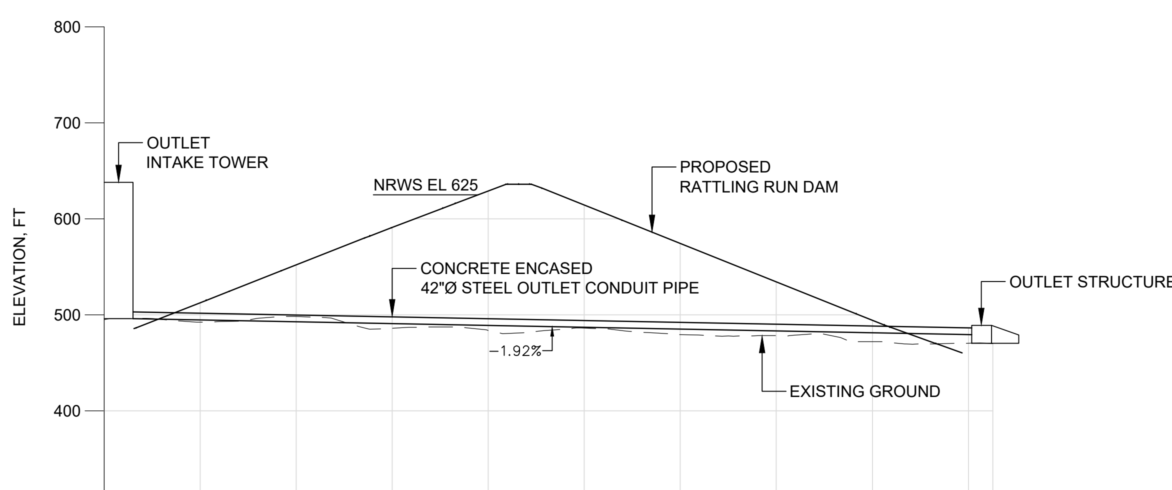


STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00
SPILLWAY INVERT ELEVATION (ft)	614.0	613.1	612.3	611.4	610.6	585.0	539.5	494.1	450.7	

4 – SPILLWAY PROFILE
RATTLING RUN DAM SPILLWAY



5 – SPILLWAY SECTION PROFILE
RATTLING RUN DAM SPILLWAY SECTION



STATION (ft)		1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	
EXISTING GROUND ELEVATION (ft)	495.0	492.3	498.3	486.1	483.8	486.1	479.4	478.2	472.1	470.3	470.0

6 – OUTLET STRUCTURE PROFILE
RATTLING RUN DAM OUTLET STRUCTURE

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 03

MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

RATTLING RUN DAM
FIGURE 03 - OUTLET STRUCTURE

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D RR_DAM.DWG

Storage Project Summary

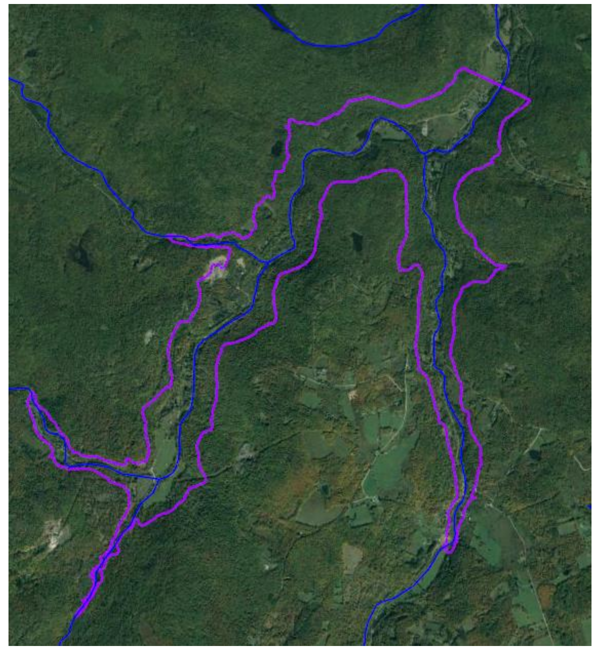
Project: Equinunk Reservoir (N5)

Location: Village of Equinunk, Wayne County, PA

Storage Type: New reservoir

Est. Volume: 42 BG

Score: 3.03



1 Project Overview

The location of the potential dam and reservoir is on Equinunk Creek, a few hundred yards from the Delaware River (Figure 1.1) in the village of Equinunk within Buckingham and Manchester Townships in Wayne County, Pennsylvania. The dam would be located just downstream of the confluence of Equinunk Creek proper and its South Branch (Figures 1.2 and 1.3). The 57 square mile watershed is mostly forested with a few farms and residential buildings.

The dam (Figure 1.4) would be a conventional embankment dam as described in Section 5.2 of the main report. At a height of 298 ft and length of 2,550 ft, this large dam would create a reservoir of about 1392 acres providing 42 BG of storage. The reservoir would flood about 100 residential buildings and about 10 miles of roads. The dam's location could be adjusted or its height reduced to reduce these impacts. The village of Equinunk lies just downstream of the dam site and would not be directly affected by the reservoir.

The reservoir would be filled by gravity; no pumps are needed. With the feeder streams combining for a mean annual flow of 110 cfs, the dam would take about 19 months to fill/refill. The outflow would enter the Delaware River 1.5 miles downstream of the dam at river mile 322, about 76 miles above the Montague gauge.

The dam was investigated in the 1976 and 1981 reports, with the 1976 report recommending that this dam location be disconsidered due to the environmental issues, low yield, and insignificant cost advantage. The 1981 Level B study rated it as having significant environmental and adverse social impact and noted it would "not be offered for inclusion in the Comprehensive Plan". It was considered here because of its large volume while displacing relatively few residences and limited impact on roads and wetlands, plus a desirable location near the Delaware River.

This reach is part of the Upper Delaware Scenic and Recreational River, regulated by the Wild and Scenic River Act. The Act prevents the federal government from approving or funding projects on tributaries that would "invade or unreasonably diminish" fish, wildlife, scenic, or recreational resources of the River, with the determination made by the National Park Service. This could greatly complicate approval for this dam.

In May 2022, the PA Fish and Boat Commission rated the South Branch of Equinunk Creek as a Pennsylvania Wild Trout Water. The federally endangered Dwarf Wedge Mussel may occupy this area. These factors complicate permitting.

The rough cost estimate of this potential project is very high, 1.1B$, because of the large size of the dam; land acquisition costs comprise only about 4% at about 40M$ and operation and maintenance costs would be about 2 M$/year. The cost effectiveness is 27 M$/BG, which is among the best for new dams, but significantly larger than for several quarries and two dam raises. Our rough estimate is that it would take about 15 years to put this project into operation, which is equivalent to other new dams. However, this might be extended for many years if complications are encountered.

Figure 1.1: Project location

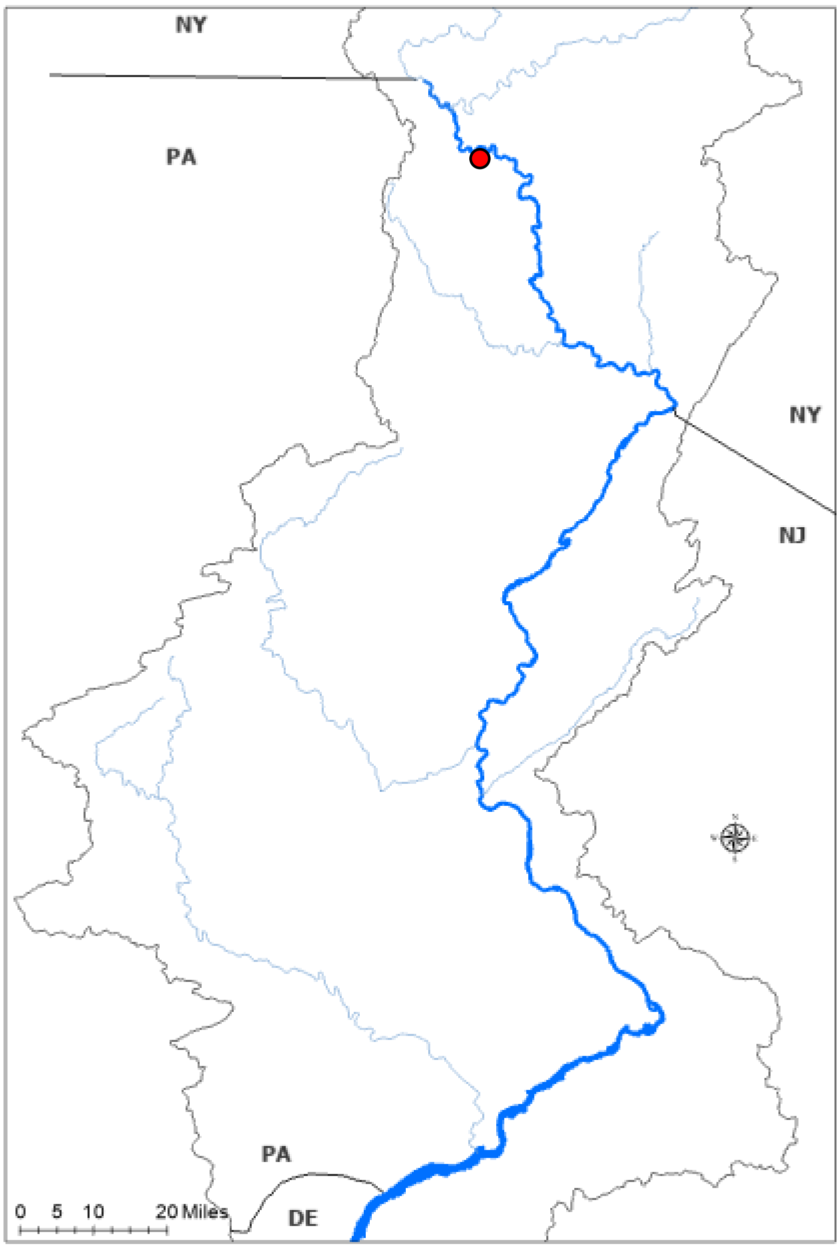


Figure 1.2: Topographic map: Drainage area in red (57 sq miles). Reservoir outline in purple. Delaware River in upper right.

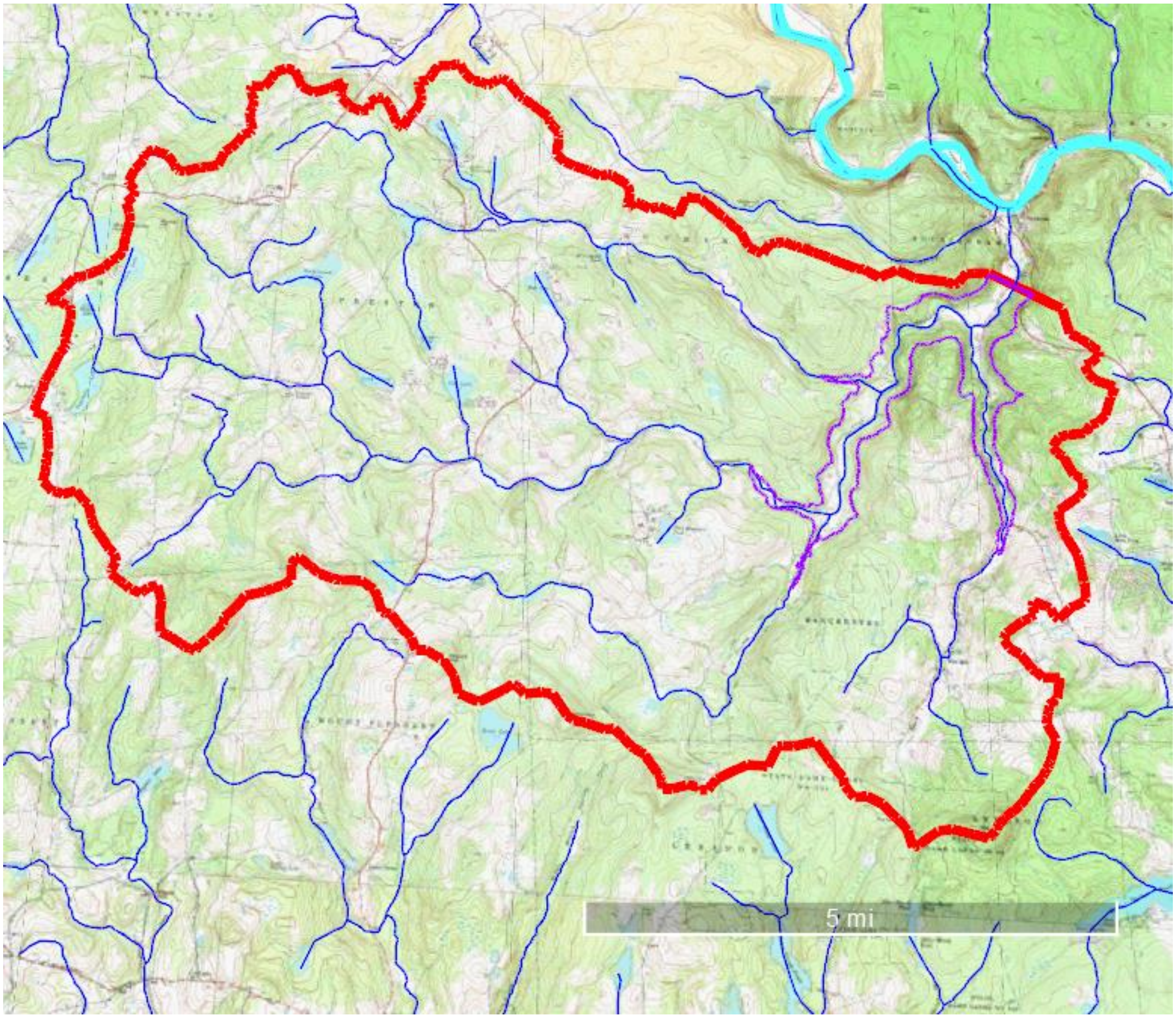


Figure 1.3: Aerial photo: Drainage area in red (57 sq miles). Reservoir outline in purple. Delaware River in upper right.

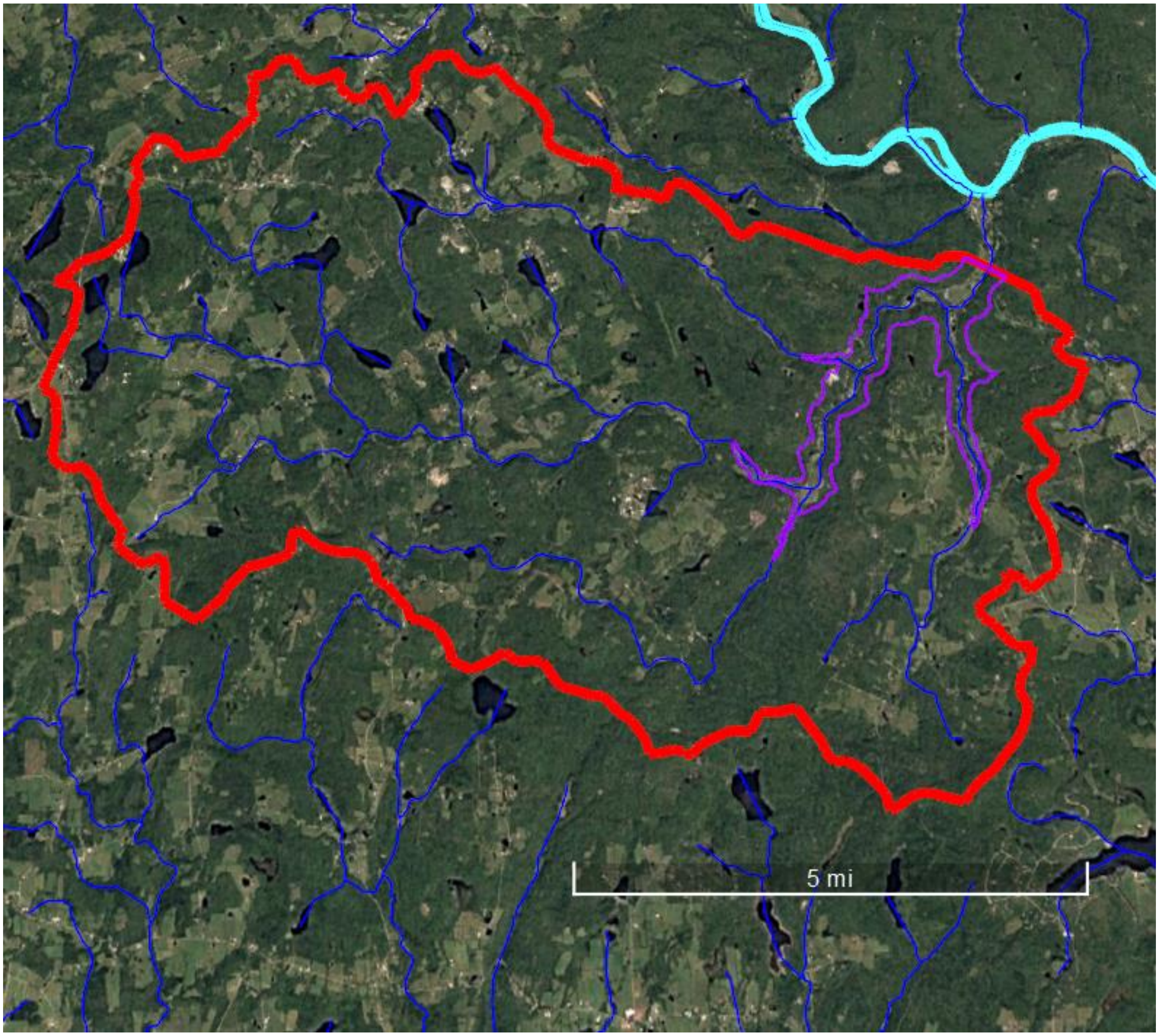
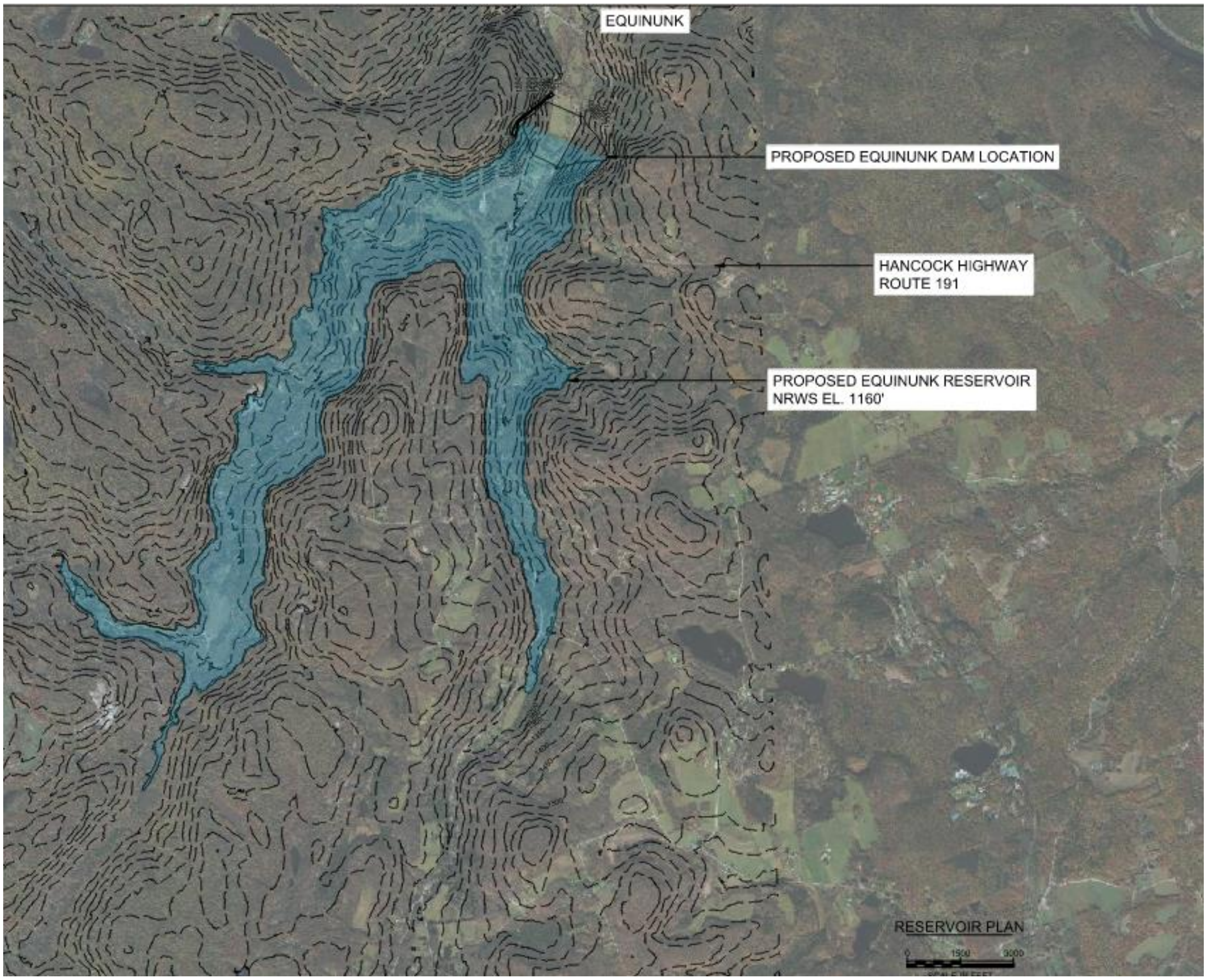


Figure 1.4: Project Schematic



2 Water Quantity & Quality

Key parameters of the potential dam and reservoir are listed in the Table 2.1 below. Detailed drawings are presented in the Appendix. The footprint of the dam, reservoir and spillway is shown in Figure 1.4.

Table 2.1: Dam, Reservoir and Spillway Parameters

DAM	
Lat/Long	41.8457, -75.2257
Size Category per PADEP	A – Equal or greater than 100 feet; Equal to or greater than 50,000 ac-ft
Hazard Potential per PADEP	1 – Substantial (Numerous homes or small businesses or a large business or school)
Dam Type	Earthen Dam with Clay Core
Dam Crest El	1178 ft
Dam Height	298 ft
Dam Crest Length	2,550 ft
Dam Crest Width	25 ft
Dam Slope Inclination	2.5h:1v Upstream 2.5h:1v Downstream
Saddle Dam	None
RESERVOIR	
Normal Reservoir Water Surface (NRWS)	1160 ft
Maximum Reservoir Water Surface at PMF (MRWS)	1176 ft
Storage Capacity at NRWS	41.6 BG / 148,640 ac-ft
Reservoir Area at NRWS	1,392 ac
Reservoir Area at MRWS	1,599 ac
Reservoir Area Footprint (50 ft Buffer)	1,713 ac
Freeboard at NRWS	17 ft
Freeboard at MRWS	2 ft
Drainage Area	57 sq mil
SPILLWAY	
Spillway Type	Concrete lined, ungated, ogee crest, “L” shaped side-channel
Spillway Crest El	1178 ft
Peak Discharge	62,100 cfs
OUTLET	
Outlet Works Type	Outlet Tower
Outlet Works Conduit	42-inch steel pipe
Outlet Elevation	851 ft
Conduit Length	1,605 ft
Required outlet capacity	174 cfs
Outlet capacity at NRWS	448 cfs

2.1 Fill and Discharge

With a drainage area of 57 square miles and a mean inflow of 113 cfs, the reservoir will fill/refill naturally in about 19 months, which indicates an intermediate reliability of supply. Consequently, pump-in is not necessary.

The chief advantage of this project is its large volume (42 BG), which could provide the desired 100 cfs of augmentation for 642 days, or a larger flow for a shorter period.

The water would be released by gravity, so a large release could be readily achieved through the 42-inch low-level outlet pipe, about 450 cfs at the NRWS. Such a large release would likely destabilize Equinunk Creek, so a stilling basin to prevent this was included in the design and cost estimate. Another advantage of this project is its proximity to the Delaware River, just 1.5 miles downstream of the dam. The outflow would enter the Delaware River about 76 miles above the Montague gauge.

2.2 Water Quality

Equinunk Creek was assessed by the PADEP in the 2022 integrated report as supporting aquatic life use while not assessed for other uses. While eutrophication is a common concern in a reservoir, other reservoirs in the Basin (e. g., Blue Marsh) that are eutrophic are currently used for flow augmentation. Given that the majority of the watershed is forested, water quality should be adequate to support flow augmentation.

3 Infrastructure Design, Construction & Operation

As detailed in the main report, conceptual designs were developed in general accordance with the Pennsylvania Code Title 25, Chapter 105, Dam Safety and Water Management. Detailed parameters are given in Table 2.1. The dam and spillway were designed to pass the “probable maximum flood” (PMF), which was estimated as described in Section 5.2 of the main report. No saddle dam or pumps are needed here. Freeboard was assumed to be 2 feet above the MRWS elevation.

An intake tower was conceptually designed with associated controls, piping, and valves housed within the tower. A 42”, concrete-encased, steel pipe travels through the dam connecting the intake tower to an outlet structure where water releases are to be made. The outlet capacity at NRWS greatly exceeds the required capacity.

Site access consisting of roads to key dam facilities has not been developed into the designs. An estimated allowance has been included in the cost estimate for project roads.

4 Environmental Impacts

The reservoir footprint (~1400 ac at NRWS) is primarily forested, covering about 80% or 1100 acres. Most of the remaining 300 acres are agricultural land, possibly used for haying or dairy ranching. A significant amount of the mixed deciduous/coniferous forested land may have been used for mining of some type. The forested areas appear to be second or third growth or younger forests as can be observed in older aerial photographs from around 2000. The riparian zone of Equinunk Creek is significantly disturbed in some locations.

The reservoir would flood about 10 miles of perennial streams, classified by the PADEP Chapter 93 as high quality, cold-water fishery (HQ-CWF). In May 2022, the PA Fish and Boat Commission rated the South Branch of Equinunk Creek to its mouth with Equinunk Creek as a Pennsylvania Wild Trout Water.

The impoundment would also flood a few small human-constructed impoundments. Definitive information regarding aquatic invertebrates and fish were not evaluated; however, popular fishing websites report large and small mouth bass and brown trout are fished from Equinunk Creek.

The dam would restrict discharge of high quality, cold water to the Delaware River thereby potentially changing the habitat in the River at the discharge point and for an unknown distance downstream. Construction of the dam would eliminate the seasonal hydroperiod, including releases to the floodplain in the reservoir footprint and would affect spring pulses throughout the season and affect discharge into the Delaware River from the entire watershed. Once the free-flowing stream is retained behind a dam the water will become warmer, it will retain nutrients and subsequently become more eutrophic. At this point, the Delaware River's watershed is about 1500 sq. mi., which is very large relative to the Equinunk Creek watershed of 57 sq. mi., so impacts would be expected to be minor.

The most significant impact of a dam constructed in the lower Equinunk Creek is the restriction of movement of aquatic organisms from the Delaware River into the 57 sq. mi. Equinunk watershed. The watershed consists of hundreds of miles of high-quality, cold-water streams. It would be difficult to obtain a permit to construct an impoundment in the Equinunk Creek Watershed.

The dam would sit just outside the boundary of the Upper Delaware Scenic and Recreational River. Section 7(a) of the Wild and Scenic River Act provides the Upper Delaware with permanent protection from federally licensed or assisted water resources projects on a tributary that would invade or unreasonably diminish the segment's fish, wildlife, scenic, or recreational resources, with the determination made by the National Park Service. Because scenic effects are considered, the permitting of this dam could be problematic.

The Pennsylvania Natural Diversity Inventory included a hit for the Dwarf Wedge Mussel, which is on the USFWS endangered species list as the only listed freshwater mussel species in the Northeast. According to the USFWS, areas around the Equinunk Creek watershed and especially the Delaware River are occupied Critical Habitat for the DWM. If DWM are found in the Equinunk Watershed, construction of an impoundment could jeopardize the existence of the species, thereby rendering such a project as not permittable.

Other endangered/threatened species are reported by the USFWS iPaC as potentially ranging in the impact location include Indiana Bat (IB), Northern Long-eared Bat (NLEB), and Monarch Butterfly. It appears preferred habitat for both bats is located within the Equinunk Creek watershed. No information was available about known maternity colonies or hibernacula in the area. A better understanding of all protected species must be obtained before understanding final impacts.

The National Wetland Inventory (NWI) does not identify many wetlands within the impoundment area (the area has high topographic relief). However, the USDA Natural Resource Conservation Service does identify poorly and somewhat poorly drained soils within the impoundment area. Wetland areas comprise about 112 acres based on both NWI wetlands and anticipated hydric and fluvaquentic soils outside of the NWI wetland areas.

5 Social and Economic Impacts

About 100 residential buildings would be flooded by the reservoir. This could be reduced by lowering the dam elevation or moving the dam upstream. Given the abundance of undeveloped land nearby, displaced residences could possibly be reconstructed near their current location. The reservoir would flood a campground, which could presumably be reconstructed outside the footprint. A quarry would also be flooded.

About 10 miles of roads would be flooded, notably Equinunk Creek Road and Pine Mill Road which connect rural residences with the village. No convenient alternate routes exist. Constructed replacement roads would be expensive because of the hilly terrain. State route 191 would just skirt the south end of dam. A small portion would need relocation or the dam could be lowered.

Regarding risk to safety of downstream residents, with modern construction technologies and monitoring, the risk of a dam failure would be low. However, the village sits only ½ mile downstream of the dam – the presence of a large dam could be disturbing to residents. There are no housing areas on the other side of the Delaware River or downstream for many miles.

The village contains the nationally designated Equinunk Historic District, consisting of 55 buildings. The map in the nomination form (https://gis.penndot.gov/CRGISAttachments/SiteResource/H105049_01H.pdf) indicates the District is 0.4 miles downstream of the dam and would not be directly impacted.

The demographics of Buckingham and Manchester Townships (which encompass the reservoir area) as reported in the 2010 census are not dominated by historically oppressed groups. Nor is there any indication that this area has been highly burdened in the past with undesirable facilities. Therefore, social equity concerns seem minor.

Except for the campground, maps do not indicate any public recreation or fishing sites within the reservoir footprint, so impacts on same are presumed minor. The reservoir may flood areas used for hunting.

Loss of tax revenue from inundated properties would be minor because most of the land is tax-advantaged farmland or undeveloped forest. The possibility of tourist facilities oriented to reservoir recreation could provide opportunities for economic development, jobs and increased tax revenue. The loss of production of some 300 acres of farmland would not be expected to burden the community.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level (level 4) cost estimate for construction costs, as detailed in Table 6.1. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) are reported in Table 6.2. This potential project does not require any pumping. Costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail.

The feasibility-level cost estimate (present value) of this project is very high, $1.1B, because of the large size of the dam; land acquisition costs comprise only about 4% at about $40M and operation and maintenance costs would be about $2M/year. The cost effectiveness is $27M/BG, which is second best for new dams, but much larger than for some other potential projects.

Table 6.1: Construction Cost Summary

Description	Unit	Quanity	Rate	Total	Comments
1.0 Dam				**$ 479,406,950**	
1.1 Excavation	CY	1,134,300	$ 20.00	$ 22,686,000	
1.2 Grout Curtain	SF	409,200	$ 110.00	$ 45,012,000	
1.3 Core Material	CY	1,521,400	$ 25.00	$ 38,035,000	Core borrow area near dam site
1.4 Filter Material	CY	100,700	$ 90.00	$ 9,063,000	Imported material
1.5 Dam Shell Material	CY	11,785,800	$ 30.00	$ 353,574,000	Shell borrow area near dam site
1.6 Riprap	CY	51,200	$ 200.00	$ 10,240,000	Improted Material
1.7 Hydroseed	SF	1,593,900	$ 0.50	$ 796,950	
2.0 Spillway				**$ 28,461,600**	
2.1 Excavation	CY	199,700	$ 30.00	$ 5,991,000	
2.2 Spillway Slab	CY	6,500	$ 850.00	$ 5,525,000	
2.3 Spillway Walls	CY	7,400	$ 1,100.00	$ 8,140,000	
2.4 Anchors	EA	2,410	$ 2,500.00	$ 6,025,000	Approx 10' spacing
2.5 Drainage Layer	CY	340	$ 90.00	$ 30,600	Slot trench every 50' of spillway chute
2.6 Drainage Pipes	LF	1,500	$ 100.00	$ 150,000	
2.7 Stilling Basin	CY	2,600	$ 1,000.00	$ 2,600,000	200' long x with 20' additional wall height
3.0 Outlet Works				**$ 10,720,000**	
3.1 Outlet Pipeline and Installation	LF	1,610	$ 2,000.00	$ 3,220,000	
3.2 Outlet Tower and Installation	10' Segment	30	$ 250,000.00	$ 7,500,000	
4.0 Access Roads				**$ 1,200,000**	
4.1 New Roads	Mile	2.0	$ 600,000.00	$ 1,200,000	Estimated from nearby existing road to key project components
5.0 Key Project Components Subtotal				**$ 519,788,550**	
5.1 Sum 1.0 thru 4.0	Subtotal			$ 519,788,550	
6.0 Contractor Allowances				**$ 217,791,402**	
6.1 Environmental Allowance: Rate x 5.0	Rate		2%	$ 10,395,771	
6.2 Materials Testing (QA/QC): Rate x 5.0	Rate		2%	$ 10,395,771	
6.3 Contractor Indirect Costs: Rate x 5.0	Rate		25%	$ 129,947,138	
6.4 Profit: Rate x (5.0 + 6.1 + 6.2 + 6.3)	Rate		10%	$ 67,052,723	
7.0 Contingencies				**$ 331,910,979**	
8.1 Design Contingency: Rate x (5.0 + 6.0)	Rate		25%	$ 184,394,988	
8.2 Construction Contingency: Rate x (5.0 + 6.0)	Rate		20%	$ 147,515,990	
8.0 Conceptual Cost Estimate Total				**$ 1,069,491,000**	
8.1 Sum 5.0 thru 7.0	Total			$ 1,069,490,931	

Table 6.2: Overall Cost Summary

Land acquisition cost ($)	38M
Construction Cost ($)	1070M
Operating Cost ($/yr)	2.1M
Overall Cost (Present value, $)	1150M
Cost effectiveness ($/BG)	27M

The schedule for the project is also very rough. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition. Fifteen years was the typical estimate for a new dam.

- Funding acquisition 5 years
- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup 2 years
- Total 15 years

7 Potential Ancillary Benefits

The major benefit would be a large, public-accessible reservoir suitable for multiple types of recreation. This would be the only such facility in the vicinity, with the New York City reservoirs subject to various restrictions on access and use. Such an amenity may support development of tourist and recreation-oriented businesses, providing jobs and increased tax revenue. The reservoir could also raise the value of surrounding property. The reservoir would create a large lake habitat, while replacing about 10 miles of stream habitat and several small ponds.

Regarding flood control, much of Equinunk Village lies in the floodplain. This dam would provide flood protection to the Village relative to Equinunk Creek, but current risk would remain from the Delaware River and Factory Creek. The dam would not provide significant flood control benefit beyond the Village because its drainage area is very small compared to the Delaware River's at this point.

8 Storage Project Score

This site was scored as described in the main report and summarized in Table 8.1 below for the six primary criteria. Each primary criterion contained subcriteria which were scored on a 1 (worst) to 5 (best) scale and averaged. Scores on the primary criteria were weighted as shown in Table 8.1 and summed to obtain an overall weighted average score. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

Table 8.1: Storage Project Score

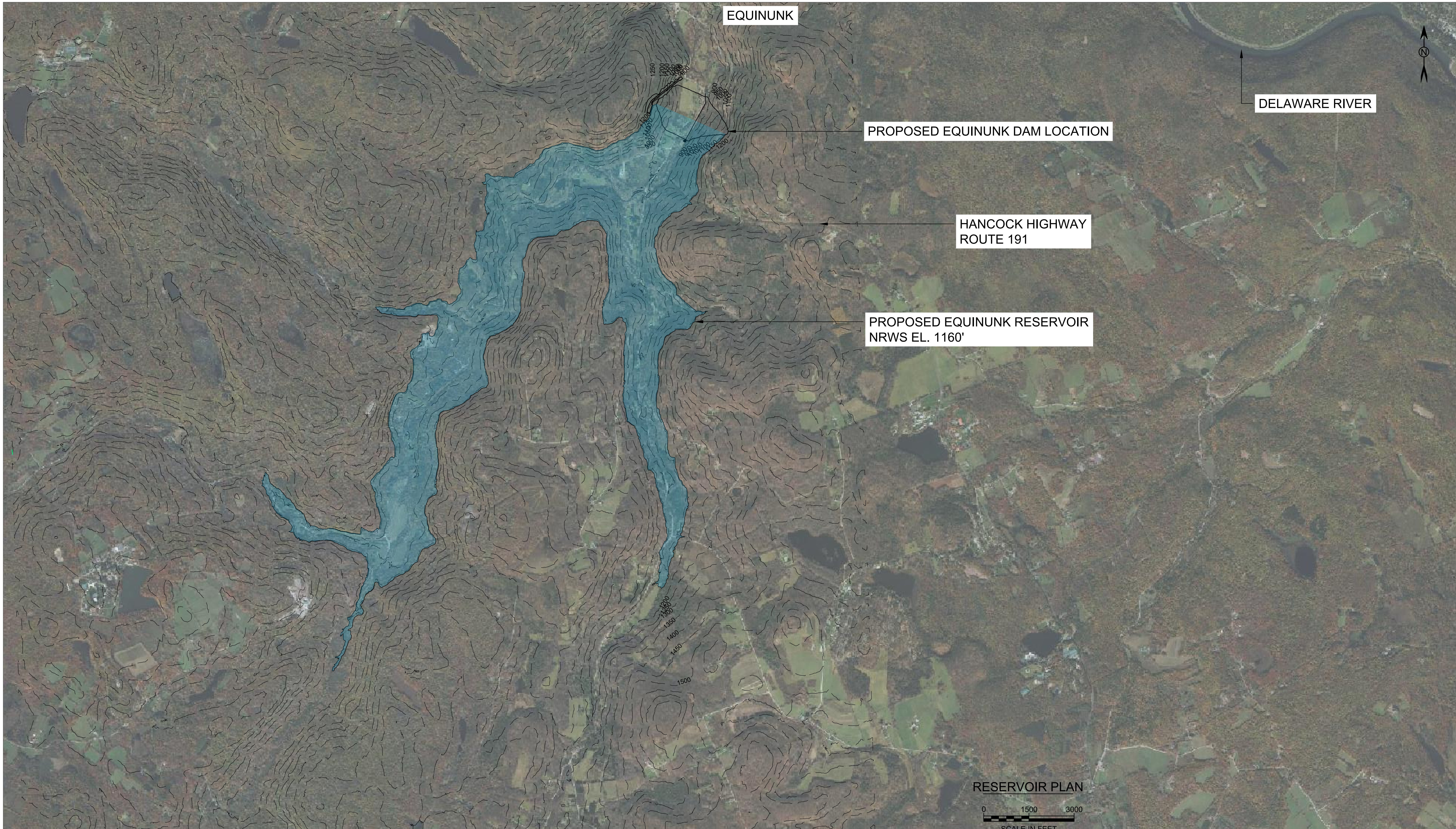
Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.50	30%	1.35
Infrastructure Design, Construction & Operation	2.60	10%	0.26
Environmental Impacts	2.00	15%	0.30
Social & Economic Impacts	3.00	10%	0.30
Project Cost & Schedule	2.33	30%	0.70
Ancillary Benefits	2.40	5%	0.12
AVERAGE	**2.81**		**3.03**

APPENDIX

Score Sheet

Drawings

Six primary criteria	Quantitative Evaluation Metric (when appropriate) (enter values only in ungreyed cells)	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
1. Water quantity and quality		4.50			30%	1.35	
o Volume of storage provided (BG)	42	5					
o Hydrologic reliability of supply (months to fill)	19	3					
o Release rate (cfs)	410	5					
o Promptness of delivery to mainstem (days)	<1	5					
o Geographic benefit		4					Above Montague
o Quality of stored water		5					Mostly forested watershed; good through put
2. Infrastructure design, construction and operation		2.60			10%	0.26	
o Site/Civil, Land & Easements		1					Many properties to acquire
o Subsurface conditions		3					
o Infrastructure Complexity		3					
o Construction complexity		3					
o Operational complexity		3					
3. Environmental impacts		2.00			15%	0.30	
o protected species		2					Bats, Dwarf Wedge Mussel occupied critical habitat
o Water quality degradation of downstream waters		4					Discharges directly to Delware River; little impact likely
o obstruction to passage of aquatic animals		1					Cuts off access to alrge watershed
o hydromodification		4					Discharges directly to Delware River, so little impact likely
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted 5=small, 1=large)			
o wetlands inundated or filled (ac)	172	1	1	1			
o stream length inundated (mi)	10	1	1	1			classified as high quality, cold-water fishery
o uplands inundated or developed (ac)	1250	1	1	1			nearly all forest
4. Social and Economic Impacts		3.00			10%	0.30	
o Disruption/displacement		1					displaced about 100 residences
o Safety and health		3					Small village lies directly downstream
o Social equity/environmental justice		4					
o Recreational loss		4					
o Cultural/historical resources		4					
o Aesthetic		4					
o Loss of tax revenue		3					
o Loss of production from farmland, timberland, quarries		3					
o Emissions of greenhouse gasses		1					Construction of very large dam
5. Project Costs & Schedule		2.33			30%	0.70	
o Land acquisition cost ($)	38.M						
o Construction Cost ($)	1070M						
o Operating Cost ($/yr)	2.1M						
o Overall Cost (Present value, $)	1150M	1					
o Cost effectiveness ($/BG)	27M	3					
o Schedule (Time to make Operational, years)	15	3					
6. Ancillary Benefits		2.40			5%	0.12	
o Flood control		3					
o Recreation/tourism		4					
o Habitat/fishery enhancement		3					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		2.81			100%	3.03	



NOTES:

1. TOPO REFERENCE: ONE THIRD ARC SECOND PUBLISHED ON 2022-04-29 (USGS NATIONAL MAP)

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 01

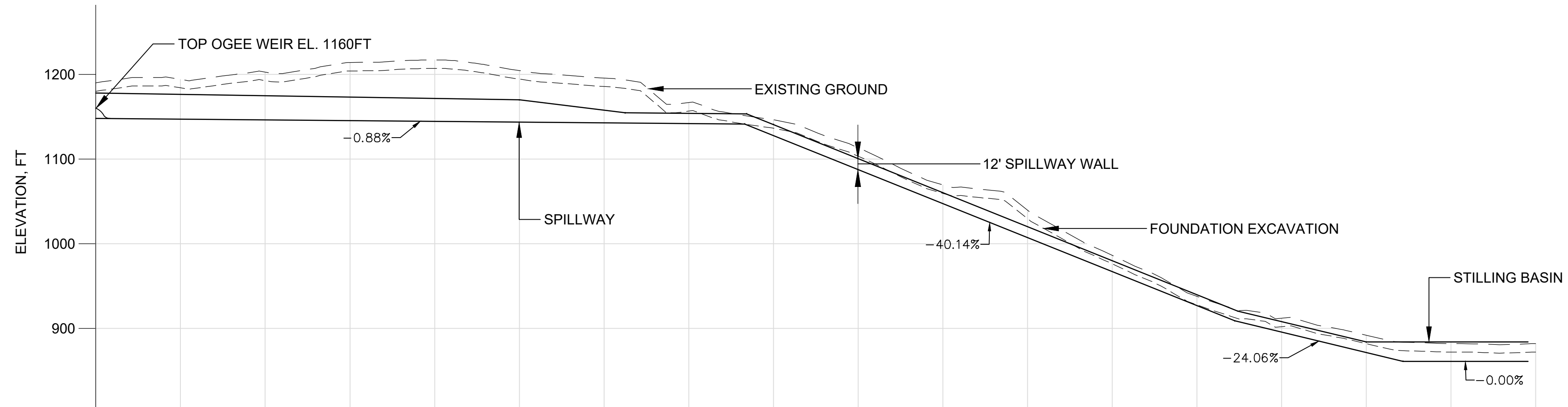
MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

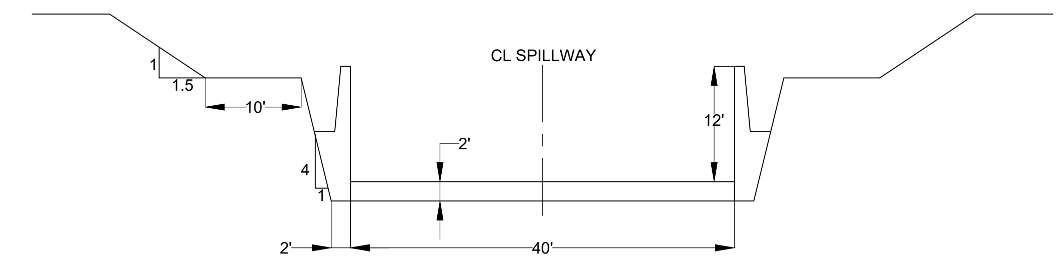
EQUINUNK DAM
FIGURE 01 - GENERAL SITE PLAN

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D EQ_DAM.DWG

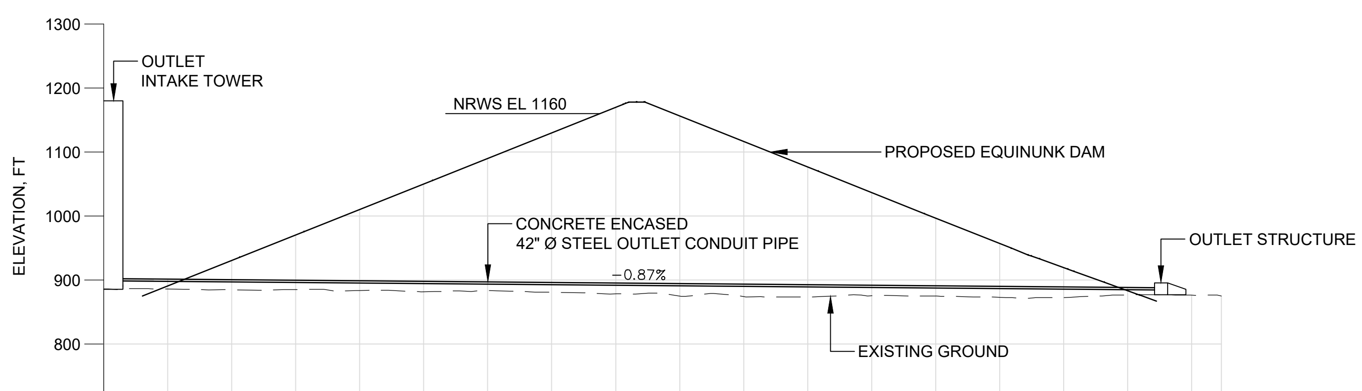


STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00	14+00	15+00	16+00	17+00
SPILLWAY INVERT ELEVATION (ft)	1148.0	1147.1	1146.2	1145.4	1144.5	1143.6	1142.7	1141.8	1127.7	1087.5	1047.4	1007.2	967.1	927.0	895.7	871.6	861.2	

4 – SPILLWAY PROFILE
EQUINUNK DAM SPILLWAY



5 – SPILLWAY SECTION PROFILE
EQUINUNK DAM SPILLWAY SECTION



STATION (ft)		1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00	14+00	15+00	16+00	17+00	
EXISTING GROUND ELEVATION (ft)	885.9	885.9	884.9	885.2	883.7	881.7	883.5	881.1	878.4	874.9	874.3	873.4	875.7	874.9	873.0	872.7	876.8	876.4	875.0

6 – OUTLET CONDUIT PROFILE
EQUINUNK DAM OUTLET CONDUIT

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 03

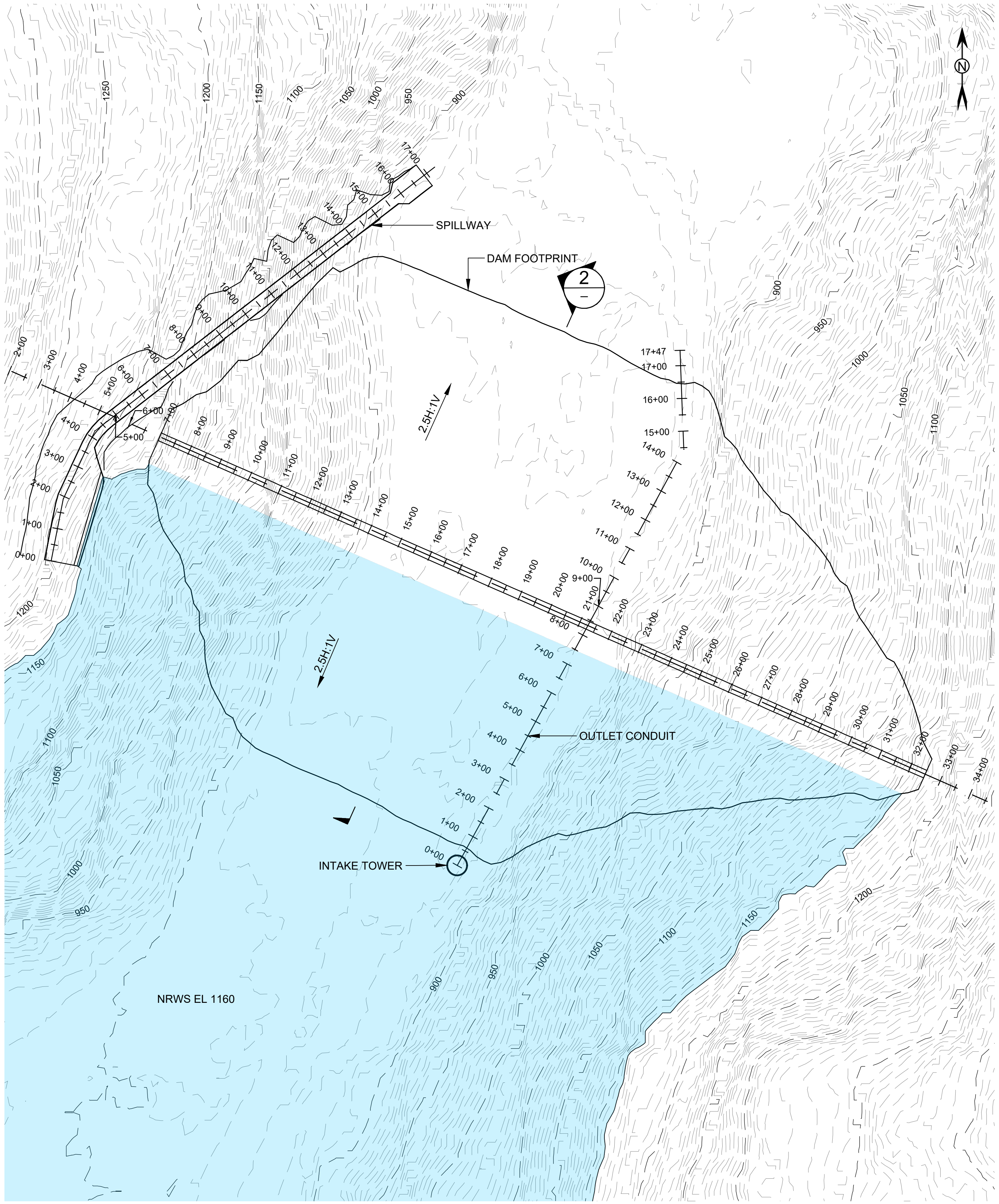
MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

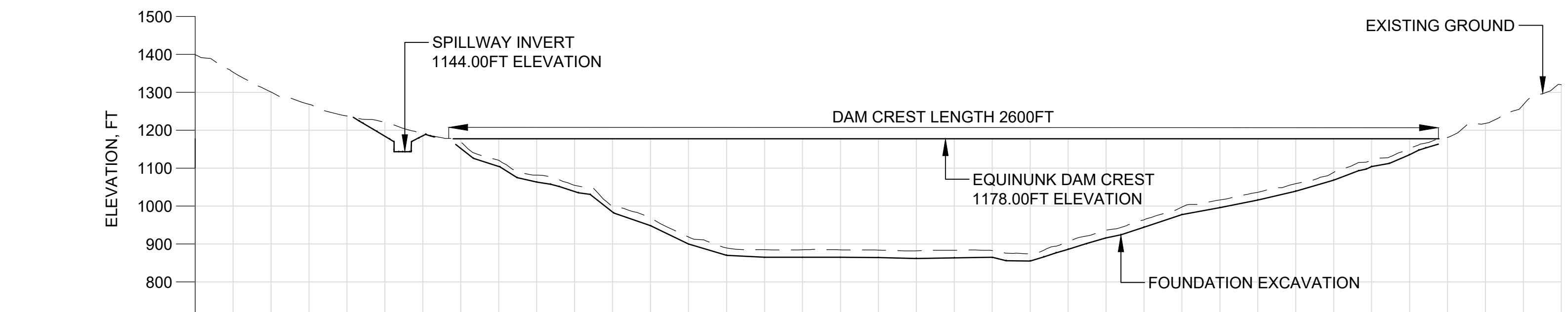
EQUINUNK DAM
FIGURE 03 - OUTLET STRUCTURE

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D EQ_DAM.DWG



PLAN VIEW - EQUINUNK DAM

0 200 400
SCALE IN FEET



STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00
EXISTING GROUND ELEVATION (ft)	1399.5	1353.1	1300.5	1268.4	1237.3	1220.5	1190.8	1168.5	1120.3	1081.5	1055.1	998.6	968.4
CORE TRENCH ELEVATION (ft)								1152.1	1104.8	1063.7	1038.8	984.4	948.4

STATION (ft)	13+00	14+00	15+00	16+00	17+00	18+00	19+00	20+00	21+00	22+00	23+00	24+00
EXISTING GROUND ELEVATION (ft)	918.9	890.1	885.0	885.1	885.1	884.1	882.2	883.8	882.9	875.0	906.3	936.8
CORE TRENCH ELEVATION (ft)	900.0	870.1	865.0	865.0	865.0	864.1	862.2	863.8	864.9	855.0	886.3	916.6

STATION (ft)	25+00	26+00	27+00	28+00	29+00	30+00	31+00	32+00	33+00	34+00	35+00	36+00
EXISTING GROUND ELEVATION (ft)	964.1	997.9	1016.4	1036.4	1059.3	1088.8	1121.2	1150.8	1181.1	1218.2	1267.7	1319.9
CORE TRENCH ELEVATION (ft)	944.1	978.0	996.4	1016.4	1039.3	1068.8	1104.2	1135.6				

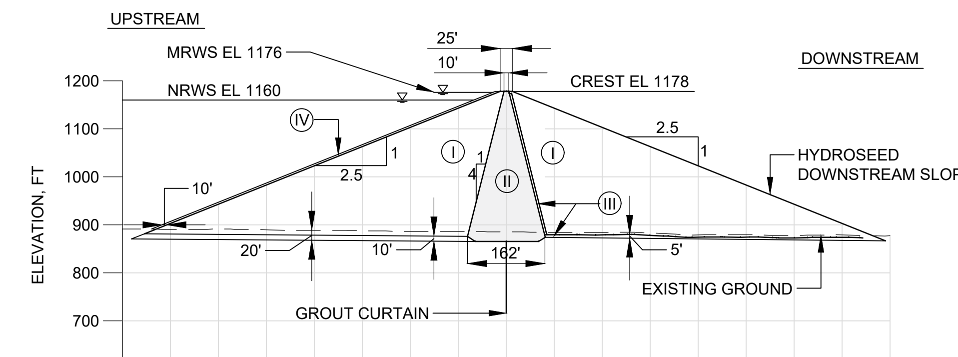
1 SECTION ALONG DAM AXIS

EQUINUNK DAM CENTERLINE

DAM TYPE	MATERIALS
I. SHELL	GENERAL FILL FROM LOCAL BORROW AREA
II. CORE	LOW PERMEABLE CLAY
III. FILTER	HIGH PERMEABLE GRANULAR
IV. RIPRAP EROSION PROTECTION	ROCKFILL BOULDERS

NOTES:

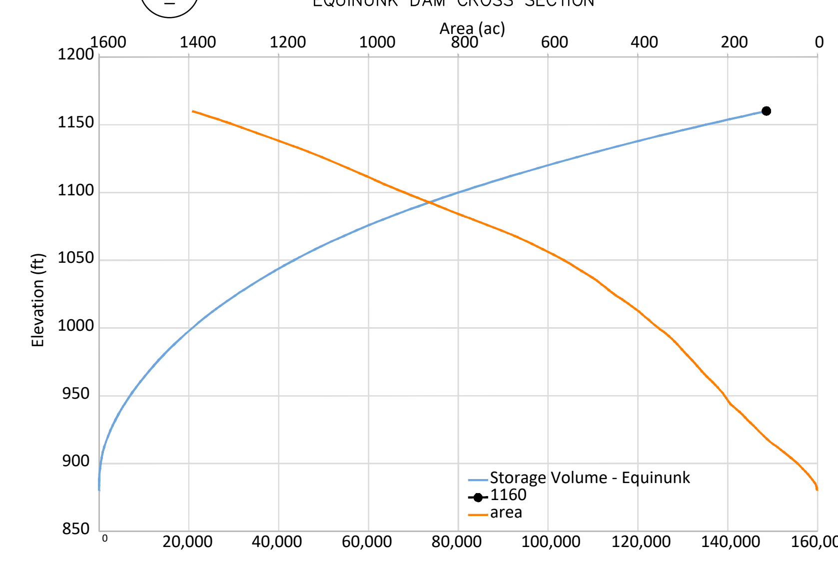
1. MAXIMUM RESERVOIR WATER SURFACE (MRWS)
2. NORMAL RESERVOIR WATER SURFACE (NRWS)



OFFSET (ft)	-8+00	-7+00	-6+00	-5+00	-4+00	-3+00	-2+00	-1+00	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00
EXISTING GROUND ELEVATION (ft)	891.3	890.5	891.6	889.4	888.3	887.6	885.9	885.9	885.1	884.1	884.1	882.8	879.2	879.2	877.7	878.9	876.9

2 MAXIMUM DAM SECTION (STA 17+00)

EQUINUNK DAM CROSS SECTION



3 STAGE STORAGE AND AREA-STORAGE CURVE

EQUINUNK DAM STORAGE AREA VOLUME

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 02

MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

EQUINUNK DAM
FIGURE 02 - PROFILE VIEWS

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D EQ_DAM.DWG

Storage Project Summary

Project:	**Hawley Reservoir (N6)**
Location:	near Hawley, Wayne County, PA
Storage Type:	New reservoir
Est. Volume:	1.3 BG
Weighted Score:	2.87

1 Project Overview

The location of the potential dam and reservoir is on Middle Creek near Hawley, Wayne County, PA, about a mile above the confluence with the Lackawaxen River (Figure 1.1). The dam's watershed is fairly large at about 82 sq. mi., mostly forested with some farmland (Figure 1.2 and 1.3).

The dam would be a conventional earthen embankment dam as described in the Section 5.2 of the main report. At a height of 118 ft and length of 1,400 ft, this dam would be smaller than the others studied (except Rattling Run), creating a reservoir covering 273 ac at normal pool and providing 1.3 BG of storage (Figure1.4).

While this small volume means Middle Creek could fill/refill the reservoir in only a month, it also means the reservoir could provide the desired level of augmentation (i. e., 100 cfs) for only 20 days.

The land within the reservoir footprint is almost completely forested. The reservoir would flood approximately six residential properties, a summer camp and about 2 miles of roads. It would flood about 3.5 miles of Middle Creek and short stretches of minor tributaries; all are rated by the State for cold water fishes but not specifically trout-designated. Four small ponds would also be flooded.

The project sits in the Lackawaxen watershed with a travel distance of about 20 miles to the Delaware River, taking less than a day. Entering the mainstem above Montague, a long section of the Delaware River would benefit from flow augmentation.

A dam at Hawley was mentioned in the 1981 Level B report but no maps, drawings or dimensions of the dam were stated. The project was selected for detailed evaluation here due to its limited impact on roads and buildings.

The rough cost estimate (present value) of this potential project is $189M, with land acquisition costs of $4M, construction costs of $178M and annual costs of $0.4M. The cost effectiveness is $145M/BG, which is very poor compared to other potential projects.

Our rough estimate is that it would take about 15 years to put this project into operation. However, this might be extended for many years if complications are encountered.

Figure 1.1: Project location

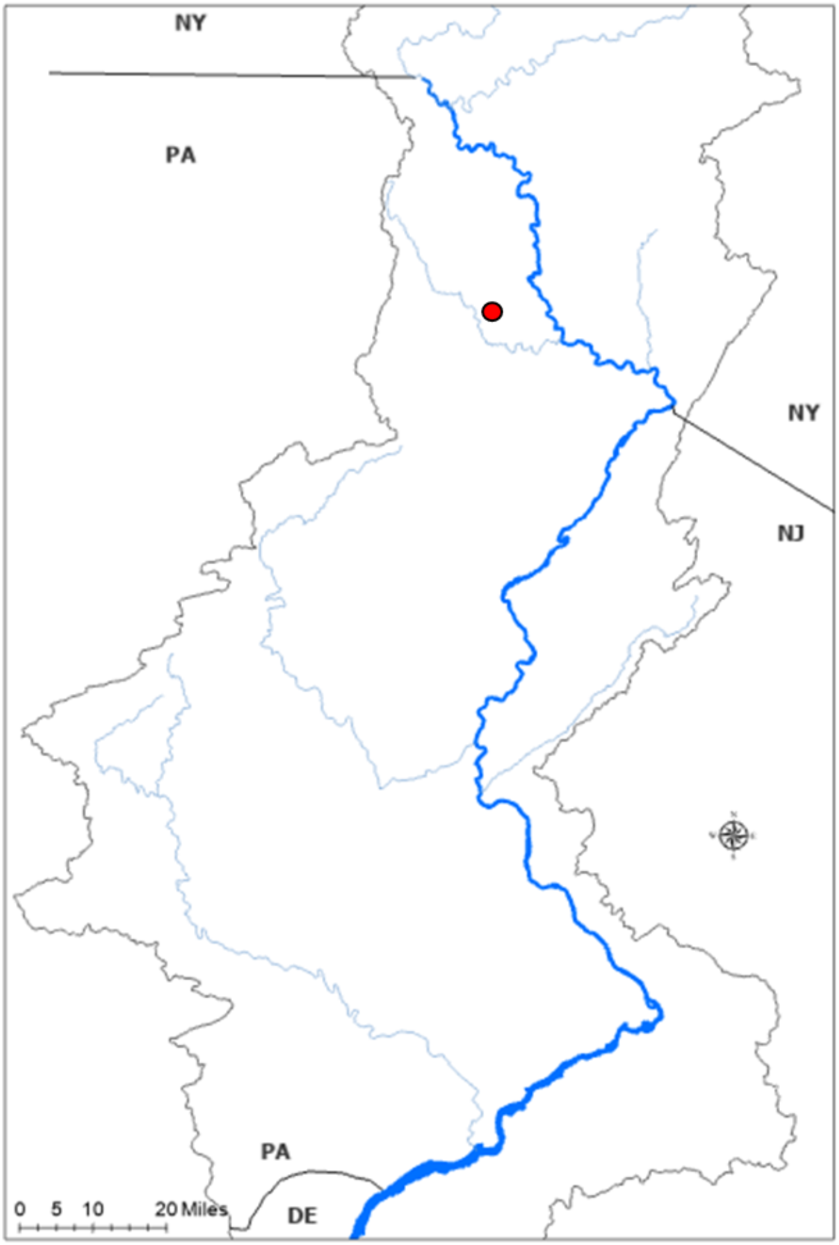


Figure 1.2: Topographic map: Drainage area in red (82 sq miles). Reservoir outline in purple.

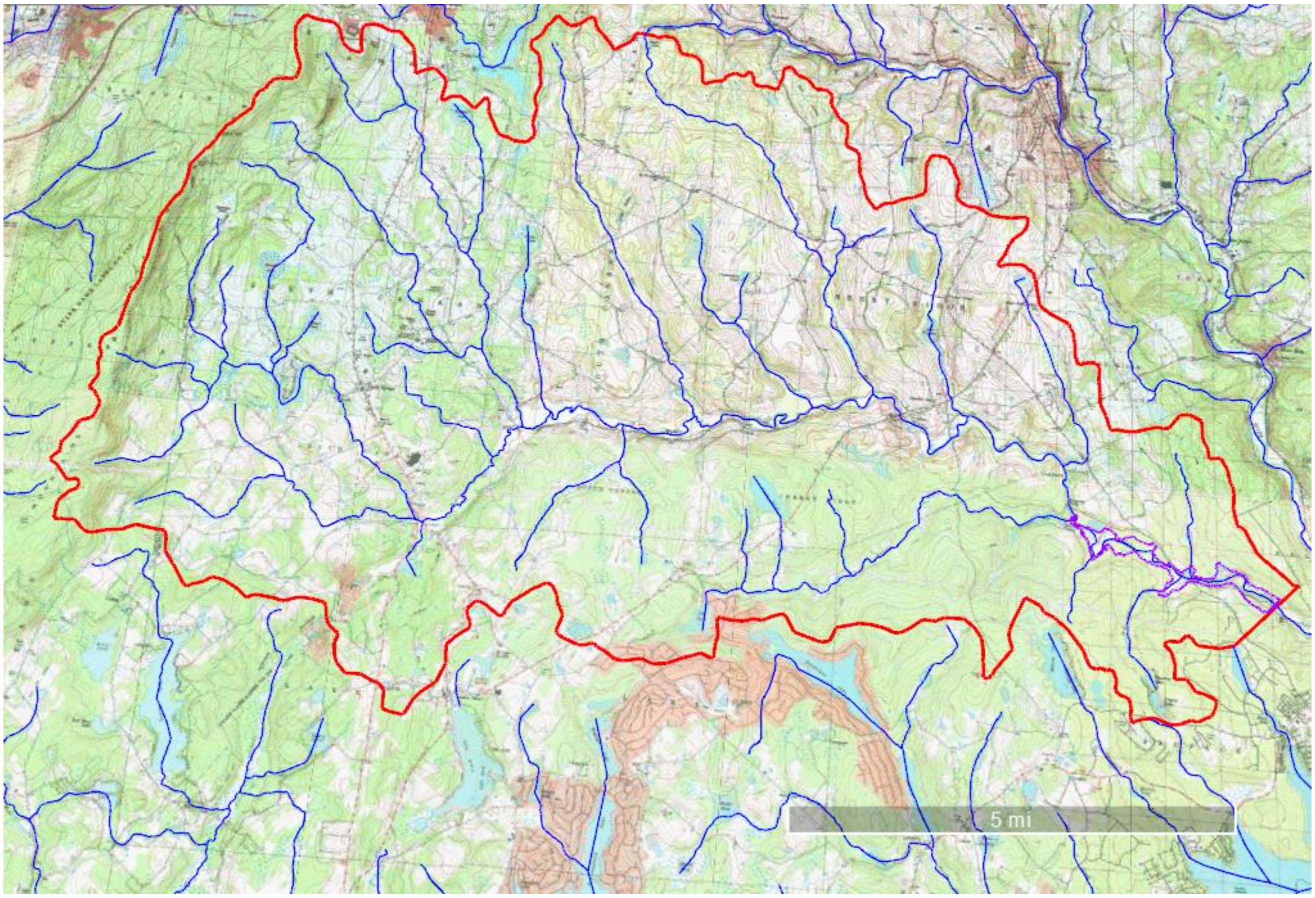


Figure 1.3: Aerial photo: Drainage area in red (82 sq miles). Reservoir outline in purple.

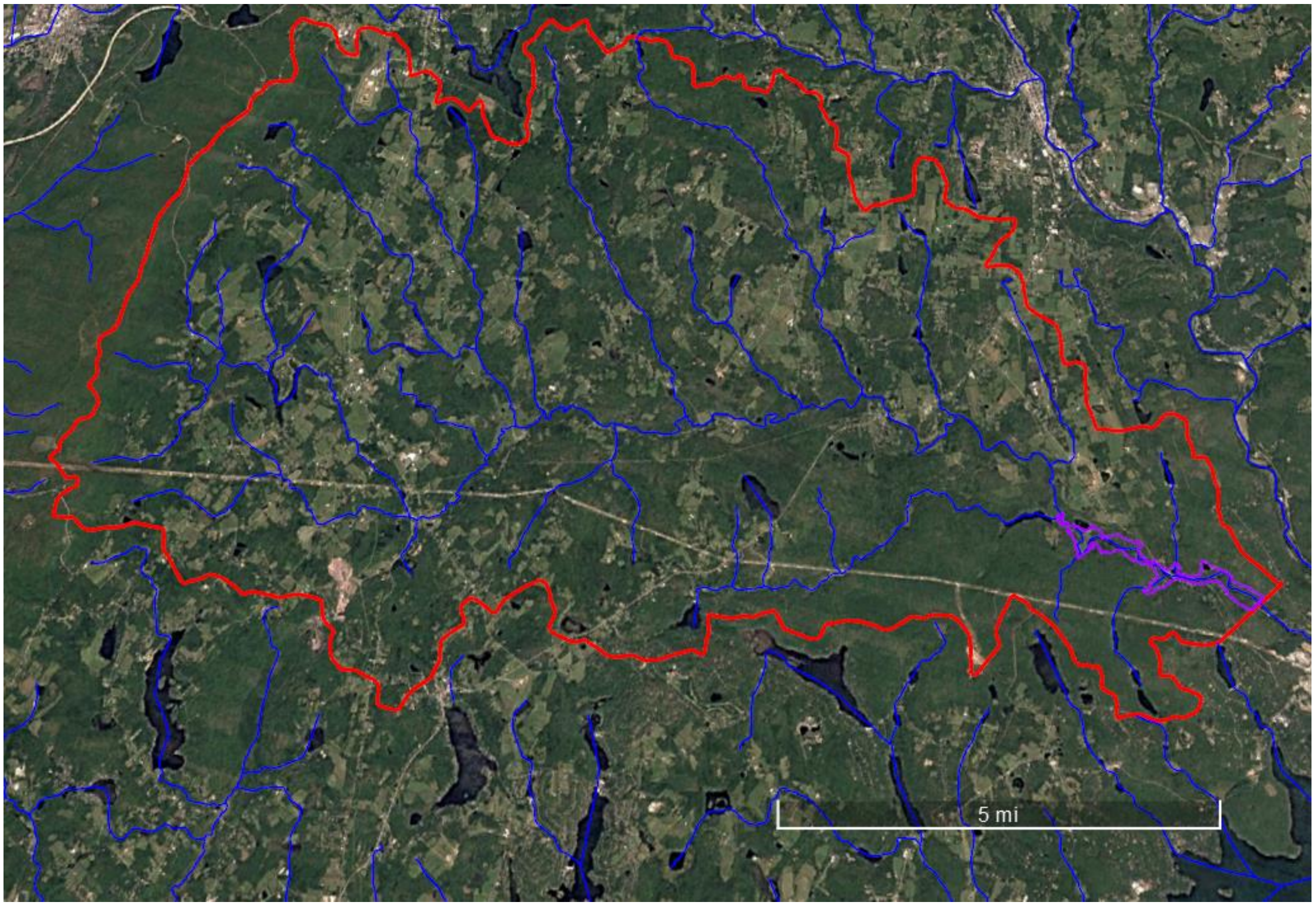
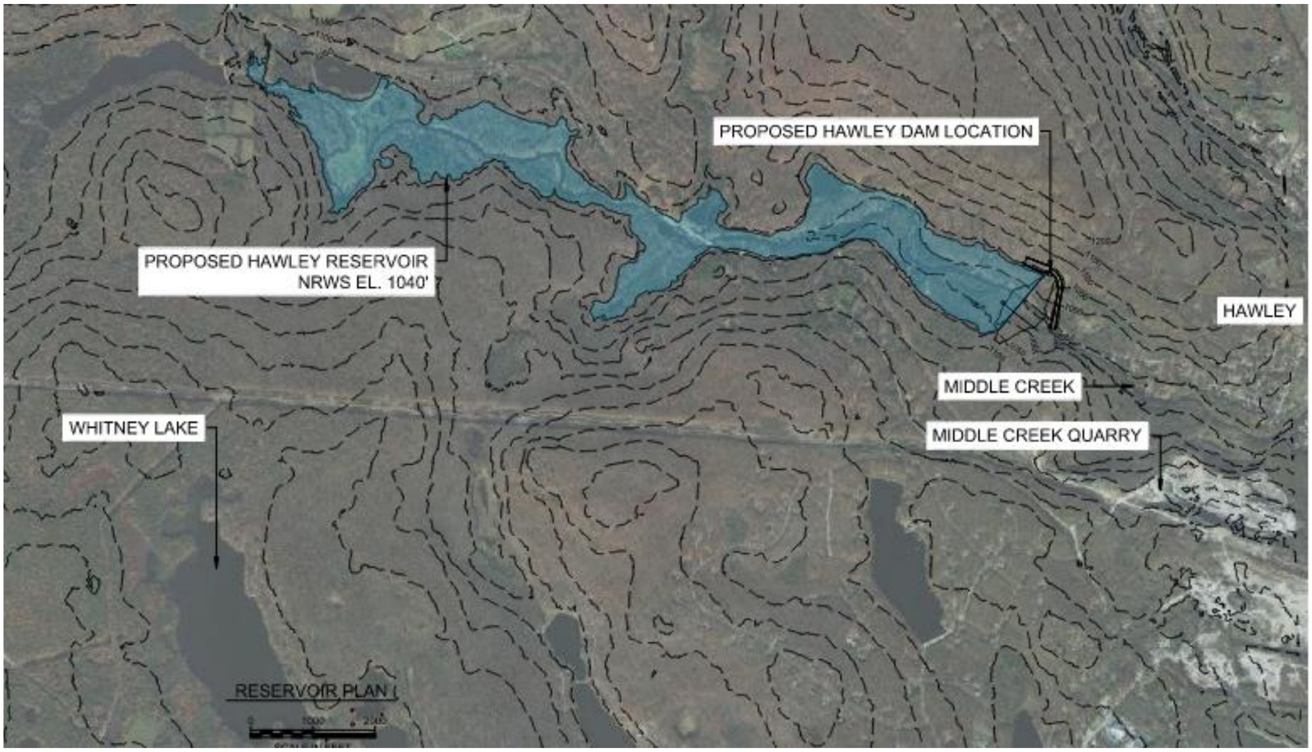


Figure 1.4: Project Schematic



2 Water Quantity & Quality

Key parameters of the potential dams and reservoir are listed in Table 2.1 below. Detailed drawings are presented in the Appendix.

At a height of 118 ft and length of 1,400 ft, this dam would be smaller than the others studied (except Rattling Run), creating a reservoir covering 273 ac at normal pool and providing 1.3 BG of storage.

Table 2.1: Dam and Reservoir Parameters

DAM	
LAT/LONG	41.4794, -75.0669
SIZE CATEGORY	B – LESS THAN 100 FT BUT GREATER THAN 40 FT; LESS THAN 50,000 AC-FT BUT GREATER THAN 1,000 AC-FT
HAZARD POTENTIAL	1 – SUBSTANTIAL (NUMEROUS HOMES OR SMALL BUSINESSES OR A LARGE BUSINESS OR SCHOOL)
Dam Type	Earthen Dam with Clay Core
Dam Crest El	1068 ft
Dam Height	118 ft
Dam Crest Length	1,400 ft
Dam Crest Width	25 ft
Dam Slope Inclination	2.5h:1v Upstream 2.5h:1v Downstream
Saddle Dam	None
RESERVOIR	
Normal Reservoir Water Surface (NRWS)	1040 ft
Maximum Reservoir Water Surface at PMF(MRWS)	1066 ft
STORAGE CAPACITY AT NRWS	1.3 BG / 4,500 AC-FT
Reservoir Area at NRWS	273 ac
Reservoir Area at MRWS	578 ac
Reservoir Area Footprint (MRWS + 50 ft Buffer)	653 ac
FREEBOARD AT NRWS	28 FT
Freeboard at MRWS	2 ft
Drainage Area	82 sq mi
SPILLWAY	
Spillway Type	Concrete lined, ungated, ogee crest, “L” shaped side-channel
SPILLWAY CREST EL	1040 FT
Peak Discharge	138,730 cfs
OUTLET	
Outlet Works Type	Outlet Tower
OUTLET WORKS CONDUIT	42-INCH STEEL PIPE
Outlet Elevation	971 ft
Conduit Length	680 ft
REQUIRED FLOW (70% HMMI + 2 FT DEPTH)	226 CFS

2.1 Fill and Discharge

With a sizeable watershed of 82 sq. mi and mean flow of 145 cfs, Middle Creek could fill/refill the modest volume of 1.3 BG quickly, in less than a month.

Water would be released by gravity, so a large release could be readily achieved through the 42-inch low-level outlet pipe, over 300 cfs at the NRWS. A stilling basin would be required and was included in the design.

The small volume means it could provide the desired 100 cfs of augmentation for only 20 days.

2.2 Water Quality

Middle Creek was assessed by the PADEP in the 2022 integrated report as supporting aquatic life use; other uses were not assessed. With a mostly forested watershed, water quality entering the reservoir should be good. Expected low inputs of nutrients and good flushing, eutrophication is not expected to be a serious problem. The water quality in the reservoir should be satisfactory for augmenting flow.

3 Infrastructure Design, Construction & Operation

As detailed in the main report, conceptual designs were developed in general accordance with the Pennsylvania Code Title 25, Chapter 105, Dam Safety and Water Management. Detailed parameters are given in Table 2.1. The dam and spillway were designed to pass the "probable maximum flood" (PMF), which was estimated as described in Section 5.2 of the main report. No saddle dam or pumps are needed here. Freeboard was assumed to be 2 feet above the MRWS elevation.

An intake tower was conceptually designed with associated controls, piping, and valves housed within the tower. A 42", concrete-encased, steel pipe travels through the dam connecting the intake tower to an outlet structure where water releases are to be made. The outlet capacity at NRWS greatly exceeds the required capacity.

Site access consisting of roads to key dam facilities has not been developed into the designs. An estimated allowance has been included in the cost estimate for project roads.

4 Environmental Impacts

Nearly all the reservoir footprint is forested with second growth deciduous trees with sporadic coniferous tree growth. It would flood about 3.5 miles of Middle Creek, including side and abandoned channels, plus small lengths of several tributaries. Middle Creek is categorized as a High-Quality Cold-Water Fishery (HQ-CWF) by Chapter 93. Neither Middle Creek, nor any of the tributaries have been assigned a natural trout population category by the PAFBC. Four small ponds would also be flooded.

At least 128 acres of wetlands would be flooded consisting of open water ponds, and emergent, shrubby and forested swamps. Most of these wetlands are associated with Middle Creek. Wetlands are also present on some tributaries, likely the result of groundwater discharge.

According to iPaC, two species of bats may be present at this impoundment location, the Indiana bat (IB) and the Northern longeared bat (NLEB). Forest cover includes mature trees, ponds, wet meadows—all habitat for the Indiana Bat. The forested areas may be too sparse and discontinuous for the area to serve as optimal NLEB habitat. Field investigates are needed.

The Reservoir would have significant wetland impacts that would need to be mitigated, and the wetland types (forested swamp and shrub swamp) are difficult to replace. Though it is not an EV or trout stream, Middle Creek is a High-Quality Cold-Water Fishery and will require significant mitigation to replace it.

5 Social and Economic Impacts

The reservoir site is currently rural, comprised mainly of forest with only about six residences. A summer camp would also be flooded. Given the abundance of undeveloped land, displaced residences and the camp could possibly be relocated near their current location.

About 2 miles of roads would be flooded. Alternative through routes are available within a short distance. A short section of a major road, the Owego Turnpike, would be flooded where it currently crosses Middle Creek. This road would need to rerouted onto existing roads, requiring upgrades, or the current bridge would need to be replaced. This replacement was not included in the cost estimate. A power line also crosses the reservoir footprint.

Regarding risk to safety of downstream residents, with modern construction technologies and monitoring, the risk of a dam failure would be low. The borough of Hawley (population 1200 in 2010) lies about ½ mile downstream. Because this dam and reservoir are significantly smaller than the others studied, the risk and perception thereof would likely be less.

The demographics of Hawley as reported in the 2010 census are not dominated by historically oppressed groups. Nor is there any indication that this area has been highly burdened in the past with undesirable facilities. Therefore, social equity concerns seem minor.

Maps do not indicate any public recreation or fishing sites within the reservoir footprint, with the exception of the summer camp.

Loss of tax revenue from inundated properties would be minor because most of the land is tax-advantaged farmland or undeveloped forest.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level (level 4) cost estimate for construction costs, as detailed in Table 6.1. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) are reported in Table 6.2. Methods are described in the main report. Costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail. This project does not require any pumping.

Combining capital and annual costs, the present value of this project is $189M, with land acquisition costs of $4M, construction costs of $178M and annual costs of $0.4M. The cost effectiveness is $145M/BG, which is very poor compared to other potential projects.

Table 6.1: Construction Cost Summary

Description	Unit	Quanity	Rate	Total	Comments
1.0 Dam				**$ 48,185,550**	
1.1 Excavation	CY	224,500	$ 20.00	$ 4,490,000	
1.2 Grout Curtain	SF	91,900	$ 110.00	$ 10,109,000	
1.3 Core Material	CY	143,000	$ 25.00	$ 3,575,000	Core borrow area near dam site
1.4 Filter Material	CY	19,400	$ 90.00	$ 1,746,000	Imported material
1.5 Dam Shell Material	CY	863,500	$ 30.00	$ 25,905,000	Shell borrow area near dam site
1.6 Riprap	CY	11,100	$ 200.00	$ 2,220,000	Improted Material
1.7 Hydroseed	SF	281,100	$ 0.50	$ 140,550	
2.0 Spillway				**$ 33,264,200**	
2.1 Excavation	CY	122,600	$ 30.00	$ 3,678,000	
2.2 Spillway Slab	CY	8,300	$ 850.00	$ 7,055,000	
2.3 Spillway Walls	CY	11,200	$ 1,100.00	$ 12,320,000	
2.4 Anchors	EA	2,690	$ 2,500.00	$ 6,725,000	Approx 10' spacing
2.5 Drainage Layer	CY	380	$ 90.00	$ 34,200	Slot trench every 50' of spillway chute
2.6 Drainage Pipes	LF	1,520	$ 100.00	$ 152,000	
2.7 Stilling Basin	CY	3,300	$ 1,000.00	$ 3,300,000	200' long x with 20' additional wall height
3.0 Outlet Works				**$ 4,360,000**	
3.1 Outlet Pipeline and Installation	LF	680	$ 2,000.00	$ 1,360,000	
3.2 Outlet Tower and Installation	10' Segment	12	$ 250,000.00	$ 3,000,000	
4.0 Access Roads				**$ 900,000**	
4.1 New Roads	Mile	1.5	$ 600,000.00	$ 900,000	Estimated from nearby existing road to key project components
5.0 Key Project Components Subtotal				**$ 86,709,750**	
5.1 Sum 1.0 thru 4.0	Subtotal			$ 86,709,750	
6.0 Contractor Allowances				**$ 36,331,385**	
6.1 Environmental Allowance: Rate x 5.0	Rate		2%	$ 1,734,195	
6.2 Materials Testing (QA/QC): Rate x 5.0	Rate		2%	$ 1,734,195	
6.3 Contractor Indirect Costs: Rate x 5.0	Rate		25%	$ 21,677,438	
6.4 Profit: Rate x (5.0 + 6.1 + 6.2 + 6.3)	Rate		10%	$ 11,185,558	
7.0 Contingencies				**$ 55,368,511**	
8.1 Design Contingency: Rate x (5.0 + 6.0)	Rate		25%	$ 30,760,284	
8.2 Construction Contingency: Rate x (5.0 + 6.0)	Rate		20%	$ 24,608,227	
8.0 Conceptual Cost Estimate Total				**$ 178,410,000**	
8.1 Sum 5.0 thru 7.0	Total			$ 178,409,646	

Table 6.2: Overall Cost Summary

Land acquisition cost ($)	4M
Construction Cost ($)	178M
Operating Cost ($/yr)	.4M
Overall Cost (Present value, $)	189M
Cost effectiveness ($/BG)	145M

The schedule for the project is also very rough. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition. Our best guess given our expectations appears below. Fifteen years was the typical estimate for a new dam.

- Funding acquisition 5 years
- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup 2 years
- Total 15 years

7 Potential Ancillary Benefits

A public-accessible reservoir would be beneficial. (Although Lake Wallenpaupack is very close, much of the shoreline is privately owned and its very large size attracts different uses). The reservoir could also raise the value of surrounding property.

The reservoir would create a large lake habitat while replacing a stream habitat. If a release is necessary, the flow into the reservoir would refill it in short order under normal conditions, but the release is likely to occur during drought, so the refill time could be much longer.

Regarding flood control, this reservoir would not provide significant benefit because of its small size relative to its watershed.

8 Storage Project Score

This site was scored relative as described in the main report and summarized in Table 8.1 for below for the six primary criteria. Each primary criterion contained subcriteria which were scored on a 1 (worst) to 5 (best) scale and averaged. Scores on the primary criteria were weighted as shown in Table 8.1 and summed to obtain and overall weighted average score. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

Table 8.1: Storage Project Score

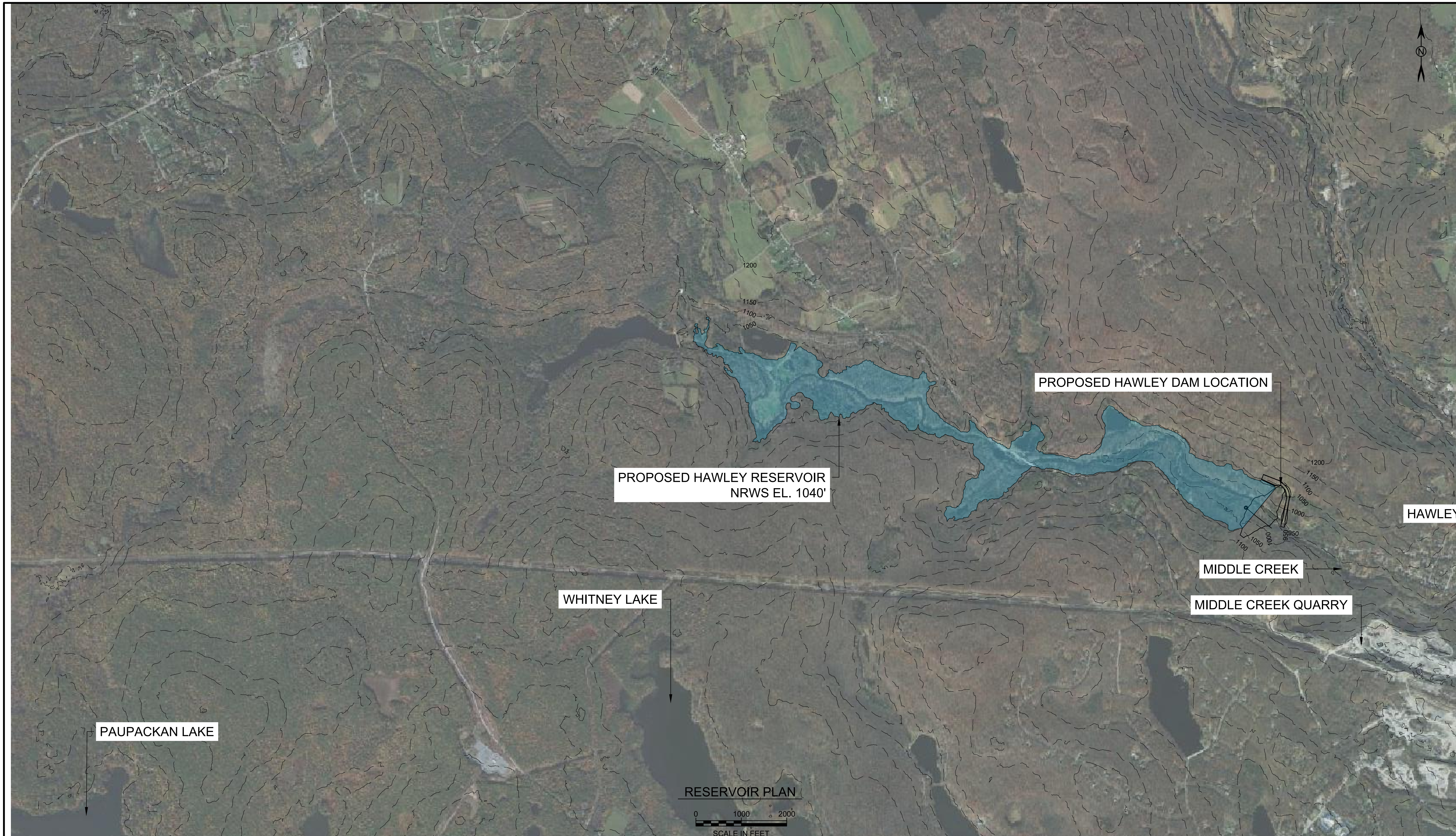
Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.17	30%	1.25
Infrastructure Design, Construction & Operation	2.80	10%	0.28
Environmental Impacts	2.18	15%	0.33
Social & Economic Impacts	3.33	10%	0.33
Project Cost & Schedule	2.00	30%	0.60
Ancillary Benefits	1.60	5%	0.08
AVERAGE	**2.68**		**2.87**

APPENDIX

Score Sheet

Drawings

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate)	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
	(enter values only in ungreyed cells)						
1. Water quantity and quality		4.17			30%	1.25	
o Volume of storage provided (BG)	1.3	2					
o Hydrologic reliability of supply (months to fill)	0.5	5					
o Release rate (cfs)	300	5					
o Promptness of delivery to mainstem (days)	<1	5					
o Geographic benefit		4					Above Montague
o Quality of stored water		4					
2. Infrastructure design, construction and operation		2.80			10%	0.28	
o Site/Civil, Land & Easements		2					Fewer land owners then other dam sites
o Subsurface conditions		3					
o Infrastructure Complexity		3					
o Construction complexity		3					
o Operational complexity		3					
3. Environmental impacts		2.18			15%	0.33	
o protected species		3					Habitat for bats; no known occurrence or hibernacula within 50 mile
o Water quality degradation of downstream waters		3					Small dam;
o obstruction to passage of aquatic animals		1					Much lost connectivity to upstream areas
o hydromodification		4					Large upstream watershed will affect downstream waters
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted 5=small, 1=large)			
o wetlands inundated or filled (ac)	128	1.25	1.5	1			
o stream length inundated (mi)	4	1.5	2	1			
o uplands inundated or developed (ac)	145	1.5	2	1			Dense forest
4. Social and Economic Impacts		3.33			10%	0.33	
o Disruption/displacement		2					Less displacement than other new dams
o Safety and health		3					Town of Hawly downstream
o Social equity		4					
o Recreational loss		3					Loss of 4 miles of fishing
o Cultural/historical resources		3					Summer camp displaced
o Aesthetic		4					
o Loss of tax revenue		4					
o Loss of production from farmland, timberland, quarries		4					Smaller footrpint than largest dams
o Emissions of greenhouse gasses		3					
5. Project Costs & Schedule		2.00			30%	0.60	
o Land acquisition cost ($)	4.M						Few buildings
o Construction Cost ($)	178M						
o Operating Cost ($/yr)	0.4M						
o Overall Cost (Present value, $)	189M	2					
o Cost effectiveness ($/BG)	145M	1					
o Schedule (Time to make Operational, years)	15	3					Assuming no endangered species impacts
6. Ancillary Benefits		1.60			5%	0.08	
o Flood control		2					Small dam; little benefit
o Recreation/tourism		2					Already a large lake nearby
o Habitat/fishery enhancement		2					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		2.68			100%	2.87	



NOTES:
1. TOPO REFERENCE: ONE THIRD ARC SECOND PUBLISHED ON 2022-04-29 (USGS NATIONAL MAP)

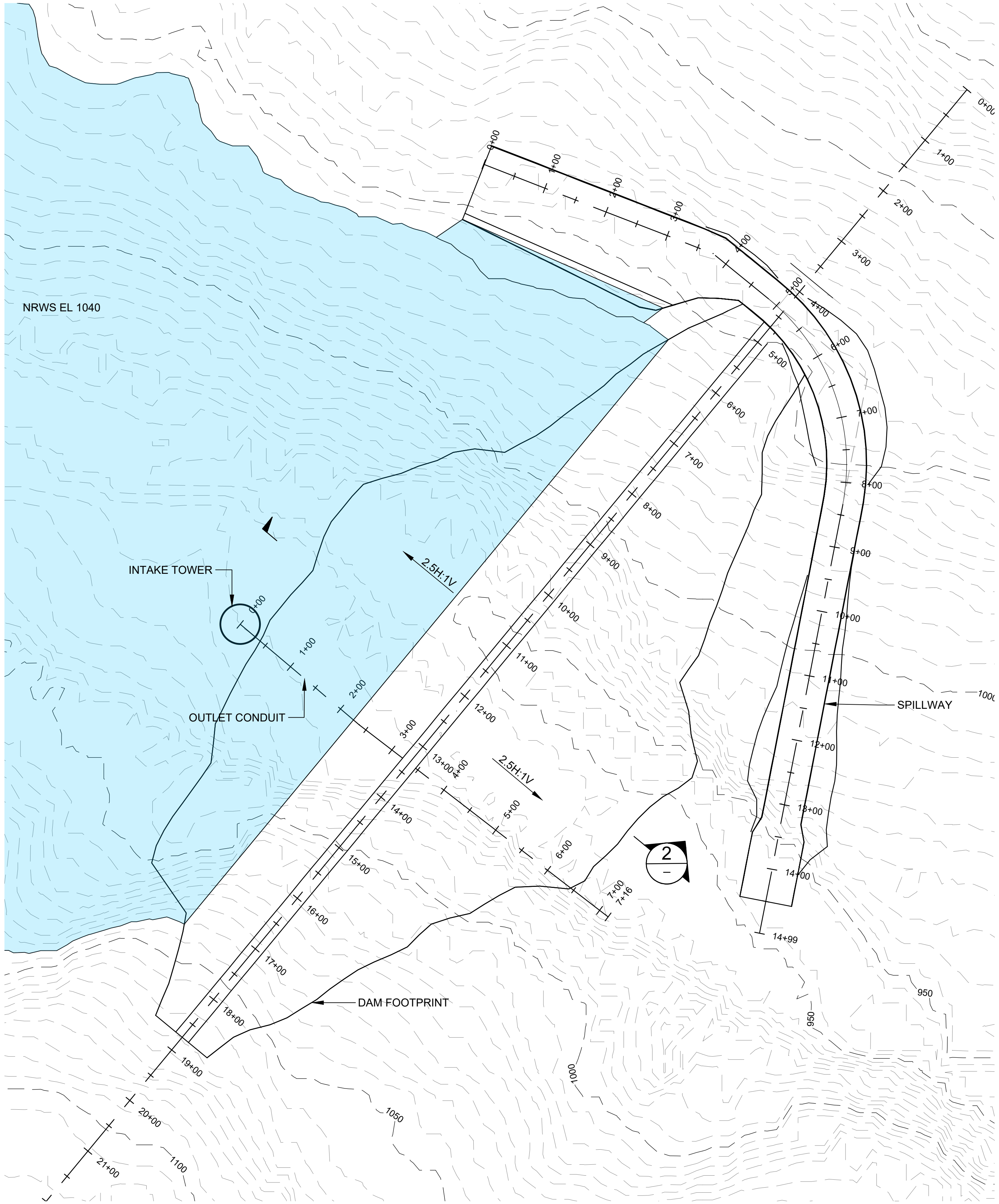
Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 01

MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

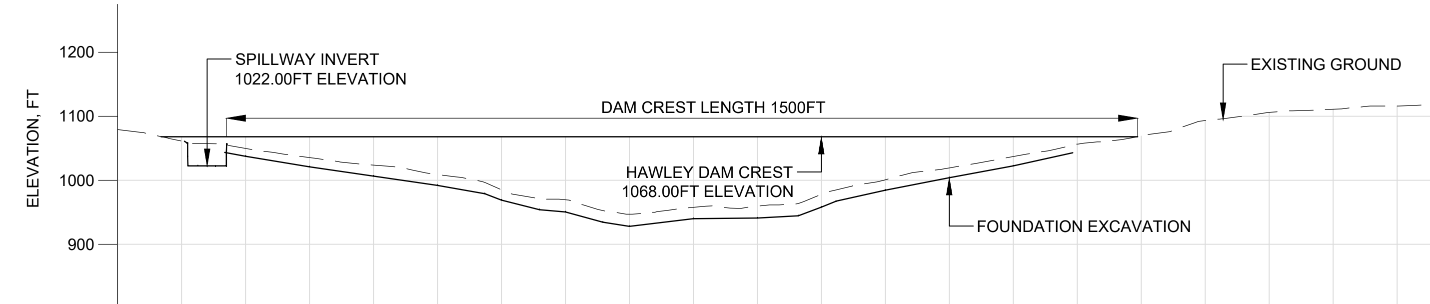
DELAWARE RIVER BASIN STORAGE STUDY

HAWLEY DAM
FIGURE 01 - GENERAL SITE PLAN



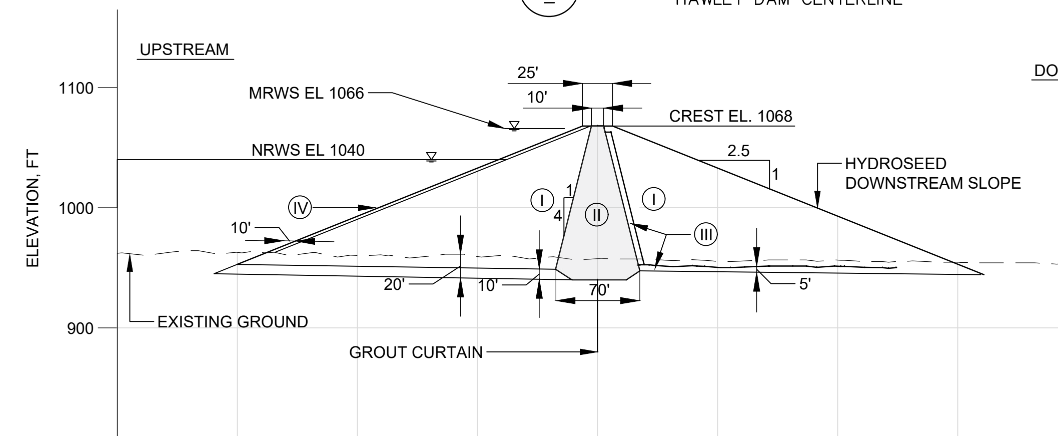
PLAN VIEW - HAWLEY DAM

0 100' 200'
SCALE IN FEET



STATION (ft)	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00	14+00	15+00	16+00	17+00	18+00	19+00	20+00	21+00	22+00	23+00	24+00
EXISTING GROUND ELEVATION (ft)	1079.3	1061.1	1049.8	1035.2	1023.4	1008.9	985.1	969.4	946.9	957.7	959.6	977.9	1000.8	1019.2	1037.0	1056.4	1069.0	1093.1	1105.9	1110.9	1115.9	1118.0
CORE TRENCH ELEVATION (ft)			1037.5	1020.9	1006.6	992.0	968.9	950.5	928.0	940.0	941.1	957.9	984.7	1004.0	1022.6							

1 SECTION ALONG DAM AXIS
HAWLEY DAM CENTERLINE

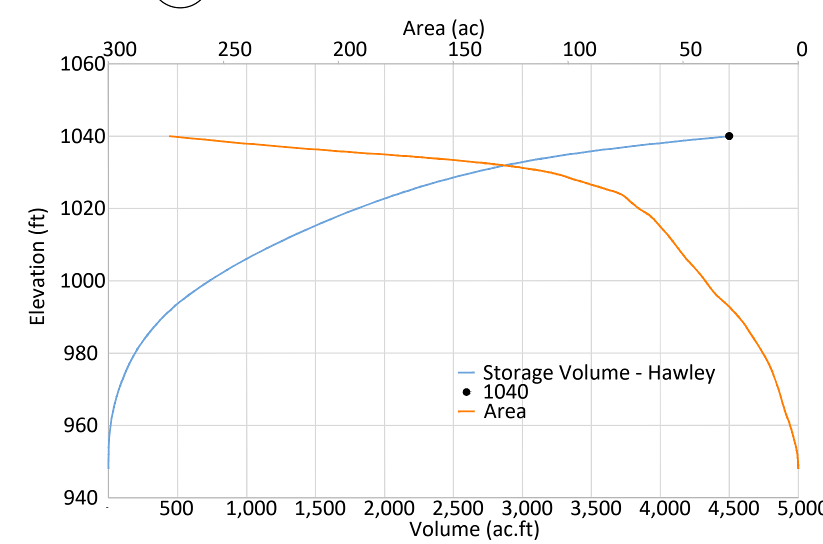


OFFSET (ft)	-4+00	-3+00	-2+00	-1+00	0+00	1+00	2+00	3+00	4+00
EXISTING GROUND ELEVATION (ft)	962.1	962.9	960.3	959.5	957.7	955.4	956.4	954.6	953.6

2 MAXIMUM DAM SECTION (STA 12+00)
HAWLEY DAM CROSS SECTION

DAM TYPE	MATERIALS
I. SHELL	GENERALL FILL FROM LOCAL BORROW AREA
II. CORE	LOW PERMEABLE CLAY
III. FILTER	HIGH PERMEABLE GRANULAR
IV. RIPRAP EROSION PROTECTION	ROCKFILL BOULDERS

NOTES:
1. MAXIMUM RESERVOIR WATER SURFACE (MRWS)
2. NORMAL RESERVOIR WATER SURFACE (NRWS)



3 STAGE STORAGE AND AREA-STORAGE CURVE
HAWLEY DAM STORAGE AREA VOLUME

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 02

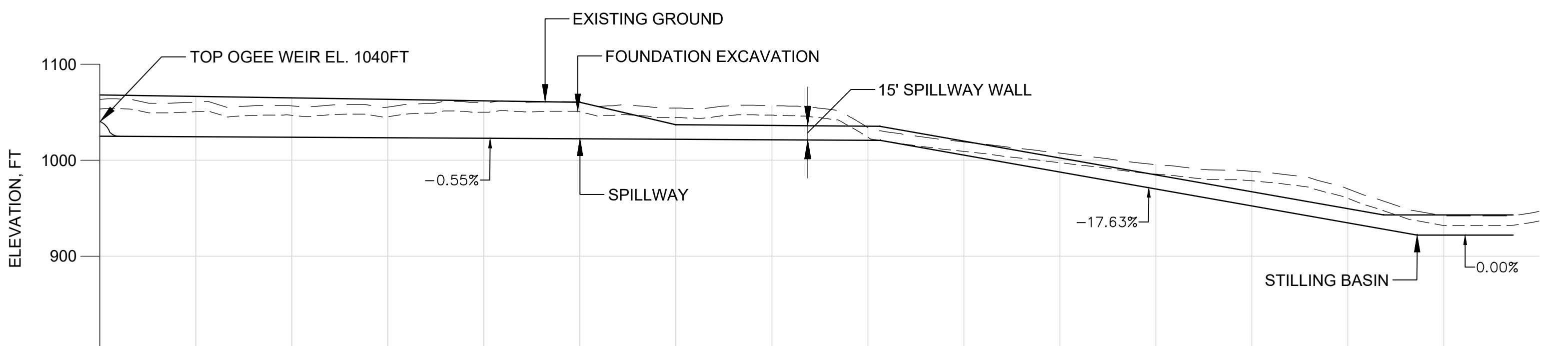
MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

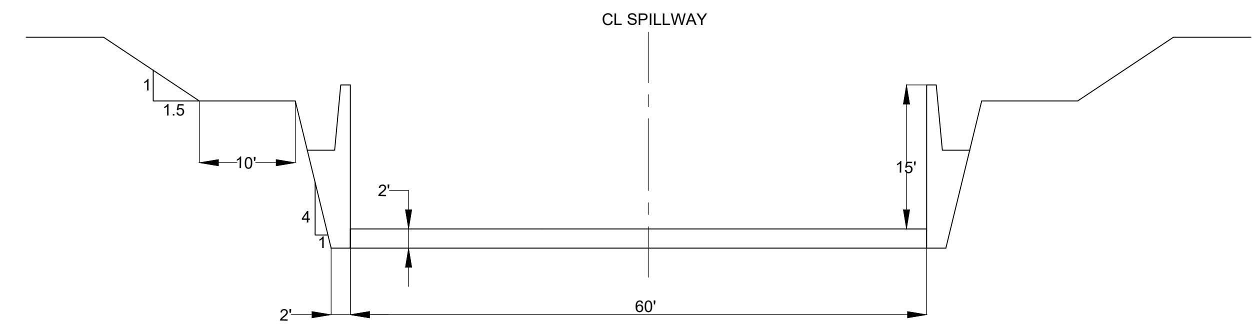
HAWLEY DAM
FIGURE 02 - PROFILE VIEWS

PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D HL_DAM.DWG

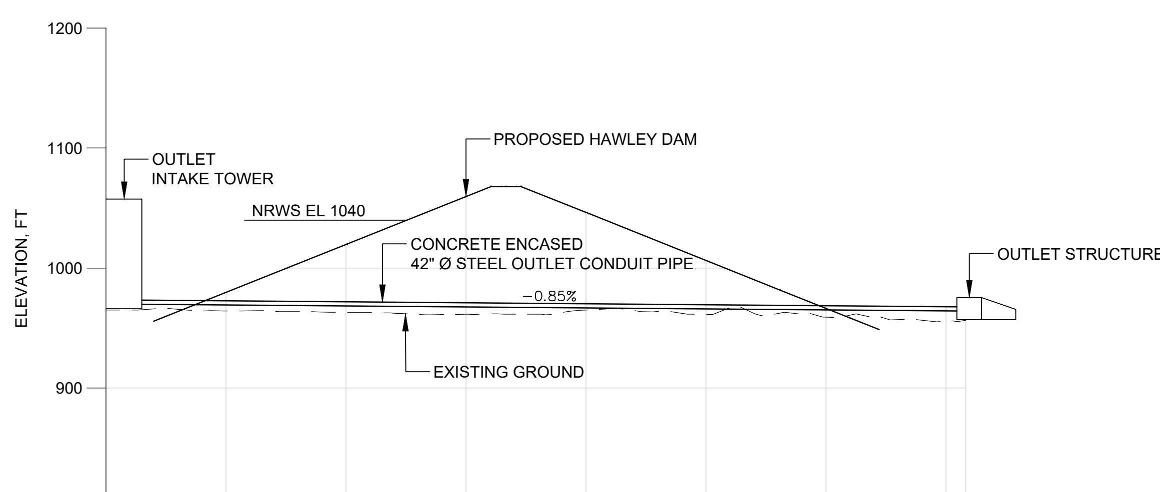


STATION (ft)	0+00	1+00	2+00	3+00	4+00	5+00	6+00	7+00	8+00	9+00	10+00	11+00	12+00	13+00	14+00	15+00
SPILLWAY INVERT ELEVATION (ft)	1025.0	1024.4	1023.9	1023.3	1022.8	1022.2	1021.7	1021.1	1020.6	1005.2	987.6	970.0	952.3	934.7	921.9	

4 – SPILLWAY PROFILE
HAWLEY DAM SPILLWAY



5 – SPILLWAY SECTION PROFILE
HAWLEY DAM SPILLWAY SECTION



STATION (ft)		1+00	2+00	3+00	4+00	5+00	6+00	7+00	
EXISTING GROUND ELEVATION (ft)	965.0	964.2	963.0	961.5	965.0	961.4	959.1	956.0	956.6

6 – OUTLET CONDUIT PROFILE
HAWLEY DAM OUTLET CONDUIT

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No: 03

MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

HAWLEY DAM
FIGURE 03 - OUTLET STRUCTURE

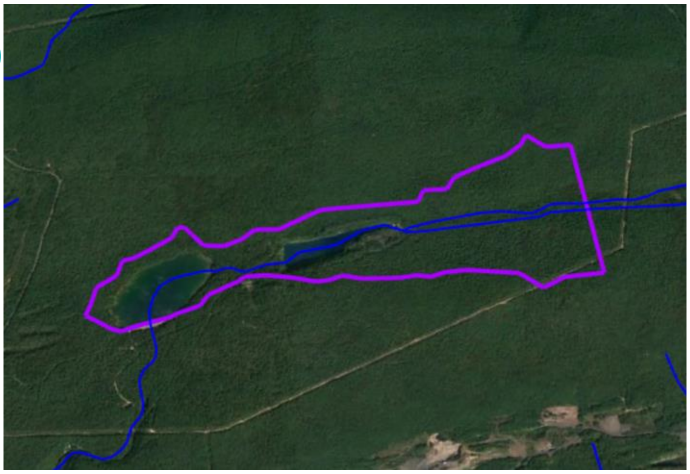
PW://MOTT-USE-PW-BENTLEY.COM:MOTT-USE-PW-03/DOCUMENTS/D HL_DAM.DWG

MOTT MACDONALD

6

Storage Project Summary

Project:	**Silver Creek/Big Creek Reservoir (N7)**
Location:	Schuylkill County, PA, near New Philadelphia
Storage Type:	New reservoir
Est. Volume:	11.2 BG
Score:	2.77



1 Project Overview

The location of the potential project is near the existing Silver Creek Dam and Reservoir, high in the Schuylkill River watershed, as shown in Figure 1.1. The project involves constructing a new, large dam on Big Creek, which flows to the east from the 22-acre water-filled Caparell mining pit (Figure 1.2 and 1.3). The resulting reservoir would flood the divide with the Silver Creek Reservoir and require the Silver Creek dam to be raised (Figure 1.4). An additional small dam would be constructed on the west end.

Most of the land is owned by Blythe Township Municipal Authority, which currently uses Silver Creek reservoir for water supply. While the area is rural and mostly forested, some areas are disturbed by mining and remain sparsely vegetated. This existing reservoir is small, covering 54 acres with 0.2 BG of storage. There is a low divide between Silver Creek and Big Creek. An engineered structure allows overflow drainage from Reservoir into the Big Creek drainage. Big Creek is fed by the overflow from the pit, flowing eastward into the small Moss Glen Reservoir about 0.7 miles downstream, which is also currently used by the Authority.

The large embankment dam on Big Creek on the east would create one large reservoir providing a normal-pool storage capacity of about 11 BG (Figure 1.4). The drainage area (red line in Figures 1.2 and 1.3) is small (less than 3 sq mi), requiring pump in.

The project has been previously studied, most thoroughly documented in the 2004 report by Skelly & Loy. The design is generally based on the one presented therein. The report proposed mining the underlying coal and using excavated material to construct the dams. While mining and reuse options remain, the reported storage volume does not include excavated coal volume (which is relatively small, estimated at 0.6 BG), and the cost estimate does not reflect the value of the coal or use of the excavated material.

Because Silver Creek reservoir is currently supplying water, an alternative water supply may be needed during raising the existing dam. Providing this alternative was not analyzed here but is discussed by Skelly & Loy.

Two abandoned mined land problem areas identified by the PADEP are nearby; these are discussed in more detail by Skelly and Loy. Area PA4054 lies just west of the proposed site of the west dike. Area PA2047 surrounds the Caparell Pit. Construction of the project could support remediation of these areas.

The overall cost of >$900M is very large and the cost effectiveness is very poor at 81 M$/BG.

Figure 1.1: Project location

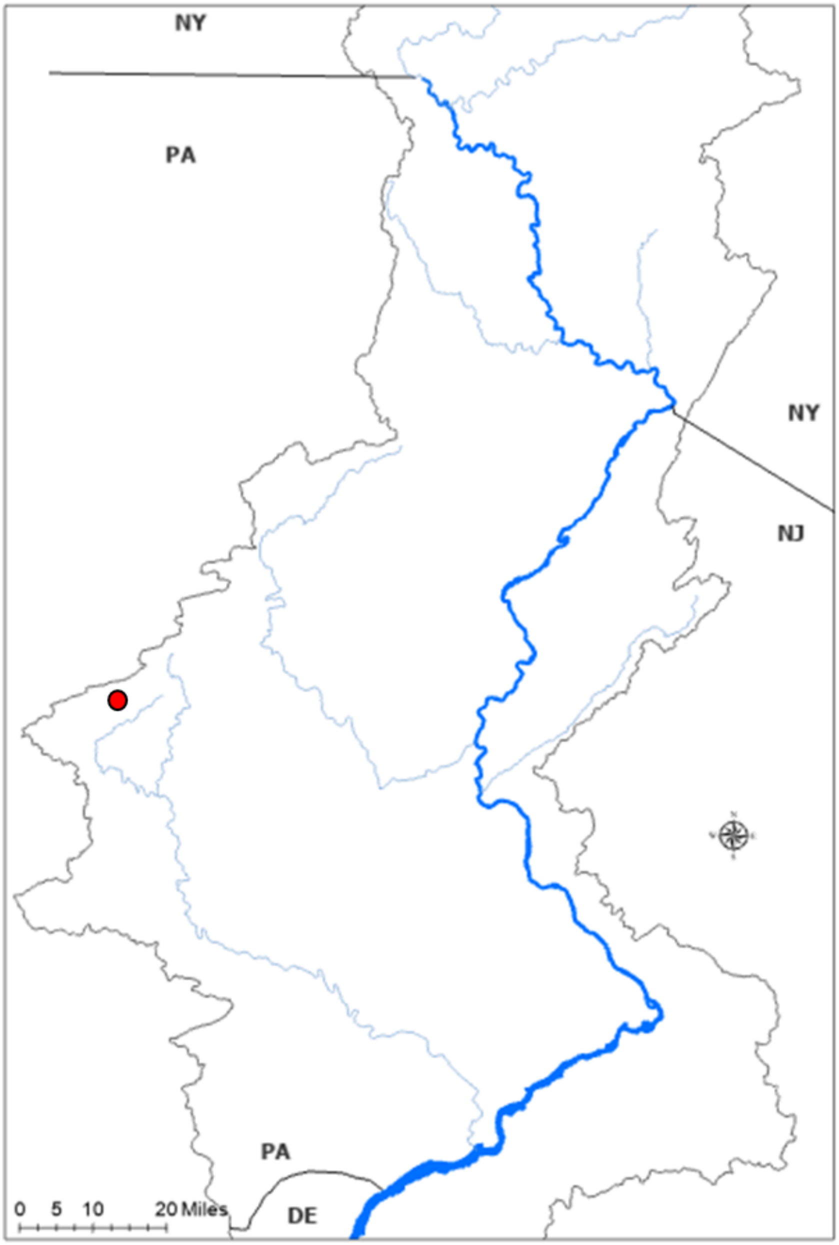


Figure 1.2: Topographic map: Drainage area in red (2.6 sq miles). Reservoir outline in purple.

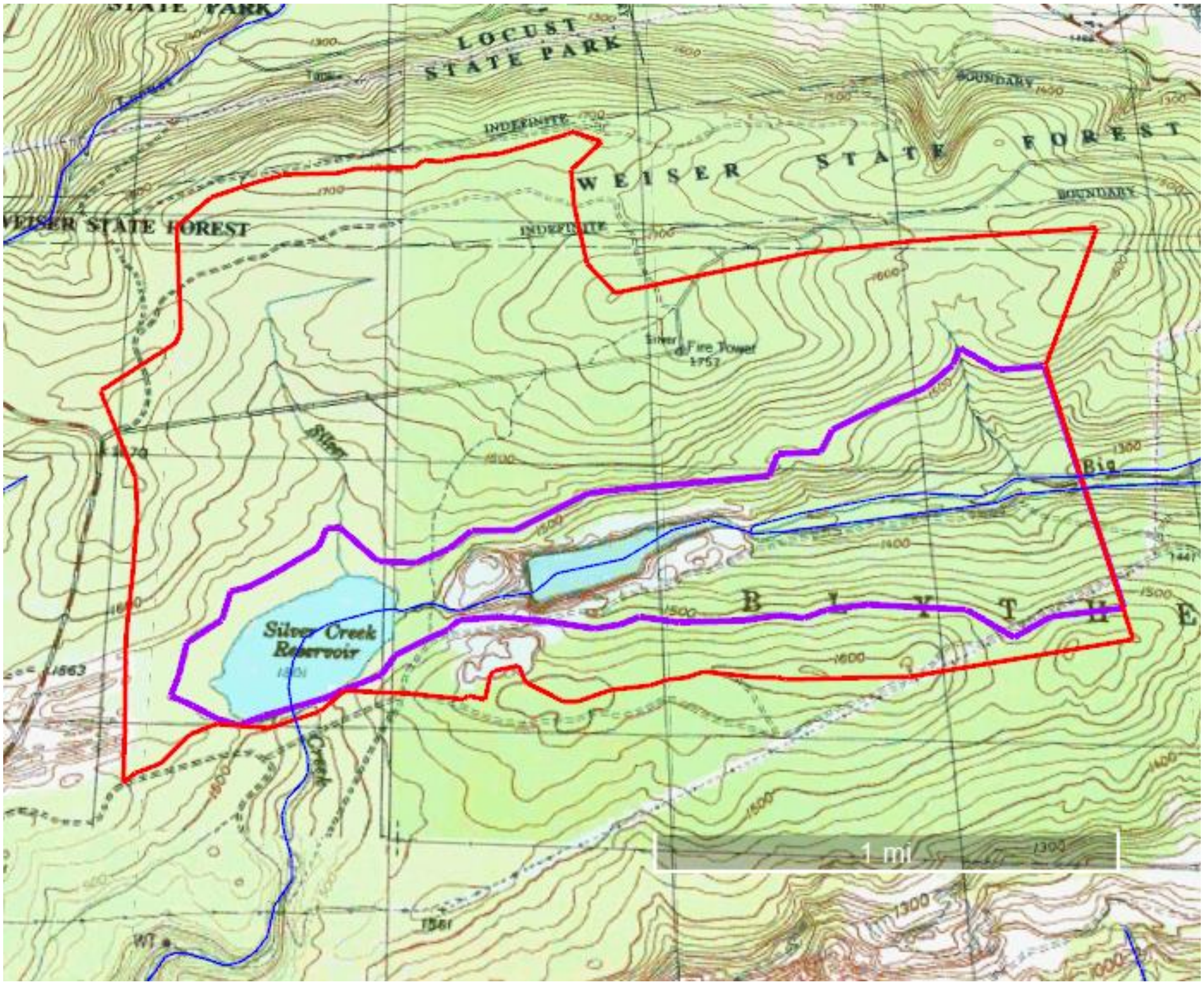


Figure 1.3: Aerial photo: Drainage area in red (2.6 sq miles). Reservoir outline in purple.

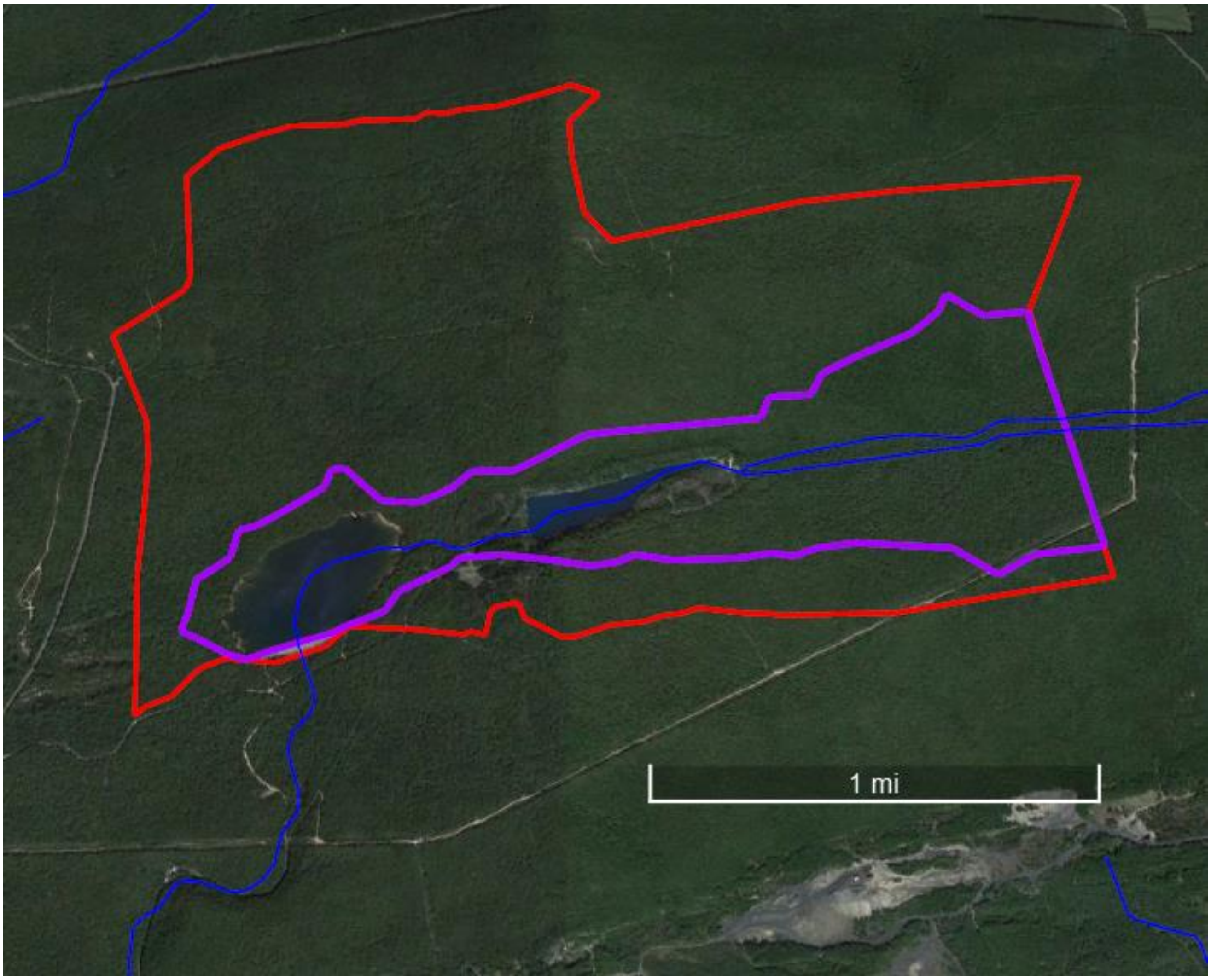
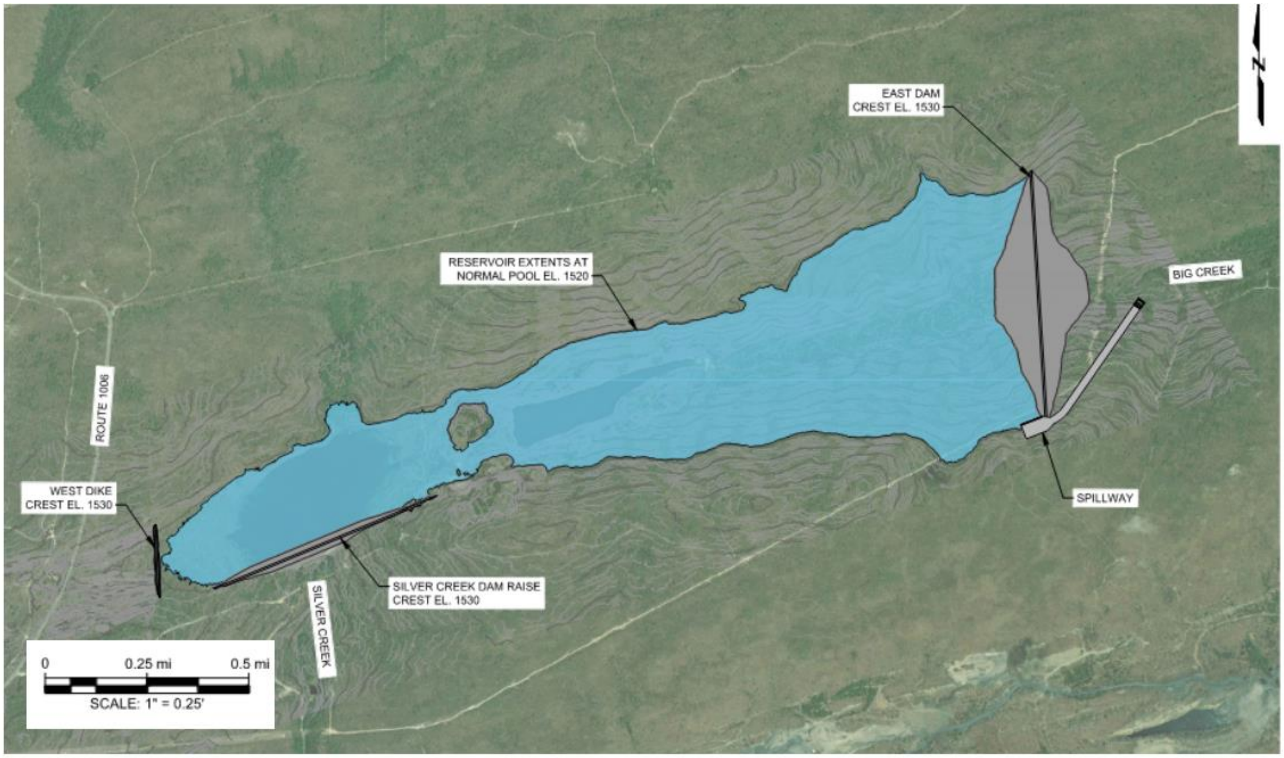


Figure 1.4: Project Schematic



2 Water Quantity & Quality

Key parameters of the potential dams and reservoir are listed in the Table 2.1 below. Detailed drawings are presented in the Appendix. The project would provide large storage volume (11.2 BG) to support flow augmentation downstream.

The crest elevation of all three dams shown in Figure 1.4 would be 1530 feet NAVD88. The elevation at the downstream toe of the large dam would be about 1270 feet, so the height of the dam at its maximum would be about 260 feet. The existing ground surface along the west dike alignment is generally around El. 1520. The existing Silver Creek Dam is an embankment dam with a crest at approximately El. 1503. The concept depicted in this evaluation is raising via the upstream dam face, but other options could include a downstream dam raise or a dam removal and replacement.

Table 2.1: Dam and Reservoir Parameters

Lat/Long	40.755639, -76.129775
Size Category per PADEP	A – Equal or greater than 100 feet; Equal to or greater than 50,000 ac-ft
Hazard Potential per PADEP	1 – Substantial (Numerous homes or small businesses or a large business or school)
Dam Type	Earthen Dam with Clay Core
Dam Crest El.	1530
Total Volume Needed for Dam/Dike Construction	7.66 Mcy
East (Main) Dam	
Dam Type	Zoned Embankment; Earthen Dam with Clay Core
Dam Height (ft)	260
Dam Length (ft)	3,330
Dam Crest Width (ft)	25
Dam Crest Elevation	1530
Upstream and Downstream Slopes	2.5H:1V
Drainage Tributary	Big Creek
Low-Level Outlet	Concrete Encased 42-inch-diameter Pipe
Outlet capacity at full dam with valve open (cfs)	1080
Intake Structure	Submerged, Reinforced Concrete
Spillway	
Spillway Type	Side Channel Uncontrolled Ogee
Spillway Crest El.	1520
Spillway Width (ft)	200 / 100
Spillway Length (ft)	2,374
Estimated Peak Inflow / Outflow during PMF	17,900 cfs / 14,000 cfs
Spillway Discharge Capacity at El. 1528	21,100 cfs
Silver Creek Dam Raise	
Dam Type	Embankment
Dam Height (ft)	65
Dam Length (ft)	3,140
Dam Crest Width (ft)	25
Dam Crest Elevation (ft)	1530
Upstream and Downstream Slopes	2.5H:1V
Drainage Tributary	Silver Creek
Low-Level Outlet	12-inch-diameter CI Pipes
Intake Structure	Tower
Spillway Type	None
West Dike	
Dam Type	Zoned Embankment
Dam Height (ft)	10 or less
Dam Length (ft)	940
Dam Crest Width (ft)	25
Dam Crest El.	1530
Drainage Tributary	None
Low-Level Outlet	None
Intake Structure	None
Spillway Type	None
RESERVOIR	
Normal Reservoir Water Surface (NRWS)	1520
Maximum Reservoir Water Surface at PMF (MRWS)	1530
Storage Capacity at NRWS	34,300 acre-ft (11.2 BG)
Reservoir Area at NRWS	473 acres
Reservoir Area at MRWS	524 acres
Freeboard at NRWS	10
Freeboard at MRWS	0
Drainage Area	2.6 sq miles

2.1 Fill and Discharge

The drainage area of under three square miles is too small to fill the proposed reservoir naturally. Instead, water must be pumped in. Finding a feasible water source is challenging because of the site's position near the boundary of the Schuylkill River watershed, combined with high elevation.

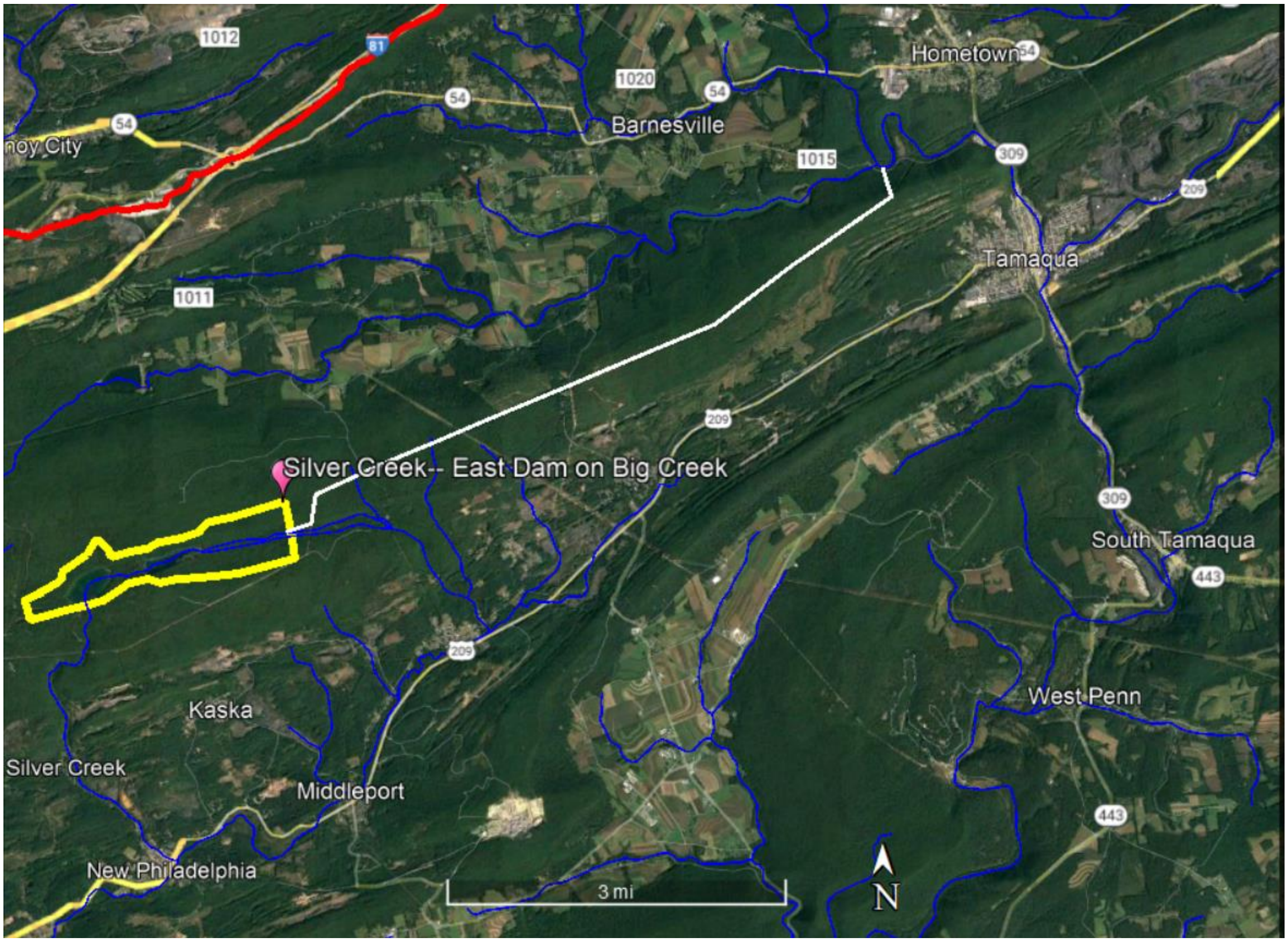
Possible sources include the Schuylkill River (about 2 miles at it closest and about 630 to 750 feet below the reservoir surface) and the Little Schuylkill River (about 6.5 miles away and about 610 feet below; See Figure 2.1). The Little Schuylkill River is preferred because of the larger drainage area at a potential withdrawal point (44 sq. mi. vs 18 sq. mi.). The mean flow there is 91 cfs.

As explained in the main report, design capacity of the pump station was set at 30 mgd or 50 cfs. In reality, the pumping would be dependent on ever-varying flow rate in the source. According to the flow pattern memo in Appendix C of the main report, to provide adequate pass-by flow in the source stream, the average pumping rate over the six-month pumping season (November through April) was assumed to be 40% of the mean flow or 35 cfs in this case. At this rate, the about four billion gallons could be pumped over a six month pumping season (Nov-Apr), so two or three years would be required to fill/refill the reservoir with 13 billion gallons. A more detailed analyses would more accurately determine the time to fill under different flow conditions.

The water would be released by gravity, so a large release could be readily achieved through the 42-inch low-level outlet pipe – about 420 cfs at the normal pool level – discharge to Big Creek. Such a large release would likely destabilize Big Creek; a stilling basin to prevent this was included in the cost estimate. The release may also impact the stability of the Moss Glen Reservoir. The 11.2 BG reservoir could provide about 170 days of flow augmentation at the desired rate of 100 cfs.

Because the project sits high in the Schuylkill River watershed the release will take a few days to travel the 120 stream miles to reach to the Delaware River. With the Schuylkill entering the mainstem at Philadelphia low in the Basin, the upper/middle Delaware will not benefit from the project, but the flow will help repel the salt front.

Figure 2.1: Preferred withdrawal point on the Little Schuylkill River and pipeline route (in white; about 6.5 miles and about 610 feet lift)



2.2 Water Quality

Silver Creek Reservoir is currently used for drinking water supply. Overflow from the Caparell Pit enters Big Creek, which flows 0.7 miles to Moss Glen Reservoir (Figure 1.2), which is also used for drinking water supply. Water from Caparell Pit has also been pumped into Silver Creek Reservoir when needed (see http://www.opportunityforblythe.com/SCRCappitAirPicwGraphics.html). Presumably, then, existing water quality is sufficient for water supply. Water to fill the proposed reservoir will be pumped in from an existing stream, the Little Schuylkill River, which is not impaired based on 303D Listing (Table 2.2). Silver Creek and Big Creek downstream from Silver Creek Reservoir have presumably impaired areas from acid mine drainage (Table 2.2). Remediation of such discharge is desirable and beneficial, but the water quality in the proposed new reservoir should be satisfactory for flow augmentation even without such remediation.

Table 2.2: 303D Listing Impairments

Uses	Assessment Results		
	Silver Creek	Big Creek	Little Schuylkill River
Aquatic Life	Impaired: sediment from coal mining; low pH from acid mine drainage	Impaired: low pH from acid mine drainage; habitat change from channelization, flow regime change from coal mining; siltation/metals from acid mine drainage	Supported
Recreational	Supported	Supported	Supported
Fish Consumption	Not assessed	Not assessed	Supported
Potable water	Supported	Supported	Not assessed

3 Infrastructure Design, Construction & Operation

3.1 Dam

As detailed in the main report, conceptual designs were developed in general accordance with the Pennsylvania Code Title 25, Chapter 105, Dam Safety and Water Management. Detailed parameters are given in Table 2.1. The dam and spillway were designed to pass the "probable maximum flood" (PMF), which was estimated as described in Section 5.2 of the main report.

The east dam (main dam) would be a zoned embankment dam approximately 260 ft tall. The Silver Creek Dam, an existing embankment dam, would be raised from about 38 ft to 65 ft tall, and the west dike would be about 10 ft tall. See attached drawings for more details. The total volume of material needed for dam and dike construction is about 7.66 Mcy. Fill for construction of the dams and dike will be borrowed from within the reservoir footprint, and any unsuitable materials will be wasted within the reservoir footprint. Deep cuts exceeding 10 feet should be anticipated. A geotechnical investigation has not been performed and the quantity and types of borrow materials within the reservoir are not known.

Based on the bedrock geologic map of the area obtained from the Pennsylvania GEOlogic Data Exploration Geological Survey website (https://www.gis.dcnr.state.pa.us/pageode/), bedrock at the east dam and Silver Creek Dam is expected to be Pottsville Formation, which in Schuylkill County consists "mainly of well- to very well cemented, medium-grained to conglomeratic sandstone beds (ranging in thickness from about 10 to 70 feet), with minor amounts of siltstone, claystone, shale, thin discontinuous coals". Bedrock at the west dike is the Llewellyn Formation, which "consists of interbedded sandstone, siltstone, shale, conglomerate, and coal. Plant fossils are common. This formation contains most of the minable coal beds in Pennsylvania's anthracite fields." The soil overburden at the existing Silver Creek Dam is described as a mixture of decomposed conglomerate and clay. Bedrock outcrops are noted to have been observed on the hillside in the vicinity of the dam (Gannet Fleming 1978). Geotechnical investigations will be needed to determine if the foundation conditions are appropriate for construction of the dams and dike. No field investigations were performed for this study.

The existing embankment dam at Silver Creek Reservoir was originally constructed around 1850 (Gannett Fleming 1978). In 2005, an earth and rock buttress was constructed on the downstream face to increase stability (Skelly & Loy, 2004 and http://www.opportunityforblythe.com/SilvCrkDamRehabPicsText.html).

Buttress construction material consisted primarily of overburden from the Caparell pit. This material was tested and approved by the PADEP prior to use. The cost estimate assumed that the existing Silver Creek Dam can be raised. Silver Creek Dam is over 170 years old, and the dam condition and foundation conditions are unknown. The dam may need to be removed and reconstructed. The amount of siltation in the reservoir upstream of the dam is unknown.

The spillway would be located on the south flank of the main dam as an uncontrolled ogee with a stilling basin (see attached drawings), providing simple operation. The capacity of the spillway is 21,100 cfs at the estimated peak elevation of the probable maximum flood.

An intake tower was conceptually designed with associated controls, piping, and valves housed within the tower. A 42", concrete-encased, steel pipe travels through the dam connecting the intake tower to an outlet structure where water releases are to be made. The outlet capacity at NRWS greatly exceeds the required capacity.

3.2 Pumping Facilities and Pipeline

Pumping and pipeline parameters are detailed in Table 3.1. Water would be pumped from the Little Schuylkill River north of Tamaqua (Figure 2.1). The pump station would have a design capacity of 50 cfs, operating at an average rate of 35 cfs over the six-month pumping season (November through April) and taking about 16 months of pumping to fill the reservoir with 11 BG. Anticipating that the reservoir might be drained about once every several years, the operating costs would be a small portion of overall costs.

As mentioned elsewhere, design capacity of the pump station was set at 30 mgd or 50 cfs. The standard configuration of the pump station is described in the main report: submerged wedgewire screen on the river bottom connected to a wetwell on the adjacent bank that will house submersible pumps for lifting and transferring river water. The proposed configuration has 3 x 10 mgd pumps in the wetwell.

While these standard pump types and configuration were assumed for cost estimating, the distance and head conditions shown in Table 3.1 would require different types of pumps and/or an intermediate booster station. These would increase pumping station capital costs and operation/maintenance costs, but the increase would be minor compared to the overall project cost of over $900M reported in Section 6 and well within the uncertainty inherent in the cost estimate.

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule. The system will function as others and be automated and monitored for remote operation.

The intake pipeline would be 6.5 miles, rising 610 feet from the withdrawal point. The pipeline would mostly follow the route of a powerline to limit environmental impacts and right-of-way problems.

Table 3.1: Pump and Pipeline Parameters

Parameter	Value
Pump Design Flow	30 mgd (50 cfs)
Pump Capacity (3 x 10 mgd)	30 mgd (50 cfs)
Pipeline Distance	6.5 mi
Elevation at Withdrawal Point	910 ft
Elevation at NRWS	1520 ft
Elevation difference	610 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

4 Environmental Impacts

The area has been heavily altered by anthracite coal mining and associated industrial development. Mine drainage has led to acidification of streams, and mining has stripped vegetation and degraded soil from many areas.

The primary impact would be loss of forest surrounding the Caparell Pit and the Silver Creek Reservoir. While the loss would be substantial in terms of acreage (about 450 acres), the project sits within an extremely large (>20,000 acres), contiguous forest atop Broad and Locust Mountains.

The project would flood about one mile of Big Creek (which has two separate channels) and about 0.25 mile of Silver Creek uphill of the reservoir. Streams flowing into and out of both reservoirs are rated by Chapter 93 as cold-water fishery. As mentioned above, water quality is rated as impaired in both creeks from acid mine drainage. If the acid drainage is remediated, water quality could be improved.

In any case, water released from the reservoir would likely not degrade downstream waters. The watershed is very small, so the modification of the hydroperiod through installation of a dam should have little effect. Likewise, there is little connectivity upstream of the existing waterbodies, so the dam should have little effect on fish passage.

No wetlands are marked on the National Wetland Inventory Maps; however, two soils mapped on the site are considered poorly drained and assumed regulated wetlands. About 49 acres of poorly drained soil will be filled or flooded. Because the waterbodies and wetlands are disturbed, it may be easier to replace them elsewhere in the watershed.

The proposed route of the water delivery pipeline is 6.5 miles from the Little Schuylkill River along a powerline corridor on the Locust Mountain Ridge and therefore does not cross any streams. However, it may disturb delicate springhead ecosystems that have formed in these almost alpine conditions. Slight diversions can likely be made to avoid impacts and, therefore, they were not considered.

Endangered/threatened species reported by the USFWS iPaC include Indiana Bat (IB), Northern Long-eared Bat (NLEB), and Monarch Butterfly. Though rare, both IB and NLEB prefer deeply wooded areas. No information was available about maternity colonies or hibernacula in the area. There is a possibility of Timber Rattlesnakes, a state-protected species, in the impoundment footprint and within the pipeline. A better understanding of all protected species must be obtained to understand impacts.

5 Social and Economic Impacts

These impacts would be very minor. There are no buildings or public roads within the limits of the proposed reservoir. About 0.5 miles of power lines would need to be relocated, or the dam could be move or lowered slightly to avoid this impact. Because Silver Creek Reservoir is currently supplying water, an alternative water supply may be needed while raising the existing dam or the project could be carefully staged to avoid interruption. Options were discussed by Skelly & Loy and alternative potable water connections now exist in the region.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level approximate (level 4) cost estimate for construction costs, as detailed in Table 6.1 for the dam and Table 6.2 for the pump station and pipeline. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billon gallons of storage) are reported in Table 6.3. Methods are described in the main report. Costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail.

Table 6.3 shows the feasibility-level cost estimate (present value) of this potential project is very high at >$900M, primarily because three dams must be constructed at an estimated cost of $819M. Plus, the cost for the pump station and pipeline is much larger ($51M) than others because of the large elevation change and long distance. Because of the high cost, the cost effectiveness is very poor at $81M/BG.

Table 6.1: Dam and Reservoir Construction Cost Estimate

Description	Unit	Quanity	Rate	Total
1.0 East Dam				**$ 310,026,681**
Excavation	CY	892,700	$ 20.00	$ 17,854,000
Foundation Treatment / Grout Curtain	SF	240,000	$ 110.00	$ 26,400,000
Core Material	CY	944,400	$ 25.00	$ 23,610,000
Filter Material	CY	257,600	$ 90.00	$ 23,184,000
Dam Shell Material	CY	6,313,600	$ 30.00	$ 189,408,000
Riprap	CY	145,000	$ 200.00	$ 29,000,000
Hydroseed	SF	1,141,363	$ 0.50	$ 570,681
2.0 Silver Creek Dam Raise				**$ 27,354,519**
Excavation	CY	78,300	$ 20.00	$ 1,566,000
Foundation Treatment / Grout Curtain	SF	57,000	$ 110.00	$ 6,270,000
Embankment Fill	CY	400,800	$ 30.00	$ 12,024,000
Filter Material	CY	-	$ 90.00	$ -
Riprap	CY	37,000	$ 200.00	$ 7,400,000
Hydroseed	SF	189,037	$ 0.50	$ 94,519
3.0 West Dike				**$ 822,293**
Excavation	CY	4,500	$ 20.00	$ 90,000
Core Material	CY	3,500	$ 25.00	$ 87,500
Dam Shell Material	CY	7,100	$ 30.00	$ 213,000
Riprap	CY	2,100	$ 200.00	$ 420,000
Hydroseed	SF	23,586	$ 0.50	$ 11,793
4.0 Spillway				**$ 42,974,000**
Excavation	CY	236,000	$ 30.00	$ 7,080,000
Reinforced Concrete Slab	CY	19,100	$ 850.00	$ 16,235,000
Spillway Walls	CY	12,800	$ 1,100.00	$ 14,080,000
Anchors	EA	650	$ 2,500.00	$ 1,625,000
Drainage Layer	CY	9,600	$ 90.00	$ 864,000
Drainage Pipes	LF	6,900	$ 100.00	$ 690,000
Stilling Basin	CY	2,400	$ 1,000.00	$ 2,400,000
5.0 Outlet Works				**$ 10,355,000**
East Dam Outlet Pipeline and Installation	LF	1,200	$ 2,300.00	$ 2,760,000
East Dam Intake Tower and Installation	10' Segment	22.5	$ 250,000.00	$ 5,625,000
Silver Creek Dam Outlet Extension	LF	150	$ 2,300.00	$ 345,000
Silver Creek Dam New Intake	10' Segment	6.5	$ 250,000.00	$ 1,625,000
6.0 Access Roads				**$ 1,200,000**
New roads	Mile	2	$ 600,000	$ 1,200,000
7.0 Reservoir Excavation				**$ 5,717,000**
Timber Harvest	Acre	419	$ 8,000	$ 3,352,000
Clear & Grub, Strip	Acre	473	$ 5,000	$ 2,365,000
8.0 Key Project Components Subtotal				**$ 398,449,493**
Sum 1.0 through 7.0				$ 398,449,493
9.0 Contractor Allowances				**$ 166,950,337**
9.1 Environmental Allowance: Rate x 8.0			2%	$ 7,968,990
9.2 Materials Testing (QA/QC): Rate x 8.0			2%	$ 7,968,990
9.3 Contractor Indirect Costs: Rate x 8.0			25%	$ 99,612,373
9.4 Profit: Rate x (8.0 + 9.1 + 9.2 + 9.3)			10%	$ 51,399,985
10.0 Contingencies				**$ 254,429,924**
10.1 Design Contingency: Rate x (5.0 + 6.0)			25%	$ 141,349,958
10.2 Construction Contingency: Rate x (5.0 + 6.0)			20%	$ 113,079,966
Conceptual Cost Estimate Total				**$ 819,829,754**

Table 6.2: Pump Station and Pipeline Cost

Item	Unit	Quantity	Cost/Unit	Extended
Fill Pumping System			**Subtotal**	**$ 3,465,500.00**
Intake				
Screens	LS	3	$ 80,000	$ 240,000
Structure	VF	12	$ 50,000	$ 600,000
Other	LS	1	$ 90,000	$ 90,000
Pumping Station				
Pumps	#	3	$ 450,000	$ 1,350,000
MEP	LS	1	$ 265,500	$ 265,500
Structure	SF	1200	$ 350	$ 420,000
Other	LS	1	$ 500,000	$ 500,000
Dissipation	LS		$ 500,000	$ -
Pipeline			**Subtotal**	**$ 33,300,000**
Pipeline	LF	39000	$ 800	$ 31,200,000
Valves	#	42	$ 50,000	$ 2,100,000
Intermediate Pumping System			**Subtotal**	**$ 2,133,000**
Intake Structure	VF		$ 25,000	$ -
Pumping Station				
Pumps	#	3	$ 500,000	$ 1,500,000
MEP	LS	1	$ 63,000	$ 63,000
Structure	SF	1200	$ 350	$ 420,000
Electrical Service	LS	1	$ 50,000	$ 50,000
Other	LS	1	$ 100,000	$ 100,000
Treatment				$ -
Access Roads				**$ 500,000**
New roads	Mile	1	$ 500,000	$ 500,000
Land Acquisition				**$ -**
Inundation Area	ACRE	2		$ -
Subtotals				
Construction Costs Subtotal				$ 39,398,500
Contingency			$ 0	$ 11,819,550
Construction Estimate + Contingency				**$ 51,218,050**

Table 6.3: Overall Cost Summary

Land acquisition cost ($)	5.M
Construction Cost ($)	874M
Operating Cost ($/yr)	2.1M
Overall Cost (Present value, $)	921M
Cost effectiveness ($/BG)	81M

The schedule for the project is also very rough. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition. Fifteen years was the typical estimate for a new dam.

- Funding acquisition 5 years
- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup 2 years
- Total 15 years

7 Potential Ancillary Benefits

The project would provide benefits regarding recreation, habitat and environment remediation. Constructing such a large project provides opportunity to remediate abandoned mined lands and acid mine drainage at a discount provided by economy of scale. The mined lands could be reclaimed and put to recreational use for local residents and tourists. This new amenity could provide incentive for private developers to remediate the abandoned mine lands to the west of the proposed reservoir.

The reservoir would provide still water habitat, while replacing streams that are currently impaired by acid mine drainage. The large reservoir would provide additional water security for the customers of the Blythe Township Municipal Authority and, perhaps, other areas, while retaining a large volume for flow augmentation.

8 Storage Project Score

This site was scored as described in the main report and summarized in Table 8.1 below for the six primary criteria. Each primary criterion contained subcriteria which were scored on a 1 (worst) to 5 (best) scale and averaged. Scores on the primary criteria were weighted as shown in Table 8.1 and summed to obtain an overall weighted average score. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

The project sored very well on criteria 1 and 4, reflecting the large volume and lack of impacted infrastructure.

It scored low on 2 and 5 due to its large cost and complicated design and construction involving three dams. The cost of >$900M is very large and the cost effectiveness is very poor at $81M/BG.

Table 8.1: Storage Project Score

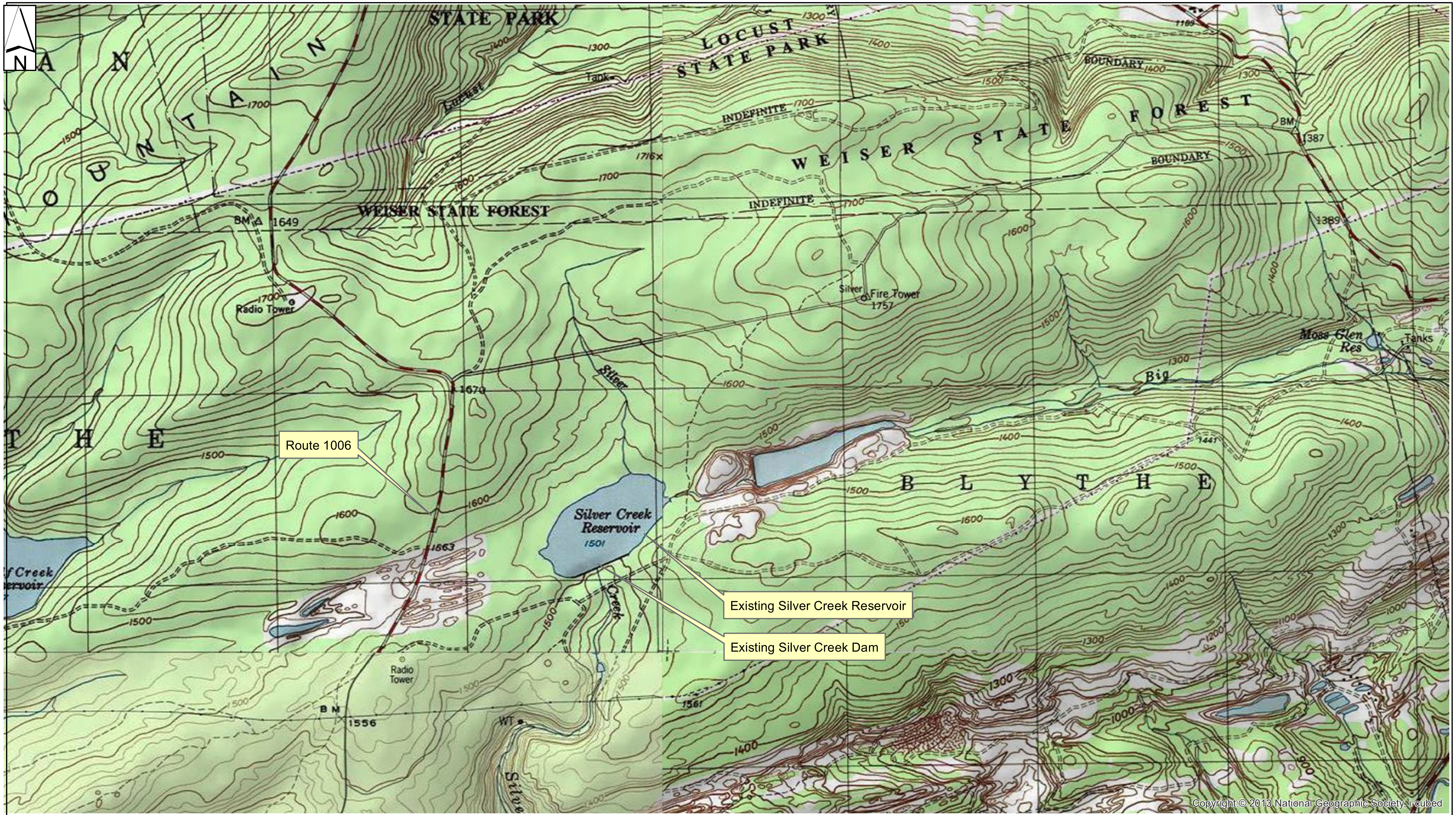
Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.50	30%	1.05
Infrastructure Design, Construction & Operation	1.80	10%	0.18
Environmental Impacts	2.68	15%	0.40
Social & Economic Impacts	4.33	10%	0.43
Project Cost & Schedule	1.83	30%	0.55
Ancillary Benefits	3.00	5%	0.15
AVERAGE	**2.86**		**2.77**

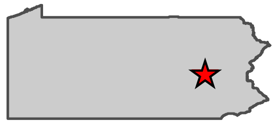
APPENDIX

Score Sheet

Drawings

Six primary criteria	Quantitative Evaluation Metric (when (enter values	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
1. Water quantity and quality		3.50			30%	1.05	
o Volume of storage provided (BG)	11.3	4					
o Hydrologic reliability of supply (months to fill)	28	2					Pumped in from Little Schuylkill R near Tamaqua
o Release rate (cfs)	400	5					
o Promptness of delivery to mainstem (days)	3	3					
o Geographic benefit		3					
o Quality of stored water		4					
2. Infrastructure design, construction and operation		1.80			10%	0.18	
o Site/Civil, Land & Easements		4					
o Subsurface conditions		2					
o Infrastructure Complexity		1					pump and 7.5 mile long pipeline
o Construction complexity		1					Need three dams, including raise on Silver Creek
o Operational complexity		1					Must monitor and adjust pumping closely
3. Environmental impacts		2.68			15%	0.40	
o protected species		3					Habitat is suitable for protected bats.
o Water quality degradation of downstream waters		4					Water quality should be as good or better as existing outflow
o obstruction to passage of aquatic animals		3					Small lakes with little connectivity upstream
o hydromodification		4					Little outflow under existing conditions
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o wetlands inundated or filled (ac)	49	1.75	2.5	1			
o stream length inundated (mi)	3	2	3	1			
o uplands inundated or developed (ac)	480	1	1	1			
4. Social and Economic Impacts		4.33			10%	0.43	
o Disruption/displacement		5					
o Safety and health		4					
o Social equity/environmental justice		5					
o Recreational loss		4					
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		1					Building three dams
5. Project Costs & Schedule		1.83			30%	0.55	
o Land acquisition cost ($)	5.M						
o Construction Cost ($)	874M						819M$ for dam + 55M$ for pump station and 7.5 mi pipeline
o Operating Cost ($/yr)	2.1M						
o Overall Cost (present value, $)	921M	1					
o Cost effectiveness ($/BG)	81M	1.5					
o Schedule (Time to make Operational, years)	15	3					
6. Ancillary Benefits		3.00			5%	0.15	
o Flood control		1					
o Recreation/tourism		5					
o Habitat/fishery enhancement		3					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		3					Opportunity for remediation of acid mine drainage
o Ability to leverage funding from other programs		3					
OVERALL		2.86			100%	2.77	



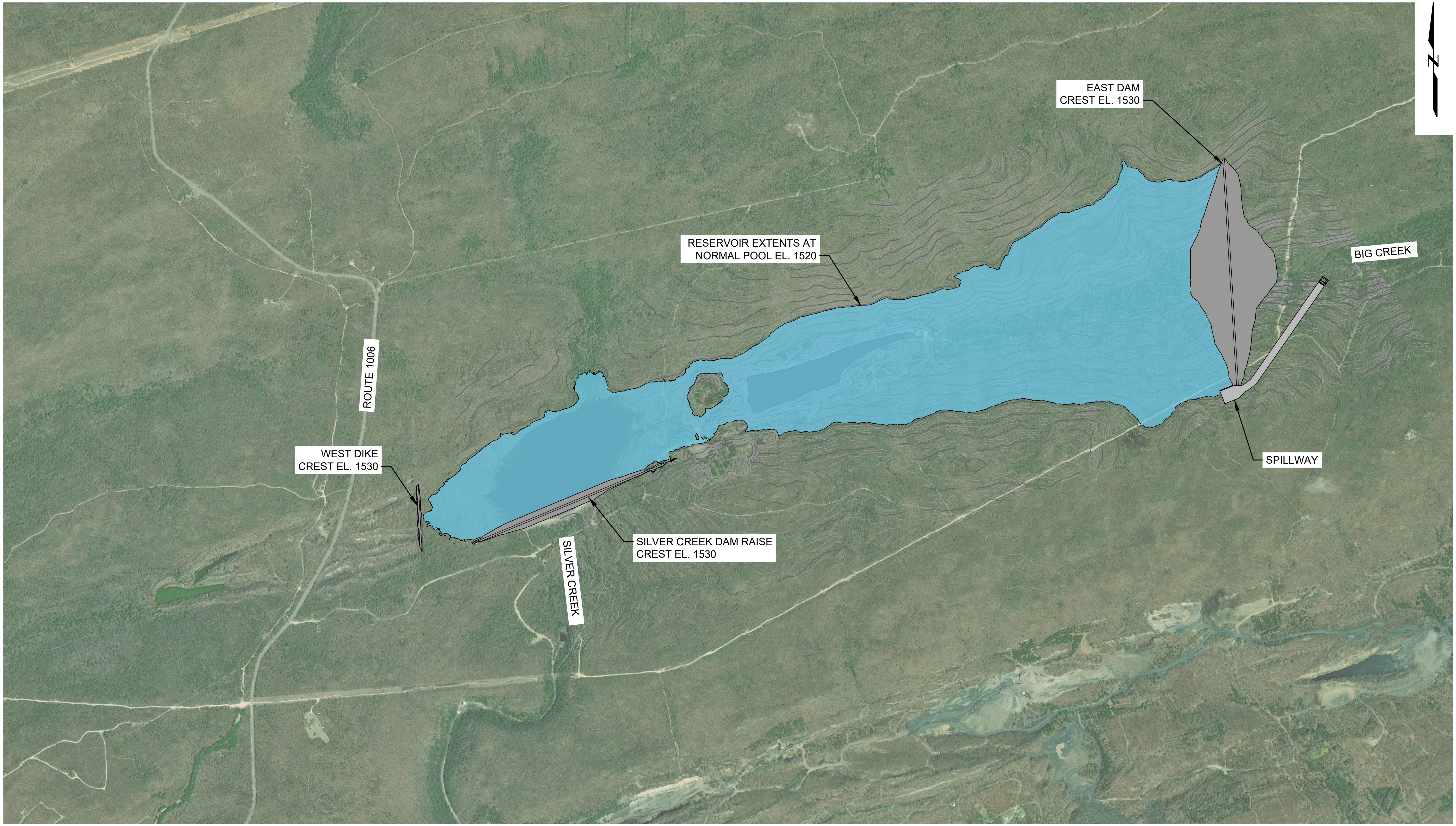


0 0.25 0.5 1

Miles

DRBC Storage Options Study Silver Creek Reservoir Blythe Twnshp, Pennsylvania	GEI Consultants	VICINITY MAP
Mott Macdonald Iselin, NJ	Project 2102438	April 2022 Fig. 1

\\geiconsultants.com\data\Data_Storage\Working\MOTT MACDONALD\2102438 DRBC Storage Options Study\00_CAD\Figures\Figure 1 - Vicinity



NOTES:

1. TOPOGRAPHY FROM USGS LIDAR (2017), NAVD88.

SOURCE:

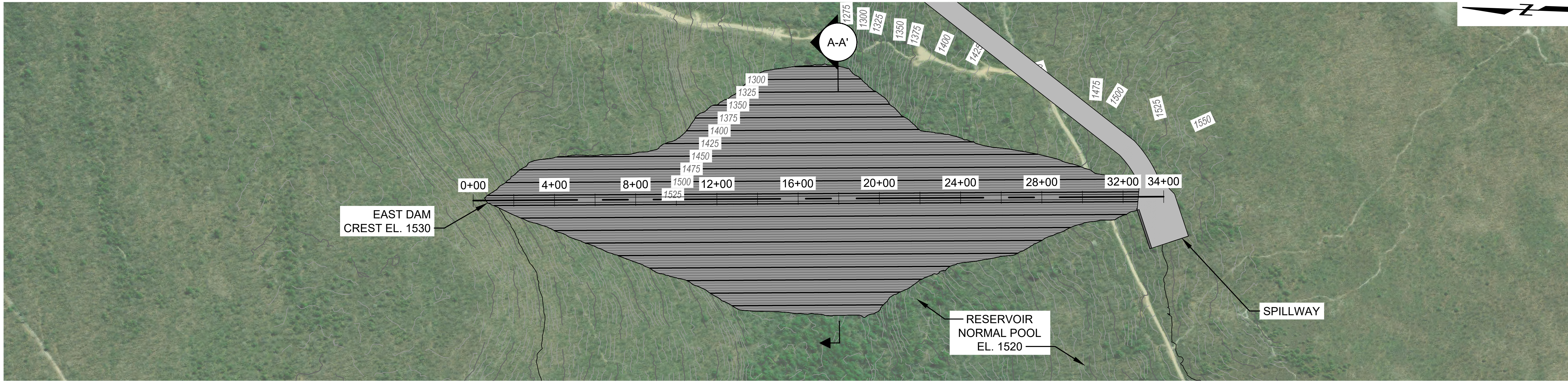
1. AERIAL IMAGERY: BING MAPS.

0 0.25 mi 0.5 mi

SCALE: 1" = 0.25'

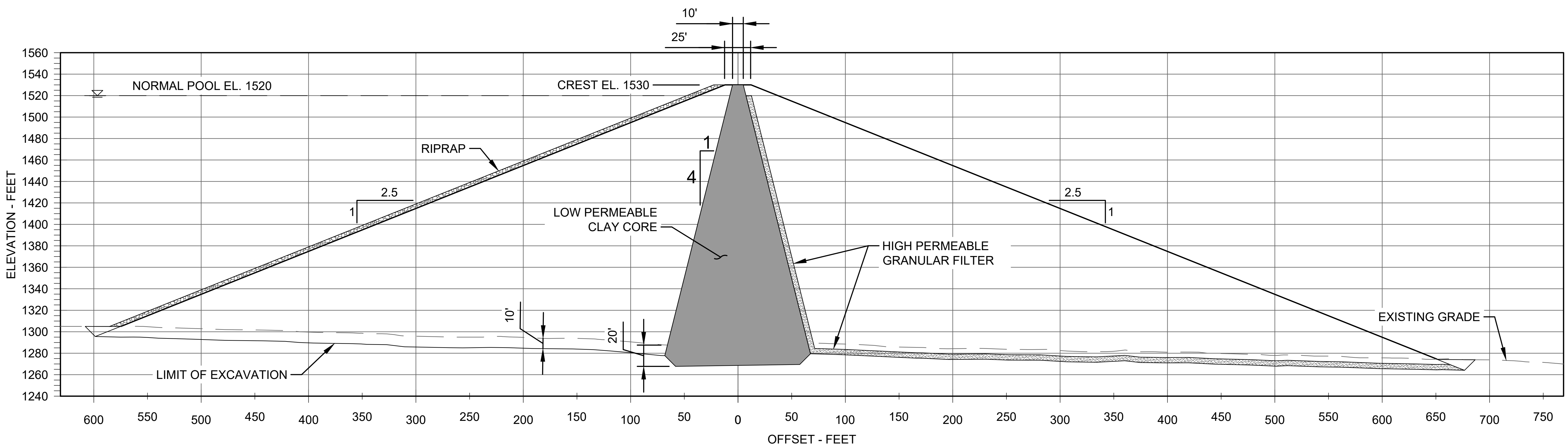
DRBC Storage Options Study Silver Creek Reservoir Blythe Twnshp, Pennsylvania	GEI Consultants	RESERVOIR EXPANSION PLAN
Mott Macdonald Iselin, NJ	Project 2102438	April 2022 Fig. 2

PELLETIER, DAN B:\Working\MOTT MACDONALD\2102438 DRBC Storage Options Study\00_CAD\Figures\2102438 - 10BG Design.dwg - 5/10/2022



PLAN VIEW

1" = 500'



SECTION A-A'

1" = 100'

NOTES:

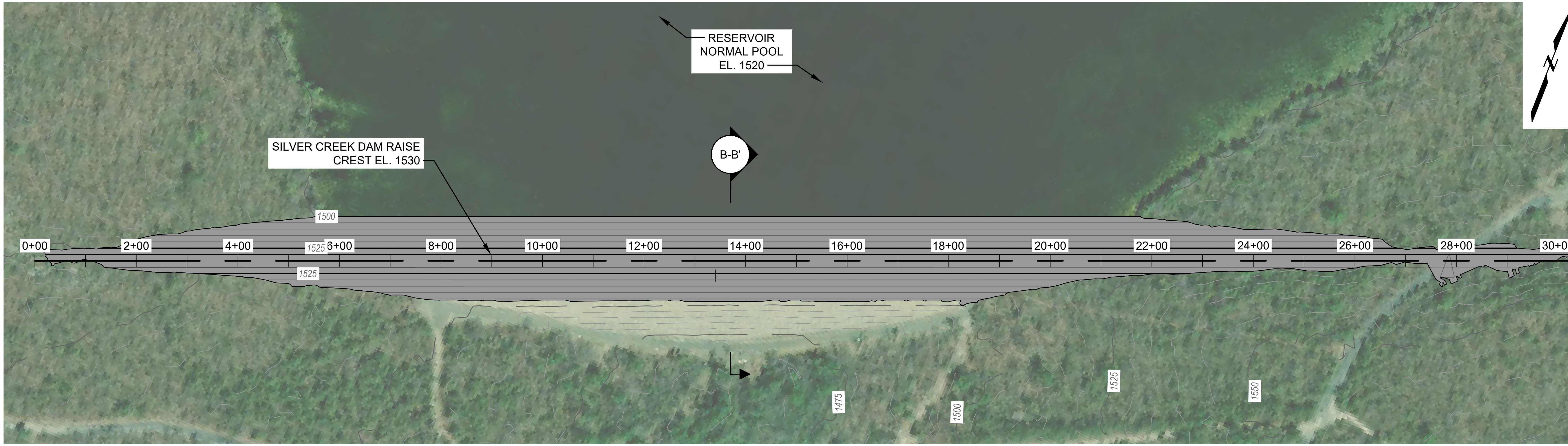
1. TOPOGRAPHY FROM USGS LIDAR (2017), NAVD88.

SOURCE:

1. AERIAL IMAGERY: BING MAPS.

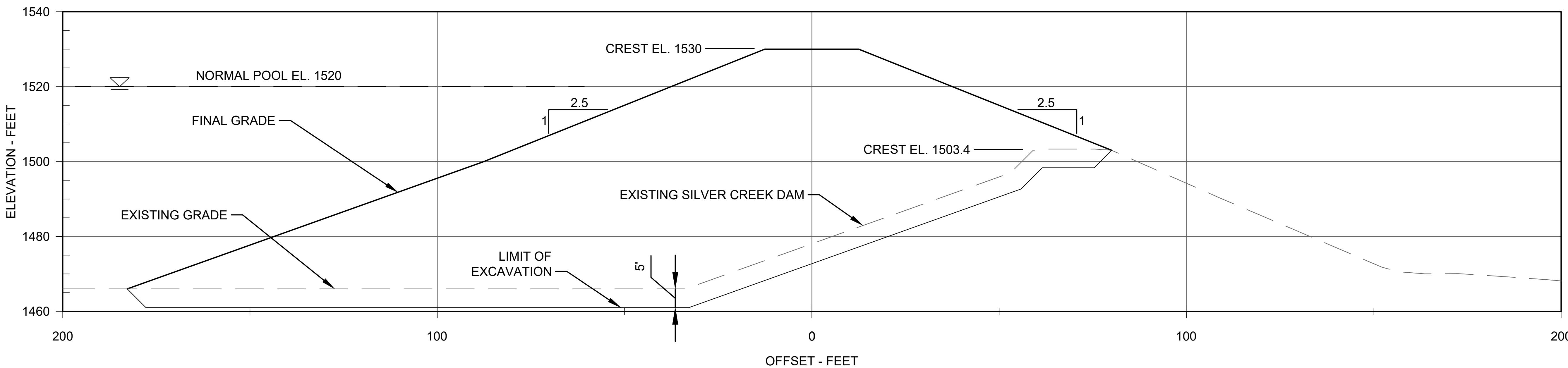
DRBC Storage Options Study Silver Creek Reservoir Blythe Twnship, Pennsylvania	GEI Consultants	EAST DAM PLAN AND SECTION
Mott Macdonald Iselin, NJ	Project 2102438	April 2022 Fig. 3

PELLETIER, DAN B:\Working\MOTT MACDONALD\2102438 DRBC Storage Options Study\00_CAD\Figures\2102438 - 10BG Design.dwg - 5/10/2022



PLAN VIEW

1" = 200'



SECTION B-B'

1" = 30'

NOTES:

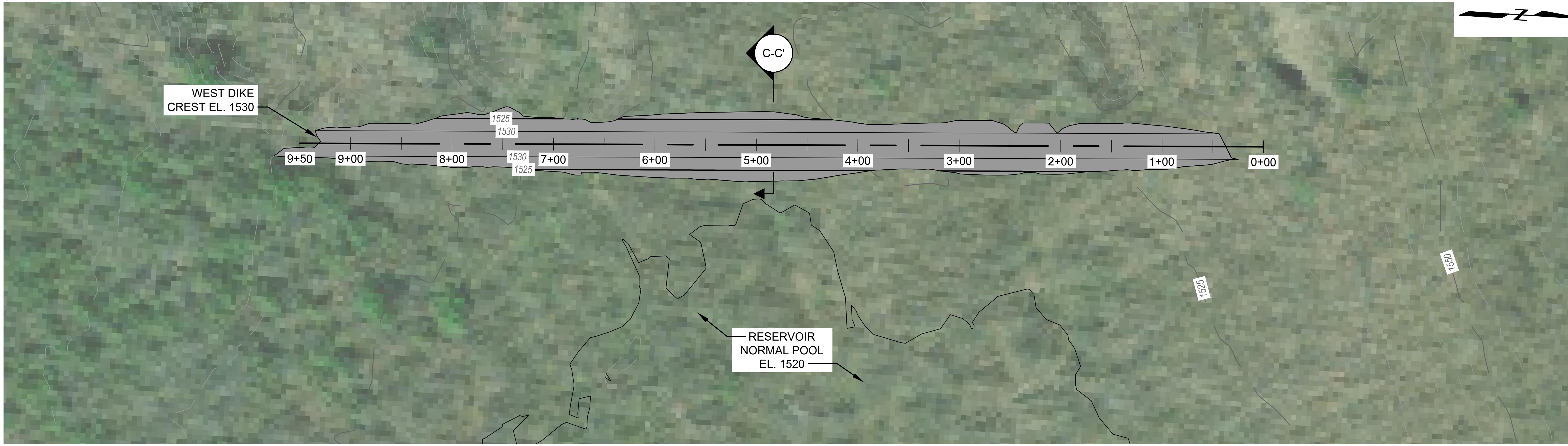
1. TOPOGRAPHY FROM USGS LIDAR (2017), NAVD88.
2. UPSTREAM TOE PROFILE OF EXISTING SILVER CREEK DAM APPROXIMATED BASED ON NDIP PHASE 1 INSPECTION REPORT (1978).

SOURCE:

1. AERIAL IMAGERY: BING MAPS.

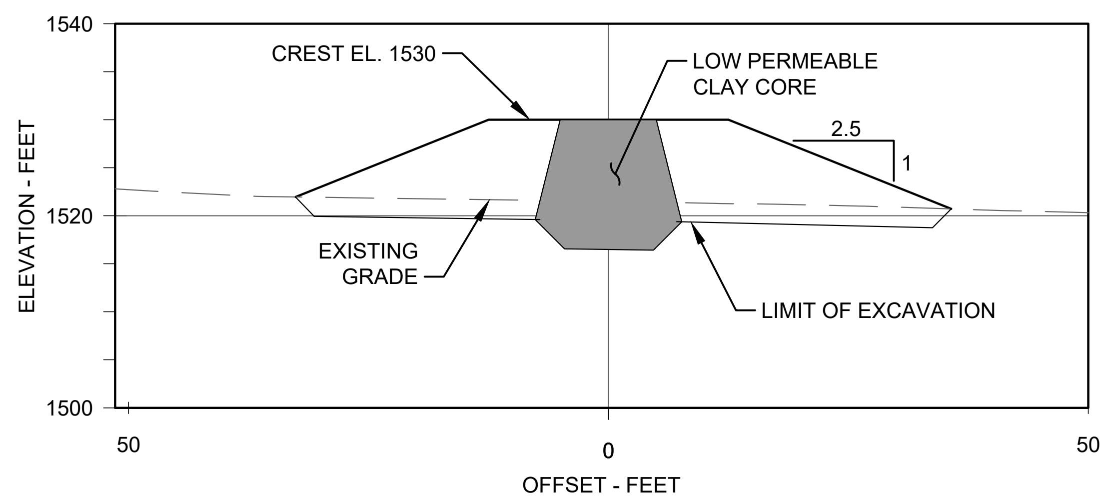
DRBC Storage Options Study Silver Creek Reservoir Blythe Twnshp, Pennsylvania	GEI Consultants	SILVER CREEK DAM RAISE PLAN AND SECTION
Mott Macdonald Iselin, NJ	Project 2102438	April 2022 Fig. 4

PELLETIER, DAN \\geiconsultants.com\data\Data_Storage\Working\MOTT MACDONALD\2102438 DRBC Storage Options Study\00_CAD\Figures\2102438 - 10BG Design.dwg - 4/8/2022



PLAN VIEW

1" = 100'



SECTION C-C'

1" = 20'

NOTES:

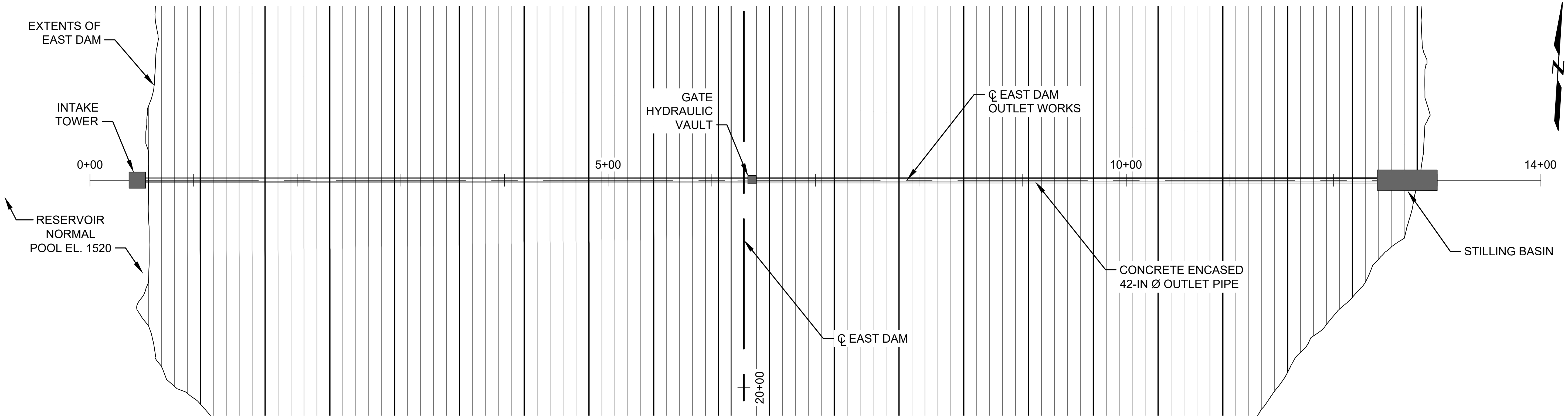
1. TOPOGRAPHY FROM USGS LIDAR (2017).
2. NORMAL POOL EL. 1520.

SOURCE:

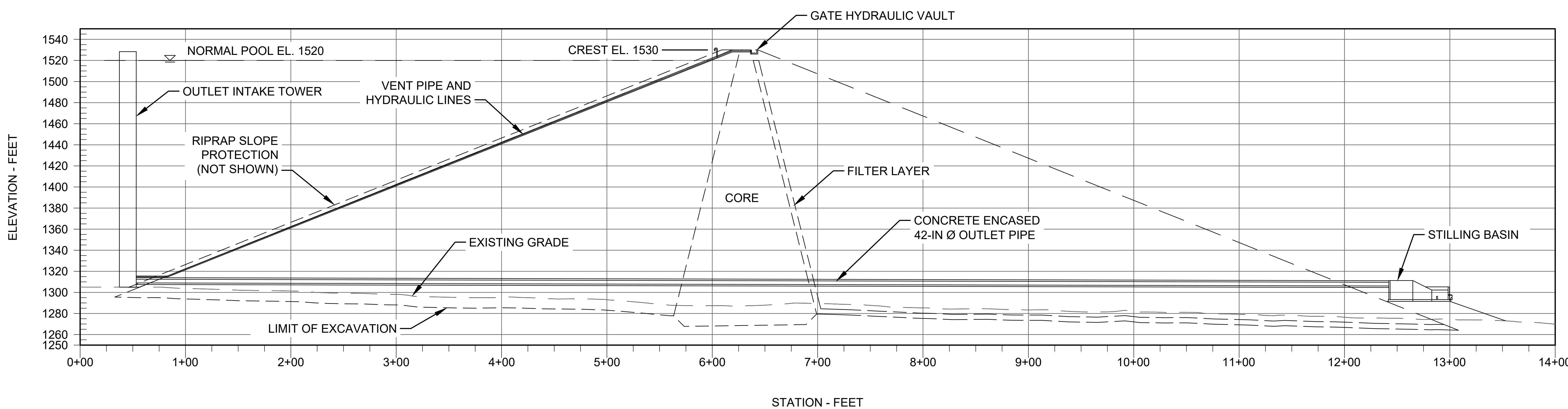
1. AERIAL IMAGERY: BING MAPS.

DRBC Storage Options Study Silver Creek Reservoir Blythe Twnship, Pennsylvania	GEI Consultants	WEST DIKE PLAN AND SECTION
Mott Macdonald Iselin, NJ	Project 2102438	April 2022 Fig. 5

PELLETIER, DAN \\geiconsultants.com\data\Data_Storage\Working\MOTT MACDONALD\2102438 DRBC Storage Options Study\00_CAD\Figures\2102438 - 10BG Design.dwg - 4/8/2022



OUTLET WORKS PLAN



OUTLET WORKS PROFILE

NOTES:

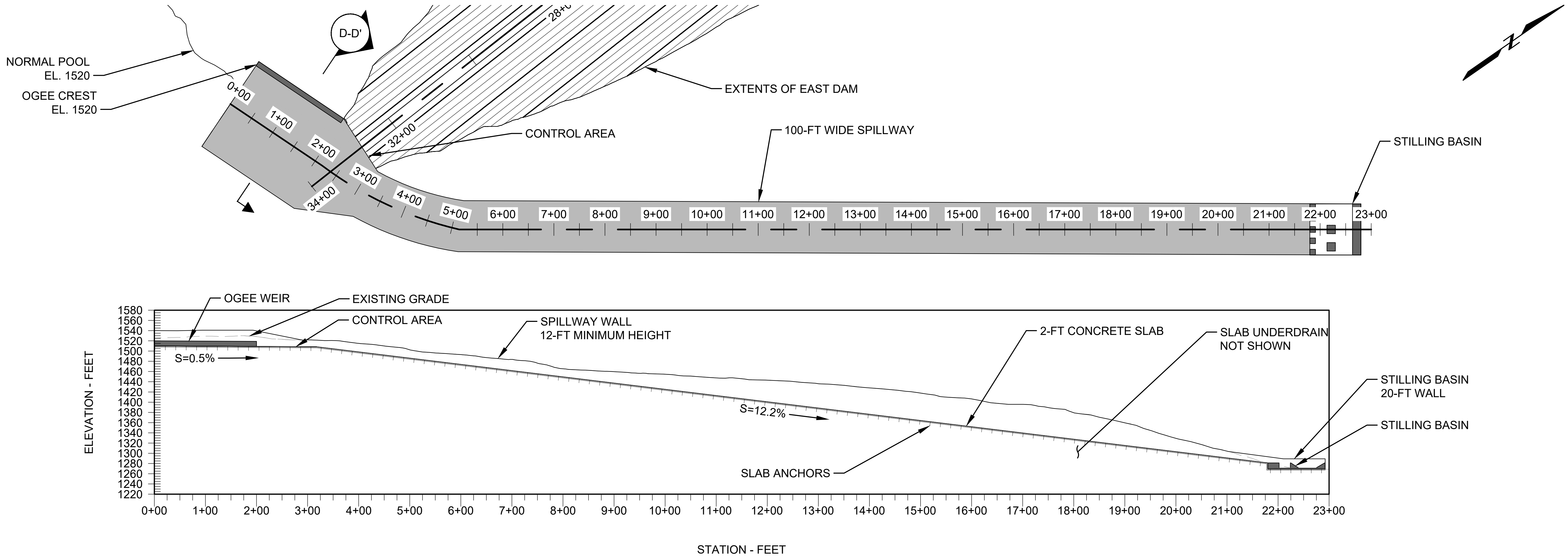
1. TOPOGRAPHY FROM USGS LIDAR (2017), NAVD88.

0 100 200

SCALE: 1" = 100'

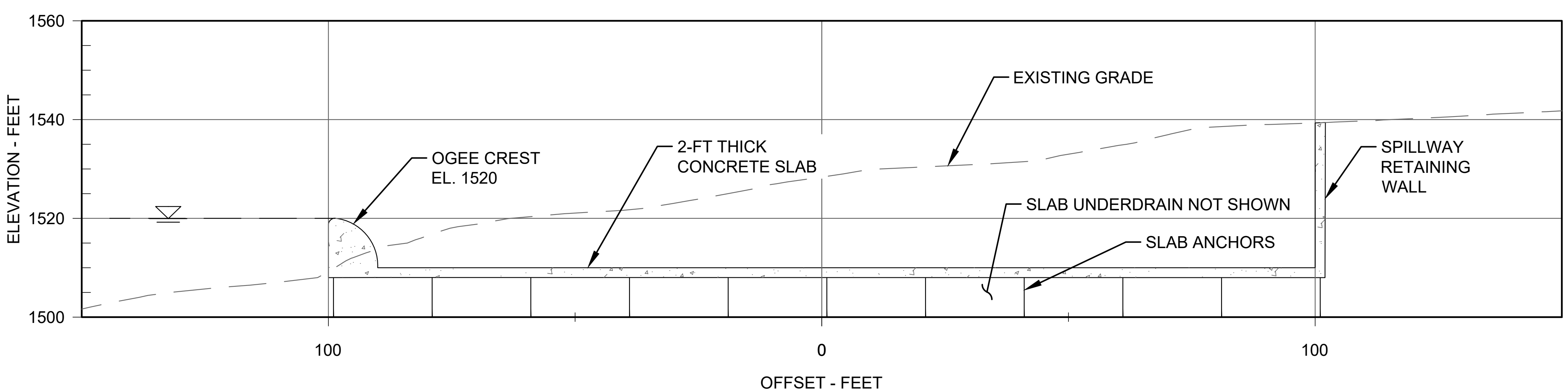
DRBC Storage Options Study Silver Creek Reservoir Blythe Twnshp, Pennsylvania	GEI Consultants	EAST DAM OUTLET WORKS PLAN AND PROFILE
Mott Macdonald Iselin, NJ	Project 2102438	April 2022 Fig. 6

PELLETIER, DAN B:\Working\MOTT MACDONALD\2102438 DRBC Storage Options Study\00_CAD\Figures\2102438 - 10BG Design.dwg - 5/10/2022



SPILLWAY PLAN & PROFILE

1"=200'



SPILLWAY SECTION D-D'

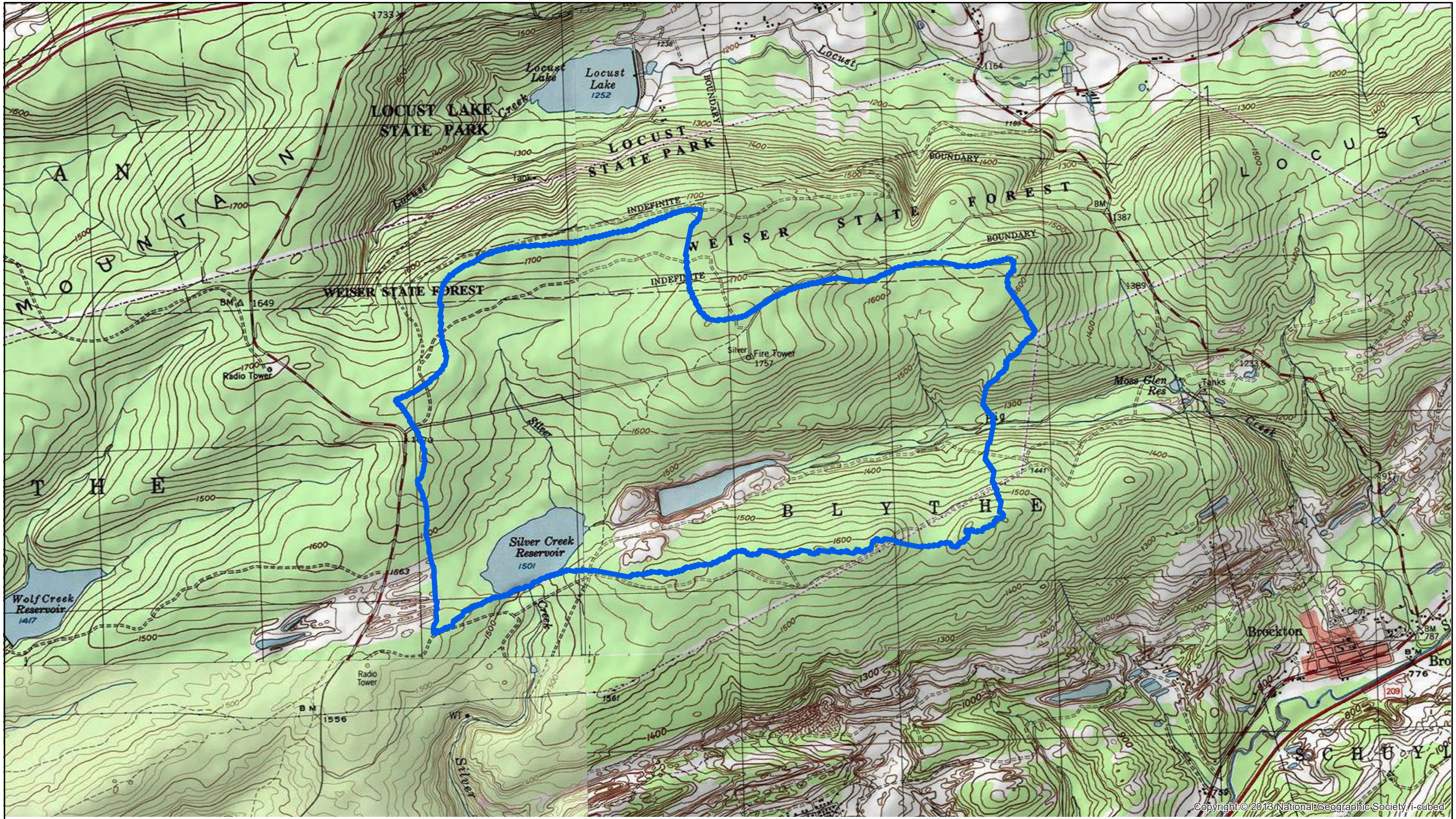
1"=30'

NOTES:

1. TOPOGRAPHY FROM USGS LIDAR (2017), NAVD88.

DRBC Storage Options Study Silver Creek Reservoir Blythe Twnshp, Pennsylvania	GEI Consultants	SPILLWAY PLAN AND PROFILE
Mott Macdonald Iselin, NJ	Project 2102438	April 2022 Fig. 7

PELLETIER, DAN B:\Working\MOTT MACDONALD\2102438 DRBC Storage Options Study\00_CAD\Figures\2102438 - 10BG Design.dwg - 5/10/2022



Legend

Proposed Reservoir Watershed Extents

0 0.25 0.5 1

Miles

DRBC Storage Options Study
Silver Creek Reservoir
Blythe Twnship, Pennsylvania

Mott Macdonald
Iselin, NJ

GEI Consultants

WATERSHED LIMITS

Project 2102438 | April 2022 | Fig. 8

\\geiconsultants.com\data\Data_Storage\Working\MOTT MACDONALD\2102438 DRBC Storage Options Study\00_CAD\Figures\Figure 8 -

MOTT MACDONALD

Storage Project Summary

Project: Wild Creek Dam Raise (E1)

Location: Carbon County and Monroe County, PA

Storage Type: Dam Raise

Est. Volume: 1 Billion Gallons

Score: 3.29

1 Project Overview

The Bethlehem Authority and the City of Bethlehem own/manage the Penn Forest and Wild Creek Reservoirs in the Lehigh River watershed as water supply reservoirs (Figure 1.1 – 1.4). The reservoirs are described in the DRBC Docket Surface Water Withdrawal and Impoundments D-1995-019 CP-2 (DRBC, 2022). This potential project involves raising the water level in Wild Creek by 10 feet to increase the storage volume by 1 BG. The dam crest and spillway would also be raised by 10 feet and the spillway would be widened, which would require significant excavation of bedrock.

The owner/operator typically maintain Wild Creek Reservoir at full capacity (i. e., at the spillway elevation) by adjusting the flow from Penn Forest reservoir into Wild Creek via a valve at the bottom outlet of Penn Forest. The potential project would deliver the stored volume when needed by adjusting the valve so that the water level in Wild Creek rises and discharges the required flow over the spillway and downstream, where it flows into Beltzville Reservoir. The DRBC already has agreements with the owner of Beltzville (Corps of Engineers) to release water when requested.

Figure 1.1: Project Location

Figure 1.2: Topographic map: Drainage area in red (22 sq miles). Wild Creek is the southern reservoir.

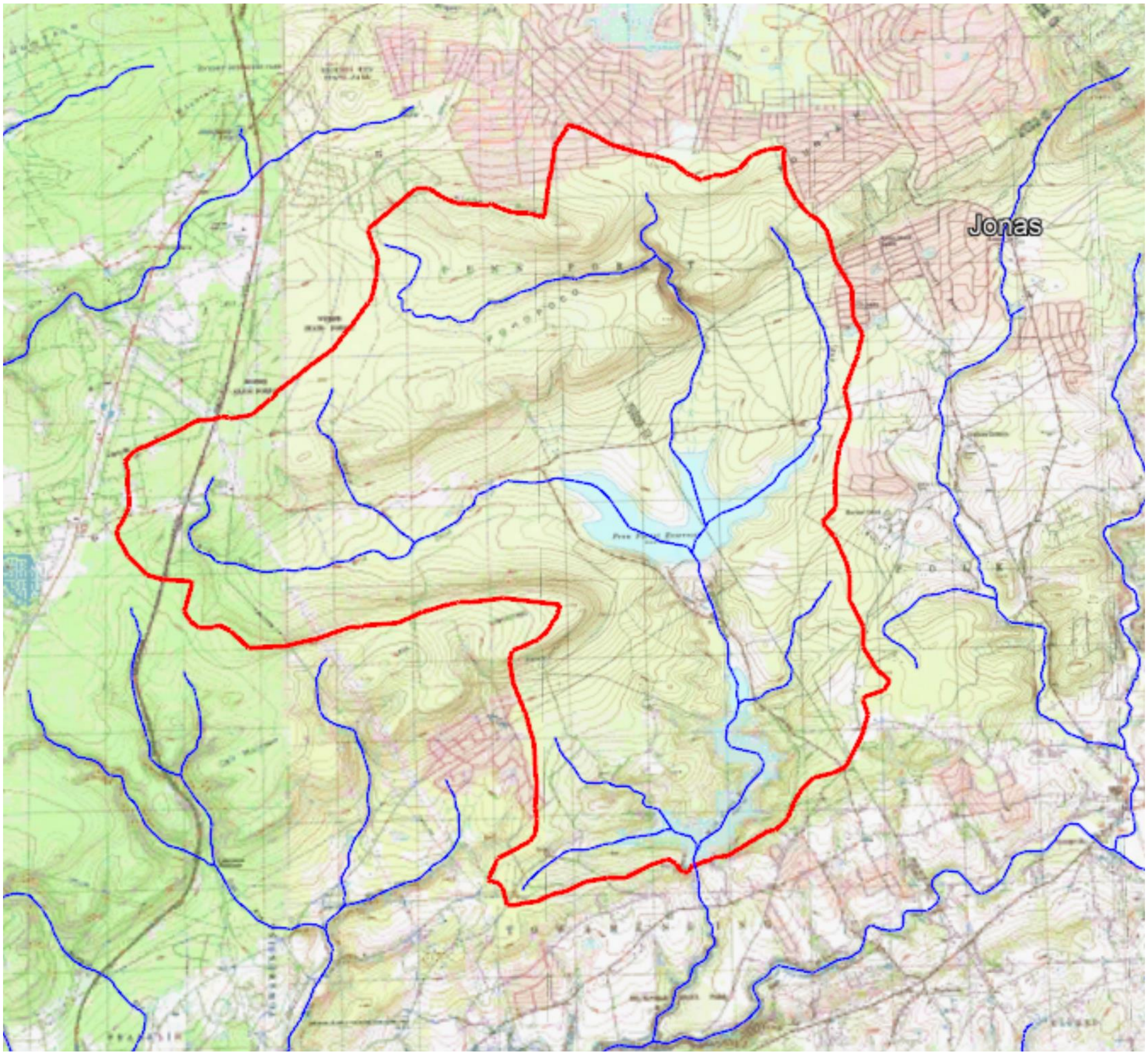


Figure 1.3: Aerial photo: Drainage area in red (22 sq miles). Wild Creek is the southern reservoir.

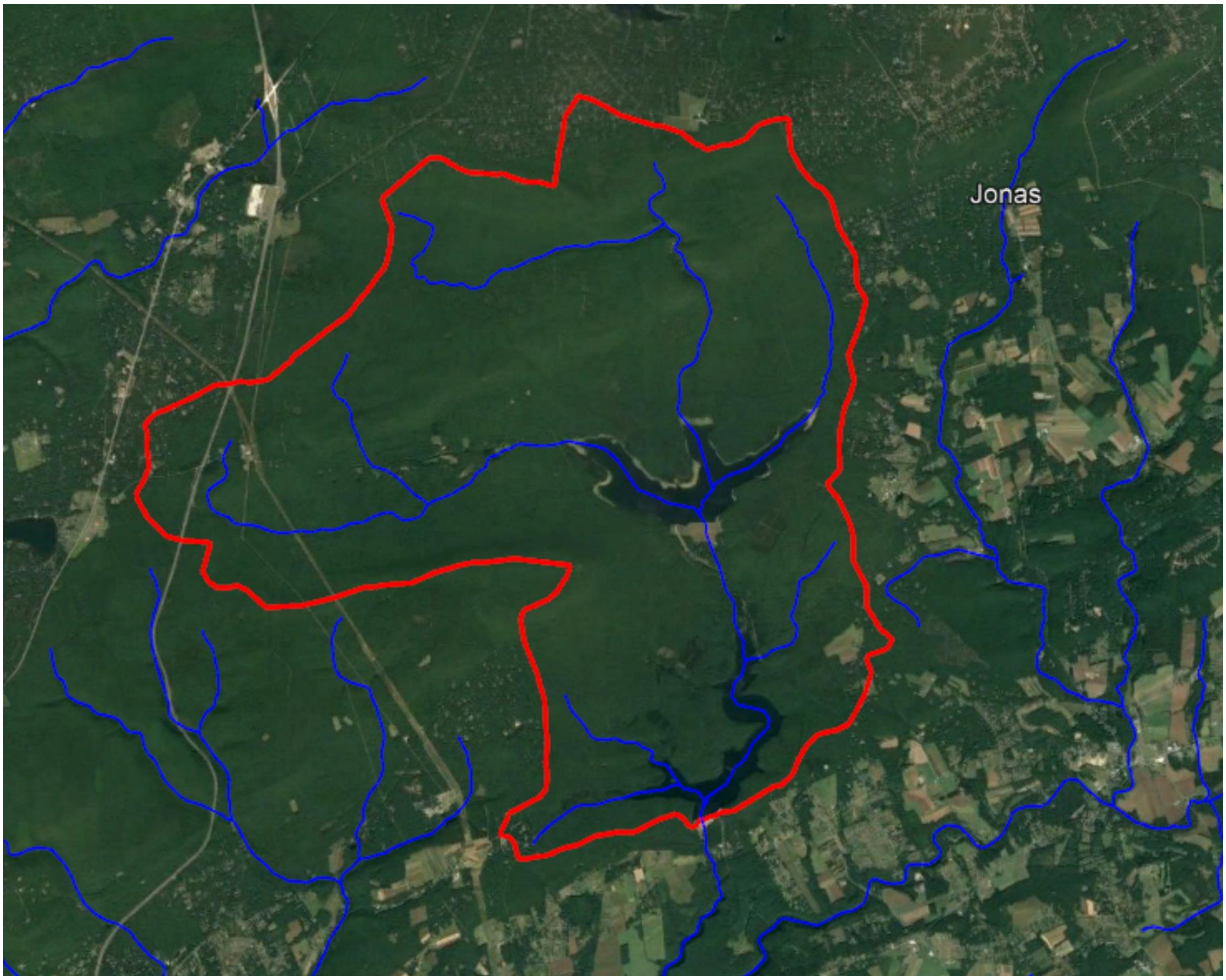


Figure 1.4: Oblique aerial photo of the Wild Creek dam looking upstream with the spillway on the left

Figure 1.5: Oblique aerial photo of the Wild Creek dam looking downstream with the spillway on the right

Figure 1.6: Looking up at spillway. (Source: PADEP, Wild Creek Dam Inspection Report, October 2021)

Figure 1.7: View of rock cliff at edge of spillway. (Source: PADEP, Wild Creek Dam Inspection Report. October 2021)

2 Water Quantity & Quality

2.1 Reservoir Storage Volume

Penn Forest and Wild Creek Reservoirs collectively hold 9.9 BG of water under normal conditions (15 BG under maximum conditions), with 6 BG in the former and 3.9 BG in the latter. Increasing the water volume in Wild Creek by 1 BG requires an increase in water surface elevation of 10 ft, from normal pool at 820 ft to 830 ft; the water surface area would increase by about 45 acres from 305 ac to 350 ac.

2.2 Fill and Discharge

The additional water would be supplied by natural drainage from the reservoirs' watershed. With an area of 22 square miles, the watershed supplies a mean flow of about 52 cfs, reaching 1 BG in about 1 month.

The owners typically maintain Wild Creek Reservoir at full capacity (i. e., the spillway elevation) by adjusting the flow from Penn Forest reservoir into Wild Creek via a valve at the bottom outlet of Penn Forest. The project would deliver the stored volume when needed by adjusting this valve so that the water level in Wild Creek rises and discharges the required flow over the spillway and downstream, where it flows into Beltzville Reservoir. The DRBC already has an agreement with the owners of Beltzville (Corps of Engineers) to release water when requested; this agreement might require renegotiation to account for extra volume from Wild Creek.

Given the expected water demand (15 MGD reported in the 2017 docket, with water usage trending downward) and the determined safe yield (≥ 18 MGD per Gannett Fleming Inc., 1995) there should always be sufficient volume in Penn Forest Reservoir to keep the water level in Wild Creek Reservoir at the spillway elevation.

As a backup method if the water level in Wild Creek drops below the spillway, the allocated storage could be released through a low-water outlet in the Wild Creek reservoir (which is rarely used now) or by diversion from the existing water supply conduit. However, the methods are likely not capable of delivering the desired flow rate of 100 cfs without significant modifications.

2.3 Water Quality

The water in Wild Creek reservoir is currently extracted for drinking water supply. Furthermore, the overflow from Wild Creek flows into Beltzville Reservoir, which the DRBC currently uses for flow augmentation. The US Army Corps of Engineers, which monitors Beltzville, reported "the trophic condition of Beltzville Reservoir was predominantly oligotrophic in 2021 (USACE 2021)." Therefore, for this project, water quality should be satisfactory to support flow augmentation.

3 Infrastructure Design, Construction & Operation

The Wild Creek Dam is an earthfill embankment dam originally constructed in 1941. The Bethlehem Authority provided drawings of the dam. The existing spillway elevation is 820 ft and the dam crest elevation is 835 ft. The existing dam would be raised by 10 ft to 845 ft, and the existing concrete spillway would similarly be raised and widened from about 42 ft to 105 ft and be extended in length approximately 200 ft. Key parameters of the raised dam are shown in Table 3.1. The proposed configuration is shown in Figure 3.1. Additional figures are presented in the Appendix.

The excavation required for the proposed spillway widening will provide a surplus of material. Assuming this surplus material can be processed and coordinated with the dam raise, there should be minimal need for import. The existing cross-section as shown on the original dam blueprints, shows a layer of rolled course fill. It is assumed this rolled course fill can be reused for the dam raise.

The downstream slope of the existing Wild Creek Dam would be excavated at a uniform 2 to 1 slope. The downstream slope would be over-excavated to a depth of 5-ft to create a keyway for the placement of the new dam material. The excavated material would be sorted and processed to maximize reuse. The new downstream slope of the dam would be placed at a constant 2.5 to 1 slope.

To handle the expected flows created by the expansion of the reservoir, the existing concrete spillway would be demolished and removed. Significant excavation into the hillside west of the existing spillway is required to create the footprint for the new 105 ft-wide spillway. The new spillway would to be graded to not exceed a 16% slope. Maintaining spillway capacity during construction would be challenging.

Foundation excavation was assumed to be 5 ft for the Wild Creek Dam raise. Actual embankment dam configurations and foundation preparation would be based on field investigations and engineering analyses during design.

It was assumed that the existing Wild Creek Dam can be raised. Wild Creek Dam is over 80 years old, and the dam condition and foundation conditions are unknown. The dam may need to be removed and reconstructed. The amount of siltation in the reservoir upstream of the dam is unknown. The existing grout curtain was assumed to be adequate for the dam raise, but further investigation is required. It was assumed that the existing concrete spillway can be removed and replaced with a wider footprint. This assumes the reservoir can be kept at a low pool to complete construction. No analysis was performed on the current intake at Wild Creek Reservoir; no changes are expected.

Figure 3.1: Proposed Configuration

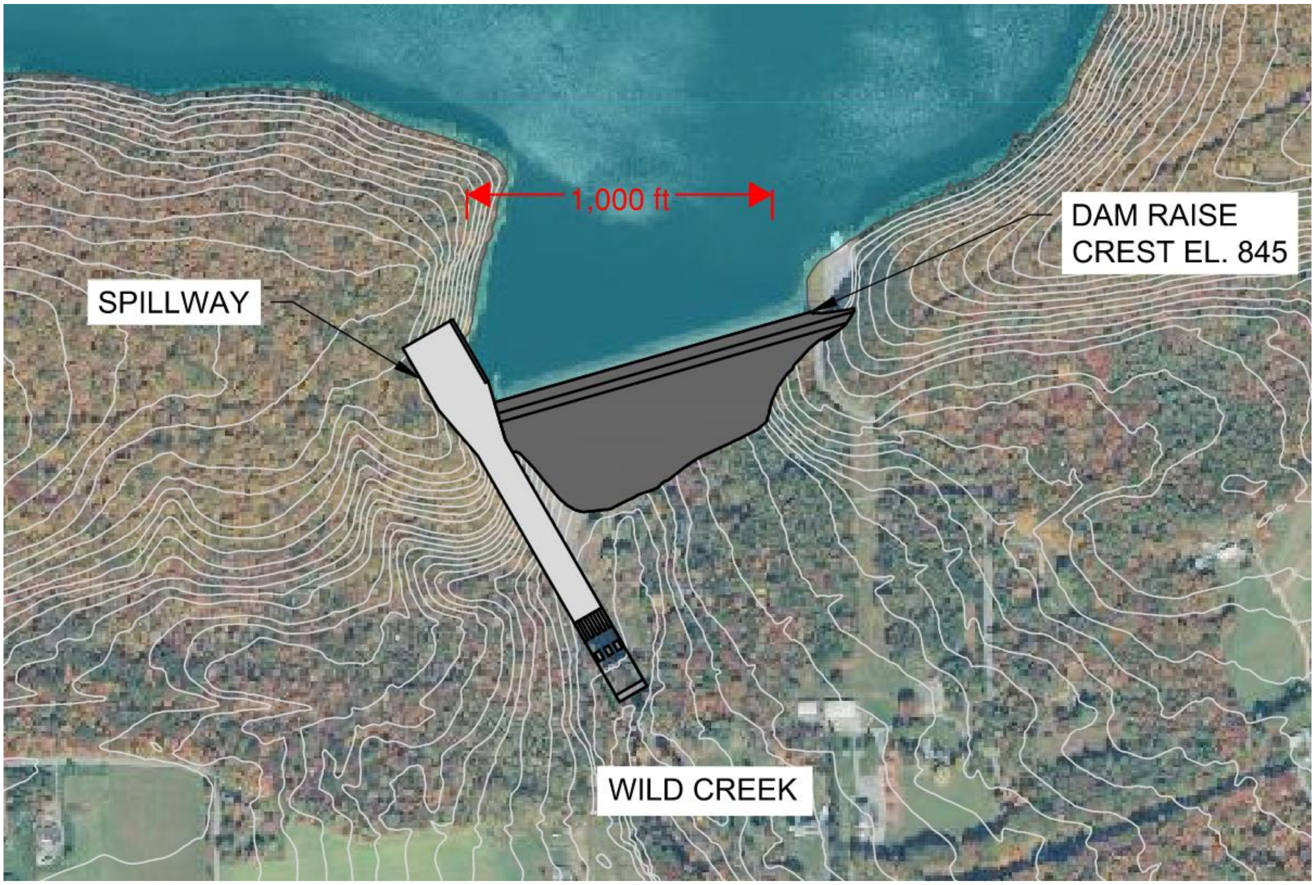


Table 3.1 Key parameters of raised dam and spillway

Dam	
Dam Type	Embankment
Dam Height (ft)	145
Dam Length (ft)	1,076
Dam Crest Width (ft)	30
Dam Crest El.	845
Upstream Slope	Variable
Downstream Slope	2.5 to 1
Drainage Tributary	Wild Creek
Low-Level Outlet	38-inch-diameter Steel Pipe
Intake Structure	Submerged, Reinforced Concrete
Spillway	
Spillway Type	Reinforced Open Channel
Reinforced Open Channel	
Spillway Type	Side Channel Uncontrolled Ogee
Spillway Elevation (ft)	830 ft
Spillway Width (ft)	190 / 105
Spillway Length (ft)	1,370
Spillway	Maximum Slope 16%
Estimated Inflow / Outflow	63,893 cfs / 49,837cfs
Spillway Discharge Capacity at El. 845 (dam crest)	50,513 cfs

4 Environmental Impacts

In general, raising a dam and subsequent water levels in a reservoir/impoundment, creating a larger lentic water body does not cause as much trauma to a naturally lotic system as when a new dam is constructed. However, the effects are more significant if the ecosystem was beginning to adapt to the permanent flooding.

The US Army Corps of Engineers in their Section 404 permitting process would consider the primary regulatory activity for a dam raise as placement of fill material in the water of the US at the dam expansion site. However, secondary effects result in significant environmental impact to a new lentic ecosystem that is attempting to repair itself. Human induced lentic systems (impoundments) are simplified aquatic ecosystems that can experience swings in climatic, biological, chemical, geological and often hydrologic conditions. A new impoundment creates a new baseline for the aquatic system that is very different than the lotic system it replaced. The more variable the conditions in the newly disturbed aquatic system, the more negatively impacted the habitat becomes, and the easier it is to come to a newly established baseline. However, if a waterbody, even a human-induced water body, experiences consistent conditions, a higher quality ecosystem will result and inhabited by organisms that are less adapted to changing conditions, less common and likely native. The food chain will be more stable, and the native species present at several levels of the food chain although perhaps a more simplified food chain than what originally existed. Waterbodies that are disturbed by fluctuating water levels, wide swings in temperature, oxygen and nutrient content, influx of non-native, invasive species often are simple ecosystems where only non-native generalist species can survive. Finally, impoundments without provision for migratory fish have significant effect on the native fishery, and migration ends with the obstruction. With a raised dam the opportunity is presented to restore fish migration by introducing a parallel bypass channel or a fish ladder.

All waters in the Commonwealth of Pennsylvania are protected for a designated aquatic life use as well as a number of water supply and recreational uses. The use designation shown in the water quality standards is the aquatic life use. These uses are Warm Water Fishes (WWF), Trout Stocking (TSF), Cold Water Fishes (CWF) and Migratory Fishes (MF).

In addition, streams with excellent water quality may be designated High Quality Waters (HQ) or Exceptional Value Waters (EV). The water quality in an HQ stream can be lowered only if a discharge is the result of necessary social or economic development, the water quality criteria are met, and all existing uses of the stream are protected. EV waters are to be protected at their existing quality; lowering water quality would not be authorized by the Commonwealth during a permitting process.

The Commonwealth of Pennsylvania requires that a water body be maintained at its current quality category and degradation caused by an activity in that water body would not be permitted. Therefore, transitioning from a smaller to a larger impoundment would likely not change the water quality category significantly, as would changing a flowing water body to a still water body, unless a parallel change in conditions accompanies the change in size.

When a waterbody is impounded in a watershed with low relief so that impoundment edges allow for growth of submerged and floating aquatic vegetation and if the littoral zone and riparian area is saturated so that wetland conditions result with growth of native wetland plants, a significantly valuable ecosystem is present. If this aquatic and wetland zone is present, deepening these vegetated edges results in elimination of the aquatic plant communities, a significant ecological loss can occur from raising impoundment elevation. However, if the impoundment has steep relief such that little wetland plant or aquatic plant communities develop along the edges or within the water body, increasing the elevation of the impoundment will have a much less significant affect.

In the case of Wild Creek, water quality designation of streams entering the current impoundment is Exceptional Value. More than ½ mile of EV streams would be impacted by deeper, lentic water which would increase temperature and change the character of the EV stream. The impoundment boundary would include high relief so likely no wetlands exist along the edges and likely limited aquatic vegetation is present. Therefore, likely only temporary impacts would occur to the impoundment itself.

Several listed species are present in this location. Coordination with the USFWS, the PA Game Commission and the PA Fish and Boat Commission would be required to know what species actually would be expected and if maternity colonies or hibernacula are present. Because the area is densely wooded, likely bat species would be prevalent. The federally listed Northeast Bulrush is also potentially present, so a study would be needed to determine if this plant, or other listed state plant species is located along the impoundment edges.

5 Social and Economic Impacts

Social and economic impacts are expected to be very minor. No residences, business or farms will be displaced. Small stretches of streams used for fishing would be inundated, but many miles of streams would remain.

6 Project Cost & Schedule

A feasibility-level (level 4) cost estimate for construction costs is presented in in Table 6.1 and Table 6.2 for overall costs. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) are reported in Table 6.3. Methods are described in the main report. Costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail.

Table 6.2 shows the overall cost (present value) is medium at $135M, but, because of the small volume provided (1 BG), the cost effectiveness is very poor at $135M/BG. The cost effectiveness might improve if the expansion was larger, but that could be infeasible because of destabilization of the dam.

Table 6.1: Construction Cost Summary

Description	Unit	Quantity	Rate	Total
1.0 Wild Creek Dam Raise				**$ 14,040,000**
1.1 Excavation	CY	156,000	$ 20.00	$ 3,120,000
1.2 Foundation Treatment/Grout Curtain	SF		$ 110.00	$ -
1.3 Embankment Fill	CY	335,000	$ 30.00	$ 10,050,000
1.4 Filter Material	CY		$ 90.00	$ -
1.5 Riprap	CY	3,600	$ 200.00	$ 720,000
1.6 Hydroseed	SF	300,000	$ 0.50	$ 150,000
2.0 Spillway Replacement				**$ 47,871,000**
2.1 Concrete Demolition	CY	40,000	$ 60.00	$ 2,400,000
2.2 Excavation	CY	450,000	$ 30.00	$ 13,500,000
2.3 Embankment Fill	CY	6,500	$ 30.00	$ 195,000
2.4 Reinforced Concrete Slab	CY	22,000	$ 850.00	$ 18,700,000
2.5 Spillway Walls	CY	2,000	$ 1,100.00	$ 2,200,000
2.6 Anchors	EA	370	$ 2,500.00	$ 925,000
2.7 Drainage Layer	CY	5,400	$ 90.00	$ 486,000
2.8 Drainage Pipes	LF	3,900	$ 100.00	$ 390,000
2.9 Stilling Basin (Slabs & Walls)	CY	9,000	$ 1,000.00	$ 9,000,000
2.10 Hydroseed Slopes	SF	150,000	$ 0.50	$ 75,000
3.0 Clear & Grub				**$ 1,014,000**
3.1 Timber Harvest	ACRE	78	$ 8,000.00	$ 624,000
3.2 Clearing & Grubbing	ACRE	78	$ 5,000.00	$ 390,000
4.0 Key Project Components Subtotal				**$ 62,925,000**
4.1 Sum 1.0 through 3.0				$ 62,925,000
5.0 Contractor Allowances				**$ 26,365,575**
5.1 Environmental Allowance: Rate x 4.0			2%	$ 1,258,500
5.2 Materials Testing (QA/QC): Rate x 4.0			2%	$ 1,258,500
5.3 Contractor Indirect Costs: Rate x 4.0			25%	$ 15,731,250
5.4 Profit: Rate x (4.0 + 5.1 + 5.2 + 5.3)			10%	$ 8,117,325
6.0 Contingencies				**$ 40,180,759**
6.1 Design Contingency: Rate x (4.0 + 5.0)			25%	$ 22,322,644
6.2 Construction Contingency: Rate x (4.0 + 5.0)			20%	$ 17,858,115
Conceptual Cost Estimate Total				**$ 129,471,334**

Table 6.2: Overall Cost Summary

Land acquisition cost ($)	0
Construction Cost ($)	130
Operating Cost ($/yr)	0.3
Overall Cost (Present value, $)	135
Cost effectiveness ($/BG)	135

The schedule for the project is also very rough. Because the dam and to-be-inundated land is controlled by the owner, this project is simpler than many others. However, permitting would still be lengthy. The estimated schedule is 10 years compared to 15 years on the new dam projects as shown below. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition.

- Funding acquisition 3 years
- Design, permitting and land acquisition 2 years
- Construction 3 years
- Startup 2 years
- Total 10 years

7 Potential Ancillary Benefits

Ancillary benefits are small. The slight expansion of the area of the reservoir would not provide a significant recreational benefit.

8 Storage Project Score

This site was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented below.

This site was scored as described in the main report and summarized in Table 8.1 below for the six primary criteria. Each primary criterion contained subcriteria which were scored on a 1 (worst) to 5 (best) scale and averaged. Scores on the primary criteria were weighted as shown in Table 8.1 and summed to obtain an overall weighted average score. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

The project scored high on criterion 1 (Water Quantity & Quality) despite scoring low on the volume subcriterion. It also scored high on criterion 4 (Social and Economic Impacts). It scored moderate on #5 (Project Cost & Schedule) despite its poor cost effectiveness.

Table 8.1: Storage Project Score

Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.00	30%	1.20
Infrastructure Design, Construction & Operation	2.80	10%	0.28
Environmental Impacts	3.50	15%	0.53
Social & Economic Impacts	4.89	10%	0.49
Project Cost & Schedule	2.50	30%	0.75
Ancillary Benefits	1.00	5%	0.05
AVERAGE	**3.11**		**3.29**

APPENDIX

Score Sheet

Drawings

Six primary criteria	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
1. Water quantity and quality		4.00			30%	1.20	
o Volume of storage provided (BG)	1	2					10 ft raise to get 1 BG
o Hydrologic reliability of supply (months to fill)	1	5					Mean inflow = 51cfs; Provides 1BG in 1 mo
o Release rate (cfs)	~50 cfs	5					discharges from Penn Forest thru spray valve, then from Wild Creek over spillway
o Promptness of delivery to mainstem (days)	~3	3					about 50 miles to mainsteam and must pass through Beltzville reservoir
o Geographic benefit		5					Enters via Lehigh River at Easton, PA, between Trenton and Montague
o Quality of stored water		4					
2. Infrastructure design, construction and operation		2.80			10%	0.28	
o Site/Civil, Land & Easements		5					
o Subsurface conditions		2					bedrock along existing spillway
o Infrastructure Complexity		3					
o Construction complexity		1					Must be careful to avoid damaging existing dam
o Operational complexity		3					must closely monitoring release rate from Penn Forest and water level in Wild Creek, and coordiate with Beltzville
3. Environmental impacts		3.50			15%	0.53	
o protected species		2					
o Water quality degradation of downstream waters		5					No additional impacts
o obstruction to passage of aquatic animals		5					No additional impacts
o hydromodification		5					No additional impacts
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o wetlands inundated or filled (ac)	<1	4	3	5			
o stream length inundated (mi)	0.7	1.5	1	2			about five short segments will be flooded; two are natural reproduction for trout, all exceptional value
o uplands inundated or developed (ac)	45	2	1	3			Pool increases from 305 ac to 350 ac, flooding about 45 ac; almost all is forest
4. Social and Economic Impacts		4.89			10%	0.49	
o Disruption/displacement		5					
o Safety and health		5					
o Social equity		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		4					
5. Project Costs & Schedule		2.50			30%	0.75	
o Land acquisition cost ($)	0						Assuming already owned by Bethlehem
o Construction Cost ($)	130						
o Operating Cost ($/yr)	0.3						
o Overall Cost ($)	135	2.5					
o Cost effectiveness ($/BG)	135	1					
o Schedule (Time to make Operational, years)	10	4					lots of complex issues with Corps projects
6. Ancillary Benefits		1.00			5%	0.05	
o Flood control		1					flood control benefit from larger pool
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		3.11			100%	3.29	

NOTES:
1. TOPOGRAPHY FROM USGS LIDAR (2011), NAD83

SOURCE:
1. AERIAL IMAGERY: BING MAPS

DRBC Storage Options Study Wild Creek Reservoir Towamensing Township, Pennsylvania	GEI Consultants	RESERVOIR EXPANSION PLAN
Mott MacDonald Iselin, NJ	Project 2102438	June 2022 Fig. 1

AVILA, JULIAN B:\Working\MOTT MACDONALD\2102438 DRBC Storage Options Study\00_CAD\Figures\Wild Creek\Wild Creek_Cover Sheet.dwg - 7/8/2022

PLAN VIEW
1" = 100'

SECTION A-A'
1" = 40'

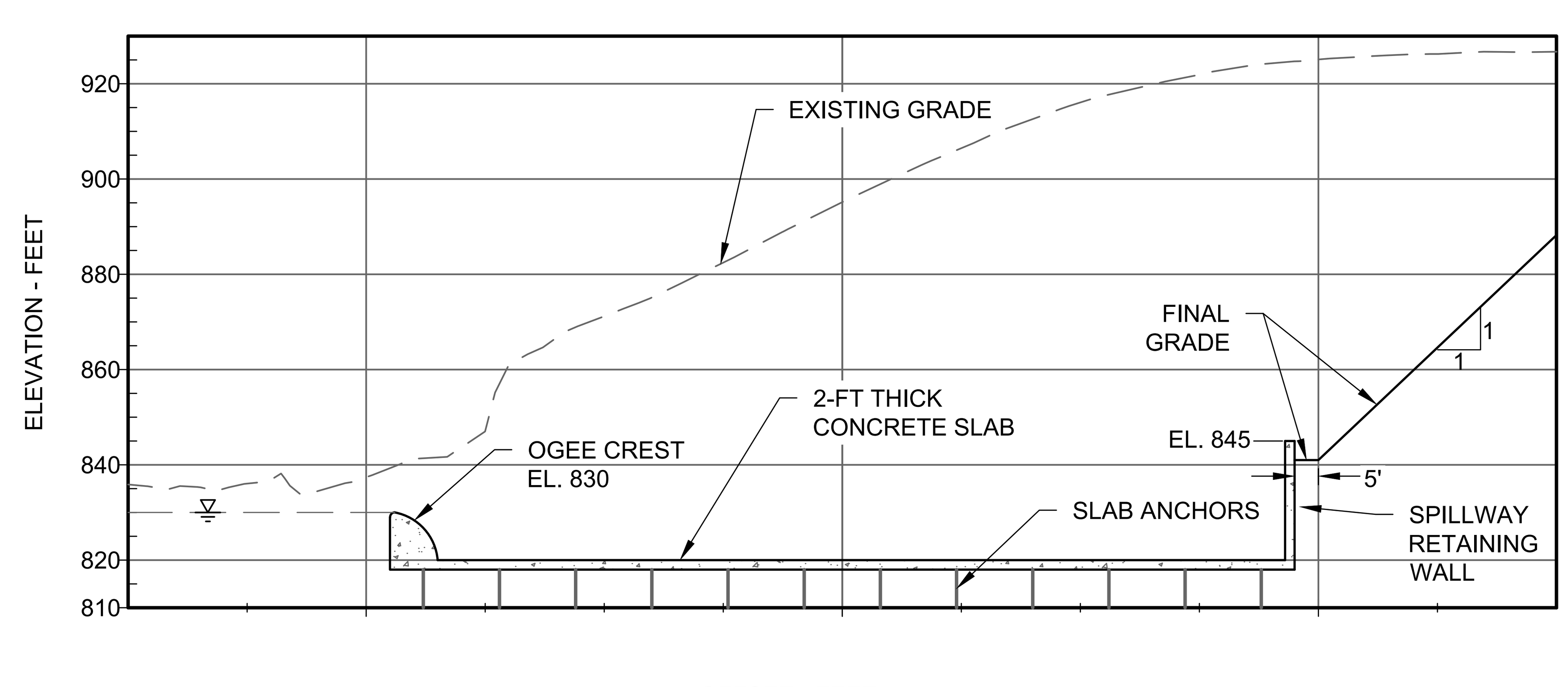
NOTES:
1. TOPOGRAPHY FROM USGS LIDAR (2011), NAD83.

SOURCE:
1. AERIAL IMAGERY: BING MAPS.

DRBC Storage Options Study Wild Creek Reservoir Towamensing Township, Pennsylvania	GEI Consultants	DAM RAISE PLAN AND SECTION
Mott Macdonald Iselin, NJ	Project 2102438	June 2022 Fig. 2

AVILA, JULIAN B:\Working\MOTT MACDONALD\2102438 DRBC Storage Options Study\00_CAD\Figures\Wild Creek\Wild Creek_Dam Plan and Section.dwg - 7/8/2022

SPILLWAY PLAN & PROFILE
1"=50'



SPILLWAY SECTION B-B'
1"=30'

NOTES:
1. TOPOGRAPHY FROM USGS LIDAR (2011),NAD83

DRBC Storage Options Study Wild Creek Reservoir Towamensing Township, Pennsylvania	GEI Consultants	SPILLWAY PLAN AND PROFILE
Mott MacDonald Iselin, NJ	Project 2102438	June 2022 Fig. 3

Storage Project Summary

Project:	**Cannonsville Reservoir Increase (E2)**
Location:	Delaware County, NY
Storage Type:	Storage increase
Est. Volume:	13 Billion Gallons
Score:	3.99

1 Project Overview

The Cannonsville Reservoir and Dam is located on the West Branch of the Delaware River in Delaware County, NY (Figure 1.1 to 1.5). It is owned by and serves as a water supply reservoir for New York City.

The potential project is to increase its storage volume by 13 BG by raising the water level 8 ft from elevation 1150 ft to elevation 1158 ft. This would be accomplished by installing movable gates on the existing spillway. The dam crest elevation would remain at 1175 feet, but a 3-ft parapet wall would be constructed on top of the dam to prevent wind-caused overflow. The proposed scheme is generally based on a previous study for the NY State Department of Environmental Conservation (Ebasco Services Inc., 1986). No significant changes to the outlet structure are proposed.

The raise would enlarge the pool footprint by about 760 acres. No buildings would be inundated but road sections would need to be elevated or relocated.

The project has an estimated cost of approximately $77M with a cost effectiveness of $6M/BG, which is by far the best of all the new dam, dam raise or storage transfer projects and the highest for any project providing over 5 BG.

Figure 1.1: Project Location

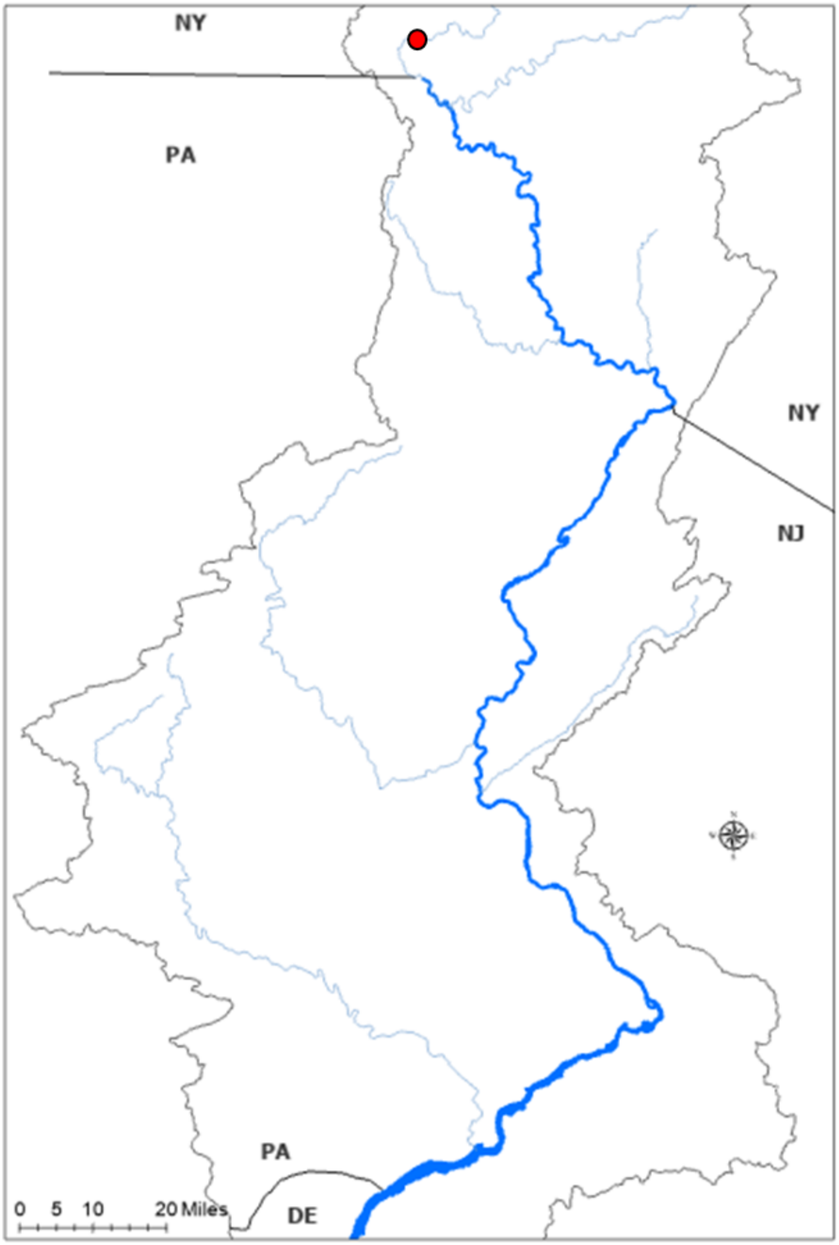


Figure 1.2: Topographic Map. Existing reservoir outlined in purple, drainage area in red (455 square miles)

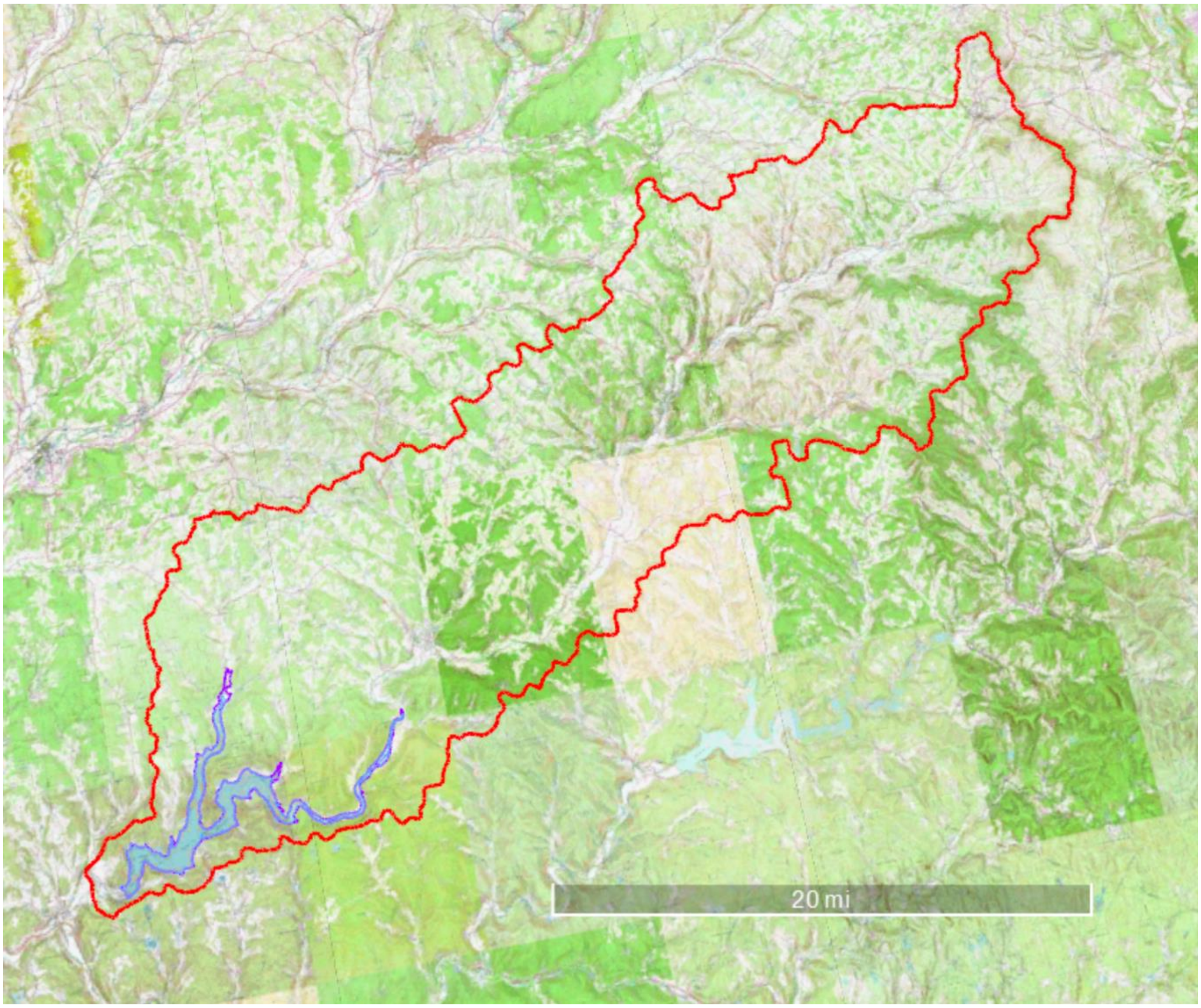


Figure 1.3: Aerial Photo. Existing reservoir outlined in purple, drainage area in red (455 square miles)

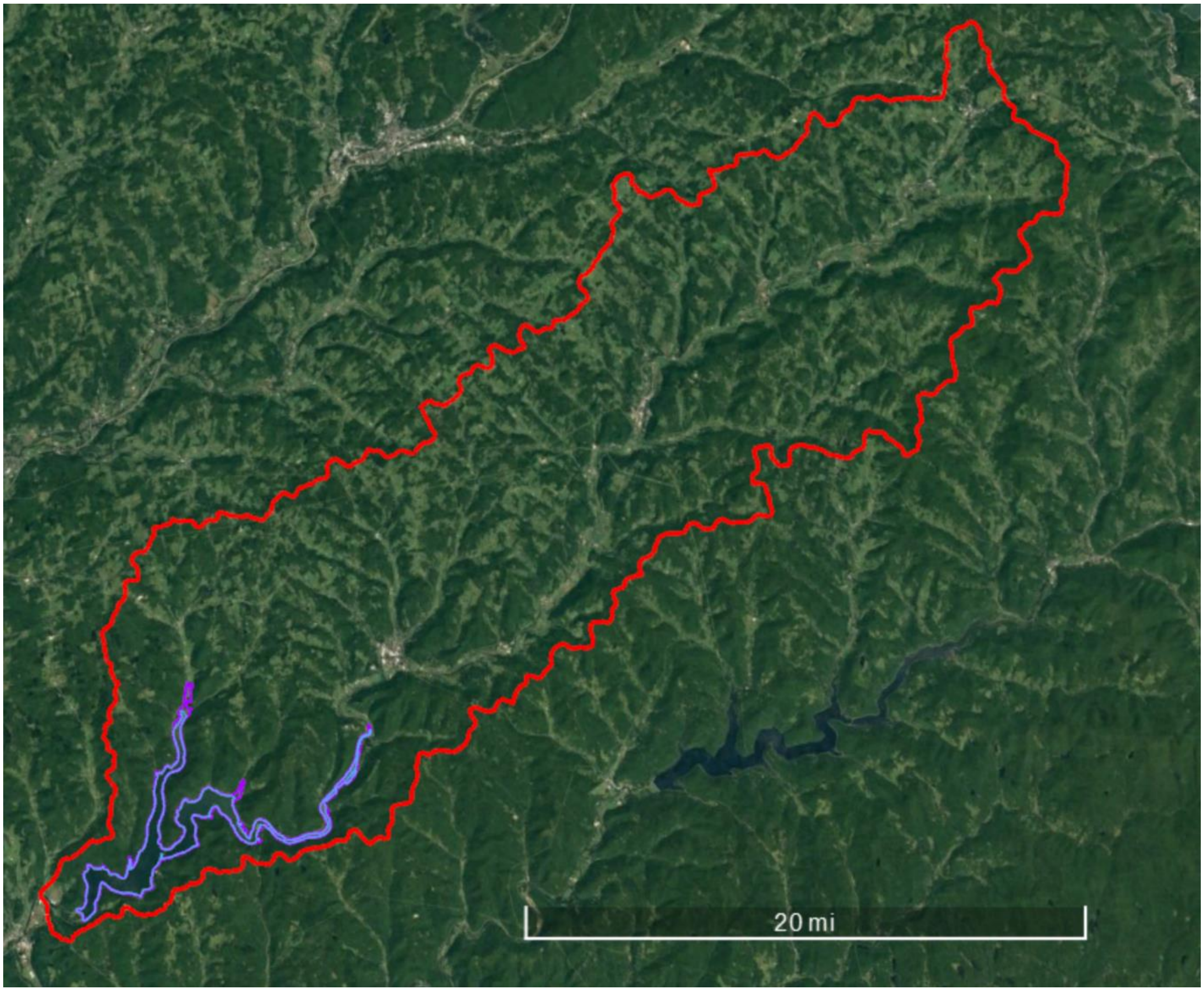


Figure 1.4: Aerial close-up of footprint of current reservoir in blue and expanded reservoir in purple

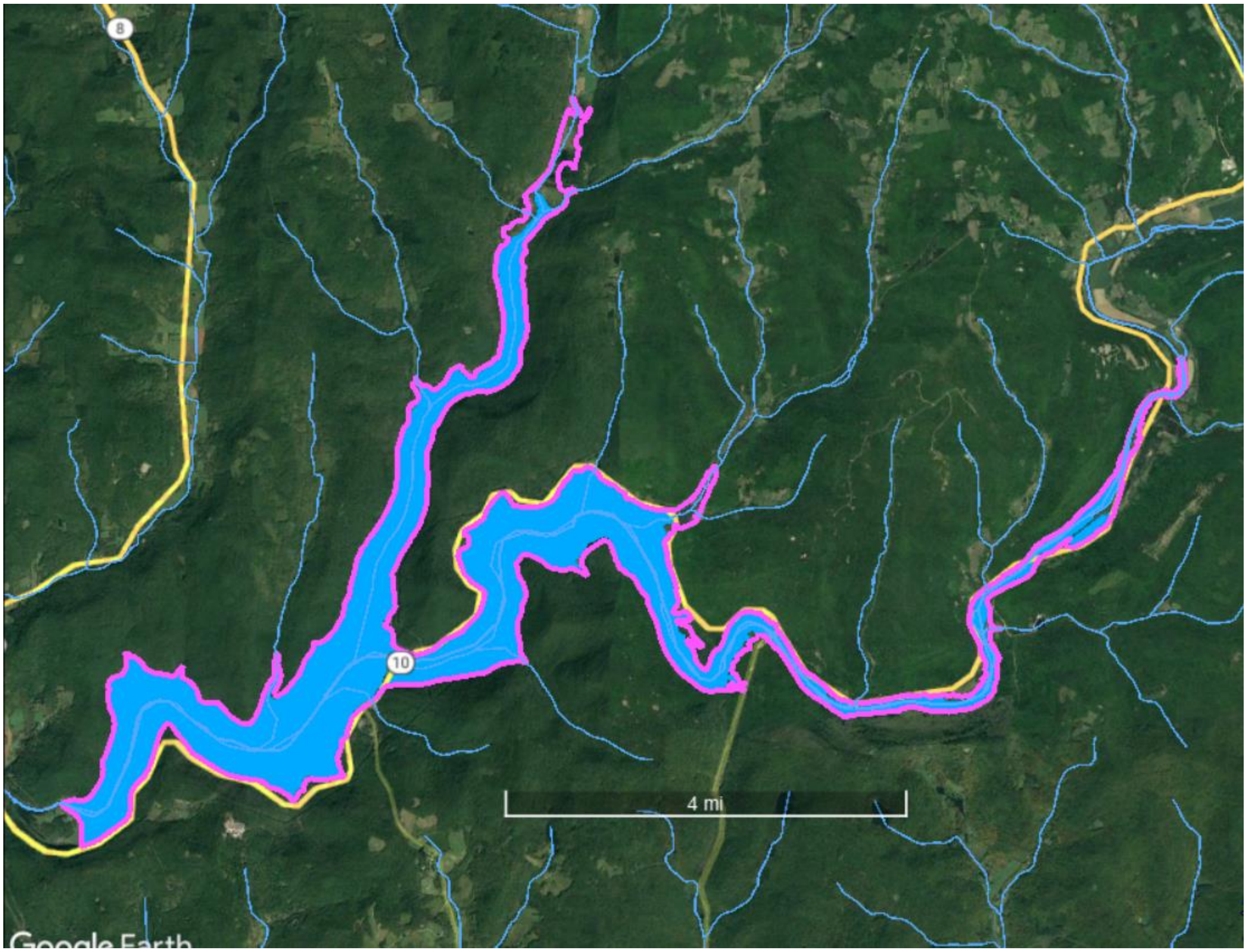


Figure 1.5: Aerial view of existing dam and spillway

2 Water Quantity & Quality

2.1 Reservoir Storage Volume

The reservoir currently holds 95.7 billion gallons (BG) when full. The dam raise adds 13 BG of storage through 8 ft of additional reservoir height. Additional storage is based on the concept expansion proposed by Ebasco Services in 1986 for New York State. Additional inundation around the reservoir is a concern that was studied by Ebasco.

2.2 Fill and Discharge

The additional 13 BG of volume would be supplied by the existing inflow, mainly the West Branch of the Delaware River. The reservoir has a drainage area of about 455 sq. mi. and a mean annual inflow of about 490 cfs, which would supply the 13 BG in about 1.4 months.

Water would be released through the existing outlet works; estimated design capacity was reported as 2400 cfs in a FERC application (NYCDEP, 2012, p 2). This capacity far exceeds the reported current maximum discharge of 1500 cfs, allowing large flow rates augmentation, possibly much greater than the minimum target flow rate of 100 cfs. The 13 BG could provide 100 cfs for about 200 days.

Releases from the Cannonsville Reservoir have a travel time of about 48 hours to reach the stream gage at Montague, NJ on the mainstem Delaware River. Fill and discharge methods are described further in Section 3 and the main report.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Properties

DESCRIPTION	VALUE
Storage	
Area (Acres)	4700 acres
Spillway elevation/ Normal reservoir water level	1150 ft.
Volume at spillway elevation (billion gallons)	96 BG
Water level increase	8 ft
Volume increase	13 BG
Inundated area increase	760 ac
Water Supply – Reservoir Fill	
Anticipated Source Stream	W. Branch Delaware River and tributaries
Anticipated Source Stream Drainage Area (Sq. Miles)	455 sq. mi.
Mean Annual Stream Flow Rate (ft3/s)	490 cfs
Water Release – Reservoir Discharge	
Capacity of low-level outlet works	1500 cfs
Water Supply – Travel to Use	
Stream Miles to Delaware River	0
Travel Time at 2 mph (hours)	5

2.3 Water Quality

The Cannonsville Reservoir historically experienced water quality problems due to excessive phosphorus loading from the agricultural areas of the watershed. However, efforts by NYC to manage the watershed above the reservoir have reduced phosphorus loads. In any case, the reservoir supplies drinking water to NYC and currently overflows into the Delaware River, so water quality is presumably suitable for flow augmentation. The minor increase in volume is not expected to noticeably affect water quality in the reservoir.

3 Infrastructure Design, Construction & Operation

3.1 Dam Raise and Spillway Modifications

The plan includes demolition and reconstruction of a portion of the existing concrete spillway (Figure 3.1 and 3.2). Adjacent to the reconstructed spillway is a new control building to house the operational gear for the new gates. No engineering plans were available on which to base the design of the dam raise or spillway modifications.

The existing dam is a zoned earthfill embankment dam originally placed in service in 1965. It has an upstream impervious zone with a downstream semi-pervious material. There are no filter zones or drains in the existing dam. No modifications to the dam are proposed but a 3-ft parapet wall would be constructed on top of the dam to prevent wind-caused splashing over the crest.

The existing spillway is adjacent to the dam, comprising an ogee-type concrete spillway with a low weir section (El. 1150) and a high weir section (El. 1158). The total spillway capacity is 19,910 cfs at 1158 ft msl and 194,400 cfs at 1172 ft msl.

A portion of the existing concrete spillway would be removed and replaced with a modified spillway to accommodate four 8-foot-high pelican type gates (Figure 3.3), each 110 foot-long with downstream operators and five-foot wide supporting piers. A total of 465-feet of existing spillway would be modified. Addition of a control building with backup generators and power pack is required. Ebasco recommended construction of an integrated new upstream reinforced concrete slab with a cut-off wall for added spillway stability.

Several minor improvements would be made within the existing dam structures to prevent water infiltration due to the higher operating level (emergency gate tower, water supply intake chamber and intake basement). Ebasco called for the existing pivot valve in the release water works to be replaced with a Poly-jet valve to increase outflow. Ebasco reported that modifications to the existing emergency gate tower and water supply intake structure are required to prevent flooding from the proposed dam raise (Ebasco Services 1986).

Minor modifications may be needed to a few bridges impacted by the water level raise. Some roads may need to be raise or relocated.

Figure 3.1: Overview of dam and spillway modifications

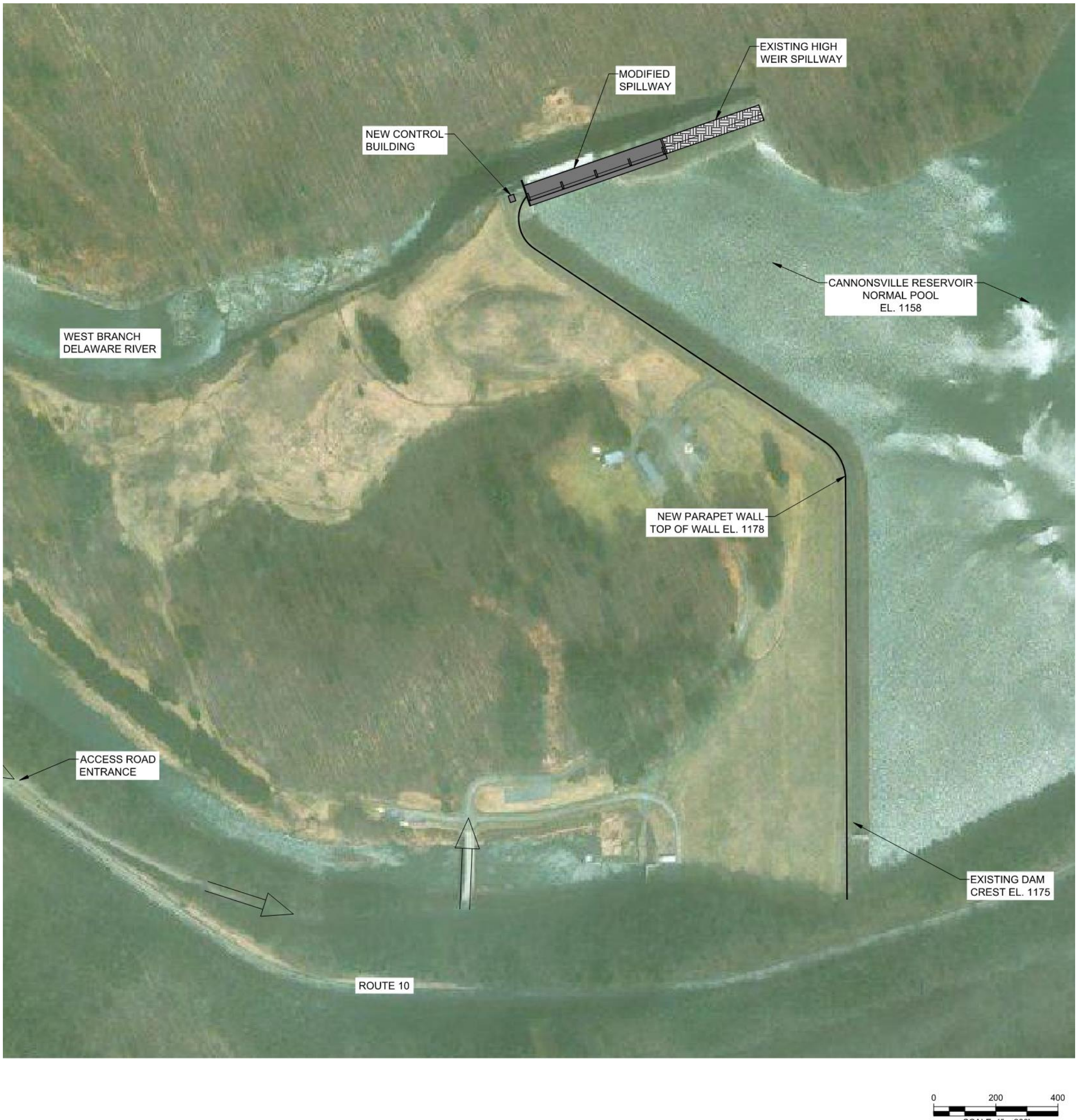


Figure 3.2: Detailed spillway modifications

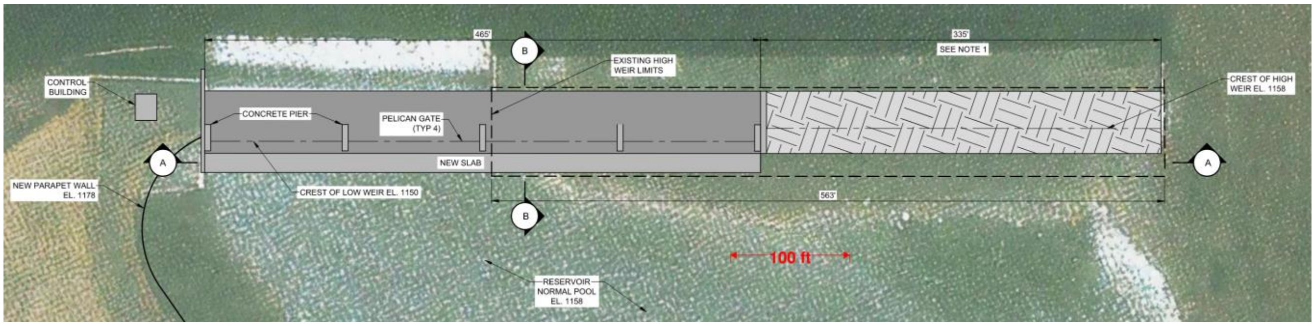
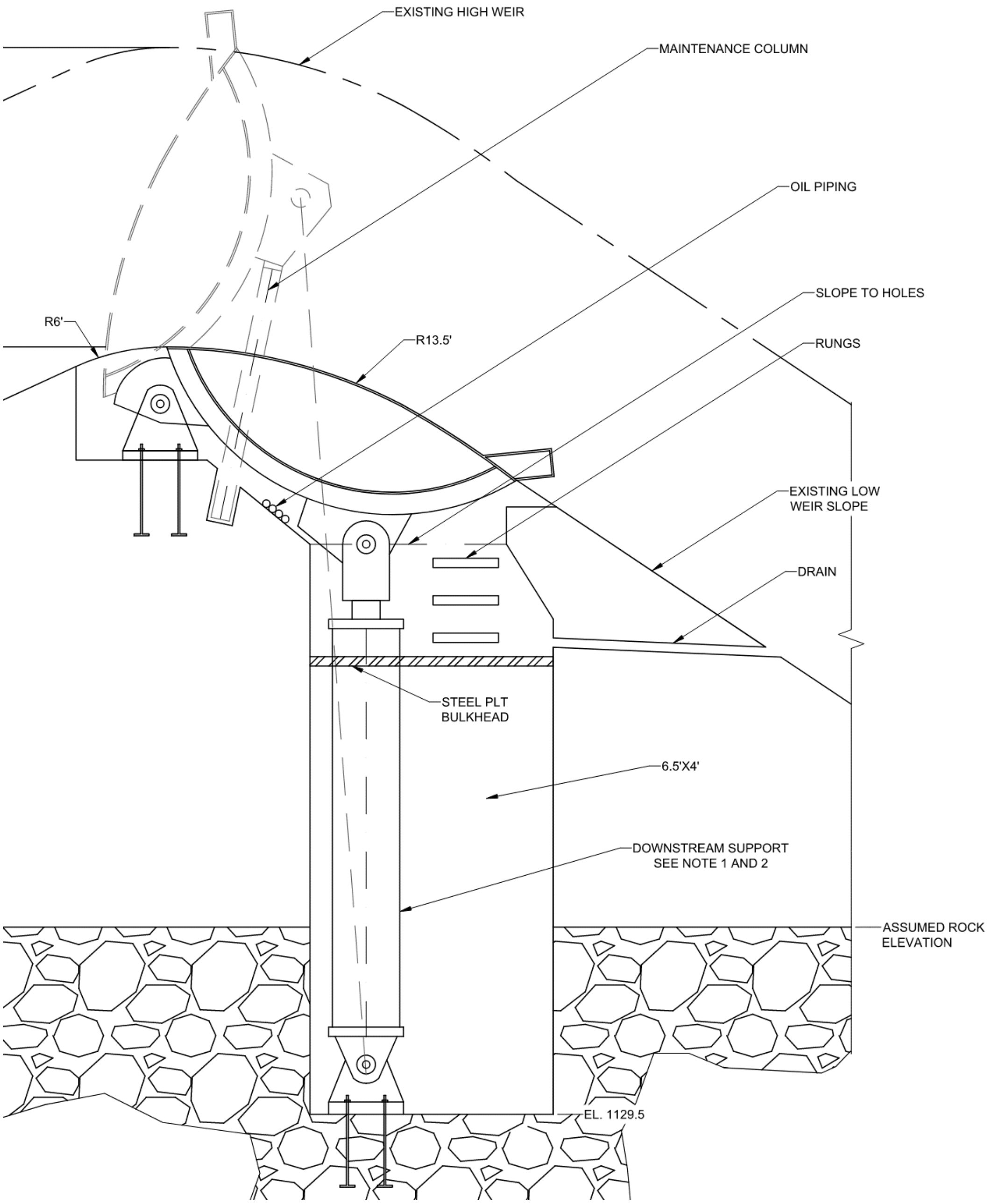


Figure 3.3: Spillway Cross-section with Proposed Gate System



3.2 Reservoir Releases

The estimated design capacity of the low-level release works was reported as 2400 cfs in the FERC application (NYCDEP, 2012, p 2), which far exceeds the reported current maximum discharge of 1500 cfs, allowing large flow rates for augmentation. Therefore, no modifications to the outlet are proposed.

The low-level release works in the Cannonsville Reservoir are described in the FERC application (NYCDEP, 2012, p 1) as follows:

> Low-level outlet release works are operated to convey flow to the West Branch of the Delaware River downstream of the dam and are located in a separate chamber at the south end of the dam. Discharges are made through a concrete intake structure at the upstream toe of the dam and then through a 17.5 foot diameter concrete diversion conduit that necks down to a 11.9-foot release water conduit. The invert elevation of the outlet works is at 999 feet above msl. The diversion conduit is located on the south side of the valley under the dam and was utilized to carry the river flow during dam construction. It is 1,280 feet long and terminates in a stilling pool that discharges into the river. A concrete plug was placed toward the end of construction to stop flow through this conduit at the gate tower. At this point, flow is diverted from the 17.5-foot-diameter conduit upward to an 11.9-foot-diameter release water conduit located immediately above it. A concrete gate tower rises above the diversion conduit through the embankment just upstream of the plug and just upstream of the dam centerline. Two Broome-type wheel gates, gate frames and guides were installed in the gate tower. These gates control water entering the release water conduit, which is constructed on top of the abandoned stream diversion conduit from the gate tower to the low-level release works. The release water conduit is an 11.9-foot-diameter cement mortar-lined steel pipe encased in reinforced concrete, which terminates in an 8.8-foot-diameter manifold. The manifold feeds five primary release lines, ranging in size from 54 to 60 inches in diameter and three smaller release lines, ranging in size from 12 to 18 inches in diameter. Flow control is achieved through selectively opening or closing various lines. Three primary release lines are each controlled by two dow pivot 60-inch valves. The other two primary release lines are each controlled by a dow-pivot valve and a polyjet valve. All lines terminate with an orifice plate downstream of the valves. Discharges are directed into a downstream stilling pool.

4 Environmental Impacts

The dam impounds both the West Branch of the Delaware River and Trout Creek, as well as several smaller tributaries. Based on the 1986 Ebasco report, there is potential for positive environmental impacts of the Cannonsville dam raise project including improvements in the quality of the cold-water fisheries resource downstream of the Reservoir particularly during drought-warning and drought periods. Elimination of daily discharge fluctuations through installation of a new valve was proposed to enhance habitat quality on the West Branch.

According to the Ebasco Report, inundation would result in loss of wildlife habitat. This study calculated 115 acres of wetlands located in mostly marshy areas in the upper delta reaches of incoming streams and 15,000 linear feet of stream would be inundated. Another 6400 acres of upland forested or agricultural lands would be inundated. According to the USFWS iPaC database the Indiana Bat may be present and removal of trees could remove swarming habitat and maternity roosts.

In general, raising a dam and subsequent water levels in a reservoir/impoundment, creates a larger lentic water body. Raising an impoundment does not cause as much trauma to the natural system as when a new dam is constructed across a flowing water body. Effects of an obstruction are far more impactful to a flowing waterbody than to a waterbody that has equilibrated to impounding by achieving an alternate ecological baseline. A newly impounded wetland and stream will adapt to permanent flooding although significant water quality degradation occurs and subsequently lower biodiversity in the aquatic ecosystem. Raising the water level of an aquatic system that is already impounded will further negatively impact that system, but the system will likely return to a similar baseline as when the first obstruction was installed.

The US Army Corps of Engineers in their Section 404 permitting process considers the primary regulatory activity for a dam raise as placement of fill material in the water of the US at the dam expansion site. However, secondary effects (impounding water) result in significant environmental impact. The new lentic ecosystem attempts repair, but water warms, organic material within the impoundment site decays and contributes significantly to eutrophication. Human induced lentic systems (impoundments) are simplified aquatic ecosystems that can experience swings in climatic, biological, chemical, geological and often hydrologic conditions. A new impoundment creates a new baseline for the aquatic ecosystem differing significantly from the lotic system it replaced. The more variable the conditions in the newly disturbed aquatic system, the more negatively impacted the habitat becomes, and the easier it is to come to the newly established baseline. However, if a waterbody, even a human-induced water body experiences consistent conditions, a higher quality ecosystem will result and be inhabited by organisms that are less adapted to changing conditions, less common and likely native. The food chain will be more stable, and the native species will be present at several levels of the food chain although perhaps a more simplified food chain than what originally existed. Waterbodies that are disturbed by fluctuating water levels, wide swings in temperature, oxygen and nutrient content, influx of non-native, invasive species often are simple ecosystems where only non-native generalist species can survive. Finally, impoundments without provision for migratory fish have significant effect on the native fishery, and natural fish migration ends with the obstruction. With a raised dam the opportunity is presented to restore fish migration by introducing a parallel bypass channel or a fish ladder.

All waters in New York State are protected for designated aquatic categories use as well as possible water supply and recreational uses. In New York State, the classification AA or A is assigned to waters used as a source of drinking water. Classification B indicates a best usage for swimming and other contact recreation, but not for drinking water. Classification C is for waters supporting fisheries and suitable for non-contact activities. The Cannonsville Reservoir and the incoming tributaries have been designated as Category A streams.

New York State requires that a water body be maintained at its current quality category and degradation caused by an activity in that water body would not be permitted. Therefore, transitioning from a smaller to a larger impoundment would not change the water quality category significantly, as would changing a flowing water body to a still water body, unless a parallel change in conditions accompanies the change in size.

When a waterbody is impounded in a watershed with low relief so that impoundment edges allow for growth of submerged and floating aquatic vegetation and if the littoral zone and riparian area is saturated so that wetland conditions result with growth of native wetland plants, a significantly valuable ecosystem is present. If this aquatic and wetland zone is present, deepening these vegetated edges results in elimination of the aquatic plant communities, a significant ecological loss can occur from raising impoundment elevation. However, if the impoundment has steep relief such that little wetland plant or aquatic plant communities develop along the edges or within the water body, increasing the elevation of the impoundment will have a much less significant affect.

In the case of Cannonsville Reservoir the state records a significant fishery consisting of Alewife, Brown Trout, Chain Pickerel, Common Carp, Longnose Sucker, White Sucker, Brown and Yellow Suckers, Small and Largemouth Bass, Black Crappie and Yellow Perch, to name a few. These species are mostly warm water fisheries, and many species are highly prized for sport fishing. Cannonsville Reservoir is also one of the four reservoirs in New York City’s water supply system

The USFWS indicates that the area around Cannonsville Reservoir may be habitat for the Indiana Bat, a species on the Endangered Species List. Indiana Bats prefer mature hardwood trees mixed with open areas and water bodies.

5 Social and Economic Impacts

Social and economic impacts are expected to be minor. The Cannonsville Reservoir and surrounding land is mostly owned by NYC. Measurements based on USGS topographic maps indicate the reservoir footprint at full pool will increase by about 815 ac (from 4700 ac to 5515 ac). In 1986, Ebasco estimated that the dam raise required 118 acres to be acquired, including 83 acres of prime agricultural land, but did not indicate where this land is located. Most of the land to be inundated sits above the upper reaches of the current reservoir on Trout Creek, Dryden Brook and the West Branch; none of this land appears to currently support agriculture.

The adjacent properties would only minimally be impacted during construction. In terms of considered sub-criteria (disruption, equity, safety, aesthetics, recreational impact, cultural/historical loss, taxes, and land disruption), this site scores favorably. No losses in aesthetics, equity, economy, or cultural resources are expected from the project. No buildings are within the expanded footprint of the normal pool, although a few buildings might need to be purchased or relocated because of increased flood risk due to the raise.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level (level 4) cost estimate for construction costs, as detailed in Table 6.1. Construction cost and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) are reported in Table 6.2. Costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail.

Table 6.2 shows the total cost estimate (present value) of $77M. Most of the land is presumed owned by NYC or NYS. Therefore, land acquisitions costs were assumed negligible, which, in any case, are very small compared to construction costs.

The cost effectiveness of $6M/BG is by far the best of all the new dam, dam raise or storage reallocation projects and the highest for any project providing over 5 BG.

Table 6.1: Construction Cost Summary

Description	Unit	Quantity	Rate	Total
1.0 Dam and Embankment Modification				**$ 16,195,000**
1.1 Demolition/Excavation	CY	7,750	$ 100	$ 775,000
1.2 Spillway Concrete	CY	4,650	$ 3,000	$ 13,950,000
1.3 Upstream Concrete	CY	370	$ 1,000	$ 370,000
1.4 CIP Parapet Wall	CY	1,100	$ 1,000	$ 1,100,000
2.0 Gates and Controls				**$ 14,350,000**
2.1 Pelican Gate (Purchase)	LS	1	$ 12,000,000	$ 12,000,000
2.2 Gate Installation	EA	4	$ 350,000	$ 1,400,000
2.3 Gate Testing	EA	4	$ 50,000	$ 200,000
2.4 Control Building	EA	1	$ 250,000	$ 250,000
2.5 Electrical Service (Permanent)	EA	1	$ 500,000	$ 500,000
3.0 Emergency Gate Tower Modification				**$ 10,294**
3.1 Emergency Gate Tower Modification	LS	1	$ 10,294	$ 10,294
4.0 Valve Modification				**$ 1,595,509**
4.1 Valve Modification	LS	1	$ 1,595,509	$ 1,595,509
5.0 Water Supply Intake Modification*				**$ 262,487**
5.1 Water Supply Intake Modification	LS	1	$ 262,487	$ 262,487
6.0 Bridges and Roads Modification				**$ 200,000**
6.1 Riprap	CY	1,000	$ 200	$ 200,000
7.0 Key Project Components Subtotal				**$ 32,613,290**
7.1 Sum 1.0 through 7.0				$ 32,613,290
8.0 Contractor Allowances				**$ 13,664,968**
8.1 Environmental Allowance: Rate x 7.0			2%	$ 652,266
8.2 Materials Testing (QA/QC): Rate x 7.0			2%	$ 652,266
8.3 Contractor Indirect Costs: Rate x 7.0			25%	$ 8,153,322
8.4 Profit: Rate x (7.0 + 8.1 + 8.2 + 8.3)			10%	$ 4,207,114
9.0 Contingencies				**$ 20,825,216**
9.1 Design Contingency: Rate x (7.0 + 8.0)			25%	$ 11,569,565
9.2 Construction Contingency: Rate x (7.0 + 8.0)			20%	$ 9,255,652
Conceptual Cost Estimate Total				**$ 67,103,475**

Table 6.2: Overall Cost Estimate Summary

Land acquisition cost ($)	0M
Construction Cost ($)	67M
Operating Cost ($/yr)	0.5M
Overall Cost (Present value, $)	77M
Cost effectiveness ($/BG)	6M

The schedule for the project is also very rough. Because the dam and to-be-inundated land is controlled by the owner or other public agency, this potential project is simpler than many others. However, permitting would still be lengthy and resident concerns could complicate matters. Time to completion is estimated at 10 years as shown below. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition.

- Funding acquisition 3 years
- Design, permitting and land acquisition 2 years
- Construction 3 years
- Startup 2 years
- Total 10 years

7 Potential Ancillary Benefits

If the gates could be raised and the additional storage evacuated before a forecasted storm, then the project could provide significant benefit regarding flood protection. In any case, the increase in the pool area would provide some additional storage of flood flows and attenuation of peak outflow.

The small increase in the size of the reservoir would not significantly increase recreational opportunities or fish/wildlife habitat.

8 Storage Project Score

The Cannonsville Reservoir expansion project was scored relative to the criteria presented in the main report. Summary categories and scores are presented in Table 8.1 below. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

The project scored the highest of all new dam or dam raise options. The project scored very well on water quantity/quality and social/economic impacts, reflecting the large (13 BG) potential storage volume and lack of impacted residences and infrastructure. It also scored well on cost: the construction cost is much lower than all new dams (while providing more or equal volume to five of the seven), but the cost is still substantial at $77M.

While the project scored poorly on ancillary benefits overall, if it can be operated to provide flood control, the benefit could be substantial and may engender support from downstream residents.

Table 8.1: Storage Project Score

Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.67	30%	1.40
Infrastructure Design, Construction & Operation	3.60	10%	0.36
Environmental Impacts	3.21	15%	0.48
Social & Economic Impacts	4.89	10%	0.49
Project Cost & Schedule	4.00	30%	1.20
Ancillary Benefits	1.20	5%	0.06
AVERAGE	**3.59**		**3.99**

Appendix

Summary of Key Information from 1986 Feasibility Study (Ebasco Services Inc., 1986)

Score Sheet

Summary of Key Information from 1986 Feasibility Study (Ebasco Services Inc., 1986).

CANNONSVILLE DAM

SUMMARY OF PRESENT FEATURES

Dam:

Type: Zoned earthfill embankment
Side Slopes: 1.5:1 to 3:1
Height: 175 ft.
Top width: 45 ft.
Length: 2800 ft.
Crest elevation: 1175 ft. MSL

Reservoir:

Drainage area: 456 sq. mi.
Name of stream: West Branch Delaware River
Volume: 300,000 acre-feet at 1150 ft. MSL
Surface area: 4800 acres at 1150 ft. MSL

Spillway

Type: Split weir with side channel
Low Level: Crest el. 1150 ft. MSL
Width: 240 ft.
Shape: ogee
Discharge coefficient: varies

High Level: Crest el. 1158 ft. MSL
Width: 560 ft.
Shape: broad-crested
Discharge coefficient: 3.09

Total capacity: 19,910 cfs at el. 1158
194,400 cfs at el. 1172

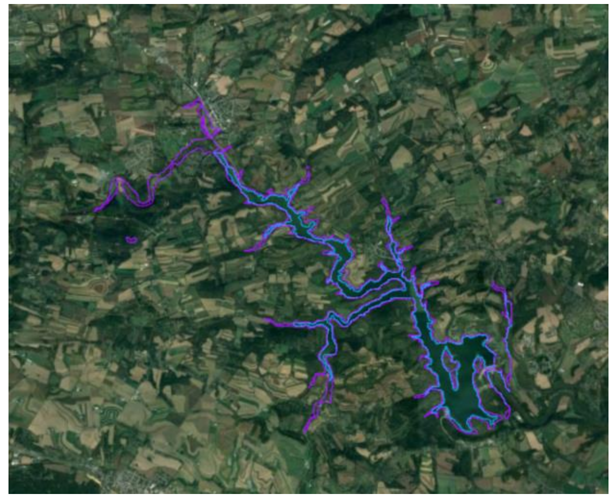
Low-Level Release Works

Main conduit: Diameter 11 ft. 11 inches
Length 1350 feet
Conduits: 5 ranging from 54 to 72 inches in diameter
3 ranging from 12 to 18 inches in diameter
Pivot valves
Capacity: 45 to 2500 cfs
Upstream invert: 1007.24 ft. MSL
Downstream invert: 1000.5 ft. MSL

Six primary criteria	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
1. Water quantity and quality		4.67			30%	1.40	
o Volume of storage provided (BG)	13	4					
o Hydrologic reliability of supply (months to fill)	1	5					Mean inflow = 480 cfs; providees 13 BG in <2 months
o Release rate (cfs)	?	5					
o Promptness of delivery to mainstem (days)	<1	5					
o Geographic benefit		4					
o Quality of stored water		5					
2. Infrastructure design, construction and operation		3.60			10%	0.36	
o Site/Civil, Land & Easements		5					
o Subsurface conditions		5					
o Infrastructure Complexity		3					
o Construction complexity		3					
o Operational complexity		2					
3. Environmental impacts		3.21			15%	0.48	
o protected species		2					Possible impact to Indiana bat
o Water quality degradation of downstream waters		5					No additional impacts
o obstruction to passage of aquatic animals		5					No additional impacts
o hydromodification		5					No significant impacts
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o wetlands inundated or filled (ac)	115	2.5	4	1			
o stream length inundated (mi)	3	1.5	2	1			Class A streamed based only on drinking water source
o uplands inundated or developed (ac)	640	1.5	2	1			
4. Social and Economic Impacts		4.89			10%	0.49	
o Disruption/displacement		5					
o Safety and health		5					
o Social equity/environmental justice		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		4					
5. Project Costs & Schedule		4.00			30%	1.20	
o Land acquisition cost ($)	0.M						Assumes all land already owned or aquired at no cost
o Construction Cost ($)	67M						Not including any bridge/road raises needed
o Operating Cost ($/yr)	0.5M						Higher than other dams because of the moveable gates
o Overall Cost ($)	77M	3					
o Cost effectiveness ($/BG)	6M	5					
o Schedule (Time to make Operational, years)	10	4					
6. Ancillary Benefits		1.20			5%	0.06	
o Flood control		2					flood control benefit from larger pool
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		3.59			100%	3.99	

Storage Project Summary

Project:	**Blue Marsh Dam Raise (E3)**
Location:	Berks County, PA, near Reading
Storage Type:	Modification to existing reservoir
Est. Volume:	5 BG increase
Score:	3.19



1 Project Overview

This potential project involves raising the Blue Marsh dam and increasing water level in its reservoir to create 5 BG of additional storage at normal pool. The dam sits on Tulpehocken Creek about six miles northwest of Reading in Berks County, PA (Figure 1.1). The reservoir stretches an additional five miles generally northwest along Rt 183 to Bernville (Figure 1.2 and 1.3). The dam/reservoir is a multi-purpose project built and operated by the U.S. Army Corps of Engineers, completed in 1979, with no major modifications since. See the project web page for more information.

The main dam and spillway are shown in Figure 1.4. There are three saddle dams noted in Figure 1.5 below (dikes A, B and C) plus another dike at the upstream end of the reservoir in Bernville that would also need to be raised. No modifications to the intake or outlet are expected.

A 5 BG (~15,000 ac ft) increase in summer storage requires a ~12-foot increase in water level from 290' to 302', which would increase the pool footprint by about 580 acres, from 1170 acres to 1750 acres (Figure 1.6). The water level is currently maintained well below the spillway elevation to provide flood storage.

Expanding the reservoir would flood about 10 private residences at the new spillway elevation of 314 ft. To avoid a higher flood risk under the raised condition, about 7 miles of roads and about 20 bridges would need to be raised (Figure 1.6), which would be very disruptive. Raising the Bernville dike may also be very disruptive, especially because a section of Route 183 may need to be relocated.

The DRBC already owns storage in Blue Marsh and can request its release to combat drought. As such, while raising the dam has it challenges, the potential project is a proven model.

Tulpehocken Creek flows into the Schuylkill River which meets the Delaware River in Philadelphia, so the upper/middle Delaware River will not benefit from the project, but the flow will help repel the salt front.

Modifying dams owned by the US Army Corps of Engineers requires a difficult and lengthy permitting process. Therefore, completion of this project would take at least 20 years – or more, if complications arise.

Figure 1.1: Project location

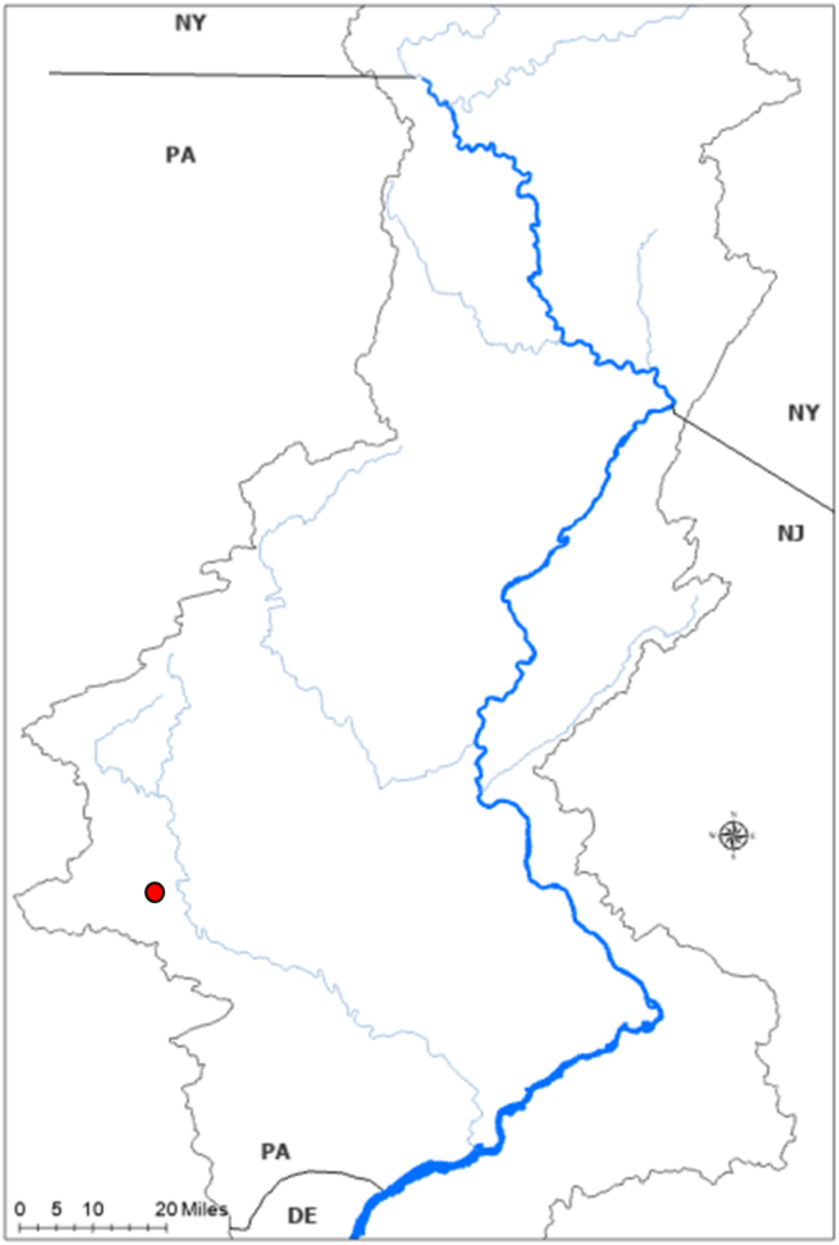


Figure 1.2: Topographic map: potential reservoir footprint in purple and drainage area in red (179 sq miles).

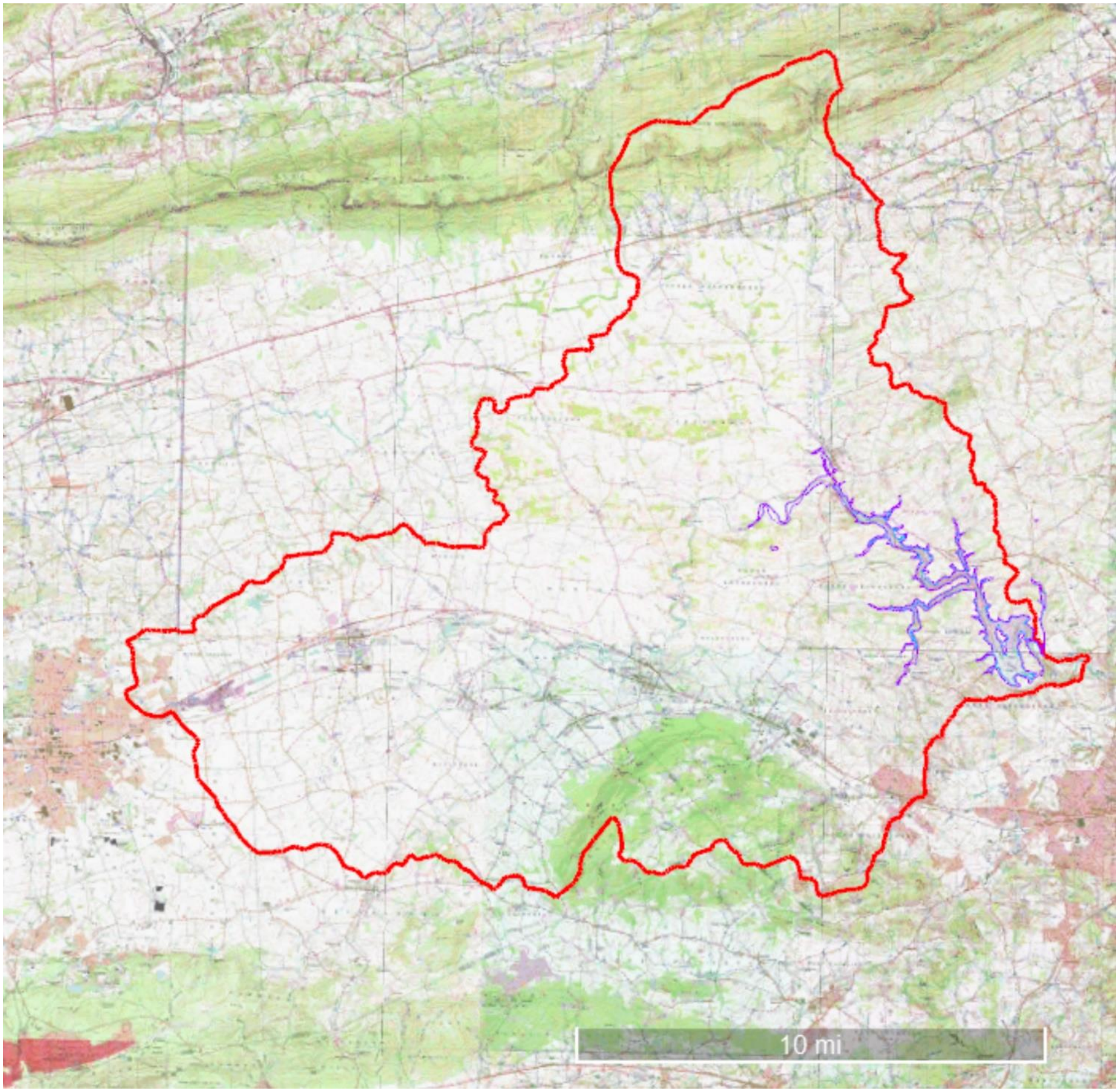


Figure 1.3: Aerial photo potential reservoir footprint in purple, and drainage area in red (179 sq miles).

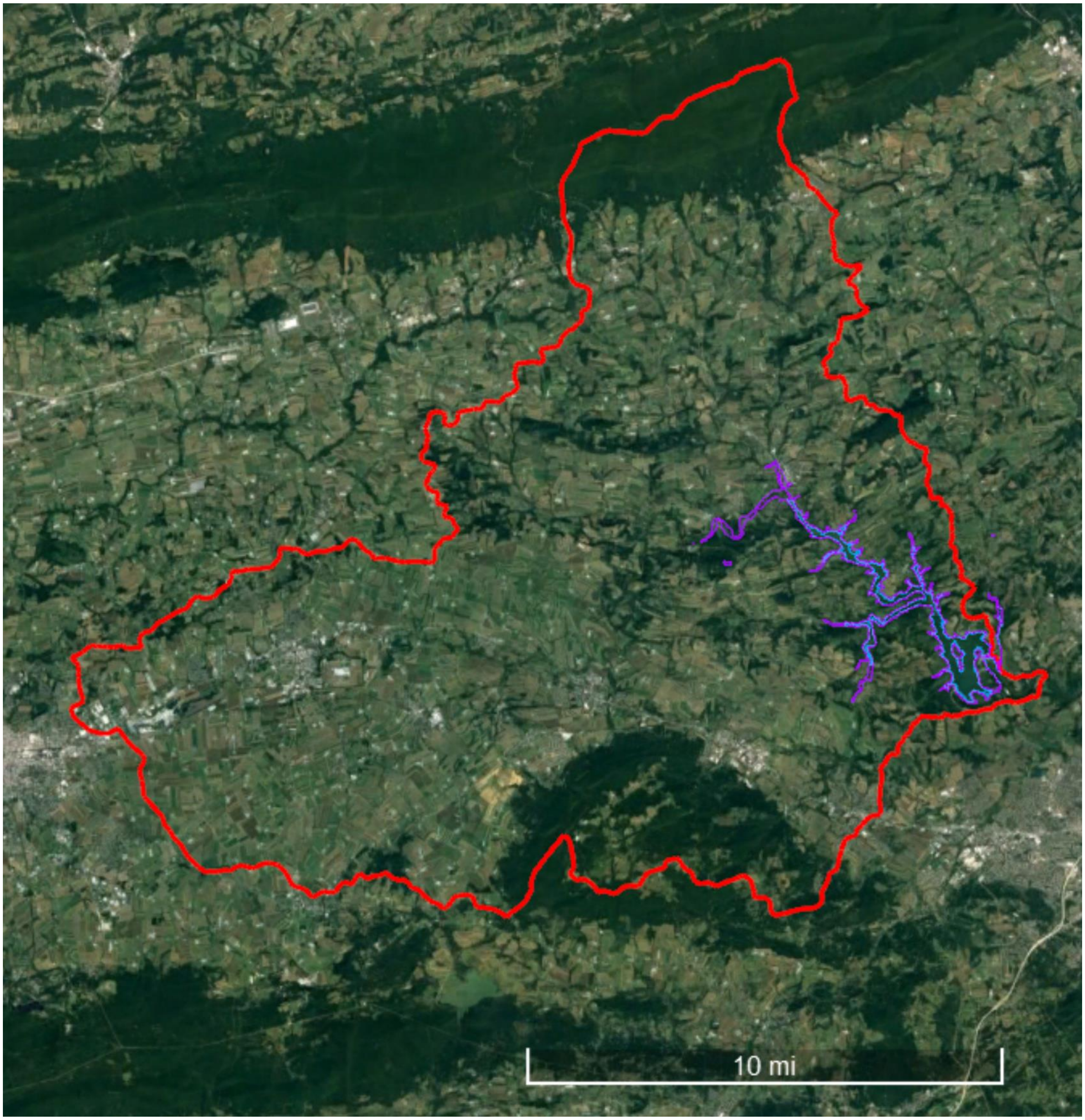


Figure 1.4: Main dam and spillway

Figure 1.5: Main dam and auxiliary dams in the vicinity (Source: [USACE 2018 water control manual]())

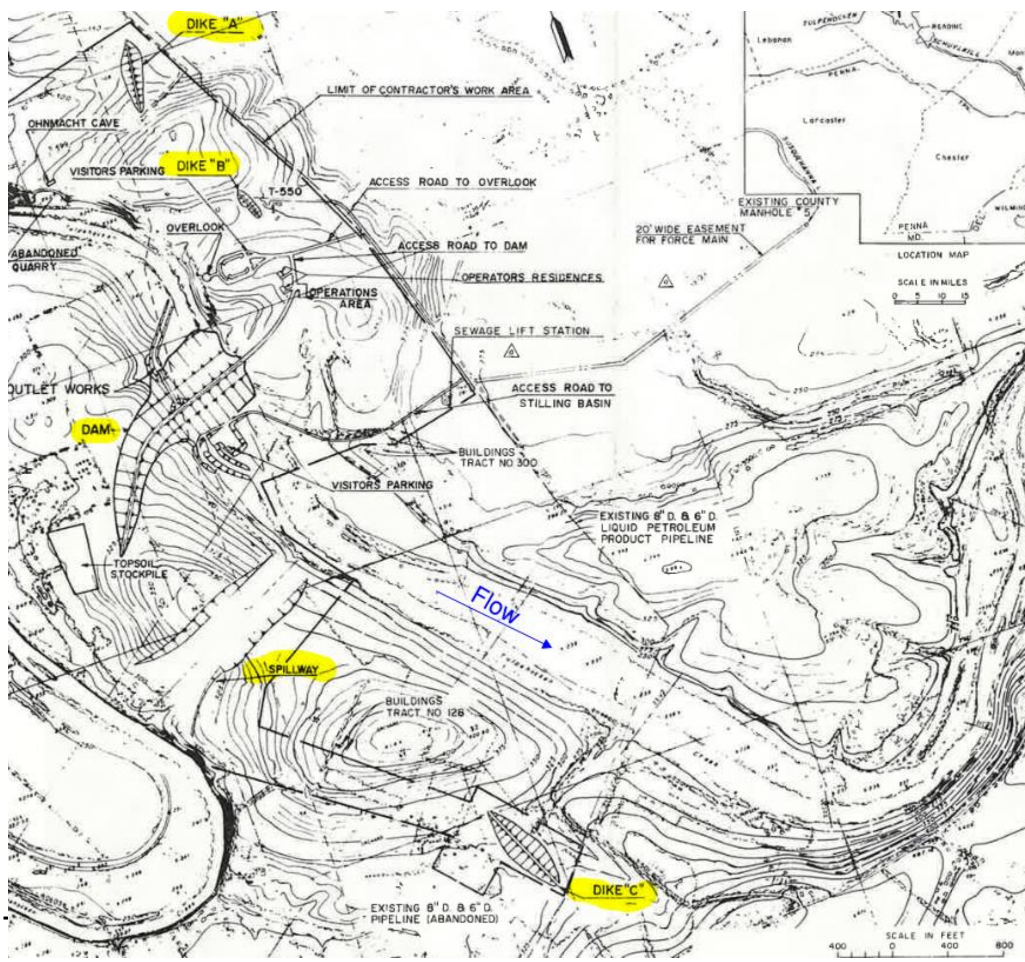
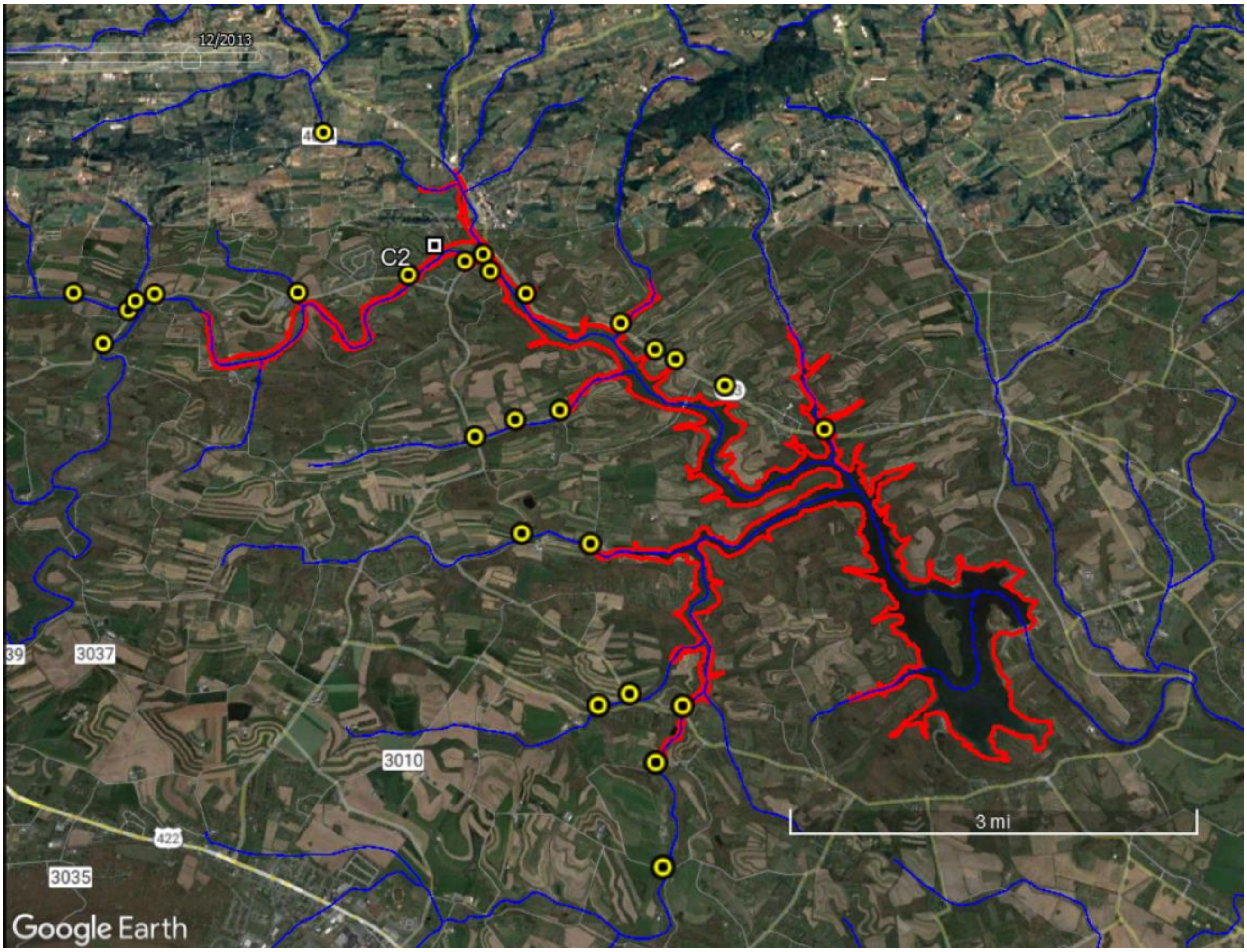


Figure 1.6 Potential approx. reservoir footprint (red line, approx. 1750 acres) at summer pool elevation of 302 ft compared with current footprint (1170 acres at 290 ft), plus 25 bridges that would likely need replacement (yellow circles)



2 Water Quantity & Quality

The Elevation-Area-Capacity table in the 2018 Water Control Manual (USACE, 2018) was used to determine the elevations corresponding to a volume increase of 5 BG for the summer pool, namely a 12 foot increase, from 290 ft to 302 ft, causing an increase of inundated area of 580 acres, from 1170 acres to 1750 acres (Figure 1.6), according to measurements of USGS topographical maps (although Corps documents state current footprint at 900 ac). The footprint of the reservoir at this level is shown in Figure 1.6.

2.1 Fill and discharge

With a drainage area of about 179 sq. mi. and mean flow of 77 cfs, Tulpehocken Creek could supply the additional 5 BG in about 3 months.

The existing intake tower and low water outlet is more than adequate to release the desired flow of 100 cfs for flow augmentation. A stilling basin already exists. No downstream channel improvements are anticipated.

2.2 Water Quality

Blue Marsh reservoir is extensively monitored by the Corps. The 2020 report classified it as "predominantly eutrophic (UASCE, 2021)." The DRBC owns storage in Blue Marsh, which is sometimes released to augment flow. Blue Marsh flows to the Schuylkill River, which is used as a drinking water source, most notably, by Philadelphia. Therefore, despite its eutrophic state, the water quality should continue to be adequate for flow augmentation.

3 Infrastructure Design, Construction & Operation

A linear extrapolation of existing stage-volume-area data was applied to estimate the increase in reservoir storage and area for elevations beyond the height of the existing dam. The existing storage volumes above the summer pool elevation to contain the summer, standard flood, and inflow design flood based on the Elevation-Area-Capacity table in the 2018 Water Control Manual were calculated. The elevations for the spillway crest, standard flood, and inflow design flood (IDF) were increased to contain the calculated volumes for each case under potential project conditions. The dam crest elevation was calculated to have 1.5 feet of freeboard above the IDF, which is similar to the current 1.4 feet of freeboard above the IDF. The spillway elevation must increase by 7 feet and the dam crest by 4.5 feet to provide similar protection for the “standard flood.” The estimated elevations calculated for each additional storage volume are presented in Table 3.1:

Table 3.1: Estimated Key Reservoir Elevations

Additional Storage	Summer Pool Elevation	Spillway Crest Elevation	Standard Flood Elevation	Inflow Design Flood (IDF) Elevation	Dam Crest Elevation
0 BG (Existing)	290 ft	307 ft	317.5 ft	330.6 ft	332 ft
1 BG	293 ft	309 ft	319 ft	332 ft	333.5 ft
2 BG	296 ft	311 ft	320 ft	333 ft	334.5 ft
5 BG	302 ft	314 ft	323 ft	335 ft	336.5 ft

In addition to the main dam and spillway, flood control structures are located along the perimeter of the reservoir. These structures consist of dikes and levees, used to contain the water in the reservoir, as well as prevent flooding during large storm events. These facilities would need to be raised to match the raised dam crest and expanded to provide the same level of protection they currently provide. The key flood control structures and their existing crest elevations are listed in the following table.

Table 3.2: Key Flood Control Structure Elevations

Feature	Saddle Elevation	Existing Crest Elevation	Required Increase to New Crest Elevation of 336.5 ft
Dike A	320 ft	332 ft	4.5 ft
Dike B	326 ft	332 ft	4.5 ft
Dike C	304 ft	332 ft	4.5 ft
Bernville Main Levee	NA	320.5 ft	16.0 ft
Bernville – South Flanking Levee	NA	320.5 ft	16.0 ft

4 Environmental Impacts

In general, raising a dam and subsequent water levels in a reservoir/impoundment, creating a larger lentic water body does not cause as much trauma to the natural system as when a new dam is constructed across a flowing water body. Effects of an obstruction are far more impactful to a flowing waterbody than to a waterbody that has equilibrated to impounding by achieving an alternate baseline. A newly impounded wetland and stream will adapt to permanent flooding although significant water quality degradation occurs and subsequent yields lower biodiversity in the aquatic ecosystem. Raising the water level of an aquatic system that is already impounded will further negatively impact that system, but the system will likely return to a similar baseline as when the first obstruction was installed.

The US Army Corps of Engineers in their Section 404 permitting process considers the primary regulatory activity for a dam raise as placement of fill material in the water of the US at the dam expansion site. However, secondary effects (impounding water) result in significant environmental impact. The new lentic ecosystem attempts repair, but water warms, organic material within the impoundment site decays and contributes significantly to eutrophication. Human induced lentic systems (impoundments) are simplified aquatic ecosystems that can experience swings in climatic, biological, chemical, geological and often hydrologic conditions. A new impoundment creates a new baseline for the aquatic ecosystem differing significantly from the lotic system it replaced. The more variable the conditions in the newly disturbed aquatic system, the more negatively impacted the habitat becomes, and the easier it is to come to the newly established baseline. However, if a waterbody, even a human-induced water body, experiences consistent conditions a higher quality ecosystem will result and be inhabited by organisms that are less adapted to changing conditions, less common and likely native. The food chain will be more stable, and the native species will be present at several levels of the food chain although perhaps a more simplified food chain than what originally existed. Waterbodies that are disturbed by fluctuating water levels, wide swings in temperature, oxygen and nutrient content, influx of non-native, invasive species often are simple ecosystems where only non-native generalist species can survive. Finally, impoundments without provision for migratory fish have significant effect on the native fishery, and natural fish migration ends with the obstruction. With a raised dam the opportunity is presented to restore fish migration by introducing a parallel bypass channel or a fish ladder.

All waters in the Commonwealth of Pennsylvania are protected for a designated aquatic life use as well as water supply and recreational uses. The use designation shown in the water quality standards is the aquatic life use. These uses are Warm Water Fishes (WWF), Trout Stocking (TSF), Cold Water Fishes (CWF) and Migratory Fishes (MF).

In addition, streams with excellent water quality may be designated High Quality Waters (HQ) or Exceptional Value Waters (EV). The water quality in an HQ stream can be lowered only if a discharge is the result of necessary social or economic development, the water quality criteria are met, and all existing uses of the stream are protected. EV waters are to be protected at their existing quality; lowering water quality would not be authorized by the Commonwealth during a permitting process.

The Commonwealth of Pennsylvania requires that a water body be maintained at its current quality category and degradation caused by an activity in that water body would not be permitted. Therefore, transitioning from a smaller to a larger impoundment would not change the water quality category significantly, as would changing a flowing water body to a still water body, unless a parallel change in conditions accompanies the change in size.

When a waterbody is impounded in a watershed with low relief so that impoundment edges allow for growth of submerged and floating aquatic vegetation and if the littoral zone and riparian area is saturated so that wetland conditions result with growth of native wetland plants, a significantly valuable ecosystem is present. If this aquatic and wetland zone is present, deepening these vegetated edges results in elimination of the aquatic plant communities, a significant ecological loss can occur from raising impoundment elevation. However, if the impoundment has steep relief such that little wetland plant or aquatic plant communities develop along the edges or within the water body, increasing the elevation of the impoundment will have a much less significant affect.

In the case of Blue Marsh Reservoir, water quality designation of streams entering the current impoundment is designated as a Warm Water Fishery. More than 30,000 feet (about 9.14 km) of WWF streams would be inundated by the project along with over 200-acres of wetlands occurring mostly in the upper portions of incoming streams. Incoming streams include Tulpehocken Creek, Licking Creek and Springhill Creek to name a few. Each of these creeks includes wetlands that would be inundated. In addition, there appears to be an old canal (Union Canal) that may hold historic significance. Finally,, civil works performed by the US Army Corps of Engineers (USACE) would result in requirement for a Section 408 process that evaluates impacts of proposed projects on the function of USACE civil works projects. Likely an increase in the impoundment size will cause some impacts to wetlands and streams, but likely these impacts will be temporary; and if room is present for current upland areas to develop into wetlands, likely these wetland systems will form within a few years; however, a more in-depth study would be required.

Several listed species are present in this location, including bats and Bog Turtles; however, it is not known if bog turtles or bog turtle habitat is present within the inundation or affected area. Coordination with the USFWS, the PA Game Commission and the PA Fish and Boat Commission would be required to know what species would be expected and if maternity colonies or hibernacula are present for bats, or nesting areas present for bog turtles. Because the area is densely wooded, likely bat species would be prevalent.

5 Social and Economic Impacts

The land around the reservoir is primarily agricultural, but the 850 acres flooded by the increase in the summer pool is along stream corridors and is primarily forested. The areas of farmland above this elevation could probably continue to be farmed, although they would be flooded more frequently.

A few residential areas would be subject to flooding at the standard flood by the project, notably in Bernville. These areas would require new or raised dikes to maintain the current flood risk. The cost of raising/extending the Bernville dyke was included in the cost estimate but doing so may also require Route 183 to be located, which would be expensive and disruptive.

Nineteen road crossings of streams were identified that would need replacing to be above the standard flood. The cost was estimated at about $28M. In addition, several miles of road would need to be raised, whose cost was not estimated. These bridges and roads include some along State Route 183. The disruption would be widespread and lengthy.

The demographics of the area as reported in the census are not dominated by historically oppressed groups. While the area was disrupted by the construction of the dam and dikes, that was completed over 40 years ago, so the area has been burdened but not repeatedly. Therefore, social equity concerns seem minor.

Recreational facilities at the reservoir would be flooded by the raise (Figure 1.6), namely the swimming beach, the Dry Brooks boat launch and the State Hill boat launch. These could be relocated above the increased summer pool.

Loss of tax revenue from inundated properties would be minor because most of the land is tax-advantaged farmland or undeveloped forest. The loss of production of farmland would not be expected to burden the community.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level (level 4) cost estimate for construction costs, as detailed in Table 6.1. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) are reported in Table 6.2. Costs for replacement bridges were estimated at$ 370/sf plus a 40% contingency. Other Methods are described in the main report. Other Costs have a 35% design contingency and a 30% construction contingency commensurate with the concept development level of detail. Note this contingency is higher than used on other similar projects due to the limited available project information. Note the costs of upgrades to the Bernville pump station and its increased operating costs because of more frequent and/or severe flooding were not included in the estimate, nor, as mentioned above, the cost for raising or relocating roads.

Table 6.2 shows the total cost estimate (present value) of raising the dams is relatively modest at $27M, with the bridge replacement nearly equal at $28M, giving a total construction cost of $55M and total overall present-value cost of $65M. The cost effectiveness of $18M/BG is better than all new dams.

Table 6.1: Dam and Dike Construction Cost Estimate Summary

Description	Unit	Quanity	Rate	Total	Comments
1a.0 Dam				**$ 5,091,800**	
1a.1 Excavation	CY	30,300	$ 20.00	$ 606,000	Excavate 2 feet of the crest, 1 foot along downstream slope, 10 feet for downstream slope foundation
1a.2 Grout Curtain	SF	-	$ 110.00	$ -	
1a.3 Core Material	CY	12,900	$ 25.00	$ 322,500	Includes excavation backfill
1a.4 Filter Material	CY	-	$ 90.00	$ -	
1a.5 Dam Shell Material	CY	120,000	$ 30.00	$ 3,600,000	Includes excavation backfill
1a.6 Riprap	CY	2,100	$ 200.00	$ 420,000	additional upstream fill
1a.7 Hydroseed	SF	286,600	$ 0.50	$ 143,300	entire downstream slope
1b.0 Dikes				**$ 2,154,100**	
1b.1 Excavation	CY	18,100	$ 20.00	$ 362,000	Similar comments to Dam
1b.2 Grout Curtain	SF	-	$ 110.00	$ -	
1b.3 Core Material	CY	6,500	$ 25.00	$ 162,500	
1b.4 Filter Material	CY	-	$ 90.00	$ -	
1b.5 Dam Shell Material	CY	38,200	$ 30.00	$ 1,146,000	
1b.6 Riprap	CY	2,100	$ 200.00	$ 420,000	
1b.7 Hydroseed	SF	127,200	$ 0.50	$ 63,600	
2.0 Spillway				**$ 2,875,000**	
2.1 Excavation	CY	-	$ 30.00	$ -	
2.2 Spillway Slab	CY	3,000	$ 850.00	$ 2,550,000	New spillway slab
2.3 Spillway Walls	CY	-	$ 1,100.00	$ -	
2.4 Anchors	EA	130	$ 2,500.00	$ 325,000	Ancors on a 10' x 10' grid across 300'x30' Sill
2.5 Drainage Layer	CY	-	$ 90.00	$ -	
2.6 Drainage Pipes	LF	-	$ 100.00	$ -	
2.7 Stilling Basin	CY	-	$ 1,000.00	$ -	
3.0 Outlet Works				**$ 1,290,000**	
3.1 Outlet Pipeline and Installation	LF	20	$ 2,000.00	$ 40,000	Additional length for increased downstream slope
3.2 Outlet Tower and Installation	10' Segment	5	$ 250,000.00	$ 1,250,000	Assume new outlet tower, may be able to be modifed depending upon condition
4.0 Access Roads				**$ -**	
4.1 New Roads	Mile	-	$ 600,000.00	$ -	
5.0 Key Project Components Subtotal				**$ 11,410,900**	
5.1 Sum 1.0 thru 4.0	Subtotal			$ 11,410,900	
6.0 Contractor Allowances				**$ 4,781,167**	
6.1 Environmental Allowance: Rate x 5.0	Rate		2%	$ 228,218	
6.2 Materials Testing (QA/QC): Rate x 5.0	Rate		2%	$ 228,218	
6.3 Contractor Indirect Costs: Rate x 5.0	Rate		25%	$ 2,852,725	
6.4 Profit: Rate x (5.0 + 6.1 + 6.2 + 6.3)	Rate		10%	$ 1,472,006	
7.0 Contingencies				**$ 10,524,844**	
8.1 Design Contingency: Rate x (5.0 + 6.0)	Rate		35%	$ 5,667,223	Increased due to limited info on drawings, additional modificaitons may be needed
8.2 Construction Contingency: Rate x (5.0 + 6.0)	Rate		30%	$ 4,857,620	Increased due to more uncertainty with borrow areas, impacts to nearby existing urbanization
8.0 Conceptual Cost Estimate Total				**$ 26,717,000**	
8.1 Sum 5.0 thru 7.0	Total			$ 26,716,911	

Table 6.2: Overall Cost Estimate Summary

Land acquisition cost ($)	8M
Construction Cost dams + bridges ($)	55M
Operating Cost ($/yr)	0.1M
Overall Cost (Present value, $)	65M
Cost effectiveness ($/BG)	13M

The schedule for the project is also very rough. Given the complexity of permitting on Army Corps projects, a 20 years is estimated before operation, as shown below. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition.

- Funding acquisition 5 years
- Design, permitting and land acquisition 8 years
- Construction 5 years
- Startup 2 years
- Total 20 years

7 Potential Ancillary Benefits

The slight expansion of the area of the reservoir would not provide a significant recreational benefit. Regarding flood control, if the extra volume could be evacuated quickly, the project could provide a significant benefit.

8 Storage Project Score

This site was scored as described in the main report and summarized in Table 8.1 for below the six primary criteria. Each primary criterion contained subcriteria which were scored on a 1 (worst) to 5 (best) scale and averaged. Scores on the primary criteria were weighted as shown in Table 8.1 and summed to obtain an overall weighted average score. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

The project scored high on criteria 4 (social and economic impacts) because of the limited displacement of residences, but it would cause significant disruption from construction of roads and bridges. This and the need to raise multiple dams/dykes is reflected by the low score on criteria 2 (Infrastructure Design, Construction & Operation).

Table 8.1: Storage Project Score

Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.83	30%	1.15
Infrastructure Design, Construction & Operation	2.20	10%	0.22
Environmental Impacts	3.43	15%	0.51
Social & Economic Impacts	4.11	10%	0.41
Project Cost & Schedule	2.67	30%	0.80
Ancillary Benefits	1.80	5%	0.09
AVERAGE	**3.01**		**3.19**

APPENDIX

Pertinent data from the USACE 2018 water control manual

Score Sheet

Map of impacted bridges

Source:

USACE 2018 water control manual

PERTINENT DATA

LOCATION	
Basin	Schuylkill River
Stream	Tulpehocken Creek
River Mile	6.4 miles upstream from the confluence with the Schuylkill River at Reading, PA
County	Lebanon and Berks
State	Pennsylvania
DRAINAGE AREA	
Above Dam	175 square miles (One inch of runoff equals 9,328 acre-feet.)
DAM	
Type	Earthfill embankment
Length	1,775 feet
Height	98 feet
Top Width	30 feet
SPILLWAY	
Type	Uncontrolled, unlined, chute-type channel with concrete sill at crest
Crest Elevation	307.0 ft. NGVD29
Width	300 feet
Design Discharge	73,900 cfs
REAL ESTATE ACQUISITION	
Fee Purchase	Elevation 290 ft. NGVD29 and 300 ft. horizontal or elevation 310 ft. NGVD29
Flowage Easement	Up to elevation 315 ft. NGVD29

Note: Elevation in NAVD88 is calculated by subtracting 0.73 from elevation in NGVD29

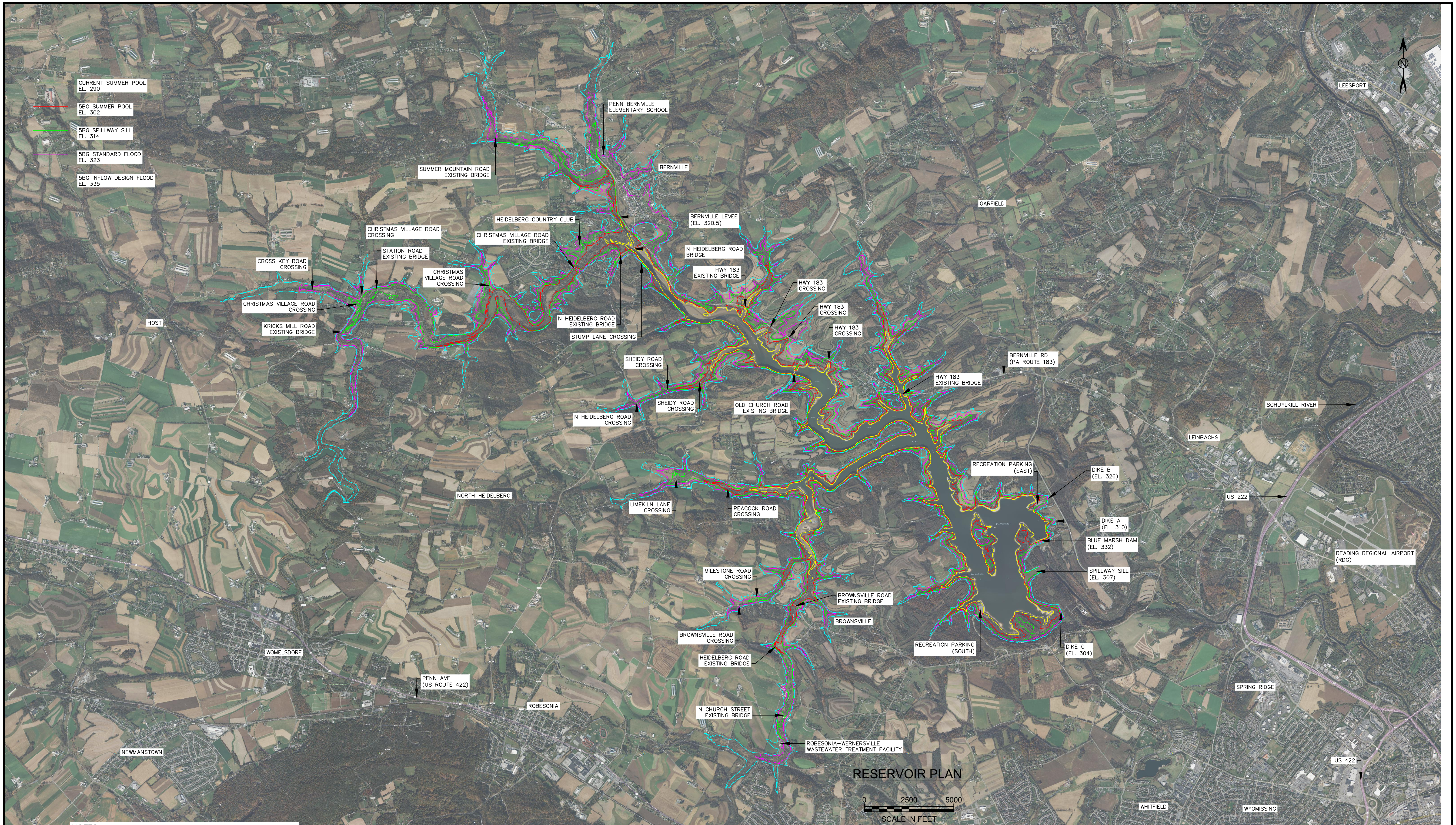
Reservoir Feature	Elevation-Area-Capacity Data*				
	Elevation (ft. NGVD29)	Surface Area (acres)	(acre-feet)	Capacity (inches of runoff)	(billion gallons)
Streambed	235.0	0	0	0	0
Top of Sediment Reserve Pool	261.0	304	2562	0.27	0.83
Top of Water Supply, Water Quality and Recreation Pool					
Winter Pool	285.0	781	16,132	1.73	5.26
Summer Pool	290.0	897	20,226	2.17	6.59
Top of Flood Control Pool (Spillway Crest)	307.0	2,081	46,334	4.97	15.10
Preliminary IDF	330.6	4,264	119,002	12.76	38.78
Top of Dam	332.0	4,557	125,113	13.41	40.77

Note: the 897 acres reported at the summer pool of 290 ft varies significantly from the measurement (1170 ac) via USGS topographic map

OUTLET WORKS	
Tunnel	
Type	Concrete conduit-modified oblong cross-section
Location	Through embankment
Inside Dimensions	9 feet 1 inch high, 10 feet 4 inches wide
Length (Bellmouth Intake to Exit Portal	520 feet
Intake Invert Elevation	237.0 ft. NGVD29
Outlet Invert Elevation	235.0 ft. NGVD29
Tower	
Type	Concrete with access bridge from top of embankment
CONTROLS	
Flood Control System Service Gates	
Type	Slide, hydraulically operated
No. and Size	Two – 6 feet by 10 feet. One is equipped with a 1 foot by 1.5ft. motor operated slide leaf gate for low flow water quality releases.
EMERGENCY GATE	
Type	Fixed wheel, crane operated, transferrable. One-6 feet by 10 feet
WATER QUALITY SELECTIVE WITHDRAWAL SYSTEM	
Water Quality Wetwell	
Selective Withdrawal Range	Elevation 271.0-279.0 ft. NGVD29 Stoplogs and aperture, mobile crane operated
Type	Two stoplogs-5 feet by 6 feet

***Revised in 2010 as a result of new sedimentation surveys, finalized in 2016.**

Six primary criteria	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
1. Water quantity and quality		3.83			30%	1.15	
o Volume of storage provided (BG)	5	3					
o Hydrologic reliability of supply (months to fill)		5					
o Release rate (cfs)		5					
o Promptness of delivery to mainstem (days)		4					check
o Geographic benefit		3					
o Quality of stored water		3					Eutrophic but satisfactory
2. Infrastructure design, construction and operation		2.20			10%	0.22	
o Site/Civil, Land & Easements		1					
o Subsurface conditions		3					
o Infrastructure Complexity		1					many bridges need replacing. Four auxilliary dams
o Construction complexity		1					
o Operational complexity		5					
3. Environmental impacts		3.43			15%	0.51	
o protected species		3					Indiana Bat, Northern long-eared bat, Bog Turtle Monarch possible
o Water quality degradation of downstream waters		5					No additional impacts
o obstruction to passage of aquatic animals		5					No additional impacts
o hydromodification		5					No additional impacts
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o wetlands inundated or filled (ac)	235	1	1	1			most wetlwands are forested scrub/shrub
o stream length inundated (mi)	6	3	5	1			mixture of stream classes
o uplands inundated or developed (ac)	580	2	3	1			mostly reverting growth
4. Social and Economic Impacts		4.11			10%	0.41	
o Disruption/displacement		2					replacement of many bridges will be disruptive
o Safety and health		4					Minor additional risk
o Social equity/environmental justice		4					Further burdens Bernsville via significantly higher dike
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		4					
o Loss of production from farmland, timberland, quarries		4					
o Emissions of greenhouse gasses		4					
5. Project Costs & Schedule		2.67			30%	0.80	
o Land acquisition cost ($)	8.M						700 acres at 11k$/ac; no homes
o Construction Cost ($)	55.M						$27M$ for dams + 28M$ for bridges
o Operating Cost ($/yr)	0.1M						
o Overall Cost ($)	65M	3.5					
o Cost effectiveness ($/BG)	13M	3.5					
o Schedule (Time to make Operational, years)	20	1					extra complex issues with Federal regulations
6. Ancillary Benefits		1.80			5%	0.09	
o Flood control		2					flood control benefit from larger pool
o Recreation/tourism		2					
o Habitat/fishery enhancement		2					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		2					
OVERALL		3.01			100%	3.19	



NOTES:
1. TOPO REFERENCE: ONE THIRD ARC SECOND PUBLISHED ON 2022-04-29 (USGS NATIONAL MAP)
2. INUNDATION ZONES SHOWN ASSUME DAM AND ASSOCIATED DIKES A, B, AND C ARE RAISED TO CONTAIN THE 5BG INFLOW DESIGN FLOOD.

Project Number: 507101042	Date: 30 JUNE 2022	Created By: DS / JW	Checked By: PS / JC	Figure No:

M M MOTT MACDONALD

Delaware River Basin Commission
DELAWARE • NEW JERSEY
PENNSYLVANIA • NEW YORK
UNITED STATES OF AMERICA

DELAWARE RIVER BASIN STORAGE STUDY

BLUE MARSH INUNDATION STUDY
FIGURE 01 - WATER ELEVATION

PW://MOTT-USE-PW-BENTLEY.COM/MOTT-USE-PW-03/DOCUMENTS/D BM.DWG

Storage Project Summary

Project:	**Prompton Dam Modification (E4)**	
Location:	Near Honesdale, Wayne County, PA	
Storage Type:	Modification to inlet on existing reservoir	
Est. Volume:	2 BG increase	
Score:	4.04	

1 Project Overview

Prompton Dam is a flood-control dam on the West Branch of the Lackawaxen River in Wayne County, PA, constructed and managed by the US Army Corps of Engineers (Figure 1.1. to 1.3). The Appendix contains important information on the dam taken from the Water Control Manual (USACE, 2018). Additional information is available on the project web page. Currently, a low-level inlet water level is kept far below the spillway elevation to reserve a large volume for flood storage (Figure 1.4 to 1.6). However, in a drought emergency in the 1980s, the USACE built a temporary structure around the low-level inlet in the reservoir that raised the permanent pool to provide water for flow augmentation. This structure was later removed and has not been replaced.

This potential project would recreate this increased pool by installing a movable gate over the existing inlet that would normally be kept closed, causing the water level to increase. A new, uncontrolled inlet would be constructed at a higher elevation than the existing inlet, which would provide about 2 BG of additional water storage (Figure 1.7). The movable gate on the existing inlet would be opened when a flood is forecast to quickly evacuate this additional water.

No modifications to the dam proper, the spillway or the downstream channel are proposed. (Raising the dam and spillway is not considered feasible because it would likely require a complete rebuild of both the dam and spillway, which was recently rebuilt, and relocation of a significant length of state highway 170). An advantage for this project is that no buildings would be flooded so socioeconomic impacts are minor. Significant challenges are navigating USACE and other Federal regulations regarding modifying the dam purpose to include flow augmentation/water supply and forecast-informed operation.

The cost estimate (present value) is $2M, the lowest cost of any project, and the cost effectiveness is $1M/BG, which is the best of any project.

This potential project is different from the proposed modification that is listed in DRBC's Comprehensive Plan. While that modification would also raise the water level to provide a larger permanent pool, it would include a tower with gates to control releases.

Figure 1.1: Project location

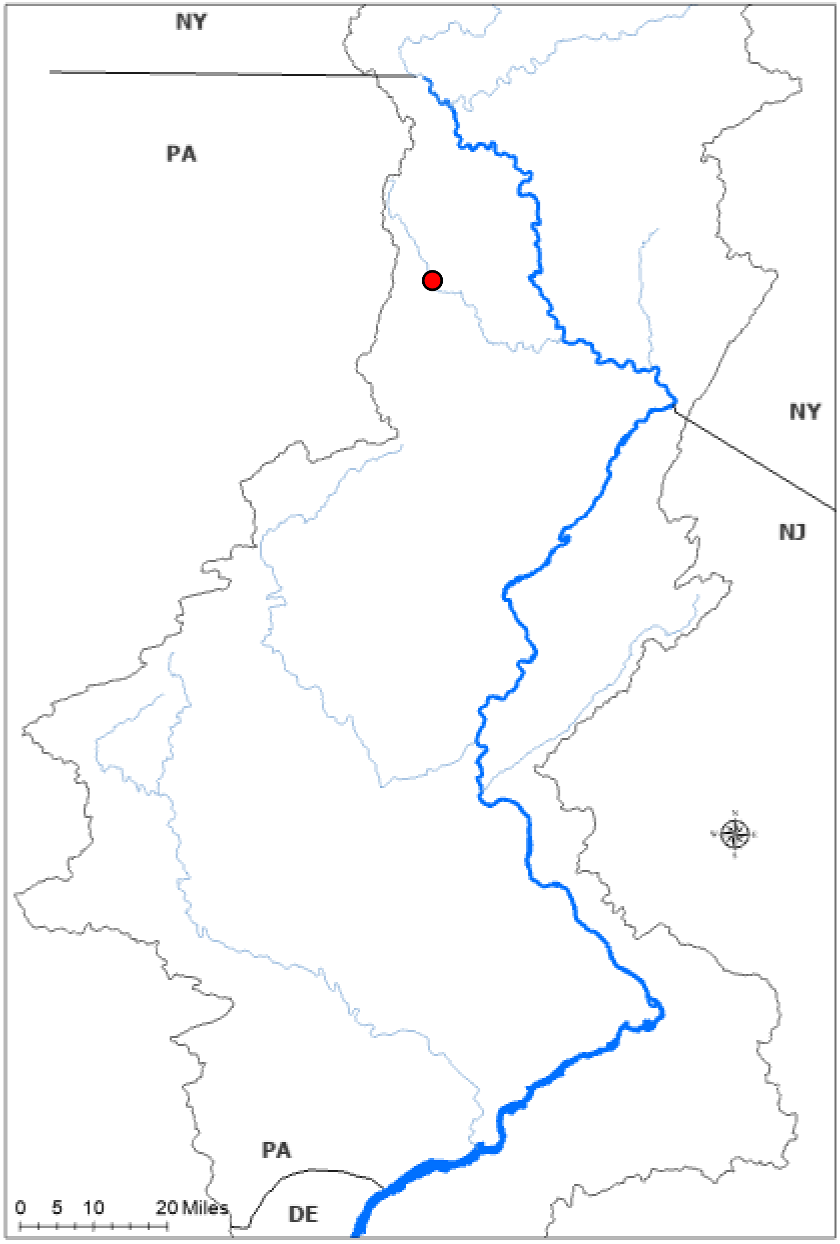


Figure 1.2: Topographic map: Existing reservoir in blue, proposed reservoir in purple, and drainage area in red (58 sq miles)

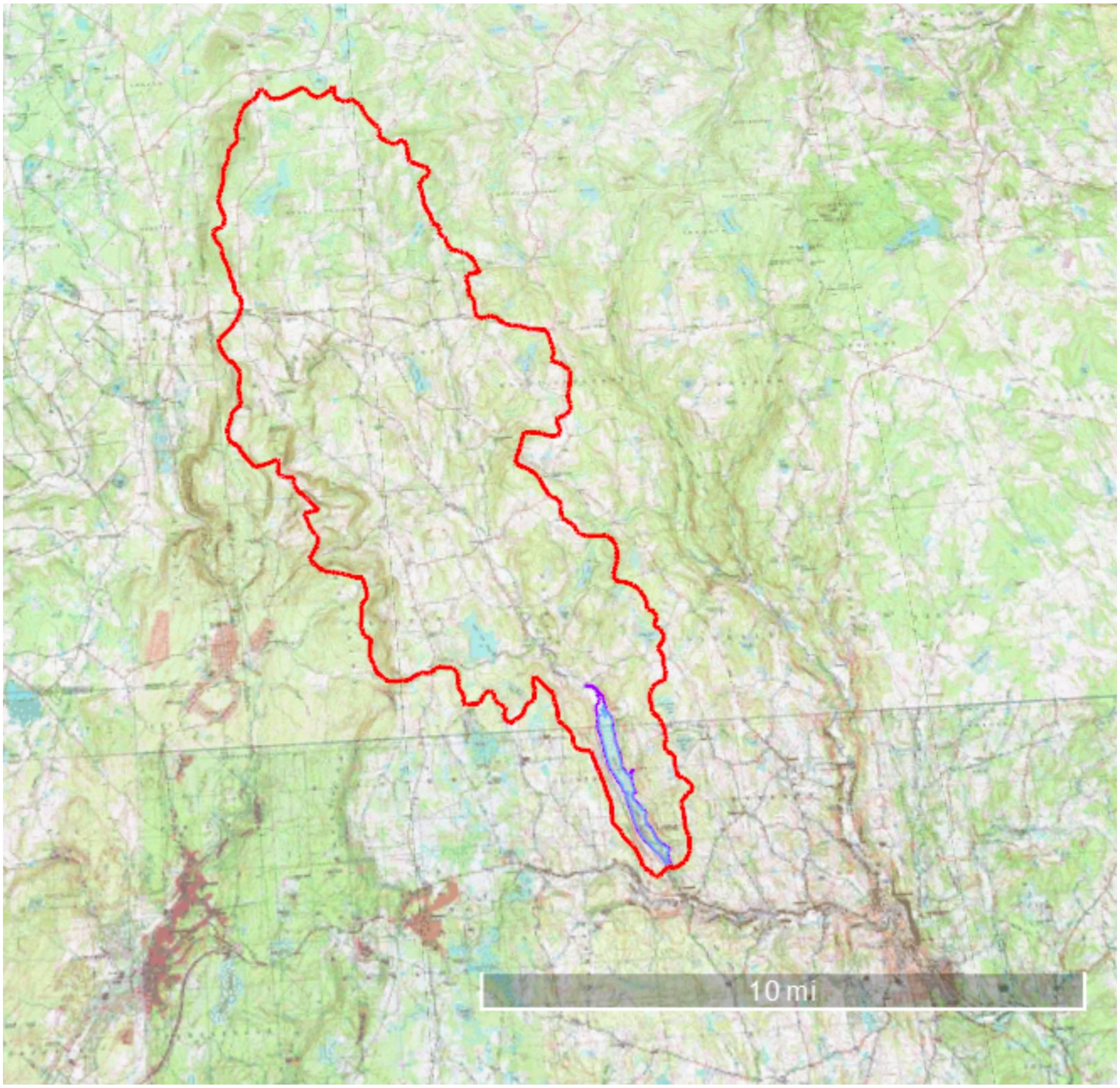


Figure 1.3: Aerial photo: Existing reservoir in blue, proposed reservoir in purple, and drainage area in red (58 sq miles)

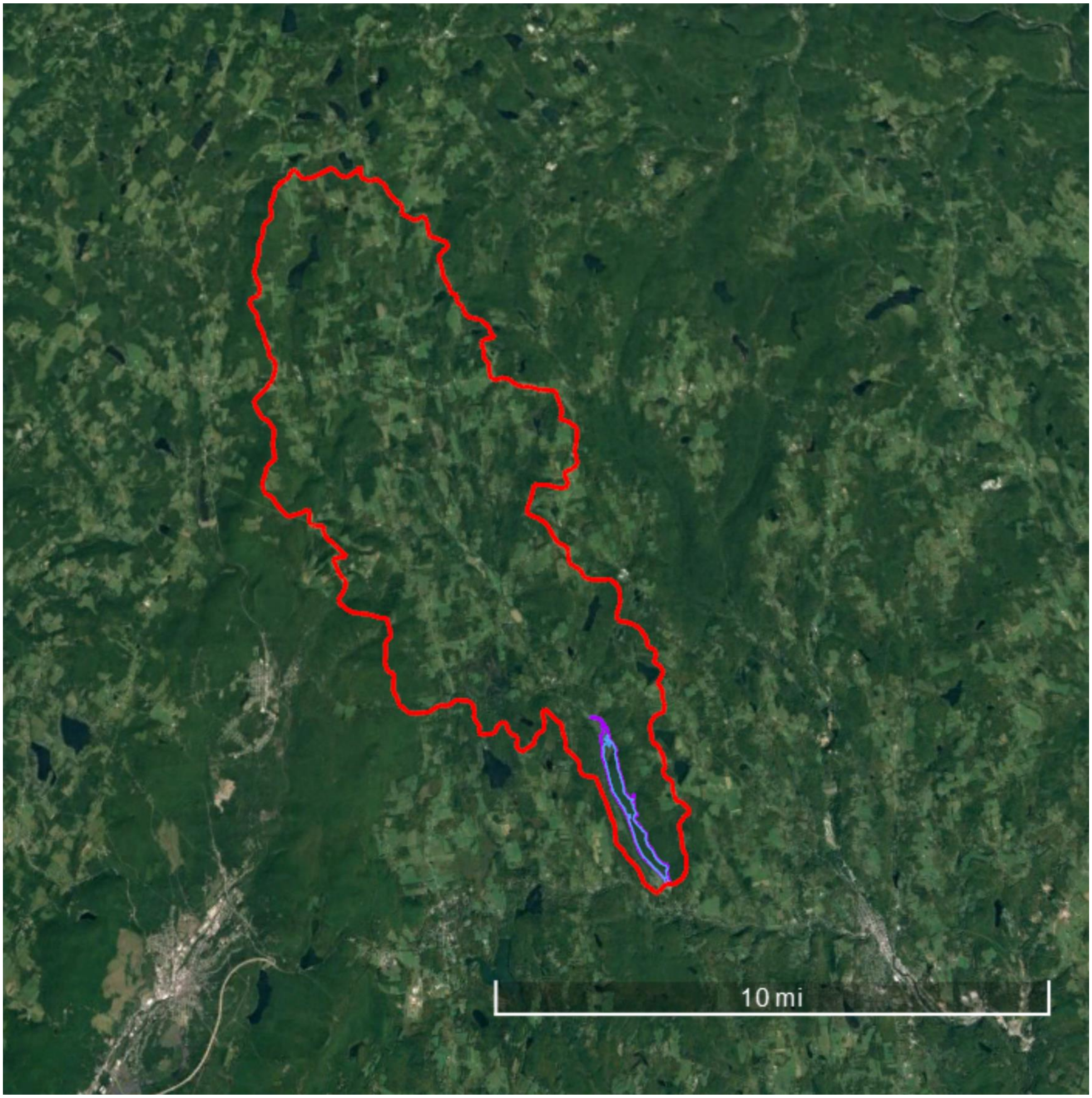


Figure 1.4: Existing dam and spillway, looking upstream

Figure 1.5 Existing dam and spillway, looking downstream. Existing inlet is visible on left side of photo.

Figure 1.6 Close up of existing inlet

Figure 1.7: Footprint of permanent pool (in purple) after 16-foot increase in the permanent pool elevation to increase storage by 2 BG

2 Water Quantity & Quality

An increase of 2 BG of storage in the permanent pool requires an increase of 16 feet in water level, from the existing permanent pool elevation of 1125 ft to 1141 ft according to the Elevation-Area-Capacity graph in the USACE 2018 Water Control Manual (see appendix). The footprint of the reservoir at this level is shown in Figure 1.4, representing an increase of about 115 acres as measured on the USGS topographic map (vs 180 acres on the USACE's graph).

2.1 Fill and Discharge

With a drainage area of about 58 sq. mi. and mean flow of 110 cfs, the West Branch of the Lackawaxen River could supply the additional 2 BG in about 2 months.

The existing low-water inlet and outlet conduit would be more than adequate to release the desired flow of 100 cfs for flow augmentation. A stilling basin already exists. Not downstream channel improvements are anticipated.

2.2 Water Quality

The USACE monitors water quality in the reservoir. The Water Control Manual states that the water quality is "satisfactory" and "in a mesotrophic-eutrophic condition throughout much of the summer season." Given that the USACE classifies Blue Marsh as "predominantly eutrophic" and that it is currently used to augment flow, the water quality in Prompton Reservoir should be satisfactory for flow augmentation.

3 Infrastructure Design, Construction & Operation

3.1 EXISTING INFRASTRUCTURE

The following information about the existing infrastructure is taken from the Water Control Manual. Much of this information is presented in the Appendix. The existing dam is a 1230-foot long, 140-foot high zoned earthfill embankment with a 22.5-foot-wide crest at elevation 1227.0 ft with an additional concrete wall constructed across the top (in 2008 giving a top elevation of 1233.0 ft. NGVD). The embankment consists of an upstream compacted earth-fill zone and a downstream compacted random fill zone separated by an inclined drainage zone. A dumped-rock face is provided on both the upstream and downstream faces for slope protection.

The original spillway was a perched-type, uncontrolled open channel, excavated through the right abutment. The rock walls on the channel were cut approximately 2V on 1H; the slopes in overburden were 1V on 2H. The spillway gradually contracted to a width of 50 feet just upstream of the crest and remained at that width throughout the remainder of the channel. The spillway reconstructed in 2012 (Figure 1.5): lowered by 5 ft, widened to 130 ft. and a 5 ft. high fuse plug was added. A concrete gravity wall was constructed along the left side of the spillway from 180 feet upstream to 370 feet downstream of the crest. The excavation slopes for the rock on the right side of the spillway are 2V to 1H. The new spillway can pass a maximum discharge of 65,000 cfs. Design of the spillway was considered adequate, so no changes were considered.

The outlet works consists of an uncontrolled drop inlet structure (Figure 1.6), a 548-foot-long reinforced concrete 8-foot diameter pipe, and a stilling basin for energy dissipation. The outlet conduit will pass 3,500 cfs when the reservoir is filled to the spillway elevation.

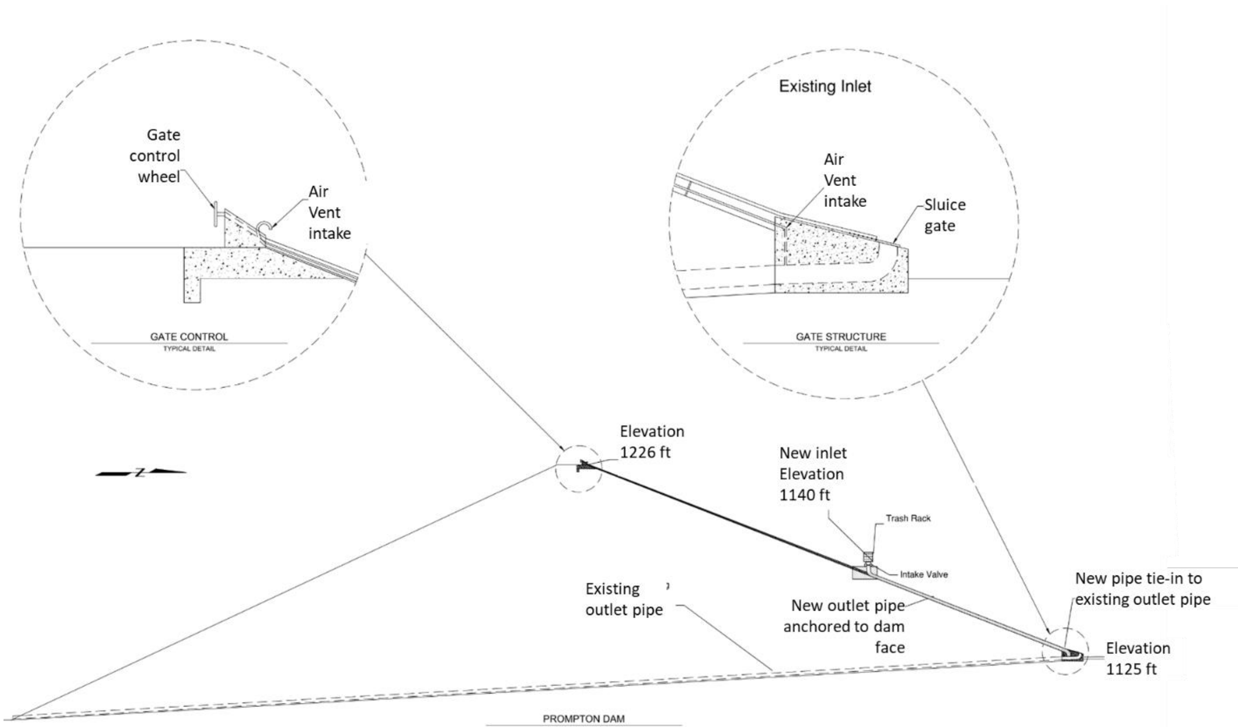
3.2 NEW INFRASTRUCTURE

The existing inlet at elevation 1125 ft would be equipped with a sliding gate or some other type of device that would normally be kept closed (Figure 3.1), increasing the permanent water level and providing additional 2

BG of storage. A new inlet would be constructed at elevation 1141 ft to maintain the permanent pool at that level (Figure 3.1). A pipe would connect the new inlet to existing outlet pipe running through the bottom of the dam. The gate on the existing inlet would be opened when a large storm is forecast to evacuate the additional storage, thereby re-establishing the original volume to store flood waters.   A robust mechanism and maintenance plan would be necessary, the design of which is beyond the scope of this study. A fail-safe could be included so that the gate would open automatically when the water reached a certain height.

The existing inlet and outlet pipe have a large flow capacity, as shown in the outlet rating curve in the Appendix. For example, the outflow rate at water surface elevation 1141 ft is about 2100 cfs. The outflow rate drops as the water level drops. It would take about 35 hours to drain the 2 BG of additional volume, which seems sufficient forewarning of approaching large tropical storms that have been the source of most major floods over the last few decades. However, a “cloudburst” can occur with little warning, but these typically affect a small area. Additional study would be required to determine the level of risk involved from raising the permanent pool.

Figure 3.1: Moveable gate over the existing inlet and new inlet constructed at higher elevation.



4 Environmental Impacts

The US Army Corps of Engineers Section 404 permitting process would apply to placement of fill material in the water of the US associated with a dam raise. However, secondary effects result in significant environmental impact to a new lentic ecosystem that is attempting to repair itself. Human induced lentic systems (impoundments) are simplified aquatic ecosystems that can experience swings in climatic, biological, chemical, geological, and often hydrologic conditions. A new impoundment creates a new baseline for the aquatic system that is very different than the lotic system it replaced. The more variable the conditions in the newly disturbed aquatic system, the more negatively impacted the habitat becomes, and the easier it is to come to the newly established baseline. However, if a waterbody, even a human-induced water body, experiences consistent conditions a higher quality ecosystem will result and be inhabited by organisms that are less adapted to changing conditions, less common and likely native. The food chain will be more stable, and the native species will be present at several levels of the food chain, although a more simplified food chain than what originally existed. Waterbodies that are disturbed by fluctuating water levels, wide swings in temperature, oxygen and nutrient content, influx of non-native, invasive species often are simple ecosystems where only non-native generalist species can survive.

In the case of Prompton Lake, water quality designation of streams entering the current impoundment is designated as High-Quality Cold-Water Fishery (HQ-CWF), and the lake itself is considered a HQ-CWF.

Almost a mile of HQ-CWF streams would be impacted by deeper, lentic water which would increase temperature and change the character of stream. The current impoundment includes few wetlands, but the upper end is dominated by emergent wetlands and scrub/shrub wetlands in some locations that have formed on the sediment delta at the entry to the existing Prompton Lake. About 70 acres of wetlands would be flooded. Higher relief around much of the reservoir may limit wetland formation and submerged aquatic vegetation, however the upper reservoir may include areas of aquatic vegetation. These delta features will restore themselves with time.

Two federally listed species are present in this location. Coordination with the USFWS, the PA Game Commission and the PA Fish and Boat Commission would be required to know what species actually are expected to range in the area proposed for flooding, and if critical habitat is present. Because much of the area is densely wooded, bat species would likely be present.

5 Social and Economic Impacts

The Water Control Manual states that land below 1131 ft was purchased, with flowage easements obtained up to 1205.0 ft. NGVD, the elevation of the spillway crest. The proposed permanent pool elevation of 1141 ft would flood about 115 acres of additional land; all of this land appears to be part of Prompton State Park and it is assumed it could be purchased or used for little to no cost. No buildings, roads or parking lots would be flooded. Existing foot trails remain above 1141 ft.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level (level 4) cost estimate for construction costs, as detailed in Table 6.1. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) are reported in Table 6.2. Other methods are described in the main report. Other costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail.

Costs associated with compliance with USACE regulations, mitigation of environmental impacts and replacement costs of recreational facilities were not assessed but could be significant relative to the low ($2M) estimated cost. These additional costs should be considered if the project advances. Regarding the regulatory compliance, the project proponent would need to fund activities such as coordination, reviewing requests, development of environmental and cultural resources final documents, risk evaluation and approval from the Risk Management Center, construction oversight and approving updates to operations and maintenance manuals related to the alteration.

Table 6.2 shows the cost estimate (present value) is $2M, the lowest cost of any project by $20M, and the cost effectiveness is $1M/BG, which is the best of any project.

Table 6.1: Capital Cost Summary

Description	Unit	Quanity	Rate	Total	Comments
1.0 Outlet Works				**$ 1,123,660**	
1.1 El 1140: Outlet Pipeline and Installation	LF	50	$ 2,000.00	$ 100,000	
1.2 El 1140: Concrete Inlet Structure	CY	270	$ 1,100.00	$ 297,000	
1.3 El 1140: Trash Rack (6' x 9.5')	EA	1	$ 8,000.00	$ 8,000	
1.4 El 1140: Valve	EA	1	$ 5,000.00	$ 5,000	General Estimate for Valve
1.5 El 1125: Concrete Intake Structure	CY	560	$ 1,100.00	$ 616,000	Estimate from GEI portion (no dimensions, so made some assumptions)
1.6 El 1125: Controls Line	LF	310	$ 50.00	$ 15,500	Estimate from online research - hydraulic line / conduit
1.7 El 1125: Slide Gate	EA	1	$ 5,000.00	$ 5,000	General Estimate for Valve
1.8 El 1125: Air Vent Intake Line	LF	310	$ 36.00	$ 11,160	6" PVC Conduit
1.9 El 1125: Concrete Gate Control	CY	60	$ 1,100.00	$ 66,000	
2.0 Contractor Allowances				**$ 470,814**	Same rates as previous dam construction cost estimates
2.1 Environmental Allowance: Rate x 1.0	Rate		2%	$ 22,473	
2.2 Materials Testing (QA/QC): Rate x 1.0	Rate		2%	$ 22,473	
2.3 Contractor Indirect Costs: Rate x 1.0	Rate		25%	$ 280,915	
2.4 Profit: Rate x (1.0 + 2.1 + 2.2 + 2.3)	Rate		10%	$ 144,952	
3.0 Contingencies				**$ 423,113**	Same rates as previous dam construction cost estimates
3.1 Design Contingency: Rate x (1.0 +2.0)	Rate		25%	$ 398,618	
3.2 Construction Contingency: Rate x (1.0 + 2.0)	Rate		20%	$ 24,495	
4.0 Conceptual Cost Estimate Total				**$ 2,018,000**	
5.1 Sum 1.0 thru 3.0	Total			$ 2,017,587	

Table 6.2: Overall Cost Summary

Land acquisition cost ($)	0M
Construction Cost ($)	2M
Operating Cost ($/yr)	0.004M
Overall Cost (Present value, $)	2M
Cost effectiveness ($/BG)	1M

The estimated schedule for the project shown below is also very rough. Although the infrastructure is not complex, navigating the USACE regulatory process can take many years; the project would likely need to be authorized for water supply purposes. The schedule could be extended for many years if complications are encountered like endangered species, mitigation of environmental impacts, or political opposition.

- Funding acquisition 3 years
- Design, permitting and land acquisition 5 years
- Construction 1 years
- Startup 1 years
- Total 10 years

7 Potential Ancillary Benefits

The slight expansion of the area of the reservoir would not provide a significant recreational or other benefit.

8 Storage Project Score

This site was scored as described in the main report and summarized in Table 8.1 below for the six primary criteria. Each primary criterion contained subcriteria which were scored on a 1 (worst) to 5 (best) scale and averaged. Scores on the primary criteria were weighted as shown in Table 8.1 and summed to obtain an overall weighted average score. The detailed scoring sheet is attached. Scores are compared among projects in Section 6 of the main report.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.17	30%	1.25
Infrastructure Design, Construction & Operation	3.80	10%	0.38
Environmental & Regulatory Considerations	3.25	15%	0.49
Stakeholder and Social Considerations	4.78	10%	0.48
Project Cost & Schedule	4.50	30%	1.35
Potential Ancillary Benefits	1.80	5%	0.09
TOTAL	**3.72**		**4.04**

Appendix

Information from Corps' 2018 water control manual

Score sheet

Information from Corps' [2018 water control manual]

PERTINENT DATA

LOCATION	
Basin	Lackawaxen River
Stream	West Branch Lackawaxen River
River Mile	Approximately 4.7 miles upstream from the confluence with the mainstem Lackawaxen River at Honesdale, PA.
County	Wayne
State	Pennsylvania
DRAINAGE AREA	
Above Dam	59.6 square miles (One inch of runoff equals 3,179 acre-feet.)
DAM	
Type	Zoned earthfill embankment
Length	1,230 feet
Height	140 feet (w/o wall)
Top Width	25.5 feet
SPILLWAY	
Type	Uncontrolled, perched-type open channel excavation
Crest Elevation	1,205 ft. NGVD (Invert of pilot channels in fuse plug) 1,200 ft. NGVD (Control sill below fuse plug)
Width	130 feet
Design Discharge	65,000 cfs
REAL ESTATE ACQUISITION	
Fee Purchase	Below elevation 1,131.0 ft. NGVD
Flowage Easement	Elevation 1,131.0 ft. to elevation 1,205.0 ft. NGVD

Note: Elevation Conversion to NAVD88: NAVD88=NGVD-0.63

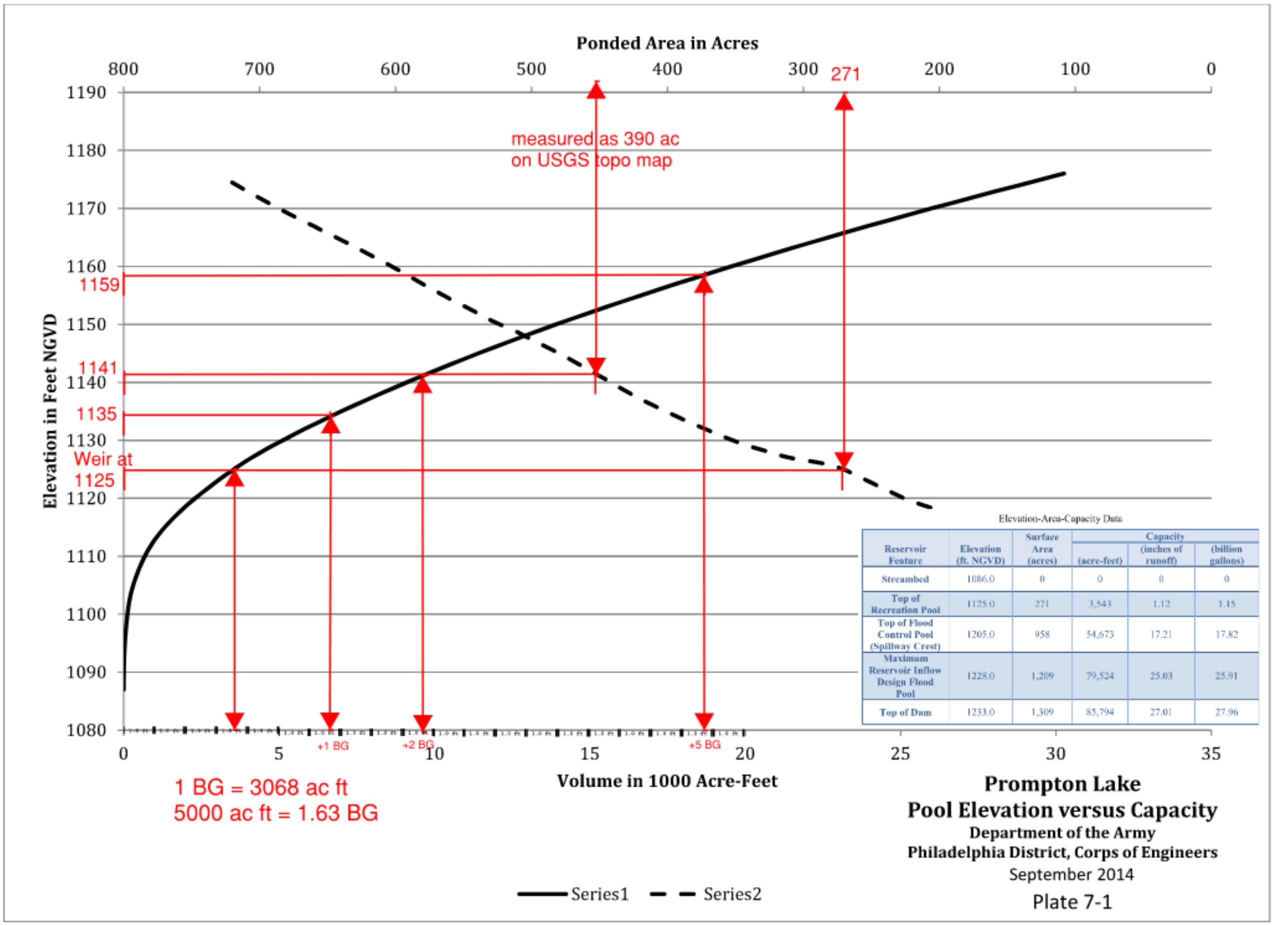
Elevation-Area-Capacity Data*

Reservoir Feature			Storage Capacity		
	Elevation (ft. NGVD)	Surface Area (acres)	(acre-feet)	Capacity (inches of runoff)	(billion gallons)
Streambed	1,086.0	0	0	0	0
Top of Recreation Pool	1,125.0	271	3,543	1.12	1.15
Top of Flood Control Pool	1,205.0	958	54,673	17.21	17.82
Top of Dam	1,233.0	1,309	85,794	27.01	27.96

***Revised in 2010 as a result of new sedimentation surveys and corrected in 2014**

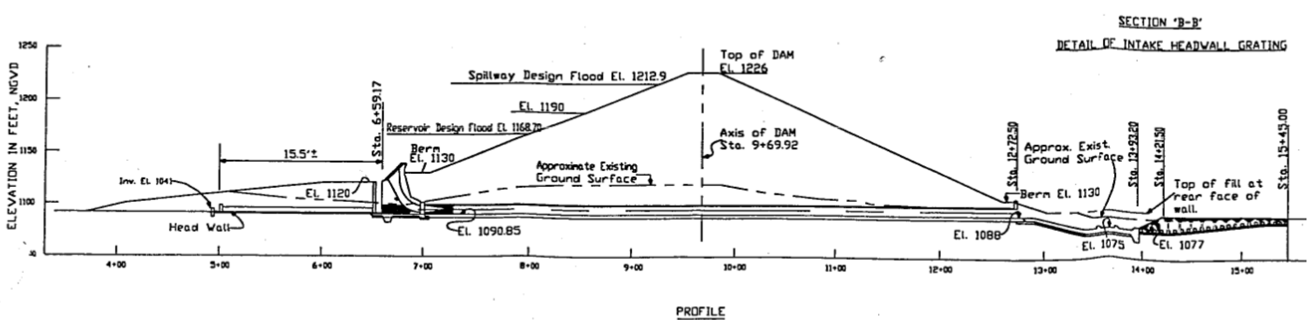
OUTLET WORKS	
Intake Structure	
Type	Ungated, Morning Glory-type uncontrolled drop intake structure with low level cool water intake
Main Weir Crest Elevation	1,125.0 ft. NGVD
Low level Cool Water Weir Crest Elevation	1,122.8 ft. NGVD
Low level Intake Conduit Invert Elevation	1,091.0 ft. NGVD
CONDUIT	
Location	Through embankment
Type	Concrete Conduit-Modified Circular Cross Section
Length	548 feet
Diameter	8.0 feet
Cross Sectional Area	58.5 square feet
Discharge Capacity (Spillway Crest Elevation 1,205.0 ft. NGVD) 3,500 cfs.	
Intake Invert Elevation	1,090.85 ft. NGVD
Outlet Invert Elevation	1,088.0 ft. NGVD
STILLING BASIN	
Trajectory Chute Length	70 feet
Basin Length	55 feet
Bottom Width	30 feet
Floor Elevation	1,075.0 ft. NGVD

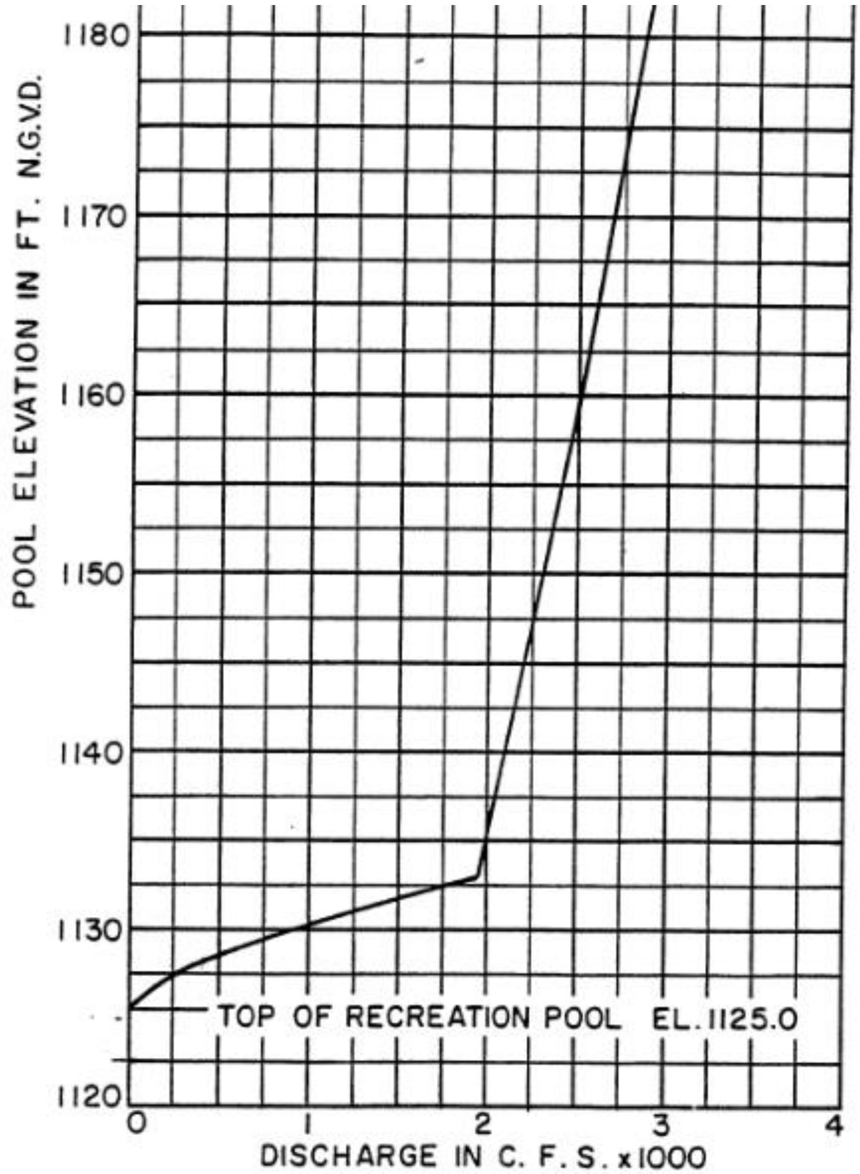
Plate 7-1 Elevation-Area-Capacity graph (current inlet at elevation 1125 ft)



Reservoir Feature	Elevation (ft. NGVD)	Surface Area (acres)	Capacity (acre-feet)	Capacity (inches of runoff)	Capacity (billion gallons)
Streambed	1086.0	0	0	0	0
Top of Recreation Pool	1125.0	271	3,543	1.12	1.15
Top of Flood Control Pool (Spillway Crest)	1205.0	958	54,673	17.21	17.82
Maximum Reservoir Inflow Design Flood Pool	1228.0	1,209	79,524	25.03	25.91
Top of Dam	1233.0	1,309	85,794	27.01	27.96

Plate 2-4: Outlet details





NOTE:
RATING CURVE OBTAINED FROM DESIGN MEMORANDUM NO. 2, "OUTLET WORKS DESIGN," APPENDIX B, SHEET 6. (n = .014)

LACKAWAXEN RIVER WATERSHED, W. BR. LACKAWAXEN RIVER, PA.

PROMPTON RESERVOIR

OUTLET RATING CURVE

DEPARTMENT OF THE ARMY
PHILADELPHIA DISTRICT, CORPS OF ENGINEERS
1997

PLATE 7-2

Six primary criteria	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
1. Water quantity and quality		4.17			30%	1.25	
o Volume of storage provided (BG)	2	2					
o Hydrologic reliability of supply (months to fill)	1	5					
o Release rate (cfs)	>>200	5					Per rating curve in Water Control Manual
o Promptness of delivery to mainstem (days)	<1	5					29 miles
o Geographic benefit		4					Lackawaxen basin; enters above Montague
o Quality of stored water		4					Corps monitoring says mesotrophic
2. Infrastructure design, construction and operation		3.80			10%	0.38	
o Site/Civil, Land & Easements		5					
o Subsurface conditions		5					
o Infrastructure Complexity		4					
o Construction complexity		4					
o Operational complexity		1					Gate must be opened before flood
3. Environmental impacts		3.25			15%	0.49	
o protected species		2					Indiana bat and northern long earned potential
o Water quality degradation of downstream waters		5					No additional impacts
o obstruction to passage of aquatic animals		5					No additional impacts
o hydromodification		5					No additional impacts
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o wetlands inundated or filled (ac)	70	1.75	2.5	1			Marsh and scrub shrub
o stream length inundated (mi)	0.8	2	3	1			A, B, and C streams present, many with trou
o uplands inundated or developed (ac)	45	2	1	3			
4. Social and Economic Impacts		4.78			10%	0.48	
o Disruption/displacement		5					
o Safety and health		3					Filling a portion of the flood pool entails some risk
o Social equity		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		5					
5. Project Costs & Schedule		4.50			30%	1.35	
o Land acquisition cost ($)	0.M	5					Assumed negible cost for state-owned, undevelopable land.
o Construction Cost ($)	2M						
o Operating Cost ($/yr)	0.004M						
o Overall Cost ($)	2M	5					
o Cost effectiveness ($/BG)	1M	5					
o Schedule (Time to make Operational, years)	10	3					complex regulatory issues with Corps projects
6. Ancillary Benefits		1.80			5%	0.09	
o Flood control		1					
o Recreation/tourism		3					Significant increase in pool level
o Habitat/fishery enhancement		3					Significant increase in pool level
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		3.72			100%	4.04	

Storage Project Summary

Project: Merrill Creek Reservoir (T1)

Location: Warren County, NJ

Storage Type: Transfer of control or ownership

Est. Volume: 2 billion gallons

Score: 3.91

1 Project Overview

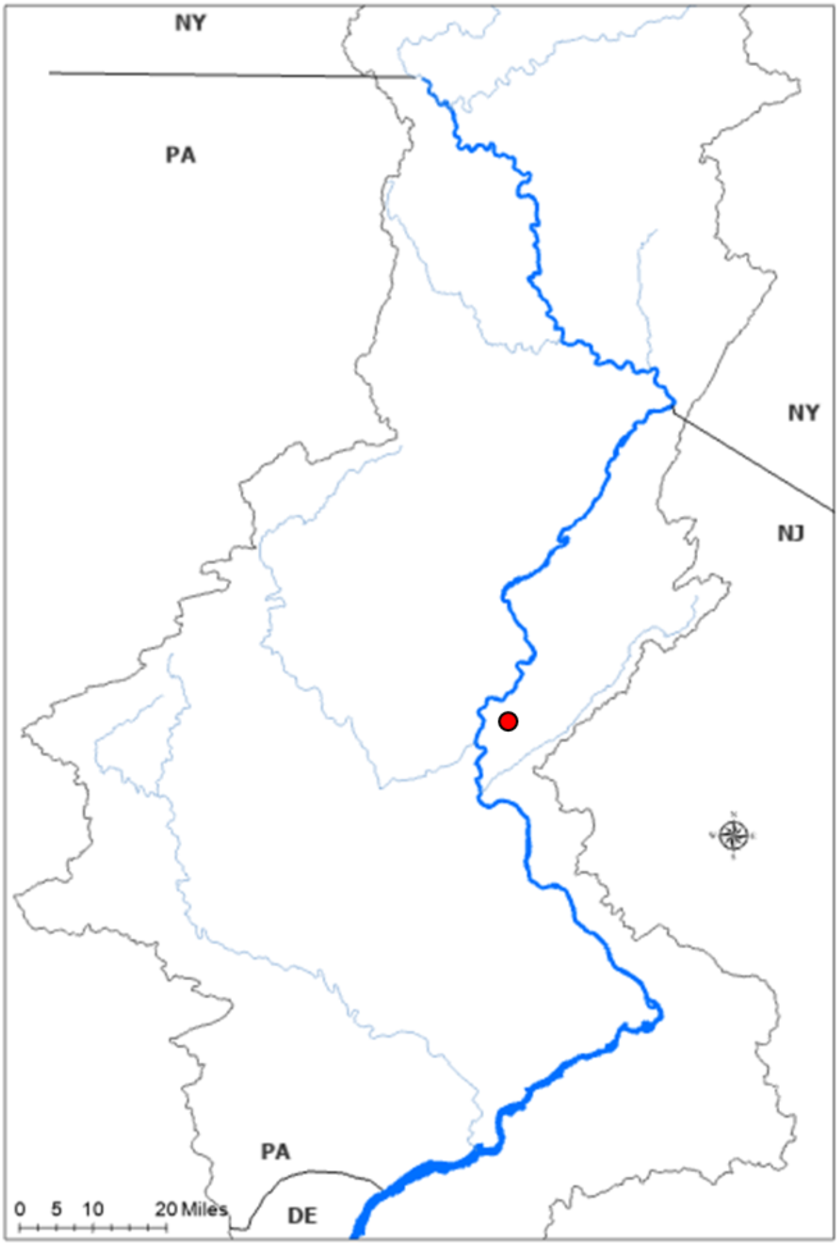
Merrill Creek Reservoir (MCR) may have excess storage whose control could be transferred by contract or lease to DRBC and released on request for flow augmentation. The reservoir, which impounds about 15 BG, was constructed in 1988 by a consortium of power companies (Merrill Creek Owner's Group, MCOG), to store water to release to the Delaware River to make up for the evaporative water usage at certain electric generating facilities in times of low flow in the river. According to the 2018 Plan of Operation (MCOG, 2018), seven companies own storage in the reservoir with percentages ranging from 4.8% to 44.2% (Exelon). Stored water may become available for purchase or lease as generating facilities shut down. The reservoir is refilled from the Delaware River by an existing pump station and pipeline.

The key advantages of this project are its negligible environmental and social impacts and (possible) short time to implementation.

It was difficult to gauge how much storage is or will be available, when it will become so, and how much it will cost. Such factors will likely be revealed only under negotiations with the MCOG. Volume of 1-2 BG may be available based on existing use reported in the DRBC Docket NO. D-1977-110 CP-19 (DRBC, 2018). Two billion gallons was assumed available for transfer to the direct control of the DRBC with the cost estimated at $6M/yr with a present value of over 30 years of $118M, giving a cost effectiveness of $59M/BG. This ranks as a poor cost effectiveness, but the cost estimate is very approximate and the actual cost negotiated with the MCOG may be much less.

Note the DRBC already has authority to direct the release of water from the Reservoir as detailed in DRBC Docket.

Figure 1.1: Project location



2 Water Quantity & Quality

2.1 Reservoir Storage Volume

The reservoir currently holds 15 billion gallons (BG) when full. Volume of 1-2 BG may be available based on existing use reported in the DRBC Docket. Two BG was assumed available to transfer to the control of the DRBC.

2.2 Fill and Discharge

The natural drainage area of Reservoir is very small at about 4 sq. mi. Therefore, it is designed to be refilled by a pump station on the Delaware River at river mile 192 (a few miles north of Phillipsburg, NJ) and a 17,000 ft pipeline. This system has a capacity of 217 cfs at maximum static head according to the Docket.

The reservoir contains a spillway which drains to a natural waterway leading to the Delaware River. Dry weather releases are made through an inlet tower leading to the abovementioned pipeline to the Delaware River. The Docket states the pipe has a diameter of 57 inches and “the reservoir could yield up to 162 cubic feet per second (cfs) during a repeat of the drought of record” but calculations show the capacity of this pipe close to 500 cfs with the water surface at the spillway elevation.

The infrastructure section below has more information on the pump station and outlet structure.

Releases from the MCR have a travel time of 25 hours to reach the gage at Trenton, NJ on the mainstem Delaware River.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Reservoir Properties

DESCRIPTION	VALUE
Storage	
Area (Acres)	650 acres
Nominal Rim Elev.	923 ft.
Bottom Elev.	723 ft.
Nominal Depth (Ft.)	200 ft.
Maximum Volume (Billion Gallons)	15 BG
Operating Volume (Billion Gallons)	15 BG
Water Supply – Reservoir Fill	
Established Source Stream	Delaware River
Anticipated Source Stream Drainage Area (Sq. Miles)	~6000 sq. mi.
Median Annual Stream Flow Rate (ft3/s)	~11,700 cfs
Maximum Pumping Rate	217 cfs, 140 mgd
Estimated Time to Fill 1 BG (Days)	7 days
Water Release – Reservoir Discharge	
Proposed discharge release rate (MGD)	162 cfs
Estimated Time to Release 1 BG (Days) from Storage	10 days
Water Supply – Travel to Use	
Pipeline Miles to Delaware River	3
Travel Time (hours)	<1

2.3 Water Quality

The source of the water to be stored in MCR comes from water pumped from the Delaware River near Phillipsburg, NJ. The water quality in the reservoir is evidently adequate to currently support flow augmentation and should continue to be so.

3 Infrastructure Design, Construction & Operation

Existing infrastructure

As reported in the Docket D, the dam has a zoned earthen embankment configuration that is approximately 260 feet high (above the original river channel) and 2,450 feet long that spans the Scotts Mountain Gap. There are three saddle dikes, two on the northwest side of the reservoir and one on the southeast side. The normal maximum surface elevation of MCR is 923 feet above mean sea level and has approximately 48,000 acre-feet (15 billion gallons) of usable water for augmentation needs. The reservoir is approximately 2 miles long and 1 mile wide at its maximum and impounds approximately 650 acres (about the area of Central Park in New York City).

The inlet-outlet tower is a vertical structure with multiple ports, approximately 200 feet in vertical height. Each port is at a different level so that water can be released from the reservoir level at which water temperature and quality most nearly match that of the Delaware River at the time of release. Also, the multiple ports permit the discharge of river water into the reservoir at the most advantageous level for control of water quality in the impoundment. The inlet-outlet tower is connected to the pump house by approximately 17,000 feet of pipeline, 1,400 feet of which is installed in a tunnel. The tunnel has a finished dimension of 96 inches. The pipe has a diameter of 57 inches and, except in the tunnel, is buried a minimum of six feet below the ground surface. The docket states “the reservoir could yield up to 162 cubic feet per second (cfs) during a repeat of the drought of record” but calculations show the capacity of this pipe close to 500 cfs with the water surface at the spillway elevation.

There is a 400 feet long emergency spillway at elevation 929.0 feet on the reservoir upstream side that spills to Lopatcong Creek. Because the reservoir has excess capacity above the normal operating level (923 feet above mean sea level) - capacity adequate to contain the probable maximum precipitation and probable maximum flood - the spillway has not been used but was constructed to insure against the remote possibility that the water level could rise above elevation 929 feet.

The pump house water intake facility is located 130 feet out from the shore of the Delaware River at river mile 192 and is connected to the pump house by three 54-inch diameter buried pipes. The intake consists of an array of 72 cylindrical wedge-wire screens, each 30 inches in diameter. The slotted screen openings are 2 millimeters (mm) each. The pump house contains three pumps, each with a capacity of 72.5 cfs at maximum static hydraulic head. Utilizing all three pumps, the pump house intake facility has the capacity to transmit water at a rate of 217 cfs from the Delaware River to MCR, based on the maximum static head.

Additional Infrastructure

No additional infrastructure is expected to be needed to facilitate the transfer of water from the Merrill Creek Reservoir to the Delaware River. Thus, no additional land is needed and there is no need to construct at the site.

4 Environmental Impacts

Environmental impacts from the transfer of storage are negligible since there is no construction involved with this project. Timing and volume of release from the reservoir to the Delaware River and filling of the reservoir from the Delaware River using the pump station follows procedures outlined in the DRBC Docket. Docket conditions are designed to minimize impacts to the receiving waters.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor. In terms of scoring criteria (disruption, equity, safety, aesthetics, recreational impact, cultural/historical loss, taxes, and land disruption), this project scores favorably. No losses in aesthetics, equity, economy, or cultural resources are expected from the project.

6 Project Cost & Schedule

The estimated costs of transfer of control of 2 BG storage from MCR are based on the method presented in Appendix B, namely past charges to another utility scaled up and normalized to cost per BG. Available storage of 2 BG is assumed for this cost estimate. Cost-sharing for Operation & Maintenance (O & M) and Annual Pumping Expenses have not been established but are expected to be small in comparison to the storage charge. Table 6.1 presents summary cost line items.

Table 6.1: **Annual Cost Summary**

Item	Unit	Quantity	Cost/Unit	Extended Cost
Commitment				
Fee per year for 30 years	Fee		$28,900	$28,900
Annual Capacity Fee				
Annual Fee	BG	2	$2.6M	$5.2M
Operation & Maintenance				
Adjustable Annual Fee	LS	1	$	$
Pumping				
Adjustable Annual Fee	LS	1	$	$
TOTAL (No Contingency)				$5.2M
Contingency for O & M and pumping (15%)				$0.8M
TOTAL COST (With Contingency)				$6.0M

There are no capital costs for this project. The present value of the annual cost of $6.0M over 30 years at 3% is $118M, with a cost effectiveness of $59M/BG. This ranks as a poor cost effectiveness, but the cost estimate is very approximate, and the actual cost negotiated with the MCO may be much less.

The schedule for putting the project in service after general concurrence of all major parties is expected to be approximately 1 year. This includes:

- Design, permitting and land acquisition 0 years
- Construction 0 years
- Use of transferable storage 1 year

7 Potential Ancillary Benefits

No ancillary benefits are identified since the project only includes transfer of water from existing storage.

8 Storage Project Score

The transfer of storage from the Merrill Creek Reservoir is scored relative to the criteria presented in the main report. Summary categories and scores are presented in Table 8.1 below. Backup details to individual scores are available in the main report. The project scored well on criteria 1, reflecting the availability of storage and lack of infrastructure costs. Also, because there is no storage construction proposed, criteria 2 (design, construction, and operation), criteria 3 (environmental) and criteria 4 (stakeholder and social) scored very well. The project scored low on criteria 5 and 6 due to its large cost and lack of additional benefits to water resources. The transfer cost of $6.01M for the 2 BG of storage per year is large and may not be worth the reservation of storage for use during rare low flow conditions in the Basin. However, partnership between DRBC and MCOG may allow for negotiation of more reasonable costs for the transfer of 2 BG of storage.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.50	30%	1.35
Infrastructure Design, Construction & Operation	4.60	10%	0.46
Environmental & Regulatory Considerations	5.00	15%	0.75
Stakeholder and Social Considerations	5.00	10%	0.50
Project Cost & Schedule	2.67	30%	0.80
Potential Ancillary Benefits	1.00	5%	0.05
TOTAL	**3.79**		**3.91**

Appendix

Score sheet

Six primary criteria	Quantitative Evaluation Metric (where appropriate)	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
	(enter values only in ungreyed cells)						
1. Water quantity and quality		4.50			30%	1.35	
o Volume of storage provided (BG)	2	2					
o Hydrologic reliability of supply (months to fill)	NA	5					
o Release rate (cfs)	>200	5					
o Promptness of delivery to mainstem (days)	<1	5					
o Geographic benefit		5					Enters near Phillipsburg NJ, between Trenton and Montague
o Quality of stored water		5					Pumped in from Delaware
2. Infrastructure design, construction and operation		4.60			10%	0.46	
o Site/Civil, Land & Easements		5					No modifications to land or infrastructure required
o Subsurface conditions		5					
o Infrastructure Complexity		5					
o Construction complexity		5					
o Operational complexity		3					operations may be complex due to many users sharing the storage during drought conditions
3. Environmental impacts		5.00			15%	0.75	
o protected species		5					
o Water quality degradation of downstream waters		5					
o obstruction to passage of aquatic animals		5					
o hydromodification		5					
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o wetlands inundated or filled (ac)	0	5	5	5			No impacts
o stream length inundated (mi)	0	5	5	5			
o uplands inundated or developed (ac)	0	5	5	5			
4. Social and Economic Impacts		5.00			10%	0.50	
o Disruption/displacement		5					No impacts
o Safety and health		5					
o Social equity/environmental justice		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		5					
5. Project Costs & Schedule		2.67			30%	0.80	
o Land acquisition cost ($)	0M						
o Construction Cost ($)	0M						
o Operating Cost ($/yr)	6.M						2 BG at $3M/BG/yr
o Overall Cost ($)	118M	1					
o Cost effectiveness ($/BG)	59M	2					
o Schedule (Time to make Operational, years)	1	5					
6. Ancillary Benefits		1.00			5%	0.05	
o Flood control		1					
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		3.79			100%	3.91	

Storage Project Summary

Project:	**Rio Reservoir (Mongaup Hydropower Reservoir, T2)**
Location:	Sullivan County, NY
Storage Type:	Transfer of control or ownership
Est. Volume:	2 billion gallons assumed, 1- 3 BG possible.
Score:	4.16

1 Project Overview

The Mongaup Hydropower Reservoir System may contain existing storage whose ownership or control can be transferred to the DRBC and released upon request for flow augmentation. There are five reservoirs controlled by Eagle Creek Hydro Power, LLC in the Mongaup River watershed (Figure 1.1 and 1.2) whose storage totals about 15 BG. Swinging Bridge, Mongaup Falls, and Rio reservoirs (Figure 1.2) are all licensed by the Federal Energy Regulatory Commission (FERC Project No. 10482, No. 10481, and No. 9690). Their current licenses expire in 2022 and Eagle Creek has initiated the relicensing process for all three projects. (Eagle Creek, 2020). More information is available on their web site.

In conversations with representatives of Eagle Creek, they indicated that storage might be available for transfer but did not specify a volume. Rio (Figure 1.3) is the most downstream reservoir and would control releases for flow augmentation . The nominal storage in Rio is about five BG. Two BG was assumed to be available, but the actual volume available and cost thereof is likely to be revealed only during negotiations between DRBC and Eagle Creek.

As a reallocation of existing storage, no infrastructure would be built, and no additional land would be flooded. Therefore, the environmental and socioeconomics impacts are negligible. The key advantages of this project are its negligible environmental and social impacts and (possible) short time to implementation.

The annual cost was estimated as $3.1M with a present value of $60M and cost effectiveness of $30M/BG, which was ranked medium, but, again, actual costs can be determined only during negotiation.

(An increase in storage via a dam raise was discussed with Eagle Creek, who considered it a possibility. However, detailed information on the design and materials of the dam could not be obtained, so the feasibility and cost of this the dam raise could not be evaluated.)

Figure 1.1: Project Location

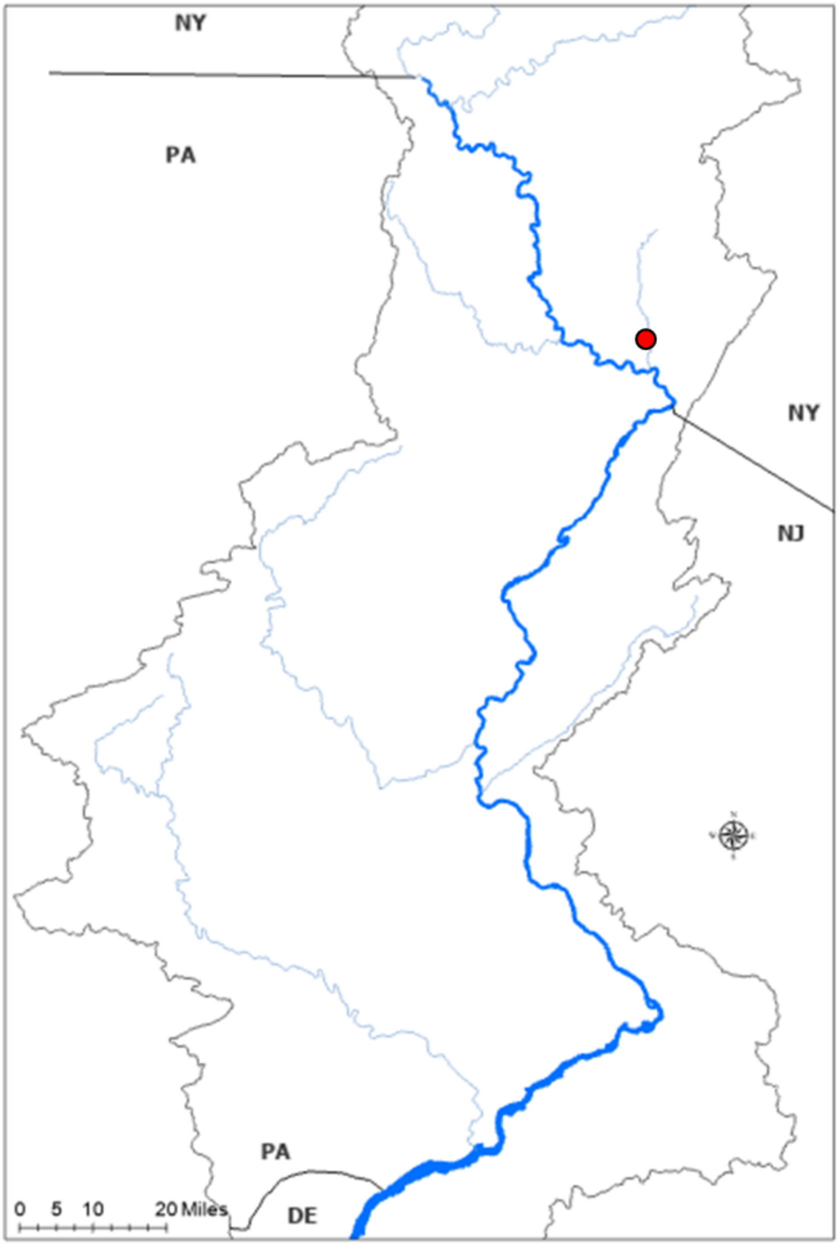


Figure 1.2: Eagle Creek’s Reservoirs in the Mongaup system (Source: Eagle Creek)

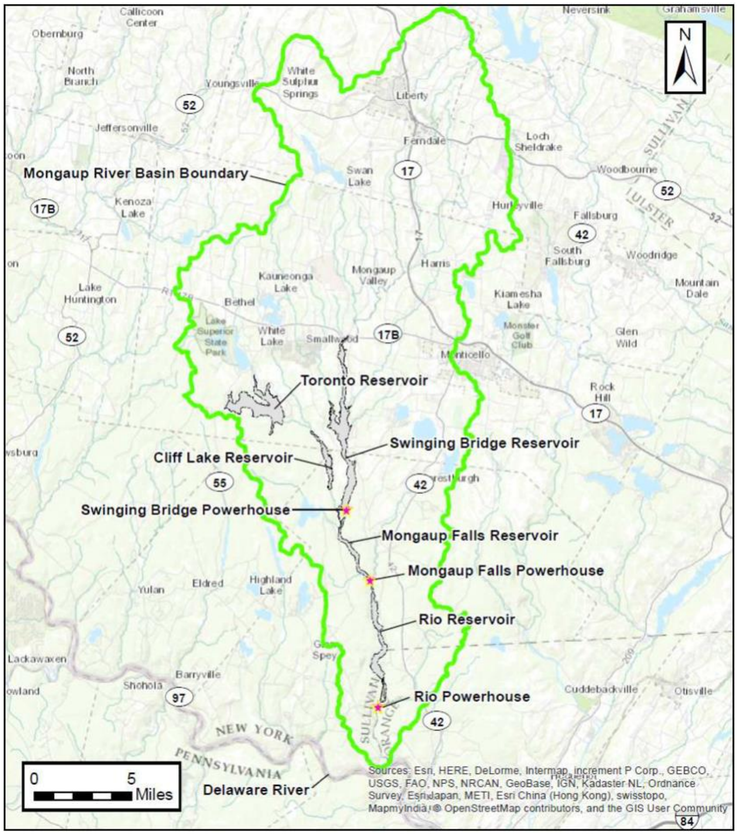


Figure 1.3 Rio Dam showing road above spillway (source: www.eaglecreekre.com)

Rio - Dam and Bypass Flow Unit

2 Water Quantity & Quality

2.1 Reservoir Storage Volume

The Mongaup Reservoir System consists of five reservoirs: Toronto, Cliff Lake, Swinging Bridge, Mongaup Falls, and Rio. Storage totals about 15 BG, primarily in Toronto, Swinging Bridge, and Rio Reservoirs. Storage capacities as reported by Eagle Creek are presented in Table 2.1.

Rio is the most downstream reservoir and would control releases for flow augmentation (Figure 1.2). The nominal storage in Rio is about 5 BG. Two BG was assumed available.

Table 2.1: Storage capacities as reported by Eagle Creek in FERC licensing reports, Volume I (Eagle Creek, 2020)

Characteristic	Reservoir				
	Swinging Bridge Project			Mongaup Falls	Rio
	Toronto	Cliff Lake	Swinging Bridge		
Normal Maximum Surface Elevation	1,220	1,071.1	1,070	935	815
Minimum Surface Elevation	1,170	1,048	1,048	910	805
Normal Maximum Surface Area (acres)	843	183	980	133	444
Gross Storage Capacity (acre-feet)	27,064	3,200	35,925	1,782	14,536
Useable Storage Capacity (acre-feet)	26,038	2,694	16,519	879	3,354

2.2 Fill and Discharge

The reservoirs in the Mongaup system are refilled after discharge from the 200 sq. mi. Mongaup River watershed above the reservoirs. The mean flow of above Rio dam is about 380 cfs. At that rate, it would take about 8 days to replenish the 2 BG after release.

The low-water outlet of Rio reservoir consists of an above-ground, eleven-foot diameter penstock pipe (visible in Figure 1.3) with a capacity of at least 900 cfs, which is more than adequate for flow augmentation. The penstock feeds turbines, but a bypass valve and pipe can convey flow directly to the River.

Minimum releases are imposed on the reservoir and are reported by Eagle Creek in licensing materials as shown in Table 2.2

Table 2.2: Minimum releases as reported by Eagle Creek

CURRENT MINIMUM FLOW REQUIREMENTS

Location	Flow Requirement
Swinging Bridge Project	---
Toronto Dam	10 cfs
Cliff Lake Dam	10 cfs
Swinging Bridge Dam	100 cfs or inflow (but not less than 60 cfs)
Mongaup Falls Project	---
Bypassed reach	70 cfs or inflow (but not less than 60 cfs)
Powerhouse	20 cfs
Rio Project	--
Bypassed Reach	100 cfs or inflow (but not less than 60 cfs)

2.3 Water Quality

According to the FERC filing by Eagle Creek, the reservoirs exhibit thermal and chemical stratification of varying strengths and depths throughout the seasons. The stratification of the reservoirs, at times, contributes to reduced DO concentrations in the riverine reaches downstream of the dam. In any case, water from the reservoirs is already flowing into the Mongaup River and the Delaware River, so it is presumed that the water quality is adequate to support flow augmentation.

3 Infrastructure Design, Construction & Operation

The Rio Reservoir is approximately 3.56 miles long and has a maximum width of 1,836 feet. The Dam is approximately 1,500 feet long; the concrete spillway is 264 feet long and 101 feet high.

No additional infrastructure is expected for the reallocation of storage. No additional land is needed and there is no need to construct at the site.

4 Environmental Impacts

Environmental impacts from the transfer of storage are negligible since there is no construction involved with this project. Timing and volume of release from the reservoirs would be designed to improve low-flow conditions in the Delaware River.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor. In terms of scoring criteria (disruption, equity, safety, aesthetics, recreational impact, cultural/historical loss, taxes, and land disruption), this project scores favorably. No losses in aesthetics, equity, economy, or cultural resources are expected from the project.

6 Project Cost & Schedule

The estimated costs for transfer of storage from the Mongaup system are based on average retail prices for raw water charged by a sample group of storage owners to wholesale customers per BG as explained in Appendix B. Available storage of 2 BG is assumed for this cost estimate. Table 6.1 presents summary cost items.

Table 6.1: **Annual Cost Summary**

Item	Unit	Quantity	Cost/Unit	Extended Cost
Annual Fee	BG	2	$1.4M	$2.8M
Contingency (10%)				$0.28M
TOTAL (With Contingency)				$3.1M

There are no new capital costs for this project. At annual cost of $3.1M, the present value over 30 years at 3% is $60M, giving a cost effectiveness of $30M/BG, ranking near the middle of all projects, but these costs have high uncertainty.

The schedule for putting the project in service after general concurrence of all major parties is expected to be approximately 1 year. This includes:

- Design, permitting and land acquisition 0 years
- Construction 0 years
- Use of transferable storage 1 year

7 Potential Ancillary Benefits

No ancillary benefits are identified because the project only includes transfer of water from existing storage.

8 Storage Project Score

The transfer of storage from the Mongaup system of reservoirs is scored relative to the criteria presented in the main report. Summary categories and scores are presented in Table 8.1 below. Backup details to individual scores are available in the main report. The detailed score sheet is attached.

The project scored above average on criterion 1, indicating good reliability, release rate, and proximity to the mainstem. Also, because there is no storage construction proposed, criterion 2 (design, construction, and operation), criterion 3 (environmental) and criterion 4 (stakeholder and social) scored very well. The project scored near average on criterion 5 as its cost and cost effectiveness are moderate. Its overall score is the highest of any project, but the volume and cost are highly uncertain.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.17	30%	1.25
Infrastructure Design, Construction & Operation	4.60	10%	0.46
Environmental & Regulatory Considerations	5.00	15%	0.75
Stakeholder and Social Considerations	5.00	10%	0.50
Project Cost & Schedule	3.83	30%	1.15
Potential Ancillary Benefits	1.00	5%	0.05
TOTAL	**3.93**		**4.16**

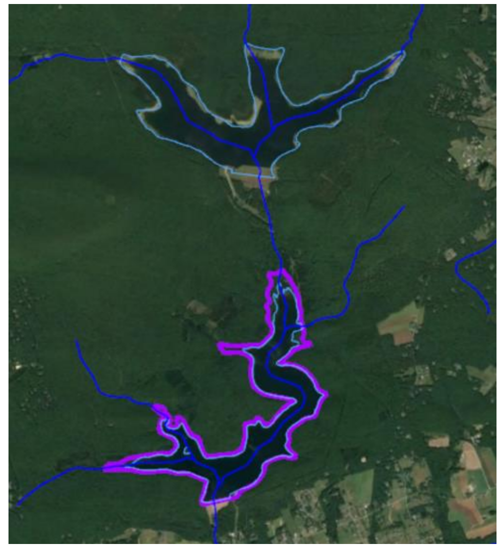
.

Appendix

Detailed Score Sheet

Six primary criteria	Quantitative Evaluation Metric (where appropriate)	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
	(enter values only in ungreyed cells)						
1. Water quantity and quality		4.17			30%	1.25	
o Volume of storage provided (BG)	2	2					
o Hydrologic reliability of supply (months to fill)	NA	5					
o Release rate (cfs)	>200	5					
o Promptness of delivery to mainstem (days)		5					About 5 miles to mainstem
o Geographic benefit		4					Above Montague
o Quality of stored water		4					Reservoirs stratified thermally, chemically and DO
2. Infrastructure design, construction and operation		4.60			10%	0.46	
o Site/Civil, Land & Easements		5					
o Subsurface conditions		5					
o Infrastructure Complexity		5					
o Construction complexity		5					
o Operational complexity		3					Competing with hydropower interest
3. Environmental impacts		5.00			15%	0.75	
o protected species		5					
o Water quality degradation of downstream waters		5					No change
o obstruction to passage of aquatic animals		5					
o hydromodification		5					
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o wetlands inundated or filled (ac)	0	5	5	5			
o stream length inundated (mi)	0	5	5	5			No modifcation to land or infrastructure
o uplands inundated or developed (ac)	0	5	5	5			
4. Social and Economic Impacts		5.00			10%	0.50	
o Disruption/displacement		5					
o Safety and health		5					
o Social equity/environmental justice		5					
o Recreational loss		5					
o Cultural/historical resources		5					No impacts
o Aesthetic		5					
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		5					
5. Project Costs & Schedule		3.83			30%	1.15	
o Land acquisition cost ($)	0M						
o Construction Cost ($)	0M						
o Operating Cost ($/yr)	3.1M						1.4M$/BG per year
o Overall Cost ($)	60M	3					
o Cost effectiveness ($/BG)	30M	3.5					
o Schedule (Time to make Operational, years)	1	5					
6. Ancillary Benefits		1.00			5%	0.05	
o Flood control		1					
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		3.93			100%	4.16	

Storage Project Summary

Project:	**Penn Forest & Wild Creek Reservoirs (T3)**	
Location:	Carbon County and Monroe County, Pennsylvania (PA)	
Storage Type:	Transfer of control or ownership	
Est. Volume:	3 billion gallons assumed; 1-5 BG possible	
Score:	3.87	

1 Project Overview

The Bethlehem Authority and the City of Bethlehem own/manage the Penn Forest and Wild Creek Reservoirs in the Lehigh River watershed as water supply reservoirs (Figure 1.1 – 1.4). The reservoirs are described in the DRBC Docket D-1995-019 CP-2 (DRBC, 2022). The reservoirs may have excess storage that could be transferred to DRBC's control by sale or lease and released upon request for flow augmentation. Penn Forest Reservoir is approximately one mile upstream from Wild Creek Reservoir in the Pohopoco Creek watershed in Carbon County and Monroe County, PA. In addition to natural drainage, the reservoirs can be filled by a withdrawal on Tunkhannock Creek about 9 miles to the north. Both drainage basins are within the Lehigh River Watershed.

The two reservoirs have a combined storage of 9.9 billion gallons (BG), which is sufficient to supply a normal flow of water to the service area for at least 12 months with no rainfall. Under normal pool elevations, the safe yield of the three sources is 22 mgd without the Tunkhannock Creek diversion compared to current withdrawals of about 15 mgd.

The key advantages of this project are its negligible environmental and social impacts and (possible) short time to implementation.

It is difficult to gauge how much storage is or will be available, and how much it will cost. Such factors will likely be revealed only under negotiations with the owner. Volume of 1-5 BG may be available based on existing use. Three billion gallons were assumed available for transfer to the direct control of the DRBC with the cost estimated at $8.25M/yr with a present value of $168M, giving a cost effectiveness of $54M/BG. This ranks as poor cost effectiveness, but the cost estimate is uncertain and the actual cost negotiated with the owner may be much less.

Per the Docket, the original Penn Forest dam was constructed in 1958 and replaced in 1998. The current dam is a roller compacted concrete dam measuring approximately 2,050 feet in length and 180 feet high. The spillway and normal pool are located at an elevation of 1000.6 feet above mean sea level (MSL). The Penn Forest Reservoir has a capacity of 6.0 BG and a drainage area of 16.5 square miles. Water from the Penn Forest Reservoir is released to Wild Creek which flows into the Wild Creek Reservoir. The Wild Creek dam sits a short distance upstream of the pool created by the USACE's Beltzville Dam. Constructed in 1941, it is a rolled earth and coarse fill embankment measuring approximately 1,076 feet long and 135 feet high. The spillway and normal pool are located at an elevation of 820 feet above MSL. The Wild Creek reservoir has a storage capacity of 3.9 BG and is supplied by releases from Penn Forest Reservoir and the additional 5.7 square mile watershed between the two reservoirs. The total drainage area above the Wild Creek Dam (including Penn Forest Reservoir) is approximately 22.2 square miles. The Wild Creek outlet structure having a capacity of 33.0 mgd delivers water to two (30- to 42-inch) diameter transmission mains and two 48-inch diameter rock tunnels that convey water to the water filtration plant. The City of Bethlehem is permitted by PADEP to withdraw up to 30.32 mgd from the Wild Creek Reservoir and is also subject to conservation release requirements of 3.9 cfs (2.5 mgd) into Wild Creek.

Figure 1.1: Project Location

Figure 1.2: Topographic map: Existing reservoirs in blue, Wild Creek outlined in purple, drainage area in red (22 sq miles)

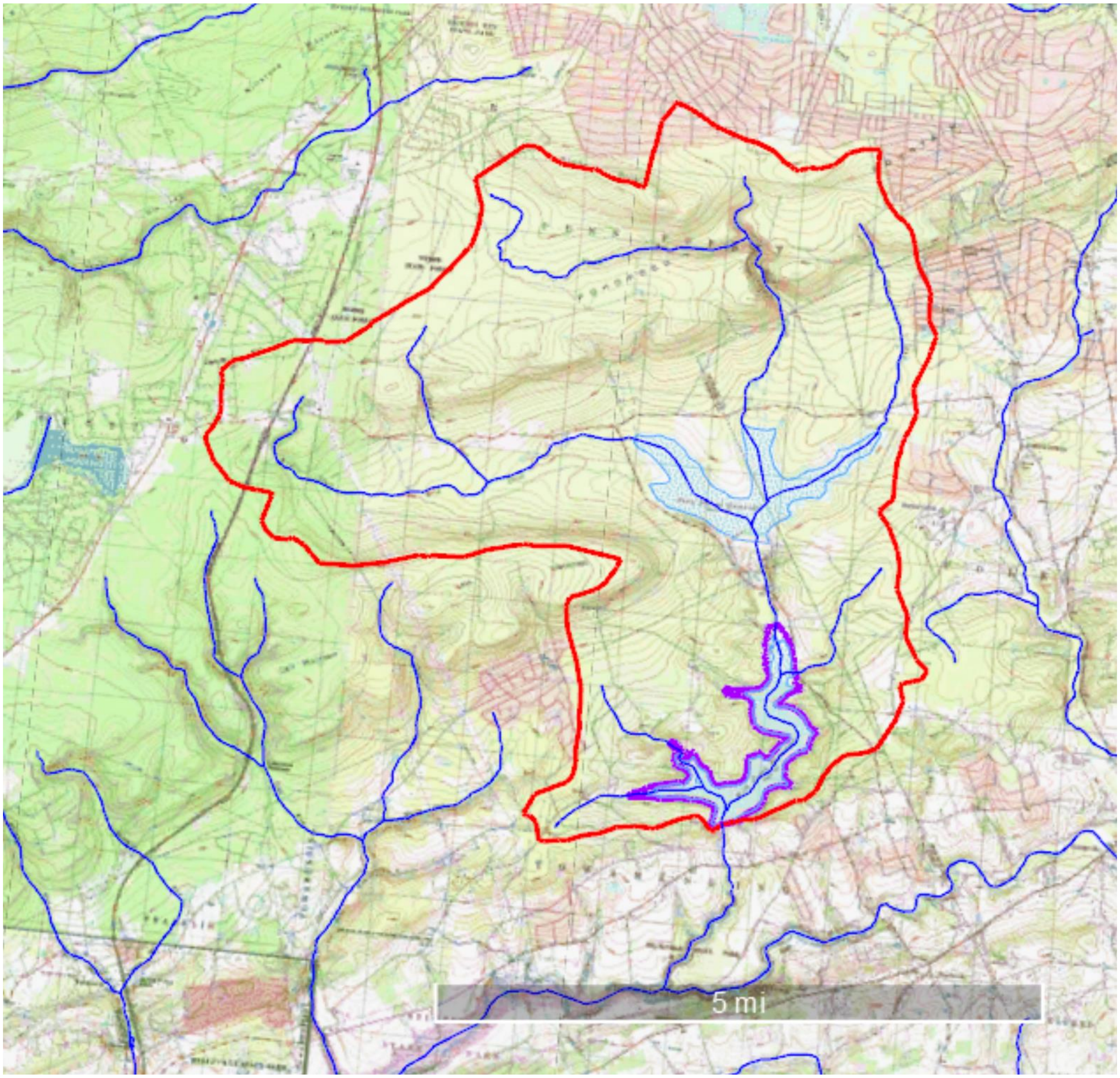


Figure 1.3: Aerial photo: Wild Creek outlined in purple, drainage area in red (22 sq miles)

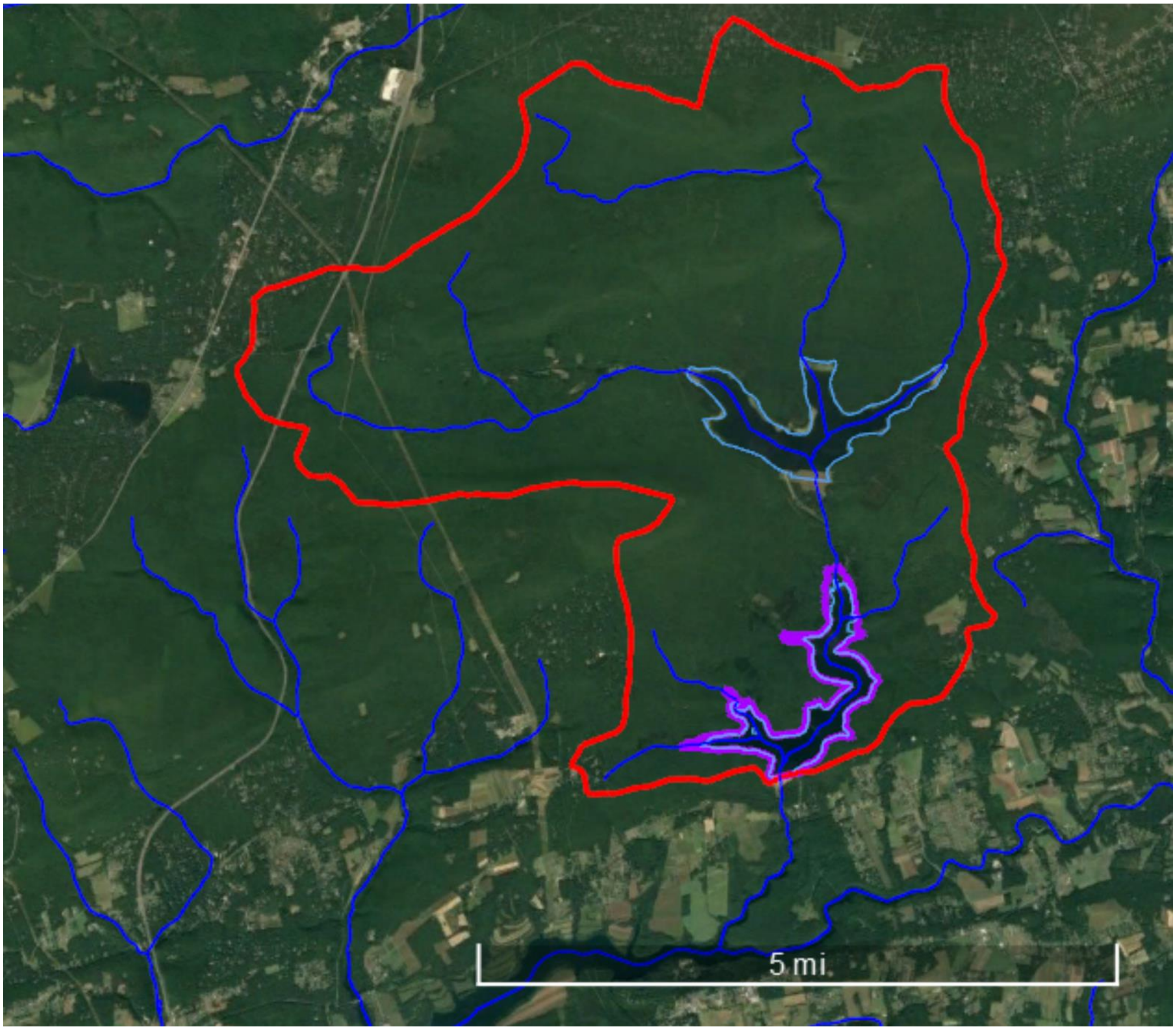


Figure 1.4: Aerial views of Penn Forest (top; low-level outflow indicated by red arrow) and Wild Creek (bottom) dams

2 Water Quantity & Quality

2.1 Reservoir Storage Volume

Penn Forest and Wild Creek Reservoirs collectively hold 9.9 BG of water under normal conditions and 15 BG under maximum conditions. Considering normal full conditions for the purposes of potential transfer, the Penn Forest Reservoir holds 6 BG and Wild Creek holds 3.9 BG. To estimate the storage that may be available for transfer, safe yield estimates computed in 1995 were used (Gannett Fleming Inc. 1995), estimated at 22 MGD per Table 2.1. About 2 MGD is required to be released to the Beltzville Reservoir and 15 MGD transmitted to the City of Bethlehem for distribution to the City and surrounding communities, leaving about 5 MGD for other uses. One reason for excess supply is the closure of the Bethlehem Steel plant in the mid-1990s. Thus, the system is being considered for its value as transferrable storage in the DRBC Storage Project, with 1-5 BG estimated as possibly available and 3 BG assumed for this analysis. Figure 2.1 shows watershed and source waters of the reservoirs. Table 2.1 shows the safe yield analysis.

Figure 2.1: Watershed and source waters of the reservoirs
(Gannett and Fleming, 1995)

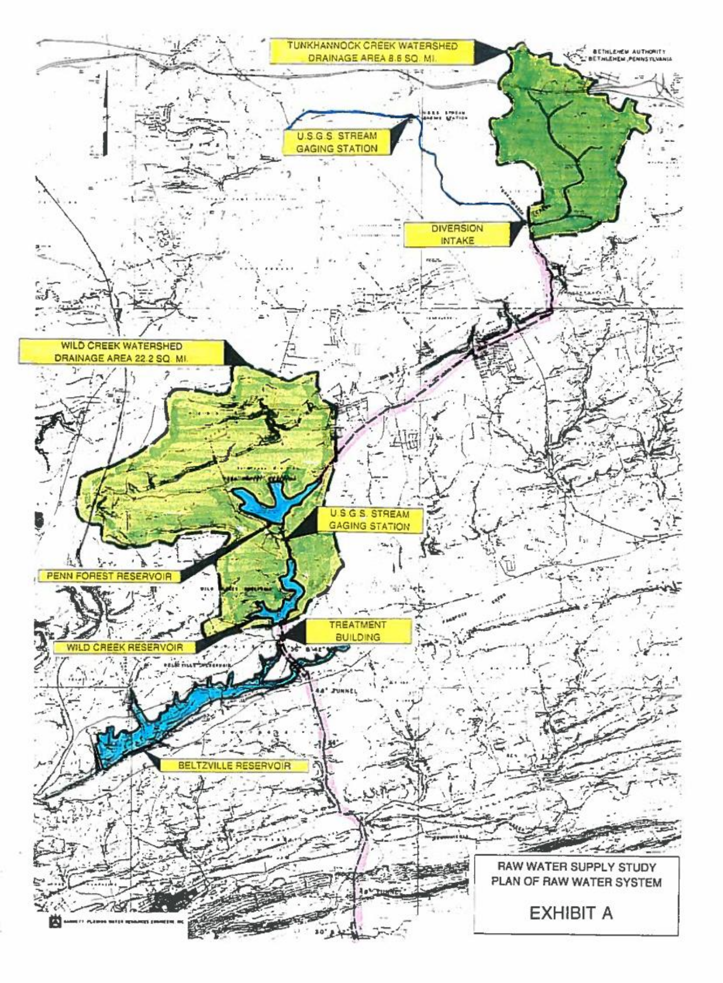


Table 2.1 Safe Yield Analysis (Gannett Fleming Inc. 1995)

Summary of Detailed Safe Yield Analyses
(Release Requirement From Wild Creek Reservoir = 1.1 mgd, Minimum Flowby at Tunkhannock Creek Diversion = 4.0 mgd)

Normal Pool Elevation			Safe Yield		
Penn Forest Reservoir (Feet)	Wild Creek Reservoir (Feet)	Total Storage (BG)	With Tunkhannock Diversion (MGD)	Without Tunkhannock Diversion (MGD)	Additional From Tunkhannock Diversion (MGD)
1,000	820	10.3	26.3	22.4	3.9
980	820	7.6	24.7	20.9	3.8
958	820	5.8	22.8	19.8	3.0
950	820	5.2	22.3	19.4	2.9
940	820	4.7	21.4	18.9	2.5
Empty	820	3.9	18.5	18.0	0.5

2.2 Fill and Discharge

Water would be released from Penn Forest Reservoir via adjusting the valve in the low-level outlet, visible in Figure 1.4, which drains into Wild Creek Reservoir. The released volume would flow into Wild Creek Reservoir, which is normally kept level with the spillway, and spill over into the Creek. Given the expected water demand supplied by the reservoirs, there should always be sufficient volume in Penn Forest Reservoir to transfer to the Wild Creek Reservoir. Wild Creek flows into Beltzville Reservoir about ½ mile downstream. The DRBC already has agreements with the ACOE regarding releases from Beltzville.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

2.3 Water Quality

The reservoirs currently serve as a drinking water source. Presumably, the water quality would be satisfactory for flow augmentation. Wild Creek, whose water quality is good, is designated by the PADEP as Exceptional Value Waters supporting migratory fishes.

Table 2.1: Storage and Fill/Discharge Properties

a. Penn Forest Reservoir

DESCRIPTION	VALUE
Storage	
Area (Acres)	480 acres
Spillway Elev.	1000.6 ft.
Bottom Elev.	723 ft.
Nominal Depth (Ft.)	150 ft.
Maximum Volume (Billion Gallons)	6.0 BG
Operating Volume (Billion Gallons)	6.0 BG
Water Supply – Reservoir Fill	
Established Source Stream	Tunkhannock Creek/Wild Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	8.6 sq. mi./16.5 sq. mi.

b. Wild Creek Reservoir

DESCRIPTION	VALUE
Storage	
Area (Acres)	304 acres
Spillway Elev.	820 ft
Maximum Volume (Billion Gallons)	3.9 BG
Operating Volume (Billion Gallons)	3.9 BG
Water Supply – Reservoir Fill	
Established Source Stream	Wild Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	22.2 sq. mi.
Target discharge for flow augmentation	100 cfs

3 Infrastructure Design, Construction & Operation

No additional infrastructure or land is needed.

According to the October 2021 Penn Forest Dam Inspection Report prepared for the Bethlehem Authority (PADEP, 2021), the dam is in very good condition and is actively maintained with crews on site daily. The gate valves for the low-level outlet within the tunnel drain were exercised by City of Bethlehem personnel on 7/9/2020 without issue.

According to the October 2021 Wild Creek Dam Inspection Report prepared for the Bethlehem Authority (PADEP, 2021), the dam is in very good condition and is actively maintained with crews on site daily. The 36" diameter gate valves for the low-level outlet within the tunnel drain were exercised by City of Bethlehem personnel on 7/9/2020 without issue.

4 Environmental Impacts

Environmental impacts from the transfer of storage are negligible since there is no construction involved with this project. Timing and volume of release from the reservoirs to the Lehigh River follows procedures outlined in the DRBC dockets and the PADEP permits. Docket and permit conditions are designed to minimize impacts to the receiving waters.

5 Social and Economic Impacts

Stakeholder and social impacts would be negligible. In terms of scoring criteria (disruption, equity, safety, aesthetics, recreational impact, cultural/historical loss, taxes, and land disruption), this project scores favorably. No losses in aesthetics, equity, economy, or cultural resources are expected from the project.

6 Project Cost & Schedule

The estimated costs for transfer of storage from Penn Forest and Wild Creek are based on retail prices for raw water charged to wholesale customers per BG. Volume of 1-5 BG may be available based on existing use reported by the City of Bethlehem. Available storage of 3 BG is assumed for this cost estimate. The rates are effectively fixed and do not vary with the volume of water used. No variable charges have been identified. Table 6.1 presents summary cost line items. Contingency costs to account for the unknown annual costs are included in Table 6.1.

Table 6.1: **Annual Cost Summary**

Item	Unit	Quantity	Cost/Unit	Extended Cost
Annual Usage Fee				
Annual Fee	BG	3	$2.5M	$7.5M
TOTAL				$7.5M
Contingency (10%)				$0.75M
TOTAL COST (With Contingency)				$8.25M

There are no new capital costs for this project. The present value of the annual cost of $8.25M over 30 years at 3% is $162M, with a cost effectiveness of $54M/BG. This ranks as a poor cost effectiveness, but the cost estimate is uncertain, and the actual cost negotiated with the owner may be much less.

The schedule for putting the project in service after general concurrence of all major parties is expected to be approximately 1 year. This includes:

- Design, permitting and land acquisition 0 years
- Construction 0 years
- Use of transferable storage 1 year

7 Potential Ancillary Benefits

No ancillary benefits are identified since the project only includes transfer of water from existing storage.

8 Storage Project Score

The transfer of storage from the Penn Forest and Wild Creek Reservoirs is scored relative to the criteria presented in the main report. Summary categories and scores are presented in Table 8.1 below. Backup details to individual scores are available in the main report.

The project scored moderate on the water quantity/quality criteria because the volume is modest, but the water enters the mainstem between Montague and Trenton, which DRBC indicated is most desirable. Because there is no construction or inundation proposed, criteria 2 (design, construction, and operation), criteria 3 (environmental) and criteria 4 (stakeholder and social) scored very well. The project scored low on criteria 5 and 6 due to its large cost and lack of additional benefits. The annual cost of $8.25M for the 3 BG of storage per year is large and has a present value of $162M over the 30-year project life, giving a poor cost effectiveness of $54M/BG.

Negotiation between DRBC and the Bethlehem Authority may produce lower costs and/or larger volumes than assumed here.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.83	30%	1.15
Infrastructure Design, Construction & Operation	4.60	10%	0.46
Environmental & Regulatory Considerations	5.00	15%	0.75
Stakeholder and Social Considerations	5.00	10%	0.50
Project Cost & Schedule	3.17	30%	0.95
Potential Ancillary Benefits	1.20	5%	0.06
TOTAL	**3.80**		**3.87**

APPENDIX

Score Sheet

Six primary criteria	Quantitative Evaluation Metric (where appropriate)	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
	(enter values only in ungreyed cells)						
1. Water quantity and quality		3.83			30%	1.15	
o Volume of storage provided (BG)	3	2.5					
o Hydrologic reliability of supply (months to fill)	1	5					Mean inflow = 51cfs; Provides 3BG in 3 mo
o Release rate (cfs)	~ 50 cfs	3.5					discharges from Penn Forest thru spray valve, then from Wild Creek over spillway
o Promptness of delivery to mainstem (days)	~3	3					about 50 miles to mainsteam and must pass through Beltzville reservoir
o Geographic benefit		5					Enters via Lehigh River at Easton, PA, between Trenton and Montague
o Quality of stored water		4					Good leaving Wild Creek but degraded in Beltzville
2. Infrastructure design, construction and operation		4.60			10%	0.46	
o Site/Civil, Land & Easements		5					
o Subsurface conditions		5					
o Infrastructure Complexity		5					
o Construction complexity		5					
o Operational complexity		3					must closely monitoring release rate from Penn Forest and water level in Wild Creek, and coordiate with Beltzville
3. Environmental impacts		5.00			15%	0.75	
o protected species		5					No impacts
o Water quality degradation of downstream waters		5					
o obstruction to passage of aquatic animals		5					
o hydromodification		5					
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o wetlands inundated or filled (ac)	0	5	5	5			No impacts
o stream length inundated (mi)	0	5	5	5			
o uplands inundated or developed (ac)	0	5	5	5			
4. Social and Economic Impacts		5.00			10%	0.50	
o Disruption/displacement		5					No impacts
o Safety and health		5					
o Social equity/environmental justice		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		5					
5. Project Costs & Schedule		3.17			30%	0.95	
o Land acquisition cost ($)	0M						
o Construction Cost ($)	0M						
o Operating Cost ($/yr)	8.3M						2.75M$/BG/yr
o Overall Cost ($)	162M	2.5					based on 30 years of costs with 3%/yr rate
o Cost effectiveness ($/BG)	54M	2					
o Schedule (Time to make Operational, years)	5	5					
6. Ancillary Benefits		1.20			5%	0.06	
o Flood control		1					
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		2					Could slightly improve wq in Beltzville
o Ability to leverage funding from other programs		1					
OVERALL		3.80			100%	3.87	

MOTT MACDONALD

Storage Project Summary

Project: Lake Ontelaunee (T4)

Location: Berks County, Pennsylvania (PA)

Storage Type: Transfer of control or ownership

Est. Volume: 1 billion gallons assumed

Score: 4.01

1 Project Overview

Lake Ontelaunee is a 1,082-acre water supply reservoir on Maiden Creek in Berks County, Pennsylvania (Figure 1.1), owned by the City of Reading and operated by the Reading Area Water Authority (RAWA). The lake may contain existing storage whose ownership or control can be transferred to the DRBC and released upon request for flow augmentation. The drainage area and reservoir are mapped in Figures 1.2 and 1.3

The dam on Maiden Creek was constructed between 1926 and 1934 having two components: a concrete gravity spillway and an earthen embankment. Route 73 runs along the top of embankment dam and the spillway (Figure 1.4).

The nominal volume of the lake is about 3.9 BG. The owner did not state a volume that may be available. One BG was assumed available for transfer. The actual volume availability and cost thereof is likely to be revealed only during negotiations between DRBC and RAWA.

As a reallocation of existing storage, no infrastructure would be built (although there is some uncertainty about the capacity of the discharge system) and no additional land would be flooded. Therefore, the environmental and socioeconomic impacts are negligible. The key advantages of this project are its negligible environmental and social impacts and (possible) short time to implementation.

The annual cost was estimated as $1.4M with a present value of $27M and cost effectiveness of $27M/BG, which was ranked medium, but, again, actual costs can be determined only during negotiation.

The large Evansville quarry (Q8) sits adjacent to the lake (Figure 1.5); see that SPS for discussion of how the lake could feed the quarry.

(An increase in storage via a dam raise was initially considered. However, detailed information on the design and materials of the dam and spillway could not be obtained, so the feasibility and cost of this option could not be evaluated.)

Figure 1.1: Project Location

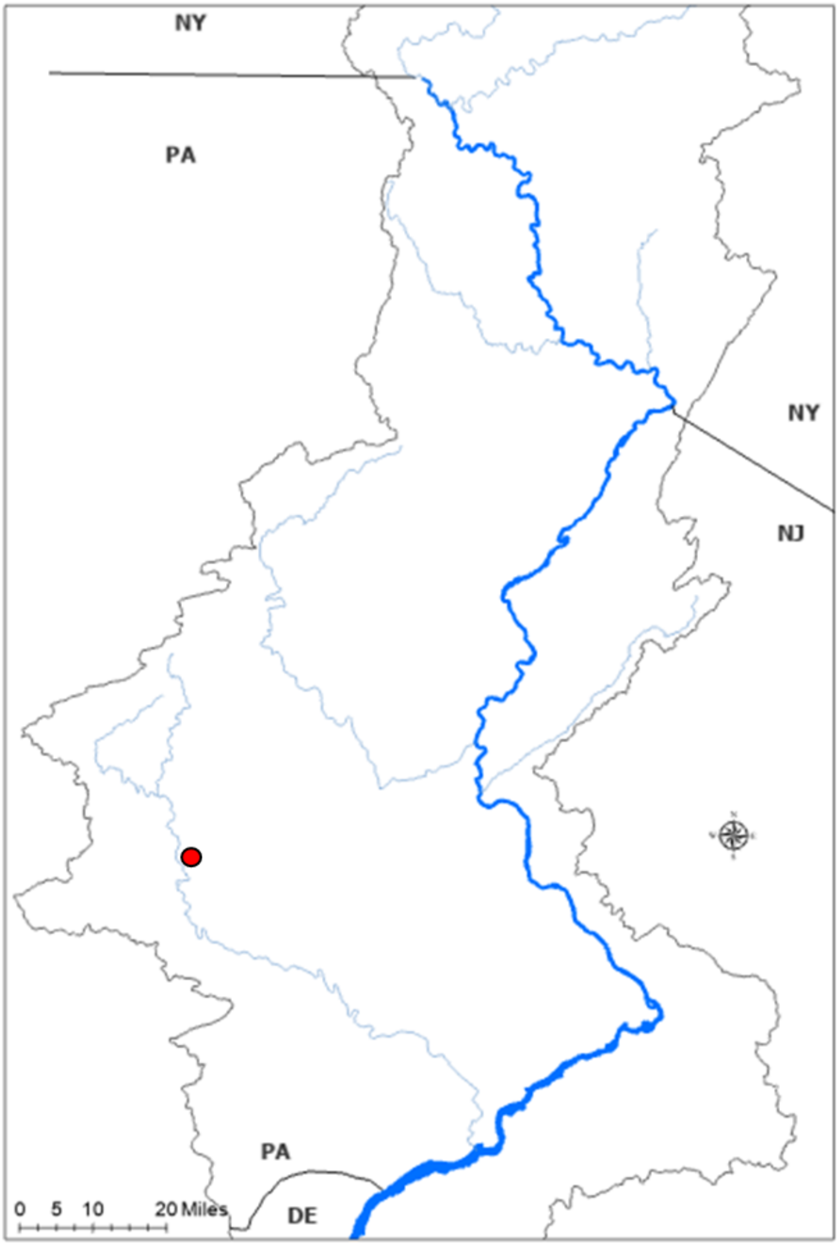


Figure 1.2: Topographic map: Reservoir outlined in purple; drainage area in red (192 sq miles)

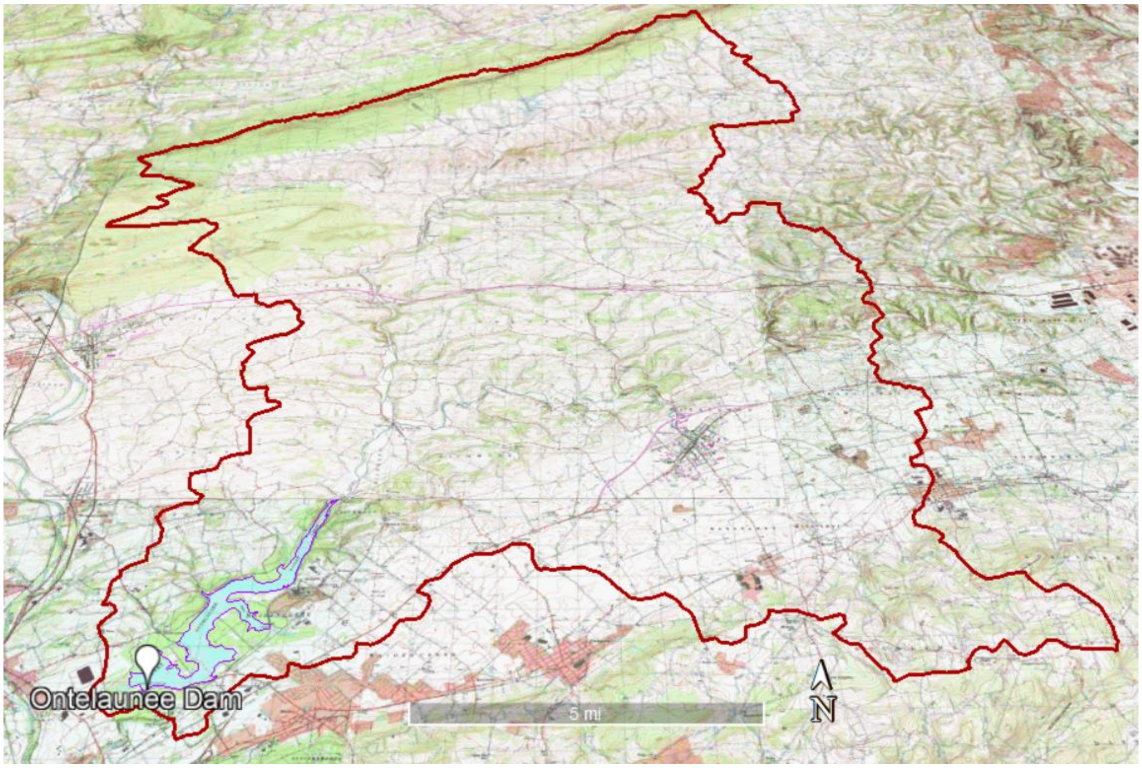


Figure 1.3: Aerial photo: Reservoir outlined in purple; drainage area in red (192 sq miles)

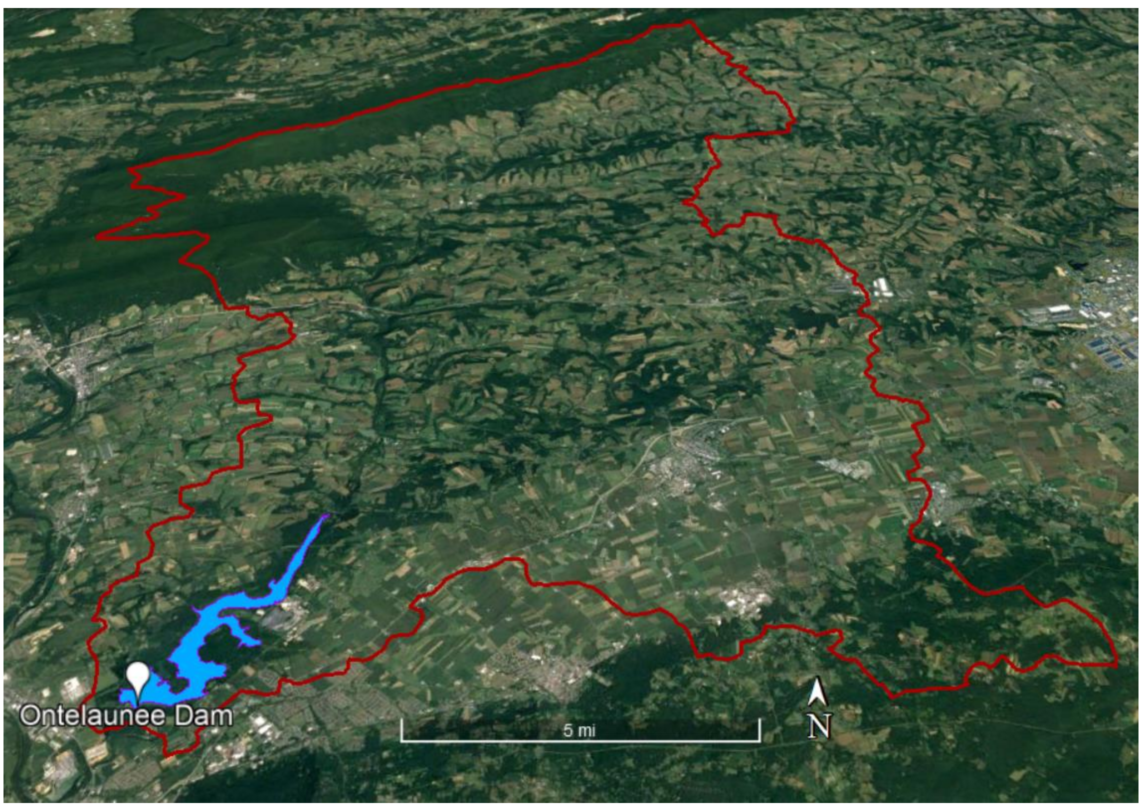


Figure 1.4: Lake Ontelaunee Spillway with Rt 73 running above

Figure 1.5: Lake, dam and adjacent Evansville quarry (Q8)

2 Water Quantity & Quality

2.1 Reservoir Storage Volume

Lake Ontelaunee has a normal water storage capacity of approximately 3.9 billion gallons (BG), of which 1 BG is being considered as available for transfer to DRBC's control for flow augmentation.

2.2 Fill and Discharge

Lake Ontelaunee is refilled from the 192 sq. mile watershed above the lake. At the mean flow of about 320 cfs, 1 BG would be replenished in about 5 days.

Regarding discharge, DRBC Docket no. D-2000-059 CP-3 (DRBC, 2021) states RAWA's existing intake at the dam has a reported capacity of 35 mgd. But RAWA's web site says "raw lake water is delivered to the Maiden Creek Filter Plant by gravity via a 2,800 foot long, concrete lined, 81 inch diameter, pressurized tunnel and a 60 inch diameter, 4,880 foot long, concrete conduit" (http://www.readingareawater.com/about-us/). These would likely have a capacity greatly in excess of 35 mgd. If 35 mgd is indeed the capacity, with an average water demand of about 15 mgd, the existing conduits leave 20 mgd or about 28 cfs for flow augmentation, which is below the target of 100 cfs.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Properties

DESCRIPTION	VALUE
Storage	
Area (Acres)	1037 acres
Spillway Elev.	303 ft.
Bottom Elev.	250 ft. approx.
Nominal Depth (Ft.)	52 ft.
Maximum Volume (Billion Gallons)	7.0 BG
Normal Volume (Billion Gallons)	3.88 BG
Water Supply – Reservoir Fill	
Established Source Stream	Maiden Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	192 sq.mi.
Median Annual Stream Flow Rate (ft3/s)	320 cfs
Estimated Time to Fill 1 BG (Days)	5 days
Water Supply – Travel to Use	
Stream Miles to Delaware River at Phila	70
Travel Time at 2 mph (hours)	35

2.3 Water Quality

The RAWA Source Water Protection Program (SSM, 2019) states the Lake Ontelaunee was placed on the 303(d) list of impaired waterways in 1996, describing Lake Ontelaunee as impaired for nutrients (phosphorus and nitrates) and sediment. In any case, the lake currently serves as the source of drinking water, so it is presumably suitable for flow augmentation.

3 Infrastructure Design, Construction & Operation

The embankment has a clay core located both above and below existing grade, a concrete cut-off wall along the top of bedrock, and a grout curtain into bedrock beneath the cut-off wall. The embankment's lakeside (northern) face is riprap covered. State Route 73 traverses both the earthen embankment and a bridge over top of the concrete gravity dam (spillway). The Ontelaunee Dam is 56 feet high and has a 500-feet wide, ogee-shaped spillway.

No additional land is needed and there is no need to construct infrastructure at the sites, assuming that existing conduits are adequate to convey water at the desired rate for flow augmentation of at least 100 cfs.

4 Environmental Impacts

Environmental impacts from the transfer of storage are negligible since there is no construction involved with this project.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor. In terms of scoring criteria (disruption, equity, safety, aesthetics, recreational impact, cultural/historical loss, taxes, and land disruption), this site scores favorably. No losses in aesthetics, equity, economy, or cultural resources are expected from the project.

6 Project Cost & Schedule

The estimated costs for transfer of storage from Lake Ontelaunee are based on average retail prices for raw water charged by a sample group of storage owners to wholesale customers per BG as explained in Appendix B. Volume of 1 BG may be available based on conversations with RAWA. The actual volume availability and cost thereof is likely to be revealed only during negotiations between DRBC and RAWA.

There are no new capital costs for this project. Usage costs for this facility are estimated to be $1.3M/BG/year. Converted to a present value assuming 30-year life and 3% interest rate gives $27M, which is a moderate cost compared to other projects, but the volume is small at 1 BG so the cost effectiveness is medium at $27M/BG.

Table 6.1: **Annual Cost Summary**

Item	Unit	Quantity	Cost/Unit	Extended Cost
Annual Usage Fee				
Annual Fee	BG	1	$1.4M	$13M
TOTAL				$1.3M
Contingency (10%)				$0.13M
TOTAL (With Contingency)				$1.4M

The schedule for putting the project in service after general concurrence of all major parties is expected to be approximately 1 year. This includes:

- Design, permitting and land acquisition 0 years
- Construction 0 years
- Use of transferable storage 1 year

7 Potential Ancillary Benefits

No ancillary benefits are identified since the project only includes transfer of water from existing storage.

8 Storage Project Score

The transfer of storage from Lake Ontelaunee is scored relative to the criteria presented in the main report. Summary categories and scores are presented in Table 8.1 below. Backup details to individual scores are available in the main report.

The project scored average on criterion 1: the storage source has good reliability and release rates, but at 70 miles, it is not near to the mainstem, and its quality is moderate. Because there is no construction proposed, the project scored very well on criterion 2 (design, construction, and operation), criterion 3 (environmental) and criterion 4 (stakeholder and social). The project scored above average on criterion 5 as its cost is moderate but low on criterion 6 due to lack of additional benefits to water resources. The cost and cost effectiveness are moderate. The overall score ranks near the top, but the volume and cost are uncertain.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.33	30%	1.00
Infrastructure Design, Construction & Operation	4.60	10%	0.46
Environmental & Regulatory Considerations	5.00	15%	0.75
Stakeholder and Social Considerations	5.00	10%	0.50
Project Cost & Schedule	4.17	30%	1.25
Potential Ancillary Benefits	1.00	5%	0.05
TOTAL	**3.85**		**4.01**

APPENDIX

Score Sheet

STORAGE PROJECT SCORING Six primary criteria	Quantitative Evaluation Metric (where appropriate)	Score (5=best, 1 = worst)			Weight	weighted score	Project specific comments
	(enter values only in ungreyed cells)						
1. Water quantity and quality		3.33			30%	1.00	
o Volume of storage provided (BG)	1	2					
o Hydrologic reliability of supply (months to fill)		5					
o Release rate (cfs)		3					Release through pipe to water treatment plant
o Promptness of delivery to mainstem (days)	2 to 3	3					Approx. 75 miles
o Geographic benefit		4					Enters via Schuylkill
o Quality of stored water		3					Lake euthrophic but used already for water supply
2. Infrastructure design, construction and operation		4.60			10%	0.46	
o Site/Civil, Land & Easements		5					
o Subsurface conditions		5					
o Infrastructure Complexity		5					
o Construction complexity		5					
o Operational complexity		3					Release through pipe to water treatment plant
3. Environmental impacts		5.00			15%	0.75	
o protected species		5					No impacts
o Water quality degradation of downstream waters		5					
o obstruction to passage of aquatic animals		5					
o hydromodification		5					
			special two-factor scoring for habitat impacts				
Habitat type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o wetlands inundated or filled (ac)	5	5	5	5			No impacts
o stream length inundated (mi)	5	5	5	5			
o uplands inundated or developed (ac)	5	5	5	5			
4. Social and Economic Impacts		5.00			10%	0.50	
o Disruption/displacement		5					No impacts
o Safety and health		5					
o Social equity/environmental justice		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		5					
5. Project Costs & Schedule		4.17			30%	1.25	
o Land acquisition cost ($)	0M						
o Construction Cost ($)	0M						
o Operating Cost ($/yr)	1.4M						$1.4M/BG
o Overall Cost ($)	27M	4.5					based on 30 years of costs with 3% rate
o Cost effectiveness ($/BG)	27M	3					
o Schedule (Time to make Operational, years)	5	5					
6. Ancillary Benefits		1.00			5%	0.05	
o Flood control		1					
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		1					
OVERALL		3.85			100%	4.01	

Storage Project Summary

Project:	**Wadesville Mine Pit (Q1)**
Location:	New Castle, Schuylkill County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	6.9 Billion Gallons
Score:	3.91

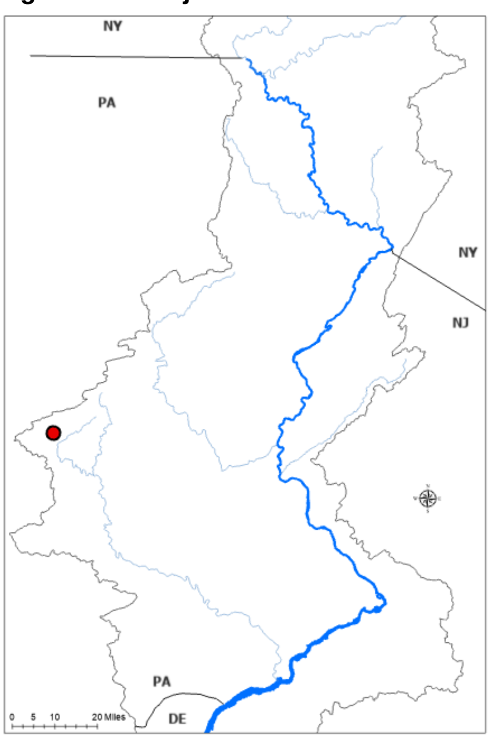
1 Project Overview

The scope of this potential storage project is to fill the Wadesville Mine Pit from Mill Creek. Water will be pumped during times of high flows and discharged into the quarry. The water will be stored until flow goes below a designated threshold level in the Delaware River Basin and then discharged back to the receiving stream.

The Wadesville Mine Pit is located in New Caste and adjacent to the St. Clair Borough, Schuylkill County, high in the Schuylkill River Watershed (Figure 1.1). The Pit was dug as part of the Wadesville Mine and has been subsequently expanded to approximately 182 acres. Because it is a surface pit, it is being considered in the quarry category. Storage in the underground Wadesville Mine Pool is considered as a separate project (M10).

The pit has a nominal rim elevation of 780 feet and at the lowest point is 380 feet. This gives the quarry a nominal depth of 400 feet. The estimated available storage volume is 6.9 BG, the largest quarry considered. The nearest sizeable stream to the quarry is Mill Creek, located about 3800 ft away but requires a 150 foot lift.

Figure 1.1: Project Location



2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 6 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or retaining walls are suggested to increase storage volume for this project. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Further analysis will be needed to account for water lost to leakage. Figure 2.1 below shows the proposed fill elevation in blue along with contours showing the depth of the quarry.

Figure 2.1: Aerial View with Contours (proposed fill elevation shown in blue line)

2.2 Fill and Discharge

The intended design is to fill the quarry to capacity and release water back into the source stream as required. Water will be withdrawn from the adjacent Mill Creek. The median annual flow was used to calculate an amount of flow acceptable to be pumped from the source stream during the wetter months of the year. The stored water in the quarry will be pumped back to Mill Creek using the same pipeline used for withdrawal from the stream. For all quarry projects, the lowest quarry withdrawal level was assumed to be limited to 20% of the quarry's total depth (representing approximately 20% of the volume), based on pump performance and constructability constraints. The extreme depth of this quarry, overall volume and practical quarry pumping further limits the potential quarry drawdown at this quarry, as will be discussed in Section 3 below.

The rate of quarry filling or discharge from the stream is controlled by available water supply in Mill Creek. The rate of discharge back to Mill Creek is governed by the limitations of the quarry pumping station and protection of the receiving stream. Fill and discharge pumping methods are described further in Section 3 and the main report.

The lowest possible dewatering level in the quarry will be elevation 460 ft, giving a working volume of 5.5 BG. With an outflow of 50cfs (32 mgd), stored water can be pumped from the quarry, releasing 1 BG every 37 days. At this rate, the quarry could release all of the operating volume within a 5.7 month period.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	182 acres
Nominal Rim Elev.	780 ft.
Bottom Elev.	380 ft.
Maximum Water Level Change (Ft.)	400 ft.
Maximum Volume (Billion Gallons)	6.9 BG
Operating Water Range (780ft-460 ft)	380 ft.
Operating Volume (Billion Gallons) - ~80% of max. volume	5.5 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Mill Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	20 sq.mi.
Mean Annual Stream Flow Rate (ft3/s / mgd)	44 cfs / 28 mgd
Proposed Average Pumping Rate (mgd)	11 mgd
Average Vol. Pumped during 6 month Pumping Term	2.1 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	780 ft to 460 ft
Proposed discharge pumping rate (MGD)	32 mgd
Estimated Time to Release Operating Volume from Storage	5.7 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	124 miles
Travel Time at 2 mph (hours)	62 hours

2.3 Water Quality

Mill Creek, the source stream, has marginal water quality based on the PA 303D listing. Table 2.2 below summarizes the listed impairments.

Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
IMPAIRED - flow regime change due to urban runoff, siltation/aluminum/iron/low pH due to acid mine drainage, habitat alteration due to channelization	Supporting	Not Assessed	Not Assessed

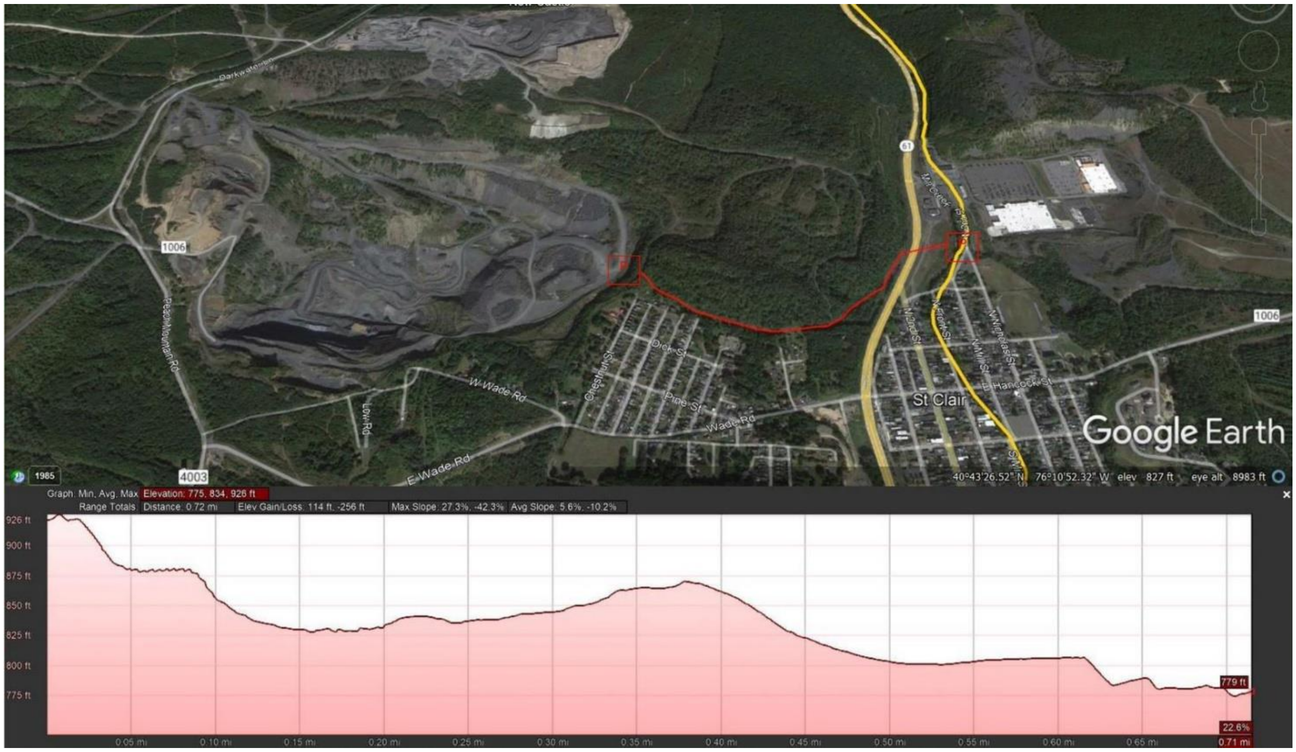
The Chapter 93 listed designated use for the Mill Creek is cold water fishery (CWF) and it is noted to support a wild trout population.

Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease relative to the Mill Creek source and that the water quality will be satisfactory to support flow augmentation. Further study will be needed to confirm this given Mill Creek's impairment shown above and possible interactions with groundwater.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities. In this quarry, no storage modifications are proposed. However, based on limited dewatering, some grouting may be required to manage quarry leakage.

Figure 3.1: Approximate Pipe Location and Elevation Profile (red line; "P" represents pump station)



3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is restricted in size and type by the Mill Creek flow. The stream intake and pumping station will include the low flow intake/pumping station (submerged half screen intake and multiple high head/low flow submersible pumps) presented in Section 5.4 of the main report. Site specific variations of this project include some stream modifications to create an intake pool and protection for energy dissipation of stored water subsequently discharged back into the stream.

The quarry discharge/stream augmentation pumping station includes the typical quarry discharge pumping station (withdrawal shaft/wetwell and high head high flow pumps). At this particular site, the type and size of the pumping facility is somewhat controlled by the extreme depth of the quarry. Submersible pumps at the desired flow rate are generally limited to approximately 250 ft of total head. Additional quarry dewatering could be achieved with different types, albeit more expensive, pumping systems. Limiting the quarry low water level still allows for significant storage and may also offer secondary benefits of better quarry stability and improved discharge water quality.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline is estimated to be typical class ductile iron pipe (DIP). This site requires approximately 3800 ft of 30" diameter DIP and assumes the pipe can be used for both filling and discharge. Connections, isolation valves, air release valves and pipe restraint would be as typical and noted in the cost detail below. Construction would be typical cut and cover excavation with conventional means at a nominal 5 ft burial depth installed in this site's open "greenfield" environment. Alternate pipe materials may be considered, such as fused HDPE, for the given site conditions and working pressures. However, for consistency, DIP was assumed. Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	11 mgd
Pump Capacity (3 x 6 mgd)	18 mgd
Quarry Discharge (Stream Augmentation)	32
Design Flow	32 mgd (50 cfs)
Pump Capacity (11 x 2.9 mgd)	32 mgd
Pipeline Distance	3,800 lf
Elevation at Discharge Point	770 ft
Elevation at High Point on Pipeline	926 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in Section 6, Project Cost & Schedule. Construction of the identified facilities would be stated above or as typical. However, there is potential for issues supplying the needed power feeds for the pumping facilities.

The pumping facilities are intended to be remotely operated and monitored as described in the main report. For the purposes of estimating costs, it was assumed that the project will be dewatered in part and refilled in the wetter offseason months.

4 Environmental Impacts

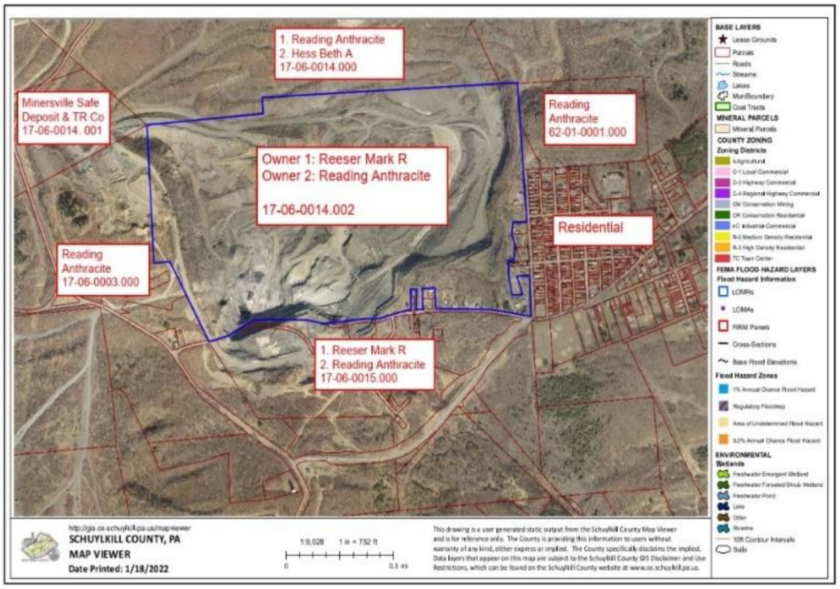
This storage project was reviewed against several environmental parameters as described in the body of the report. Overall, the project scored above average to very good, indicating a high level of compatibility with the environment and only limited impact potential.

Permitting the project appears achievable and should occur within an acceptable timeframe. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor. The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1. The adjacent residential area should only minimally be impacted during pipeline construction. In terms of considered sub-criteria (disruption, equity, safety, aesthetics, recreational impact, cultural/historical loss, taxes and land disruption), this project scores favorably.

Figure 5.1: Land Ownership



6 Project Cost & Schedule

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING SYSTEM			Subtotal	$3,965,500.00
Intake				
Screens	LS	3	$80,000	$240,000
Structure	VF	12	$50,000	$600,000
Other	LS	1	$90,000	$90,000
Pumping Station				
Pumps	#	3	$450,000	$1,350,000
MEP	LS	1	$265,500	$265,500
Structure	SF	1200	$350	$420,000
Other	LS	1	$500,000	$500,000
Dissipation	LS	1	$500,000	$500,000
PIPELINE			Subtotal	$3,290,000
Pipeline	LF	3800	$800	$3,040,000
Valves	#	5	$50,000	$250,000
DISCHARGE PUMPING SYSTEM			Subtotal	$13,422,000

Item	Unit	Quantity	Cost/Unit	Extended Cost
Intake Structure	VF	320	$25,000	$8,000,000
Pumping Station				
Pumps	#	11	$450,000	$4,950,000
MEP	LS	1	$42,000	$42,000
Structure	SF	800	$350	$280,000
Electrical Service	LS	1	$50,000	$50,000
Other	LS	1	$100,000	$100,000
Treatment				$-
ACCESS ROAD				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
LAND ACQUISITION				$-
Inundation Area	ACRE	2		$-
SUBTOTALS				
Construction Costs Subtotal				$21,677,500
Contingency			50%	$10,838,750
CONST. COST + CONTINGENCY				$32,516,250

The total capital is shown above. Land costs are not included in the above. Online tax assessment information is limited in Schuylkill County. Therefore, the project team estimated land cost based on comparable quarries with assessments and assigned $4M as the project land cost.

Operating costs for quarry storage can be significant relative to other storage types. This site has a large head difference to pump and a low flow stream supply translating into generally higher operating costs. Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 5.5 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $43.8M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 7.5 years. This includes

- Design, permitting and land acquisition 3 years
- Construction 3 years
- Startup and initial filling of quarry 1.5 years

7 Potential Ancillary Benefits

Converting the Wadesville Mine Pit to water storage may have several ancillary benefits beyond providing needed additional storage in the Basin. The created storage reservoir may create a recreational amenity in the area. In addition, converting an active quarry to a reservoir will likely benefit the adjacent residents by decreasing noise and dust. Potentially, construction of the improved facilities could be coupled with other surrounding site improvements or coupled with other funding sources to allow mining reclamation or Acid Mine

Drainage (AMD) improvements. In general, the conversion of the quarry to a storage reservoir is believed to have positive benefits for the region.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are summarized in Table 8.1 below.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.42	30%	1.03
Infrastructure Design, Construction & Operation	3.40	10%	0.34
Environmental Impacts	4.21	15%	0.63
Social & Economic Impacts	4.63	10%	0.46
Project Cost & Schedule	4.17	30%	1.25
Ancillary Benefits	4.00	5%	0.20
AVERAGE	**3.97**		**3.91**

Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Appendix

Score Sheet

STORAGE PROJECT SCORING

STORAGE PROJECT: Q1
Wadesville Mine Pit

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.42**			30%	**1.03**	
o Volume of storage provided (BG)	6.9	3					
o Hydrologic reliability of supply (months to fill)	6.1	4.5					
o Release rate (cfs)	50	3					
o Promptness of delivery to mainstem (day)	2.6	3					
o Geographic Benefit		3					
o Quality of stored water		4					Quarry water should be better than source after settling
2. Infrastructure Design, Construction and Operation		**3.40**			10%	**0.34**	
o Site/Civil, Land & Easements		4					Site is typical; pipeline along dirt road
o Subsurface conditions		3					
o Infrastructure Complexity		4					Typical infra. Design
o Construction complexity		3					Typical infra. construction; quarry shaft deep at this site
o Operational complexity		3					Automated operations
3. Environmental Impacts		**4.21**			15%	**0.63**	
o Protected species		4					Potential for bats, but may stay in road and no impact
o Water quality degradation		5					Temperature on discharge could be a concern based on withdrawal
o Obstruction to passage of aquatic animals		5					
o Hydromodification		3					Withdraw in wet colder months; low streamrm flow in source
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)	0	5	5	5			
o Stream length inundated (mi)	CWF; 0.1 mile	3.5	3	4			
o Uplands inundated or developed (ac)		4	4	4			Quarry and pipeline have minor impacts
4. Social and Economic Impacts		**4.63**			10%	**0.46**	
o Disruption/displacement		4					
o Safety and health		5					
o Social equity		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					Land improvements
o Loss of tax revenue		4					Quarrying would cease
o Loss of production from farmland, timberland, quarries		4					Qaurry would cease
o Emission of greenhouse gases		3					No data
5. Project Costs & Schedule		**4.17**			30%	**1.25**	
o Land acquisition cost ($)	~$4M						
o Construction Cost ($)	$32.50						
o Operating Cost ($/yr)	~$0.375M						
o Overall Cost ($)	43.8	4					
o Cost effectiveness ($/BG)	$6.40	4.5					
o Schedule (Time to make Operational, years)	7.5	4					
6. Ancillary Benefits		**4.00**			5%	**0.20**	
o Flood control		4					Could help manage downstream flooding
o Recreation/tourism		4					Reservoir replacing quarry
o Habitat/fishery enhancement		4					Reservoir replacing quarry
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					Support to AMD
o Ability to leverage funding from other programs		4					AMD and recreastional money may be leveraged
OVERALL		3.97				**3.91**	

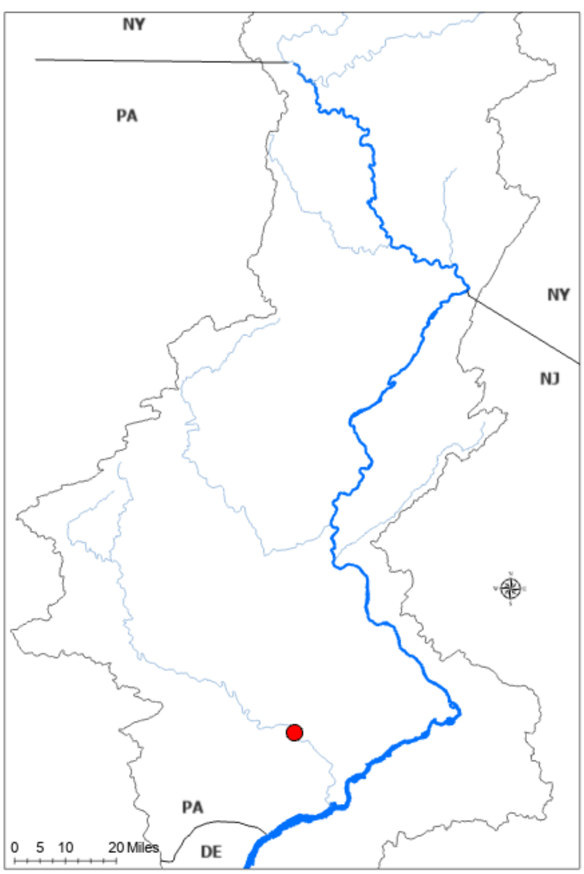
Storage Project Summary

Project:	**McCoy Quarry (Q2)**
Location:	King of Prussia, Montgomery County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	6.2 Billion Gallons
Score:	4.06

1 Project Overview

The McCoy Quarry is located in King of Prussia within Upper Merion Township and is adjacent to Plymouth Township, Pennsylvania (Figure 1.1). The quarry has a maximum estimated volume of 6.2 billion gallons. This quarry is approximately 123 acres in area and has an estimated fillable rim elevation of 70 ft. At the quarry's deepest point, it has an elevation of -237 ft, giving the quarry a nominal depth of 307 ft. The Schuylkill River is about 1040 ft away. The quarry is composed of quartz sand and gravel and generally mined for aggregate products. Water would be extracted during times of high flows (possibly by gravity) from the Schuylkill River, stored in the quarry, then discharged back to the River to augment flow during low flow.

Figure 1.1 Project location



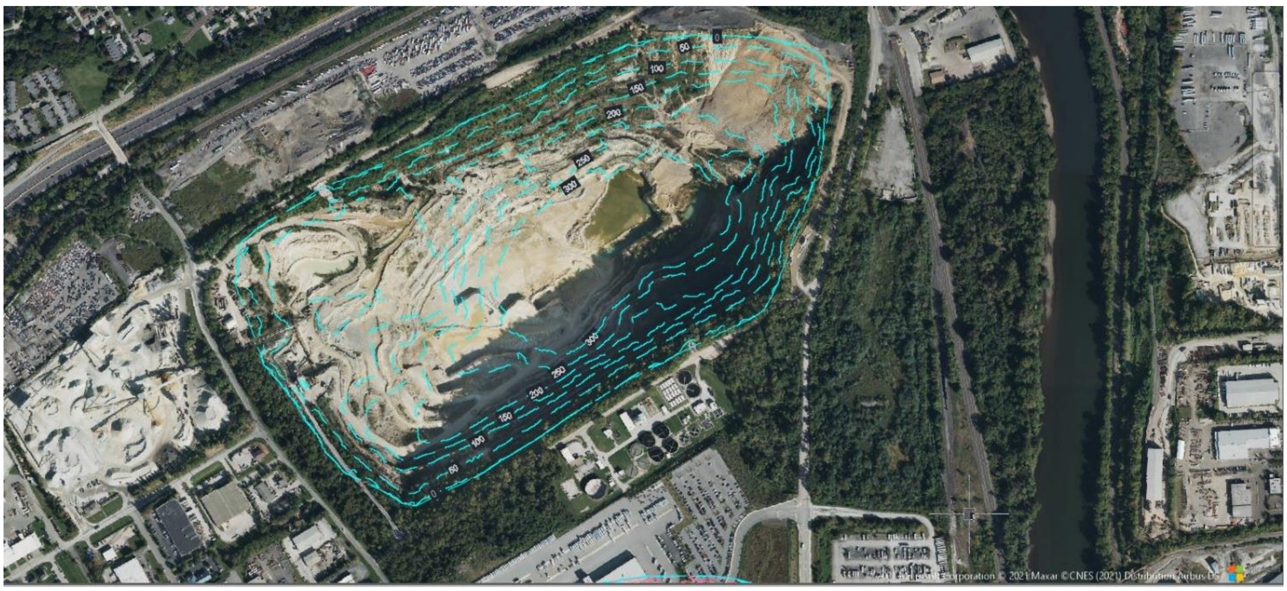
2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume of over 5.0 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. The quarrying over the years excavated from an essentially flat surface grade, creating a deepening depression. Therefore, no additional structures such as dams or retaining walls are needed to further increase the storage volume for this project. Figure 2.1 below shows contours showing the depth of the quarry. The stored water volume assumes the interior of the quarry to generally be impervious with minimal leakage. Further analysis will be needed to account for storage lost to pervious areas.

Figure 2.1: Arial View with Contours



2.2 Fill and Discharge

This project is unique in its proximity to a major river and the potential to gravity feed into the quarry for a large portion of the storage volume. Additional gravity filling or low head pumping could be performed during high flow periods of the adjacent Schuylkill River, allowing for the project to effectively “skim” flows from the Schuylkill River.

The key parameters relating to storage volume and fill/discharge supply are also summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	123 acres
Nominal Rim Elev.	70 ft.
Bottom Elev.	-237 ft.
Maximum Water Level Change (Ft.)	307 ft.
Maximum Volume (Billion Gallons)	6.2 BG
Operating Water Range (70 ft to -176 ft)	246 ft.
Operating Volume (Billion Gallons) - ~80% of max. vol.	5.0 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Schuylkill River
Anticipated Source Stream Drainage Area (Sq. Miles)	1770 sq. mi.
Mean Annual Stream Flow Rate (cfs/mgd)	2910 cfs / 1880 mgd
Proposed Average Pumping Rate (mgd)	31 mgd
Average Vol. Pumped during 6 month Pumping Term	5.6 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	70 ft to -176 ft
Proposed discharge pumping rate (cfs/mgd)	50 cfs / 32 mgd
Estimated Time to Release Operating Volume from Storage	5.1 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	67.7 miles
Travel Time at 2 mph (hours)	56 hours

2.3 Water Quality

The Schuylkill River has marginal to good water quality based on the PA 303D listing. Table 2.2 below summarizes the listed impairments.

Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
IMPAIRED - siltation due to urban runoff, habitat alterations other than hydromodification, flow regime modification due to urban runoff, point discharges and agriculture	Not Assessed	Impaired - PCBs	Supporting

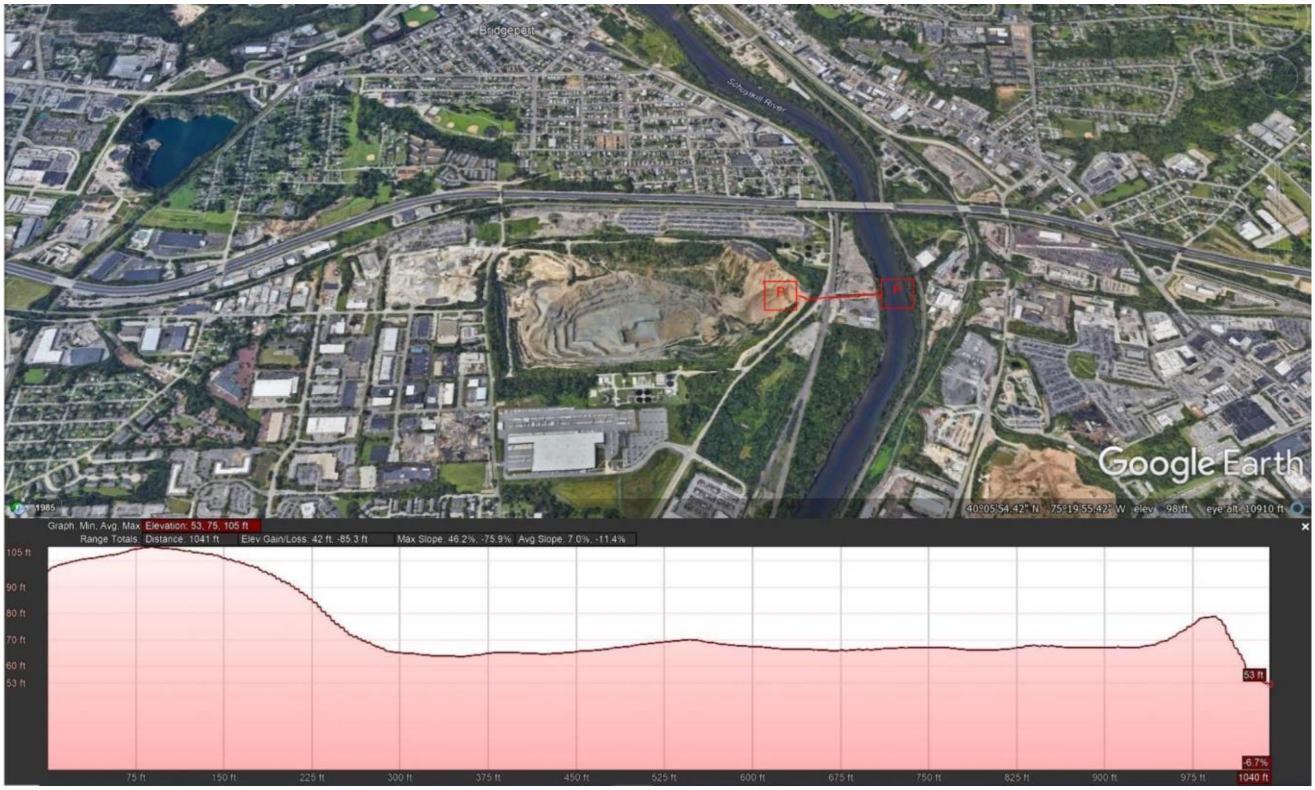
The Chapter 93 stream designation is warm water fishery (WWF).

Water quality may change after pumping from the Schuylkill River and settling in the quarry. There may be potential for mixing with adjacent groundwater quality. It is assumed that the stored quality will not decrease relative to the source stream, and quality will likely increase by settling of suspended solids similar to other upstream desilting facilities located on the Schuylkill River. The water quality should be adequate for flow augmentation but this needs to be confirmed by further investigation.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the typical major facilities required.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile



The elevation of the Schuylkill River is approximately 53 ft, the quarry rim is 70 ft (90 ft highpoint shown in the above profile). This geometry may allow for gravity "skimming" of the river as will be explained further below. Even if pumping is used to fill the quarry storage, the geometry is advantageous relative to others in that the distance is minimal and the static head to overcome for filling the quarry is low.

However, for consistency and comparison with other facilities, filling by pumping was assumed, as described below. The option for gravity will be mentioned in a later section.

3.1 Pumping Facilities

The base case quarry fill/stream withdrawal pumping station is envisioned to be the typical standard intake and pumping arrangement. Submerged screen intakes would be placed on the river bottom adjacent to the proposed fill/stream withdrawing pumping station shaft. The shaft and facilities would be fitted with pumps as noted below. The total head to overcome by lifting water from the river elevation above the highpoint of the proposed pipeline is relatively small. Given the relatively high flows of the Schuylkill River, the source does not limit withdrawal pumping. Rather, the pumping rate is based on the practical pumping station sizing. Larger intakes and pumping arrangements can be considered, as shown by other downstream potable water pumping facilities. However, there is no need given the quarry filling objectives.

The quarry discharge/stream augmentation pumping station would include the typical withdrawal shaft and pumping arrangement as described in the body of the report. Given the depth of the quarry, significant head must be overcome to pump from the lowest quarry operating level and over the rim and pipeline highpoint for discharge back to the Schuylkill River.

3.2 Pipeline

The proposed pipeline route is also schematically shown in Figure 3.1. The pipeline is assumed to be 30 inch diameter ductile iron pipe (DIP) installed at nominal depths below grade on essentially a direct alignment from the river pumping station to the quarry. A private easement would be required for a portion of the pipeline, but other public right-of-way (ROW) options exist. The pipeline would need to cross under a railroad and state Route 23. These crossings would be accomplished with typical trenchless methods. Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (3 x 10.4 mgd)	31 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	31.64 mgd (50 cfs)
Pump Capacity (5 x 7.2 mgd)	36 mgd
Pipeline Distance	1,040 lf
Elevation at Discharge Point	52 ft
Elevation at High Point on Pipeline	100 ft
Static Head	48 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

The pumping facilities are intended to be remotely operated and monitored as described in the main report. For the purposes of estimating costs, the quarry is assumed to be dewatered during the dry season and refilled in the wetter off-season months. However, given the high flows in the Schuylkill River, the pump can run continuously to fill the quarry storage as needed.

3.3 Alternate Pumping/Piping Configuration

As mentioned above, a gravity fill option exists on this site. This would require a trenchless installation of a conveyance conduit between the river and quarry at an approximately elevation of +40 ft. Conceptually, this would involve a 42" microtunnelled conduit connecting the intake wetwell and the quarry wetwell/shaft. Valve controls and by-pass pipe connections would be installed such that one could fill most of the quarry by gravity and utilize the same conduit to convey discharge water from the quarry back to the stream, albeit discharging into the river at a separate outfall point. While some additional infrastructure costs are incurred, this could eliminate the need to pump from the river to fill the quarry, thereby eliminating the recurring operating cost. Under this passive filling option, the quarry storage volume is reduced to approximately 3.5 BG.

4 Environmental Impacts

This storage project was reviewed against several environmental parameters as described in the body of the report. Overall, the project scored high because it reuses a mined quarry and anticipated environmental impacts are negligible. Minimal impacts would occur to wetlands, forests, streams, endangered species or other concerns. Intakes and pumping would consider fish impingement and other permitted criteria. No other significant environmental impacts are apparent. In addition, there could possibly be improvements to the river by adding the stored and settled quarry water back to the river, particularly during periods of low flow.

Permitting the project appears achievable and should occur within an acceptable timeframe. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor. The area immediately surrounding the quarry is industrial, but transitions to residential. The quarry site, transitioned to a water storage reservoir, could conceivably be converted to an environmental enhancement and, if so, could have a positive impact on the social and economic outcome in the area. Figure 5.1 provided some land use information for the surrounding area.

Figure 5.1: Land Ownership

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level cost estimate consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Additional cost estimating justification can be provided upon request. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$1,082,000.00
Pipeline	LF	1040	$800.00	$832,000.00
Valves	#	5	$50,000.00	$250,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$8,847,000.00
Intake Structure	VF	245	$25,000.00	$6,125,000.00
Pumping Station				
Pumps	#	5	$450,000.00	$2,250,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$14,494,500
Contingency			50%	$7,247,250
CONST. COST + CONTINGENCY				$21,741,750

The total capital is shown above. Land costs are not included and are assumed to be approximately $4M based on comparable quarry values in the region.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 5.5 BG and subsequent filling for the following year. Assuming a 30 year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $31.05.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 7 years. This includes:

- Design, permitting and land acquisition 3 years
- Construction 3 years
- Startup and initial filling of quarry 1 years

7 Potential Ancillary Benefits

Converting the quarry to water storage could provide ancillary benefits. There may be environmental benefit as mentioned above. Also, there could be additional social and economic benefits associated with a water reservoir in the community.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are summarized in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.50	30%	1.05
Infrastructure Design, Construction & Operation	3.10	10%	0.31
Environmental Impacts	4.61	15%	0.69
Social & Economic Impacts	4.75	10%	0.48
Project Cost & Schedule	4.50	30%	1.35
Ancillary Benefits	3.60	5%	0.18
AVERAGE	**4.01**		**4.06**

Appendix

Score sheet

STORAGE PROJECT SCORING

STORAGE PROJECT: Q2
NAME: McCoy Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.50**			30%	**1.05**	
o Volume of storage provided (BG)	6.2	3					
o Hydrologic reliability of supply (months to fill)	5.5	5					
o Release rate (cfs)	50	3					
o Promptness of delivery to mainstem (day)	2.33	3					
o Geographic Benefit		3					
o Quality of stored water		4					Same as source, but settled
2. Infrastructure Design, Construction and Operation		**3.10**			10%	**0.31**	
o Site/Civil, Land & Easements		2					Typical, but need private easement for pipeline
o Subsurface conditions		3					
o Infrastructure Complexity		4					Typical; shorter pipeline
o Construction complexity		3					Typical
o Operational complexity		3.5					Automated ops;. Possible option for gravity fill
3. Environmental Impacts		**4.61**			15%	**0.69**	
o Protected species		5					Potential for freshwater mussels issues, but no protected
o Water quality degradation		5					Should be minimal; potential for improvement
o Obstruction to passage of aquatic animals		5					None identified
o Hydromodification		4					Minimal impacts, if any; easy to assimmilate flows
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		4.75	4.5	5			Minor disruptions from intake/bank
o Stream length inundated (mi)	WWF; 0.1 mile	4	4	4			
o Uplands inundated or developed (ac)		4.5	5	4			Short pipeline in industrial area
4. Social and Economic Impacts		**4.75**			10%	**0.48**	
o Disruption/displacement		4					
o Safety and health		5					
o Social equity		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					Land improvements
o Loss of tax revenue		4					Quarrying would cease
o Loss of production from farmland, timberland, quarries		5					Minor quarry impact
o Emission of greenhouse gases		3					No data
5. Project Costs & Schedule		**4.50**			30%	**1.35**	
o Land acquisition cost ($)	~$4M						
o Construction Cost ($)	$21.7M						
o Operating Cost ($/yr)	~$0.375M						Possible lower cost with gravity fill
o Overall Cost ($)	$31.05M	4.5					
o Cost effectiveness ($/BG)	5	5					
o Schedule (Time to make Operational, years)	7	4					
6. Ancillary Benefits		**3.60**			5%	**0.18**	
o Flood control		3					No real benefit perceived
o Recreation/tourism		4					Increase in residential urban area a plus
o Habitat/fishery enhancement		4					Potential for creation of new habitat
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		3					May support reclamation efforts
o Ability to leverage funding from other programs		4					Recreational and reclamation money may be available
OVERALL		4.01				**4.06**	

Storage Project Summary

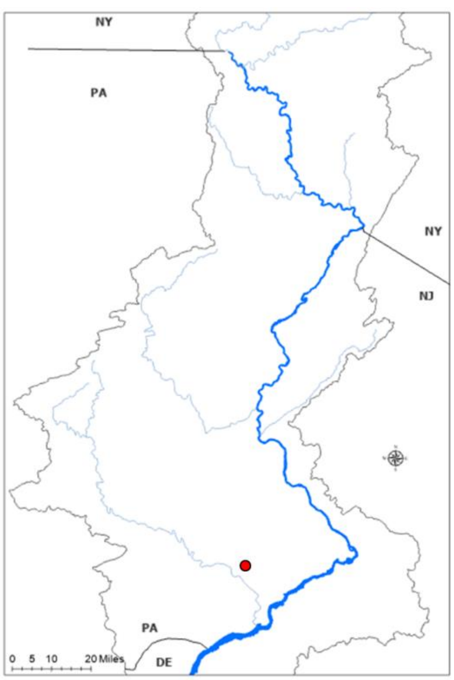
Project:	Plymouth Meeting Quarry (Q3)
Location:	Whitemarsh/Plymouth Meeting, Montgomery County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	3.5 Billion Gallons
Score:	3.76

1 Project Overview

This potential storage project involves storage in the Plymouth Meeting Quarry (Figure 1.1). Like other quarry storage projects, water will be pumped into the quarry from a nearby stream during times of high flows, stored in the quarry, then discharged back to the stream to augment flow during low flow. This active quarry is located within Whitemarsh Township and adjacent to Plymouth Township, Pennsylvania. The quarry has a maximum volume of 3.5 billion gallons. This quarry is approximately 122 acres in area and has an estimated fillable rim elevation of 160 ft. At the quarry's deepest point, it has an elevation of -107 ft, giving the quarry a nominal depth of 267 ft. The nearest sizable stream to the quarry is the Wissahickon Creek, located about 2 miles away.   The Schuylkill River may be an alternate fill/discharge point, located approximately 3.5 miles away.

The quarry is primarily composed of limestone.   The quarry is the oldest continuously operating limestone quarry in the United States and provides a variety of clean stone and aggregate products to the highway and construction industry.

Figure 1.1



2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume of almost 3 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or retaining walls are suggested to increase storage volume for this project. The calculated volume assumes the entire interior of the quarry to be available for storage and to generally be impervious with minimal leakage. For all quarry projects, an operational volume was defined based on the highest water level in storage and an elevation of 20% of the quarry's total depth. This operational low water level is based on pump performance and constructability constraints. Figure 2.1 shows contours indicating the depth of the quarry.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

The intended design is to fill the quarry to capacity and release water back into the source stream as required. Water could be withdrawn to fill the quarry from either the Schuylkill River or the Wissahickon Creek. The Schuylkill River has a much larger drainage area and significantly higher flows. However, it is approximately twice as far as the Wissahickon and requires a much more complex pipeline. The Wissahickon Creek has a 47.5-acre drainage area, a mean annual flow of 72 cfs (47 mgd) and a 7Q10 flow of 3 cfs. Given the relatively low flow of the stream, the withdrawal will be limited. Withdrawal will occur during the wetter 6 months of the year and the withdrawal rate will vary based on available flow and the minimum pass-by flow. As described in the main report, the average pumping rate during this period is estimated as 0.4 of the mean flow, or 19 mgd. The rate of discharge back to the stream is governed by the limitations of the quarry pumping station and protection of the receiving stream. The discharge rate back into the stream has been established at 50 cfs (32 mgd).

Given the above stated storage configuration and the limitations/assumptions associated with pumping, the 3.5 BG of quarry filling can occur over a six-month period. Given the quarry discharge pumping rate, the operating volume of 2.8 BG can be transferred in approximately 2.9 months.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below. Fill and discharge pumping methods are described further in Section 3 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	122 acres
Nominal Rim Elev.	160 ft.
Bottom Elev.	-107 ft.
Maximum Water Level Change (Ft.)	267 ft.
Maximum Volume (Billion Gallons)	3.5 BG
Operating Water Range (160 ft to -54 ft)	214 ft.
Operating Volume (Billion Gallons) - ~20% full	2.8 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Wissahickon Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	47.5 sq.mi.
Mean Annual Stream Flow Rate (mgd/cfs)	47 mgd (72 cfs)
Proposed Average Pumping Rate (mgd)	19 mgd
Average Vol. Pumped during 6 month Pumping Term	5.6 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	160 ft to -54 ft
Proposed discharge pumping rate (mgd)	32 mgd
Estimated Time to Release Operating Volume from Storage	2.9 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	22 miles
Travel Time at 2 mph (hours)	11 hours

2.3 Water Quality

The source stream has impaired water quality based on the PA 303D listing (Table 2.2). The Chapter 93 designated use is trout stocking (TSF) and the PA Fish & Game Commission designates the source as “Trout Stocked Flowing Waters”. The water quality should be adequate for flow augmentation, but this needs to be confirmed by further investigation. Table 2.2 below summarizes the listed impairments.

Table 2.2: 303D Listing Impairments for Wissahickon Creek

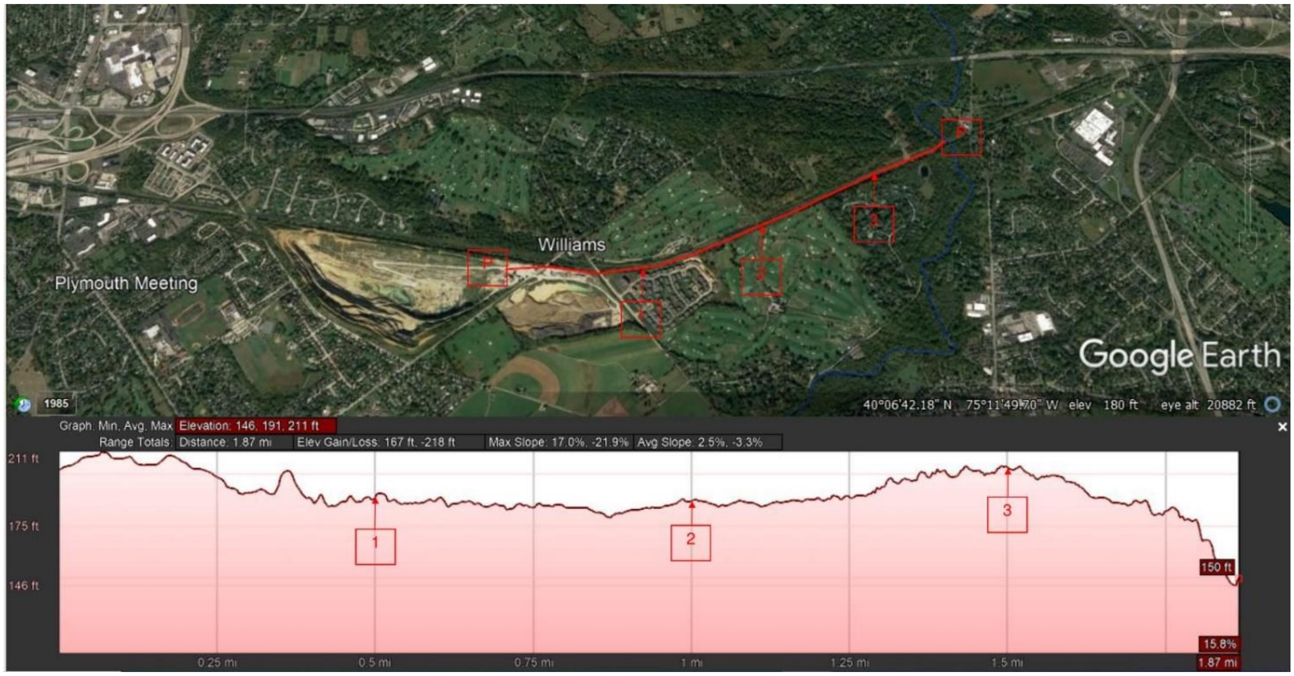
IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
IMPAIRED- flow regime change/siltation due to surface mining, habitat alterations, nutrients due to urban runoff	Not Assessed	Supporting	Not Assessed

Water quality may change after pumping and settling in the quarry. Temperature impacts also need to be considered. It is assumed that the stored quality will not decrease relative to the source stream and discharge back to the source stream will be permitted. The water quality should be adequate for flow augmentation but this needs to be confirmed by further investigation.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities for the scenario with fill from and discharge to the Wissahickon Creek.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile



3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is restricted in size and type by the limited flow of the Wissahickon Creek. The intake will be typical, as described in Section 5.4 of the main report including submerged half screens seated on the creek bottom and connecting to a wetwell on the adjacent bank. The pumping facilities include 3 pumps of 9 mgd each for a total pumping capacity of 27 mgd. Pumping will operate individually or in combination based on available stream flow. Again, unlike large streams, this pumping arrangement needs to pump more during high stream flow to achieve quarry filling within the targeted period of approximately 6 months.

The quarry discharge/stream augmentation pumping station includes facilities as described in the main report. This includes a deep shaft at the quarry location and connection into quarry storage. Quarry discharge pumping must overcome significant head differential, approximately 260 ft, when the quarry is at the low operating level elevation. This requires high-head pumps with a total design capacity of approximately 32 mgd (50 cfs), consisting of 5 x 7.2 mgd pumps.

Other features of the intake and discharge pumping station are described in Section 5 of the main report. Itemization and cost of the components are outlined further below in Section 6 of this summary.

3.2 Pipeline

The proposed pipeline route is also schematically shown in Figure 3.1. The pipeline is shown aligned following the existing railroad line providing a direct corridor between locations. The pipeline is approximately 9875 lf of 30 inch diameter ductile iron pipe (DIP). The pipeline would be installed by cut and cover methods on the edge of the railroad right-of-way (ROW) and should be permittable as shown. Alternate pipe materials may be used. Table 3.1 below summarizes the key piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	19 mgd
Pump Capacity (3 x 9 mgd)	27 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (5 x 7.2 mgd)	36 mgd
Pipeline Distance	9,875 lf
Elevation at Discharge Point	155 ft
Elevation at High Point on Pipeline	211 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

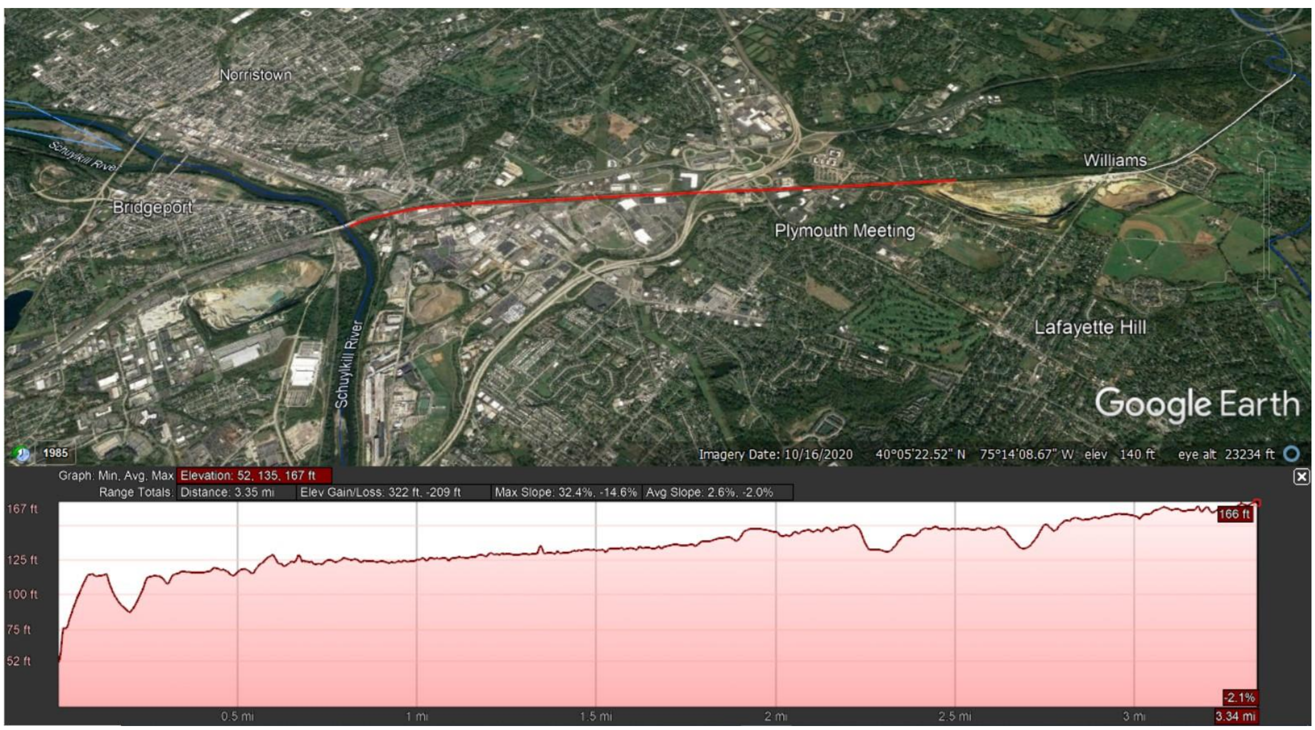
Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

Pumping facilities are intended to be remotely operated and monitored as described in the main report. For the purposes of estimating costs, the quarry will be dewatered in part and refilled in the wetter offseason months. Maintenance of the facilities would be as typical.

3.3 Alternate Pumping/Piping Configuration

The team evaluated an alternative configuration for piping and pumping with connection to the Schuylkill River. The alternate plan and profile are shown in Figure 3-2 below.

Figure 3-2: Alternate Pipeline Configuration to Schuylkill River



This option, when combined with a deep trenchless installation of the conveyance pipe, would allow for gravity drainage of a portion of the operating level of the quarry storage back to the Schuylkill River. While an advantage in reducing operational cost, as indicated previously, there is a significant capital cost to install the deep trenchless (microtunneled) conveyance. This 3.35 mile alternate conveyance would cost on the order of $70M, and not offset the operational cost difference.

4 Environmental Impacts

This storage project was reviewed against several environmental parameters as described in the body of the report. Overall, the project is scored high for potential environmental impacts meaning impacts where minimal. Development of the quarry would have minimal to no impact. The installation of the pipeline along the railroad also appears to have minimal impact. Some minor impacts would occur, as typical with intake and pumping station construction but would be controllable. There are noted high quality wetlands on the opposite bank from the proposed intake location. Some impact of the proposed water withdrawal rates from the limited Wissahickon flow could be an issue. However, as mentioned for other quarry projects, the conversion of the quarry to a water reservoir could have far reaching positive environmental implications.

Permitting the facility appears achievable and should occur within an acceptable timeframe. In addition to typical approvals, it should be noted that the facility is close to Wissahickon Valley Park and Fort Washington Park. The major permits for this facility, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor. The quarry site is surrounded by residential and recreational properties as shown in Figure 5.1 below.

Figure 5.1: Land Ownership

Similar to other quarry storage projects, conversion to the reservoir could be a social and economic amenity. Given the surrounding land use, relative to some other quarry projects, this location will further benefit. Converting the area to a reservoir with controlled open space access will benefit the region. The Moores Station Quarry and Redevelopment project in Mercer County, NJ is an example of possible beneficial improvements. For the above and related reasons, this project ranks high in potential social and economic improvements.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a 50% contingency commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$8,550,000.00
Pipeline	LF	9875	$800.00	$7,900,000.00
Valves	#	13	$50,000.00	$650,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$8,047,000.00
Intake Structure	VF	213	$25,000.00	$5,325,000.00
Pumping Station				
Pumps	#	5	$450,000.00	$2,250,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$21,162,500
Contingency			50%	$10,581,250
CONST. COST + CONTINGENCY				$31,743,750

Land acquisition costs are highly variable and dependent on the land valuations process, the options for lease or purchase and potential offsets to obligatory quarry remediation costs. For this project, assessed value of the quarry as available in real estate data bases indicates a land cost of around $4,500,000.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 2.8 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $43.97M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 8 years. This includes

- Design, permitting and land acquisition 4 years
- Construction 3 years
- Startup and initial filling of quarry 1 years

7 Potential Ancillary Benefits

Potential ancillary benefits are subjective. Section 5 elaborated on some of the potential benefits of converting the quarry to a storage reservoir. Additional benefits could be realized by combining this use with other local and state park and open space programs. Wissahickon Creek has historically been impacted during low flows and would especially benefit from flow augmentation provided by this project. In general, this project is viewed as an overall benefit to the region and the environment.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are summarized in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.50	30%	1.05
Infrastructure Design, Construction & Operation	3.10	10%	0.31
Environmental Impacts	3.89	15%	0.58
Social & Economic Impacts	4.75	10%	0.48
Project Cost & Schedule	3.83	30%	1.15
Ancillary Benefits	3.80	5%	0.19
AVERAGE	**3.81**		**3.76**

APPENDIX

Score Sheet

STORAGE PROJECT SCORING

STORAGE PROJECT: Q3
Name: Plymouth Meeting

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.50**			30%	**1.05**	
o Volume of storage provided (BG)	3.5	2.5					
o Hydrologic reliability of supply (months to fill)	6+	4.5					
o Release rate (cfs)	50	3					
o Promptness of delivery to mainstem (day)	0.46	5					
o Geographic Benefit		3					
o Quality of stored water		3					Some concern for trout population
2. Infrastructure Design, Construction and Operation		**3.10**			10%	**0.31**	
o Site/Civil, Land & Easements		2.5					Typical, but pipeline could be challenging
o Subsurface conditions		3					
o Infrastructure Complexity		4					Typical infra. Design
o Construction complexity		3					Typical infra. construction; quarry shaft deep at this site
o Operational complexity		3					Automated operations
3. Environmental Impacts		**3.89**			15%	**0.58**	
o Protected species		5					None identified; data sources incomplete
o Water quality degradation		4					None expected, but concern for higher quality Wissahickon
o Obstruction to passage of aquatic animals		4.5					None expcted, but 9,800 lf pipeline might encounter
o Hydromodification		2					Recharge in summer to creek could be a concern for quality
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small 1=large)**			
o Wetlands inundated or filled (ac)		4.5	4	5			Possible sites on pipeline and at intake
o Stream length inundated (mi)	0.1 mile	3	3	3			Potential minor impact at intake
o Uplands inundated or developed (ac)		4.25	4	4.5			Pipeline along railroad or transmission ROW and intake may impact
4. Social and Economic Impacts		**4.75**			10%	**0.48**	
o Disruption/displacement		4					
o Safety and health		5					
o Social equity		5					
o Recreational loss		5					Potential gain
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		4.5					Quarry stops, but offset by potential for recreation/habitat
o Loss of production from farmland, timberland, quarries		4.5					
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**3.83**			30%	**1.15**	
o Land acquisition cost ($)	~$4M						
o Construction Cost ($)	$27.5M						
o Operating Cost ($/yr)	~$0.375M						
o Overall Cost ($)	$43.97M	4					
o Cost effectiveness ($/BG)	$12.56M	3.5					
o Schedule (Time to make Operational, years)	8	4					
6. Ancillary Benefits		**3.80**			5%	**0.19**	
o Flood control		4					Could skim high flows
o Recreation/tourism		4					Reservoir replacing quarry
o Habitat/fishery enhancement		4					Reservoir replacing quarry
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					Could settle solids and replenish stream at low flows
o Ability to leverage funding from other programs		3					Possilbe recreational funding
OVERALL		3.81				**3.76**	

MOTT MACDONALD

Storage Project Summary

Project: Penns Park Quarry (Q4)

Location: Wrightstown, Bucks County, PA

Storage Type: Quarry (Fill & Draw)

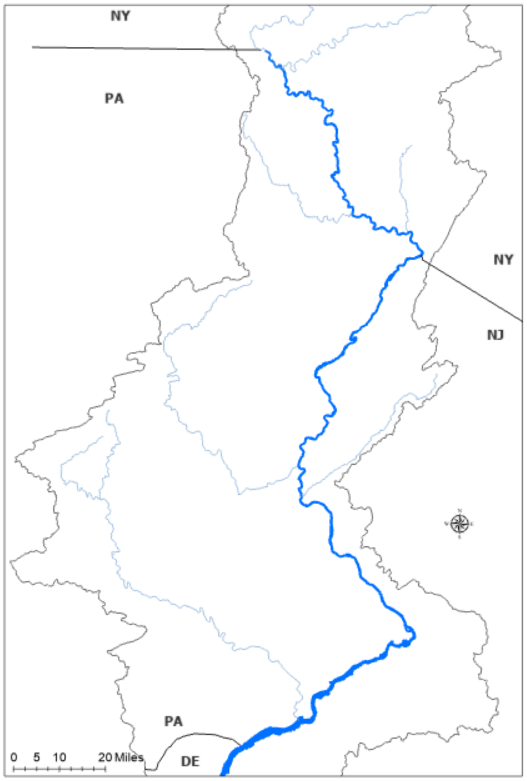
Est. Volume: 3.3 Billion Gallons

Score: 4.04

1 Project Overview

The scope of this storage project is similar to other quarry storage in that water from the nearby Neshaminy Creek will be redirected to the Penns Park Quarry pit for storage and subsequently released to augment stream flow when required. The Penn Park Quarry is located in Wrightstown, PA within Bucks County (Figure 1.1). The quarry has a maximum volume of 3.3 billion gallons and an area of 87 acres. It has an estimated fillable rim elevation of 180 and at the deepest point the elevation is –138. This gives the quarry a nominal depth of 318 feet. The nearest significant stream to this quarry is the Neshaminy Creek, located about 2500 feet away.

Figure 1.1: Project Location



2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 2.6 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or retaining walls are suggested to increase storage volume for this project site. The project development defines an operational volume as the volume from the top elevation of full storage to a bottom elevation corresponding to 20% of the total depth. This depth considers practical constraints for pumping and storage water quality. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Further analysis will be needed to account for storage lost to pervious areas. Figure 2.1 below shows the proposed fill elevation (blue line) along with contours showing the depth of the quarry.

Figure 2.1: Aerial View Showing Fill Elevation (blue line) and Contours

2.2 Fill and Discharge

The intended design is to fill the quarry from the Neshaminy Creek located approximately 0.5 miles away. Consideration was given to connecting the quarry to the larger Delaware River. However, the 7 mile distance makes the pipeline and pumping logistics challenging. The Neshaminy has a 156 sq.mi. drainage area and mean annual flow of 228 cfs (146 mgd). The flow of the source is substantial and should not limit the planned pumping and requirement to replenish the storage within a 6 month period. Based on the approach defined in the main report and referenced appendix, the average expected withdrawal, available flow less by-pass, is approximately 29 mgd. Based on this withdrawal rate, pumping can more than fill and replenish the storage within the targeted 6-month period of time. The rate of quarry discharge to the stream is more governed by the limitations of the conceived quarry pumping station and protection of the receiving stream. The discharge rate back into the stream has been established at 50 cfs (32 mgd).

Given the above stated storage configuration and the limitations/assumptions associated with pumping, over 5 BG could be pumped over a six month period, greater than the available storage volume. Given the quarry discharge pumping rate, the operating volume of 2.6 BG can be transferred in approximately 2.7 months.

Fill and discharge pumping methods are described further in Section 3 below.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	87 acres
Nominal Rim Elev.	180 ft.
Bottom Elev.	-138 ft.
Maximum Water Level Change (Ft.)	318 ft.
Maximum Volume (Billion Gallons)	3.3 BG
Operating Water Range (180 ft to -74 ft)	254 ft.
Operating Volume (Billion Gallons) - ~80% of max. vol.	2.6 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Neshaminy Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	156 sq.mi.
Mean Annual Stream Flow Rate (cfs/mgd)	228 cfs / 147 mgd
Proposed Average Pumping Rate (mgd)	31 mgd
Average Vol. Pumped during 6 month Pumping Term	3.4 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	180 ft to -74 ft
Proposed discharge pumping rate (mgd)	32 mgd
Estimated Time to Release Operating Volume from Storage	2.7 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	9 miles
Travel Time at 2 mph (hours)	5 hours

2.3 Water Quality

The source stream, Neshaminy Creek, has marginal to good water quality based on the PA 303D listing, supporting aquatic uses. It is a designated warm water fishery (WWF) and is also a significant source of downstream potable water supply. Table 2.2 below summarizes the listed impairments. Note the impairment for PFOS.

Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
SUPPORTING	Not Assessed	Impaired PFOS	Not Assessed

Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease relative to the source stream. The water quality should be adequate for flow augmentation, but this needs to be confirmed by further investigation.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities with withdrawal from the nearby Neshaminy Creek. Note the location of the pipeline relative to the adjacent Eureka Quarry (Q19; left side of Figure 3.1). This will be discussed further in Section 3.3.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile

3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station will be configured with intake screens on the riverbed connected to the adjacent withdrawal pumping shaft/wetwell, as described in the main report. The proposed pumping scenario is not stream-flow limited and it is projected that the 31 mgd can be withdrawn within the designated 6-month pumping period. This will be accomplished with and arrangement of 3 x 9.6 mgd pumps in the wetwell.

The quarry discharge/stream augmentation pumping station includes components as generally described in the main report. The targeted rate for discharge from the quarry back to the source stream is approximately 50 cfs (32 mgd). Given high head conditions to lift the water from the quarry at its lowest operating levels, this will require 5 x 7.2 mgd pumps in the quarry shaft wetwell.

Other features of the intake and discharge pumping station are described in Section 5 of the main report. Itemization and cost of the components are outlined further below in Section 6 of this summary.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline is shown aligned on the quarry access road and a direct route between the stream and quarry. The pipeline is projected to be 2500 lf of 30 inch diameter ductile iron pipe (DIP). Pipe will be installed as conventional cut & cover construction. A piping alternative will be discussed further in Section 3.3 below.

Table 3.1 below summarizes the piping and pumping facility parameters for the base case of storage connected to the Neshaminy Creek. Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

The pumping facility is intended to be remotely operated and monitored as described in the main report. For the purposes of estimating costs, the quarry will be dewatered in part and refilled in the wetter offseason months. Maintenance of the facilities would be as typical. Operations would be impacted if this project was combined with the Eureka Quarry (Q19) as explained in Section 3.3.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (3 x 9.6 mgd)	29 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (5 x 7.2 mgd)	36 mgd
Pipeline Distance	2,500 lf
Elevation at Discharge Point	135 ft
Elevation at High Point on Pipeline	179 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

3.3 Alternate Pumping/Piping Configuration

The quarry storage size and pumping/piping configuration of this potential project provides reasonable storage volume. However, the adjacent Eureka Quarry (Q19) may provide an opportunity to combine storage projects and allow for a more efficient pumping/piping arrangement. Figure 3.2 introduces a concept for combining the two projects by connecting them hydraulically through a pipe and also make a direct connection from the Eureka quarry to the Neshaminy Creek. The details of this is described further in the Q19 SPS description.

Figure 3.2: Approximate Location of Pipe (red line) Connecting Q4 and Q19

4 Environmental Impacts

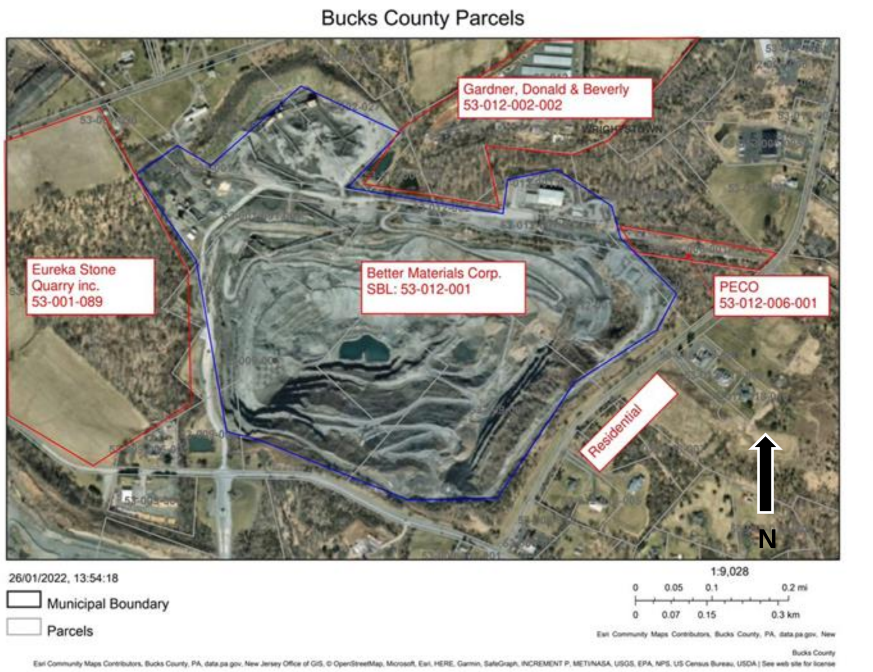
This storage project was reviewed against several environmental scoring parameters as described in the body of the report. The pumping station shafts and pipeline should be located to avoid direct environmental impacts to wetlands, forested uplands or protected species. Some limited clearing will be required to install the withdrawal intake/pumping station. Wetlands were identified on the south side of the creek, opposite the intake location. Stream impacts will be limited and as typical for comparable intakes on a relatively small stream. The majority of the work is performed on the quarry site or adjacent quarry haul roads. Overall, the project is scored as relatively high having relatively low probability of negative impacts. As other storage projects, augmenting the receiving stream with flow from storage during low flow conditions is advantageous.

Permitting the project appears achievable and should occur within an acceptable timeframe. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder and social/economic impacts are expected to be minor. Similarly, direct positive impacts should be minor. The quarry site and surrounding land is generally restricted ownership, with only minor residential property in this rural area as shown in Figure 5.1.

Figure 5.1: Land Ownership



The soicial impacts, positive or negative, should be minimal. Converting the quarry to storage and possible recreation should have minor impact given limited surrounding residential properties and the fact that other water recreational facilities (Peace Valley and Nockamixon) are nearby. Economically, the local impact should be minor. According to publically avaialble information, the quarry directly employs 30 workers.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$2,300,000.00
Pipeline	LF	2500	$800.00	$2,000,000.00
Valves	#	6	$50,000.00	$300,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$9,072,000.00
Intake Structure	LS	254	$25,000.00	$6,350,000.00
Pumping Station				
Pumps	#	5	$450,000.00	$2,250,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$15,937,500
Contingency			50%	$7,968,750
CONST. COST + CONTINGENCY				$23,906,250

Note that land acquisition costs are not included in the above capital cost. The Bucks County Tax Assessment information set the market value of the quarry at approximately $3M so this was carried forward as the land cost, absent other information.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 2.6 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $34.25M. Of course, operating costs would be impacted if this storage project was coupled with the Eureka project as suggested above.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 8 years. This includes:

- Design, permitting and land acquisition 3 years
- Construction 3 years
- Startup and initial filling of quarry 2 years

7 Potential Ancillary Benefits

Ancillary benefits consider such items as flood control, recreational/tourism, habitat enhancement, related potential environmental benefits (remediation, reclamation, etc.) and leveraging related local/state/federal programs that may improve the proposed project.

As mentioned previously, ancillary benefits are likely limited and is scored accordingly.

8 Storage Project Score

This site was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are summarized in Table 8.1 below.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.58	30%	1.08
Infrastructure Design, Construction & Operation	3.60	10%	0.36
Environmental Impacts	4.57	15%	0.69
Social & Economic Impacts	4.88	10%	0.49
Project Cost & Schedule	4.17	30%	1.25
Ancillary Benefits	3.60	5%	0.18
AVERAGE	**4.07**		**4.04**

Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

APPENDIX

Score sheet

STORAGE PROJECT SCORING

STORAGE PROJECT: Q4
NAME: Penns Park Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.58**			30%	**1.08**	
o Volume of storage provided (BG)	3.3	2.5					
o Hydrologic reliability of supply (months to fill)	2.8	5					
o Release rate (cfs)	50	3					
o Promptness of delivery to mainstem (day)	0.21	5					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**3.60**			10%	**0.36**	
o Site/Civil, Land & Easements		3.5					Typical, but in quarry and pipe on access road
o Subsurface conditions		3					
o Infrastructure Complexity		4					Proven systems
o Construction complexity		4					Typical, with good working areas
o Operational complexity		3.5					Ranked higher than normal because of options for joint storage
3. Environmental Impacts		**4.57**			15%	**0.69**	
o Protected species		5					
o Water quality degradation		5					
o Obstruction to passage of aquatic animals		5					
o Hydromodification		4					Potential concerns for flow in low flow stream
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		3.5	2	5			Concern for wetland on opposite bank from intake location
o Stream length inundated (mi)		4.5	5	4			Minor intake disturbance
o Uplands inundated or developed (ac)		5	5	5			Minor intake disturbance
4. Social and Economic Impacts		**4.88**			10%	**0.49**	
o Disruption/displacement		5					
o Safety and health		5					
o Social equity		5					
o Recreational loss		5					Potential minor gain
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		4.5					Minor quarry loss
o Loss of production from farmland, timberland, quarries		4.5					
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**4.17**			30%	**1.25**	
o Land acquisition cost ($)	$3M						
o Construction Cost ($)	$21M						
o Operating Cost ($/yr)	$.375M						
o Overall Cost ($)	$34.25M	4.5					
o Cost effectiveness ($/BG)	$10.4M	4					
o Schedule (Time to make Operational, years)	8	4					
6. Ancillary Benefits		**3.60**			5%	**0.18**	
o Flood control		3					
o Recreation/tourism		4					Some potential
o Habitat/fishery enhancement		4					Some potential
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					Could settle solids and replenish stream at low flows
o Ability to leverage funding from other programs		3					Potential rec. funds, but local competition
OVERALL		4.07				**4.04**	

MOTT MACDONALD

Storage Project Summary

Project:	**Lehigh Nazareth Quarry (Q5)**
Location:	Nazareth, Northampton County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	4.2 Billion Gallons
Score:	3.37

1 Project Overview

This storage project would store water in the Lehigh Nazareth Quarry (distinct from the NESL Nazareth Quarry, Q27), located as show in Figure 1.1. The source water would be from the Bushkill Creek.

The quarry has a maximum volume of 4.2 billion gallons. This quarry is approximately 102 acres in area and has an estimated fillable rim elevation of 450 ft. At the quarry's deepest point, it has an elevation of 220 ft, giving the quarry a nominal depth of 230 feet. The nearest sizable stream to the quarry is the Bushkill Creek, located about 21,000 feet away. The quarry is composed of shale and limestone and mined for aggregate and related construction materials.

Figure 1.1: Project Location

2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 3.4 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or retaining walls are suggested to increase storage volume for this project. For all quarry projects, operational volume ranges from the highest water level in storage to an elevation of 20% of the quarry's total depth. This operational low water level considers pump performance and constructability constraints. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Further analysis will be needed to account for storage lost to pervious areas. Figure 2.1 below shows contours indicating the depth of the quarry.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

While the quarry provides significant volume, filling the quarry will be a challenge based on the limited flow of the Bushkill Creek as well as the distance of the creek to the quarry. The team considered a direct connection to the Delaware River providing sufficient supply and a direct replenishment from storage. However, the 7.5 mile straight line distance to the Delaware River was deemed to be too far and a pipeline connection too costly.

The Bushkill Creek is a high-quality cold water fishery (HQ-CWF) and has a drainage are of only 31 sq. mi.

The creek has a mean annual flow of 49 cfs (31 mgd) and a 7Q10 flow of 2 cfs. This is one of the smaller watersheds of the quarry sources considered. Reliable withdrawal from this source may not be possible or permittable and will be considered in the evaluation. This small flow limits withdrawal and will follow the approach discussed in the main report of pumping only during the 6-month high flow period and adjusting withdrawal rates to track and maximize withdrawal during high flow, effectively skimming flows. Based on the adopted approach, approximately 12 mgd can be withdrawn, on average, over the 6-month high flow period. Given the above stated flows and assumptions, the inflow pumping can not fill the operational volume of storage in the project withing targeted six-month high-flow period.

The discharge pumping from storage back to the creek is effectively controlled by the practical limits of the discharge pumps and the ability of the stream to dissipate and assimilate the flow. The design discharge rate for the pump station is 50 cfs (31.64 mgd), which is equal the mean annual flow. For the outflow pumping, the operational volume could provide 50 cfs of flow augmentation for about 7 months. The discharge flow rate may have to be reduced, and flow re-introduced to the stream will need to be dissipated. It could be problematic for the stream to see this continuous high flow; this will likely be a regulatory concern.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	102 acres
Nominal Rim Elev.	450 ft.
Bottom Elev.	220 ft.
Maximum Water Level Change (Ft.)	230 ft.
Maximum Volume (Billion Gallons)	4.2 BG
Operating Water Range (450 ft - 266 ft)	184 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	3.4 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Bushkill Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	31.2 sq.mi.
Mean Annual Stream Flow Rate (cfs/mgd)	49 cfs / 31 mgd
Proposed Average Pumping Rate (mgd)	12 mgd
Average Vol. Pumped during 6 month Pumping Term	1.2 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	450 ft to 266 ft
Proposed discharge pumping rate (mgd)	32 mgd
Estimated Time to Release Operating Volume from Storage	3.5 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	9 miles
Travel Time at 2 mph (hours)	5 hours

2.3 Water Quality

The source stream, Bushkill Creek, has good quality based on the PA 303D listing and Chapter 93 information. The stream is classified as a high-quality, cold-water fishery (HQ-CWF) and supports both stocked and wild trout populations. Table 2.2 below summarizes the 303D listed impairments.

Table 2.2: 303D Listing Impairments

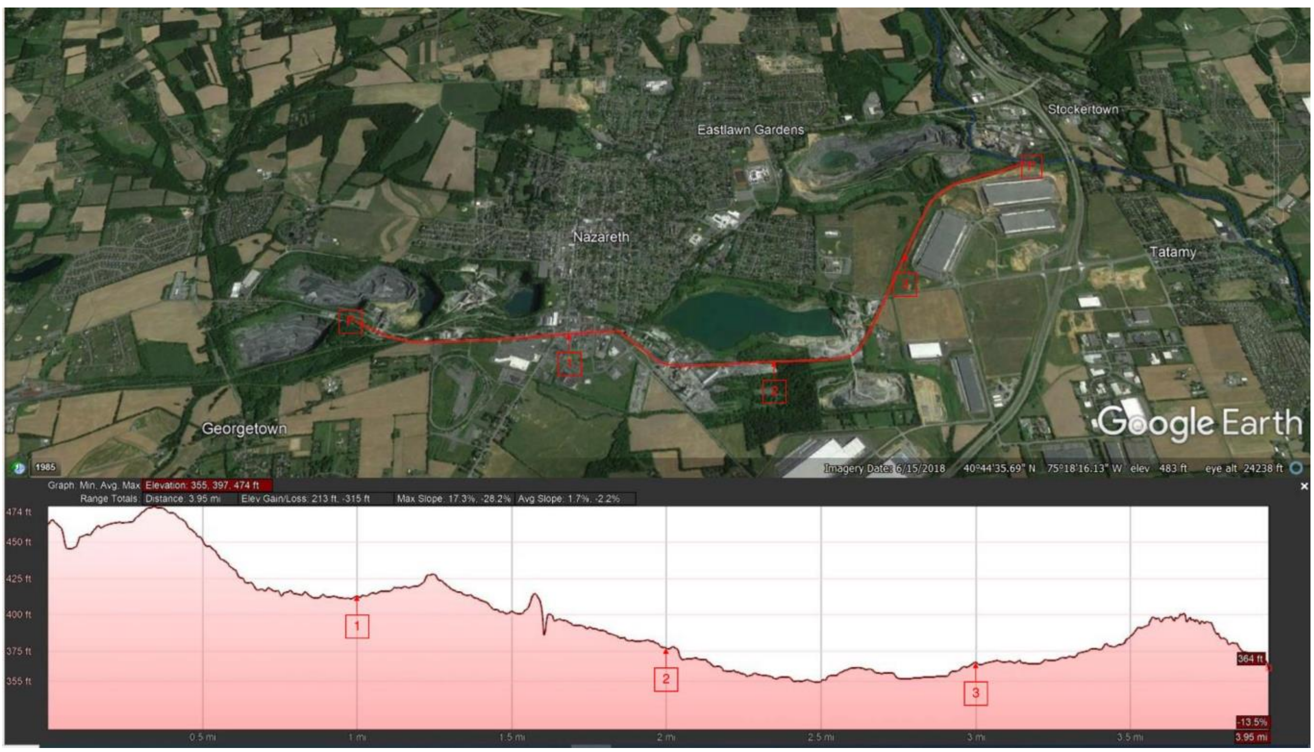
IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
Supporting	Not Assessed	Impaired - atmospheric deposition due to mercury,	Not Assessed

Future Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease after settling in the quarry. However, temperature differences between the stored water and stream flow may be an environmental issue and therefore a regulatory concern. The water quality should be adequate for flow augmentation, but this needs to be confirmed by further investigation.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and the interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities. The inflow pumping station is shown on the banks of the Bushkill Creek and the quarry pumping station is shown adjacent to the quarry. The red line in plan tracks a proposed pipeline route. The numbers on the corresponding plan/profile are provided for reference between the two figures.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile



3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is envisioned to be as typical with wedgewire half screens on the stream bottom and an onshore wetwell. However, withdrawal on such a low flow stream can be a challenge. Some stream bottom modification may be needed to get adequate screen submergence depth.

The adjacent wetwell with be fitted with 3 x 6 mgd submersible pumps. One pump will pump the anticipated average withdrawal and the other two pumps will be activated during periods of high flow as needed. As noted above, limited withdrawal rate will not allow the quarry to be filled to a high elevation if the operational volume is used during the dryer months.

The quarry discharge/stream augmentation pumping station includes components as generally described in the main report. The design flow rate for the discharge pump station is 50 cfs (32 mgd). This will be accomplished with four 8.6 mgd pumps operating with variable speed drives. Given the discharge rate and stream flow as mentioned above, sufficient energy dissipations will be required at the outfall. No dissipation concept engineering was performed, but it is expected that the dissipation will require a dissipating structure at the outfall and not just armoring. This was included in the cost estimating for this project.

Other features of the intake and discharge pumping station are described in Section 5 of the main report. Itemization and cost of the components are outlined further below in Section 6 of this summary.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline is 20,858 feet of 30 inch diameter ductile iron pipe (DIP) and would be installed in the public right-of-way (ROW) in the roadway/footway where possible to connect from the quarry to the river. Note that approximately 1 mile of the pipeline would be installed in Nazareth streets presumably creating additional challenges working around conflicting urban utilities. In addition, several locations along the alignment appear to be private industrial roadways that will require special easement agreements for installation.

Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	6 mgd
Pump Capacity (3 x 6 mgd)	18 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	31 mgd (50 cfs)
Pump Capacity (Z x Y mgd)	4 x 8.6 mgd
Pipeline Distance	20,858 lf
Elevation at Discharge Point	374 ft
Elevation at High Point on Pipeline	474 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

The pumping facilities will be automatically operated as the other quarry concepts. However, given the flow constraints and concerns at discharge for energy dissipation, this location will require some additional controls and may require periodic inspection to check automatic performance.

4 Environmental Impacts

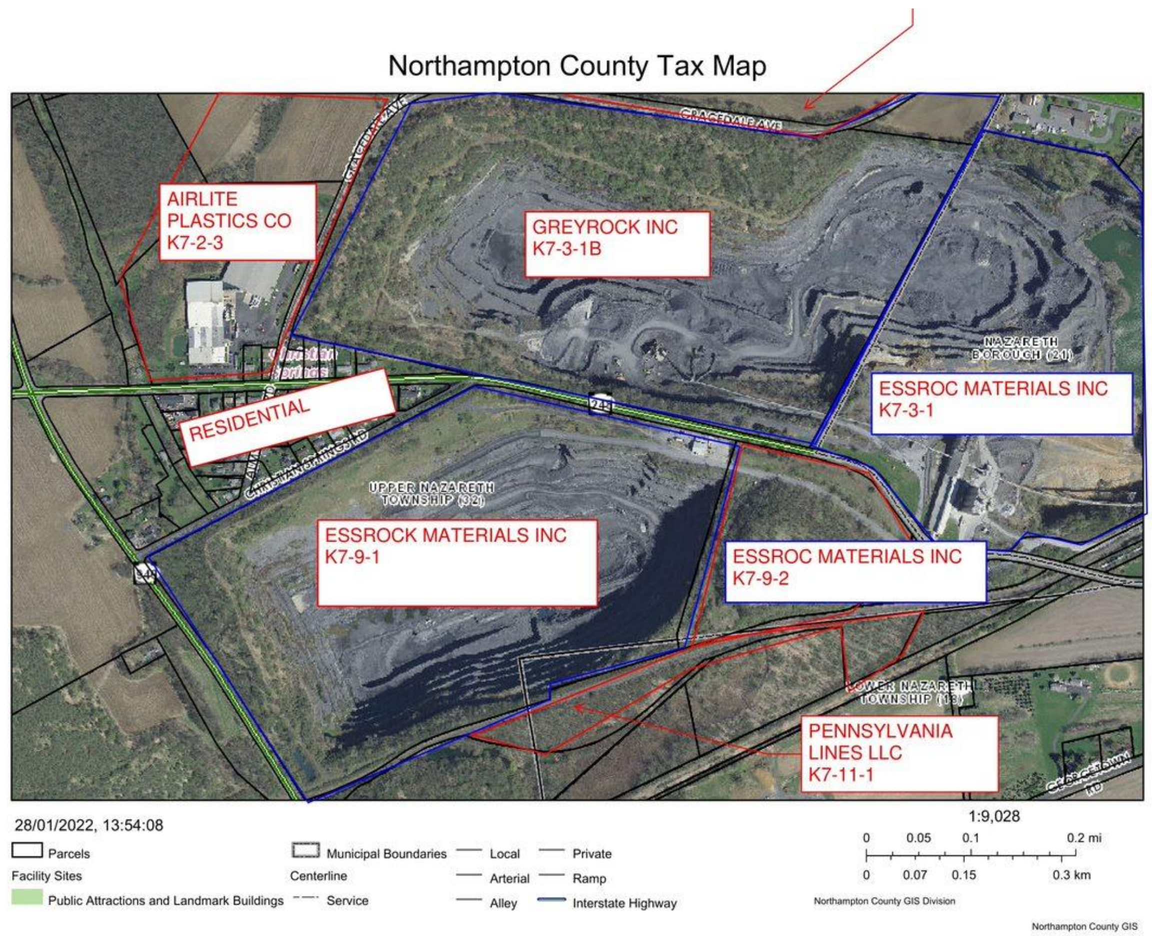
This storage project was reviewed against several environmental parameters as described in the body of the report. Overall, the project is scored moderate given potential for impacts of the pipeline construction and the intake and related discharge. The environmental impacts related to the quarry storage are expected to be minimal. The 20,000+ feet of connecting pipeline appears not to encounter wetlands or other sensitive areas, as it traverses this industrialized area of the Lehigh Valley. Some minor wetlands have been identified, but should be able to be avoided. Potential for Bog Turtles was also identified in the area. The greatest environmental impacts will be at the intake and withdrawal pumping station. As noted, the Bushkill is a CW/HQ stream. There will be temporary disruption during the intake construction. Of greater concern is the potential long-term impact of hydromodification during withdrawal and subsequent discharge. Correspondingly, this scored low to moderate for environmental variables.

Permitting the project appears achievable and should occur within an acceptable timeframe. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor. The quarry site and surrounding land is generally industrial with quarry and cement/concrete facilities. The ownership in the vicinity is generally shown in Figure 5.1. The adjacent residential areas are a moderate distance away and should not be impacted by construction or operations. In terms of the scoring subcriteria listed in the main report, the impacts are deemed to be generally favorable.

Figure 5.1: Land Ownership



6 Project Cost & Schedule

Mott MacDonald prepared feasibility-level costs for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$17,884,800.00
Pipeline	LF	20856	$800.00	$16,684,800.00
Valves	#	24	$50,000.00	$1,200,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$6,872,000.00
Intake Structure	VF	184	$25,000.00	$4,600,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$29,322,300
Contingency			50%	$14,661,150
CONST. COST + CONTINGENCY				$43,983,450

The total capital is shown above. Land costs are not included in the total. The quarry appears to be separated into at least two major parcels as shown in Figure 5-1. Based on the Northampton County tax parcel information, the two primary parcels have an appraised value or approximately $3M. This may not accurately reflect the market value if repurposed for use as a reservoir but was used as the land cost in the estimates, as with other projects, for consistency.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 3.4 BG and subsequent filling for the following year. Additional operating cost may be necessary for this project because of the need for more closely monitoring pumping withdrawal rate, concerns for discharge and the need to have some physical inspection to monitor the automated facility. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $54.33M

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 8 years. This includes:

- Design, permitting and land acquisition 4 years
- Construction 3 years
- Startup and initial filling of quarry 1 years

7 Potential Ancillary Benefits

Flood control benefits should not be realized. Given the industrial area in the vicinity, creating a recreational facility out of the quarry storage may not be desirable. Other similar facilities exist in the area. No water quality or fisheries enhancement are envisioned as part of this project. As noted in Section 6, Environmental Impacts, there could be a negative impact. For these reasons the Potential Ancillary Benefits ranked low for this project.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.25	30%	0.98
Infrastructure Design, Construction & Operation	2.30	10%	0.23
Environmental Impacts	3.00	15%	0.45
Social & Economic Impacts	4.38	10%	0.44
Project Cost & Schedule	3.83	30%	1.15
Ancillary Benefits	2.60	5%	0.13
AVERAGE	**3.23**		**3.37**

Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

APPENDIX

Score sheet

STORAGE PROJECT SCORING

STORAGE PROJECT: Q5
NAME: Nazareth Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.25**			30%	**0.98**	
o Volume of storage provided (BG)	4.2	2.5					
o Hydrologic reliability of supply (months to fill)	7	4					
o Release rate (cfs)	<50	2					Reduced rating because of dissipation concerns
o Promptness of delivery to mainstem (day)	0.2	5					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**2.30**			10%	**0.23**	
o Site/Civil, Land & Easements		2.5					Intake requires atypical mods.; pipeline is challenging
o Subsurface conditions		2.5					In know Karst area
o Infrastructure Complexity		2					Design for low flow stream is challenging
o Construction complexity		2.5					Typical intake/PS; pipe is challenge
o Operational complexity		2					Problem filling in time; discharge may be too high
3. Environmental Impacts		**3.00**			15%	**0.45**	
o Protected species		4					May be issues on pipeline; flows in creek may be disruptive
o Water quality degradation		3					Transferring such high flows in small stream may be problematic
o Obstruction to passage of aquatic animals		3					Assumed some obstruction
o Hydromodification		1					Changes on the CWF
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		3.5	2	5			Small areas appear along pipeline
o Stream length inundated (mi)		3	2	4			Some impact to HQ stream at/near intake
o Uplands inundated or developed (ac)		3.5	2	5			pipeline traverses established forests in areas
4. Social and Economic Impacts		**4.38**			10%	**0.44**	
o Disruption/displacement		4					Minor disruption by pipeline
o Safety and health		3					Potential safety by withdrawal/discharge of high flows from creek
o Social equity		5					
o Recreational loss		5					Potential gain
o Cultural/historical resources		5					
o Aesthetic		5					Area improvement
o Loss of tax revenue		4					Loss of large quarry in area
o Loss of production from farmland, timberland, quarries		4					Loss of large quarry in area
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**3.83**			30%	**1.15**	
o Land acquisition cost ($)	$3M						
o Construction Cost ($)	$44M						
o Operating Cost ($/yr)	$7.35M						
o Overall Cost ($)	$54.33	4					
o Cost effectiveness ($/BG)	$12.93M	3.5					
o Schedule (Time to make Operational, years)	8	4					
6. Ancillary Benefits		**2.60**			5%	**0.13**	
o Flood control		3					
o Recreation/tourism		3					Not significant given area
o Habitat/fishery enhancement		2					No benefit; could impacts
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		2					No benefit; could impacts
o Ability to leverage funding from other programs		3					
OVERALL		3.23				**3.37**	

MOTT MACDONALD

Storage Project Summary

Project: Imperial Quarry (Q6)

Location: Nazareth, Northampton County, PA

Storage Type: Quarry (Fill & Draw)

Est. Volume: 3.8 Billion Gallons

Score: 3.34

1 Project Overview

The Imperial Quarry project (Figure 1.1) is essentially the same as its adjacent Lehigh Nazareth Quarry (Q5); both are currently owned by Lehigh Cement. The Imperial Quarry has a maximum volume of 3.8 billion gallons. This quarry is approximately 71 Acres in area and has an estimated fillable rim elevation of 400 ft. At the quarry's deepest point, it has an elevation of 114 ft, giving the quarry a nominal depth of 286 feet. In comparison to the adjacent Q5, the Imperial Quarry is slightly smaller and lies at a lower elevation, as well as generally deeper. Similar to the Q5 site, the nearest reasonably sized stream to this quarry is the Bushkill Creek, located approximately 20,850 feet away. The quarry is composed of shale and limestone.

Figure 1.1: Project Location

2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 3 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or retaining walls are suggested to increase storage volume for this project site. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Further analysis will be needed to account for storage lost to pervious areas. Figure 2.1 below shows the proposed fill elevation of 400 ft along with contours showing the depth of the quarry.

Figure 2.1: Arial View with Contours

2.2 Fill and Discharge

The fill and discharge arrangement is the same as described in the SPS for Q5, Lehigh Nazareth Quarry. The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	71 acres
Nominal Rim Elev.	400 ft.
Bottom Elev.	114 ft.
Maximum Water Level Change (Ft.)	286 ft.
Maximum Volume (Billion Gallons)	3.8 BG
Operating Water Range (400ft-171 ft)	229 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	3.0 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Bushkill Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	31 sq.mi.
Mean Annual Stream Flow Rate (cfs/mgd)	49 cfs / 31 mgd
Proposed Average Pumping Rate (mgd)	12.5 mgd
Average Vol. Pumped during 6 month Pumping Term	2.3 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	400 ft to 171 ft
Proposed discharge pumping rate (mgd)	32 mgd
Estimated Time to Release Operating Volume from Storage	3.1 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	9 miles
Travel Time at 2 mph (hours)	5 hours

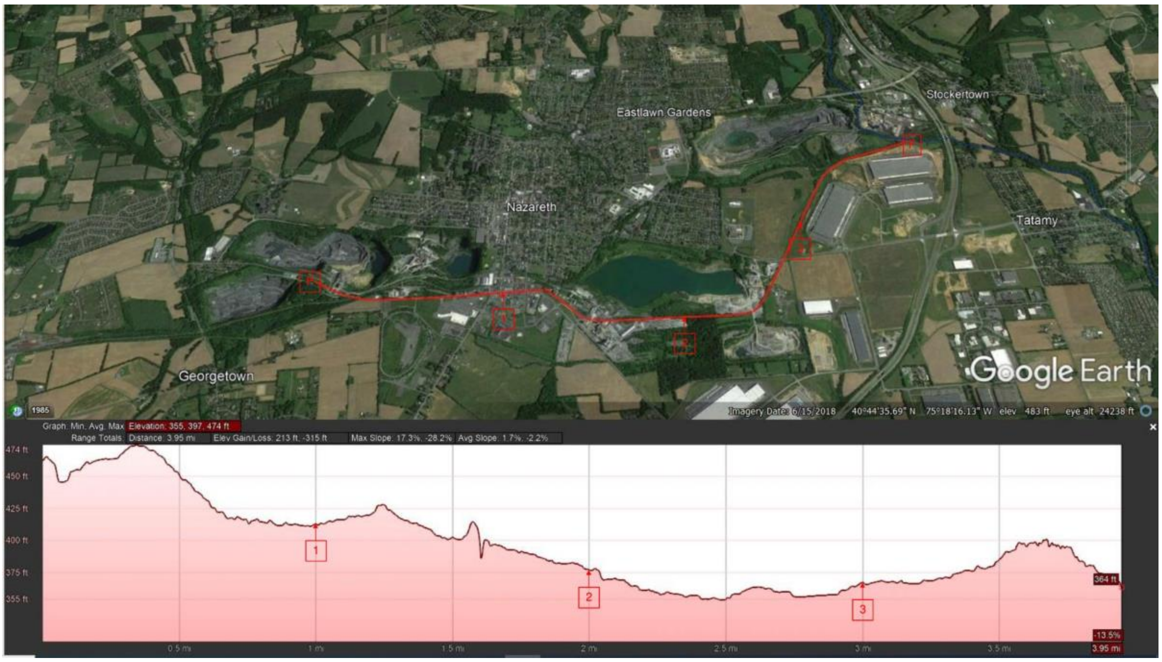
2.3 Water Quality

Water quality may change after pumping and settling in the quarry. The water quality should be adequate for flow augmentation, but this needs to be confirmed by further investigation. Please refer to the Q5, Lehigh Nazareth Quarry discussion on water quality for more details.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities. This alignment is the same as presented in the adjacent Q5, the Lehigh Nazareth Quarry.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile



3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is envisioned to be basically the same as presented in the Q5 Lehigh Nazareth Quarry SPS. The quarry discharge/stream augmentation pumping station would have comparable components but is slightly different based on the changing head conditions associated with the deeper Q6 quarry configurations.

3.2 Pipeline

The proposed pipeline route is shown in Figure 3.1 and again is the same Q5, the Lehigh Nazareth Quarry site. An alternative piping arrangement will be presented in Section 3.3. Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	19 mgd
Pump Capacity (3 x 6 mgd)	18 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (5 x 7.2 mgd)	35 mgd
Pipeline Distance	20,858 lf
Elevation at Discharge Point	374 ft
Elevation at High Point on Pipeline	474 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule. In terms of operations of the project, the process will be automatic and as described for the Q5, Lehigh Nazareth Quarry project.

3.3 Alternate Pumping/Piping Configuration

The Q6 project evaluation and scoring will be very comparable to the Q5, Lehigh Nazareth Quarry project. As an alternate configuration, the Q6 storage volume can conceivable be combined with the Q5 storage volume by hydraulically connecting the two storage volumes with a pipe. The concept would be to drill and blast a connecting opening, measuring approximately 800 lf, that would be lined with a cast-in-place concrete lining or concrete pipe to allow free transfer of stored water between the facilities. The operating depth of the combined project would be based on the lower rim elevation of Q6 and the higher base elevation of Q5. Effectively making the depth range of the combined projects from elevation 400 to elevation 220 feet, having a combined volume of approximately 6 BG. This is advantageous in creating more volume. However, the combined project is still constrained by the limited supply of the Bushkill creek as described in the Q5 SPS. Scoring of the Q6 project will consider this alternate combined project option, as described in Section 8.

4 Environmental Impacts

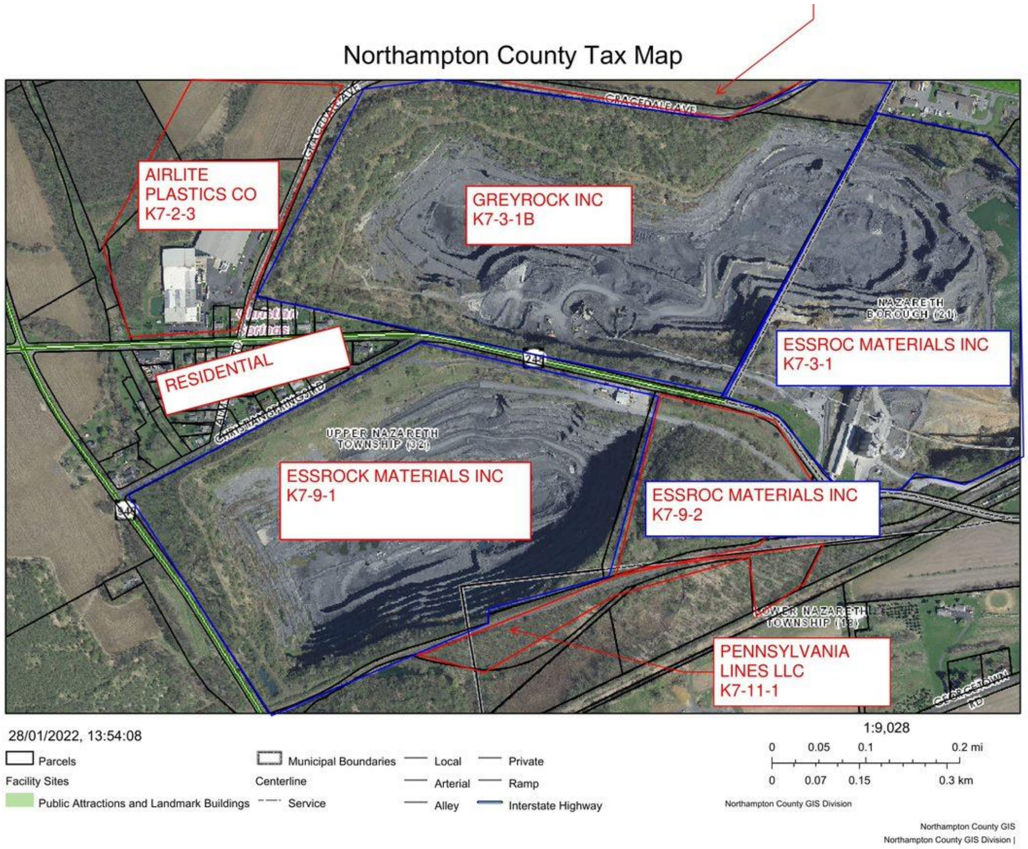
This potential environmental impacts on this Q6 project are essentially the same as the Q5 project and are driven by pumping from the Bushkill Creek. The scoring for environmental impacts on this site is the same as the Q5 site.

Permitting the project appears achievable and should occur within an acceptable timeframe. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor and the related scoring for the Q6 site is the same as assigned for the Q5 site. The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1.

Figure 5.1: Land Ownership



6 Project Cost & Schedule

Mott MacDonald prepared a cost estimate for this storage option consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The costs of the Q6 site buildout area very comparable to the Q5 cost. The only difference is the slight change in discharge pumping facilities at the quarry. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$17,884,800.00
Pipeline	LF	20856	$800.00	$16,684,800.00
Valves	#	24	$50,000.00	$1,200,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$8,422,000.00
Intake Structure	VF	228	$25,000.00	$5,700,000.00
Pumping Station				
Pumps	#	5	$450,000.00	$2,250,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$30,872,300
Contingency			50%	$15,436,150
CONST. COST + CONTINGENCY				$46,308,450

The total capital is shown above. Land costs are not included in the total. The quarry appears to be separated into at least two major parcels as shown in Figure 5-1, with the 9-1 parcel including the mined quarry. Based on the Northampton County tax parcel information, the two primary parcels have an appraised value of approximately $3.2M. This may not accurately reflect the market value if repurposed for use as a reservoir but was used as the land cost in the estimates, as with other projects, for consistency.

Operating costs for this project are estimated to be approximately $0.375M/year, as presented for the Q5 project. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $56.85M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 8 years, as presented for Project Q5. This includes:

- Design, permitting and land acquisition 4 years
- Construction 3 years
- Startup and initial filling of quarry 1 years

7 Potential Ancillary Benefits

The ancillary benefits of the Q6 project area essentially equal to the Q5 project and are not considered significant.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	2.5	30%	0.00
Infrastructure Design, Construction & Operation	2.30	10%	0.23
Environmental Impacts	3.14	15%	0.47
Social & Economic Impacts	4.38	10%	0.44
Project Cost & Schedule	3.67	30%	1.10
Ancillary Benefits	2.60	5%	0.13
AVERAGE	**3.22**		**3.34**

Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

APPENDIX

Score Sheet

STORAGE PROJECT SCORING

STORAGE PROJECT: Q6
NAME: Imperial Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.25**			30%	**0.98**	
o Volume of storage provided (BG)	3.8	2.5					
o Hydrologic reliability of supply (months to fill)	13.5	3					
o Release rate (cfs)	50	3					
o Promptness of delivery to mainstem (day)	0.2	5					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**2.30**			10%	**0.23**	
o Site/Civil, Land & Easements		2.5					Intake requires atypical mods.; pipeline is challenging
o Subsurface conditions		2.5					In know Karst area
o Infrastructure Complexity		2					Design for low flow stream is challenging
o Construction complexity		2.5					Typical intake/PS; pipe is challenge
o Operational complexity		2					Problem filling in time; discharge may be too high
3. Environmental Impacts		**3.14**			15%	**0.47**	
o Protected species		4					May be issues on pipeline, but should be able to avoid; flows in creek may be disruptive
o Water quality degradation		3					Transferring such high flows in small stream may be problematic
o Obstruction to passage of aquatic animals		3					Assumed some obstruction
o Hydromodification		2					Changes on the CWF
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=large, 1=small)**			
o Wetlands inundated or filled (ac)		3.5	2	5			Small areas appear along pipeline
o Stream length inundated (mi)		3	2	4			Some impact to HQ stream at/near intake
o Uplands inundated or developed (ac)		3.5	2	5			pipeline traverses established forests in areas
4. Social and Economic Impacts		**4.38**			10%	**0.44**	
o Disruption/displacement		4					Minor disruption by pipeline
o Safety and health		3					Potential safety by withdrawal/discharge of high flows from creek
o Social equity		5					
o Recreational loss		5					Potential gain
o Cultural/historical resources		5					
o Aesthetic		5					Area improvement
o Loss of tax revenue		4					Loss of large quarry in area
o Loss of production from farmland, timberland, quarries		4					Loss of large quarry in area
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**3.67**			30%	**1.10**	
o Land acquisition cost ($)	$3.2M						
o Construction Cost ($)	$46.3M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	$56.85M	3.5					
o Cost effectiveness ($/BG)	$14.96M	3.5					
o Schedule (Time to make Operational, years)	8	4					
6. Ancillary Benefits		**2.60**			5%	**0.13**	
o Flood control		3					
o Recreation/tourism		3					Not significant given area
o Habitat/fishery enhancement		2					No benefit; could impact
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		2					No benefit; could impact
o Ability to leverage funding from other programs		3					
OVERALL		3.22				**3.34**	

MOTT MACDONALD

Storage Project Summary

Project:	**Stockertown Quarry—Delaware River Option (Q7D)**
Location:	Stockertown, Northampton County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	4.6 Billion Gallons
Score:	4.01

1 Project Overview

The scope of this storage project is to store water in the Stockertown Quarry using the Delaware River as the source and subsequent discharge point.

The Stockertown Quarry is an active quarry located in Stockertown, PA in Northampton County just east of the Nazareth Borough, Pennsylvania (Figure 1.1). The quarry is composed of shale and limestone and mined for construction materials. The quarry has a maximum volume of 4.6 billion gallons, the third largest quarry storage reviewed. This quarry is approximately 120 Acres in area and has an estimated fillable rim elevation 300 ft. At the quarry's deepest point, it has an elevation of 65 ft, giving the quarry a nominal depth of 235 ft. The closest pumpable stream to the quarry is the Bushkill Creek, located only about 150 feet away. However, concerns for the Bushkill's low flow and environmental impacts have prompted this evaluation using the larger Delaware River as a source and discharge point. This SPS assumes a pipe connection with the Delaware River. This project was also evaluated and scored based on the Bushkill source.

Figure 1.1 Project Location

2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 3.7 BG. The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or retaining walls are suggested to increase storage volume for this project since the historical excavation created the mine pit from approximate level grade. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Further analysis is needed to account for storage lost to pervious areas and to further understand the interconnection with the local groundwater regime. Figure 2.1 below shows the proposed fill elevation (300') along with contours showing the depth of the quarry.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

This Q7-Delaware source assumes withdrawal from the Delaware River and subsequent discharge back to the Delaware. The Delaware River has significant flow and therefore the withdrawal is not source limited. The Delaware has a drainage area of approximately 6,700 sq. mi. area and a mean annual flow of 12,400 cfs with an estimated 7Q10 flow of almost 1560 cfs. This allows for unencumbered withdrawal and subsequent discharge of the design pump station flow of 50 cfs.

Given the above stated storage configuration and the assumptions associated with pumping, the 4.6 BG of quarry storage can be filled within six-months. Given the quarry discharge pumping rate of 50 cfs, the operating volume of 3.7 BG can sustain approximately 4 months of flow augmentation.

The key parameters relating to storage volume and Delaware River fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	120 acres
Nominal Rim Elev.	300 ft.
Bottom Elev.	65 ft.
Maximum Water Level Change (Ft.)	235 ft.
Maximum Volume (Billion Gallons)	4.6 BG
Operating Water Range (300ft-112 ft)	188 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	3.7 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Delaware River
Anticipated Source Stream Drainage Area (Sq. Miles)	6,700 sq. mi.
Mean Annual Stream Flow Rate (cfs/mgd)	12,400 cfs / 8014 mgd
Proposed Average Pumping Rate (mgd)	32 mgd
Average Vol. Pumped during 6 month Pumping Term	5.6 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	300 ft to 112 ft
Proposed discharge pumping rate (MGD)	32 mgd
Estimated Time to Release Operating Volume from Storage	4 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	~0 miles
Travel Time at 2 mph (hours)	~0 hours

2.3 Water Quality

The water quality of the Delaware River at this location is generally good. The information from the 303 D listing is provided below in Table 2.2.

Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
	Supported	Impaired - mercury	Supporting

The Chapter 93 designated use is warm water fishery (WWF).

Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease relative to the source stream and the reintroduction of stored water into the Delaware, at just a fraction of the river flow, will not impair the Delaware River quality.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities. Note that the profile is shown along the red line shown on the plan view and extends from the stream withdrawal on the Delaware to the quarry discharge point adjacent to the quarry.

Figure 3.1: Approximate Pipe (red line) and Pump Station Location and Profile

3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is not flow limited withdrawing from the Delaware River. For consistency, the intake is conceived to be wedgewire screens on the river bottom, but could also be a number of other options given the size of Delaware River. The pumping station will consist of a wetwell on the adjacent bank with a connecting pipe section. Withdrawn water will be pumped at a high constant rate, sufficient to reasonably fill the quarry. Again, this source and intake are not stream flow limited.

Similarly, the quarry discharge station will consist of a shaft and pumping facilities as described in the body of the report and consistent with other quarry alternatives.

3.2 Pipeline

The proposed direct pipeline route is schematically shown in Figure 3.1. The pipeline is assumed to be approximately 3.91 miles (20,644 lf) of 30-inch diameter ductile iron pipe (DIP) installed conventionally at nominal depth. The route is a direct straight line to the river and assumes that easements for this direct route can be obtained.

Alternatively, the pipeline could be aligned as much as possible in the right-of-way (ROW). This would probably locate the pipeline in the road shoulder for the majority of the route. This alignment would be installed with cut and cover conventional methods. However, a trenchless installation will be required to cross under Route 33. While the alignment is longer and more expensive, it is more likely to be permitted and approved. Figure 3.2 presents this ROW option. This measures 5.58 miles (29,462 lf).

Figure 3.2: Alternate Pipe (red line) and Pump Station Location and Profile

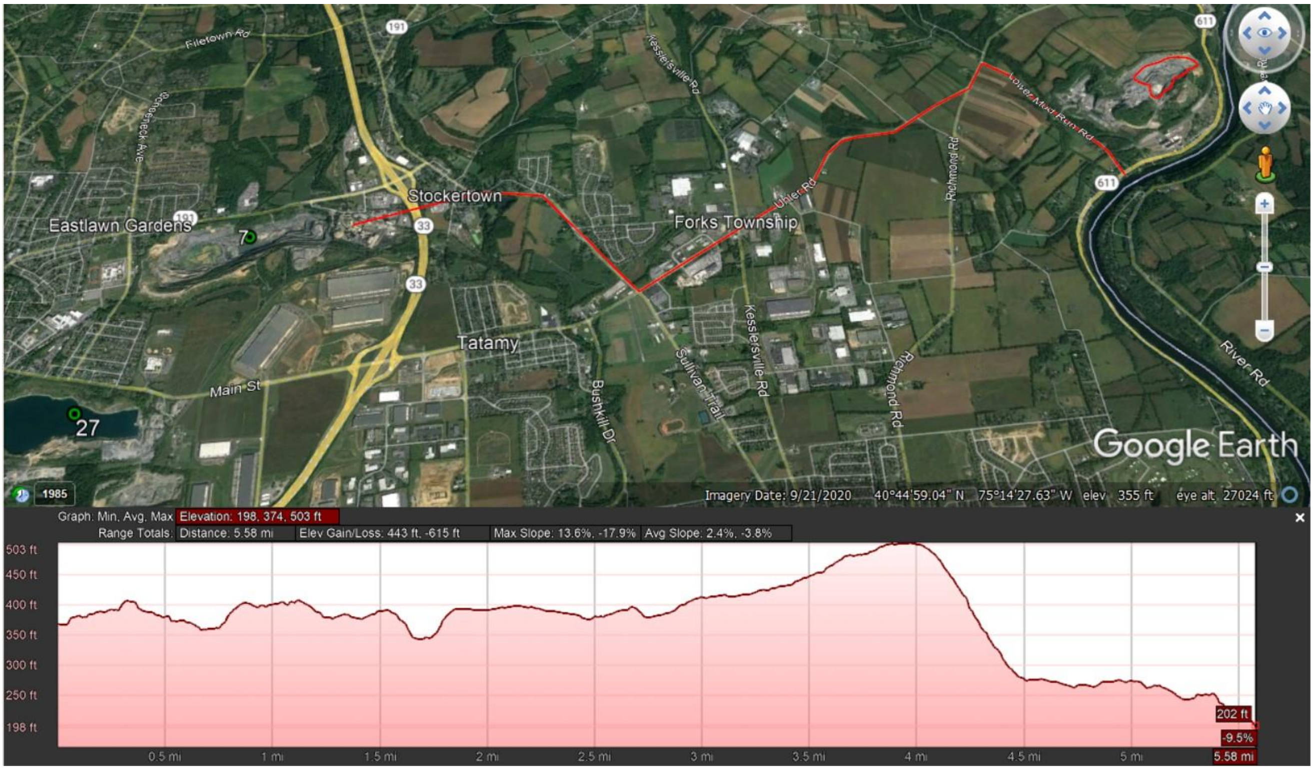


Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (3 x 10 mgd)	30 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (4 x 8.6 mgd)	35 mgd
Pipeline Distance (Direct)	20,644 lf
Pipeline Distance (Indirect-ROW)	29,462 lf
Elevation at Discharge Point (Quarry)	374 ft
Elevation at High Point on Pipeline (straight/ROW)	431 ft / 503 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

In terms of operations of the project, the process will be automatic as described in the main report. Given the source stream is not flow limited, the fill pumping should continue at constant rate for the required period.

4 Environmental Impacts

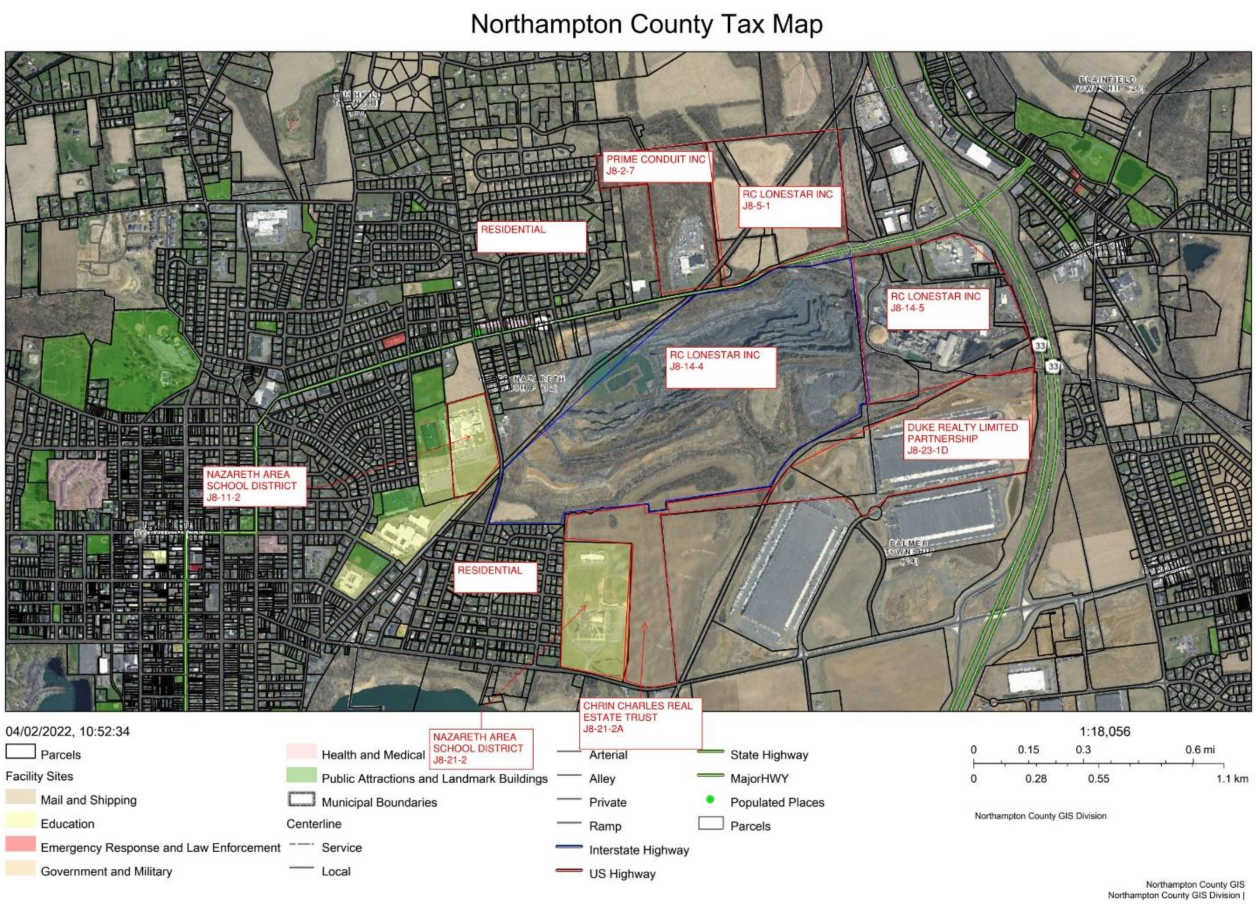
The environmental impacts of this project appear minimal. Overall, the project is scored high, in contrast to the Q7 option from the Bushkill Creek. No wetlands or sensitive environments should be impacted. Assuming the pipeline is placed in the ROW, there will be no pipeline impacts. The intake and fill pumping station will require routine disturbance on the banks of the Delaware, but is controllable and permittable. Unlike the Bushkill Creek option, there should be no hydromodification or impact from the withdrawn and later discharged flows.

Permitting the project appears achievable and should occur within an acceptable timeframe. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor similar to the Q5 and Q6 evaluations. The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1. The adjacent residential area may benefit from the conversion of the quarry to an environmental/recreational amenity. Local tax rateables could be reduced if the quarry ceases active mining operation.

Figure 5.1: Land Ownership



6 Project Cost & Schedule

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. Note the cost of the pipeline (ROW option) is included and is a significant cost to the project. However, connection along the ROW to the Delaware creates several benefits and leads to higher scores in multiple categories. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$24,819,600.00
Pipeline	LF	29462	$800.00	$23,569,600.00
Valves	#	25	$50,000.00	$1,250,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$6,972,000.00
Intake Structure	VF	188	$25,000.00	$4,700,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$36,357,100
Contingency			50%	$18,178,550
CONST. COST + CONTINGENCY				$54,535,650

The total capital cost is shown above. Land costs are not included in the above. Based on review of comparables from the Northampton County Tax website, the approximate value of the quarry is believed to be $3M. This value will be carried as land cost for the estimate and evaluation.

Operating costs for this project are estimated to be approximately $0.375M/year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $64.88M

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 9 years. This includes

- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup and initial filling of quarry 1 years.

7 Potential Ancillary Benefits

The potential ancillary benefits of this project area comparable to the Q7-Bushkill option. The Q7 site may lend itself to the creation of a recreational/environmental amenity with plentiful and good water quality in the Delaware River. Possibly, other mine restoration or local/state/federal parks & recreation funding might be leveraged to create the recreational/environmental amenity.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.5	30%	1.23
Infrastructure Design, Construction & Operation	3.70	10%	0.37
Environmental Impacts	4.93	15%	0.74
Social & Economic Impacts	4.25	10%	0.43
Project Cost & Schedule	3.67	30%	1.10
Ancillary Benefits	3.00	5%	0.15
AVERAGE	**3.94**		**4.01**

Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

APPENDIX

Score Sheet

STORAGE PROJECT SCORING

STORAGE PROJECT:Q7
Stockertown Quarry (Delaware Source)

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**4.08**			30%	**1.23**	
o Volume of storage provided (BG)	4.6	3.5					
o Hydrologic reliability of supply (months to fill)	4	5					
o Release rate (cfs)	50	3					
o Promptness of delivery to mainstem (day)	~0	5					
o Geographic Benefit		5					Above Trenton and the Lehigh confluence
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**3.70**			10%	**0.37**	
o Site/Civil, Land & Easements		4					In road ROW and straight forward
o Subsurface conditions		2.5					Typical. But Karst area could be an issue
o Infrastructure Complexity		4					Should not be issues, even given long pipeline
o Construction complexity		4					Should not be issues, even given long pipeline
o Operational complexity		4					Operation with Delaware source is a benefit
3. Environmental Impacts		**4.93**			15%	**0.74**	
o Protected species		5					Typical and pipeline in ROW
o Water quality degradation		5					Large flow source
o Obstruction to passage of aquatic animals		5					None identified
o Hydromodification		5					None based on high flow source
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		5	5	5			No apparent issues
o Stream length inundated (mi)		4.5	4	5			Minor impact, if any
o Uplands inundated or developed (ac)		5	5	5			Cropped/developed with most work in the ROW
4. Social and Economic Impacts		**4.25**			10%	**0.43**	
o Disruption/displacement		4					Minor typipcal disruption by pipeline, despite length
o Safety and health		3					No real issues
o Social equity		5					
o Recreational loss		5					Potential gain
o Cultural/historical resources		4					Potential for some issues along pipeline ROW
o Aesthetic		5					Area improvement
o Loss of tax revenue		4					Loss of large quarry in area
o Loss of production from farmland, timberland, quarries		4					Loss of large quarry in area
o Emissions of greenhouse gasses							
5. Project Costs & Schedule		**3.67**			30%	**1.10**	
o Land acquisition cost ($)	$3M						
o Construction Cost ($)	$54.53M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	$64.88M	3.5					
o Cost effectiveness ($/BG)	$14.10M	3.5					
o Schedule (Time to make Operational, years)	9	4					
6. Ancillary Benefits		**3.00**			5%	**0.15**	
o Flood control		3					
o Recreation/tourism		3					Not significant given area
o Habitat/fishery enhancement		3					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		3					
o Ability to leverage funding from other programs		3					
OVERALL		3.94				**4.01**	

Storage Project Summary

Project: Stockertown Quarry—Bushkill Creek Option (Q7B)

Location: Stockertown, Northampton County, PA

Storage Type: Quarry (Fill & Draw)

Est. Volume: 4.6 Billion Gallons

Score: 3.47

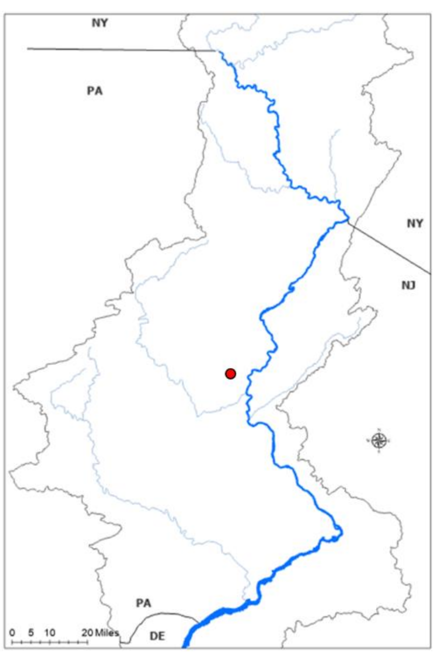
1 Project Overview

The scope of this storage project is to store water in the Stockertown Quarry using the Bushkill Creek as the source and subsequent discharge point.

The Stockertown Quarry is an active quarry located in Stockertown, PA in Northampton County just east of the Nazareth Borough, Pennsylvania (Figure 1.1). The quarry has a maximum volume of 4.6 billion gallons, the third largest quarry storage reviewed. This quarry is approximately 120 acres in area and has an estimated fillable rim elevation of 300 ft. At the quarry's deepest point, it has an elevation of 65 ft, giving the quarry a nominal depth of 235 ft. The closest pumpable stream to the quarry is the Bushkill Creek, located about 150 feet away. The quarry is composed of shale and limestone and mined for construction materials.

Note that this project, while close to the Bushkill Creek, has the challenges of withdrawing and discharging back to the low flow Bushkill Creek, similar to the Q5 and Q6 sites. This SPS and scoring evaluates the project based on the Bushkill source. A separate evaluation and SPS with an alternate score was developed for the Q7 site assuming withdrawal from the Delaware River.

Figure 1.1: Project Location



2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 3.7 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or retaining walls are suggested to increase storage volume for this project site, given that the historical excavation created the mine pit from approximate level grade. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Further analysis is needed to account for storage lost to pervious areas and to further understand the interconnection with the local groundwater regime. Figure 2.1 below shows the proposed fill elevation (300') along with contours showing the depth of the quarry.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

This Q7-Bushkill source assumes withdrawal from the adjacent Bushkill Creek and subsequent discharge back to the Bushkill Creek. The fill and discharge arrangement is the same as described for Q5 Nazareth Quarry and for Q6 Imperial Quarry. See the Q5 SPS and Q6 SPS documents for additional fill and discharge information. The key parameters relating to storage volume and Bushkill Creek fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	120 acres
Nominal Rim Elev.	300 ft.
Bottom Elev.	65 ft.
Maximum Water Level Change (Ft.)	235 ft.
Maximum Volume (Billion Gallons)	4.6 BG
Operating Water Range (300ft-112 ft)	188 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	3.7 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	**Bushkill Creek**
Anticipated Source Stream Drainage Area (Sq. Miles)	31 sq. mi.
Mean Annual Stream Flow Rate (cfs/mgd)	49 cfs / 31 mgd
Proposed Average Pumping Rate (mgd)	12 mgd
Average Vol. Pumped during 6 month Pumping Term	1.2 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	300 ft to 112 ft
Proposed discharge pumping rate (mgd)	32 mgd
Estimated Time to Release Operating Volume from Storage	3.8 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	9 miles
Travel Time at 2 mph (hours)	5 hours

2.3 Water Quality

Water quality may change after pumping and settling in the quarry. Please refer to the Q5, the Nazareth Quarry and Q6 Imperial Quarry discussion on water quality for more details.

Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
Impaired -	Supporting	Not Assessed	Not Assessed

Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease relative to the source stream and will be acceptable for flow augmentation.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities. Note that the profile is shown along the red line indicated on the plan view and consequently is exaggerated horizontally relative to other SPS plan/profile views. The proximity of the Bushkill Creek is advantageous, despite its lower flows.

Figure 3.1: Approximate Pipe (red line) and Pump Station Location and Profile

3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is envisioned to be basically the same as for Q5 Nazareth Quarry and Q6 Imperial Quarry. As noted, this includes halfsceen intakes on the creek bottom and a wetwell on the adjacent bank to house pumping equipment to fill the quarry. The fill pumping rates are limited by the available stream flow.

The quarry discharge/stream augmentation pumping station would have comparable components to the Q5 and Q6 projects, but is slightly different based on the changing head conditions associated with the deeper Q7 quarry and the reduced pipeline length.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline is assumed to be approximately 150 lf of 30-inch diameter ductile iron pipe (DIP) installed conventionally at nominal depth. Again, the location of the creek next to the quarry offers advantages. Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	19 mgd
Pump Capacity (3 x 6 mgd)	18 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (4 x 8.6 mgd)	35 mgd
Pipeline Distance	150 lf
Elevation at Discharge Point	374 ft
Elevation at High Point on Pipeline	372 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

In terms of operations of the facility, the process will be automatic and as described for the Q5 and Q6 projects.

3.3 Alternative Gravity Filling

The proximity and elevations of the Bushkill Creek and quarry present an opportunity to fill the quarry by gravity. A stream bank intake and gravity pipeline into the quarry would be constructed. Weir or level controls would spill water to the quarry during periods of sufficient flow on the Bushkill. This alternative eliminates stream withdrawal pumping from the Bushkill Creek. However, it also will likely lead to a long period to fill and replenish the quarry volumes. The project team has not fully examined this option, but it warrants further consideration.

4 Environmental Impacts

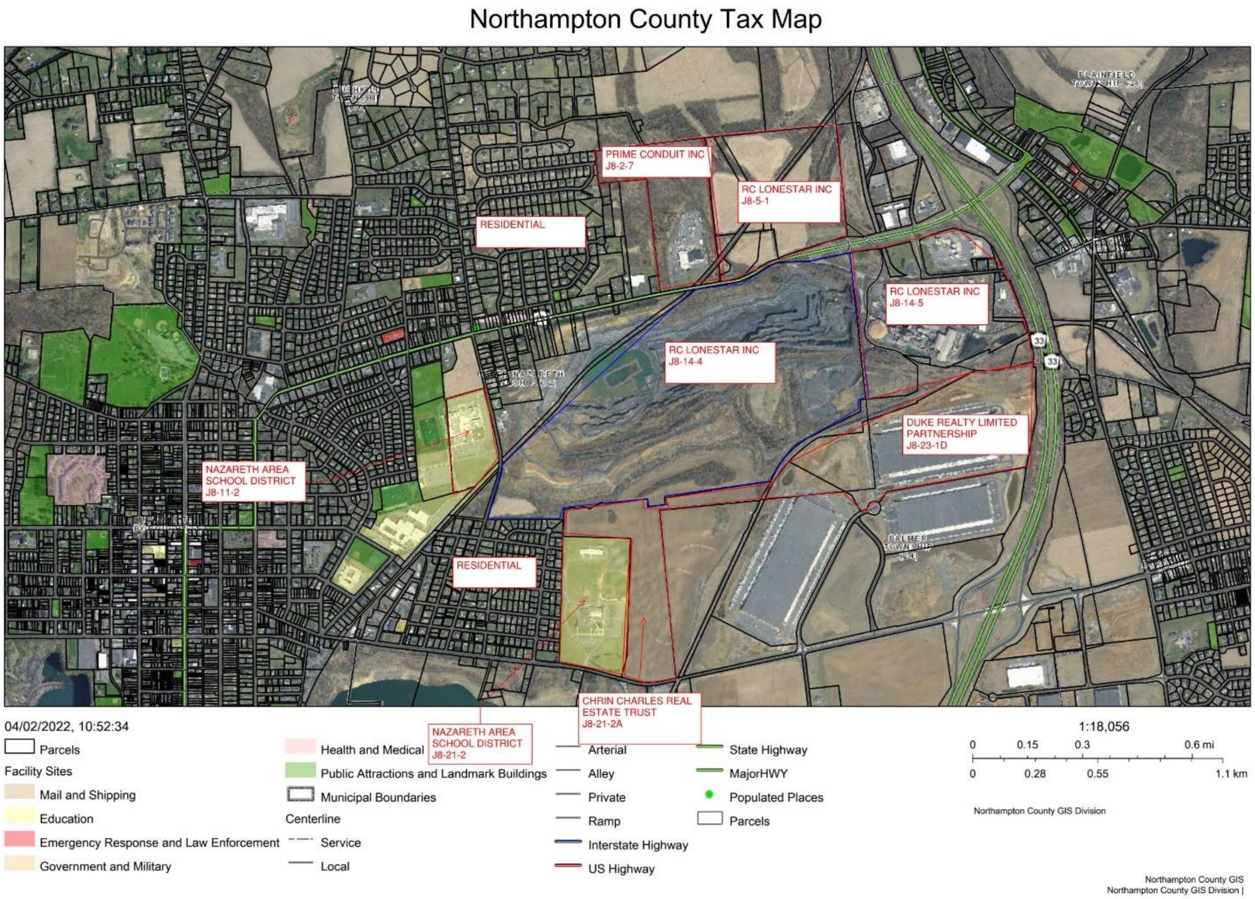
This storage project was reviewed against several environmental parameters as described in the body of the report. Overall, the project is scored low to moderate and similar to the Q5 and Q6. The gravity filling option may reduce the impacts associated with stream withdrawal.

Permitting the project appears achievable and should occur within an acceptable timeframe. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor similar to the Q5 and Q6. The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1. The adjacent residential area may benefit from the conversion of the quarry to an environmental/recreational facility. Local tax rateables could be reduced if the quarry ceases active mining operation.

Figure 5.1: Land Ownership



6 Project Cost & Schedule

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$320,000.00
Pipeline	LF	150	$800.00	$120,000.00
Valves	#	4	$50,000.00	$200,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$6,972,000.00
Intake Structure	VF	188	$25,000.00	$4,700,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$11,857,500
Contingency			50%	$5,928,750
CONST. COST + CONTINGENCY				$17,786,250

The total capital is shown above. Land costs are not included in the above. Based on review of comparable properties from the Northampton County Tax website, the value of the quarry is believed to be approximately $3M. This value will be carried as land cost for the estimate and evaluation.

Operating costs for this project are estimated to be approximately $0.375M/year, comparable to Q5 and Q6 operation. If gravity feed filling is selected, the operating cost will decrease. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $28.13M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 8 years. This includes:

- Design, permitting and land acquisition 4 years
- Construction 3 years
- Startup and initial filling of quarry 1 years

7 Potential Ancillary Benefits

The potential ancillary benefits of this project are comparable to as described in the Q5 SPS and Q6 SPS. Somewhat in contrast, the Q7 site may better lend itself to the creation of a recreational/environmental amenity. If possible other mine restoration or local/state/federal parks and recreation funding might be leveraged.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.42	30%	1.03
Infrastructure Design, Construction & Operation	2.50	10%	0.25
Environmental Impacts	3.43	15%	0.51
Social & Economic Impacts	4.50	10%	0.45
Project Cost & Schedule	3.67	30%	1.10
Ancillary Benefits	2.60	5%	0.13
AVERAGE	**3.35**		**3.47**

Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

APPENDIX

Score sheet

STORAGE PROJECT SCORING

STORAGE PROJECT: Q7B
NAME: Stockertown Quarry (Bushkill Source)

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		3.42			30%	1.03	
o Volume of storage provided (BG)	4.6	3.5					
o Hydrologic reliability of supply (months to fill)	22	3					
o Release rate (cfs)	50	3					
o Promptness of delivery to mainstem (day)	0.2	5					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		2.50			10%	0.25	
o Site/Civil, Land & Easements		3					Intake requires atypical mods.; pipeline is short
o Subsurface conditions		2.5					In know Karst area
o Infrastructure Complexity		2					Design for low flow stream is challenging
o Construction complexity		3					Typical intake/PS; pipe is typical
o Operational complexity		2					Problem filling in time; discharge may be too high
3. Environmental Impacts		3.43			15%	0.51	
o Protected species		4					Possible minor issues on pipeline; flows in creek may be disruptive
o Water quality degradation		3					Transferring such high flows in small stream may be problematic
o Obstruction to passage of aquatic animals		3.5					Assumed no obstruction; very short pipeline
o Hydromodification		2					Changes on the CWF
			special two-factor scoring for habitat impacts				
Habitat Type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o Wetlands inundated or filled (ac)		5	5	5			No apparent areas along pipeline
o Stream length inundated (mi)		3	2	4			Some impact to HQ stream at/near intake
o Uplands inundated or developed (ac)		3.5	2	5			Minor pipeline traverse of established forests in areas
4. Social and Economic Impacts		4.50			10%	0.45	
o Disruption/displacement		5					Minimal disruption by pipeline
o Safety and health		3					Potential safety by withdrawal/discharge of high flows from creek
o Social equity		5					
o Recreational loss		5					Potential gain
o Cultural/historical resources		5					
o Aesthetic		5					Area improvement
o Loss of tax revenue		4					Loss of large quarry in area
o Loss of production from farmland, timberland, quarries		4					Loss of large quarry in area
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		3.67			30%	1.10	
o Land acquisition cost ($)	$3M						
o Construction Cost ($)	$17.78M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	$28.13M	4.5					
o Cost effectiveness ($/BG)	$6.11M	4.5					
o Schedule (Time to make Operational, years)	8	2					
6. Ancillary Benefits		2.60			5%	0.13	
o Flood control		3					
o Recreation/tourism		3					Not significant given area
o Habitat/fishery enhancement		2					No benefit; could impact
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		2					No benefit; could impact
o Ability to leverage funding from other programs		3					
OVERALL		3.35				3.47	

MOTT MACDONALD

Storage Project Summary

Project:	**Evansville Quarry (Q8)**
Location:	Evansville, Berks County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	3.1 Billion Gallons
Score:	3.91

1 Project Overview

The scope of this storage project is to store water from Maiden Creek/Lake Ontelaunee in the quarry, then later release it back to Maiden Creek below the Ontelaunee Dam, which flows to the Schuylkill River.

The Evansville Quarry is located in Berks County, PA just north of Reading, Pennsylvania (Figure 1.1). The quarry is active and sits adjacent to Lake Ontelaunee, a 3.2 BG water supply and recreational facility. Lake Ontelaunee is owned by the City of Reading and associated water treatment facilities are owned and operated by the Reading Area Water Authority (RAWA).

The quarry has a maximum volume of 3.1 billion gallons. This quarry is approximately 88 acres in area and has an estimated fillable rim of elevation 320 ft. The quarry's deepest point has an elevation of 86 ft, giving the quarry a nominal depth of 234 ft. The nearest water source is the adjacent Lake Ontelaunee, which is an impoundment of Maiden Creek. The quarry is composed primarily of limestone and is mined for related construction materials.

Figure 1.1: Project Location

2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 2.5 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as saddle dams or levee walls are suggested to increase storage volume for this site. Some modification may be required for connection to the adjacent Lake Ontelaunee, as will be discussed further below. Figure 2.1 below shows contours indicating the depth of the quarry.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

The storage offered by the quarry needs to be independently controlled such that stored water can be released when needed. Concepts of simply breaching the area separating the quarry and lake to create volume do not add any needed control for release. The proximity of the lake to the quarry does provide an opportunity to fill the quarry by gravity and forgo pumping. However, pumping can also be an option.

Maiden Creek has a drainage area of 182 sq. mi. in the Schuylkill subbasin. Its mean annual flow is approximately 292 cfs (189 mgd) and the 7Q10 flow is approximately 26 cfs. While not a high-flow stream, it should not limit withdrawal to fill the quarry. In any case, under typical conditions Lake Ontelaunee will provide a pool to withdraw from. Further, gravity flow from a controlled overflow structure on Lake Ontelaunee into the quarry appears possible and required infrastructure will be discussed further below.

Discharge of stored water would be accomplished with pumps and piping as described in Section 3. This would route stored water downstream of the dam to augment Maiden Creek and in turn the Schuylkill and Delaware Rivers. The design pumped discharge rate is 50 cfs (31.64 mgd) as typical. This is approximately one third of the mean flow and significantly less than bank full flow in Maiden Creek.

Given the above stated storage configuration and flows, the 3.1 BG quarry storage can be filled within the six-month period of time with a withdrawal pumping system. A gravity filling system should also enable filling in the required period, but requires further analysis. Discharge pumping from quarry storage back to Maiden Creek can be performed at the targeted 50 cfs rate and can sustain flow augmentation for 2.6 months.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	88 acres
Nominal Rim Elev.	320 ft.
Bottom Elev.	86 ft.
Maximum Water Level Change (Ft.)	234 ft.
Maximum Volume (Billion Gallons)	3.1 BG
Operating Water Range (320ft-133 ft)	187 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	2.5 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Stream
Anticipated Source Stream Drainage Area (Sq. Miles)	182 sq.mi.
Mean Annual Stream Flow Rate (ft3/s/mgd)	292 cfs (189 mgd)
Proposed Average Pumping Rate (mgd)	31 mgd
Average Vol. Pumped during 6 month Pumping Term	5.6 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	320 ft to 133 ft
Proposed discharge pumping rate (MGD)	32 mgd
Estimated Time to Release Operating Volume from Storage	2.6 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	88 miles
Travel Time at 2 mph (hours)	44 hours

2.3 Water Quality

Maiden Creek/Lake Ontelaunee has marginal water quality and impaired according to the PA 303D listing. The stream has a Chapter 93 designated use as a warm water fishery (WWF) and no trout status. Many of the impairment issues reportedly stem from the upstream agricultural areas and high nutrient loading. Table 2.2 below summarizes the listed impairments.

Table 2.2: 303D Listing Impairments

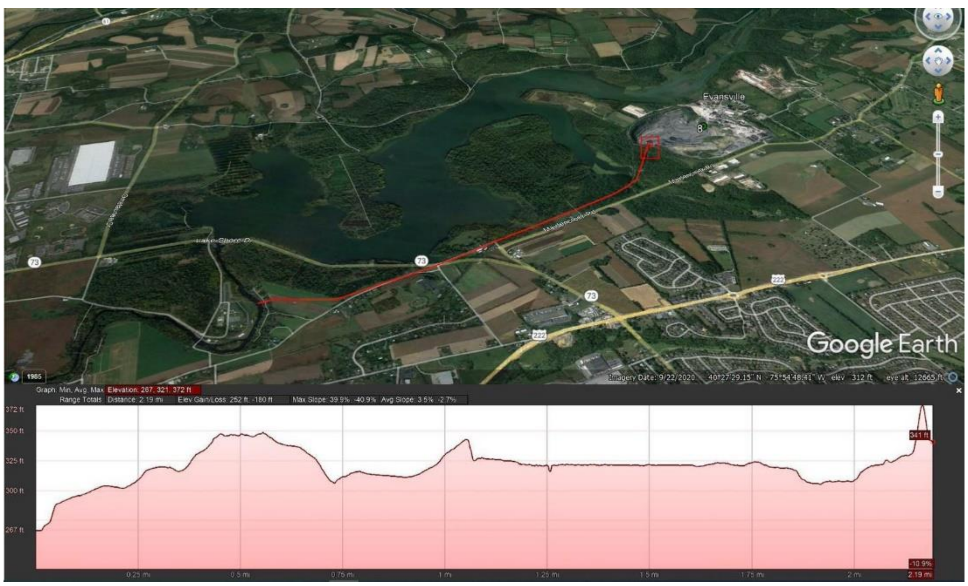
IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
Impaired - nutrients/TSS due to agriculture/municipal discharges/onsite treatment systems/urban runoff		Supporting	Supporting

Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease relative to the source stream. Because Lake Ontelaunee is currently used for water supply, the quality of water transmitted from the lake into the quarry is presumed to be adequate for flow augmentation.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities.

Figure 3.1: Approximate Discharge Pipe (red line) and Pump Station (P) Location and Profile



3.1 Pumping Facilities

The quarry fill/stream withdrawal can be achieved either by active pumping or possibly by gravity from the lake into the quarry. Both options are explored. The lake withdrawal pumping facilities will be similar to those presented in the body of the report. The bottom intake would be placed in Lake Ontelaunee with a connected wetwell/shaft on the bank that would then in turn pump to the quarry. The wetwell would be fitted with 3 x 10 mgd pumps. As noted, stream flow does not limit withdrawal, so pumping at 30 mgd can proceed to fill the quarry as needed. The option for gravity filling the quarry is outlined in Section 3.3.

The quarry discharge/stream augmentation pumping station will consist of a shaft adjacent to the quarry serving as a wetwell for quarry pumping the high head conditions to lift the water from the quarry to the discharge pipeline highpoint, requiring 4 x 8.6 mgd high lift pumps.

Other features of the intake and discharge pumping stations are described in Section 5 of the main report. Itemization and cost of the components are outlined further below in Section 6 of this summary.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline connects the quarry shaft/wetwell to the discharge point at the Maiden Creek downstream of the Ontelaunee Dam. The pipeline is expected to follow public right-of-way (ROW) and would be installed with conventional cut and cover methods. The pipeline will consist of 11,600 lf of 30-inch diameter ductile iron pipe (DIP) and typical ancillary features.

A tunneling concept was explored that could allow for partial gravity discharge of the quarry stored water to the downstream Maiden Creek. However, the cost of tunnelling and the limited gravity drained volume, given storage elevation constraints, did not justify further study so was abandoned.

Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (3 x 10 mgd)	30 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (4 x 8.6 mgd)	33 mgd
Pipeline Distance	11,600 lf
Elevation at Discharge Point	267 ft
Elevation at High Point on Pipeline	272 ft
Static Head	239.2 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

In terms of operations of the project, the pump in and pump out operation is envisioned to be as typical for the quarry projects and will effectively be automatic and monitored. If gravity filling of the quarry is utilized, passive control structures can discharge from the reservoir to fill the quarry, further decreasing operational costs.

3.3 Alternative Pumping Configuration (Gravity Filling)

The proximity and elevations of the quarry to the lake present an opportunity to gravity drain from Lake Ontelaunee to fill and maintain the quarry water level. A stream bank intake and gravity pipeline into the quarry would be constructed. The bank intake would be typical. The interconnecting pipeline should be constructable with conventional means over the estimated 600 lf reach. The diameter of the pipeline is expected to be on the order of 60”, but needs to be further defined with detailed hydraulics. Weir or level controls would spill water to the quarry during periods of sufficient water level in Lake Ontelaunee. This alternative eliminates stream withdrawal pumping from the lake. The project team has not fully evolved the hydraulics of this option.

4 Environmental Impacts

This storage project was reviewed against several environmental parameters as described in the body of the report. These included protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project is scored high because of the limited impacts. The discharge of stored water downstream should be comparable to reservoir releases and have no meaningful impact. The lake intake and quarry fill facilities, whether pumping or gravity, will have typical minor impacts of construction, but should have no longer term impacts. The pipeline route may intersect a small tributary stream, but would be addressed with typical trenchless methods and force the pipeline route to the public ROW as much as possible. One of these crossings is St. Peter's Creek and will be a sensitive crossing. The work should also consider the lakeside and aquatic habitat of Lake Ontelaunee. Based on this cursory review and review of these features with relevant environmental mapping, the impacts are minor and the corresponding score is high.

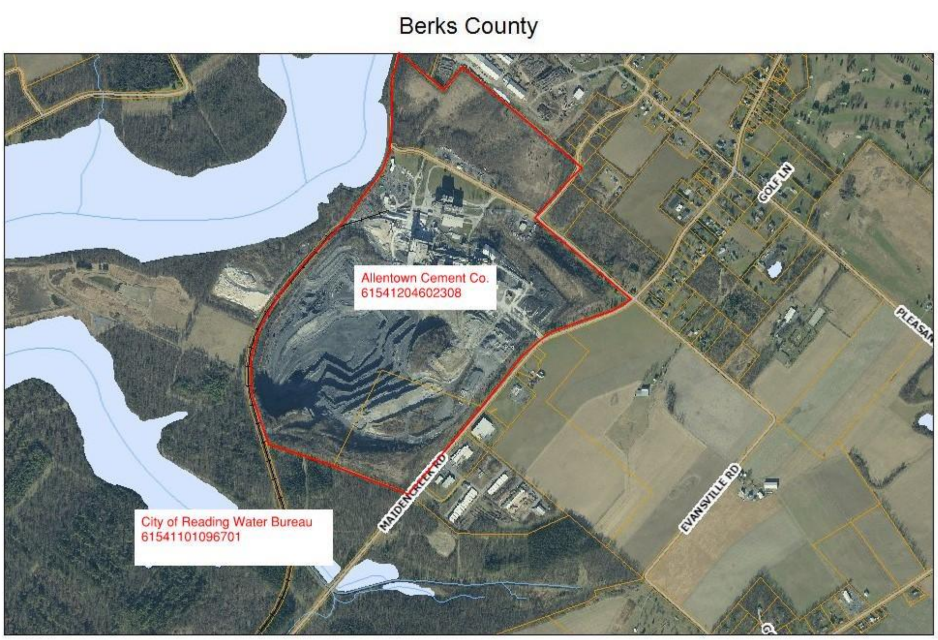
Permitting the project should be very achievable. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder, social and economic impacts are expected to be minor and therefore scores high. This category considers general disruption, safety/health, equity, recreational loss, cultural/historical resources, aesthetic and loss of revenue/production. The quarry ceasing operation could have a local impact on labor and rateables, but should be relatively minor. Many of the other areas of consideration should not be impacted and could be improved, as will be discussed further in Section 7, Potential Benefits.

The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1. The adjacent residential areas surrounding the site are limited and somewhat distant.

Figure 5.1: Land Ownership



6 Project Cost & Schedule

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Additional cost estimating justification can be provided upon request. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$10,030,000.00
Pipeline	LF	11600	$800.00	$9,280,000.00
Valves	#	15	$50,000.00	$750,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$6,947,000.00
Intake Structure	VF	187	$25,000.00	$4,675,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$21,542,500
Contingency			50%	$10,771,250
CONST. COST + CONTINGENCY				$32,313,750

The total capital is shown above. Land cost is not included in the estimate. Based on the Berks County tax parcel information, the assessed value of the quarry site is approximately $9M. While this does not necessarily reflect market value or consider reclamation costs and other site costs, this basis was carried forward as the land cost for this storage project.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 2.5 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $44.35M

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 10 years. This includes:

- Design, permitting and land acquisition 5 years
- Construction 4 years
- Startup and initial filling of quarry 1 year

7 Potential Ancillary Benefits

This category of potential ancillary benefits considers such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funds to achieve a greater level of overall improvement. Converting this quarry site to storage may provide some ancillary benefits. Flood control is unlikely but skimming high flow to fill and replenish the reservoir may have a beneficial impact. A flooded quarry can create more open water for environmental and recreational benefit. If the quarry is used for public water storage it is conceivable that the private quarry land could convert to lands governed by conservation easements or other protections. It could also serve as an emergency water supply if the lake drops too low to be usable. In this example, water could be pumped back into the lake or diverted from the discharge pipe to the treatment plant. Under this situation, noncomsumptive use of water delivered by the plant would be returned to a waterway for flow augmentation. Further, complimentary funding by use of the quarry reclamation bond or other local/state/federal recreational funding could be a possibility and leverage the additional funds to bring about these ancillary benefits.

8 Storage Project Score

This site was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.75	30%	1.13
Infrastructure Design, Construction & Operation	3.20	10%	0.32
Environmental Impacts	4.79	15%	0.72
Social & Economic Impacts	4.00	10%	0.40
Project Cost & Schedule	3.83	30%	1.15
Ancillary Benefits	3.90	5%	0.20
AVERAGE	**3.91**		**3.91**

APPENDIX

Score sheet.

STORAGE PROJECT SCORING

STORAGE PROJECT: Q8
NAME: Evansville Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.75**			30%	**1.13**	
o Volume of storage provided (BG)	3.1	2.5					
o Hydrologic reliability of supply (months to fill)	2.5	5					
o Release rate (cfs)	50	5					
o Promptness of delivery to mainstem (day)	1.83	4					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**3.20**			10%	**0.32**	
o Site/Civil, Land & Easements		3					Assumes quarry will sell; pipeline easement are achievable
o Subsurface conditions		2.5					Know dewatering from quarry to lake
o Infrastructure Complexity		3.5					Generally straight forward
o Construction complexity		3					Typical, but gravity option could be a challenge
o Operational complexity		4					Good with interesting gravity fill option
3. Environmental Impacts		**4.79**			15%	**0.72**	
o Protected species		4.5					Potential for impact along pipeline; minor and trenchless approach will circumvent
o Water quality degradation		5					minimal if any impacts
o Obstruction to passage of aquatic animals		5					Should not be any
o Hydromodification		5					Withdrawal form lake pool; donwstream discharge typical
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		4.5	5	4			Trenchless crossing to avoid impact
o Stream length inundated (mi)		4.5	5	4			WWF and minor impact
o Uplands inundated or developed (ac)		5	5	5			Minor upland development
4. Social and Economic Impacts		**4.00**			10%	**0.40**	
o Disruption/displacement		5					Minor disruption
o Safety and health		5					Long term improvement
o Social equity		3					
o Recreational loss		4					Potential gain
o Cultural/historical resources		4					May be some disturbance along pipeline
o Aesthetic		5					Filled quarry is an advantage
o Loss of tax revenue		3					Some tax decreas if quarry closes
o Loss of production from farmland, timberland, quarries		3					Some impact to quarry close, but may not be local impact
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**3.83**			30%	**1.15**	
o Land acquisition cost ($)	$9M						
o Construction Cost ($)	$32.2M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	$48.65M	4					
o Cost effectiveness ($/BG)	$15.69M	3.5					
o Schedule (Time to make Operational, years)	10	4					
6. Ancillary Benefits		**3.90**			5%	**0.20**	
o Flood control		3.5					Could offer some skimming storage
o Recreation/tourism		4					Could expaand Ontelaunee recreational facilities
o Habitat/fishery enhancement		4					Could expand fishing and allow for water quality control
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					Could allow for water quality control
o Ability to leverage funding from other programs		4					Adjacent recreation could leverage local, state, federal funds
OVERALL		3.91				**3.91**	

Storage Project Summary

Project:	**Solebury Quarry (Q12)**
Location:	Solebury Twp, Bucks County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	2.3 Billion Gallons
Score:	4.03

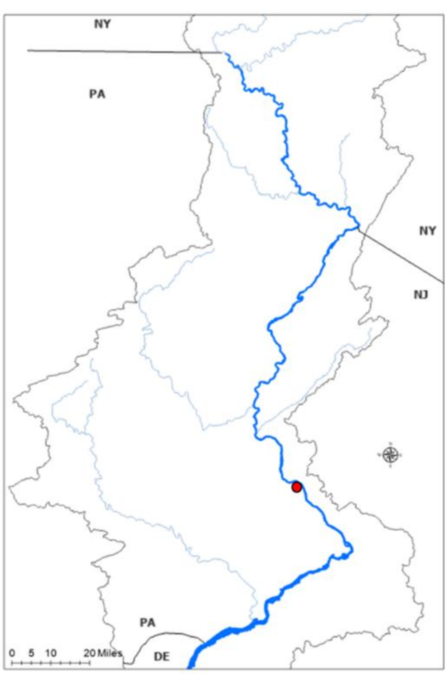
1 Project Overview

The scope of this storage project is to store water that is pumped from the nearby Delaware River in the quarry in Solebury PA (owned by New Hope Crushed Stone) and subsequently released back to the Delaware River when needed to augment flow (Figure 1.1).

The quarry has a maximum volume of 2.3 billion gallons. This quarry is approximately 82 acres in area and has an estimated fillable rim elevation 100 ft. At the quarry's deepest point, it has an elevation of -100 ft, giving the quarry a nominal depth of 200 feet. The nearest reasonably sized water source is the Delaware River, located less than a mile away. The quarry is composed primarily of limestone and was mined for related construction materials.

The quarry was recently closed and is no longer active. The quarry is undergoing maintenance and phased reclamation led by PADEP, with long-term plans uncertain.

Figure 1.1 Project location



2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 1.8 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or retaining walls are suggested to increase storage volume for this project. The calculated volume assumes the interior of the quarry to generally be flat. The operating volume of 1.8 BG is estimated using a bottom elevation that is 20% higher than the topographic bottom elevation. This considers the practicality of the pumping system, water quality and other considerations. The storage concept assumes the quarry is impervious with minimal leakage. Information from the Solebury Township website describing the history of the site indicates that approximately 500,000 gallons/day (0.5 mgd) were pumped to maintain a dewatered quarry. This water was pumped to a downstream point on Primrose Creek that generally maintained creek flow and stream health. Now that the quarry is closed and without active dewatering, it has been refilling and will presumably reach a natural level with the surrounding groundwater table and balance with inflow from Primrose Creek, and allow natural or managed outflow.

Figure 2.1 below shows the proposed fill elevation (100 ft) along with contours showing the depth of the quarry. This estimated depth has been confirmed with PADEP records.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

The nearby Delaware River provides ample supply, particularly during high flow periods, and the opportunity to directly augment the river in times of need. The Delaware River has significant flow and therefore the withdrawal is not source limited. The Delaware has a drainage area of approximately 6,670 sq. mi. area and a mean annual flow of 12,400 cfs with an estimated 7Q10 flow of almost 1560 cfs. This allows for unencumbered withdrawal and subsequent discharge of the project targeted 50 cfs flows. While the Delaware has ample flow, the needed pumping system could be controlled to only skim during high flow for storage in the quarry, if deemed advantageous.

Stored water would be pumped from the quarry to the Delaware River during time of need. Again, the size of the Delaware does not restrict the discharge rate and the project design pumping rate of 50 cfs (31.64 mgd) is assumed. Gravity discharge from the quarry to the river is possible, but volumes are limited based on controlling elevations as will be discussed further in Section 3 below.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	82 acres
Nominal Rim Elev.	100 ft.
Bottom Elev.	-100 ft.
Maximum Water Level Change (Ft.)	200 ft.
Maximum Volume (Billion Gallons)	2.3 BG
Operating Water Range (100 ft to -60 ft)	160 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	1.8 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Delaware River
Anticipated Source Stream Drainage Area (Sq. Miles)	6,670 sq.mi.
Mean Annual Stream Flow Rate (cfs/mgd)	12,400 cfs / 8010 mgd
Proposed Average Pumping Rate (cfs/mgd)	50 cfs (31 mgd)
Average Vol. Pumped during 6 month Pumping Term	5.6 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	100 ft to -60 ft
Proposed discharge pumping rate (MGD)	32 mgd
Estimated Time to Release Operating Volume from Storage	1.9 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	0 mile
Travel Time at 2 mph (hours)	<1 hour

2.3 Water Quality

The water quality of the Delaware River is generally good at this location. The Chapter 93 designated used is warm water fishery (WWF). The information form the 303 D listing is provided below in Table 2.

Table 2.2: 303D Listing Impairments

	IMPAIRMENT		
Aquatic Use	Recreational	Fish Consumption	Potable Supply
	Supported	Impaired - mercury	Supporting

Water quality may change after pumping and settling in the quarry. The inflow and outflow to Primrose Creek can impact quality, but is not expected to be negative. It is assumed that the stored quality will not decrease relative to the source stream and the reintroduction of stored water into the Delaware, at just a fraction of the river flow, will not impair the Delaware River.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities. The red line in plan denotes the profile location. Numbered boxes are provided for correlation only. The location of the fill and discharge pumping facilities are shown with a symbol.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile

3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is not flow limited, withdrawing from the Delaware River. For consistency, the intake is conceived to be wedgewire screens on the river bottom, but the river geometry and depth could also support different intake options. The pumping station will consist of a wetwell on the adjacent bank with a connecting pipe section. Withdrawn water will be withdrawn with submersible pumps (3 x

10 mgd) at a high constant rate sufficient to fill and maintain the quarry level. Controls could also be modified to withdraw water only during high river flows (i.e., skim) if desired.

Similarly, the quarry-discharge pump station will consist of a shaft adjacent to the quarry and pumping facilities as described in the body of the report. Quarry head conditions require different pumps to meet system requirements. The stored quarry water will be withdrawn with submersible pumps (4 x 8.6 mgd) at a high, constant rate.

The project team examined the possibility of gravity draining the stored water back to the Delaware River. This would require a deep conveyance pipe installed with trenchless technology from the quarry to the outfall point. While technically possible, the installation would cost in excess of $15M. Further the gravity discharge would only achieve the level of the River, which on average only provides 50 feet of water column (Rim Elev. =100 ft; Discharge/River Elev. = 49 ft.). Therefore, this option was not considered further.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline is projected to be 6,100 lf of 30 inch diameter ductile iron pipe (DIP). The area of the pipe route shown follows an electrical transmission main right-of-way (ROW) and other public land as much as possible. Pipeline construction would be typical cut and cover installation. At least two at grade road crossing and a crossing of the Delaware Canal are required and can be installed with short trenchless technology methods. Easements are expected to be obtainable.

Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (3 x 10 mgd)	30 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (4 x 8.6 mgd)	34 mgd
Pipeline Distance	6,100 lf
Elevation at Discharge Point	49 ft
Elevation at High Point on Pipeline	156 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

In terms of operations of the facility, the pump in and pump out operation is envisioned to be as typical for the quarry projects and will effectively be automatic and monitored. Operation would also have to consider any required coordination with other future uses. In addition, the Primrose Creek downstream of the quarry requires constant flow and would have to be accommodated in some way using the installed pumping system or other stream restoration work.

4 Environmental Impacts

This storage project was reviewed against several environmental parameters as described in the body of the report. These included protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project is scored high because the impacts are limited, and may actually create environmental benefits as will be described in Section 7.

The conversion of the quarry to storage should not have negative environmental impacts. Provisions would be included to maintain flow in Primrose Creek. The general area of work at the quarry does not appear to have sensitive habitat or areas that would be directly impacted. The intake work at the Delaware River would have typical riverside construction and negligible impacts. The Delaware Canal is in the alignment and work can cross the canal without impact. The pipeline alignment, as described above, can avoid wetlands and related sensitive areas, but they do exist in the general area. There is at least one stream that would be crossed appropriately to limit any impact. Given the above and other supporting analysis, this project scores high, with minimal to no impacts expected.

Permitting associated with the Canal Park will be difficult but should be achievable. It is a state park under the control of PADCNR, but is on the National List of Historic Places and will require coordination with the National Park Service and the Corps of Engineers. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

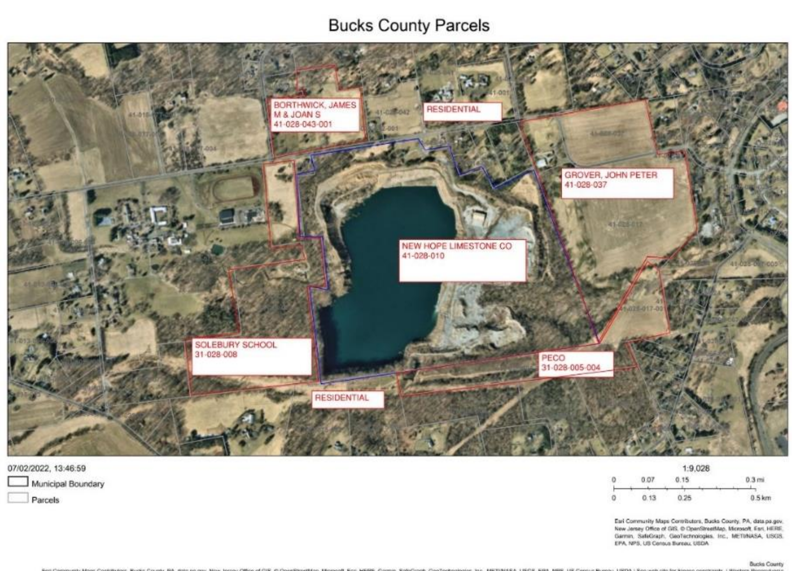
5 Social and Economic Impacts

Stakeholder, social and economic impacts are expected to be minor and therefore scores high. This category considers general disruption, safety/health, equity, recreational loss, cultural/historical resources, aesthetic and loss of revenue/production.

Solebury Township generally supports the quarry conversion. The quarry is no longer in operation and therefore has no negative economic impact from a changed use. Converting the quarry to a recreational or environmental beneficial reuse project should improve safety/health in the area, potentially create amenities and improve the area aesthetics. The impacts should be positive in all categories and therefore this project scored high in this category.

The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1. The adjacent areas are generally residential or agricultural. The past quarry ownership is shown in the figure. The site could be undergoing a transfer in ownership and based on conversations with Solebury Township, transfer to some form of public ownership appears feasible.

Figure 5.1: Land Ownership



6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$5,380,000.00
Pipeline	LF	6100	$800.00	$4,880,000.00
Valves	#	10	$50,000.00	$500,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$6,272,000.00
Intake Structure	VF	160	$25,000.00	$4,000,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$16,217,500
Contingency			50%	$8,108,750
CONST. COST + CONTINGENCY				$24,326,250

The total capital cost is shown above. Land costs are not included. As mentioned, the operation has stopped and the ownership may be in a state of transition. Based upon the Bucks County Tax Assessment information the parcel in question has an assessed value of $764,000 and a market value of approximately $9,200,000. This may not reflect the true market value based on issues described herein. However, for consistency with other projects, this value was used as the land cost in our further evaluation. The possible lower market value is noted in the attached score sheet.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1.8 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $40.87M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 11 years. This includes:

- Design, permitting and land acquisition 5 years
- Construction 5 years
- Startup and initial filling of quarry 1 year

7 Potential Ancillary Benefits

Converting the quarry to storage may have several ancillary benefits. Environmental benefit may be created by creating habitat by filling and maintaining the quarry water level. Stability of flows entering Primrose Creek could also be realized. Safety, aesthetics, recreational use could accompany the conversion. PADEP is involved in interim pumping that could be ended with completion of the project. Remaining quarry bond funding might be available to support reclamation integrated to the storage conversion. These improvements would be favorable to the Township, its residents and generally to land values. Finally, such a project with quarry reclamation need, ample public support and located in a favorable water storage setting, may attract funding from other programs to support what appears to be a very beneficial project for multiple parties.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.75	30%	1.13
Infrastructure Design, Construction & Operation	3.20	10%	0.32
Environmental Impacts	4.57	15%	0.69
Social & Economic Impacts	5.00	10%	0.50
Project Cost & Schedule	4.00	30%	1.20
Ancillary Benefits	4.00	5%	0.20
AVERAGE	**4.09**		**4.03**

APPENDIX

Score Sheet

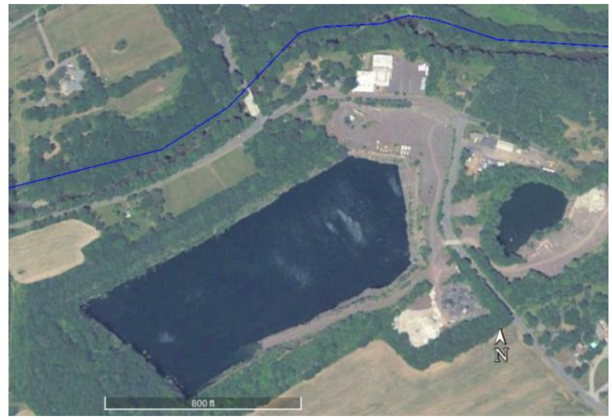
STORAGE PROJECT SCORING

STORAGE PROJECT: Q12
NAME: Solebury Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.75**			30%	**1.13**	
o Volume of storage provided (BG)	2.3	1.5					
o Hydrologic reliability of supply (months to fill)	2	5					
o Release rate (cfs)	50	5					
o Promptness of delivery to mainstem (day)	0	5					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**3.20**			10%	**0.32**	
o Site/Civil, Land & Easements		4					Land should be attainable; pipeline easements should be achievable
o Subsurface conditions		3					
o Infrastructure Complexity		3					Typical, even with pipeline length
o Construction complexity		3					Trenchless crossing are more invovled, but typical
o Operational complexity		3					May be easier with high flows
3. Environmental Impacts		**4.57**			15%	**0.69**	
o Protected species		5					Controlled crossings; bats in forested areas
o Water quality degradation		4					Need to understand any impact to Primrose Creek
o Obstruction to passage of aquatic animals		5					Should be none
o Hydromodification		5					Large source is advantageous
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		3.75	3	4.5			Foresteed/shrub wetlands
o Stream length inundated (mi)		4.5	4	5			Potential for stream impacts, but should be avoided with pipeline
o Uplands inundated or developed (ac)		4.75	5	4.5			Dicharge PS could require more upland behind the Canal
4. Social and Economic Impacts		**5.00**			10%	**0.50**	
o Disruption/displacement		5					Minor typical construction
o Safety and health		5					Should create area improvements
o Social equity		5					Equitable
o Recreational loss		5					Planned recreational improvements
o Cultural/historical resources		5					No impact
o Aesthetic		5					Will greatly improve the area, as desired by locals.
o Loss of tax revenue		5					No real loss since quarry is closed
o Loss of production from farmland, timberland, quarries		5					No relative loss since quarry is closed
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**4.00**			30%	**1.20**	
o Land acquisition cost ($)	$9.2M						
o Construction Cost ($)	$24.32M						
o Operating Cost ($/yr)	$0.375						
o Overall Cost ($)	$40.87M	4.5					If land =$3.2M - Overall Cost = $31.55M; No score change
o Cost effectiveness ($/BG)	$17.77M	3.5					If land =$3.2M - Cost Effec. = $12.1M/BG; No score change
o Schedule (Time to make Operational, years)	10	4					
6. Ancillary Benefits		**4.00**			5%	**0.20**	
o Flood control		3					No real impact
o Recreation/tourism		5					Opportunity for recreation
o Habitat/fishery enhancement		4					Enhancement should improve local creeks and area
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					Storage project will resolve the reclamation need and PADEP pumping
o Ability to leverage funding from other programs		4					Advantages should create good opportunity to leveage more funds
OVERALL		4.09				**4.03**	

Storage Project Summary

Project:	**Telford Quarry (Q14)**
Location:	Telford, Bucks County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	1 Billion Gallons
Score:	3.5



1 Project Overview

The scope of this storage project is to store water in this inactive quarry. This storage project creates some challenges in that the volume is relatively small and the source stream, albeit nearby, is relatively low flow. Further, the project has a history of public opposition to mining and, presumably, to change of the inactive quarry status, as will be explored further below.

The quarry is an inactive quarry located in Telford, PA in Bucks County within West Rockhill Township (Figure 1.1). It is currently abandoned and mostly filled with water. The quarry has a maximum volume of 1.0 billion gallons. This quarry is approximately 20 acres in area and has an estimated fillable rim elevation of 300 ft. At the quarry's deepest point, it has an elevation of 50 ft, giving the quarry a nominal depth of 250 ft. The nearest pumpable stream to the quarry is the East Branch of the Perkiomen Creek, located about 650 feet away.

The quarry is composed primarily of shale and siltstone and mined for construction products. In the last few years, the quarry has ceased mining because of concerns over quarry rock containing asbestos. The current status is that the quarry is inactive, under regulatory review and being monitored. The future of mining at the site is questionable.

Figure 1.1: Project Location

2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated total volume of 1 BG and an operable water storage volume approximately 0.8 BG. The operating volume assume a higher lowest water (20% of the total height) so the quarry is never fully dewatered, for more practical pumping hydraulics and for water quality purposes.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or retaining walls are suggested since this mining extended from a relatively flat surface with steep walls. Because the quarry is full of water, the team used historical aerial photos with elevation information from when the quarry was actively mined and then computed the volume from that surface and the proposed top elevation. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Rock grouting would be used as needed to create less permeable rock walls and bottom to facilitate storage. Figure 2.1 below shows the full quarry with surface contours, but does not indicate the depth of the quarry.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

The intended design is to fill the quarry from the East Branch of the Perkiomen Creek, store, and discharge when water is needed in the Basin. The East Branch is a relatively small stream with only a 36 sq. mi. drainage area. Mean annual flow is 53 cfs (33 mgd) and the estimated 7Q10 flow is only 1 cfs. The project is not stream flow limited, however, because it could be filled within the 6-month period primarily because operational storage is small (0.8 BG). However, such a low flow stream will be problematic to pump and will generally require skimming at high flows. While perhaps a challenge to use for filling the quarry, the proximity of the creek and the elevation relative to the quarry offers some advantages and may allow some gravity filling.

The discharge of stored flow will be discharged back to the East Branch, as typical. The targeted design rate is 50 cfs (32 mgd). Bank full flow is reportedly 2,830 cfs. However, the proposed discharge rate is high relative to mean flow and will require controlled dissipation as flow re-enters the stream.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	20 acres
Nominal Rim Elev.	300 ft.
Bottom Elev.	50 ft.
Maximum Water Level Change (Ft.)	250 ft.
Maximum Volume (Billion Gallons)	1.0 BG
Operating Water Range (300 ft - 100 ft)	200 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	0.8 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Perkiomen Creek (East Branch)
Anticipated Source Stream Drainage Area (Sq. Miles)	36 sq.mi.
Mean Annual Stream Flow Rate (cfs/mgd)	53 cfs (34 mgd)
Proposed Average Pumping Rate (MGD)	13.7 mgd
Average Vol. Pumped during 6 month Pumping Term	2.5 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	300 ft to 100 ft
Proposed discharge pumping rate (cfs/mgd)	50 cfs (32 mgd)
Estimated Time to Release Operating Volume from Storage	0.8 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	73 miles
Travel Time at 2 mph (hours)	36 hours

2.3 Water Quality

The source stream has generally good water quality based on the PA 303D listing. Table 2.2 below summarizes the listed impairments.

Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
Supporting	Supporting		

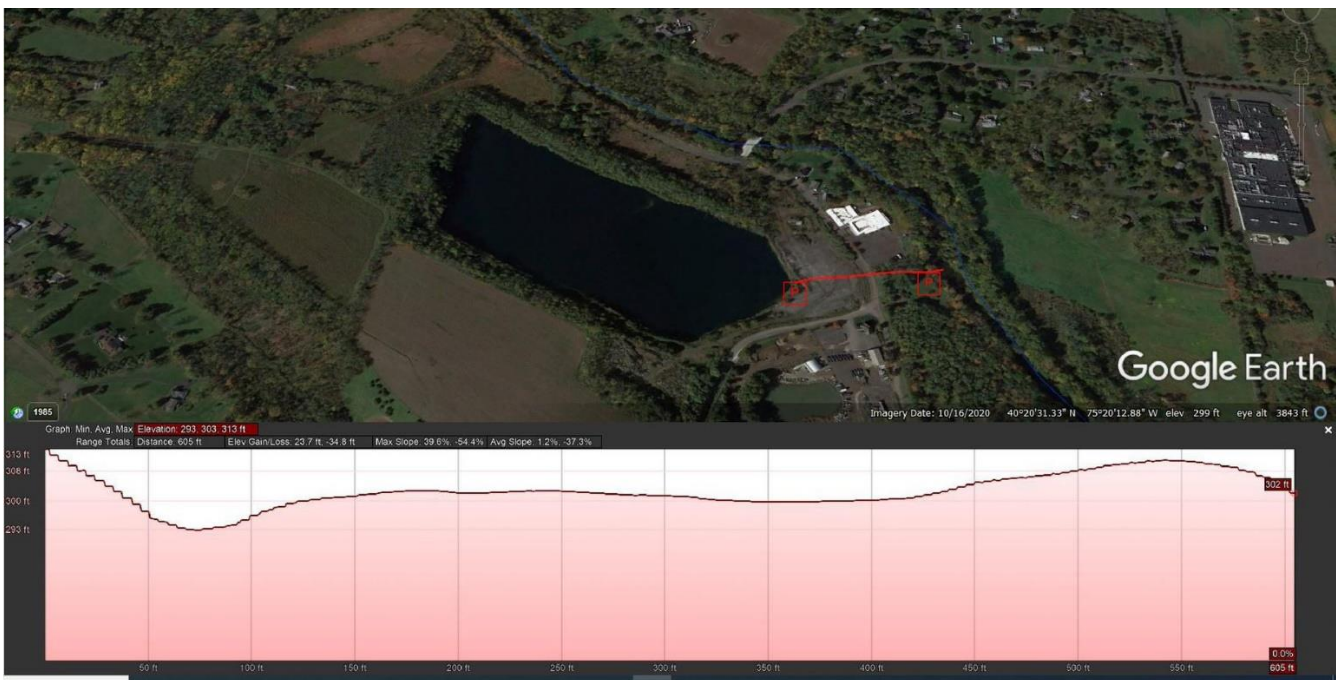
Further, the Chapter 93 designated use identifies the stream as TSF (Trout Stocking). However, the 2021 PA Fish and Game has no trout status under the trout designation.

Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease relative to the source stream and will be acceptable for flow augmentation.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile



3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping stations and connecting pipe are shown above in plan and profile. The distance between the stream and quarry is only approximately 600 feet, hence the exaggerated horizontal scale on the profile. Also note that the elevation shown for the discharge point is 312 ft and the quarry rim is shown at about the same elevation of approximately 300 ft.

The creek intake and fill pumping station will be as typical and as noted in the main report. This will consist of semicircular wedgewire screens on the stream bottom connected to the pumping station wetwell on the adjacent bank. Note that submergence of the screens at the low stream flow condition will be a design issue and needs to be further explored. The withdrawal system is concept designed to pump on average approximately 13 mgd with the ability to pump up to 21 mgd, if stream flow allows.

The quarry discharge/stream augmentation pumping station includes the shaft and connecting conduit with submersible pumps to lift the water and convey to the East Branch for needed supply. The discharge shaft will be fitted with 4 by 10.1 mgd pumps to deliver the lift and required flow rate.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline is 650 lf of 30-inch diameter ductile iron pipe that will be installed with conventional cut and cover methods. Appropriate ancillary facilities will be included. Given the surrounding land ownership, easements to the stream and for the pipeline appear achievable. Table 3.1 below summarizes the piping and pumping facility parameters. Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	21 mgd
Pump Capacity (3 x 7 mgd)	21 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	31+ (50 cfs+)
Pump Capacity (4 x 10.1 mgd)	40 mgd
Pipeline Distance	650 lf
Elevation at Discharge Point	312 ft
Elevation at High Point on Pipeline	313 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

In terms of operations of the facility, the pumping stations would generally be operated as typical. However, the low flow on the stream withdrawal will likely require more active monitoring of stream pumping. The pipeline and stream connections may possibly be installed and controlled to allow gravity filling from the East Branch after some volume has been discharged from the quarry. However, even if this is possible in some operating conditions, the stream withdrawal/filling pumping station will be installed as typical, and any possible gravity filling will be an operational savings.

4 Environmental Impacts

This storage project was reviewed against several environmental parameters as described in the body of the report. These included protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project is scored medium in that some categories see no impact, but the hydromodification and related issues scored lower.

The pipeline and discharge pumping station installation should not create environmental impacts. Some minor wetlands exist in the area, but should be avoidable. The area also has probable bats and bog turtles that should be considered. The stream withdrawal intake and shaft will have minor typical impacts. Operation of the withdrawal and subsequent high flow discharge returning to this low flow stream may create hydromodification and could create impacts.

Permitting the quarry for dewatering appears difficult based on our current understanding of the project and regulatory monitoring. This is addressed further below.

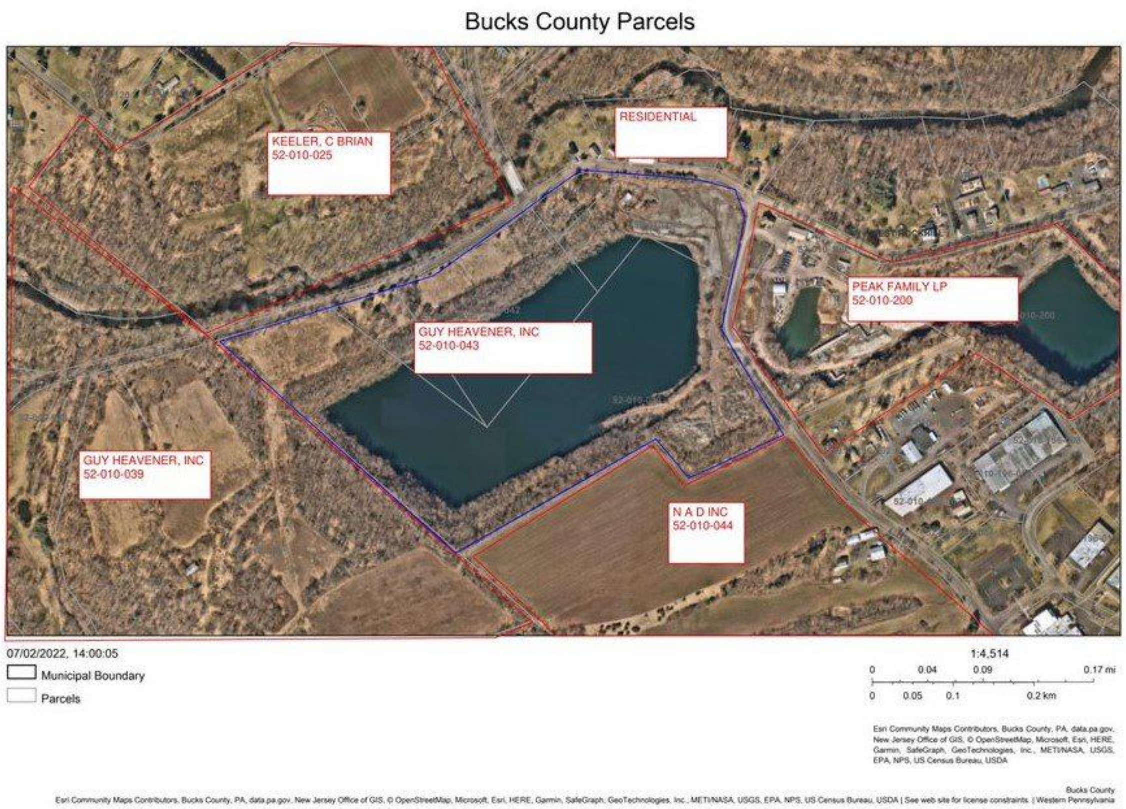
5 Social and Economic Impacts

Stakeholder, social and economic impacts are expected to be minor and therefore scores high. This category considers general disruption, safety/health, equity, recreational loss, cultural/historical resources, aesthetic and loss of revenue/production.

The PADEP has stopped all mining and dewatering operations at the quarry over concerns for naturally occurring asbestos and safety/health exposure to the surrounding residential areas. According to news reports (Ullery, 2021), the quarry was dormant for about 30 years and reopened in 2017 by another operator. That operator ended their relationship with the owner, Hanson Aggregates Pennsylvania. Hanson is working with PADEP to meet testing requirement and extend the mining permit. Local environmental and political organizations have aggressively pushed to permanently shut down the operation and not extend the mining permit.

The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1. The adjacent residential areas immediately around the quarry are limited. However, a local environmental organization, Rockhill Environmental Preservation Alliance, has gathered local support to close the quarry operation.

Figure 5.1: Land Ownership



6 Project Cost & Schedule

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,405,500.00
Intake				
Screens	LS	1	$80,000.00	$80,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$720,000.00
Pipeline	LF	650	$800.00	$520,000.00
Valves	#	4	$50,000.00	$200,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$7,272,000.00
Intake Structure	VF	200	$25,000.00	$5,000,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$12,397,500
Contingency			50%	$6,198,750
CONST. COST + CONTINGENCY				$18,596,250

The total capital cost estimate is shown above. Land costs are not included. The Bucks County Tax Assessment Records were queried for a market value of the quarry. The records are inconclusive. Three parcels listed under Guy Heavener, Inc lie in part in the quarry. The market value listed is approximately $1M combined. This does not include all the quarry land. In the absence of good records and further research, a market value of $2M was assumed for the quarry parcels.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 0.8 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $27.95M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 10 years. This includes:

- Design, permitting and land acquisition 6 years
- Construction 3 years
- Startup and initial filling of quarry 1 year.

7 Potential Ancillary Benefits

This category of potential ancillary benefits considers such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement. It is unclear if there will be any ancillary benefits if this project were to proceed. If converting the quarry to water storage advanced closure of the quarry, satisfying the regulators and other stakeholders, then ceasing mining and potential asbestos exposure would be an ancillary, if not direct, benefit. This site and its current status of scrutiny make it difficult to emphatically recognize an ancillary benefit. Therefore, this is scored moderate.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.17	30%	0.95
Infrastructure Design, Construction & Operation	2.90	10%	0.29
Environmental Impacts	4.07	15%	0.61
Social & Economic Impacts	4.75	10%	0.48
Project Cost & Schedule	3.67	30%	1.10
Ancillary Benefits	1.40	5%	0.07
AVERAGE	**3.33**		**3.50**

APPENDIX

Score Sheet.

STORAGE PROJECT SCORING

STORAGE PROJECT: Q14
NAME: Telford Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.17**			30%	**0.95**	
o Volume of storage provided (BG)	1	1.5					
o Hydrologic reliability of supply (months to fill)	6	5					
o Release rate (cfs)	<50	2.5					Ranked lower due to flow dissipation concerns
o Promptness of delivery to mainstem (day)	1.5	4					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**2.90**			10%	**0.29**	
o Site/Civil, Land & Easements		4					Quarry not in operation so available; pipe easements probable
o Subsurface conditions		2					Leakage obvious; potential issue with asbestos
o Infrastructure Complexity		3					Typical
o Construction complexity		3					No major issues
o Operational complexity		2.5					Potential gravity options, but problems with low stream flow
3. Environmental Impacts		**4.07**			15%	**0.61**	
o Protected species		5					None expected
o Water quality degradation		4					Potential for stream quality when discharging back to the low flow
o Obstruction to passage of aquatic animals		5					None expected
o Hydromodification		1					Major changes can be expected with low flow conditions
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		5	5	5			No impact identifed
o Stream length inundated (mi)		3.5	3	4			Assummed some impact from discharge
o Uplands inundated or developed (ac)		5	5	5			None expected
4. Social and Economic Impacts		**4.75**			10%	**0.48**	
o Disruption/displacement		5					Quarry already dormant
o Safety and health		3					Potential safety risk from asbestos, but controllable without mining
o Social equity		5					No perceived issues
o Recreational loss		5					No impact
o Cultural/historical resources		5					None identified
o Aesthetic		5					Quarry already dormant
o Loss of tax revenue		5					Quarry already dormant
o Loss of production from farmland, timberland, quarries		5					Quarry already dormant
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**3.67**			30%	**1.10**	
o Land acquisition cost ($)	$2M						
o Construction Cost ($)	$18.6M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	27.95M	4.5					
o Cost effectiveness ($/BG)	$27.95M	2.5					Low volume influences
o Schedule (Time to make Operational, years)	10	4					
6. Ancillary Benefits		**1.40**			5%	**0.07**	
o Flood control		1					
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1					
o Ability to leverage funding from other programs		3					Perhaps some funding based on current status and asbestos issue
OVERALL		3.33				**3.50**	

MOTT MACDONALD

Storage Project Summary

Project:	Temple Quarry (Q16)	
Location:	Muhlenberg Twp., Berks, County, PA	
Storage Type:	Quarry (Fill & Draw)	
Est. Volume:	1.0 Billion Gallons	
Score:	3.42	

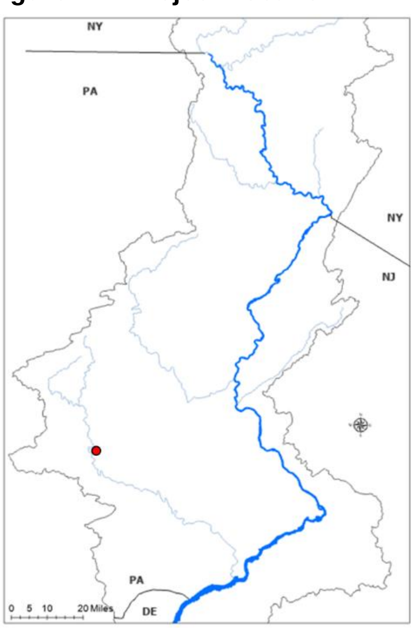
1 Project Overview

The scope of this urban quarry storage project is to store water in the quarry, then discharge to the Schuylkill River when needed for flow augmentation. The quarry would be replenished by groundwater, springs and pumped Schuylkill River surface water.

The quarry is located in Temple, PA within Muhlenberg Township in Berks County just north of Reading (Figure 1.1). It is currently inoperative and mostly filled with water. The quarry has a maximum volume of 1.0 billion gallons. This quarry is approximately 42 Acres in area and has an estimated fillable rim elevation of 280 ft. The quarry's deepest point has an elevation of 130 ft., giving the quarry a nominal depth of 150 ft. The nearest sizeable water source to the quarry is the Schuylkill River, located about 6,800 feet away.

The quarry was owned and operated by the Berks Products Corporation and actively mined for limestone until the 1980s after which point it was inoperative. The quarry is now owned by the Muhlenberg Township Authority, a separate but related entity to Muhlenberg Township that operates the water and sewer utilities. The quarry site is inactive. The Township has identified the area around the quarry for long term development as described in their Comprehensive Plan.

Figure 1.1: Project Location



2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 0.8 BG.

The storage volume was calculated using available surface topographic information from Pennsylvania Spatial Data Access and manual approximations. The top elevation of full storage was assumed to be the stated rim elevation. The bottom elevation was estimated based on available mining information and an average volume calculation was used. No additional structures such as dams or retaining walls are suggested to increase storage volume for this project as the quarrying excavated down over the years from a relatively flat surface elevation. It is assumed that the interior of the quarry has limited leakage and can be hydraulically isolated to support withdrawal and filling. However, connection to springs and leakage is obvious based on current filling and lack of contributary surface drainage. This will be discussed further below and require additional analysis if this storage alternative is considered further. Figure 2.1 below shows the nominal water surface along with surface contours, but the depth of the quarry is not indicated.

Figure 2.1: Topographic Map

2.2 Fill and Discharge

The quarry has been inactive for decades and is now full of water. Reportedly, groundwater and springs recharge the quarry. Presumably, some minor surface water also contributes to filling. Utilizing this full quarry in a limestone geology located in an urban area may be problematic. Either the quarry can be isolated hydraulicly with grout curtains or other physical barriers, or the impact of quarry drawdown on the surrounding groundwater and potential impact to natural and man-made systems/structures must be understood.

Assuming the quarry could successfully be used for storage, water could be withdrawn from the Schuylkill River to replenish the quarry when drawn down. Similarly, stored quarry water would be discharged to the Schuylkill River to augment flows.

The Schuylkill River is a substantial water course with a 680 sq. mi. drainage area. Mean annual flow is 1190 cfs (769 mgd) and the estimated 7Q10 flow is 153 cfs. The storage project is not stream-flow limited given the Schuylkill River flows, and the quarry can easily be filled within the target 6-month period, especially given the small operational storage volume of only 0.8 BG.

Stored water would be discharged to the Schuylkill, as typical. The design rate is the typical 50 cfs (32 mgd). The proposed discharge rate is low relative to the high mean flow in the River and will have no issues being dissipated into the main river flows.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	42 acres
Nominal Rim Elev.	280 ft.
Bottom Elev.	130 ft.
Maximum Water Level Change (Ft.)	150 ft.
Maximum Volume (Billion Gallons)	1.0 BG
Operating Water Range (280 ft - 160 ft)	120 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	0.8 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Schuylkill River
Anticipated Source Stream Drainage Area (Sq. Miles)	648 sq.mi.
Mean Annual Stream Flow Rate (cfs/mgd)	1190 cfs (769 mgd)
Proposed Average Pumping Rate (MGD)	31 mgd
Average Vol. Pumped during 6 month Pumping Term	5.6 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	280 ft to 160 ft
Proposed discharge pumping rate (MGD)	32 mgd
Estimated Time to Release Operating Volume from Storage	0.8 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	70 miles
Travel Time at 2 mph (hours)	35 hours

2.3 Water Quality

The source stream has average water quality based on the PA 303D listing. It is characterized as a warm water fishery (WWF) and in spots can support a trout population. Table 2.2 below summarizes the 303D listed impairments. Water quality may change after pumping and settling in the quarry. Temperature changes may also occur based on quarry withdrawal point. It is assumed that the stored quality will not decrease relative to the source stream and will be adequate for flow augmentation.

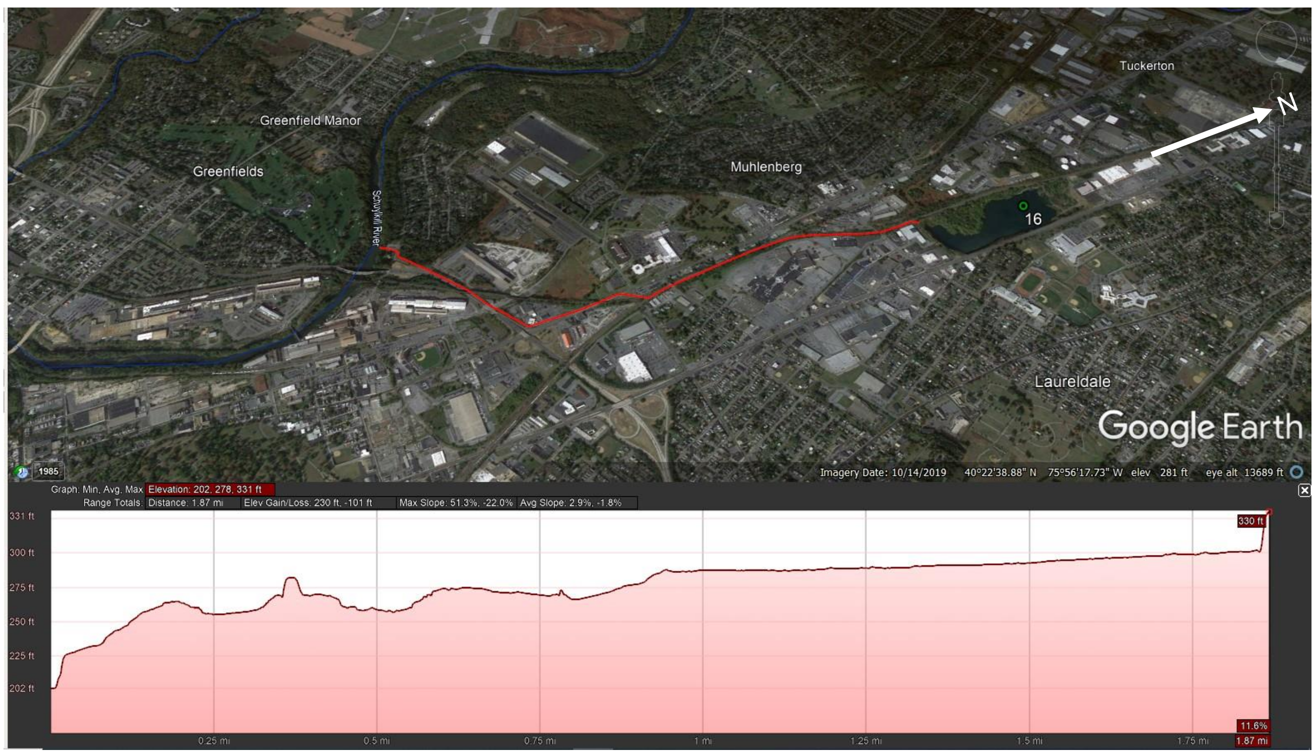
Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
Impaired - metals/TDS due to industrial discharge	Supporting	Not Assessed	Not Assessed

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Presumably, there is a need to at least partially hydraulically separate the quarry groundwater interaction, so costs are included in the project estimate to grout portions of the quarry. This is an approximation given no detailed geologic information is available at this point. The configuration of pumping and piping facilities are shown in Figure 3.1, presenting a schematic plan and profile of major facilities.

Figure 3.1: Approximate Pipe (red line) and Pump Station Location and Profile



3.1 Pumping Facilities

The quarry fill/stream withdrawal intake and pumping station are concepted as typical and presented in the main report. The intake screens would be placed on the river bottom with adjacent wetwell on the shoreline. The flows of the Schuylkill River can support other intake types, but this concept will continue with the assumed approach. The pumping is not stream-flow limited and the wetwell will be equipped with 3 by 10 mgd pumps for a 30 mgd filling capacity.

The quarry discharge/stream augmentation pumping station includes the shaft and connecting conduit with submersible pumps to lift the water from the quarry to the Schuylkill River. The discharge shaft will be fitted with 4 by 10.1 mgd pumps to deliver the lift and required flow rate for discharge.

As noted previously, filling and discharge are easily accomplished within the projected 6-month operational period.

3.2 Pipeline

The proposed pipeline route will be a considerable project hurdle. While the distance is a moderate 6,800 lf, the route is in a congested urban setting. The conceived route's plan and profile are shown schematically in Figure 3.1. The pipeline follows a railroad right-of-way (ROW) for most of the route and then other public ROW. Installation along a railroad ROW is convenient, but easements and permitting will be challenging. The urban environment increases typical cut and cover piping costs. Further, there are at least three areas requiring some form of trenchless crossing, further increasing the cost. Assuming these items are overcome, approximately 6,800 lf of 30 inch diameter ductile iron pipe (DIP) would be installed to make the connection between the quarry and the river.

Based on the profile and given the cost of conventional pipeline installation, an option to install a microtunneled connection between the quarry and the river could be considered. Given the elevation of the quarry and the discharge elevation at the Schuylkill River, some gravity discharge can be achieved. That said, the cost for this installation is very high and the volume is relatively low. Therefore, the project team did not consider this alternative further.

Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (3 x 10 mgd)	30 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (4 x 10.1 mgd)	40 mgd
Pipeline Distance	6,800 lf
Elevation at Discharge Point	202 ft
Elevation at High Point on Pipeline	330 ft
Static Head (filling)	128 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in Section 6, Project Cost & Schedule.

In terms of operations of the project, the pumping operation will be run similarly to other quarry projects and the pumping facilities will be heavily automated and monitored.

4 Environmental Impacts

This storage project was reviewed against several environmental parameters as described in the body of the report. These included wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project is scored medium to high in that some categories see no impact, especially given the urbanized setting of the pipe installation. There will be typical minor, but manageable, impacts associated with river intake construction.

Permitting the project appears achievable from a construction perspective. However, easements for the pipeline will be difficult and could have some environment impacts.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be a concern. This category considers general disruption, safety/health, equity, recreational loss, cultural/historical resources, aesthetic and loss of revenue/production. The Muhlenberg Municipal Authority owns the quarry. There are long term plans to develop the region with the quarry being a recreational amenity. Figure 5.1 below shows a concept from their recent Comprehensive Plan (MMA, 2003).

Figure 5.1: Comprehensive Plan Concept

Areas labeled O and R in the above figure designate the “Quarry Commuity Park” and the “Quarry Nature Center”, respectively. Periodically dewatering the quarry during storage relase is likely not compatible with this type of long term urban recreational use. Therefore, social and related economic impacts of limiting the regional development could be significant and consequently scored this category lower.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500
Intake				
Screens	LS	3	$80,000	$240,000
Structure	VF	12	$50,000	$600,000
Other	LS	1	$90,000	$90,000
Pumping Station				
Pumps	#	3	$450,000	$1,350,000
MEP	LS	1	$265,500	$265,500
Structure	SF	1200	$350	$420,000
Other	LS	1	$100,000	$100,000
Dissipation	LS	1	$500,000	$500,000
PIPELINE			Subtotal	$5,940,000
Pipeline	LF	6800	$800	$5,440,000
Valves	#	10	$50,000	$500,000
DISCHARGE PUMPING SYSTEM			Subtotal	$5,272,000
Intake Structure	VF	120	$25,000	$3,000,000
Pumping Station				
Pumps	#	4	$450,000	$1,800,000
MEP	LS	1	$42,000	$42,000
Structure	SF	800	$350	$280,000
Electrical Service	LS	1	$50,000	$50,000
Other	LS	1	$100,000	$100,000
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$15,777,500
Contingency			50%	$7,888,750
CONST. COST + CONTINGENCY				$23,666,250

The total capital is shown above. Land cost is not included in the above. The area of the quarry is owned by the Muhlenberg Municipal Authority. Berks County Tax Parcel and assessment information was insufficient to adequately estimate the land market value. Based on comparable quarries in the area, a market value of $2.5M is a reasonable estimate. This should be confirmed but was carried forward in the analysis as the land cost.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 0.8 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $33.52M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 9 years. This includes:

- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup and initial filling of quarry 1 year.

7 Potential Ancillary Benefits

This category of potential ancillary benefits consider such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement.

It is difficult to estimate the benefits and score for this project. If conversion to storage enables the conversion to controlled recreation and nature/environmental education as planned, and it is compatible with that use, then the score could be high. However, if storage is not compatible with the goals and there is risk associated with this use, then there are no benefits.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.25	30%	0.98
Infrastructure Design, Construction & Operation	2.20	10%	0.22
Environmental Impacts	4.64	15%	0.70
Social & Economic Impacts	3.25	10%	0.33
Project Cost & Schedule	3.67	30%	1.10
Ancillary Benefits	2.00	5%	0.10
AVERAGE	**3.17**		**3.42**

APPENDIX

Score Sheet

STORAGE PROJECT SCORING

STORAGE PROJECT: Q16
NAME: Temple Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.25**			30%	**0.98**	
o Volume of storage provided (BG)	1	1.5					
o Hydrologic reliability of supply (months to fill)	0.8	5					
o Release rate (cfs)	50	3					
o Promptness of delivery to mainstem (day)	1.45	4					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**2.20**			10%	**0.22**	
o Site/Civil, Land & Easements		2					Quarry may not be for sale; pipeline easements will be a challenge
o Subsurface conditions		2					Known springs and leakage; grouting in limestone required
o Infrastructure Complexity		2					Trenchless piping and potential impact to structures complicates
o Construction complexity		2					Trenchless piping and potential impact to structures complicates
o Operational complexity		3					Typical; high stream flows an advantage
3. Environmental Impacts		**4.64**			15%	**0.70**	
o Protected species		4					None apparent, but could exist along pipeline
o Water quality degradation		5					None expected
o Obstruction to passage of aquatic animals		5					None expected
o Hydromodification		4					Lower ranking due to groundwater interaction
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		4.5	5	4			None expected, but may exist along pipeline
o Stream length inundated (mi)		5	5	5			No impact
o Uplands inundated or developed (ac)		5	5	5			Urban area and minor disturbance
4. Social and Economic Impacts		**3.25**			10%	**0.33**	
o Disruption/displacement		3					Some disruption, construction and longer term
o Safety and health		3					Safety issues with recreational and storage combined
o Social equity		3					No real permanent issues
o Recreational loss		2					Ranked lower because of the potential storage impcompatibilty
o Cultural/historical resources		3					None apparent
o Aesthetic		3					Could impact if future recreational plan is limited
o Loss of tax revenue		4					Could impact if future recreational plan is limited
o Loss of production from farmland, timberland, quarries		5					Quarry inactive
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**3.67**			30%	**1.10**	
o Land acquisition cost ($)	$2.5M						
o Construction Cost ($)	$23.67M						
o Operating Cost ($/yr)	0.375M						
o Overall Cost ($)	$33.52M	4.5					
o Cost effectiveness ($/BG)	$33.52M	2.5					
o Schedule (Time to make Operational, years)	10	4					
6. Ancillary Benefits		**2.00**			5%	**0.10**	
o Flood control		1					Not practical
o Recreation/tourism		3					Ranked moderate because of unknown compataibility
o Habitat/fishery enhancement		1					Not likley
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		2					Some potential, but unlikley
o Ability to leverage funding from other programs		3					If compataible use, could leverage goals and funds
OVERALL		3.17				**3.42**	

Storage Project Summary

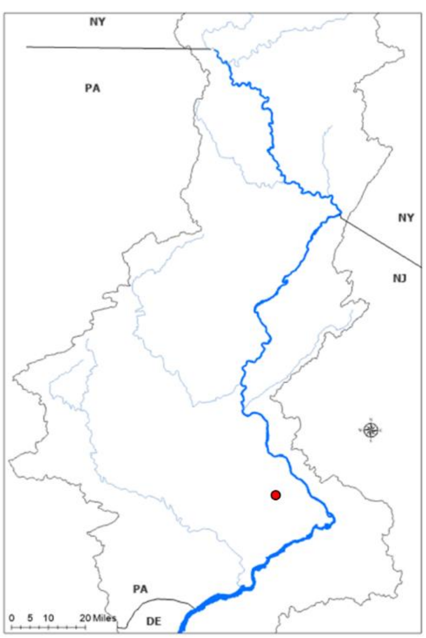
Project:	**Eureka Rush Valley Quarry (Q19)**
Location:	Furlong, Bucks County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	1.7 Billion Gallons
Score:	4.07

1 Project Overview

The scope of this storage project is to draw water from the adjacent Neshaminy Creek and store it in the Eureka Rush Valley Quarry for later discharge to the Creek when needed for flow augmentation. Note that this quarry is adjacent to Q4 (Penns Park Quarry) and the reader is referred to that SPS for additional information about possibly combining storage of the two sites.

The Eureka Rush Valley Quarry is an active quarry located in Furlong, PA in Bucks County, Pennsylvania (Figure 1.1). The site lies within Buckingham Township and borders Wrightstown Township, Doylestown Township, and Warwick Township. The quarry has a maximum volume of 1.7 billion gallons. This quarry is approximately 97 acres in area and has an estimated fillable rim elevation 160 ft. At the quarry's deepest point, it has an elevation of 50 ft, giving the quarry a nominal depth of 110 feet. The nearest pumpable stream to the quarry is the Neshaminy Creek, located about 100 feet away. The quarry is composed primarily of siltstone and mined for various aggregate products.

Figure 1.1



2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 1.4 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as saddle dams or earthen berm were included in the analysis to increase storage volume. However, this project may justify a review of the advantage of added structures for increased storage volume. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Further analysis will be needed to account for storage lost to pervious areas. Figure 2.1 below shows the proposed fill elevation (blue line) along with contours showing the depth of the quarry.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

The intended design is to fill the quarry from the Neshaminy Creek located only about 250 ft away from the quarry interior. Neshaminy creek has a 156 sq. mi. drainage area and mean annual flow of 228 cfs (146 mgd), and an estimated pass-by flow of 29 mgd. The flow of the source is substantial and should not affect the planned pumping rate and project target to replenish the storage within a 6-month period. Based on the approach defined in the main report and referenced appendix, the planned average withdrawal is approximately 29 mgd.

The discharge of quarry storage back to augment stream flow in times of need is more governed by the limitations of the conceived quarry pumping station and protection of the receiving stream from erosion. The discharge rate back into the stream has been established at 50 cfs (31 mgd). Note the bank-full flow in the Neshaminy Creek is approximately 6,520 cfs.

Given the above stated storage configuration and the limitations/assumptions associated with pumping, stream flow can fill the quarry withing the six-month period and easily discharge from storage back to the stream at the targeted 50 cfs (31 mgd) flow rate. Also note, there may be an opportunity to flow by gravity between the creek and quarry to fill and replenish the quarry storage. This will be explored further below in Section 3.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	97 acres
Nominal Rim Elev.	160 ft.
Bottom Elev.	50 ft.
Maximum Water Level Change (Ft.)	110 ft.
Maximum Volume (Billion Gallons)	1.7 BG
Operating Water Range (160 ft to 72 ft)	88 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	1.4 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Neshaminy Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	156 sq. mi.
Mean Annual Stream Flow Rate (ft3/s/mgd)	228 cfs / 146 mgd
Proposed Average Pumping Rate (MGD)	31 mgd
Average Vol. Pumped during 6 month Pumping Term	5.6 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	160 ft to 72 ft
Proposed discharge pumping rate (MGD)	32 mgd
Estimated Time to Release Operating Volume from Storage	1.4 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	67 miles
Travel Time at 2 mph (hours)	33 hours

2.3 Water Quality

The source stream, has marginal to good water quality based on the PA 303D listing, supporting aquatic uses. It is a designated warm water fishery (WWF) and is also a significant source of downstream potable water supply. Table 2.2 below summarizes the listed impairments. Note the impairment for PFOS. Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease relative to the source stream and will be acceptable for flow augmentation.

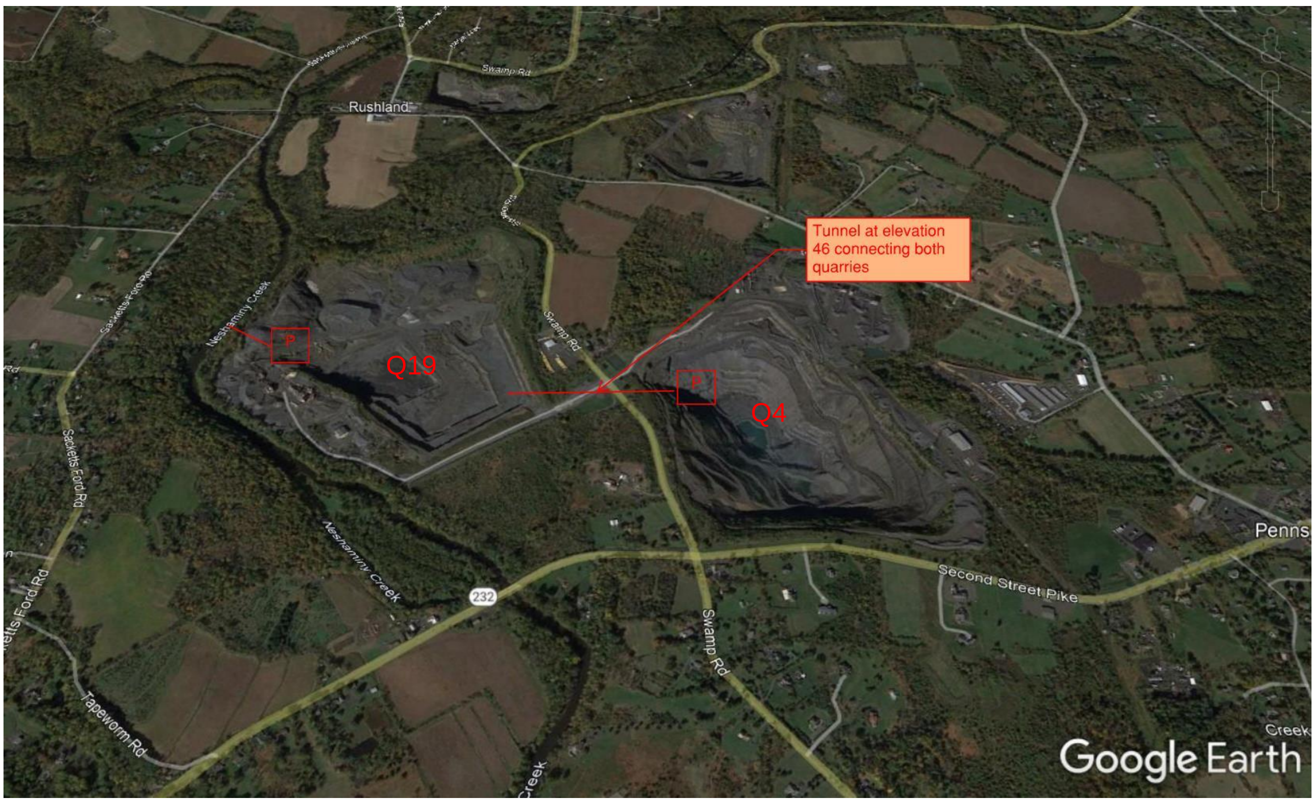
Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
SUPPORTING	Not Assessed	Impaired PFOS	Not Assessed

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities in the configuration in which the Q19 and Q4 are connected by a conduit.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location Plan



3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station will be configured with intake screens on the riverbed connected to the adjacent withdrawal pumping shaft/wetwell, as described in the main report. The proposed pumping scenario is not stream flow limited and it is projected that the 29 mgd can be withdrawn within the designated minimum 6 month filling period. This will be accomplished with an arrangement of 3 x 10 mgd pumps in the wetwell.

The quarry discharge/stream augmentation pumping station includes components as generally described in the main report. The targeted rate for discharge from the quarry back to the source stream is approximately 50 cfs (32 mgd). Given high head conditions to lift the water from the quarry at its lowest operating levels, this will require 4 x 8.6 mgd pumps in the quarry shaft wetwell.

Other features of the intake and discharge pumping station are described in Section 5 of the main report. Itemization and cost of the components are outlined further below in Section 6 of this summary.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline is relatively short consisting of approximately 250 feet of 30-inch diameter ductile iron pipe (DIP). It is costed to be installed with conventional cut and cover methods; however, a trenchless installation approach may be advantageous and should be considered. The route of the piping can vary and easements are likely achievable.

3.3 Alternate Piping/Pumping Configuration

The quarry storage total depth range is 160 ft to 50 ft, with an operating level of 160 ft to 72 ft. The elevation of the stream intake is approximately 107 ft. A trenchless installed conveyance pipe with adequate controls could connect the intake to the quarry and allow gravity filling to the elevation of the creek. After that point is reached, the stream withdrawal pumping station would be used to fill the quarry to the rim elevation of 160. Similarly, gravity flow could be used to transfer some stored water back to Neshaminy Creek. Again, the quarry discharge pumping station would be used below the common storage level to transfer additional stored water out of the quarry to the creek. This option does not eliminate the planned pumping stations and facilities, but would reduce the operating costs of pumping over the life of the project as gravity flow is utilized.

The reader is referred to the Q4 SPS where the opportunity of connecting Q19 and Q4 is further described.

Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (3 x 10 mgd)	30 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	31 mgd (50 cfs)
Pump Capacity (4 x 8.6 mgd)	34 mgd
Pipeline Distance (includes connection pipeline)	250 lf
Elevation at Discharge Point	135 ft
Elevation at High Point on Pipeline	179 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

In terms of operations of the facility, the typical quarry pumping operations would be employed. If the option for a gravity connection is constructed then the operating costs are estimated to be reduced by approximately one half.

4 Environmental Impacts

This storage project was reviewed against several environmental scoring parameters as described in the body of the report and is similar in scoring to the adjacent Q4. The pumping station shafts and short pipeline should be located to avoid direct environmental impacts to wetlands, forested uplands or protected species. Some limited clearing will be required to install the withdrawal intake/pumping station. Stream impacts will be limited and as typical for comparable intakes on a relatively small stream. Overall, the project is scored as relatively high having relatively low probability of negative impacts. As other storage projects, augmenting the receiving stream with flow from storage during low flow conditions is advantageous.

Permitting the project appears very feasible. The pipeline is very short and the other pumping facilities are typical. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

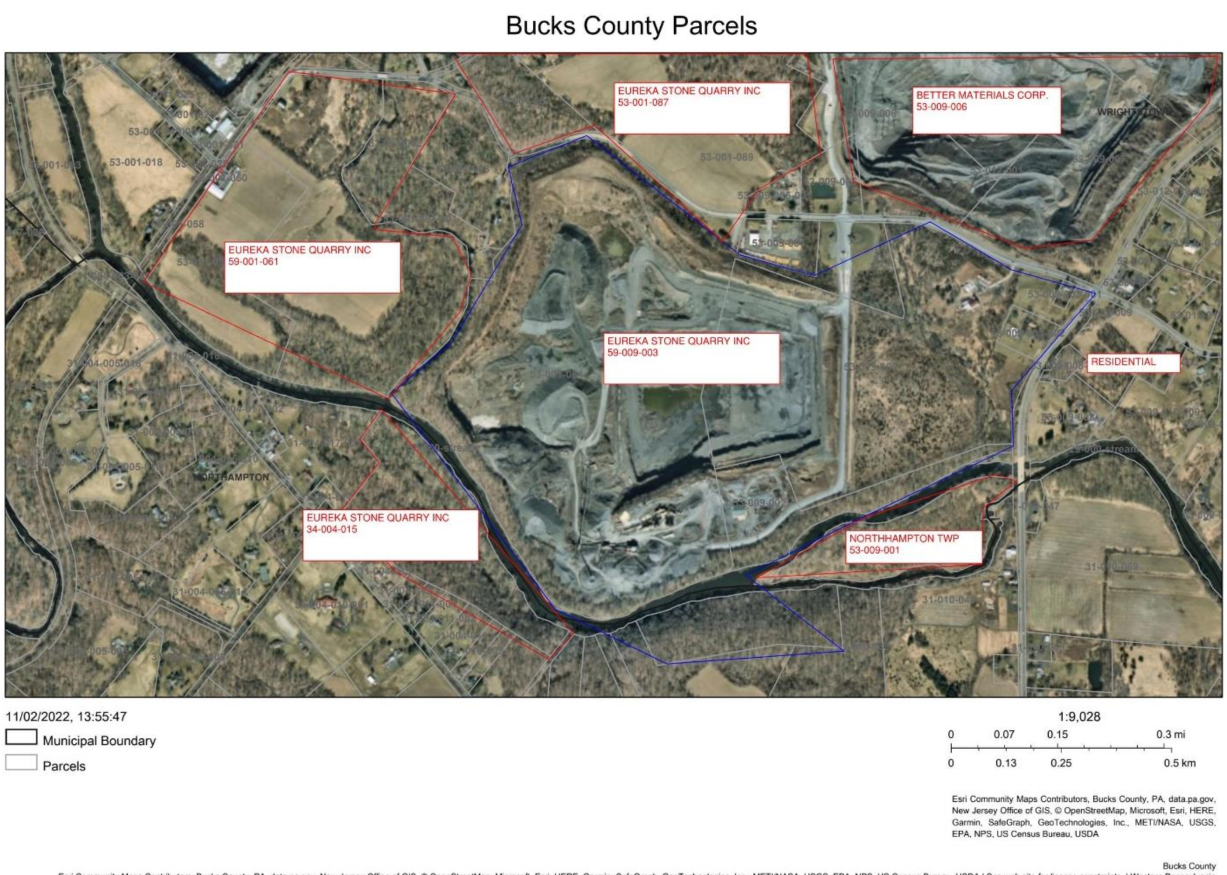
5 Social and Economic Impacts

Stakeholder, social and economic impacts are expected to be minor and therefore scores high. This category considers general disruption, safety/health, equity, recreational loss, cultural/historical resources, aesthetic and loss of revenue/production.

The area near the site is generally industrial or agricultural with some scattered residential. The quarry closing will have some economic impact, albeit minor. Truck traffic would be reduced and the conversion of the quarry to a natural amenity would be a positive impact. Correspondingly, this category scores high because the anticipated impacts are minor, with potential for offsetting positives.

The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1.

Figure 5.1: Land Ownership



6 Project Cost & Schedule

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$500,000.00
Pipeline	LF	250	$800.00	$200,000.00
Valves	#	6	$50,000.00	$300,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$4,472,000.00
Intake Structure	VF	88	$25,000.00	$2,200,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$9,537,500
Contingency			50%	$4,768,750
CONST. COST + CONTINGENCY				$14,3006,250

The total capital is shown above. Land costs are not included. However, based on information available in the

Bucks County Tax Parcel database the main property has a value of approximately $1.7M. This may not reflect true market value and appears low relative to comparable quarries, but $2M was carried for land costs associated with this project.

Note that provided costs do not include additional costs for the gravity feed options. However, these should not be significant.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1.4 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $23.65M

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 9 years. This includes:

- Design, permitting and land acquisition 4 years
- Construction 4 years
- Startup and initial filling of quarry 1 year

7 Potential Ancillary Benefits

This category of potential ancillary benefits considers such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement. As mentioned previously, the local impact of any ancillary benefit is likely limited. Given this and the understanding of the project and proposed improvements, the potential for positive impacts are only moderate relative to other storage projects and is scored accordingly.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.75	30%	1.13
Infrastructure Design, Construction & Operation	3.60	10%	0.36
Environmental Impacts	4.79	15%	0.72
Social & Economic Impacts	4.88	10%	0.49
Project Cost & Schedule	4.00	30%	1.20
Ancillary Benefits	3.60	5%	0.18
AVERAGE	**4.10**		**4.07**

APPENDIX

Score sheet

DRBC
Feasibility Evaluation of Additional Storage Options

STORAGE PROJECT SCORING

STORAGE PROJECT: Q19
NAME: Rush Valley Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		3.75			30%	1.13	
o Volume of storage provided (BG)	1.7	2					
o Hydrologic reliability of supply (months to fill)	1.1	5					
o Release rate (cfs)	50	5					
o Promptness of delivery to mainstem (day)	1.4	4.5					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		3.60			10%	0.36	
o Site/Civil, Land & Easements		4					Should be achievable
o Subsurface conditions		3					Typical
o Infrastructure Complexity		4					Typical and short pipe intall
o Construction complexity		4					Typical and short pipe intall
o Operational complexity		3					Low flow stream, but possible gravity
3. Environmental Impacts		4.79			15%	0.72	
o Protected species		5					
o Water quality degradation		5					
o Obstruction to passage of aquatic animals		5					
o Hydromodification		4					
			special two-factor scoring for habitat impacts				
Habitat Type		Combined average	replaceability (5=easy; 1 =difficult)	quantity impacted (5=small, 1=large)			
o Wetlands inundated or filled (ac)		5	5	5			
o Stream length inundated (mi)		4.5	5	4			Minor intake disturbance
o Uplands inundated or developed (ac)		5	5	5			Minor intake disturbance
4. Social and Economic Impacts		4.88			10%	0.49	
o Disruption/displacement		5					
o Safety and health		5					
o Social equity		5					
o Recreational loss		5					Potential minor gain
o Cultural/historical resources		5					
o Aesthetic		5					
o Loss of tax revenue		4.5					Minor quarry loss
o Loss of production from farmland, timberland, quarries		4.5					
o Emissions of greenhouse gasses		3					
5. Project Costs & Schedule		4.00			30%	1.20	
o Land acquisition cost ($)	$2M						
o Construction Cost ($)	$14.3M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	$23.6M	4.5					
o Cost effectiveness ($/BG)	$13.9M	3.5					
o Schedule (Time to make Operational, years)	9	4					
6. Ancillary Benefits		3.60			5%	0.18	
o Flood control		3					
o Recreation/tourism		4					Some potential
o Habitat/fishery enhancement		4					Some potential
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					Could settle solids and replenish stream at low flows
o Ability to leverage funding from other programs		3					Potential rec. funds, but local competition
OVERALL		4.10				**4.07**	

Storage Project Summary

Project:	**Ormrod Quarry (Q21)**
Location:	Coplay, Lehigh County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	1.3 Billion Gallons
Score:	3.92

1 Project Overview

This storage project would extract water from the Lehigh River, store it in the Ormrod Quarry and release it when needed for flow augmentation. This project has access to a high flow stream and could connect with another quarry project (Q22 Whitehall) to increase storage volume while sharing infrastructure.

This active quarry is located in Coplay within North Whitehall Township of Lehigh County, Pennsylvania (Figure 1.1). The quarry has a maximum volume of 1.3 billion gallons. This quarry is approximately 87 acres in area and has an estimated fillable rim elevation 350 ft. At the quarry's deepest point, it has an elevation of 240 ft, giving the quarry a nominal depth of 110 feet. Coplay Creek is located adjacent to the site but has low flows. The nearest significant stream to the quarry is the Lehigh River, located about 3 miles away.

The Ormrod Quarry (Q21) is one of several quarries in the region as shown in Figure 1.2. Only the quarries labelled Q21 and Q22 passed the supplemental screening to become one of the eighteen quarries evaluated.

Figure 1.1

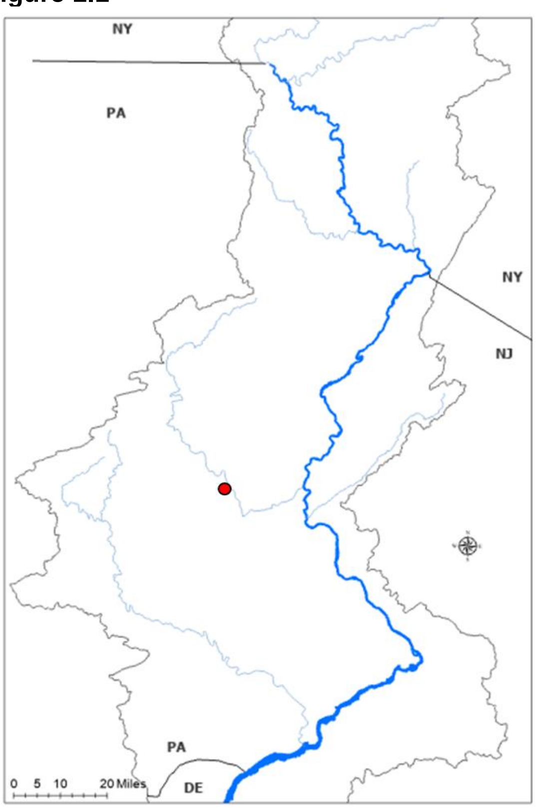
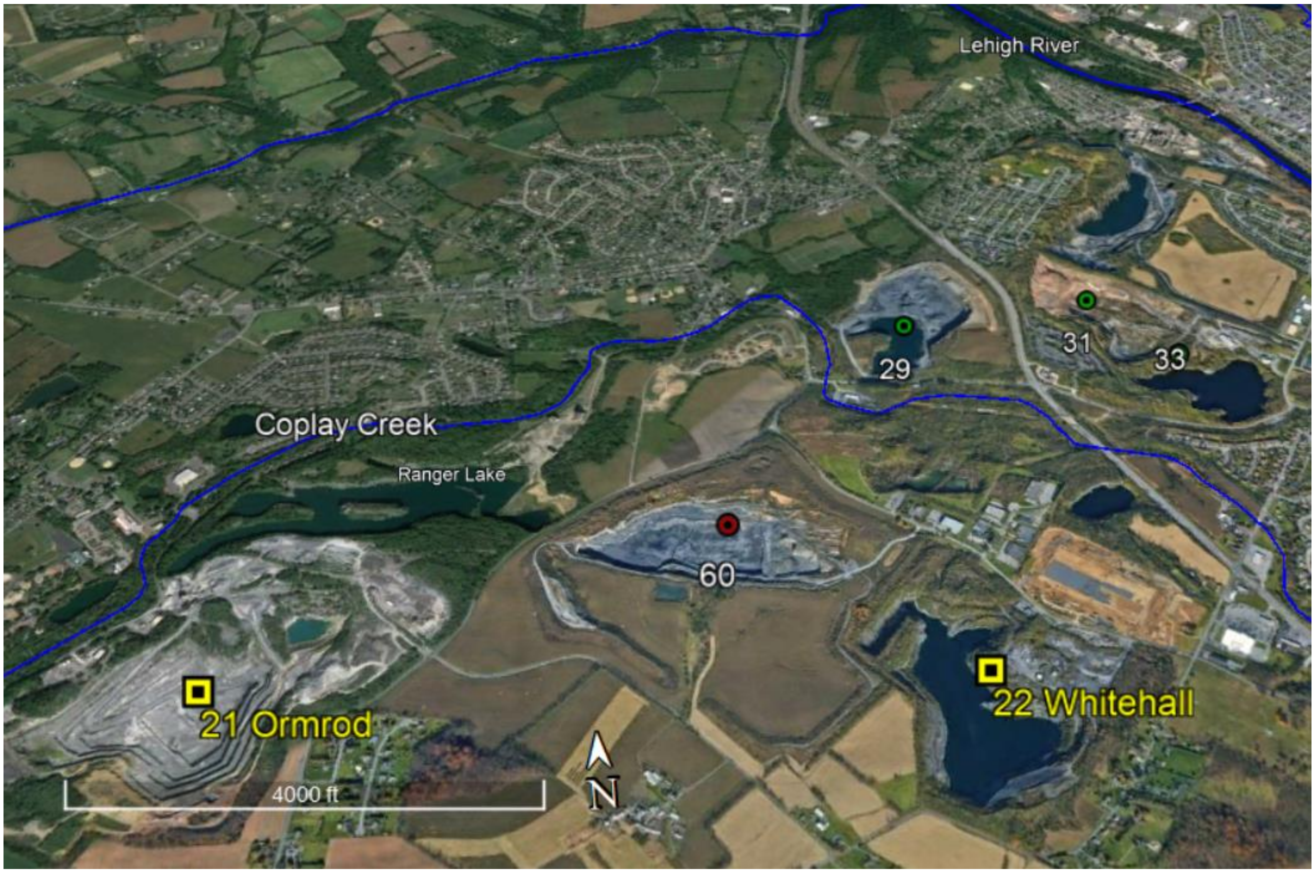


Figure 1.2: Oblique Areal View with Regional Quarries



2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume of over 1.0 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or berms are suggested to increase storage volume for this project. Some opportunity to increase the volume of the quarry may be realized with additional permitted mining. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Further analysis will be needed to account for storage lost to pervious areas. Figure 2.1 below shows the proposed fill elevation (350’) along with contours showing the depth of the quarry. Again, additional storage volume might be realized by deeper mining and/or joining multiple quarries in the region.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

The quarry fill and discharge approach utilizes the high flows of the Lehigh River, albeit some distance removed. The Lehigh River is a substantial river with a drainage area of about 940 sq. mi at this location. Mean annual flow is 1,880 cfs, 7Q10 flow is approximately 194 cfs, and bank full flow is on the order of 18,300 cfs. The Lehigh can easily provide and assimilate the fill/discharge flow anticipated for this storage project.

The filling of the quarry is not stream-limited; the Lehigh will sustain pumping at a practical pumping station flow rate, established at 50 cfs. The discharge of stored water in the quarry will be released back to the Lehigh at the target rate of 50 cfs. These rates can fill the storage volume in less than 3 months and provide flow augmentation at 50 cfs for a similar period.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	87 acres
Nominal Rim Elev.	350 ft.
Bottom Elev.	240 ft.
Maximum Water Level Change (Ft.)	110 ft.
Maximum Volume (Billion Gallons)	1.3 BG
Operating Water Range (350 ft-262 ft)	88 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	1.0 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Lehigh River
Anticipated Source Stream Drainage Area (Sq. Miles)	940 sq. mi.
Mean Annual Stream Flow Rate (cfs/mgd)	1880 cfs/1214 mgd
Proposed Average Pumping Rate (MGD)	31 mgd
Average Vol. Pumped during 6 month Pumping Term	5.6 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	350 ft to 262 ft
Proposed discharge pumping rate (MGD)	32 mgd
Estimated Time to Release Operating Volume from Storage	1.1 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	24 miles
Travel Time at 2 mph (hours)	12 hours

2.3 Water Quality

The Lehigh River's PA 303D listed impairments are summarized in Table 2.2. The Lehigh's Chapter 93 designated use is TSF for trout stocking. Water quality may change after pumping and settling in the quarry. Temperature changes should be considered with discharging stored water back to the Lehigh near this site. It is assumed that the stored quality will not decrease relative to the source stream and water quality in the quarry will be adequate for flow augmentation.

Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
Impaired - siltation due to urban runoff, organic enrichment/oxygen depletion due to municipal discharges		Supporting	

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities. The fill pumping station is located on the Lehigh (P) and the discharge pumping station will be located at the Ormrod Quarry.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile

3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is conceived as described in the main report with submerged wedgewire screen on the river bottom connected to a wetwell on the adjacent bank that will house submersible pumps for lifting and transferring river water to the quarry. The proposed configuration has 3 x 10 mgd pumps in the wetwell.

The quarry discharge/stream augmentation pumping station will be as typical with high-capacity pumps in the shaft at the quarry connected to the stored water. The proposed configuration has 4 x 8.6 mgd pumps for discharge.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline plan/profile shows intermediate stations correlated by number. The pipeline measures approximately 3 miles in length and is expected to be 30-inch diameter ductile iron pipe (DIP). The pipe route is aligned in public streets over almost its entire length. Prior to dropping in elevation to the river, it traverses a mobile home park that again should allow alignment and installation in the roadway (public or private). Construction should be typical cut and cover installation. Some trenchless technology could be used for a major road crossing, but should not be required.

3.3 Alternate Piping/Pumping Configuration

Several other quarries lie generally along the pipeline illustrated in Figure 3.1. As shown in Figure 1-2, Quarries numbered 22, 29, 31, 33, and 60 lie between the Ormrod Quarry (Q21) and the Lehigh River and are herein referred to as the Coplay Cluster. It could be possible to have the pipeline to Ormrod function as a transmission main with lateral pipelines connecting the other quarries in the cluster. Of course, each quarry would require an individual discharge pumping station to move water into the transmission main. It is conceivable that the transmission main concept can also be used to withdraw water from the Lehigh to fill the various quarries. Therefore, each added quarry storage project takes advantage of a common pipeline and a common intake/withdrawal pumping station, lowering the cost/gallon of stored water. The scoring of this project was evaluated only on connecting Ormrod Quarry to the pipeline. The potential advantages of operating the Coplay Cluster concept will be scored as an ancillary benefit in Section 7.

Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (3 x 10 mgd)	30 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (4 x 8.6 mgd)	35 mgd
Pipeline Distance	15,312 lf
Elevation at Discharge Point	290 ft
Elevation at High Point on Pipeline	481 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

In terms of operations of the project, the Ormrod project will function as other quarry storage projects and be automated and monitored for remote operation. The concept of operation of the Coplay Cluster is more complicated, but possible, and could be addressed later.

4 Environmental Impacts

This storage project was reviewed against several environmental parameters as described in the body of the report. These included wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project is scored medium to high in that some categories see no impacts. There will be typical minor, but manageable, impacts associated with river intake construction. The pipeline traverses almost 3 miles, but does so generally in roadway right-of-way (ROW) with no sensitive crossings. The flow into and out of the Lehigh should not have an impact on the river given the pumped flows relative to the overall river flows. Filling the quarry assumes there are no impacts to any sensitive areas in the quarry, which is likely. Flooding the quarry also has the opportunity to enhance local habitat. Again, the project is scored medium to high.

Permitting the project appears manageable. Of course, with all quarry's, the filling and withdrawal of water needs to meet regulatory scrutiny. If permitted the other typical construction permits should be achievable.

The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

This category considers general disruption, safety/health, equity, recreational loss, cultural/historical resources, aesthetic and loss of revenue/production. Stakeholder and social impacts and related scoring are difficult to determine at this point in the project development. Economically, tax ratables could be lost with a quarry conversion but should not be significant. Socially, the quarry closing would likely be viewed positively by the surrounding residential community in terms of reduced disruption, general safety, preserving resources and general aesthetics. The possibility of creating a managed recreational or natural resource should be well received. Ranger Lake (Figure 1.2) is a converted quarry. Correspondingly, this project scores high in this category. Additional comments are provided in Section 7.

The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1.

Figure 5.1: Land Ownership

6 Project Cost & Schedule

Mott MacDonald prepared feasibility-level costs for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$13,199,600.00
Pipeline	LF	15312	$800.00	$12,249,600.00
Valves	#	19	$50,000.00	$950,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$4,472,000.00
Intake Structure	VF	88	$25,000.00	$2,200,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$22,237,100
Contingency			50%	$11,118,550
CONST. COST + CONTINGENCY				$33,355,650

The total capital cost is shown above. The land cost is not included. The Lehigh County Tax Assessment information was used to determine the assessed value of $8.75M. This does not necessarily reflect market value but was carried forward as the land value for estimating purposes.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a rounded total of $49M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 9 years. This includes:

- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup and initial filling of quarry 1 year.

7 Potential Ancillary Benefits

This category of potential ancillary benefits consider such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement.

If repurposing the quarry for storage enables the quarry conversion to controlled recreation and nature/environmental education, and it is compatible with that use, then the score could be high. The adjacent Ranger Lake is a converted cement quarry and supports active recreation. Further, a concept to manage all the water resources in the Coplay Cluster could present substantial benefit to balance industry, water resources, recreation/environmental improvements and the general region’s development. Correspondingly, the potential ancillary benefits are considered high.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.83	30%	1.15
Infrastructure Design, Construction & Operation	3.10	10%	0.31
Environmental Impacts	4.93	15%	0.74
Social & Economic Impacts	4.63	10%	0.46
Project Cost & Schedule	3.50	30%	1.05
Ancillary Benefits	4.20	5%	0.21
AVERAGE	**4.03**		**3.92**

APPENDIX

Score sheet

DRBC
Feasibility Evaluation of Additional Storage Options

STORAGE PROJECT SCORING

STORAGE PROJECT: Q21
NAME: Ormrod Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.83**			30%	**1.15**	
o Volume of storage provided (BG)	1.3	2					
o Hydrologic reliability of supply (months to fill)	1.4	5					
o Release rate (cfs)	50	5					
o Promptness of delivery to mainstem (day)	0.5	5					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**3.10**			10%	**0.31**	
o Site/Civil, Land & Easements		3					Quarry assumed; Pipeline is primarily in ROW
o Subsurface conditions		2.5					Know Karst area, but should be acceptable
o Infrastructure Complexity		3					Pipeline is longer, but typical
o Construction complexity		3					Pipeline is longer, but typical
o Operational complexity		4					Typical; could be more efficient with the Cluster
3. Environmental Impacts		**4.93**			15%	**0.74**	
o Protected species		5					None known
o Water quality degradation		5					Water assimmilated into the Lehigh easily
o Obstruction to passage of aquatic animals		5					None known
o Hydromodification		5					Minimal modification at intake
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		5	5	5			Little if anything at the intake; none apparent on pipeline
o Stream length inundated (mi)		4.5	5	4			Minor impact at intake
o Uplands inundated or developed (ac)		5	5	5			Minimal and most along roadway for pipeline
4. Social and Economic Impacts		**4.63**			10%	**0.46**	
o Disruption/displacement		5					Minor during construction
o Safety and health		5					Minimal consrtruction risk and long term improvement
o Social equity		5					No perceived equity issues
o Recreational loss		5					No loss and possible gain
o Cultural/historical resources		4					Unlikley, but could encounter some areas along pipeline/canal
o Aesthetic		5					No loss and possible gain
o Loss of tax revenue		4					Could be impact with quarry closing, but may be offset and minor
o Loss of production from farmland, timberland, quarries		4					Loss of quarry, but should be minor
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**3.50**			30%	**1.05**	
o Land acquisition cost ($)	$8.75						
o Construction Cost ($)	$33.35M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	$49.45M	4					
o Cost effectiveness ($/BG)	$38.04M	2.5					
o Schedule (Time to make Operational, years)	9	4					
6. Ancillary Benefits		**4.20**			5%	**0.21**	
o Flood control		3					Volumes are realatively small and requries pumping
o Recreation/tourism		5					Potential for major improvement
o Habitat/fishery enhancement		5					Potential to create habitat and enhancement; perhaps regional
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					Reclaims the quarry and may lead to others in the Cluster
o Ability to leverage funding from other programs		4					Reclamation bonds and local/state/federal funds might be leveraged
OVERALL		4.03				**3.92**	

Storage Project Summary

Project:	**Whitehall Quarry (Q22)**	
Location:	Whitehall, Lehigh County, PA	
Storage Type:	Quarry (Fill & Draw)	
Est. Volume:	1.2 Billion Gallons	
Score:	3.97	

1 Project Overview

This storage project would involve water pumped from the Lehigh River, stored in the Whitehall Quarry and later returned to the Lehigh. This project is part of the Coplay Cluster of quarries and may offer opportunity to combine storage.

The Whitehall Quarry is a partially active quarry located in Whitehall Township of Lehigh County, Pennsylvania (Figure 1.1). The quarry has a maximum volume of 1.2 billion gallons. This quarry is approximately 62 acres in area and has an estimated fillable rim elevation 360 ft. At the quarry's deepest point, it has an elevation of 240 ft, giving the quarry a nominal depth of 120 feet. Coplay Creek is located immediately adjacent to the site but has low flows. The nearest significant stream to the quarry is the Lehigh River, located less than 2 miles away.

The quarry is composed primarily of limestone and was mined for related construction products. A large portion of the site area is partly filled with water and the balance of the area is actively mined.

The Ormrod Quarry (Q21) is one of several quarries in the region, herein referred to as the Coplay Cluster as shown in Figure 1.2. Only the quarries labelled Q21 and Q22 passed the supplemental screening to become one of the eighteen quarries evaluated.

Figure 1.1 Project Location

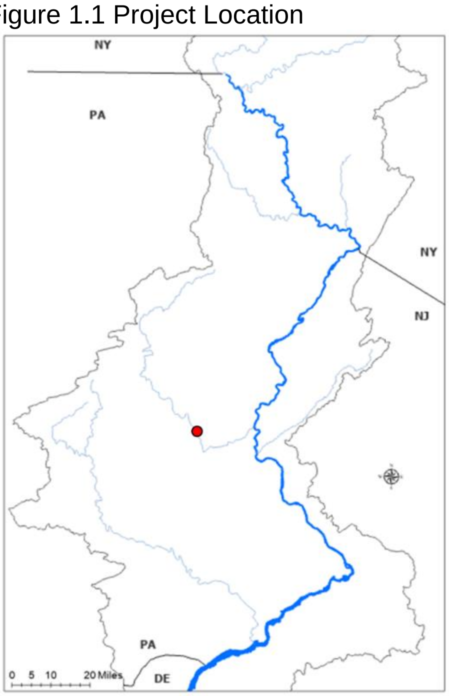
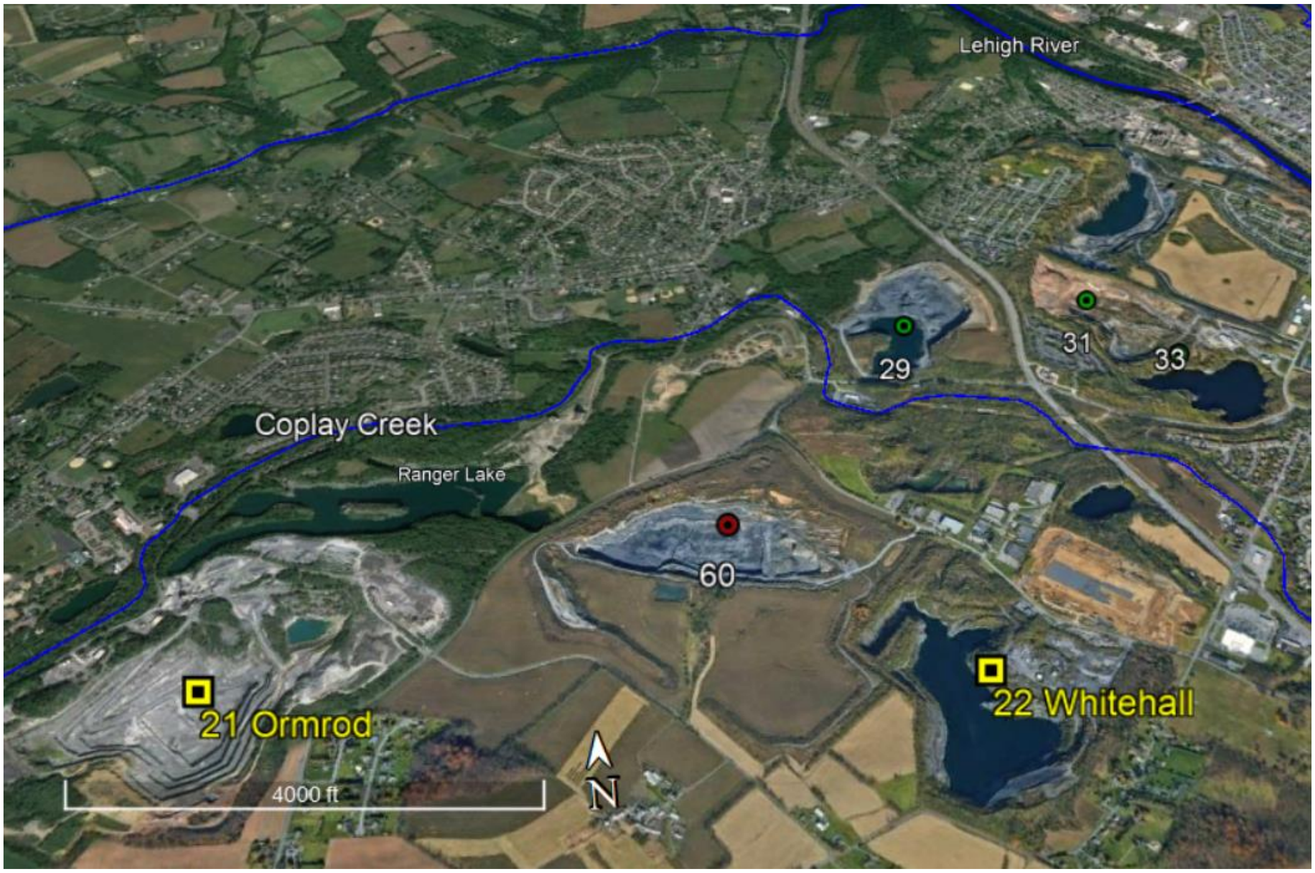


Figure 1.2: Aerial View with Regional Quarries (Cluster)



2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume of approximately 1 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. The rim elevation varies over 100 feet from one side to the other. Additional structures such as dams or embankments may be appropriate to increase storage volume for this project. These are not considered in the cost estimate. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. The limestone geology indicates potential for groundwater interaction. Further analysis will be needed to account for this impact. Figure 2.1 below shows contours indicating the depth of the quarry.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

The intended design is similar to other projects, particularly Q21, located 1.2 miles away. The quarry fill and discharge approach utilizes the flows of the Lehigh River, located about 2 miles east of the site. The Lehigh River is a substantial river with a has a drainage area of about 940 sq. mi, at this location. Mean annual flow is 1,880 cfs, 7Q10 flow is approximately 194 cfs, and bank full flow is on the order of 18,300 cfs. The Lehigh can easily provide and assimilate the fill/discharge flow anticipated for this storage project.

The filling of the quarry is not stream-limited; the Lehigh will sustain pumping at a practical pumping station flow rate, established at 50 cfs. The discharge of stored water in the quarry will be released back to the Lehigh at the target rate of 50 cfs. These rates can fill the storage volume in less than 3 months and provide flow augmentation at 50 cfs for a similar period.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	62 acres
Nominal Rim Elev.	360 ft.
Bottom Elev.	240 ft.
Maximum Water Level Change (Ft.)	120 ft.
Maximum Volume (Billion Gallons)	1.2 BG
Operating Water Range (360 ft-264 ft)	96 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	1.0 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Lehigh River
Anticipated Source Stream Drainage Area (Sq. Miles)	940 sq. mi.
Mean Annual Stream Flow Rate (cfs/mgd)	1880 cfs/1214 mgd
Proposed Average Pumping Rate (mgd)	31 mgd
Average Vol. Pumped during 6 month Pumping Term	> Op. Vol. (5.6 BG)
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	360 ft to 264 ft
Proposed discharge pumping rate (mgd)	32 mgd
Estimated Time to Release Operating Volume from Storage	1.0 month
Water Supply – Travel to Use	
Stream Miles to Delaware River	21 miles
Travel Time at 2 mph (hours)	10 hours

2.3 Water Quality

The Lehigh River's PA 303D listed impairments are summarized in Table 2.2. The Lehigh River's Chapter 93 designated use is TSF for trout stocking. Water quality may change after pumping and settling in the quarry. Temperature changes should be considered with discharging stored water back to the Lehigh near this site. It is assumed that the stored quality will not decrease relative to the source stream and water quality in the quarry will be adequate for flow augmentation.

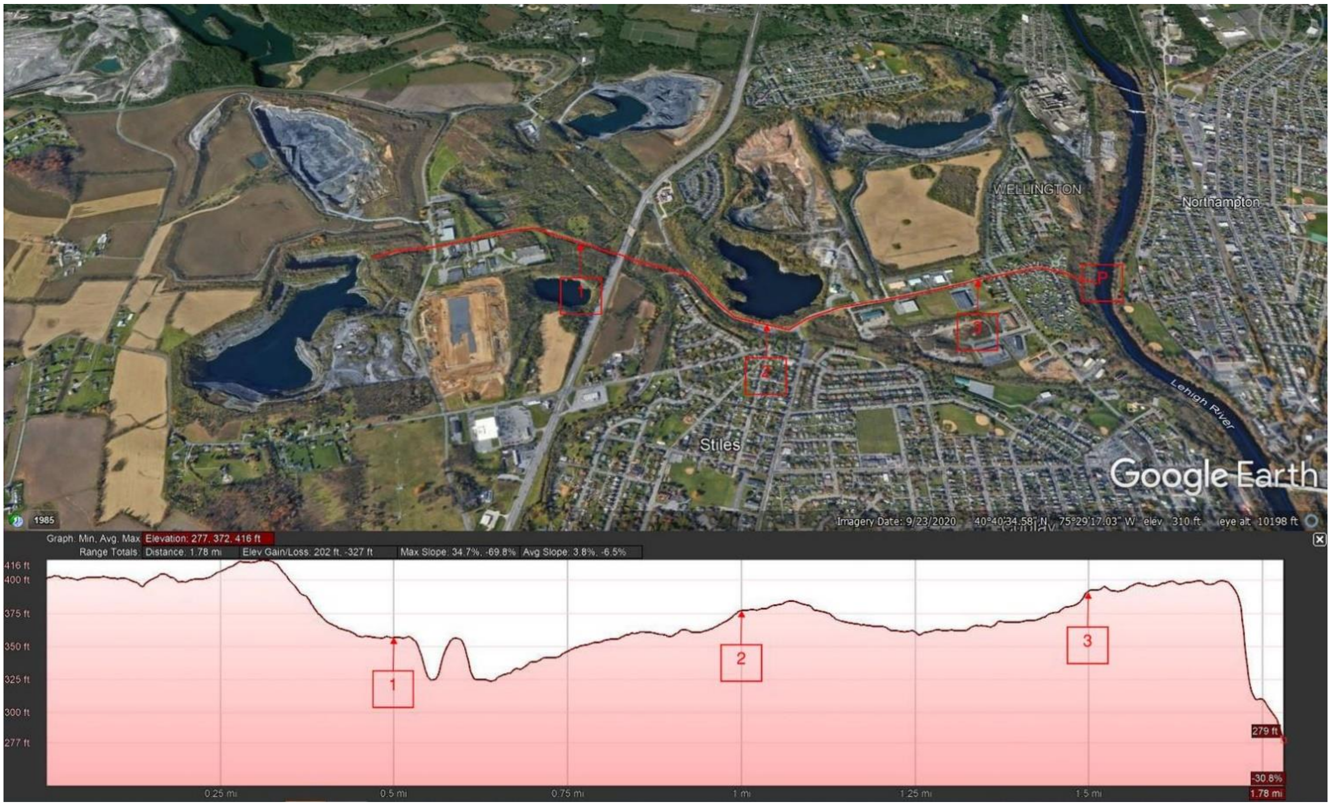
Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	**Recreational**	**Fish Consumption**	**Potable Supply**
Impaired - siltation due to urban runoff, organic enrichment/oxygen depletion due to municipal discharges	Not Assessed	Supporting	Not Assessed

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile



3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is conceived as described in the main report with submerged wedgewire screen on the river bottom connected to a wetwell on the adjacent bank that will house submersible pumps for lifting and transferring river water to the quarry. The proposed configuration has 3 x 10 mgd pumps in the wetwell.

The quarry discharge/stream augmentation pumping station will be as typical with high-capacity pumps in the shaft at the quarry connected to the stored water. The proposed configuration has 4 x 8.6 mgd pumps for discharge.

This fill and discharge pumping arrangement is essentially the same as project Q21 since the pumping/system geometry is basically the same and only the pipeline route changes.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1 and provides plan and profile. The plan/profile indicate the withdrawal pumping station location at the river and assumed location at the quarry. The pipeline shows three numbered correlation points for reference. The pipeline is estimated to be 9,400 lf of 30- inch diameter ductile iron pipe (DIP). The pipeline route will offer some challenges for access and construction. Leaving the site and approaching Point #1, private easements will be required. Leaving point #1, a stream crossing (Coplay Creek) and road crossing (McArthur Road) will be required using trenchless methods. Additional private easements will be needed before aligning on Chestnut Street. Public right-of-way (ROW) can be followed on Chestnut and W. Coplay Road and continuing to Stone Terrace drive. Some additional minor private easements may be needed to access the river. The construction will be typical cut and cover installation except for the trenchless crossing.

This SPS and score are based on the proposed pipeline and other facilities. However, it should be noted as described in the SPS for Q21, this Whitehall Quarry could possibly be connected to a regional Coplay Cluster pipeline that would offer project savings and other advantages. Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (3 x 10 mgd)	30 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (4 x 8.6 mgd)	34 mgd
Pipeline Distance	9,400 lf
Elevation at Discharge Point	266 ft
Elevation at High Point on Pipeline	481 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

In terms of operations of the project, the Whitehall system will function as other quarry storage project and be automated and monitored for remote operation. The concept of operation for Coplay Cluster is more efficient. It is also more complicated, but possible, and will be addressed later if DRBC sees the value in developing this concept further.

4 Environmental Impacts

This storage project was reviewed against several environmental parameters as described in the body of the report. These included wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project is scored medium in that some categories see no to minor impacts. There will be typical minor, but manageable, impacts associated with river intake and pumping station construction. The pipeline does traverse some likely sensitive areas along the 2 miles corridor, with at least one stream crossing and through some forested habitat. The flow into and out of the Lehigh should not have an impact on the river given the pumped flows relative to the overall river flows. Filling the quarry assumes there are no impacts to any sensitive areas in the quarry, which appears reasonable given topography and water level in the quarry. Again, the project is scored medium to high.

Permitting the project appears manageable. Of course, with all quarry’s the filling and withdrawal of water needs to meet regulatory scrutiny. If permitted the other typical construction permits should be achievable.

Permitting the project appears achievable, but the pipeline permits and easement may be challenging.

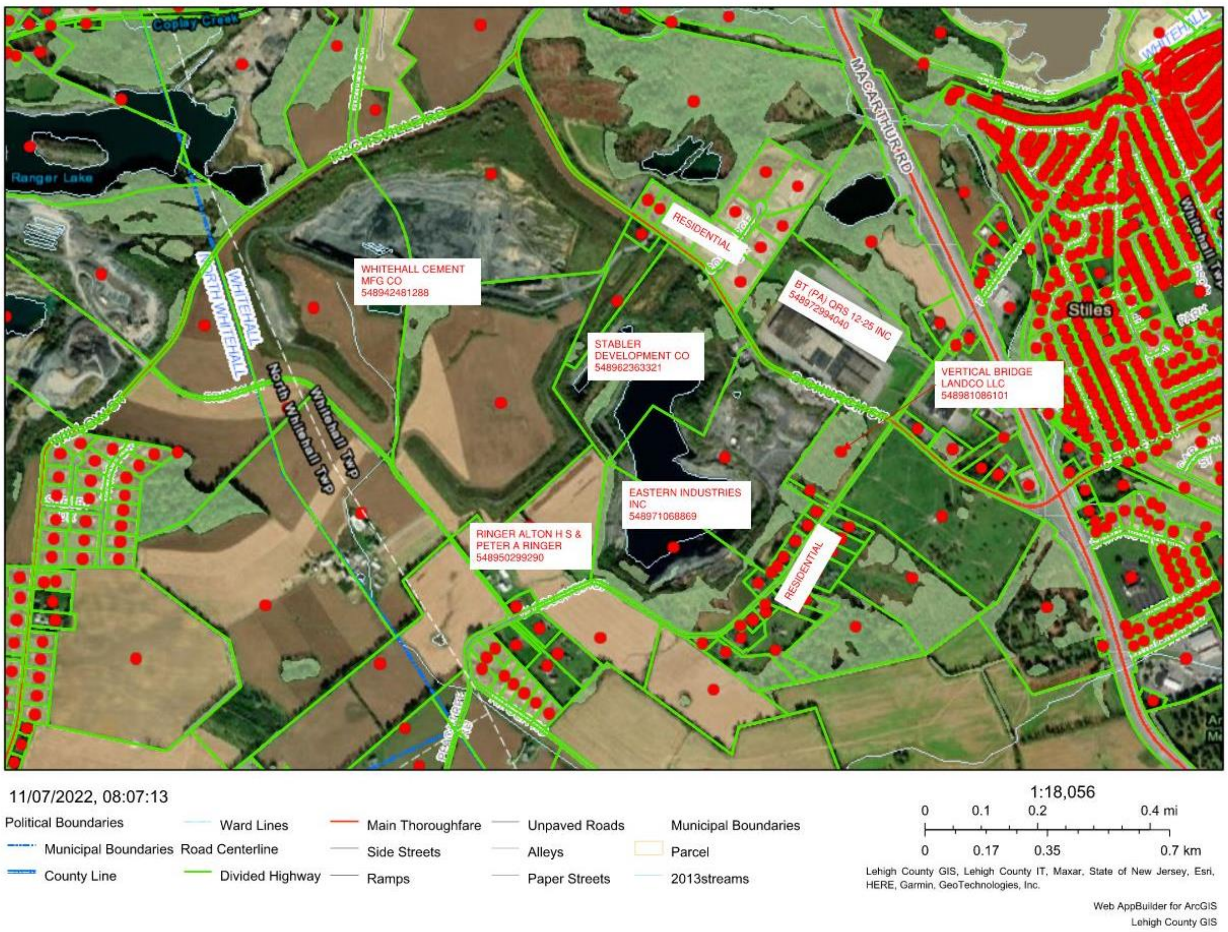
The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder and social impacts and related scoring are difficult to determine at this point in the project development. Economically, since the quarry is effectively inactive, tax ratables without with a quarry conversion should not be changed. Socially, the quarry closing would likely be viewed positively by the surrounding residential community in terms of reduced disruption, general safety, preserving resources and general aesthetics. The possibility of creating a controlled recreational or natural resource should be well received. Correspondingly, this project scores high in this category.

The quarry site and surrounding land is generally restricted ownership, with some surrounding residential development, as shown in Figure 5.1. The majority of the project area is industrial, agricultural or open space.

Figure 5.1: Land Ownership-Parcel Map



6 Project Cost & Schedule

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$8,170,000.00
Pipeline	LF	9400	$800.00	$7,520,000.00
Valves	#	13	$50,000.00	$650,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$4,672,000.00
Intake Structure	VF	96	$25,000.00	$2,400,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$17,407,500
Contingency			50%	$8,703,750
CONST. COST + CONTINGENCY				$26,111,250

The total capital cost is shown above. The land cost is not included. The Lehigh County Tax Assessment information was used to determine the assessed value of $3.66M. This does not necessarily reflect market value but was carried forward as the land value for estimating purposes.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a total of $37.12M

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 11 years. This includes:

- Design, permitting and land acquisition 6 years
- Construction 4 years
- Startup and initial filling of quarry 1 year.

7 Potential Ancillary Benefits

This category of potential ancillary benefits consider such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement.

If conversion to storage enables the permanent conversion to controlled recreation and nature/environmental education as planned and it is compatible with that use, then the score could be high. The nearby Ranger Lake is a converted quarry and supports active recreation. Further, a concept to manage all the water resources in the Coplay Cluster could present substantial benefit to balance industry, water resources, recreation/environmental improvements and the general region's development. Correspondingly, the potential ancillary benefits are considered high.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.83	25%	0.96
Infrastructure Design, Construction & Operation	3.00	20%	0.60
Environmental Impacts	4.86	20%	0.97
Social & Economic Impacts	4.69	15%	0.47
Project Cost & Schedule	3.67	15%	0.55
Ancillary Benefits	4.20	5%	0.42
AVERAGE	**4.04**		**3.97**

APPENDIX

Score sheet

STORAGE PROJECT SCORING

STORAGE PROJECT: Q22
NAME: Whitehall Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.83**			25%	**0.96**	
o Volume of storage provided (BG)	1.2	2					
o Hydrologic reliability of supply (months to fill)	1.3	5					
o Release rate (cfs)	50	5					
o Promptness of delivery to mainstem (day)	0.42	5					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**3.00**			20%	**0.60**	
o Site/Civil, Land & Easements		2.5					Site is normal; pipeline easements will be an issues
o Subsurface conditions		2.5					Karst area so may require extra work
o Infrastructure Complexity		3					Typical and pipeline is long but typical
o Construction complexity		3					Typical and pipeline is long but typical
o Operational complexity		4					Typical; could be more efficient with the Cluster
3. Environmental Impacts		**4.86**			20%	**0.97**	
o Protected species		5					None known
o Water quality degradation		5					Water assimmilated into the Lehigh easily
o Obstruction to passage of aquatic animals		5					None known
o Hydromodification		5					Minor if at all
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		5	5	5			Little if anything at the intake; none apparent on long pipeline
o Stream length inundated (mi)		4.5	5	4			Minor impact at intake
o Uplands inundated or developed (ac)		4.5	5	4			Some disturbance along pipeline, but minor
4. Social and Economic Impacts		**4.69**			10%	**0.47**	
o Disruption/displacement		5					Minor during construction
o Safety and health		4.5					Minimal consrtruction risk and long term improvement
o Social equity		5					No perceived equity issues
o Recreational loss		5					No loss and possible gain
o Cultural/historical resources		4					Unliklely, but could encounter some areas along pipeline/canal
o Aesthetic		5					No loss and possible gain
o Loss of tax revenue		4.5					Could be impact with quarry closing, but may be very minor
o Loss of production from farmland, timberland, quarries		4.5					Loss of quarry, but should be very minor
o Emissions of greenhouse gasses							
5. Project Costs & Schedule		**3.67**			15%	**0.55**	
o Land acquisition cost ($)	$3.66M						
o Construction Cost ($)	$26.11M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	$37.12M	4.5					
o Cost effectiveness ($/BG)	$30.93M	2.5					
o Schedule (Time to make Operational, years)	11	4					
6. Ancillary Benefits		**4.20**			10%	**0.42**	
o Flood control		3					Volumes are realatively small and requries pumping
o Recreation/tourism		5					Potential for major improvement
o Habitat/fishery enhancement		5					Potential to create habitat and enhancement; perhaps regional
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					Reclaims the quarry and may lead to others in the Cluster
o Ability to leverage funding from other programs		4					Reclamation bonds and local/state/federal funds might be leveraged
OVERALL		4.04				**3.97**	

Storage Project Summary

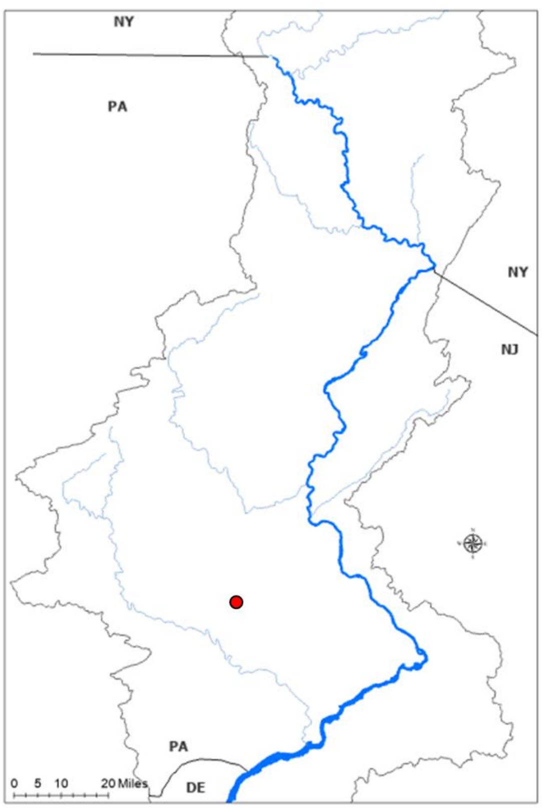
Project:	**Perkiomenville Quarry (Q23)**
Location:	Perkiomenville, Montgomery County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	1.0 Billion Gallons
Score:	3.91

1 Project Overview

In this storage project, water would be pumped from the Unami Creek to fill and store in the Perkiomenville Quarry, then later released for needed flow augmentation.

The Perkiomenville Quarry is an active quarry located in Perkiomenville, PA in Montgomery County (Figure 1.1). It is within Marlborough Township which borders Upper and Lower Frederick Townships and Upper Safford Township. The quarry has a maximum volume of 1.0 billion gallons. This quarry is approximately 33 acres in area and has an estimated fillable rim elevation 200 feet. At the quarry's deepest point, it has an elevation of -20 feet, giving the quarry a nominal depth of 220 feet. The nearest pumpable stream to the quarry is the Unami Creek, located about 450 feet away. The quarry is composed primarily of siltstone.

Figure 1.1 Project Location



2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 0.8 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. The quarry rim elevation extends above 200 ft in many places. Additional structures such as dams or berms/levees could possibly increase storage volume for this project, but were not included in the design or cost estimate. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Further analysis will be needed to account for storage lost to pervious areas. Figure 2.1 below shows the proposed fill elevation (200') along with contours showing the depth of the quarry.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

The intended design is to fill the quarry from the relatively low-flow Unami Creek. The intake point is near the confluence with Perkiomen Creek. The Perkiomen has higher normal flow and is controlled upstream by the Green Lane Reservoir and Knight Lake. The Unami is a high-quality cold-water fishery (HQ-CWF). The creek has a relatively small drainage area of only 49 sq. mi. This area develops a mean annual flow rate of 75 cfs (48 mgd), 7Q10 flow of 3 cfs and a bank full flow of 3470 cfs for the Unami Creek.

Reasonably reliable withdrawal from this source may not be possible or permittable. This source would not necessarily limit withdrawal because of low stream flow as established for this study. The stream flow should allow the storage to be filled during the 6-month high flow target period, despite the low-flow source because the storage volume is so low.

The discharge pumping from storage back to the creek is effectively controlled by the practical limits of the discharge pumps and the ability of the stream to dissipate and assimilate the flow. The assigned target discharge rate is 50 cfs (31.64 mgd), which is near the mean annual stream flow. This discharge rate was used for cost estimating but it may have to be reduced or dissipated when released to the stream.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	33 acres
Nominal Rim Elev.	200 ft.
Bottom Elev.	-20 ft.
Maximum Water Level Change (Ft.)	220 ft.
Maximum Volume (Billion Gallons)	1.0 BG
Operating Water Range (200ft to 24 ft)	176 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	0.8 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Unami Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	48.7 sq. mi.
Mean Annual Stream Flow Rate (cfs/mgd)	75 cfs / 48 mgd
Proposed Average Pumping Rate (mgd)	19.4 mgd
Average Vol. Pumped during 6 month Pumping Term	5.2 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	200 ft to 24 ft
Proposed discharge pumping rate (mgd)	32 mgd
Estimated Time to Release Operating Volume from Storage	0.8 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	66 miles
Travel Time at 2 mph (hours)	33 hours

2.3 Water Quality

The source stream, Unami Creek, has moderate to good water quality with some impairment based on the PA 303D listing. Table 2.2 below summarizes the listed impairments. The Chapter 93 designated use for Unami Creek is HQ-CWF (High Quality - Cold Water Fishes).

Table 2.2: 303D Listing Impairments

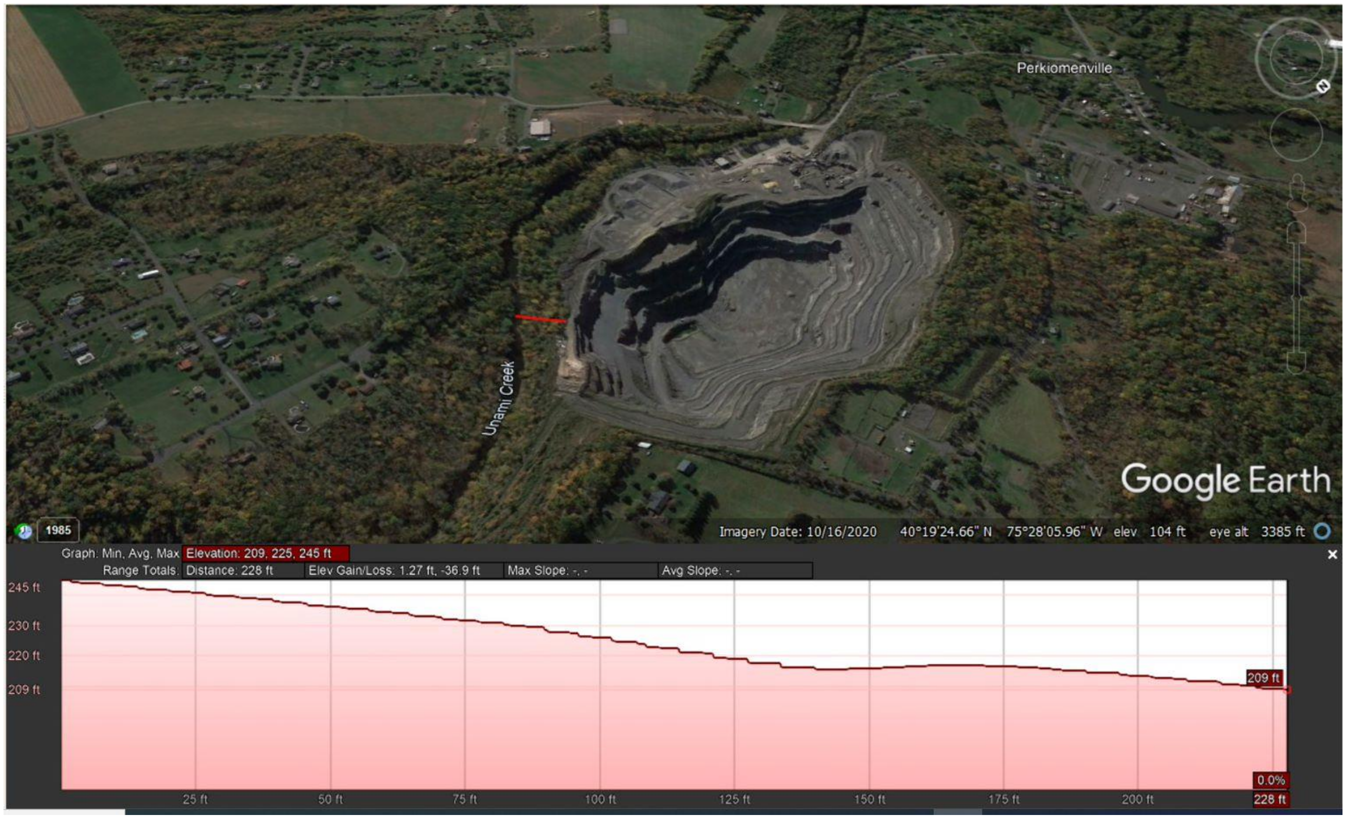
IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
Impaired - urban runoff, agriculture	Not Assessed	Not Assessed	Not Assessed

Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease relative to the source stream. However, temperature differences and reintroduction to the HQ-CWF Unami may be an issue. Water quality in the quarry should be adequate for flow augmentation.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities.

Figure 3.1: Approximate Pipe (red line) and Pump Station Location and Profile



3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is envisioned as described in the main report with submerged wedgewire screens in the creek connected to an onshore wetwell. The wetwell will be fitted with 3 x 10 mgd pumps with variable speed drives to control the withdrawal rate. The low flow of the Unami will force the withdrawal to the colder and higher flow months. Pumping will have to be greater during higher stream flows to effectively fill and replenish the quarry.

The quarry discharge/stream augmentation pumping station includes the typical components with a shaft or wetwell at the quarry and connecting pipe into the quarry pool. Stored water will be pumped from the shaft/wetwell using 4 x 8.6 mgd submersible pumps.

The balance of the connecting piping, valves and facilities will be as described in the main report.

Note that the proximity of the quarry to the creek and the elevation difference may allow for a gravity fill by skimming high stream flows, as will be discussed in Section 3.3.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline is approximately 230 lf of 30-inch diameter ductile iron pipe and related appurtenances. The pipeline should be able to be installed with deep cut and cover construction. The route from quarry to stream is short and property appears to be part of the quarry parcel or adjacent property that can be eased.

3.3 Alternate Piping/Pumping Configuration

The proximity and elevations of the quarry and stream may allow gravity filling of the quarry or skimming at high flows on the Unami. Table 2.1 and Table 3.1 provide some key elevations. The quarry rim is listed as 200 ft, but in many places is much higher, particularly along the creek. The creek elevation is approximately 225 ft. Therefore, a bank intake and short conveyance pipe with appropriate gates/valves could be used to allow the Unami to gravity feed into the quarry. If necessary, the withdrawal pumping facilities could be used to further fill the quarry, but it is really not required given the varying rim elevation on the opposite side of the quarry. This arrangement could allow for skimming only during high flows and effectively eliminate the withdrawal pumping system. Of course, the discharge pumping system will still be required to pump from the quarry back to the creek.

Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (3 x 10 mgd)	30 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (4 x 8.6 mgd)	31 mgd
Pipeline Distance	230 lf
Elevation at Discharge Point	225 ft
Elevation at High Point on Pipeline	245 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

Operations of this project would be automated as described for other projects. However, if gravity filling is employed, this could offer capital and operational savings as will be described further below.

4 Environmental Impacts

This storage project was reviewed against several environmental parameters as described in the body of the report. These included wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. There is some potential for hydromodification and stream change related to withdrawal from the low-flow Unami Creek and discharge back at high rates. This should be overcome by controlled withdrawal and even more so if a gravity filling concept is employed. Further, water quality (and temperature) may be a concern for the Unami given its HQ-CWF designation. However, this connection would be low in the watershed and near the confluence of the Perkiomen Creek.

Overall, the project is scored moderately high because the impacts are generally minor, given the site, the short pipeline and potential for managed withdrawal. Permitting of the project appears feasible, with some potential for regulatory concerns about the withdrawal amount and approach.

The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1. The adjacent area has some low density residential, but is primarily agricultural, industrial or open space.

Figure 5.1: Land Ownership

Social and economic impacts generally consider disruption/displacement, safety/health, social equity, recreational loss, aesthetics or loss of revenue or related production. Disruption should be minimal given the site and limited pipeline work. Safety and health should generally improve as the quarry shuts down. There will be no recreational loss and could possibly be an increase. The quarry shutting down could have a minor economic/tax ratables impact and production decrease, but should have minimal local impact.

6 Project Cost & Schedule

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Additional cost estimating justification can be provided upon request. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$384,000.00
Pipeline	LF	230	$800.00	$184,000.00
Valves	#	4	$50,000.00	$200,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$6,672,000.00
Intake Structure	VF	176	$25,000.00	$4,400,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$11,621,500
Contingency			50%	$5,810,750
CONST. COST + CONTINGENCY				$17,432,250

The total capital is shown above. Land costs are not included. Montgomery tax records were searched for tax assessment or market value. The site has an estimated value of $0.7M, but its most recent transaction was sold for $2.2M, leading to an estimated value of $3.5M as the land cost. This may not reflect the actual current or future market value, but was carried as the land costs in the evaluation.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 0.8 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the Present Value (NPV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $28.28M.

Assuming the passive filling options is developed, the operating costs may be reduced about one half or $250,000/year. This translates to an operating cost PV of $4.9M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 10 years. This includes:

- Design, permitting and land acquisition 4 years
- Construction 3 years
- Startup and initial filling of quarry 3 years.

7 Potential Ancillary Benefits

This category of potential ancillary benefits consider such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement. Flood control is unlikely. It is possible to see conversion to recreation, but the demand may be low given surrounding reservoirs and other recreational facilities. Environmental enhancements are likely as the quarry converts to storage, whether managed or natural enhancements. Regarding leveraging complimentary programs, the project could receive reclamation/restoration funding but the site is not large and the area demand may be less than other projects so competitive funding may be difficult to procure.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.58	30%	1.08
Infrastructure Design, Construction & Operation	3.80	10%	0.38
Environmental Impacts	4.79	15%	0.72
Social & Economic Impacts	4.88	10%	0.49
Project Cost & Schedule	3.67	30%	1.10
Ancillary Benefits	3.00	5%	0.15
AVERAGE	**3.95**		**3.91**

APPENDIX

Score Sheet.

DRBC
Feasibility Evaluation of Additional Storage Options

STORAGE PROJECT SCORING

STORAGE PROJECT: Q23
NAME: Perkiomenville Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.58**			30%	**1.08**	**#NAME?**
o Volume of storage provided (BG)	1	2					
o Hydrologic reliability of supply (months to fill)	1.1	5					Reduced pumping may be needed, but doesn't change score
o Release rate (cfs)	50	4.5					May need to reduce discharge
o Promptness of delivery to mainstem (day)	1.4	4					
o Geographic Benefit		3					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**3.80**			10%	**0.38**	
o Site/Civil, Land & Easements		4					Pipeline and land in one parcel and easy civil work
o Subsurface conditions		3					Typical
o Infrastructure Complexity		4					Short pipeline and gravity feed simplify design
o Construction complexity		4					Short pipeline and gravity feed simplify construction
o Operational complexity		4					Gravity option can simplify and reduce operational needs
3. Environmental Impacts		**4.79**			15%	**0.72**	
o Protected species		5					No know impacts; short pipeline
o Water quality degradation		4.5					None expected, but concern for HQ stream
o Obstruction to passage of aquatic animals		5					None expected
o Hydromodification		4					Potential concern for high flows from/to low for stream
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		5	5	5			None expected
o Stream length inundated (mi)		5	5	5			Intake are is minor
o Uplands inundated or developed (ac)		5	5	5			Pipeline is short
4. Social and Economic Impacts		**4.88**			10%	**0.49**	
o Disruption/displacement		5					All work onsite
o Safety and health		5					No issues
o Social equity		5					Equitable
o Recreational loss		5					No loss and potential for gain
o Cultural/historical resources		5					None expected; small work footprint
o Aesthetic		5					Improves area
o Loss of tax revenue		4.5					Some loss, but minor in area
o Loss of production from farmland, timberland, quarries		4.5					Some loss, but minor in area
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**3.67**			30%	**1.10**	
o Land acquisition cost ($)	$3.5M						
o Construction Cost ($)	$17.43M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	$28.28	4.5					
o Cost effectiveness ($/BG)	$28.28M	2.5					
o Schedule (Time to make Operational, years)	9	4					
6. Ancillary Benefits		**3.00**			5%	**0.15**	
o Flood control		1					
o Recreation/tourism		4					Some opportunity
o Habitat/fishery enhancement		4					Some opportunity
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		3					Nothing outstanding
o Ability to leverage funding from other programs		3					Nothing outstanding
OVERALL		3.95				**3.91**	

MOTT MACDONALD

Storage Project Summary

Project:	**Oxford Quarry (Q25)**
Location:	Oxford, Warren County, NJ
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	1.2 Billion Gallons
Score:	4.02

1 Project Overview

The scope of this storage project is to use the Tilcon Oxford quarry to store water pumped form the adjacent Pequest River and the later discharge to the Pequest River during time of need.

The Tilcon Oxford Quarry is an active quarry located in Oxford Township Warren County in west central New Jersey. It borders White, Washington, and Mansfield Townships (Figure 1.1).

The quarry has a maximum volume of 1.2 billion gallons. This quarry is approximately 64 acres in area and has an estimated fillable rim elevation 530 ft. At the quarry's deepest point, it has an elevation of 370 ft, giving the quarry a nominal depth of 160 feet. This quarry storage is shallow compared to the majority of other quarry projects.

The nearest pumpable stream to the quarry is the Pequest River, located about 3,000 feet away. However, the Delaware River, offering substantial flows, is located approximately 3 miles to the west.

The quarry is composed primarily of siltstone.

Figure 1.1 Project Location

2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume of over 1.0 BG.

The storage volume was calculated using available topographic information from available GIS sources and AutoCAD Civil 3D 2020. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as dams or berms/levees are suggested to increase storage volume for this project. The calculated volume assumes the interior of the quarry to generally be impervious with minimal leakage. Figure 2.1 below shows contours indicating the depth of the quarry.

Figure 2.1: Aerial View with Contours

2.2 Fill and Discharge

The intended design is to withdraw from and discharge to the Pequest River. However, limited flows and regulatory requirements could require usage of the Delaware River, as will be discussed further below. The Pequest has a drainage area of 115 sq. mi. and a mean annual flow of 198 cfs. The 7Q10 flow is 65 cfs with a bank full flow of 2,610 cfs. In the area of the site, the river is broad and relatively shallow and intake withdrawal may require river bottom modification to form a withdrawal pool. Based on the average winter month withdrawal approach described in the main report and referenced Technical Memorandum, the river could on average yield approximately 50 mgd. Given the small quarry volume, this site is not considered stream limited, and should be able to pump at the targeted average 31 mgd range.

The discharge pumping from quarry storage back to the Pequest River is effectively controlled by the practical limits of the discharge pumps and the ability of the stream to dissipate and assimilate the flow. The assigned target discharge rate is 50 cfs (31.64 mgd), which is much less than the mean annual stream flow. For the purposes of this storage project, this discharge rate was used for cost estimating. The discharge flow rate may have to be reduced and flow reintroduced to the stream may need to be dissipated

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	64 acres
Nominal Rim Elev.	530 ft.
Bottom Elev.	370 ft.
Maximum Water Level Change (Ft.)	160 ft.
Maximum Volume (Billion Gallons)	1.2 BG
Operating Water Range (530ft-402 ft)	128 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	1.0 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Pequest River
Anticipated Source Stream Drainage Area (Sq. Miles)	115 sq.mi.
Mean Annual Stream Flow Rate (cfs/mgd)	198 cfs / 128 mgd
Proposed Average Pumping Rate (mgd)	31 mgd
Average Vol. Pumped during 6 month Pumping Term	5.6 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	530 ft to 402 ft
Proposed discharge pumping rate (mgd)	32 mgd
Estimated Time to Release Operating Volume from Storage	1 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	4 miles
Travel Time at 2 mph (hours)	2 hours

2.3 Water Quality

The Pequest River has some impairments and marginal water quality based on the 303D listing. Table 2.2 below summarizes the listed impairments. New Jersey classifies the Pequest River as FW2-TMC1 (Freshwater 2 – Trout Maintenance, Category 1 Waters). Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease relative to the source stream and that the quarry water quality will be acceptable for flow augmentation.

Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
Impaired - DO, arsenic	Impaired	Not Assessed	Impaired

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile

3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is envisioned as typical with the intake as wedgewire halfscreens on the river bottom, possibly placed in a constructed river pool for additional submergence. Adequate submergence at low flows will be an issue. However, if withdrawal is restricted to higher flows this should be acceptable, but requires detailed design. The intake will connect to the onshore wetwell, fitted with submersible pumps (4 x 9 mgd pumps). Facilities will be automated as typical.

The quarry discharge/stream augmentation pumping station includes the typical components with a shaft or wetwell at the quarry and connecting pipe into the quarry pool. Stored water will be pumped from the shaft/wetwell using 4 x 8.6 mgd submersible pumps.

The balance of the connecting piping, valves and other pumping station facilities will be as described in the main report.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline is only about 3000 lf to the Pequest River and may be shorter based on the actual intake location. The pipeline is anticipated to be the typical 30 inch diameter ductile iron pipe (DIP) installed at nominal burial depth with conventional cut and cover methods. The pipeline route traverses public or utility right-of-way (ROW) for approximately 2000 lf with the balance requiring clearing of forested lands to access the river. Easements and environmental requirements in this area could be problematic.

3.3 Alternate Piping/Pumping Configuration

Gravity discharge from the quarry to the river could be feasible. Note the elevations in Table 2.1 of the quarry rim/bottom (~530/~370 ft) relative to the Pequest River elevation (~380 ft). The configuration could enable gravity release from the quarry storage back to the Pequest River. This may enable the use of the pipe for filling and perhaps complete elimination of the quarry discharge pumping facilities. This may be a significant savings in capital and operational costs as will discussed further below.

A second alternate for this project is the option to use the Delaware for source water and discharge with a pipeline connection from quarry to the river. A direct route would be approximately 3.5 miles and an indirect route following primarily roadway and utility ROW is approximately 5 miles. Such a connection provides ample supply and direct discharge to the Delaware River at an important location. A pipeline to the Delaware may also offer a gravity release option, as can be further evaluated.

The cost and scoring implications of this option will be discussed in later sections.

Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	31 mgd
Pump Capacity (4 x 9 mgd)	36 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (4 x 8.6 mgd)	34 mgd
Pipeline Distance	3,000 lf
Elevation at Discharge Point	380 ft
Elevation at High Point on Pipeline	632 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule. In terms of operations of the project, they would be as typical if there is no gravity option. Provided a gravity release option, the operations will be reduced considerably.

4 Environmental Impacts

This storage project was reviewed against several environmental parameters as described in the body of the report. These included wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project using the Pequest River is scored relatively high. No wetlands are expected to be encountered. There is some potential for protected species and habitat impacts when clearing for the pipeline as it moves from the ROW to the river. The river is not large but should have sufficient flow that controlled pumping should not create impacts or hydromodification. Generally, the impacts are expected to be minimal.

Permitting the project appears possible. However, permitting planned withdrawal from this creek may be a challenge in New Jersey. If using the Pequest is not possible, the option for the Delaware River source is a reasonable, albeit more expensive, alternate. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

Stakeholder and social impacts are expected to be minor. The quarry site and surrounding land is generally restricted ownership as shown in Figure 5.1. The adjacent area is industrial, agricultural or open space with limited residential. The pipeline route traverses ROW and some private land.

Figure 5.1: Land Ownership

Social and economic impacts generally consider disruption/displacement, safety/health, social equity, recreational loss, aesthetics or loss of revenue or related production. These all appear to be fairly benign for this project. There may be an economic impact to the community if the quarry ceases, but this should not be a significant impact.

6 Project Cost & Schedule

Mott MacDonald a cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,565,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$50,000.00	$600,000.00
Other	LS	1	$90,000.00	$90,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$265,500.00	$265,500.00
Structure	SF	1200	$350.00	$420,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$2,750,000.00
Pipeline	LF	3000	$800.00	$2,400,000.00
Valves	#	7	$50,000.00	$350,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$5,472,000.00
Intake Structure	VF	128	$25,000.00	$3,200,000.00
Pumping Station				
Pumps	#	4	$450,000.00	$1,800,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS	1		$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$12,787,500
Contingency			50%	$6,393,750
CONST. COST + CONTINGENCY				$19,181,250

The total capital is shown above. Land cost is not included. Limited information was publicly available to assess land costs of the quarry. Based on comparably sized facilities in other locations, $4M was used for the land cost and will carry forward in the evaluation.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $30.53M.

Assuming the passive gravity discharge, the operating costs may be reduced to about $250,000/year. This translates to a PV of $4.9M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 9 years. This includes:

- Design, permitting and land acquisition 5 years
- Construction 3 years
- Startup and initial filling of quarry 1 year.

7 Potential Ancillary Benefits

This category of potential ancillary benefits considers such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement. Flood control is unlikely. Some recreational/tourism and environmental enhancements may be possible, but given the surrounding area, this is believed to be limited. Some Green Acres or similar funding might be available, but again, given the area this is probably limited.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.00	30%	1.20
Infrastructure Design, Construction & Operation	3.60	10%	0.36
Environmental Impacts	4.57	15%	0.69
Social & Economic Impacts	4.88	10%	0.49
Project Cost & Schedule	3.83	30%	1.15
Ancillary Benefits	2.80	5%	0.14
AVERAGE	**3.95**		**4.02**

Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

The above scores are for the base case of pumping from/to the Pequest River. Assuming a gravity discharge from the quarry to the Pequest, the capital and operations cost may reduce by $5M and $2.45M respectively. This changes the weighted score very slightly, from 3.67 to 3.69. Assuming a Delaware River source and gravity discharge, the project cost increases by approximately $14M and some other individual scores are improved, but the overall score is comparable.

APPENDIX

Score sheet.

STORAGE PROJECT SCORING

STORAGE PROJECT: Q25
NAME: Tilcon Oxford Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**4.00**			30%	**1.20**	
o Volume of storage provided (BG)	1.2	2					
o Hydrologic reliability of supply (months to fill)	1.3	5					
o Release rate (cfs)	50	5					
o Promptness of delivery to mainstem (day)	0.08	5					
o Geographic Benefit		4					
o Quality of stored water		3					
2. Infrastructure Design, Construction and Operation		**3.60**			10%	**0.36**	
o Site/Civil, Land & Easements		4					Assume quarry available; some minor easements for pipeline
o Subsurface conditions		4					No karst and lower permiability
o Infrastructure Complexity		3					Typical and pipeline straight forward design
o Construction complexity		3					Typical and pipeline straight forward construction
o Operational complexity		4					Operations could be improved with gravity feed
3. Environmental Impacts		**4.57**			15%	**0.69**	
o Protected species		5					None known
o Water quality degradation		5					Should be none
o Obstruction to passage of aquatic animals		5					None known
o Hydromodification		4.5					Minimal potential for low flow stream impact
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		5	5	5			Non or little
o Stream length inundated (mi)		4	3	5			Should be none
o Uplands inundated or developed (ac)		3.5	2	5			Minor at forest installation of pipeline
4. Social and Economic Impacts		**4.88**			10%	**0.49**	
o Disruption/displacement		5					No issues
o Safety and health		5					Potential improvement
o Social equity		5					No issues
o Recreational loss		5					Potential for gain
o Cultural/historical resources		5					Non apparent
o Aesthetic		5					Site improvement
o Loss of tax revenue		4.5					Minor loss expected
o Loss of production from farmland, timberland, quarries		4.5					Minor loss expected
o Emissions of greenhouse gasses		3					No data
5. Project Costs & Schedule		**3.83**			30%	**1.15**	
o Land acquisition cost ($)	$4M						
o Construction Cost ($)	$19.18M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	$30.53M	4.5					
o Cost effectiveness ($/BG)	$25.44M	3					
o Schedule (Time to make Operational, years)	9	4					
6. Ancillary Benefits		**2.80**			5%	**0.14**	
o Flood control		2					Unlikley
o Recreation/tourism		3					Possible but given the area may be limited
o Habitat/fishery enhancement		3					High elevation setting limits fishery enhancement
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		3					None apparent
o Ability to leverage funding from other programs		3					Possible Green Acres and related funding to leverage
OVERALL		3.95				**4.02**	

MOTT MACDONALD

Storage Project Summary

Project:	**New Enterprise Nazareth Quarry (Q27)**
Location:	Nazareth, Northampton County, PA
Storage Type:	Quarry (Fill & Draw)
Est. Volume:	1.5 Billion Gallons
Score:	3.86

1 Project Overview

The scope of this storage project is to draw water from the Bushkill Creek, similar to projects Q5, Q6 and Q7, which are nearby. Water will be stored in the Nazareth Quarry and returned to the creek when needed to supplement the Basin.

The New Enterprise Stone and Lime Co. Nazareth Quarry is an inactive quarry located in Nazareth, PA in Northampton County (Figure 1.1). The quarry has a maximum volume of 1.5 billion gallons. This quarry is approximately 151 acres in area and has an estimated fillable rim elevation 380. At the quarry's deepest point, it has an elevation of 320, giving the quarry a nominal depth of 60 feet. This is unusually shallow for a quarry of this size in this area. The nearest reasonably sized stream to the quarry is the Bushkill Creek, located about 7900 feet away.

The quarry operated for many years, mined primarily for limestone. Between 1999 and 2005 operations presumably ceased and the quarry filled with water. The quarry is currently inactive.

Figure 1.1 Project Location

2 Water Quantity & Quality

2.1 Quarry Storage Volume

Table 2.1 presents key dimensions of the quarry, foremost its estimated operable water storage volume over 1.2 BG.

The storage volume was calculated using available topographic information from Pennsylvania Spatial Data Access and AutoCAD Civil 3D 2020. Limited data was available given the quarry has been full of water since 2005. Historical Google Earth images allowed for approximating elevations of the quarry when actively mined. AutoCAD and average end area methods approximated the volume as stated. The top elevation of full storage was assumed to be the stated rim elevation. No additional structures such as saddle dams or levees are suggested to increase storage volume for this project. The calculated volume assumes the interior of the quarry to generally be flat. Storage assumes the quarry is impervious with minimal leakage or can be made such. Given the filling over the years, the quarry is apparently communicating with the surrounding groundwater. Further analysis will be needed to account for storage lost and groundwater interaction. Figure 2.1 below shows one of several historical images used to reconstruct the quarry volume.

Figure 2.1: Historical aerial view (1993)

2.2 Fill and Discharge

The intended design is to fill from and discharge to the Bushkill Creek. The Bushkill is a relatively low-flow stream and is located approximately 1.5 miles away. The Delaware River is another possible connection but is 5 miles away by straight distance and approximately 7 miles away following public right-of-way to minimize easement issues.

While the quarry provides a reasonable volume, refilling the quarry will be a challenge based on the limited flow of the Bushkill Creek as well as the distance of the creek to the quarry. Groundwater and some surface water recharge will occur, but are ignored in this analysis. Given the 7-mile pipeline line distance to the Delaware River and its likely high cost, this project was developed with the Bushkill source, despite some flow concerns. However, if this project became part of a cluster with adjacent quarries a pipeline to the Delaware River may be feasible.

The Bushkill Creek is a high quality cold water fishery (HQ-CWF) and has a drainage are of only 31 sq.mi.. The creek has a mean annual flow of 49 cfs (31 mgd) and a 7Q10 flow of 2 cfs. Reasonably reliable withdrawal from this source may not be possible or permittable. This low flow limits withdrawal and would follow the approach discussed in the main report of pumping only during the 6-month high flow period and adjusting withdrawal rates to track flow and maximize withdrawal during high flow, effectively skimming flows. Based on the adopted approach, approximately 6 mgd can be withdrawn, on average, over the 6-month high flow period. However, the pumping station will be designed to withdraw up to 18 mgd when source water supply is adequate.

The discharge pumping from storage back to the creek is effectively controlled by the practical limits of the discharge pumps and the ability of the stream to dissipate and assimilate the flow. The assigned target discharge rate is 50 cfs (31.64 mgd), which is near the mean annual flow. This discharge rate was used for cost estimating. The discharge flow rate may have to be reduced, and flow re-introduced to the stream will need to be dissipated.

The key parameters relating to storage volume and fill/discharge supply are summarized in Table 2.1 below.

Table 2.1: Storage and Fill/Discharge Parameters

DESCRIPTION	VALUE
Storage	
Area (Acres)	151 acres
Nominal Rim Elev.	380 ft.
Bottom Elev.	320 ft.
Maximum Water Level Change (Ft.)	60 ft.
Maximum Volume (Billion Gallons)	1.5 BG
Operating Water Range (380ft-332 ft)	48 ft.
Operating Volume (Billion Gallons) - ~80% max. vol.	1.2 BG
Water Supply – Quarry Fill (Stream Withdrawal)	
Anticipated Source Stream	Bushkill Creek
Anticipated Source Stream Drainage Area (Sq. Miles)	31.2 sq.mi.
Mean Annual Stream Flow Rate (cfs/mgd)	49 cfs / 31 mgd
Proposed Average Pumping Rate (mgd)	6-18 mgd (avg. 6)
Average Vol. Pumped during 6 month Pumping Term	1.1 BG
Water Release – Quarry Discharge (Stream Augmentation)	
Quarry Operating Water Elevation Range (ft)	380 ft to 332 ft
Proposed discharge pumping rate (mgd)	32 mgd
Estimated Time to Release Operating Volume from Storage	1.2 months
Water Supply – Travel to Use	
Stream Miles to Delaware River	9 miles
Travel Time at 2 mph (hours)	5 hours

2.3 Water Quality

Bushkill Creek has marginal water quality based on the PA 303D listing. Table 2.2 below summarizes the listed impairments. Despite some impairments, the stream has a Chapter 93 classification of a high-quality, cold-water fishery (HQ-CWF) and supports both stocked and wild trout populations. Water quality may change after pumping and settling in the quarry. It is assumed that the stored quality will not decrease relative to the source stream and will be acceptable for discharge back to the stream.

Table 2.2: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
Supporting	Not Assessed	Impaired - mercury atmospheric deposition	Not Assessed

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the quarry storage, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Figure 3.1 shows a schematic plan and profile illustrating the major facilities.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile

3.1 Pumping Facilities

The quarry fill/stream withdrawal pumping station is expected to be the typical bottom intake and wetwell pumping system as other projects. The bottom intake on a low flow stream may create some design challenges or require creation of a pumping pool for screen submergence. The withdrawal pumping station will be fitted with 3 x 6 mgd pumps for a total maximum capacity of approximately 18 mgd.

The quarry discharge/stream augmentation pumping station includes the shaft/wetwell at the quarry and submersible pumps to lift the water from the quarry at a suitable target flow rate to recharge the stream. The discharge pumping will be completed with 3 x 11.5 mgd pumps to meet the discharge flow target. Returning that flow rate to the stream may require significant dissipation at the creek.

3.2 Pipeline

The proposed pipeline route is schematically shown in Figure 3.1. The pipeline is approximately 7900 lf of 30" diameter ductile iron pipe (DIP) installed with conventional means. The pipe alignment is generally along a railroad right-of-way (ROW), which is possible but may be difficult and time consuming to secure easements/access.

Table 3.1 below summarizes the piping and pumping facility parameters.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Quarry Fill (Stream Discharge)	
Design Flow	18 mgd
Pump Capacity (3 x 6 mgd)	18 mgd
Quarry Discharge (Stream Augmentation)	
Design Flow	32 mgd (50 cfs)
Pump Capacity (3 x 11.5 mgd)	34.5 mgd
Pipeline Distance	7,900 lf
Elevation at Discharge Point	374 ft
Elevation at High Point on Pipeline	403 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in

Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

This project will be automatically operated as the other quarry concepts. However, given the flow constraints and concerns at discharge for energy dissipation, this location will require some additional controls and my require periodic inspection to double check automatic performance.

4 Environmental Impacts

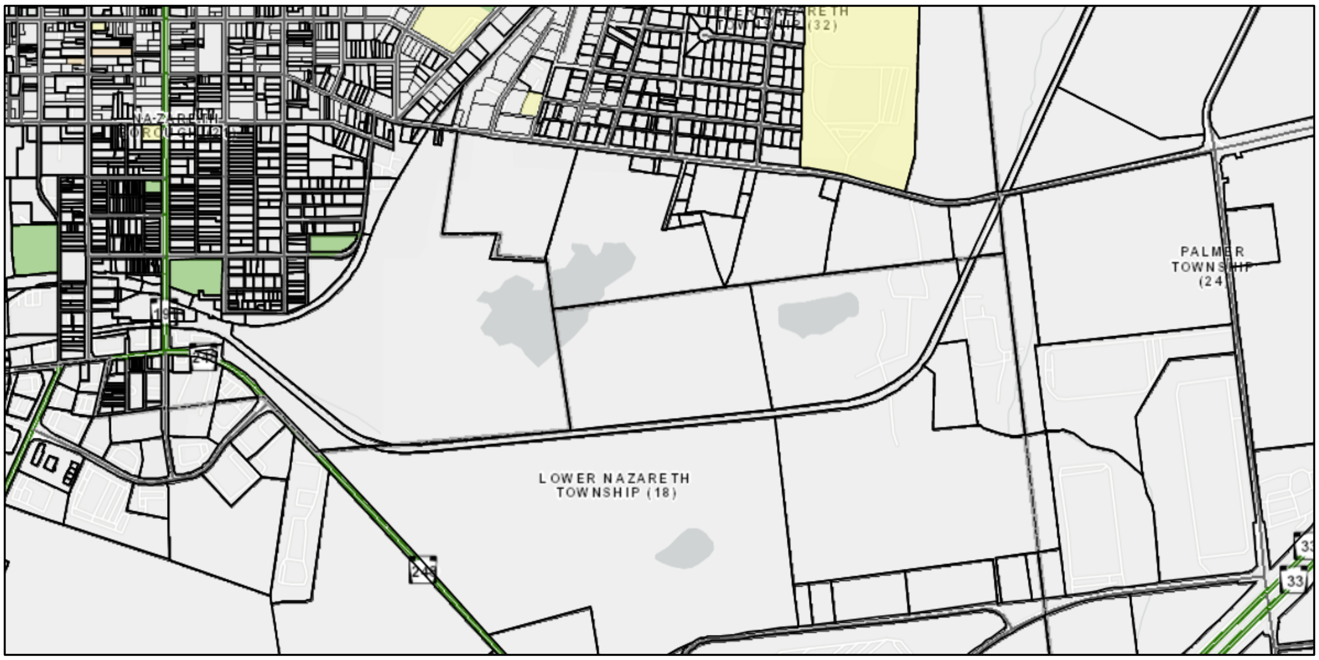
This storage project was reviewed against several environmental parameters as described in the body of the report. These included wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the impacts should be minor. The intake and stream withdrawal pumping station will have typical minor disturbances. The pipeline, while 7900 lf is proposed to follow the railroad ROW for its entire length. There is one identified stream crossing along the route, but this can be accomplished with trenchless methods if required. No heavily established forested areas or wetlands should be impacted.

Permitting the project appears technically practical. There may be concerns about proposed water withdrawal levels from the Bushkill Creek, given its low flow. Other permits are as typical. The major permits for this project, as can be reasonably identified at this concept level of development, are discussed further in the main report. Additional permits may be required.

5 Social and Economic Impacts

The quarry site and surrounding land is industrial or agricultural and generally restricted ownership as shown in Figure 5.1. The adjacent residential area or other public areas a reasonably distant.

Figure 5.1: Land Ownership



Land ownership of the quarry is in multiple parcels and multiple owners.

Social and economic impacts generally consider disruption/displacement, safety/health, social equity, recreational loss, aesthetics or loss of revenue or related production. These all appear to not be negatively impacted. The quarry is essentially dormant so converting to storage should not have a negative impact. The change from an abandoned quarry to a storage reservoir with environmental or recreational improvements would be viewed favorably and have a positive social impact.

6 Project Cost & Schedule

Mott MacDonald prepared a feasibility-level cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
FILL PUMPING STATION			Subtotal	$3,749,500.00
Intake				
Screens	LS	3	$80,000.00	$240,000.00
Structure	VF	12	$75,000.00	$900,000.00
Other	LS	1	$135,000.00	$135,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$244,500.00	$244,500.00
Structure	SF	800	$350.00	$280,000.00
Other	LS	1	$100,000.00	$100,000.00
Dissipation	LS	1	$500,000.00	$500,000.00
PIPELINE			Subtotal	$6,870,000.00
Pipeline	LF	7900	$800.00	$6,320,000.00
Valves	#	11	$50,000.00	$550,000.00
DISCHARGE PUMPING SYSTEM			Subtotal	$2,522,000.00
Intake Structure	VF	28	$25,000.00	$700,000.00
Pumping Station				
Pumps	#	3	$450,000.00	$1,350,000.00
MEP	LS	1	$42,000.00	$42,000.00
Structure	SF	800	$350.00	$280,000.00
Electrical Service	LS	1	$50,000.00	$50,000.00
Other	LS	1	$100,000.00	$100,000.00
Treatment	LS			$-
ACCESS ROADS				$1,000,000
New roads	Mile	2	$500,000	$1,000,000
SUBTOTALS				
Construction Costs Subtotal				$14,141,500
Contingency			50%	$7,070,750
CONST. COST + CONTINGENCY				$21,212,250

The total capital is shown above. Land costs are not included. Tax parcel information and assessment records were used to establish an approximate land cost. The assessed value of identified tax parcels is approximately $1.5M. A current market value of $3.5M based on the tax parcel information and value of comparable quarry land was used for the cost estimate.

Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1.5 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $32.06M

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 10 years. This includes:

- Design, permitting and land acquisition 6 years
- Construction 3 years
- Startup and initial filling of quarry 1 years

7 Potential Ancillary Benefits

This category of potential ancillary benefits consider such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement. There is minimal opportunity for flood control given the hydraulics of the system. In terms of recreational/environmental benefits, the quarry area could be converted to improved habitat and open to controlled recreation similar to other facilities in the area. Finally, there may be an opportunity to leverage reclamation funds, as well as local/state/federal funds for greenspace preservation and recreational improvements. In general, this project scores high for potential ancillary benefits.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.67	30%	1.10
Infrastructure Design, Construction & Operation	3.40	10%	0.34
Environmental Impacts	4.21	15%	0.63
Social & Economic Impacts	5.00	10%	0.50
Project Cost & Schedule	3.83	30%	1.15
Ancillary Benefits	2.80	5%	0.14
AVERAGE	**3.82**		**3.86**

APPENDIX

Scoresheet

STORAGE PROJECT SCORING

STORAGE PROJECT: Q27
NAME: New Enterprise Nazareth Quarry

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate)	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
	(enter values only						
1. Water Quantity and Quality		**3.67**			30%	**1.10**	
o Volume of storage provided (BG)	1.5	2					
o Hydrologic reliability of supply (months to fill)	4	5					
o Release rate (cfs)	50	3					
o Promptness of delivery to mainstem (day)	0.4	5					
o Geographic Benefit		4					
o Quality of stored water		3					; some concern for discharge back to the Bushkill
2. Infrastructure Design, Construction and Operation		**3.40**			10%	**0.34**	
o Site/Civil, Land & Easements		3					Facility land possible; pipeline ROW at railroad will be a challenge
o Subsurface conditions		4					Karst conditions may pose challenges
o Infrastructure Complexity		3					Relatively straight forward, but pipeline is significant
o Construction complexity		4					Reasonab construction
o Operational complexity		3					typical
3. Environmental Impacts		**4.21**			15%	**0.63**	
o Protected species		5					Most of the work is in the quarry or along the railroad
o Water quality degradation		3					Quality of disharge fine but quanity is high relative to stream; groundwater could be impacted
o Obstruction to passage of aquatic animals		5					None
o Hydromodification		2					Potential for issues with high flow to Bushkill; temperature concerns
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		5	5	5			
o Stream length inundated (mi)		4.5	5	4			Minor intake modification
o Uplands inundated or developed (ac)		5	5	5			Work in quarry or ROW
4. Social and Economic Impacts		**5.00**			10%	**0.50**	
o Disruption/displacement		5					None
o Safety and health		5					Construction is in non-residential area
o Social equity		5					No issues
o Recreational loss		5					Could be improvement
o Cultural/historical resources		5					No know impact
o Aesthetic		5					Could be improvement
o Loss of tax revenue		5					None, given abandoned
o Loss of production from farmland, timberland, quarries		5					None, given abandoned
o Emissions of greenhouse gasses		3					No calculation to support
5. Project Costs & Schedule		**3.83**			30%	**1.15**	
o Land acquisition cost ($)	3.5M						Estimate from comparables
o Construction Cost ($)	$21.21M						
o Operating Cost ($/yr)	$0.375M						
o Overall Cost ($)	$32.06M	4.5					
o Cost effectiveness ($/BG)	$21.37	3					
o Schedule (Time to make Operational, years)	10	4					
6. Ancillary Benefits		**2.80**			5%	**0.14**	
o Flood control		1					None Likely
o Recreation/tourism		3					Some opportunity to enhance
o Habitat/fishery enhancement		3					Some opportunity to enhance
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		3					Quarry permanently reclaimed with conversion
o Ability to leverage funding from other programs		4					Combining funding may be possible
OVERALL		3.82				**3.86**	

Storage Project Summary

Project:	**Silver Creek Mine (M5)**	
Location:	Blythe Township, Schuylkill County, PA	
Storage Type:	Deep Coal Mine (Draw)	
Est. Volume:	1.77 Billion Gallons	
Score:	3.12	

1 Project Overview

The scope of this storage project is to utilize the water stored in the Silver Creek Mine pool, and extract as needed to supplement the Basin flows.

The mine pool is located primarily in Blythe Township, near the town of Silver Creek in Schuylkill County, PA. This is high in the Schuylkill River watershed and Delaware River Basin as shown in Figure 1.1. Note there are related physical features in the area with similar names: the town of Silver Creek, the stream of Silver Creek and the Silver Creek Reservoir. The Silver Creek reservoir is the subject of a new-reservoir storage project (N7).

The mine operated for many years, but is currently inactive.

Figure 1.1 Project Location

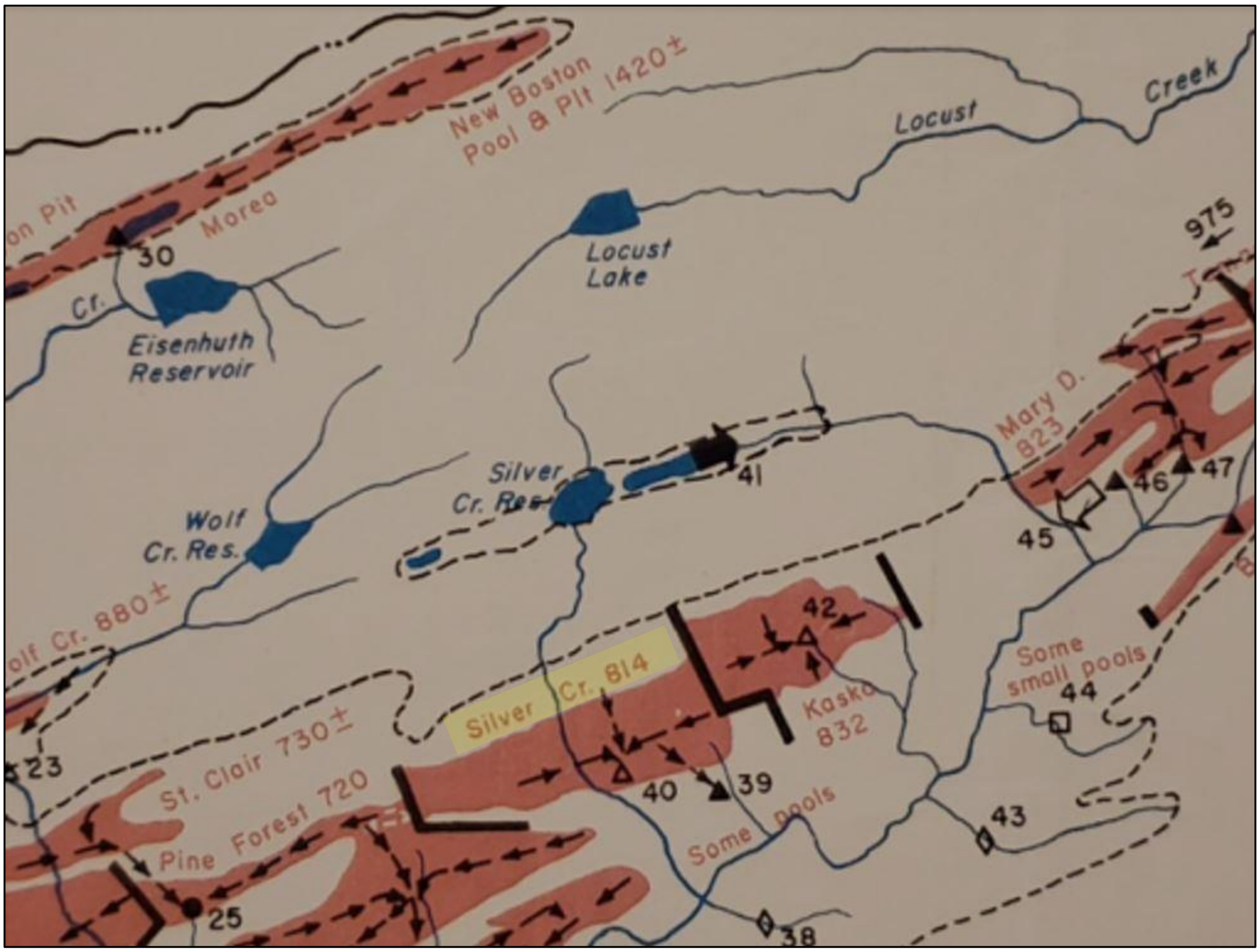
2 Water Quantity & Quality

2.1 Storage Volume

The storage volume of 1.77 BG was estimated by Ash et. al (1949) as described in the main report. This is the complete mine pool volume and assumes all water would be usable. Figure 2.1 below shows the mine pool as mapped by the PA Dept. of Forests and Waters (PADFW, 1968), as an update to information originally compiled by Ash et al.

The figure shows the general plan view configuration of the Silver Creek Pool. It also provides interpreted direction of flow (arrows); overflow elevations (red values) and barrier pillars (dark black lines). Also note the surrounding mine pools, particularly the Morea Mine Pool (M32).

Figure 2.1: Mine Pool Map-Silver Creek Area (Source: PADFW, 1968)



2.2 Fill and Discharge

The intended design is to utilize a portion of the mine pool volume for usable storage and pump out as required to augment flow downstream. The mine pool currently overflows at an elevation of approximately 800 ft MSL and reportedly discharges into Silver Creek. Silver Creek is a small stream that flows into and out of Silver Creek Reservoir and has a mean annual flow of 44 cfs. Table 2.1 below provides some additional summary details of storage and discharge related parameters.

Table 2.1: Storage and Discharge Parameters

DESCRIPTION	VALUE
Storage	
Maximum Volume (Billion Gallons)	1.77 BG
Operating Volume (Assumes 50% usable)	0.88 BG
Water Supply – Mine Pool Volume & Recharge	
Proposed Average Pumping Rate (mgd)	NA
Water Release – Mine Discharge (Stream Augmentation)	
Mine Gravity Overflow Point (ft)	~800 ft
Mine Pool Assumed Operating Water Elevation Range (ft)	800 ft to 700 ft
Proposed Discharge Pumping Rate	25 cfs/16 mgd
Estimated Time to Release Operating Volume from Storage	1.8 months
Water Supply – Travel to Use	
Receiving Stream	Silver Creek (to Schuylkill River)
Receiving Stream Flows (Mean, 7Q10, Bank Full)	6.22 cfs / 2.87 cfs/ 113 cfs
Stream Miles to Delaware River	125 miles
Travel Time at 2 mph (hours)	63 hours

2.3 Water Quality

The water quality of stored mine water is unknown. Some historical information adapted from Wood (Wood, 1996) is provided in Table 2.2. It shows varying water quality among the considered mine pools with water quality at Silver Creek having low pH, moderate sulfates and high iron.

Table 2.2: Mine Pool Water Quality Samples (after Wood, 1996)

Proj .ID	Proj. Name	Description	Sample Date	Water Temp. (°C)	Spec. Conduct. (uS/cm)	pH	Sulfate (mg/l)	Iron (mg/l)	Manganese (mg/l)	Alkalinity at pH 4.5 as $CaCO_3$ (mg/l)
M4	**Silver Creek**	**Tunnel**	**4-22-75**	**12.5**	**500**	**4.5**	**270**	**20**	**-**	**0**
M4	**Silver Creek**	**Tunnel**	**11-7-91**	**11.5**	**630**	**6**	**300**	**27**	**3.5**	**54**
M10	Wadesville	Pump	4-22-75	14.0	1500	7.1	630	1	2.3	380
M10	Wadesville	Pump	11-6-91	14.0	1190	7.1	350	2	3.2	275
M19	Phoenix	-	-	-	-	-	-	-		-
M20	Otto	Airshaft	4-23-75	10.5	800	4.7	430	26	4.4	10
M20	Otto	Airshaft	10-31-91	10.3	730	6.1	300	15	3.0	66
M32	Morea	Strip Pool	4-16-75	8.0	440	3.2	140	10	-	0
M32	Morea	Strip Pool	11-6-91	8.0	308	4.0	110	9.7	1.6	0

The receiving stream, Silver Creek, has marginal water quality based on the PA 303D listing. Table 2.3 below summarizes the listed impairments.

Table 2.3: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
IMPAIRED - iron/manganese due to acid mine drainage, siltation due to coal mining, habitat alterations due to channelization	Supporting	Not Assessed	Not Assessed

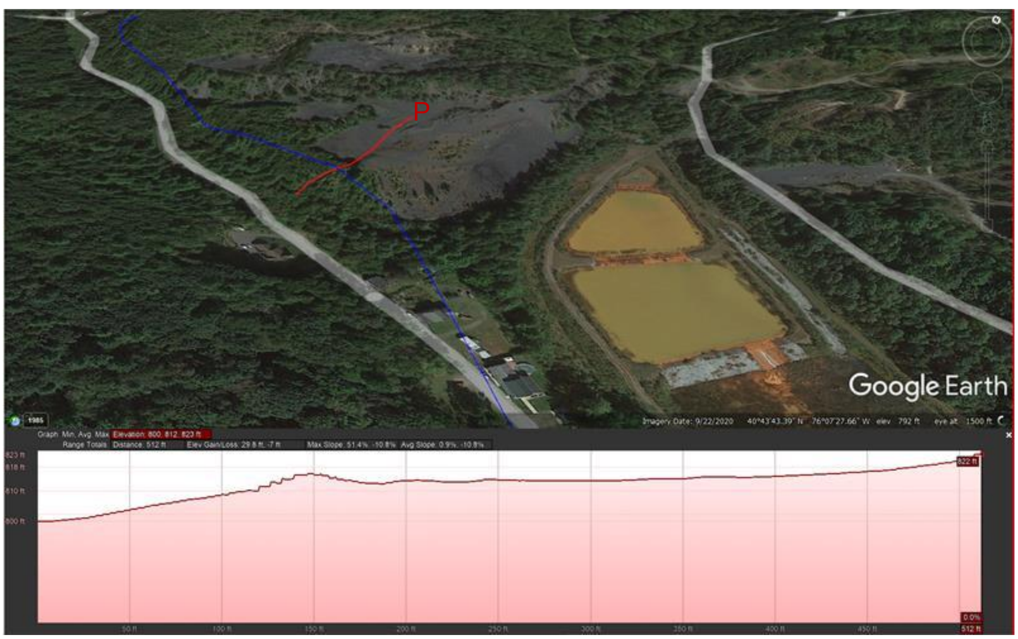
Despite some impairments, the stream has a Chapter 93 classification of a high-quality cold-water fishery (HQ-CWF) and supports both stocked and wild trout populations.

Water quality of the receiving stream may be impacted by the mine water quality, especially at suggested discharge rates. However, water quality is currently impaired from other AMD sources in the area. As discussed in the main report, it was assumed that active treatment of the mine pool water will be required for permitted discharge to Silver Creek.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the mine storage access, withdrawal pumping facilities, treatment and discharge piping to the receiving stream. Figure 3.1 shows a marked-up area plan and profile to help describe the general location of major facilities. The pumping and treatment are planned at the northern/upstream end of the proposed pipeline shown in red. The pipeline discharges into Silver Creek.

Figure 3.1: Approximate Pipe (red line) and Pump Station (P) Location and Profile



The location of the withdrawal pumping facilities and any required treatment facilities are approximate. For the concept development stage, the approximate elevation range is sufficient since the feasibility and overall cost are not impacted considerably by actual location. Surface grades in the area vary but are in the 850 ft-950 ft range. The mine overflow elevation is reported as approximately 800 ft MSL. Access into the mine pool was assummed at an elevation of approximately 100 ft below the overflow.

3.1 Pumping & Piping Facilities

The mine withdrawal pumping station is envisioned to include a drilled shaft to access the mine pool at required depths and submersible pumps similar to the configuration described in Section 5.4 of the main report for quarry water withdrawal. Pumped water would be conveyed to the treatment facility and on to the appropriate discharge point on the nearby Silver Creek. A cursory review of locations indicates a pipeline of approximately 500 lf will be required. In addition, improvements for energy dissipation will be needed at the discharge point. Table 3.1 below summarizes the key pumping and piping parameters.

3.2 Treatment

As noted in Section 5.5 of the main report, it was conservatively assumed that treatment will be required to meet discharge requirements. This will require the construction and operation of primary treatment or other contract treatment arrangements. The level of this evaluation does not allow a detailed analysis of treatment requirements. Therefore, an estimated capital cost and ongoing operation cost was assigned based on industry references.

Table 3.1: Facility Parameters

Parameter	Value
Mine Status Discharge Head (850'-700')	150 ft (100' pool)
Design Flow	16 mgd (25 cfs)
Pump Capacity (2 x 8 mgd)	16 mgd
Pipeline Distance (approx.)	500 lf
Elevation at Discharge Point	800 ft
Elevation at High Point on Pipeline	823 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in
Treatment	(See main report)

Components and quantities of the envisioned pumping/treatment facilities are detailed further in Section 6, Project Cost & Schedule.

In terms of operations of the facilities, the pumping equipment can be automatically operated, and described for the quarry projects. However, given the flow and active treatment requirements, a partially manned facility is assumed for the mine pool operations.

3.3 Other Infrastructure Considerations

The Commonwealth has funded a passive AMD treatment facility in the area. Figure 3.2 shows an aerial view of the passive facility providing typical lime buffering and primary settling through cascaded ponds. Using these facilities for active treatment is not practical. However, there may be some potential to combine deep mine withdrawal and the current AMD treatment to improve regional water quality. It should also be noted that if active pumping/treatment changes the mine overflow elevation, this may impact the current passive treatment pond operation.

Figure 3.2: Existing Passive Treatment Ponds

4 Environmental Impacts

This storage project was reviewed at a high level against several environmental parameters as described in the body of the report. These included wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project scores high and is somewhat comparable to quarry storage projects. Construction of pumping/treatment facilities will have minimal impact, especially given the already scarred landscape of this region. The pipeline is relatively short to Silver Creek, so impacts are negligible. The proposed discharges are reasonable relative to typical silver Creek flows.

5 Social and Economic Impacts

The mine and surrounding land is industrial and appears impacted from prior mining practices. Surrounding private residences are very limited.

Social and economic impacts generally consider disruption/displacement, safety/health, social equity, recreational loss, aesthetics or loss of revenue or related production. These all appear to be negligible in this past anthracite mining area and consequently the project scored high in this category.

6 Project Cost & Schedule

Mott MacDonald prepared feasibility-level costs for this storage project consistent with the general approach described in the main report for deep mines. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
PIPELINE			SUBTOTAL	$550,000
Pipeline	LF	500	$800	$400,000
Valves	#	3	$50,000	$150,000
MINE PUMPING SYSTEM			SUBTOTAL	$5,257,000
Intake Structure	VF	150	$25,000	$3,750,000
Pumping Station				
Pumps	#	2	$450,000	$900,000
Structure	SF	800	$350	$280,000
MEP	LS (%)	1	$177,000	$177,000
Electrical Service	LS	1	$50,000	$50,000
Other	LS	1	$100,000	$100,000
TREATMENT SYSTEM			SUBTOTAL	$6,025,000
Tanks	LS	1	$3,000,000	$3,000,000
Chem Feed	LS	1	$1,000,000	$1,000,000
Pumping	LS	1	$500,000	$500,000
MEP	LS (%)	1	$675,000	$675,000
Structure	SF	2000	$350	$700,000
Electrical Service	LS	1	$50,000	$50,000
Other	LS	1	$100,000	$100,000
LAND ACQUISITION				$100,000
Area	ACRE	2	$50,000	$100,000
SUBTOTALS				
Const. Costs Subtotal				$11,932,000
Contingency			50%	$5,966,000
COST + CONTINGENCY				$17,898,000

The total capital is shown above. Operating costs for this facility are estimated to be approximately $1.25M/year. This is approximated based on annually discharging and treating an operating volume of mine storage (50% of total volume), according to other industry standard metrics for similar facilities. Again, these costs are very approximate given the development stage of the project. Assuming a 30 year operating horizon, the present value (PV) of the operating cost is $24.5M. This brings the combined total of capital and PV of operating cost to a project total of $42.4M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 12 years. This includes:

- Design, permitting and land acquisition 7 years
- Construction 4 years
- Startup and initial filling of mine 1 year.

7 Potential Ancillary Benefits

This category of potential ancillary benefits considers such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement. Flood control and recreational/tourism benefits are not likely. However, environmental enhancement by mine water treatment may be very beneficial. As mentioned, a passive treatment system operates in the area. Active treatment and controlled discharge of water to Silver Creek could help maintain flows and improve water quality in the creek and downstream Schuylkill River. Consequently, this project scores high in this potential benefits category.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.00	30%	0.90
Infrastructure Design, Construction & Operation	3.20	10%	0.32
Environmental Impacts	4.50	15%	0.68
Social & Economic Impacts	5.00	10%	0.50
Project Cost & Schedule	2.00	30%	0.60
Ancillary Benefits	2.40	5%	0.12
AVERAGE	**3.35**		**3.12**

Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Appendix

Scoresheet

STORAGE PROJECT SCORING

STORAGE PROJECT: M5
NAME: Silver Creek Deep Mine

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.00**			30%	**0.90**	
o Volume of storage provided (BG)	1.77	2					
o Hydrologic reliability of supply (months to fill)	???	4					Mine should recharge withing 12 months
o Release rate (cfs)	25 cfs	2					**Slower release than targeted for other storage**
o Promptness of delivery to mainstem (day)	2.6	3					
o Geographic Benefit		3					
o Quality of stored water		4					
2. Infrastructure Design, Construction and Operation		**3.20**			10%	**0.32**	
o Site/Civil, Land & Easements		4					No major issues likely
o Subsurface conditions		2					Some risk related to unknown mines
o Infrastructure Complexity		4					Design is normal, with some subsurface risk
o Construction complexity		4					Construction is normal, with some subsurface risk
o Operational complexity		2					Treatment complicates operations
3. Environmental Impacts		**4.50**			15%	**0.68**	
o Protected species		5					No issues identified
o Water quality degradation		5					Should not be degradation with treatment
o Obstruction to passage of aquatic animals		5					No issues identified
o Hydromodification		2					Some change with discharge, but minor
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=large, 1=small)**			
o Wetlands inundated or filled (ac)		5	5	5			
o Stream length inundated (mi)		5	5	5			
o Uplands inundated or developed (ac)		4.5	5	4			Could be some minor impact form pipeline and plant construction
4. Social and Economic Impacts		**5.00**			10%	**0.50**	
o Disruption/displacement		5					
o Safety and health		5					
o Social equity		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					Reclamation may be improved in the area
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		3					Not know
5. Project Costs & Schedule		**2.00**			30%	**0.60**	
o Land acquisition cost ($)	$0.1M						
o Construction Cost ($)	$17.8M						
o Operating Cost ($/yr)	1.25M						
o Overall Cost ($)	$42.4M	2					
o Cost effectiveness ($/BG)	24	1					
o Schedule (Time to make Operational, years)	12	3					
6. Ancillary Benefits		**2.40**			5%	**0.12**	
o Flood control		1					
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					
o Ability to leverage funding from other programs		5					Should be able to leverage some reclamation funds
OVERALL		3.35				**3.12**	

Storage Project Summary

Project:	**Wadesville Mine Pool (M10)**	
Location:	New Castle, Schuylkill County, PA	
Storage Type:	Deep Coal Mine (Draw)	
Est. Volume:	3.56+ Billion Gallons	
Score:	NA	

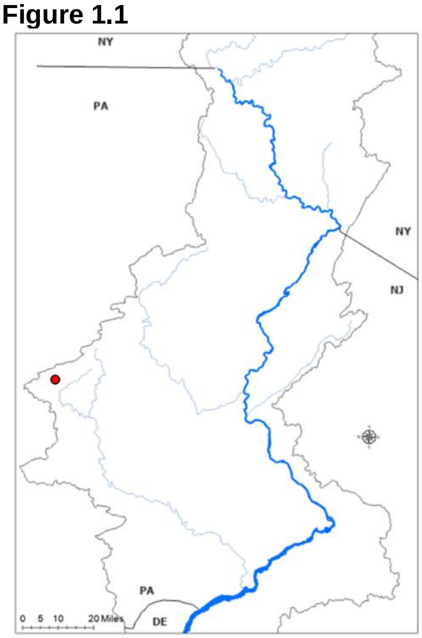
1 Project Overview

The scope of this storage project is to utilize the water stored in the Wadesville Mine pool for flow augmentation in the Schuylkill River flows and, in turn, the Delaware River. The mine pool is located primarily in New Castle, west of the town of St. Clair, in Schuylkill County, PA. Much has been reported on the Wadesville mine pool related to its use as supplemental water supply for the Exelon Corporation, including in the DRBC Docket no. D-1969-210 CP-14 (DRBC, 2015).

The Wadesville Mine Pool has been developed, but may not be fully exploited. Water withdrawal for flow augmentation may be possible while continuing to meet Exelon's future need. In addition, reports indicate that the adjacent Tracy Mine may have supplemental supply. Finally, the surrounding mine pools, as will be discussed further below, may provide the potential for additional interconnected supply.

This project was not scored because of insufficient information. However, the SPS is included because of the potential for some future development of the mine area and/or the potential for a shared water resources development project with Exelon at the Wadesville Mine Pool. Surface storage in the Wadesville Mine Pit was considered as a separate project (Q1) and reported in a separate SPS.

Figure 1.1



2 Water Quantity & Quality

2.1 Storage Volume

The storage volume of 3.56 BG was estimated by Ash et al. (1949) as described in the main report. The mine pool and its development by Exelon are summarized by Veil and Puder (2006) and the EPCAMR report (Hughes et al, 2011). Figure 2.1 below shows the mine pool as compiled by Ash et al.

As mentioned above, it has been reported that the Tracy shaft (not shown) may provide additional mine pool water. The other adjacent mine pools might be options for additional water supply. The adjacent pools shown in Figure 2.1 are also summarized in Table 2.1.

Figure 2.1: Large Southern Region Mine Pool Map-Wadesville & Surrounding Pools

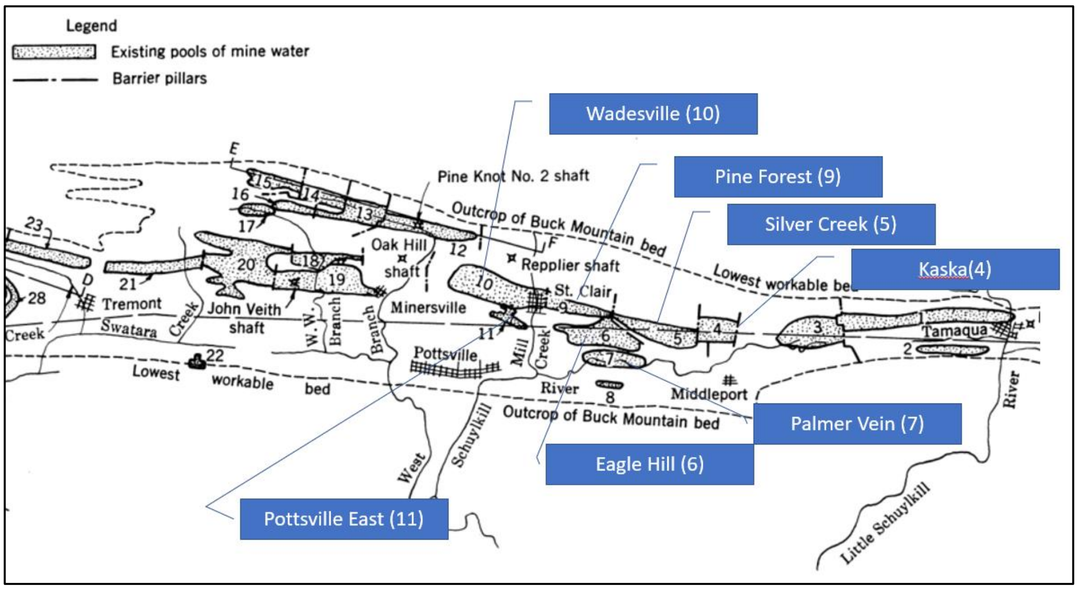


Table 2.1: Region Mine Pools

Site No.	Site Name	Est. Volume (gal.)	Est. Altitude of Water (ft MSL)	Remarks
4	Kaska	600,000,000	832	May not reflect current vol. & level
5	Silver Creek	1,774,000,000	814	May not reflect current vol. & level
6	Eagle Hill	727,000,000	680	May not reflect current vol. & level
7	Palmer Vein	400,000,000	694	May not reflect current vol. & level
9	Pine Forest	419,000,000	560	May not reflect current vol. & level
10	Wadesville	3,582,000,000	732	May not reflect current vol. & level
11	Pottsville East	125,000,000	713	May not reflect current vol. & level
	Combined Total	7,627,000,000		

2.2 Fill and Discharge

The project concept cannot be further developed at this time. Additional details of the ongoing Exelon withdrawals and the feasibility of expanding the volume or sharing mine resources must be better understood before advancing this potential project.

2.3 Water Quality

Some historical information adapted from Wood (1996) is provided in Table 2.2. It shows varying water quality among the regionally considered mine pools with generally good water quality at Wadesville having neutral pH and low sulfate/iron concentrations.

Table 2.2: Mine Pool Water Quality Samples (after Wood, 1996)

Proj. #	Proj. Name	Description	Sample Date	Water Temp. (°C)	Spec. Conduct. (uS/cm)	pH	Sulfate (mg/l)	Iron (mg/l)	Manganese (mg/l)	Alkalinity at pH 4.5 as $CaCO_3$ (mg/l)
M4	Silver Creek	Tunnel	4-22-75	12.5	500	4.5	270	20	-	0
M4	Silver Creek	Tunnel	11-7-91	11.5	630	6	300	27	3.5	54
M10	**Wadesville**	**Pump**	**4-22-75**	**14.0**	**1500**	**7.1**	**630**	**1**	**2.3**	**380**
M10	**Wadesville**	**Pump**	**11-6-91**	**14.0**	**1190**	**7.1**	**350**	**2**	**3.2**	**275**
M19	Phoenix	-	-	-	-	-	-	-		-
M20	Otto	Airshaft	4-23-75	10.5	800	4.7	430	26	4.4	10
M20	Otto	Airshaft	10-31-91	10.3	730	6.1	300	15	3.0	66
M32	Morea	Strip Pool	4-16-75	8.0	440	3.2	140	10	-	0
M32	Morea	Strip Pool	11-6-91	8.0	308	4.0	110	9.7	1.6	0

The water quality at the Wadesville pool is better than other projects. The Exelon project, as described by Veil (2007) and also as described by EPCAMR (Hughes et al., 2011), indicates that discharge requirements were satisfied without water treatment. However, rigorous ongoing monitoring was required to prove the discharged mine water did not impact the receiving waters and the environment.

3 Infrastructure Design, Construction & Operation

The infrastructure required cannot be defined at this point in the project development.

4 Environmental Impacts

The potential environmental impacts of this project cannot be defined at this point in the project development.

5 Social and Economic Impacts

The potential social and economic impacts cannot be determined at this time.

6 Project Cost & Schedule

The project cost and schedule of this project cannot be defined at this point in the project development.

7 Potential Ancillary Benefits

The potential ancillary benefits cannot be defined at this time.

8 Storage Project Score

This project was not scored because of insufficient information. However, the SPS is included because of the potential for some future development of the mine area and/or the potential for a shared water resources development project with Exelon at the Wadesville Mine Pool.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	--	--	--
Infrastructure Design, Construction & Operation	--	--	--
Environmental Impacts	--	--	--
Social & Economic Impacts	--	--	--
Project Cost & Schedule	--	--	--
Ancillary Benefits	--	--	--
AVERAGE	--	--	--

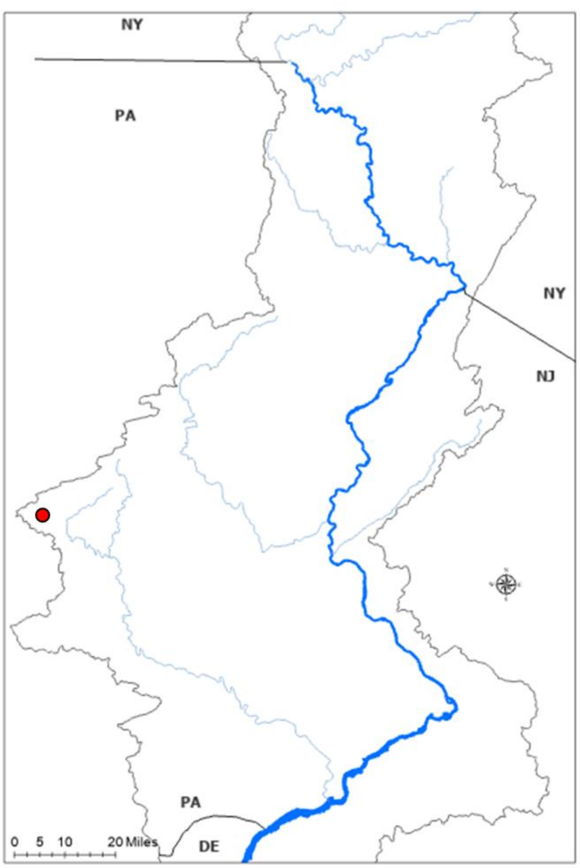
Storage Project Summary

Project:	Phoenix Park Mine (M19)
Location:	Branch Township, Schuylkill County, PA
Storage Type:	Deep Coal Mine (Draw)
Est. Volume:	2.05 Billion Gallons
Score:	2.99

1 Project Overview

The scope of this storage project is to utilize the water stored in the Phoenix Park Mine pool to provide flow augmentation. The mine pool is located primarily in Branch Township, west of the town of Minersville in Schuylkill County, PA. The exact location of the mine pool mapped to the surface has not been determined based on available data. This area is high in the Schuylkill River watershed and Delaware River Basin as shown in Figure 1.1. Like other mines in the area, the mine has operated for many years but is currently inactive.

Figure 1.1 Project Location

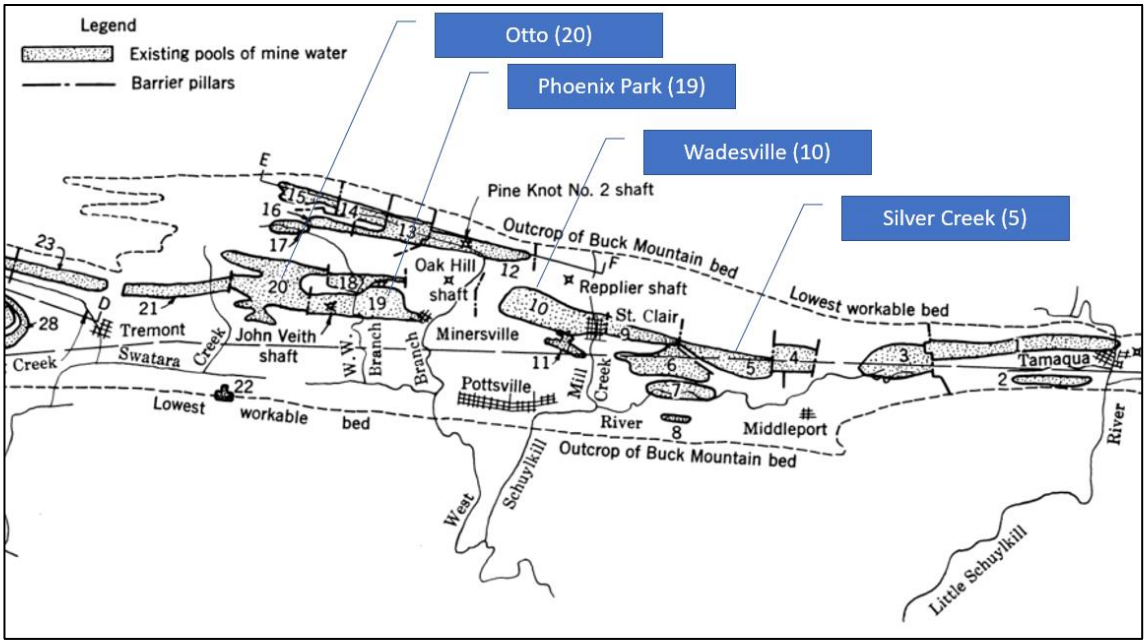


2 Water Quantity & Quality

2.1 Storage Volume

The total storage volume of 2.05 BG was estimated by Ash et al. (1949) as described in the main report. Figure 2.1 below shows the mine pool as compiled by Ash et al. Other adjacent larger pools are shown for reference. The figure shows the general plan view configuration of the Phoenix Park Pool and also provides surrounding mine pools for reference.

Figure 2.1: Large Southern Region Mine Pool Map-Phoenix Park



2.2 Fill and Discharge

The intended design is to utilize a portion of the mine pool volume for usable storage and pump out as required to augment flow downstream. EPCAMR researched water levels in the mines in the area and reported surface elevations near the shaft of approximately 840 ft MSL and a highest water level of 740 ft MSL (Hughes et al., 2011). This information was collected in a borehole. No mapped overflow elevation was available in researched reports.

Pumped mine pool water is assumed to discharge to West Creek, which, in turn, flows into the West Branch of the Schuylkill River. Information for streams in the area is limited. Table 2.1 below provides some additional summary details of storage and discharge related parameters.

Table 2.1: Storage and Discharge Parameters

DESCRIPTION	VALUE
Storage	
Maximum Volume (Billion Gallons)	2.05 BG
Operating Volume (Assumes 50% usable)	1.025 BG
Water Supply – Mine Pool Volume & Recharge	
Proposed Average Pumping Rate (mgd)	NA
Water Release – Mine Discharge (Stream Augmentation)	
Mine Gravity Overflow Point (ft)	~NA ft
Mine Pool Assumed Operating Water Elevation Range (ft)	740 ft to 650 ft (90' pool)
Proposed Discharge Pumping Rate	25 cfs/16 mgd
Estimated Time to Release Operating Volume from Storage	2.1 months
Water Supply – Travel to Use	
Receiving Stream	West Creek (to W. Schuylkill River)
Receiving Stream Flows (Mean, 7Q10, Bank Full)	17.3 cfs / 7.6 cfs/ 297 cfs
Stream Miles to Delaware River	125 miles
Travel Time at 2 mph (hours)	63 hours

2.3 Water Quality

The water quality of stored mine water is unknown. Some historical information adapted from Wood (1996) is provided in Table 2.2. No data was available for the Phoenix project.

Table 2.2: Mine Pool Water Quality Samples (after Wood, 1996)

Proj. #	Proj. Name	Description	Sample Date	Water Temp. (°C)	Spec. Conduct. (uS/cm)	pH	Sulfate (mg/l)	Iron (mg/l)	Manganese (mg/l)	Alkalinity at pH 4.5 as $CaCO_3$ (mg/l)
M4	Silver Creek	Tunnel	4-22-75	12.5	500	4.5	270	20	-	0
M4	Silver Creek	Tunnel	11-7-91	11.5	630	6	300	27	3.5	54
M10	Wadesville	Pump	4-22-75	14.0	1500	7.1	630	1	2.3	380
M10	Wadesville	Pump	11-6-91	14.0	1190	7.1	350	2	3.2	275
M19	**Phoenix**	-	-	-	-	-	-	-		-
M20	Otto	Airshaft	4-23-75	10.5	800	4.7	430	26	4.4	10
M20	Otto	Airshaft	10-31-91	10.3	730	6.1	300	15	3.0	66
M32	Morea	Strip Pool	4-16-75	8.0	440	3.2	140	10	-	0
M32	Morea	Strip Pool	11-6-91	8.0	308	4.0	110	9.7	1.6	0

No stream quality information was readily available for West Creek. Water quality of the receiving stream may be impacted by the mine water quality, especially at suggested discharge rates relative to natural flow rates. Water quality is currently impaired from other AMD sources in the area.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the mine storage access, discharge pumping facilities and discharge piping to the receiving stream. Figure 3.1 shows the area plan that would host the major facilities.

Figure 3.1: Approximate Mine Pool Location

The location of the withdrawal pumping facilities and any required treatment facilities are assummed to be located on abandoned mining areas immediately south of the “Life Flight 5 Hangar”. While important in any design, for the concept development stage, the approximate location is sufficient for feasibility and overall cost estimating. Surface grades in the area vary, but are on average about 840 ft-850 ft MSL. The mine withdrawal elevations were provided as noted.

3.1 Pumping & Piping Facilities

The mine discharge/stream augmentation pumping station is envisioned to include a drilled shaft to access the mine pool at required depths and submersible pumps for withdrawing quarry source water, similar to the configuration described in Section 5.4 of the main report. Pumped water would be conveyed some distance to the appropriate discharge point on the nearby West Creek. A cursory review of discharge locations indicates a pipeline of approximately 4500 fl will be required. In addition, improvements for energy dissipation will be needed at the discharge point. Table 3.1 below summarizes the key pumping and piping facility parameters.

3.2 Treatment

As noted in Section 5.5 of the main report, water treatment was assumed to be required in order to meet discharge requirements. This requirement will involve the construction and operation of primary treatment or other contract treatment arrangements. Again, the level of this evaluation does not allow a detailed analysis of treatments requirements. Therefore, treatment was assigned an approximate capital cost and ongoing operation cost based on some industry references. Components and quantities of the envisioned facilities are detailed further in the Section 6, Project Cost & Schedule.

Table 3.1: Piping and Pumping Facility Parameters

Parameter	Value
Mine Status Discharge Head (840’-650’)	190 ft (90’ pool)
Design Flow	16 mgd (25 cfs)
Pump Capacity (2 x8 mgd)	16 mgd
Pipeline Distance (approx.)	4500 lf
Elevation at Discharge Point	730ft
Elevation at High Point on Pipeline	956ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in
Treatment	(See main report)

In terms of operations of the facilities, pumping can be automatically operated, as typical and described in the quarry storage concepts. However, given the flow and active treatment requirements a partially manned treatment plant is assumed for the mine pool operations.

3.3 Other Infrastructure Considerations

The final configuration of the pumping facilities is only approximated. If the mine pool daylights in the adjacent surface pit or the overflow is known and accessible, the pumping head requirements and pumping infrastructure may be different than presented.

4 Environmental Impacts

This storage project was reviewed at a high level against several environmental parameters as described in the body of the report. These included wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project scores high and is somewhat comparable to quarry storage facilities and the other mine pool scenarios presented. Construction of pumping/treatment facilities will have minimal impact, especially given the already scarred landscape of this region. The pipeline to West Creek is the longest of the mine projects and appears to cross some sensitive areas and may have minor impacts. The pipeline installation also traverses heavily wooded areas. While not pristine areas, some impacts would likely occur during construction. West Creek may be undersized for the planned discharge flow; a pipe to the West Branch of the Schuylkill could be and alternative, but significantly longer and more costly.

5 Social and Economic Impacts

The mine and surrounding land is industrial and appears impacted from prior mining practices. Surrounding private residences are very limited.

Social and economic impacts generally consider disruption/displacement, safety/health, social equity, recreational loss, aesthetics or loss of revenue or related production. These all appear to be negligible in this past anthracite mining area and consequently the project scored high in this category.

6 Project Cost & Schedule

Mott MacDonald prepared feasibility- level costs for this storage project consistent with the general approach described in the main report for deep mines. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
PIPELINE			SUBTOTAL	$4,000,000
Pipeline	LF	4500	$800	$3,600,000
Valves	#	8	$50,000	$400,000
MINE PUMPING SYSTEM			SUBTOTAL	$6,257,000
Intake Structure	VF	190	$25,000	$4,750,000
Pumping Station				
Pumps	#	2	$450,000	$900,000
Structure	SF	800	$350	$280,000
MEP	LS (%)	1	$177,000	$177,000
Electrical Service	LS	1	$50,000	$50,000
Other	LS	1	$100,000	$100,000
TREATMENT SYSTEM			SUBTOTAL	$6,025,000
Tanks	LS	1	$3,000,000	$3,000,000
Chem Feed	LS	1	$1,000,000	$1,000,000
Pumping	LS	1	$500,000	$500,000
MEP	LS (%)	1	$675,000	$675,000
Structure	SF	2000	$350	$700,000
Electrical Service	LS	1	$50,000	$50,000
Other	LS	1	$100,000	$100,000
LAND ACQUISITION				$150,000
Area	ACRE	3	$50,000	$150,000
SUBTOTALS				
Const. Costs Subtotal				$16,432,000
Contingency			50%	$8,216,000
COST + CONTINGENCY				$24,648,000

The total capital cost is shown above. Land costs cannot be estimated accurately; $50,000 per acre was assumed.

Operating costs for this facility are estimated to be approximately $1.25M/year. This is approximated based discharging and treating an operating volume of mine storage (50% of total volume), according to other industry standard metrics for similar facilities. Again, these costs are very approximate given the development level of the project, but have been compared with costs for other similar operating facilities. Assuming a 30-year operating horizon, the present value (PV) of the operating cost is $24.5M. This brings the combined total of capital and PV of operating cost to a project total of $49M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 13 years. This includes:

- Design, permitting and land acquisition 7 years
- Construction 5 years
- Startup and initial filling of mine 1 year.

7 Potential Ancillary Benefits

This category of potential ancillary benefits considers such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement. Flood control and recreational/tourism benefits are not likely. However, environmental enhancement by supporting mine water treatment may be beneficial but not readily apparent based on the limited project information. Consequently, this project scores moderately high in this potential benefits category.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	2.83	30%	0.85
Infrastructure Design, Construction & Operation	2.90	10%	0.29
Environmental Impacts	4.21	15%	0.63
Social & Economic Impacts	5.00	10%	0.50
Project Cost & Schedule	2.00	30%	0.60
Ancillary Benefits	2.40	5%	0.12
AVERAGE	**3.22**		**2.99**

APPENDIX

Scoresheet

STORAGE PROJECT SCORING

STORAGE PROJECT: M19
NAME: Phoenix Park Deep Mine

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**2.83**			30%	**0.85**	
o Volume of storage provided (BG)	2.05	1					
o Hydrologic reliability of supply (months to fill)	?	4					Recharge of the mine is unclear; others have recharged quickly
o Release rate (cfs)	25	2					May need to further reduce relase rate or change discharge
o Promptness of delivery to mainstem (day)	2.6	3					
o Geographic Benefit		3					
o Quality of stored water		4					Assumes treatment
2. Infrastructure Design, Construction and Operation		**2.90**			10%	**0.29**	
o Site/Civil, Land & Easements		3					Longer pipeline may create land issues
o Subsurface conditions		2					Mines create complexity
o Infrastructure Complexity		4					No complex design
o Construction complexity		3.5					Pipeline construction can be difficult
o Operational complexity		2					Treatment makes for more complex operations
3. Environmental Impacts		**4.21**			15%	**0.63**	
o Protected species		4					None known, but likely
o Water quality degradation		5					Quality may be improved by treatment
o Obstruction to passage of aquatic animals		5					Not likely
o Hydromodification		1					Change to low flow stream; mine dewatering will have likely impact
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=large, 1=small)**			
o Wetlands inundated or filled (ac)		5	5	5			
o Stream length inundated (mi)		5	5	5			
o Uplands inundated or developed (ac)		4.5	5	4			Pipeline could minimially impact
4. Social and Economic Impacts		**5.00**			10%	**0.50**	
o Disruption/displacement		5					
o Safety and health		5					
o Social equity		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					May prompt furhter area reclamation
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		3					
5. Project Costs & Schedule		**2.00**			30%	**0.60**	
o Land acquisition cost ($)	$0.150M						
o Construction Cost ($)	$23M						
o Operating Cost ($/yr)	$1.25M						
o Overall Cost ($)	$49M	2					
o Cost effectiveness ($/BG)	24	1					
o Schedule (Time to make Operational, years)	13	3					
6. Ancillary Benefits		**2.40**			5%	**0.12**	
o Flood control		1					
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					Could be flow related stream impacts
o Ability to leverage funding from other programs		5					
OVERALL		3.22				**2.99**	

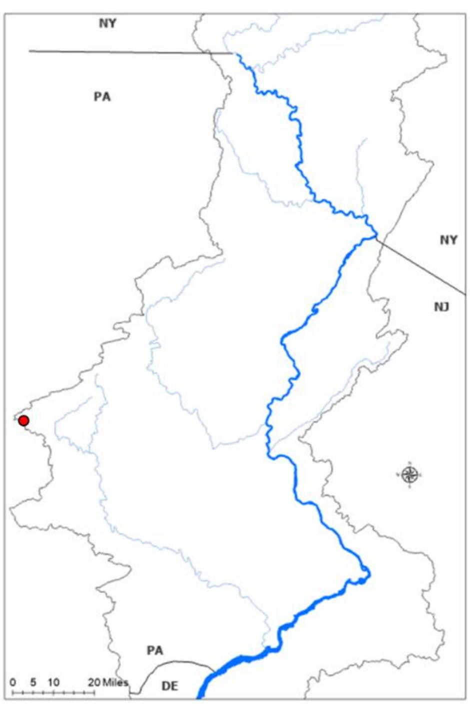
Storage Project Summary

Project:	**Otto Mine (M20)**
Location:	Branchdale (Reilly Township, Schuylkill County, PA
Storage Type:	Deep Coal Mine (Draw)
Est. Volume:	2.26 Billion Gallons
Score:	3.53

1 Project Overview

The scope of this storage project is to utilize the water stored in the Otto Mine pool to augment flows. The mine pool is located primarily in Branchdale (Reilly Township), west of the town of Minersville in Schuylkill County, PA. The exact shaft location is unclear, however; the surface overflow point is identified by others and will be described below. This area is on the western flank of the mine pools located in the Delaware River Basin and is high in the Schuylkill River watershed as shown in Figure 1.1. A portion of the mine pool may possibly drain to the Susquehanna River Basin. However, based on available data, it was assumed that the entire volume can be drained to the Delaware River Basin. Like other mines in the area, this mine has operated for many years. Much has been written about the Colliery (mine & supporting structures) due to multiple disasters in the mine over its operating life. It had a long history but is currently inactive and is one of the largest AMD discharging mine pools in the Southern Anthracite Region.

Figure 1.1 Project Location



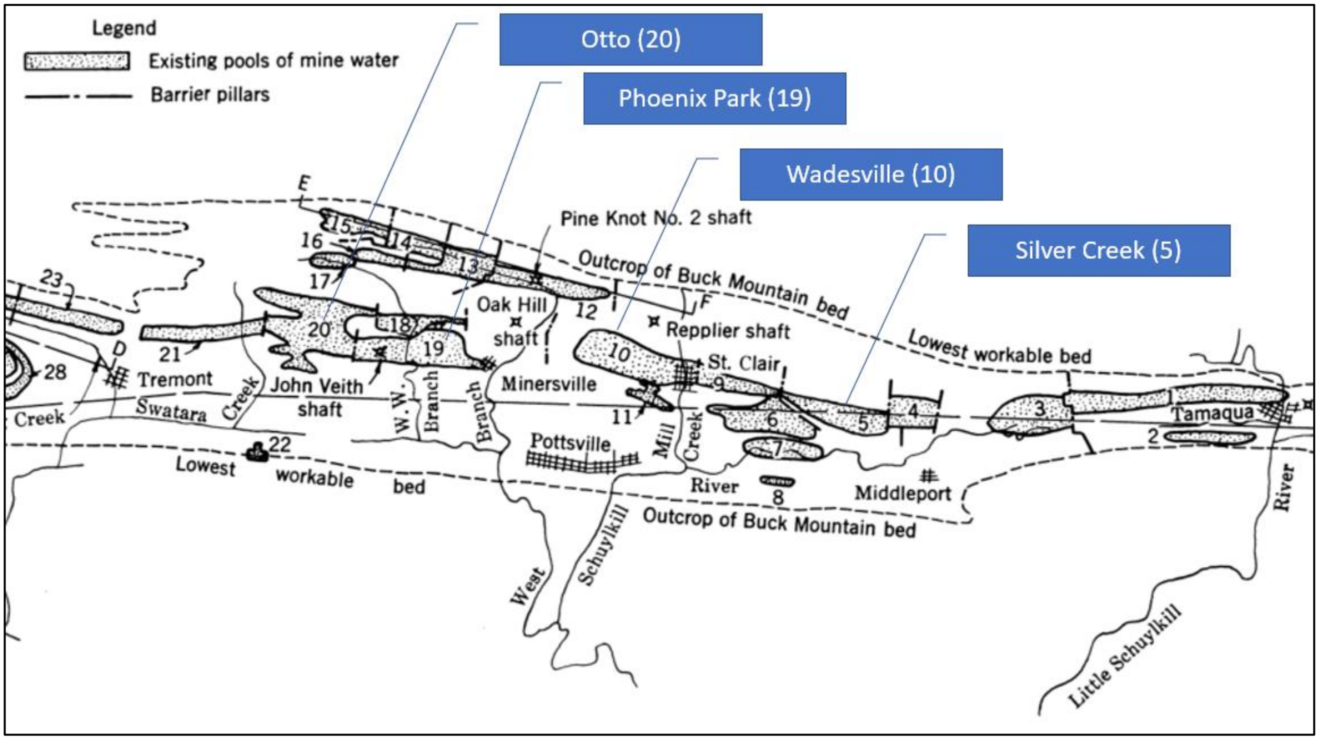
2 Water Quantity & Quality

2.1 Storage Volume

The storage volume of 2.26 BG was estimated by Ash et al. (1949) as described in the main report. Figure 2.1 below shows the mine pool as compiled by Ash et al. Other adjacent larger pools are shown for reference.

The figure shows the general plan view configuration of the Otto Pool. It also provides some approximate barrier pillars (dark black lines) with adjacent mines. Also note the surrounding mine pools, particularly the adjacent Phoenix Mine Pool (M19), which is also a potential mine pool storage project.

Figure 2.1: Large Southern Region Mine Pool Map-Otto



2.2 Fill and Discharge

The intended design is to utilize a portion of the mine pool volume for usable storage and pump out as required to augment flow downstream. Research by Ash et al. and EPCAMR (Hughes et al., 2011) identified the surface elevation at the shaft of approximately 960 ft MSL and the maximum water level of approximately 840 ft MSL. Work by others as part of acid mine drainage (AMD) remediation initiatives (Schuylkill Headwaters, 2005) identified the location of the downgradient overflow point (approx. elevation of 840 ft MSL). For the purposes of estimating, the surface and related pumping/treatment facilities were assumed to be located at approximately elevation 900 ft MSL, with a mine-pool, low-water withdrawal elevation established at 750 ft MSL.

Pumped mine pool water is assumed to discharge to Muddy Branch and onto West Creek, that in turn flows into the West Branch of the Schuylkill River. Information about small streams in the area is limited. Table 2.1 below provides additional details of storage and discharge related parameters.

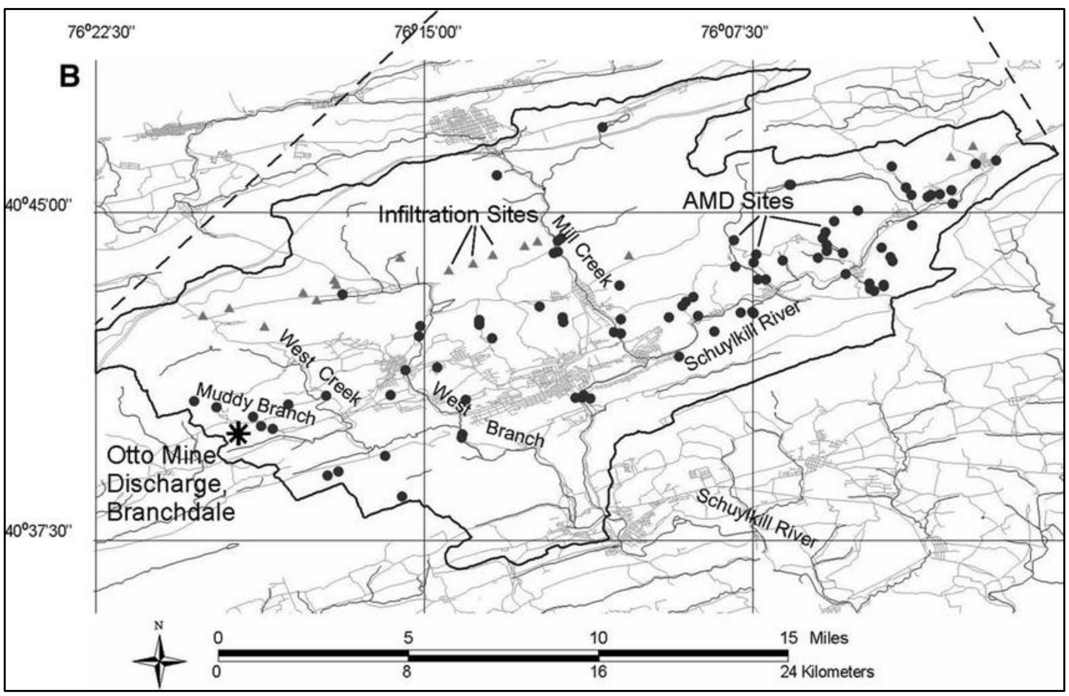
Table 2.1 Storage and Discharge Parameters

DESCRIPTION	VALUE
Storage	
Maximum Volume (Billion Gallons)	2.26 BG
Operating Volume (Assumes 50% usable)	1.13 BG
Water Supply – Mine Pool Volume & Recharge	
Proposed Average Pumping Rate (mgd)	NA
Water Release – Mine Discharge (Stream Augmentation)	
Mine Gravity Overflow Point (ft)	~840 ft
Mine Pool Assumed Operating Water Elevation Range (ft)	840 ft to 750 ft (surface at 900')
Proposed Discharge Pumping Rate	25 cfs/16 mgd
Estimated Time to Release Operating Volume from Storage	2.4 months
Water Supply – Travel to Use	
Receiving Stream	Muddy/West Creek (to W. Schuylkill River)
Receiving Stream Flows (Mean, 7Q10, Bank Full)	3.32 cfs / 1.42 cfs/ 77.3 cfs (Muddy Branch)
Stream Miles to Delaware River	125 miles
Travel Time at 2 mph (hours)	63 hours

2.3 Water Quality

The water quality of stored mine water is not explicitly known. However, the Otto Mine is one of the largest AMD sites in the Southern Anthracite region and research and remediation of AMD have taken place. Figure 2.2 illustrates the AMD sites in the Otto region as documented by Cravotta (Cravotta, 2008). This paper also documents mine water quality, constructed passive treatment, and treated water quality.

Figure 2.2: AMD of the Otto Mine Region (Cravotta, 2008)



The water quality of stored mine water is partially characterized here. Select historical information adapted from Wood (1996) is provided in Table 2.2. More recent data is available from AMD treatment work (Cravotta, 2008). The regional data in Table 2.2 shows varying water quality among the considered mine pools with water quality at Otto having low to neutral pH, high sulfates/iron/manganese.

Table 2.2: Mine Pool Water Quality Samples (after Wood, 1996)

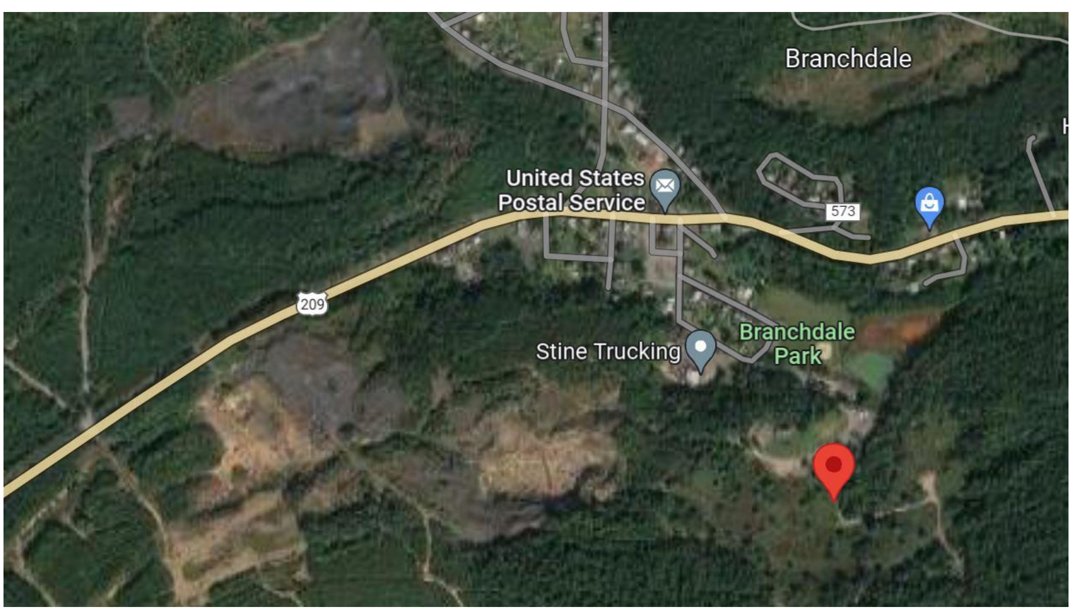
Proj. #	Proj. Name	Description	Sample Date	Water Temp. (°C)	Spec. Conduct. (uS/cm)	pH	Sulfate (mg/l)	Iron (mg/l)	Manganese (mg/l)	Alkalinity at pH 4.5 as $CaCO_3$ (mg/l)
M4	Silver Creek	Tunnel	4-22-75	12.5	500	4.5	270	20	-	0
M4	Silver Creek	Tunnel	11-7-91	11.5	630	6	300	27	3.5	54
M10	Wadesville	Pump	4-22-75	14.0	1500	7.1	630	1	2.3	380
M10	Wadesville	Pump	11-6-91	14.0	1190	7.1	350	2	3.2	275
M19	Phoenix	-	-	-	-	-	-	-		-
M20	**Otto**	**Airshaft**	**4-23-75**	**10.5**	**800**	**4.7**	**430**	**26**	**4.4**	**10**
M20	**Otto**	**Airshaft**	**10-31-91**	**10.3**	**730**	**6.1**	**300**	**15**	**3.0**	**66**
M32	Morea	Strip Pool	4-16-75	8.0	440	3.2	140	10	-	0
M32	Morea	Strip Pool	11-6-91	8.0	308	4.0	110	9.7	1.6	0

Water quality of the receiving stream may be impacted by the proposed treated mine water quality, especially at suggested discharge rates and considering the low-flow receiving stream. However, water quality is currently impaired from other AMD sources in the area and the proposed treated discharge is not viewed as a further impairment, but a probable improvement.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the mine storage access, discharge pumping facilities and discharge piping to the receiving stream. Figure 3.1 shows an annotated area plan that identifies the general location of major facilities.

Figure 3.1: Approximate Facilities Location



The location of the overflow to AMD treatment is shown by the red pin. Withdrawal pumping facilities and any required treatement facilities are assummed to be located to the west on abandoned mining areas. While location is important in any detailed design, for the concept development stage, the approximate area and elevation range is sufficient for feasibility and overall cost estimating. Surface grades in the area vary, but are on average about 900 ft MSL. The mine withdrawal elevations were provided as noted.

3.1 Pumping & Piping Facilities

The mine withdrawal pumping station is envisioned to include a drilled shaft to access the mine pool at required depths and submersible pumps similar to the configuration described in Section 5.4 of the main report. Pumped water would be conveyed some distance to the treatment facility and onto the appropriate discharge point on the nearby Muddy Creek, similar to the current AMD passive treatment. A cursory review of discharge locations indicates a pipeline of approximately 2500 lf will be required (1500 lf from overflow to Muddy Creek + 1000 lf to deep mine facilities). In addition, improvements for energy dissipation will likely be needed at the discharge point. Table 3.1 below summarizes the key pumping and piping facility parameters.

3.2 Treatment

As noted in Section 5.5 of the main report, it was conservatively assumed that treatment will be required to meet discharge requirements. This will require the construction and operation of primary treatment as described or other contract treatment arrangements. Again, the level of this evaluation does not allow a detailed analysis of treatments requirements. Therefore, approximate capital cost and ongoing operation cost based were assigned based on industry references.

Table 3.1: Facility Parameters

Parameter	Value
Mine Status Discharge Head (900'-750')	150 ft (90' pool)
Design Flow	16 mgd (25 cfs)
Pump Capacity (2 x 8 mgd)	16 mgd
Pipeline Distance (approx.)	2500 lf
Elevation at Discharge Point	790 ft
Elevation at High Point on Pipeline	860ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in
Treatment	(See main report)

Components and quantities of the envisioned pumping/treatment facilities are detailed further in the Section 6, Project Cost & Schedule.

In terms of operations of the facility, the pumping can be automatically operated, as described in the quarry storage projects. However, given the flow and active treatment requirements, a partially manned treatment plant is assumed for the mine pool operations.

3.3 Other Infrastructure Considerations

The actual configuration of the pumping/treatment facilities are only an estimate. Dewatering the deep mine pool in the area may impact the existing passive AMD treatment facilities operation.

4 Environmental Impacts

This storage project was reviewed at a high level against several environmental parameters as described in the body of the report. These included wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project scores high and is somewhat comparable to quarry storage facilities and other mine pool projects. Construction of pumping/treatment facilities will have minimal impact, especially given the already scarred landscape of the old colliery area. The pipeline to the Muddy Creek is longer than typical. The pipeline installation traverses some open, partially reclaimed and wooded areas. While not pristine areas, some impacts would likely occur during construction. Discharge of mine dewatering flows to the low-flow receiving stream may create hydromodification and environmental impacts. That said, environmental impacts appear relatively minor.

5 Social and Economic Impacts

The mine and surrounding land is industrial and appears impacted from prior mining practices. Surrounding residential sites are very limited.

Social and economic impacts generally consider disruption/displacement, safety/health, social equity, recreational loss, aesthetics or loss of revenue or related production. These all appear to be negligible in this anthracite mining area and consequently the project scored high in this category.

6 Project Cost & Schedule

The project team prepared feasibility-level costs for this storage project consistent with the general approach described in the main report for deep mines. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
PIPELINE			SUBTOTAL	$2,250,000
Pipeline	LF	2500	$800	$2,000,000
Valves	#	5	$50,000	$250,000
MINE PUMPING SYSTEM			SUBTOTAL	$5,257,000
Intake Structure	VF	150	$25,000	$3,750,000
Pumping Station				
Pumps	#	2	$450,000	$900,000
Structure	SF	800	$350	$280,000
MEP	LS (%)	1	$177,000	$177,000
Electrical Service	LS	1	$50,000	$50,000
Other	LS	1	$100,000	$100,000
TREATMENT SYSTEM			SUBTOTAL	$6,025,000
Tanks	LS	1	$3,000,000	$3,000,000
Chem Feed	LS	1	$1,000,000	$1,000,000
Pumping	LS	1	$500,000	$500,000
MEP	LS (%)	1	$675,000	$675,000
Structure	SF	2000	$350	$700,000
Electrical Service	LS	1	$50,000	$50,000
Other	LS	1	$100,000	$100,000
LAND ACQUISITION				$150,000
Area	ACRE	3	$50,000	$150,000
SUBTOTALS				
Const. Costs Subtotal				$13,682,000
Contingency			50%	$6,841,000
COST + CONTINGENCY				$20,523,000

The total capital is shown above. Operating costs for this facility are estimated to be approximately $1.25M/year. This is approximated based on annually discharging and treating an operating volume of mine storage (50% of total volume), according to industry standard metrics for similar facilities. Again, these costs are very approximate given the development stage of the project, but have been compared with costs for other similar operating facilities. Assuming a 30-year operating horizon, the present value (PV) of the operating cost is $24.5M. This brings the combined total of capital and PV of operating cost to a project total of $45M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 13 years. This includes:

- Design, permitting and land acquisition 7 years
- Construction 5 years
- Startup and initial filling of mine 1 year.

7 Potential Ancillary Benefits

This category of potential ancillary benefits considers such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement. Flood control and recreational/tourism benefits are not likely. However, environmental enhancement through mine water treatment efforts may be beneficial. Consequently, this project scores moderately high in this potential benefits category.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.17	30%	0.95
Infrastructure Design, Construction & Operation	3.00	10%	0.30
Environmental Impacts	4.43	15%	0.66
Social & Economic Impacts	5.00	10%	0.50
Project Cost & Schedule	3.33	30%	1.00
Ancillary Benefits	2.40	5%	0.12
AVERAGE	**3.55**		**3.53**

APPENDIX

Scoresheet

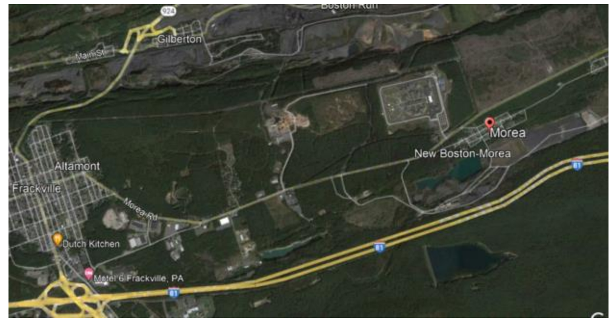
STORAGE PROJECT SCORING

STORAGE PROJECT: M20
NAME: Otto Deep Mine

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.17**			30%	**0.95**	
o Volume of storage provided (BG)	2.26	2					
o Hydrologic reliability of supply (months to fill)	?	4					Recharge of the mine is unclear; others have recharged quickly
o Release rate (cfs)	25	2					
o Promptness of delivery to mainstem (day)	2.6	3					
o Geographic Benefit		4					
o Quality of stored water		4					Assumes treatment of discharge
2. Infrastructure Design, Construction and Operation		**3.00**			10%	**0.30**	
o Site/Civil, Land & Easements		3					Typical but pipeline may create a challenge
o Subsurface conditions		2					Mines and reclamation at WTP site create complexity
o Infrastructure Complexity		4					Reasonable, but mine complexity
o Construction complexity		4					Reasonable, but mine complexity
o Operational complexity		2					Treatment adds complexity to operations
3. Environmental Impacts		**4.43**			15%	**0.66**	
o Protected species		5					None known
o Water quality degradation		5					Should be none and possible improvement
o Obstruction to passage of aquatic animals		5					None known
o Hydromodification		1					Discharge to small stream an issue; mine dewatering impacts possible
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		5	5	5			No expected impact
o Stream length inundated (mi)		5	5	5			No expected impact
o Uplands inundated or developed (ac)		5	5	5			No expected impact
4. Social and Economic Impacts		**5.00**			10%	**0.50**	
o Disruption/displacement		5					
o Safety and health		5					
o Social equity		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					Potential reclamation and stream improvement in the area
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		3					
5. Project Costs & Schedule		**3.33**			30%	**1.00**	
o Land acquisition cost ($)	$0.150M						
o Construction Cost ($)	$19M						
o Operating Cost ($/yr)	$1.25M						
o Overall Cost ($)	$45M	4					
o Cost effectiveness ($/BG)	19.9	3					
o Schedule (Time to make Operational, years)	13	3					
6. Ancillary Benefits		**2.40**			5%	**0.12**	
o Flood control		1					
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					
o Ability to leverage funding from other programs		5					Permitting may be a delay
OVERALL		3.55				**3.53**	

Storage Project Summary

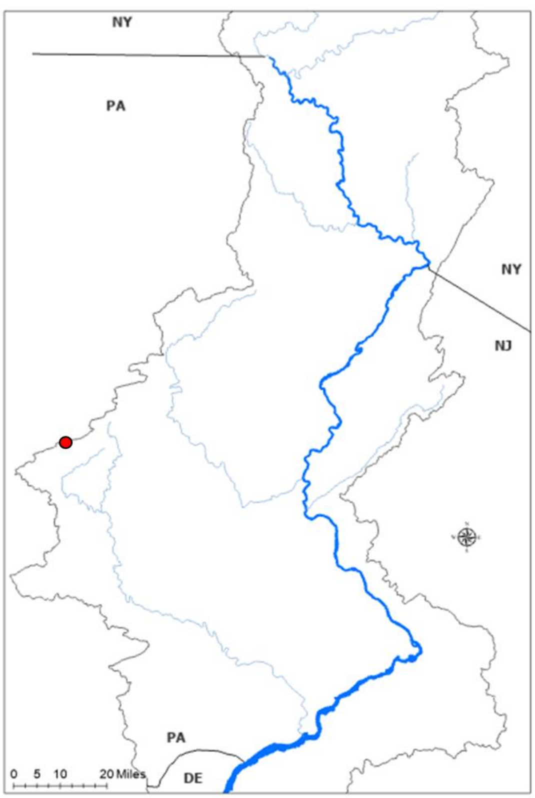
Project:	**Morea Mine (M32)**
Location:	Morea, Schuylkill County, PA
Storage Type:	Deep Coal Mine (Draw)
Est. Volume:	2.67 Billion Gallons
Score:	3.58



1 Project Overview

The scope of this storage project is to utilize the water stored in the Morea deep mine pool, and extract as needed to augment flows. The mine is located in Morea, east of Frackville in Schuylkill County, PA. This is high in the Schuylkill River watershed as shown in Figure 1.1. The mine was operated for many years (reportedly 1888-1932) as a major colliery in the region. The mine is currently inactive. However, the adjacent area and region to the northeast is owned and operated by Wheelabrator to process energy from anthracite coal mining waste (culm).

Figure 1.1 Project Location

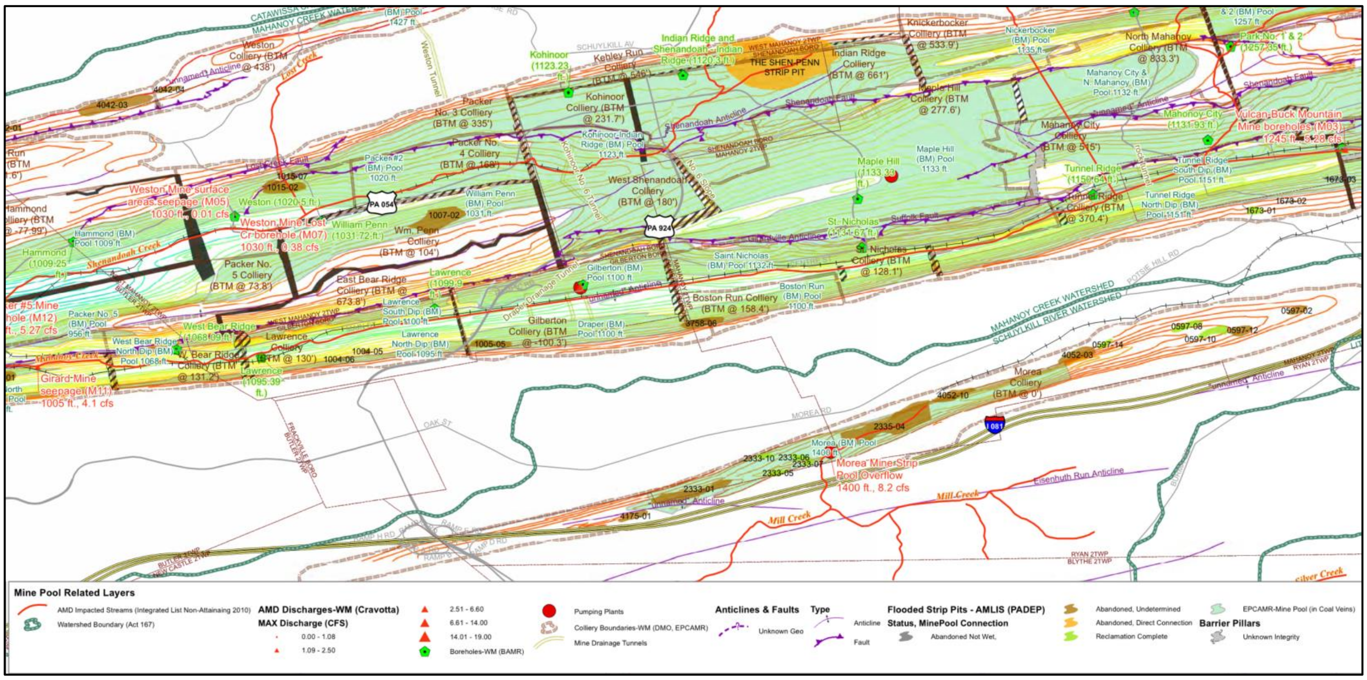


2 Water Quantity & Quality

2.1 Storage Volume

The storage volume of 2.67 BG was estimated by Ash et al. (1949) as described in the main report. This is the total mine pool volume. Figure 2.1 below shows the mine pool as mapped by EPCAMR (Hughes et al., 2011), as an update to information originally compiled by Ash et al.

Figure 2.1: Morea Mine Pool Map



2.2 Fill and Discharge

The intended design is to utilize a portion of the mine pool volume for usable storage and pump out as required to augment flow downstream. The mine pool currently overflows at an elevation of 1400 ft MSL at a relatively low flow rate into Mill Creek. Mill Creek is a small stream with a mean annual flow of 44 cfs. Table 2.1 below provides some additional summary details of storage and discharge related parameters.

Table 2.1: Storage and Discharge Parameters

DESCRIPTION	VALUE
Storage	
Maximum Volume (Billion Gallons)	2.67 BG
Operating Volume (Assumes 50% usable)	1.35 BG
Water Supply – Mine Pool Volume & Recharge	
Proposed Average Pumping Rate (mgd)	NA
Water Release – Mine Discharge (Stream Augmentation)	
Mine Gravity Overflow Point (ft)	1400 ft
Mine Pool Assumed Operating Water Elevation Range (ft)	1400 ft to 1300 ft
Proposed Discharge Pumping Rate	25 cfs/16 mgd
Estimated Time to Release Operating Volume from Storage	2.8 months
Water Supply – Travel to Use	
Receiving Stream	Mill Creek
Receiving Stream Flows (Mean, 7Q10, Bank Full)	44 cfs / 4 cfs/ 801 cfs
Stream Miles to Delaware River	129 miles
Travel Time at 2 mph (hours)	65 hours

2.3 Water Quality

The water quality of stored mine water is unknown. Some historical information adapted from Wood (1996) is provided in Table 2.2. It shows varying water quality among the considered mine pools with water quality at Morea having low pH and relatively high iron.

Table 2.2: Mine Pool Water Quality Samples (after Wood, 1996)

Proj. #	Proj. Name	Description	Sample Date	Water Temp. (°C)	Spec. Conduct. (uS/cm)	pH	Sulfate (mg/l)	Iron (mg/l)	Manganese (mg/l)	Alkalinity at pH 4.5 as $CaCO_3$ (mg/l)
M4	Silver Creek	Tunnel	4-22-75	12.5	500	4.5	270	20	-	0
M4	Silver Creek	Tunnel	11-7-91	11.5	630	6	300	27	3.5	54
M10	Wadesville	Pump	4-22-75	14.0	1500	7.1	630	1	2.3	380
M10	Wadesville	Pump	11-6-91	14.0	1190	7.1	350	2	3.2	275
M19	Phoenix	-	-	-	-	-	-	-		-
M20	Otto	Airshaft	4-23-75	10.5	800	4.7	430	26	4.4	10
M20	Otto	Airshaft	10-31-91	10.3	730	6.1	300	15	3.0	66
M32	**Morea**	**Strip Pool**	**4-16-75**	**8.0**	**440**	**3.2**	**140**	**10**	**-**	**0**
M32	**Morea**	**Strip Pool**	**11-6-91**	**8.0**	**308**	**4.0**	**110**	**9.7**	**1.6**	**0**

The receiving stream, Mill Creek, has marginal water quality based on the PA 303D listing. Table 2.3 below summarizes the listed impairments.

Table 2.3: 303D Listing Impairments

IMPAIRMENT			
Aquatic Use	Recreational	Fish Consumption	Potable Supply
Supporting	Not Assessed	Impaired - mercury atmospheric deposition	Not Assessed

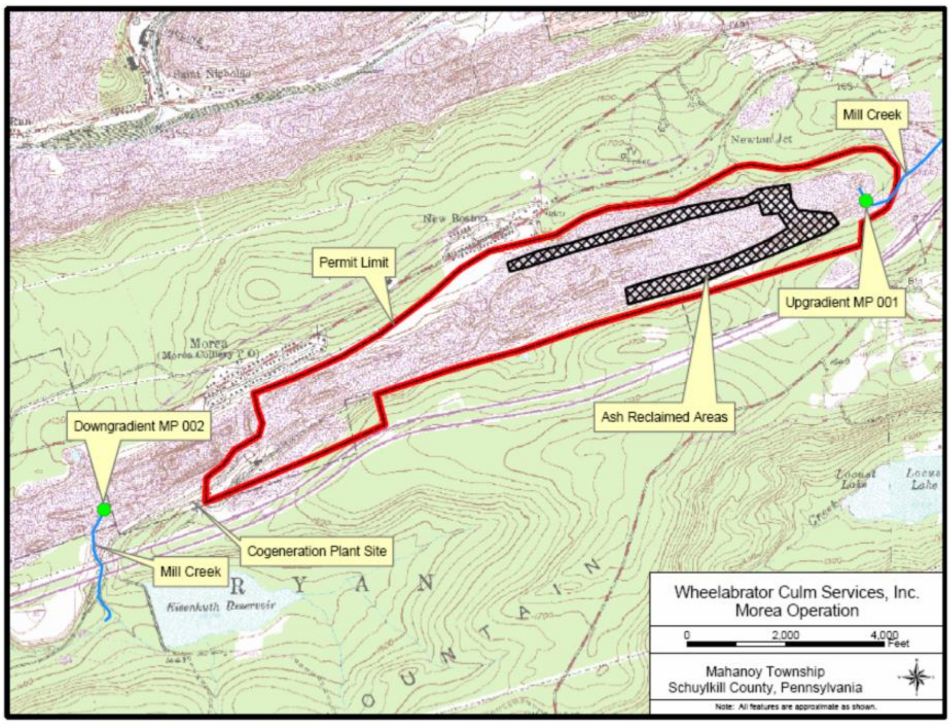
Despite some impairments, the stream has a Chapter 93 classification of a high quality cold water fishery (HQ-CWF) and supports both stocked and wild trout populations.

Water quality of the receiving stream may be impacted by the mine water quality, especially at suggested discharge rates. Additional study is required and monitoring is likely. That said and as discussed further, it is assumed that active treatment of the mine pool water will be required.

3 Infrastructure Design, Construction & Operation

The infrastructure required includes the mine storage access, discharge pumping facilities and discharge piping to the receiving stream. Figure 3.1 shows an area plan to help describe the major facilities.

Figure 3.1: Approximate Facilities Location (from Hornberger et al., 2011)



It is assumed that all pumping and required treatment facilities would be located on or near the Wheelabrator cogeneration plant site. Exact locations cannot be determined in this level of study. Surface grades are approximatley 1475 ft MSL and the avaialble mine overflow elevation is reported at 1400 ft MSL. It is assummed that access into the mine pool to an elevation of 1300 ft MSL will be required.

3.1 Pumping & Piping Facilities

The mine withdrawal pumping station is envisioned to include a drilled shaft to access the mine pool at required depths and submersible pumps similar to the configuration described in Section 5.4 of the main report for quarry water withdrawal. Pumped water would be conveyed to a treatment facility and onto the appropriate discharge point on the nearby Mill Creek. A cursory review of locations indicates a pipeline of approximately 550 lf will be required. In addition, improvements for energy dissipation will be needed at the discharge point on Mill Creek. Table 3.1 below summarizes the key pumping and piping parameters.

3.2 Treatment

As noted in Section 5.5 of the main report, treatment was assumed to meet discharge requirements. This will require the construction and operation of onsite primary treatment, or other contract treatment arrangements. The level of this evaluation does not allow a detailed analysis of treatment requirements. Therefore, approximate capital cost and ongoing operation cost were assumed based on industry references.

Table 3.1: Facility Parameters

Parameter	Value
Mine Static Discharge Head (1475'-1300')	175 ft (100' pool)
Design Flow	16 mgd (25 cfs)
Pump Capacity (2 x 8 mgd)	16 mgd
Pipeline Distance (approx.)	550 lf
Elevation at Discharge Point	1418 ft
Elevation at High Point on Pipeline	1468 ft
Pipe Diameter with 10 ft/s Velocity Limit	30 in
Treatment	(See main report)

Components and quantities of the envisioned pumping/treatment facilities are detailed further in the Section 6, Project Cost & Schedule.

In terms of operations of the project, the pumping can be automatically operated, as described in the quarry storage concepts. However, given the flow and active treatment requirements a partially manned treatment facility is assumed for the mine pool operations.

3.3 Other Infrastructure Considerations

The adjacent Wheelabrator Cogeneration facility used the Morea Mine Pool at times for cooling water makeup. According to Argonne National Laboratory report (Veil and Pruder, 2006), the plant has withdrawn between 300-700 gpm and treated it as required for cooling water and some boiler feed water. Utilizing these facilities, presumably expanded and on a contract basis, may be a viable alternative for mine pool treatment for water supply and should be considered if this storage project advances in the evaluation.

4 Environmental Impacts

This storage project was reviewed at a high level against several environmental parameters as described in the body of the report. These included wetlands, protected species, water quality, hydromodification, and impacts to flora/fauna/habitat. Overall, the project scores high and is somewhat comparable to quarry storage facilities. Construction of pumping/treatment facilities will have minimal impact. The pipeline is relatively short and Mill Creek is nearby, so impacts are negligible. The proposed discharges to Mill Creek are high relative to mean flow, but not excessive. Treatment of the discharge water is assumed, so quality differences are not a concern.

5 Social and Economic Impacts

The mine and surrounding land is industrial and appears to generally be restricted ownership with Wheelabrator owning the majority of the property.

Social and economic impacts generally consider disruption/displacement, safety/health, social equity, recreational loss, aesthetics or loss of revenue or related production. These all appear to be negligible in this case and consequently the project scored high.

6 Project Cost & Schedule

The project team prepared a feasibility-level cost estimate for this storage project consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined in Section 3 above. The following Table 6.1 presents summary capital cost line items. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.

Table 6.1: Capital Cost Summary

Item	Unit	Quantity	Cost/Unit	Extended Cost
PIPELINE			SUBTOTAL	$540,000
Pipeline	LF	550	$800	$440,000
Valves	#	2	$50,000	$100,000
MINE PUMPING SYSTEM			SUBTOTAL	$5,882,000
Intake Structure	VF	175	$25,000	$4,375,000
Pumping Station				
Pumps	#	2	$450,000	$900,000
Structure	SF	800	$350	$280,000
MEP	LS (%)	1	$177,000	$177,000
Electrical Service	LS	1	$50,000	$50,000
Other	LS	1	$100,000	$100,000
TREATMENT SYSTEM			SUBTOTAL	$6,025,000
Tanks	LS	1	$3,000,000	$3,000,000
Chem Feed	LS	1	$1,000,000	$1,000,000
Pumping	LS	1	$500,000	$500,000
MEP	LS (%)	1	$675,000	$675,000
Structure	SF	2000	$350	$700,000
Electrical Service	LS	1	$50,000	$50,000
Other	LS	1	$100,000	$100,000
LAND ACQUISITION				$100,000
Area	ACRE	2	$50,000	$100,000
SUBTOTALS				
Const. Costs Subtotal				$12,547,000
Contingency			50%	$6,273,500
COST + CONTINGENCY				$18,820,500

The total capital is shown above. Operating costs for this facility are estimated to be approximately $1.25M/year. This is approximated based on annually discharging and treating an operating volume of mine storage (50% of total volume), according to industry standard metrics for similar facilities. Again, these costs are very approximate given the development stage of the project, but have been compared with costs for other similar operating facilities. Assuming a 30-year operating horizon, the present value (PV) of the operating cost is $24.5M. This brings the combined total of capital and PV of operating cost to a project total of $43.2M.

The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 12 years. This includes:

- Design, permitting and land acquisition 7 years
- Construction 4 years
- Startup and initial filling of mine 1 year.

7 Potential Ancillary Benefits

This category of potential ancillary benefits considers such items as possible flood control, recreation/tourism, environmental enhancements, reclamation related improvements and the ability to leverage complimentary funding to achieve a greater level of overall improvement. Flood control and recreational/tourism benefits are not likely. However, environmental enhancement by mine water treatment efforts may be very beneficial. This could include supporting abandoned mine land reclamation in the area, actively addressing the AMD from the Morea mine by intercepting/controlling the current untreated overflow, and generally managing the mine pool while providing final discharge to Mill Creek with higher quality water. Further, a joint effort between this project and the ongoing Wheelabrator reclamation project has the potential to realize even greater regional benefits. Consequently, this project scores high in this potential benefits category.

8 Storage Project Score

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented in Table 8.1 below. Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

Table 8.1: Storage Project Score

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.08	30%	0.93
Infrastructure Design, Construction & Operation	3.20	10%	0.32
Environmental Impacts	4.43	15%	0.66
Social & Economic Impacts	5.00	10%	0.50
Project Cost & Schedule	3.50	30%	1.05
Ancillary Benefits	2.40	5%	0.12
AVERAGE	**3.60**		**3.58**

APPENDIX

Scoresheet

STORAGE PROJECT SCORING

STORAGE PROJECT: M32
NAME: Morea Basin Deep Mine

SIX PRIMARY CRITERIA	Quantitative Evaluation Metric (when appropriate) (enter values only	Score (5=best, 1 = worst)			Weight	Weighted Score	Project Specific Comments
1. Water Quantity and Quality		**3.08**			30%	**0.93**	
o Volume of storage provided (BG)	2.67	2.5					
o Hydrologic reliability of supply (months to fill)	??	4					Recharge of the mine is unclear; Others have recharged quickly
o Release rate (cfs)	25	2					Slower release based on dewatering limit and receiving stream
o Promptness of delivery to mainstem (day)	2.7	3					
o Geographic Benefit		3					
o Quality of stored water		4					Assumes treatment required
2. Infrastructure Design, Construction and Operation		**3.20**			10%	**0.32**	
o Site/Civil, Land & Easements		4					No major issues; pipeline is short
o Subsurface conditions		2					Mines creates complexity and unknowns
o Infrastructure Complexity		4					Reasonable; but mine access is a challenge
o Construction complexity		4					Reasonable; but mine access is a challenge
o Operational complexity		2					treatment plant operation will be a challenge
3. Environmental Impacts		**4.43**			15%	**0.66**	
o Protected species		5					None known
o Water quality degradation		5					Treated AMD will be an improvement
o Obstruction to passage of aquatic animals		5					None known
o Hydromodification		1					Discharge stream change limited; mine dewatering impact unclear
			special two-factor scoring for habitat impacts				
Habitat Type		**Combined average**	**replaceability (5=easy; 1 =difficult)**	**quantity impacted (5=small, 1=large)**			
o Wetlands inundated or filled (ac)		5	5	5			No anticipated impact
o Stream length inundated (mi)		5	5	5			No anticipated impact
o Uplands inundated or developed (ac)		5	5	5			No anticipated impact
4. Social and Economic Impacts		**5.00**			10%	**0.50**	
o Disruption/displacement		5					
o Safety and health		5					
o Social equity		5					
o Recreational loss		5					
o Cultural/historical resources		5					
o Aesthetic		5					Potential for more reclamation
o Loss of tax revenue		5					
o Loss of production from farmland, timberland, quarries		5					
o Emissions of greenhouse gasses		3					Not known
5. Project Costs & Schedule		**3.50**			30%	**1.05**	
o Land acquisition cost ($)	$0.1M						
o Construction Cost ($)	$18.7M						
o Operating Cost ($/yr)	$1.25M						
o Overall Cost ($)	$43.4M	4					
o Cost effectiveness ($/BG)	16.2	3.5					
o Schedule (Time to make Operational, years)	12	3					Permitting may be a delay
6. Ancillary Benefits		**2.40**			5%	**0.12**	
o Flood control		1					
o Recreation/tourism		1					
o Habitat/fishery enhancement		1					
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		4					
o Ability to leverage funding from other programs		5					
OVERALL		3.60				**3.58**	

Appendix B – Technical Memorandum

Estimate of Cost of Transferable Storage from Existing Reservoirs in the Delaware River Basin

MOTT MACDONALD

Title:	Estimate of Cost of Transferable Storage from Existing Reservoirs in the Delaware River Basin		
Prepared by:	Kenneth Najjar		
Approved by:	Kirk Barrett	**Date:**	5/19/2022; Revised 11/7/22

1 Introduction

Transferable storage is one of the alternative sources of water being considered in the Delaware River Basin (DRB) Storage Options Project. The project seeks to identify sources of water that can meet Delaware River Basin Commission (DRBC) storage requirements of 1, 5, 10 and 20 billion gallons (BG). The project team has identified existing reservoirs in the Basin that may have excess capacity, which could be sold or leased to DRBC to augment low flows in the Basin. The purpose of this memo is to identify those existing facilities, determine the amount of excess storage available, and estimate the cost of utilization by DRBC.

2 Method

There are many variables (both certain and uncertain) that are used to valuate water, which is an elastic commodity subject to routine changes in supply, which, in turn, are affected by conditions beyond human control (e.g., climate, weather, changes in use, etc.). Water, like any other commodity, is subject to market forces of supply and demand when determining its price at any moment in time. Both aspects (supply and demand) are affected by the uncertainties mentioned above.

Yet, while often difficult to pin down, the price of water is typically established using standard economic approaches for estimation (e.g., capital, operating, and other costs) and transaction (e.g., sale, lease, etc.). Costs are divided into fixed and variable elements.

The fixed costs vary with the capacity of the transfer from the existing reservoir and would typically include:

- Capital cost
- Operating costs that do not vary with use, like staff costs and costs of operating at minimum flows
- Maintenance costs

Variable costs typically include:

- Power and chemical costs, over and above the costs of operating at minimum flows

To be economically efficient, the price would ideally reflect the underlying split of fixed and variable costs. So, a fixed charge would cover financing of the asset and a variable charge would cover the annual adjustable costs. Calculation of the fixed charge will depend upon the source of funding, including repayment period and interest rate.

For uses of transferable storage by DRBC, it can be assumed that the storage will not be called upon in all years. Thus, if a higher proportion of the cost is allocated to the variable charge than is reflected in the underlying costs, there is a significant risk that the project will not recover sufficient revenue to cover fixed costs. So, it is best to keep the charges cost reflective.

In the cost analysis and negotiation, the actual price/rate to transfer excess water stored in existing reservoirs will follow common economic principles. The price is set at an equilibrium cost that a buyer is willing to pay, and seller is willing sell. Complicating factors is the DRBC's desire for reserve storage are timing and frequency of use. These factors differentiate the water resources agency's need to augment basin flows during low flow conditions (although not necessarily declared drought conditions) from a water utility's desire for using water to meet its regular customer demands.

Request for releases of storage secured by DRBC in agreements with reservoir owners will occur when supply of water is low (e.g., low stream flows and/or storage volumes) and of high value to both DRBC and the owner. This may result in a higher price rate for the reserved storage as the overall demand for water may exceed transient supplies. Also, one would expect the frequency of use of the storage reserve by DRBC to be low and irregular, dependent of stream gage data that indicate low flow conditions requiring augmentation.

The uncertainty in the timing and frequency of use of reserve storage by DRBC would require the facility owners to review the availability of their excess capacity versus time. We would expect that they would be conservative in the estimation of available storage during low rainfall and discharge periods, and they may charge a premium for its use. Thus, a successful agreement between DRBC and facility owners may need to consider year-round and seasonal utilization of water storage.

3 Results & Discussion

Four facilities in the Delaware River Basin (labeled DRB 1 through 3) were evaluated for transferable storage. These are identified as T1- T4 elsewhere in the report.

- T1 Merrill Creek reservoir is an existing pump-storage facility located in northwest New Jersey. The reservoir has a capacity of about 15 BG of which 1-2 BG may be available for transfer (2 BG is assumed for costing purposes). Many of the costs are effectively fixed costs (i.e., they do not vary with the volume of water used) but the variable charges are reopened annually.
- T2 is the Mongaup Reservoir System in New York, specifically the Rio Reservoir. No cost information could be obtained on which to base an estimate, as shown in Table 1 below.
- T3 Penn Forest/Wild Creek Reservoirs have a complex system of dams/spillways that collectively hold about 10 BG along with tunnels to provide water to its destinations. An estimated 1-5 BG may be available (3 BG is assumed for costing purposes). The cost rate provided in Table 1 is based on retail raw water prices currently being charged to water companies.
- T4 Lake Ontelaunee is in southeast Pennsylvania and provides storage from an existing reservoir to users in the region. Total storage in the reservoir is about 7 BG of which about 1 BG may be available.

For additional comparators, four additional reservoirs (labeled Additional 1 through 4), where water transfers/sales already exist, are also presented. These facilities sell raw water to utilities who need the additional supplies to satisfy current and/or future customer water needs. They are not under consideration for transfer to DRBC.

Table 1: Transferable Storage Data

Facility	Available Volume	Upfront Costs	O & M	Usage Rate	Annual Cost per BG	Comments
T1 Merrill Creek	1-2 BG	$289K	O&M and pumping costs are extra	$2.6M/BG Capacity Fee	$2.89M plus O&M and pump	Available Volume per docket
T2 Rio/Mongaup	2 BG					Insufficient cost data available
T3 Penn Forest/Wild Creek Reservoirs	1-5 BG	None	None	$2500/MG	$2.50M	Retail prices assumed
T4 Lake Ontelaunee	1 BG	$80K	None	$200/MG	$0.24M	
A1 New Jersey Water Supply Authority – Raritan system	N/A	N/A	N/A	$336/MG	$0.34M	NJWSA Raritan
A2: New Jersey Water Supply Authority– Manasquan system	N/A	N/A	N/A	$1010.75/MG	$1.01M	NJWSA Manasquan
A3: Anglian Water in the United Kingdom	3.5 BG	$4.7M	N/A	$1209/MG	$2.55M	Anglian Water UK
A4: Bucks County Water and Sewer Authority	1.63 BG	$24.7M over 50 yrs	BCWSA is responsible	N/A - County owned lake	$0.31M plus O&M	BCWSA Lake Galena
Annual Average Cost					**$1.4M/BG**	
Annual Median Cost					**$1.0M/BG**	

4 Conclusions

This paper reviews existing water storage in the basin that may be available for transfer/release for DRBC uses. Several conclusions can be drawn:

- Transferable storage offers an opportunity for DRBC to have direct control of additional storage without having to build or expand physical storage facilities. However, control should not be considered additional storage because the water maybe controllable by DRBC under emergency conditions.
- Very few facilities (only 4) in the DRB have been identified for consideration and the volume available from these facilities is small, about 1-5 BG.
- The cost of transfer is significant if the rates are consistent with existing sales shown in Table 1. The average annual cost is about $1.4M per BG of storage, which may not include critical annual costs to operate and maintain the storage. The median cost is about $1.0M per BG. Nonetheless, these costs may compare favorably with other storage options (new dams, quarries, etc.), which are likely to have high capital costs for construction.
- A complicating factor in any agreement between DRBC and facility owners for use of storage is that these facilities are under the regulatory review and permitting of DRBC. Any arrangements for the use of existing storage will need to be written carefully to avoid a conflict of interest.
- Transferable storage remains a viable option in this project but more serious discussion regarding volume, frequency of use, timing, and cost needs to occur between the owners and DRBC to determine if this option would work for DRBC.

Appendix C - Technical Memorandum
Representative Pattern of Monthly Flow in Streams in the Delaware River Basin

Title:	Representative pattern of monthly flow in streams in the Delaware River Basin		
Prepared by:	Harsho Sanyal		
Approved by:	Kirk Barrett	**Date:**	3/17/2022

1 Introduction

Several quarries considered by the Delaware River Basin Storage Options Project are near small streams. The rate of pumping is limited by the flow in the stream which varies daily, seasonally and annually. The purpose of this study was to establish a method for determining the design pumping rate for sizing a pump station on a stream and for estimating the allowable pumping rate for each month.

2 Method

The approach was to use gauged streams as reference sites to develop a representative annual flow pattern that could be applied to the streams by the quarries. The statistic of the pattern was the median of the mean flow for each month, expressed as a fraction of mean flow. The statistic for all gauges was averaged to provide the representative value for each month.

Each monthly value was multiplied by the mean flow at each quarry withdrawal point reported by USGS StreamStats to estimate the median flow rate for each month in the quarry stream. We assumed that pumping would occur from November to April to avoid pumping during late-spring fish reproduction and summer low flows. To be conservative, we assumed that the allowable pumping rate was half of the month's median flow. This will leave 20% of the mean flow in the stream as required by regulation.

All quarries considered are in Pennsylvania (expect one in New Jersey, which is not on a low-flow stream). Consequently, USGS stream gages in eastern Pennsylvania were reviewed and 13 with records >20 years and without extreme regulation were selected for analysis.

For each gage, flow data was downloaded from the USGS web site comprising the median of the daily mean for each day of the year over the period of record. (The median was used instead of the mean because the latter can be skewed by a few days of very high flood flows.)

3 Results & Discussion

Figure 1 maps the gauges used in the analysis; they are also listed in Table 1. Several streams experienced some regulation, which is inevitable given the high density of dams in the area.

Table 1 also shows the monthly median of mean daily flow data as a fraction of the annual flow for each of the 13 stream gages. For example, at Little Lehigh Creek near Allentown, PA, the annual mean flow is 108 cfs. In the month of January, the median of the mean daily flow was 88 cfs (not shown in the table); so the fraction of the annual mean flow is 88/108 or 0.81 for January. Figure 2 plots these fractional values for all 13 gauges for each month. All show the expected pattern of low flows in late summer and early fall and high flows in winter and early spring, although the degree of variation relative to mean flow varies considerably.

The table reports the mean for each month for all gauges; for example, 0.70 for January, which was taken as the representative value for that month to be applied to the quarry streams. The mean for each month is also plotted on Figure 2.

Results for each gauge are presented in the appendix.

Figure 1: Map of gauges used in the study

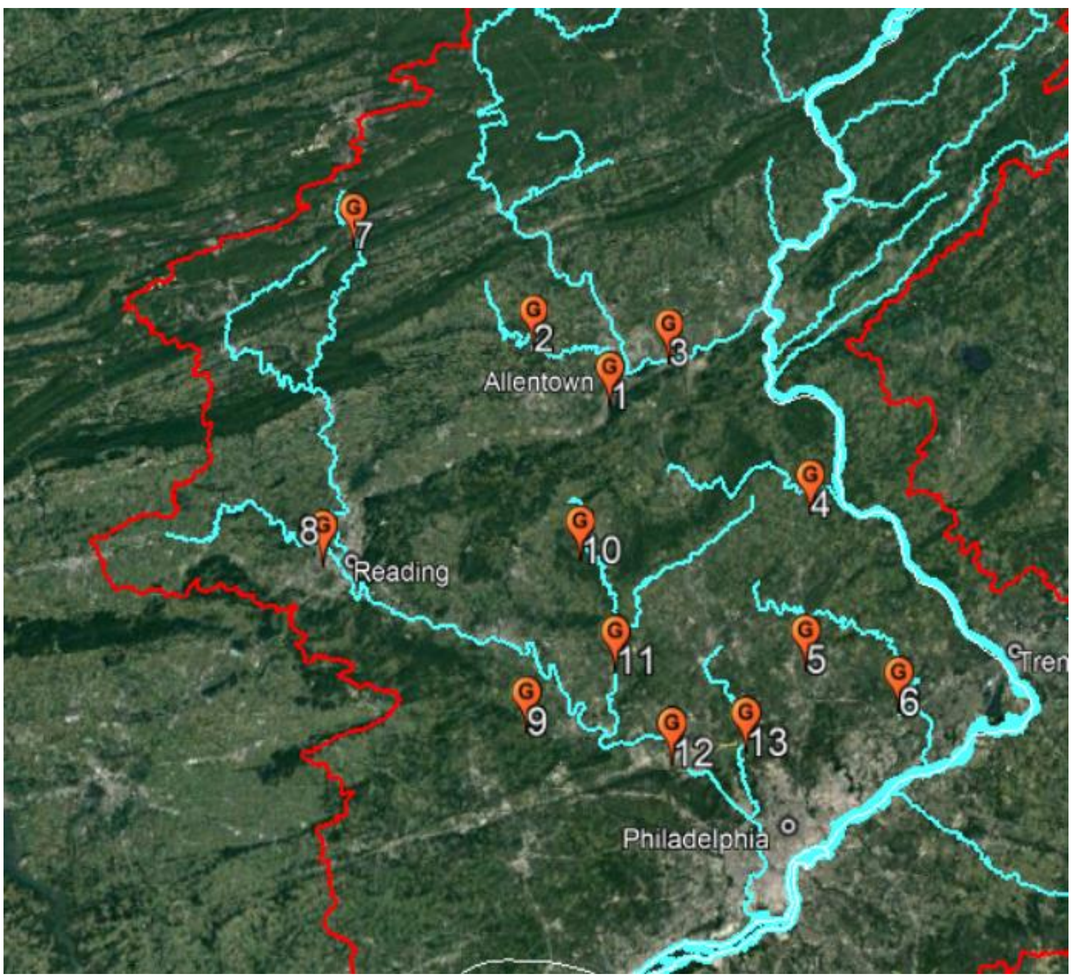
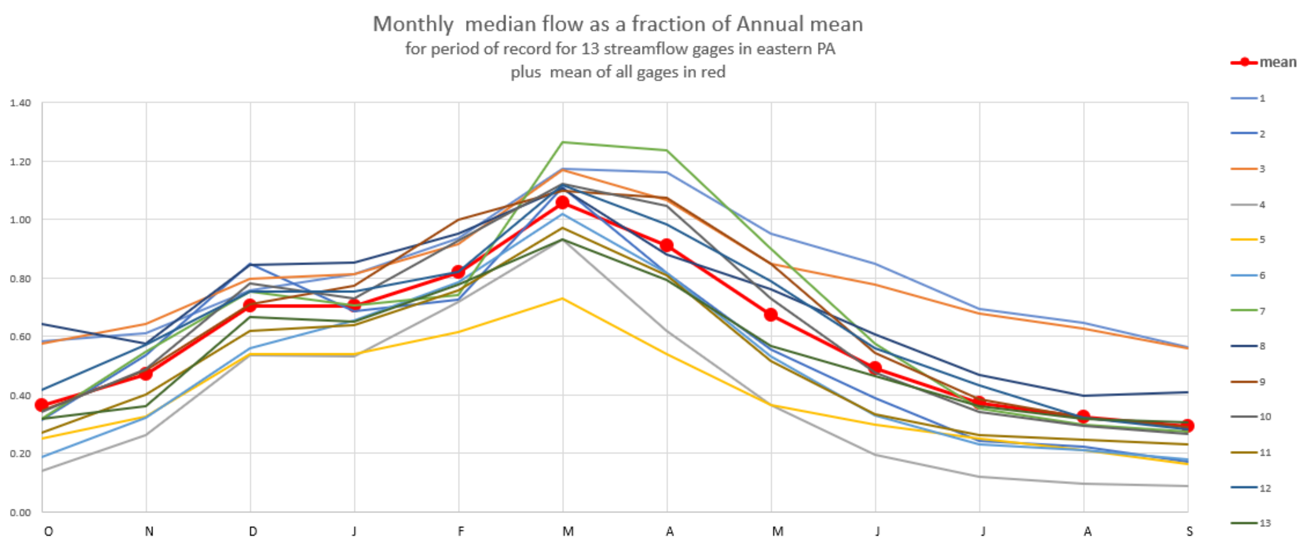


Table 1: Gages and Results

	Gage #	Description	DA (sq. mi)	Period of record	Years	Mean flow, cfs		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
								Median of mean daily flow as fraction of mean flow											
1	1451500	Little Lehigh Creek near Allentown, PA	80.8	1945 - 2021	76	108		0.58	0.61	0.76	0.81	0.94	1.18	1.16	0.95	0.85	0.69	0.65	0.56
2	1451800	Jordan Creek near Schnecksville, PA	53	1966 - 2021	55	99		0.31	0.54	0.85	0.69	0.73	1.11	0.82	0.56	0.39	0.24	0.22	0.17
3	1452500	Monocacy Creek at Bethlehem, PA	44.5	1948 - 2021	73	59		0.58	0.64	0.80	0.81	0.92	1.17	1.07	0.85	0.78	0.68	0.63	0.56
4	1459500	Tohickon Creek near Pipersville, PA	97.4	1973 - 2021	48	173		0.14	0.26	0.54	0.53	0.72	0.93	0.62	0.36	0.19	0.12	0.10	0.09
5	1464907	Little Neshaminy C at Valley Road nr Neshaminy PA	26.8	1998 - 2021	23	52		0.25	0.33	0.54	0.54	0.62	0.73	0.54	0.37	0.30	0.25	0.21	0.16
6	1465500	Neshaminy Creek near Langhorne, PA	210	1934 - 2021	87	333		0.19	0.32	0.56	0.65	0.78	1.02	0.82	0.53	0.33	0.23	0.21	0.18
7	1469500	Little Schuylkill River at Tamaqua, PA	42.9	1919 - 2021	102	88		0.32	0.55	0.75	0.71	0.74	1.27	1.24	0.90	0.58	0.35	0.30	0.27
8	1471000	Tulpehocken Creek near Reading, PA	211	1950 - 2021	71	351		0.64	0.57	0.85	0.85	0.95	1.11	0.88	0.76	0.61	0.47	0.40	0.41
9	1472157	French Creek near Phoenixville, PA	59.1	1968 - 2021	53	93		0.34	0.48	0.71	0.77	1.00	1.10	1.08	0.85	0.54	0.39	0.32	0.29
10	1472199	West Branch Perkiomen Creek at Hillegass, PA	23	1981 - 2021	40	41		0.34	0.49	0.78	0.73	0.93	1.12	1.05	0.73	0.48	0.34	0.29	0.27
11	1473000	Perkiomen Creek at Graterford, PA	279	1957 - 2021	64	439		0.27	0.40	0.62	0.64	0.76	0.97	0.81	0.52	0.33	0.26	0.25	0.23
12	1473500	Schuylkill River at Norristown, PA	1760	2001 - 2021	20	3084		0.42	0.57	0.75	0.75	0.82	1.12	0.98	0.79	0.56	0.43	0.32	0.28
13	1473900	Wissahickon Creek at Fort Washington, PA	40.8	2000 - 2021	21	72		0.32	0.36	0.67	0.65	0.78	0.93	0.79	0.57	0.47	0.36	0.32	0.31
															Statistics for all gages				
							mean	**0.36**	**0.47**	**0.71**	**0.70**	**0.82**	**1.06**	**0.91**	**0.67**	**0.49**	**0.37**	**0.32**	**0.29**
							min	0.14	0.26	0.54	0.53	0.62	0.73	0.54	0.36	0.19	0.12	0.10	0.09
							max	0.64	0.64	0.85	0.85	1.00	1.27	1.24	0.95	0.85	0.69	0.65	0.56

Figure 2



The design flow rate for pumping was selected as the median flow in March, which is 1.06 times the mean flow. This represents the maximum flow rate that could be pumped out of the stream. Most of the time, the actual pumping rate will be less – sometimes much less because of the common requirement to leave 0.2 times the mean annual flow as pass-by in the stream.

To estimate the volume that could be pumped over the six months pumping season, we conservatively estimated the average allowable pumping to be half of the month's median flow. Applying this over the pumping from November through April, the average allowable pumping rate is 0.39 the mean flow.

4 Conclusions

From the above calculations, the following table of multipliers can be derived. For each month, the coefficient can be multiplied by the average flow of the stream that will supply a quarry to estimate the median flow for that month.

Month	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Multiplier on mean flow	0.36	0.47	0.71	0.70	0.82	1.06	0.91	0.67	0.49	0.37	0.32	0.29

The design (maximum) pumping rate is the median flow in March, which is 1.06 times the mean flow. The average allowable pumping rate over the November through April pumping season is 0.39 the mean flow. Mean flow was estimated at each pump-out location using USGS StreamStats. The pumping values are contained in the storage project summary for each quarry.

These conclusions apply assuming pumping rate is limited by streamflow. They do not apply to larger rivers, in which case the design pumping rate is limited by the practical size of a pump station.

APPENDIX -- Median flows for each day of the year and mean for each month for each gage analyzed

Gauge 1: Little Lehigh Creek

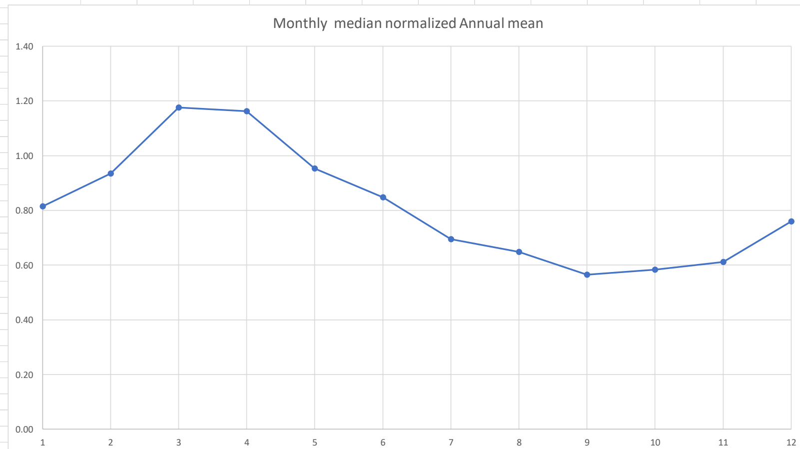
1451500 Little Lehigh Creek near Allentown, PA

Drainage Area, sq mi	80.8
Annual mean flow	108
period	1945
to	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	88	101	127	126	103	92	75	70	61	63	66	82	83
mean	87	103	126	125	106	91	75	70	62	63	67	80	88
min	81	88	114	111	99	82	71	61	59	59	60	67	
max	94	131	141	137	116	105	82	77	68	68	73	88	
median normalized by annual mean	**0.81**	**0.94**	**1.18**	**1.16**	**0.95**	**0.85**	**0.69**	**0.65**	**0.56**	**0.58**	**0.61**	**0.76**	

Day of month 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	81	88	114	133	111	103	80	73	62	66	62	69
2	86	95	118	132	112	105	82	72	60	62	66	68
3	85	102	120	135	116	102	78	70	61	61	67	70
4	85	105	121	137	112	103	76	69	60	63	63	71
5	86	103	115	129	110	99	75	70	59	61	66	67
6	81	96	114	128	114	98	74	69	61	62	64	70
7	87	97	118	130	111	98	77	69	62	60	65	75
8	82	95	116	128	110	93	77	69	61	59	62	72
9	88	94	119	127	109	91	74	71	59	64	60	78
10	89	95	114	129	103	92	74	77	59	67	66	83
11	85	98	119	122	105	93	73	75	62	68	66	83
12	88	96	121	124	108	96	77	72	60	65	66	81
13	86	97	120	131	108	94	76	68	61	63	66	82
14	82	97	128	127	103	87	79	73	61	64	66	85
15	88	96	123	128	103	92	78	74	61	63	65	86
16	88	98	130	126	103	94	77	66	60	61	66	85
17	82	100	129	124	101	88	74	72	65	63	66	87
18	82	105	126	128	106	92	73	73	66	62	68	88
19	91	104	133	125	104	90	72	70	62	62	67	83
20	94	101	129	125	102	85	73	72	62	62	67	81
21	93	103	133	124	103	84	75	72	61	62	69	85
22	92	104	140	124	102	88	71	70	64	62	69	84
23	94	106	141	119	99	86	75	68	59	65	71	79
24	90	108	138	119	108	87	74	67	59	65	71	86
25	92	115	135	117	99	84	75	68	61	64	70	83
26	87	117	133	119	102	83	74	68	64	67	69	84
27	88	113	132	113	102	82	76	66	64	62	70	82
28	89	118	131	113	102	82	73	67	68	64	71	81
29	89	131	127	111	102	83	73	65	62	68	73	81
30	88		131	111	100	84	74	62	59	66	72	82
31	89		134		102		76	61		64		80



Gage 2: Jordan Creek Streamflow Patterns

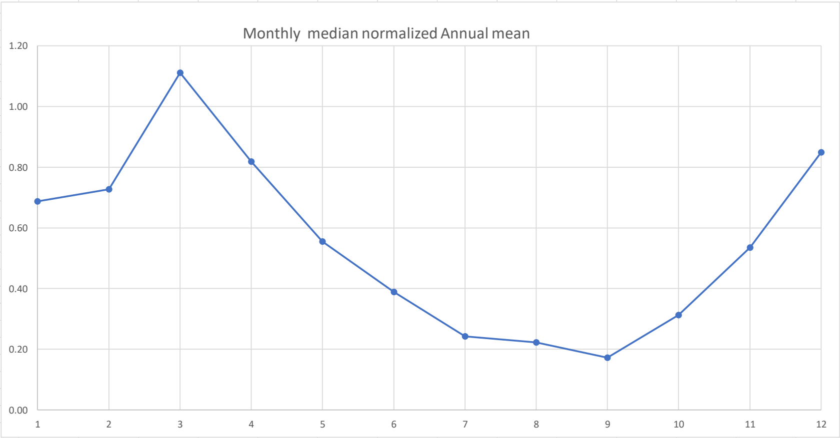
1451800	**Jordan Creek near Schnecksville, PA**		
Drainage Area, sq mi		53
Annual mean flow		99
period		1966
to		2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	68	72	110	81	55	39	24	22	17	31	53	84	53
mean	67	76	111	87	54	38	24	22	19	33	53	87	56
min	0	64	81	71	40	30	18	16	15	27	44	69	
max	92	98	148	117	68	49	28	32	27	54	68	187	

median normalized by annual mean	**0.69**	**0.73**	**1.11**	**0.82**	**0.56**	**0.39**	**0.24**	**0.22**	**0.17**	**0.31**	**0.54**	**0.85**

Day of month — 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	66	99	105	68	42	28	22	17	30	51	69
2	88	71	95	117	62	49	27	24	17	31	46	70
3	86	81	94	104	63	45	28	23	17	28	48	79
4	82	79	84	108	60	41	28	25	16	28	49	84
5	73	71	90	116	57	43	25	31	16	29	49	80
6	80	75	83	116	58	44	24	26	15	31	49	87
7	75	71	85	107	62	42	23	23	15	31	54	80
8	68	64	81	104	53	46	26	21	17	27	45	76
9	69	66	88	95	58	44	27	21	15	30	45	81
10	65	68	89	87	58	41	25	23	15	31	44	85
11	69	67	96	88	54	41	26	26	15	33	53	83
12	70	69	103	81	53	39	25	32	16	31	51	83
13	75	69	105	85	55	41	21	27	15	30	50	92
14	71	66	127	85	56	40	24	25	15	28	53	83
15	68	65	117	77	56	35	23	25	15	30	50	99
16	65	66	105	72	58	32	28	22	17	31	49	86
17	65	72	98	79	60	34	25	20	17	32	53	91
18	62	76	110	87	62	36	24	23	19	32	59	88
19	55	73	113	77	65	34	25	24	20	30	57	87
20	58	77	131	71	55	40	23	21	21	33	56	76
21	61	71	126	78	52	38	22	21	20	28	62	71
22	56	74	130	81	49	33	20	20	22	30	57	72
23	56	77	143	76	48	34	21	19	23	32	55	75
24	60	90	147	72	48	33	18	22	22	32	54	85
25	71	97	148	77	44	34	21	20	19	36	53	83
26	92	96	135	71	45	33	23	18	20	37	53	91
27	74	97	130	72	43	30	25	18	23	40	63	96
28	70	98	132	72	40	32	25	18	26	39	57	90
29	67	87	123	72	42	30	22	17	27	49	56	89
30	68		114	73	41	34	23	17	25	54	68	90
31	66		112		46		22	16		51		187



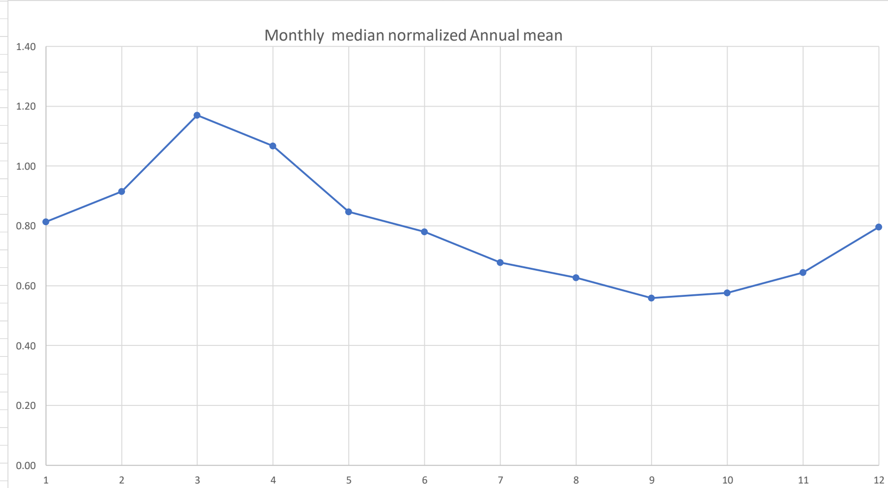
Gage 3: Monocacy Creek Streamflow Patterns

1452500	**Monocacy Creek at Bethlehem, PA**
Drainage Area, sq mi	44.5
Annual mean flow	59
period	1948
to	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	48	54	69	63	50	46	40	37	33	34	38	47	45
mean	47	56	69	64	51	46	40	37	33	35	38	48	47
min	42	46	64	53	46	40	37	34	31	31	34	40	
max	53	75	76	75	59	52	43	43	37	39	42	92	
median normalized by annual mean	**0.81**	**0.92**	**1.17**	**1.07**	**0.85**	**0.78**	**0.68**	**0.63**	**0.56**	**0.58**	**0.64**	**0.80**	

Day of month — 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	51	46	65	67	55	50	40	38	34	34	37	41
2	53	47	65	72	56	52	42	37	34	34	35	40
3	50	49	65	72	59	51	43	37	33	34	38	43
4	49	52	65	75	57	49	41	38	33	34	34	43
5	50	55	67	72	57	50	43	36	32	34	38	41
6	46	52	69	68	55	51	43	35	32	34	37	40
7	49	54	67	66	56	49	42	39	34	32	36	45
8	48	55	64	67	54	46	41	38	32	34	35	43
9	46	54	66	65	53	47	41	40	32	34	34	43
10	43	53	65	66	53	46	42	43	33	34	36	47
11	43	52	65	66	50	46	43	41	33	36	36	45
12	45	52	66	64	50	45	42	37	32	35	36	45
13	43	51	70	63	51	45	40	36	31	34	38	44
14	44	48	69	62	52	43	42	40	31	35	36	49
15	46	48	68	66	49	49	41	37	32	34	37	49
16	42	54	68	66	48	46	40	38	32	35	39	46
17	42	52	71	61	47	47	39	38	34	33	38	50
18	43	55	70	62	47	46	39	37	33	34	40	49
19	44	55	74	63	52	43	41	35	33	33	39	44
20	43	54	68	59	48	44	42	35	33	34	41	46
21	48	57	69	60	47	43	40	35	33	31	41	47
22	47	62	76	62	46	46	39	35	33	31	40	47
23	49	64	75	60	46	41	40	35	32	33	42	51
24	48	60	76	62	47	45	39	34	31	38	38	54
25	50	63	73	60	47	41	37	34	31	39	40	52
26	49	66	71	59	47	44	39	37	32	36	40	50
27	48	69	71	56	47	44	38	36	35	35	39	49
28	49	66	69	56	46	44	40	36	37	37	38	48
29	48	75	68	56	48	43	39	35	35	39	41	49
30	48		69	53	52	40	38	35	37	38	38	47
31	47		69		50		39	35		38		92



Gage 4: Tohickon Creek Streamflow Patterns

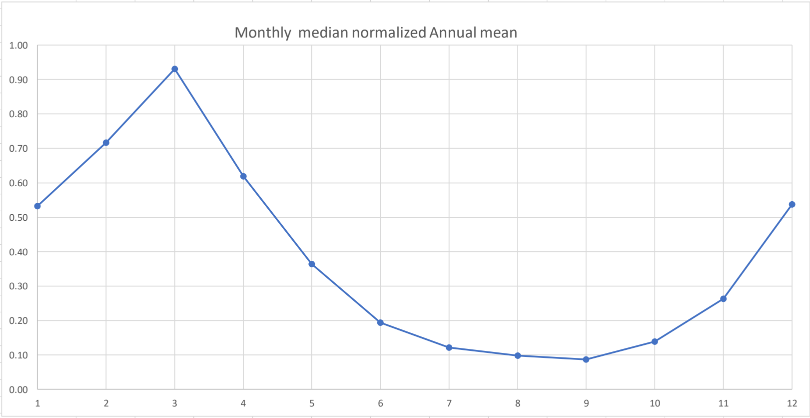
1459500 Tohickon Creek near Pipersville, PA

Drainage Area, sq mi	97.4
Annual mean flow	173
period	1973
to	2022

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	92	124	161	107	63	34	21	17	15	24	46	93	56
mean	95	116	168	113	62	35	21	18	16	28	46	96	68
min	75	71	107	75	42	22	18	14	12	19	18	55	
max	127	176	304	173	84	60	29	23	25	64	102	171	
median normalized by annual mean	**0.53**	**0.72**	**0.93**	**0.62**	**0.36**	**0.19**	**0.12**	**0.10**	**0.09**	**0.14**	**0.26**	**0.54**	

Day of month — 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	102	88	117	151	84	48	25	23	14	21	62	93
2	103	107	116	136	84	51	23	21	14	20	60	74
3	95	105	107	173	79	48	23	20	13	22	65	99
4	82	92	126	166	78	60	20	20	14	20	56	115
5	90	94	130	152	82	53	21	19	12	20	71	102
6	91	90	116	144	74	47	23	18	13	20	40	98
7	92	79	119	119	62	46	21	16	13	19	32	75
8	84	95	145	99	59	42	20	17	12	20	23	61
9	84	88	162	122	73	44	20	16	13	21	19	68
10	80	71	162	113	68	38	20	16	14	22	18	80
11	84	81	153	105	63	38	18	14	14	29	21	77
12	113	90	172	107	68	36	19	15	15	27	20	64
13	99	93	183	110	72	33	20	14	16	25	24	55
14	103	128	180	94	70	34	20	16	15	24	25	81
15	86	124	164	106	75	30	21	16	14	22	24	89
16	88	134	146	111	74	29	21	18	15	23	25	102
17	75	115	174	112	63	34	18	21	15	30	38	92
18	95	134	201	139	62	33	18	21	15	22	43	123
19	97	133	222	120	71	34	22	21	17	26	55	106
20	102	150	304	107	56	31	19	23	15	24	47	84
21	96	145	261	102	52	28	20	23	16	24	45	91
22	85	126	266	101	50	26	20	21	16	25	47	84
23	97	128	199	90	46	28	19	19	16	23	46	88
24	102	132	233	85	42	29	22	17	16	30	51	96
25	127	140	187	75	49	26	23	16	15	28	46	171
26	124	176	148	82	47	24	22	16	16	32	44	148
27	99	162	139	96	43	22	20	15	22	39	70	118
28	89	129	129	94	43	23	29	15	25	38	72	102
29	91	142	145	90	47	22	23	14	23	59	74	113
30	88		161	91	50	24	26	14	24	53	102	115
31	87		156		48		24	14		64		99



Gage 5: Little Neshaminy Creek Streamflow Patterns

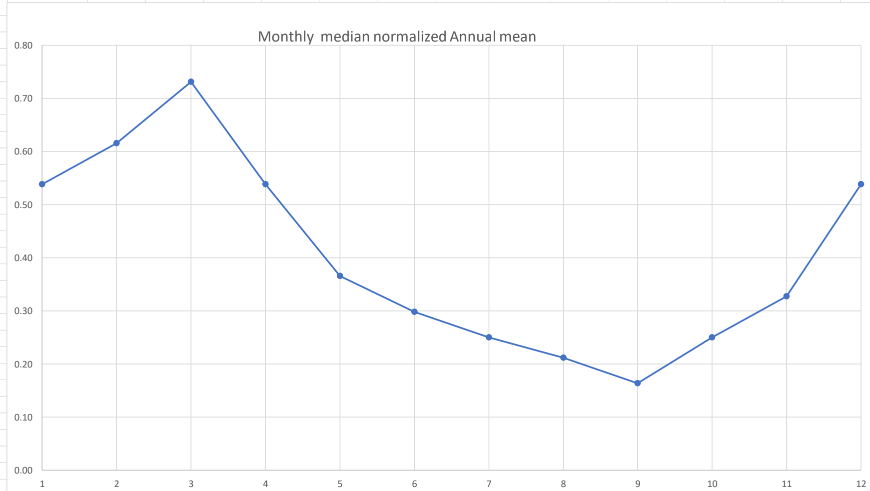
1464907 Little Neshaminy C at Valley Road nr Neshaminy PA

Drainage Area, sq mi	26.8
Annual mean flow	52
period	1998
to	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	28	32	38	28	19	16	13	11	9	13	17	28	20
mean	28	34	40	29	20	17	13	12	9	15	18	31	22
min	23	22	30	22	14	9	9	8	6	9	12	18	
max	40	50	63	39	25	29	20	19	18	33	28	53	
median normalized by annual mean	**0.54**	**0.62**	**0.73**	**0.54**	**0.37**	**0.30**	**0.25**	**0.21**	**0.16**	**0.25**	**0.33**	**0.54**	
Mean of	54	61	78	60	44	55	36	41	53	37	45	69	52.75

Day of month — 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	30	22	39	32	22	16	9.1	12	12	17	23	28
2	30	29	34	33	24	14	13	18	9.1	12	20	34
3	32	29	34	31	23	20	13	12	9.3	12	16	27
4	31	26	33	39	23	29	12	19	8.7	11	14	24
5	30	23	33	35	22	25	13	11	7.2	10	13	21
6	28	32	36	28	17	24	12	10	8.5	8.8	16	20
7	28	32	42	26	15	22	11	15	9.5	11	17	20
8	26	28	40	30	21	23	9.9	9.9	8.9	12	15	18
9	24	29	50	29	22	22	9.1	15	7.8	12	14	23
10	24	29	38	28	19	19	10	14	9.9	11	13	30
11	31	32	30	31	17	14	8.8	12	8.3	12	14	26
12	40	33	45	35	18	18	8.5	16	7.9	18	12	28
13	29	32	39	39	22	20	12	12	9.5	13	14	26
14	27	30	33	28	21	20	14	17	11	13	14	35
15	25	31	30	28	22	23	18	15	7.9	13	15	32
16	28	45	32	31	22	17	16	9.1	8.4	22	18	37
17	30	39	34	28	18	14	15	8.6	6.7	16	22	36
18	30	39	43	23	19	14	16	7.9	7.1	16	18	29
19	31	34	43	22	20	15	13	9.6	7.7	15	19	26
20	28	32	46	29	20	12	10	12	8.1	15	17	25
21	24	32	63	28	18	12	11	11	11	14	17	28
22	25	39	55	30	19	17	14	13	9.2	13	17	27
23	25	37	59	29	18	14	11	11	8.5	12	17	37
24	23	28	50	28	25	12	10	8.9	6	15	18	53
25	30	41	41	27	20	9.5	19	8.4	6.5	14	22	49
26	27	50	37	27	17	9.6	20	8.1	7.3	13	28	48
27	24	50	36	26	17	12	14	8.1	7.6	14	24	41
28	24	42	32	24	17	14	16	11	11	18	23	35
29	23	41	35	26	19	13	16	12	9.5	33	22	35
30	24		43	27	17	9.3	15	11	18	28	22	34
31	23		37		14		13	8.2		24		28



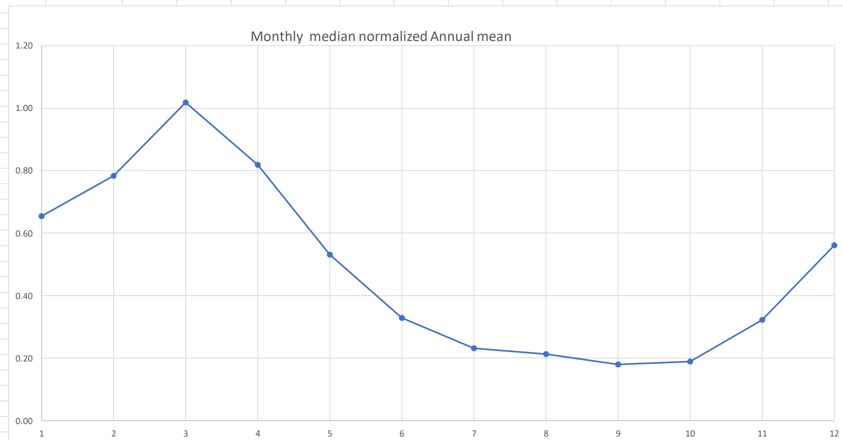
Gage 6: Neshaminy Creek Streamflow Patterns

1465500	**Neshaminy Creek near Langhorne, PA**
Drainage Area, sq mi	210
Annual mean flow	333
period	1934
to	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	218	261	339	273	177	110	77	71	60	63	108	187	142
mean	216	265	334	269	175	111	77	75	60	65	115	193	163
min	186	220	264	205	138	81	67	60	51	49	87	150	
max	241	320	406	326	220	142	86	92	71	100	179	258	
median normalized by annual mean	**0.65**	**0.78**	**1.02**	**0.82**	**0.53**	**0.33**	**0.23**	**0.21**	**0.18**	**0.19**	**0.32**	**0.56**	

Day of month — 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	215	223	280	326	194	134	76	92	65	65	87	167
2	214	220	280	305	209	142	79	83	68	64	90	150
3	217	244	264	308	220	137	76	77	67	62	90	165
4	220	240	304	306	214	135	71	76	57	63	100	160
5	229	246	318	322	200	132	69	78	53	57	107	172
6	223	256	338	300	184	136	71	90	51	53	118	178
7	241	295	356	294	192	131	69	76	53	49	115	176
8	230	277	323	273	183	120	70	79	55	52	100	180
9	221	257	342	302	205	115	77	86	51	59	94	177
10	218	230	298	299	202	115	83	90	51	66	100	173
11	222	228	310	293	178	110	72	85	56	64	96	171
12	219	254	322	288	182	114	80	85	56	58	96	181
13	226	256	354	296	176	118	85	81	55	55	114	210
14	203	261	362	268	183	142	78	70	66	55	108	201
15	221	269	360	269	183	129	80	68	71	53	103	218
16	231	252	351	268	177	106	86	60	70	52	97	245
17	210	255	351	314	173	104	76	71	70	57	96	258
18	202	286	339	278	159	99	73	75	64	51	94	232
19	202	270	370	272	168	103	67	73	60	58	106	206
20	213	292	376	256	174	109	79	68	58	65	119	196
21	222	268	406	243	179	97	77	67	56	63	129	210
22	219	295	383	237	164	99	85	69	52	64	124	197
23	220	320	375	232	163	95	82	71	61	71	123	183
24	216	281	353	226	162	96	81	70	57	71	127	196
25	231	299	368	220	149	99	75	71	61	75	126	177
26	217	261	345	214	141	86	76	71	60	78	137	182
27	207	302	328	211	139	85	71	71	62	84	137	196
28	200	287	299	227	138	82	79	68	62	82	160	187
29	186	272	288	226	143	81	84	64	66	100	171	205
30	186		309	205	149	81	74	64	61	92	179	214
31	212		297		142		79	62		84		208



Gage 7: Little Schuylkill River Streamflow Patterns

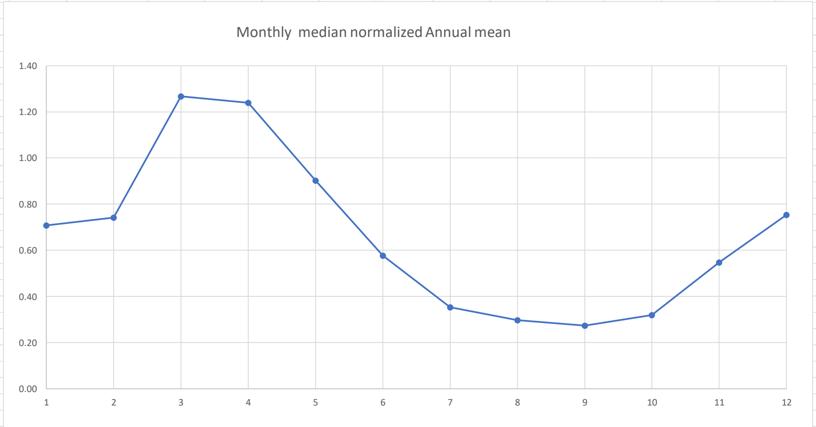
1469500 Little Schuylkill River at Tamaqua, PA

Drainage Area, sq mi	42.9
Annual mean flow	88
period	1919
to	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	62	65	111	109	79	51	31	26	24	28	48	66	60
mean	59	66	106	108	77	49	31	25	24	28	51	67	58
min	0	57	79	90	62	37	25	21	22	23	39	62	
max	79	83	133	128	84	63	38	29	28	35	67	73	
median normalized by annual mean	**0.71**	**0.74**	**1.27**	**1.24**	**0.90**	**0.58**	**0.35**	**0.30**	**0.27**	**0.32**	**0.55**	**0.75**	

Day of month — 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	0	57	82	115	84	61	36	29	23	27	40	73
2	0	59	79	112	84	61	35	28	24	26	39	70
3	72	61	84	114	79	57	34	24	24	28	39	71
4	79	65	83	116	82	60	36	26	24	26	41	64
5	72	63	83	118	84	63	38	25	23	28	43	66
6	73	66	84	117	80	56	35	27	24	23	44	65
7	68	62	87	119	74	56	36	26	23	23	47	67
8	65	61	85	127	79	54	37	26	25	23	47	69
9	66	76	81	128	80	54	33	25	25	24	45	70
10	65	66	86	121	79	54	32	27	25	25	48	70
11	68	65	83	122	82	54	31	24	23	26	43	66
12	62	70	86	117	82	50	32	25	24	25	46	68
13	62	69	94	112	82	52	30	26	24	30	47	68
14	65	64	107	104	82	51	30	26	22	30	47	65
15	63	66	110	104	78	53	33	24	24	27	48	66
16	62	66	112	106	76	54	30	26	23	28	46	66
17	62	68	111	110	73	50	32	24	24	29	48	63
18	60	62	117	107	72	45	35	24	23	28	49	66
19	60	64	118	114	81	41	31	26	24	27	51	65
20	56	61	120	105	79	43	30	26	23	27	51	70
21	56	62	127	100	76	49	27	28	25	27	49	70
22	62	60	119	98	83	43	27	26	25	26	54	65
23	60	58	133	99	83	41	26	26	24	28	65	67
24	58	63	132	101	74	40	27	26	24	29	67	66
25	56	70	127	95	71	42	29	21	24	29	63	64
26	62	72	126	94	73	39	28	22	25	29	62	68
27	62	76	133	97	70	38	27	22	24	30	64	64
28	64	83	128	95	69	37	25	24	25	32	62	62
29	60	83	123	94	62	38	27	22	26	34	60	65
30	60		121	90	62	37	26	24	28	35	60	68
31	57		118		62		27	27		34		72



Gage 8: Tulpehocken Creek Streamflow Patterns

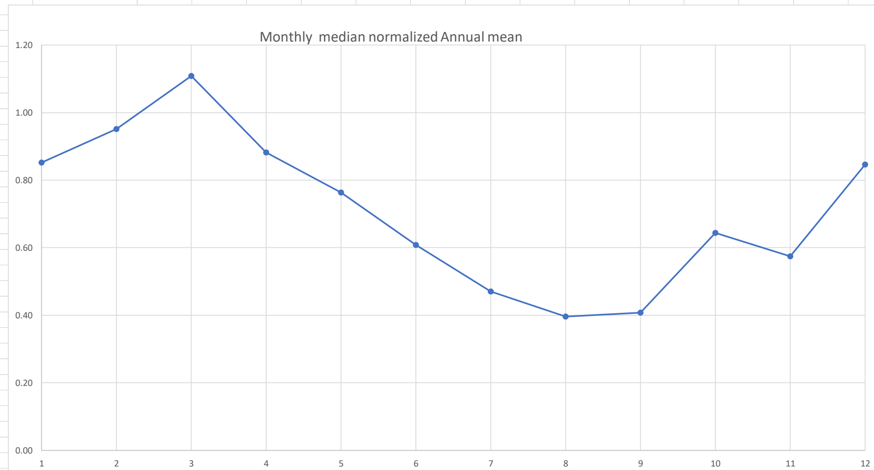
1471000 Tulpehocken Creek near Reading, PA

Drainage Area, sq mi	211
Annual mean flow	351
period	1950
to	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	299	334	389	310	268	214	165	139	143	226	202	297	252
mean	302	331	397	316	271	212	170	137	143	225	204	301	251
min	253	273	346	251	230	157	150	102	104	172	161	253	
max	368	393	509	411	310	271	213	163	165	275	285	409	
median normalized by annual mean	**0.85**	**0.95**	**1.11**	**0.88**	**0.76**	**0.61**	**0.47**	**0.40**	**0.41**	**0.64**	**0.57**	**0.85**	

Day of month — 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	337	286	362	364	280	269	150	151	104	172	170	261
2	343	289	390	319	298	271	162	146	114	180	169	293
3	323	295	361	334	293	267	171	143	131	201	180	311
4	368	326	373	300	296	236	166	147	142	223	184	289
5	344	381	364	300	310	243	172	135	142	249	186	289
6	321	344	358	271	292	231	168	157	148	233	190	273
7	267	321	346	251	291	245	175	144	147	232	196	270
8	287	328	390	256	296	217	162	131	133	233	201	255
9	310	339	365	263	290	221	172	117	158	229	161	259
10	309	316	386	271	277	241	160	139	153	228	166	253
11	298	294	383	277	268	212	164	131	143	226	167	299
12	305	281	389	316	264	213	165	158	151	226	183	300
13	299	288	379	373	266	220	199	147	154	224	185	297
14	295	273	432	350	264	226	185	137	141	222	202	274
15	294	281	415	335	286	220	213	127	132	244	190	289
16	253	314	406	361	281	223	203	121	134	250	188	318
17	287	324	361	411	267	202	184	124	142	204	213	310
18	306	345	405	411	278	192	172	132	156	196	211	310
19	305	334	443	348	288	209	166	119	154	226	209	290
20	305	347	474	336	278	214	172	139	159	194	206	271
21	283	353	509	324	250	190	165	161	146	202	236	298
22	295	356	448	347	266	188	160	163	142	195	204	293
23	285	355	434	336	240	182	155	152	137	203	241	285
24	297	371	434	289	247	182	160	153	143	248	225	314
25	315	393	409	268	247	178	159	155	148	264	236	314
26	329	368	393	282	246	174	161	143	137	233	216	369
27	304	380	387	281	240	179	181	128	141	255	236	327
28	272	353	393	298	230	187	160	126	152	266	238	303
29	271	364	362	290	251	173	161	121	155	275	285	363
30	256		387	303	261	157	158	111	165	251	260	409
31	284		371		254		160	102		183		356



Gage 9: French Creek Streamflow Patterns

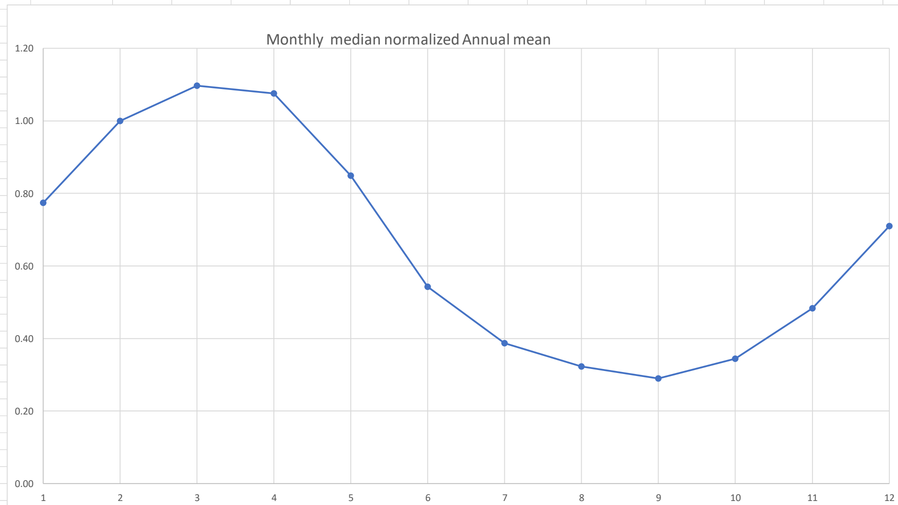
1472157 French Creek near Phoenixville, PA

Drainage Area, sq mi	59.1
Annual mean flow	93
period	1968
to	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	72	93	102	100	79	51	36	30	27	32	45	66	59
mean	73	93	104	102	76	52	36	30	27	32	45	65	61
min	61	76	92	85	62	39	30	26	22	27	35	54	
max	80	115	129	123	92	66	40	34	33	43	58	81	
median normalized by annual mean	**0.77**	**1.00**	**1.10**	**1.08**	**0.85**	**0.54**	**0.39**	**0.32**	**0.29**	**0.34**	**0.48**	**0.71**	

Day of month 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	70	76	96	121	78	60	38	32	25	31	38	56
2	75	96	94	114	79	64	39	33	25	31	37	68
3	71	100	92	114	83	61	39	30	28	31	36	59
4	78	94	97	123	80	66	39	34	29	29	35	64
5	74	93	96	111	88	63	38	29	27	28	37	57
6	70	93	97	107	86	63	35	32	28	27	45	58
7	68	93	100	100	79	63	39	33	28	27	43	63
8	70	89	100	114	82	56	37	31	27	27	39	54
9	72	82	99	108	82	56	36	32	28	33	36	55
10	77	76	93	100	92	55	37	33	27	33	37	60
11	80	77	99	98	85	53	35	33	26	30	43	68
12	80	87	105	102	84	53	36	34	25	32	39	59
13	69	90	102	105	84	53	33	31	26	31	44	58
14	68	90	108	93	84	48	40	32	26	28	45	72
15	73	92	102	100	82	51	38	32	26	28	45	72
16	69	95	95	110	82	53	39	30	26	32	43	69
17	61	88	98	102	78	50	37	31	26	30	52	70
18	75	89	110	100	79	48	34	30	28	29	57	69
19	80	94	115	98	75	50	32	30	28	31	51	67
20	75	106	108	95	74	48	31	30	26	35	52	62
21	68	97	129	97	71	47	33	29	24	32	44	66
22	71	94	120	100	70	47	33	30	27	32	45	69
23	79	105	122	92	67	48	36	27	23	33	45	69
24	79	102	113	88	67	44	38	27	22	32	50	81
25	80	96	104	98	67	45	36	26	27	34	47	75
26	78	93	114	98	64	42	32	27	29	34	51	70
27	77	102	111	95	65	40	37	29	33	38	50	64
28	68	98	106	96	64	41	30	27	32	34	55	64
29	70	115	102	93	62	40	33	27	32	40	58	63
30	71		98	85	64	39	34	26	31	43	57	72
31	70		106		63		35	26		36		74



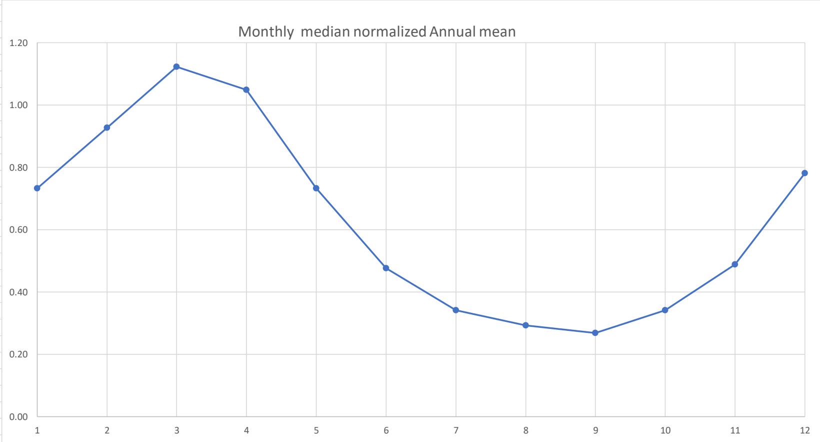
Gage 10: West Branch Perkiomen Creek Streamflow Patterns

1472199	**West Branch Perkiomen Creek at Hillegass, PA**
Drainage Area, sq mi	23
Annual mean flow	41
period	1981
to	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	30	38	46	43	30	20	14	12	11	14	20	32	26
mean	30	37	46	43	31	21	14	12	11	14	20	31	26
min	26	28	40	35	26	15	12	10	10	11	15	22	
max	37	51	61	50	37	28	17	15	14	21	25	41	
median normalized by annual mean	**0.73**	**0.93**	**1.12**	**1.05**	**0.73**	**0.48**	**0.34**	**0.29**	**0.27**	**0.34**	**0.49**	**0.78**	

Day of month 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	37	31	42	50	34	26	16	13	10	12	16	28
2	34	38	41	46	34	23	17	12	10	12	16	27
3	30	40	41	47	36	23	15	11	10	12	15	35
4	29	38	41	47	37	26	14	11	10	13	15	32
5	29	37	41	49	37	28	14	11	9.9	13	19	22
6	26	39	40	45	37	27	14	11	11	11	20	30
7	27	35	42	44	36	27	14	11	12	12	18	28
8	28	32	43	45	33	24	15	11	12	13	16	25
9	27	29	43	43	35	25	15	12	11	13	16	24
10	29	28	44	40	32	23	13	14	11	14	19	30
11	29	28	47	41	31	22	13	15	12	13	19	31
12	33	32	51	45	30	22	13	15	11	14	18	29
13	30	33	48	48	31	20	13	11	12	15	19	26
14	27	33	51	39	30	18	16	15	11	15	21	34
15	32	35	46	42	28	19	16	14	9.9	15	21	33
16	30	35	41	43	33	19	16	13	10	15	22	34
17	29	38	44	44	31	18	14	12	11	15	24	33
18	32	34	44	45	28	18	13	13	11	13	23	33
19	33	38	48	42	28	23	12	13	11	13	21	28
20	30	39	51	40	30	22	13	13	11	13	20	28
21	30	39	61	43	29	18	12	13	10	13	20	33
22	28	40	50	44	27	19	13	12	11	13	21	34
23	32	44	51	40	27	19	13	12	11	14	20	35
24	31	44	48	40	30	17	15	12	10	17	21	38
25	37	40	46	35	27	17	13	11	11	15	18	41
26	33	38	46	41	29	15	16	11	12	16	24	35
27	29	40	45	35	29	16	17	11	13	18	24	30
28	30	40	43	38	28	17	17	12	14	17	23	28
29	28	51	46	38	28	17	15	12	13	20	25	32
30	30		46	37	29	16	14	9.7	12	21	25	37
31	28		48		26		15	9.9		18		34



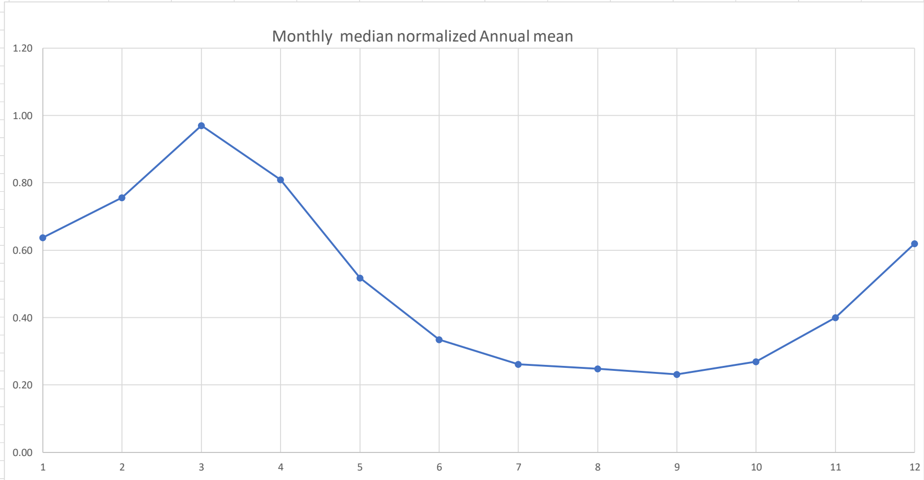
Gage 11: Periomen Creek Streamflow Patterns

1473000	**Perkiomen Creek at Graterford, PA**
Drainage Area, sq mi	279
Annual mean flow	439
period	1957
to	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	280	332	426	355	227	147	115	109	102	118	176	272	200
mean	279	336	435	355	226	154	116	108	102	122	174	275	223
min	222	258	343	282	179	118	105	90	90	101	131	228	
max	324	443	569	468	280	207	137	129	117	151	258	338	
median normalized by annual mean	**0.64**	**0.76**	**0.97**	**0.81**	**0.52**	**0.33**	**0.26**	**0.25**	**0.23**	**0.27**	**0.40**	**0.62**	

Day of month 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	304	258	357	410	277	205	122	129	104	113	138	246
2	319	280	383	468	272	197	125	120	97	118	131	240
3	324	317	343	393	273	200	127	114	93	121	138	248
4	280	332	362	464	280	207	119	109	105	119	140	251
5	275	320	394	450	271	190	117	107	99	111	150	228
6	289	320	387	414	268	194	124	109	107	105	161	251
7	280	354	459	388	235	189	117	101	100	101	164	261
8	283	347	425	343	244	173	115	108	103	105	162	229
9	280	300	418	399	245	167	112	117	104	119	147	254
10	283	266	439	384	241	161	121	109	100	118	167	250
11	268	299	426	365	227	155	110	112	100	118	166	284
12	317	302	446	368	225	146	113	116	102	116	159	299
13	288	322	478	379	227	151	105	110	106	111	160	280
14	270	335	455	365	237	141	126	114	104	107	178	306
15	279	307	438	333	233	153	131	110	102	112	178	297
16	293	328	402	376	234	158	137	109	100	120	174	338
17	270	297	434	345	221	144	123	107	102	117	180	297
18	273	311	463	333	229	140	117	108	104	113	178	300
19	270	338	527	305	230	129	107	105	95	105	186	272
20	297	400	501	294	227	125	115	109	90	114	184	248
21	260	361	569	290	209	144	111	102	94	118	177	259
22	250	334	548	309	200	148	110	101	100	128	182	250
23	275	384	553	288	196	136	110	103	100	126	164	298
24	311	366	484	301	207	128	109	105	98	144	181	285
25	312	374	439	285	200	131	110	114	102	149	178	310
26	297	443	404	282	179	119	108	110	97	145	203	312
27	256	407	404	287	186	118	106	106	101	149	202	259
28	234	374	400	355	185	122	109	104	110	131	208	270
29	222	382	378	355	180	124	108	108	117	151	225	300
30	251		379	308	189	128	112	95	114	143	258	308
31	240		400		182		119	90		137		289



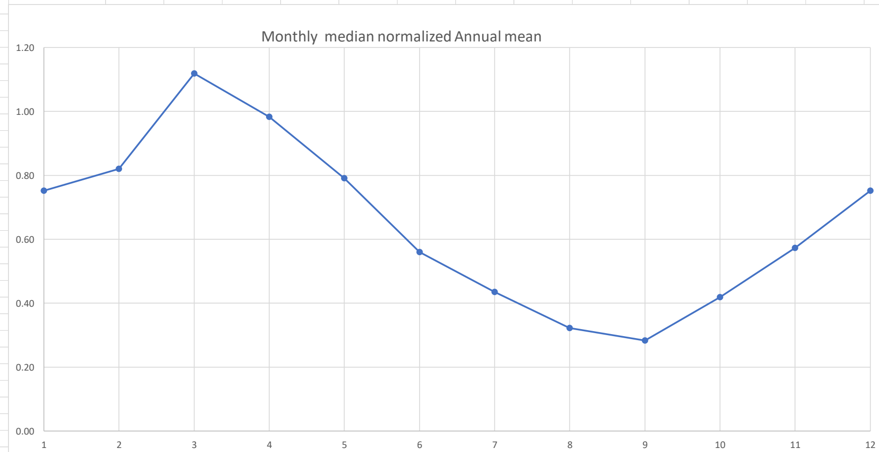
Gage 12: Schuykill River Streamflow Patterns

1473500	**Schuylkill River at Norristown, PA**
Drainage Area, sq mi	1760
Annual mean flow	3084
period	2001
to	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	2320	2530	3450	3030	2440	1725	1340	994	874	1290	1765	2320	1970
mean	2330	2557	3384	3027	2360	1725	1355	1018	920	1423	1809	2598	2041
min	1700	1760	2550	2560	1910	1330	944	747	693	1010	1370	1860	
max	3550	3720	4130	3620	3010	2250	1970	1470	1400	2820	2380	4380	
median normalized by annual mean	**0.75**	**0.82**	**1.12**	**0.98**	**0.79**	**0.56**	**0.43**	**0.32**	**0.28**	**0.42**	**0.57**	**0.75**	

Day of month 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3550	1760	2900	3460	2460	1970	1180	1110	693	1170	2040	2120
2	3060	1780	3190	3350	2440	1880	1120	1280	802	1110	1890	2240
3	2890	2070	2990	3620	2680	1850	1060	1020	1400	1030	2280	2760
4	2900	2260	2950	3380	2810	1870	944	1000	1160	1060	2380	2370
5	2600	2410	2730	3210	2630	1860	991	901	989	1030	2060	2000
6	2630	2480	2550	3070	3010	2080	1400	917	1050	1080	1880	1860
7	2600	2660	2600	2830	2930	2250	1410	863	1030	1010	1710	2120
8	2410	2810	2920	2830	2590	1870	1340	915	885	1130	1700	1990
9	2300	2900	3520	2730	2940	2250	1480	895	926	1230	1650	2000
10	2720	2440	3520	2650	2860	1960	1460	1010	934	1170	1440	1930
11	2350	2010	3420	2590	2540	2040	1390	1220	865	1350	1420	2130
12	2600	2140	3520	3040	2480	1740	1390	1300	974	1290	1510	2270
13	2780	2090	3590	3540	2460	1800	1900	1310	871	1310	1420	2160
14	2430	2150	3860	2890	2270	2000	1970	1470	1010	1170	1370	2130
15	2320	2320	3780	2860	2550	1710	1790	1270	946	1150	1500	2380
16	2340	2830	3240	3610	2620	1930	1710	1040	858	1260	1630	2460
17	2150	2410	2990	3320	2440	1650	1590	1040	778	1450	1720	2110
18	2590	2440	3020	3070	2180	1710	1450	833	822	1470	1900	2800
19	2310	2530	3930	2910	2190	1620	1310	801	877	1540	1910	2140
20	2270	2870	4120	2750	1970	1570	1240	781	828	1630	2260	1950
21	2090	2670	4130	2560	2070	1430	1120	805	829	1420	1940	2320
22	1930	2680	3850	3100	2030	1520	1160	889	802	1490	1770	2630
23	1910	2930	3500	3020	1990	1330	1410	1400	793	1400	1760	2700
24	1810	2850	3910	3110	2040	1520	1290	1070	799	1290	1890	2940
25	1880	3080	3500	2830	2120	1340	1490	919	838	1290	1740	3320
26	2050	3200	3310	3230	2020	1380	1270	846	810	1350	1890	4380
27	1880	3720	3240	3100	1970	1380	1160	994	825	1600	2130	3620
28	1750	3080	3600	2700	1910	1360	1460	944	980	2220	1960	3950
29	1730	2570	3450	2800	2020	1490	1180	1000	933	2330	1750	3870
30	1700		3630	2650	2000	1380	1200	961	1280	2820	1760	3440
31	1710		3440		1940		1150	747		2270		3440



Gage 13: Wissahickon Creek Streamflow Patterns

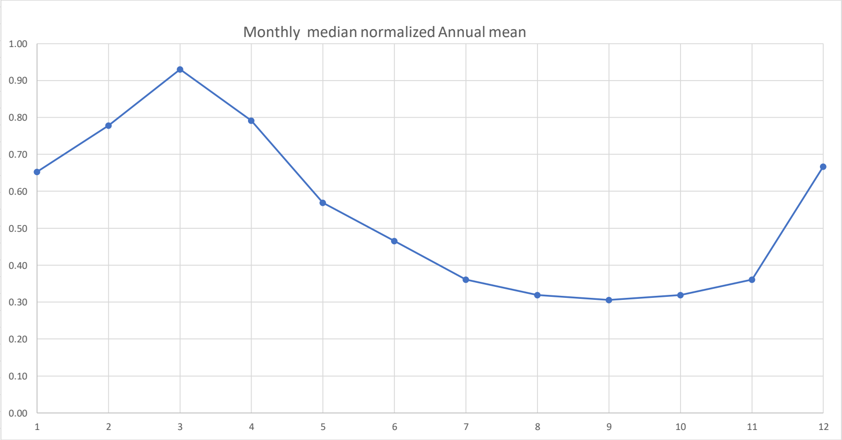
1473900 Wissahickon Creek at Fort Washington, PA

Drainage Area, sq mi		40.8
Annual mean flow		72
period		2000
2021	2021	2021

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
	1	2	3	4	5	6	7	8	9	10	11	12	yr
median of daily means	47	56	67	57	41	34	26	23	22	23	26	48	36
mean	48	56	69	56	42	34	27	24	21	24	27	46	40
min	41	46	56	45	35	26	22	20	17	19	23	32	
max	59	71	93	64	50	48	38	31	25	32	36	60	
median normalized by annual	**0.65**	**0.78**	**0.93**	**0.79**	**0.57**	**0.47**	**0.36**	**0.32**	**0.31**	**0.32**	**0.36**	**0.67**	

Day of month 50th percentile (median) of daily mean values for each day for water year of record in, ft3/s

Day of month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	51	46	62	63	48	43	25	27	24	23	26	42
2	48	52	73	64	48	35	25	24	25	20	27	35
3	51	56	63	62	50	48	24	24	25	21	25	32
4	46	53	62	62	41	44	24	31	23	22	24	45
5	42	52	62	57	41	38	27	24	17	21	24	38
6	53	56	69	57	42	44	27	23	22	19	29	36
7	51	54	68	55	39	40	28	22	23	21	26	32
8	50	53	65	61	48	36	29	20	19	22	23	35
9	47	59	64	60	47	34	29	21	21	24	23	35
10	51	49	63	56	45	33	31	28	22	23	23	41
11	56	56	56	56	40	30	26	26	23	23	28	40
12	57	57	82	60	47	39	26	22	23	25	25	55
13	51	56	74	56	47	35	25	20	24	23	27	48
14	49	48	67	57	41	31	31	21	23	21	27	57
15	48	50	63	59	48	34	38	23	23	26	26	43
16	46	71	63	63	49	30	31	21	22	26	25	48
17	45	60	67	57	46	29	26	28	20	25	26	52
18	59	54	74	52	43	36	27	20	17	22	28	56
19	57	59	76	51	45	30	26	30	17	23	26	48
20	55	62	76	58	41	28	26	28	20	20	24	41
21	47	56	93	57	42	29	25	26	21	24	24	42
22	45	58	83	58	40	30	23	28	21	23	24	42
23	45	60	75	55	38	29	26	28	20	22	26	59
24	47	55	77	55	39	30	25	22	19	25	26	56
25	47	57	73	54	35	26	33	21	20	26	36	60
26	41	60	66	50	35	27	27	21	20	26	35	56
27	44	66	66	53	36	34	27	20	22	23	31	52
28	44	65	67	50	37	37	29	22	21	25	31	53
29	43	52	64	51	40	32	28	24	22	32	32	57
30	43		60	45	38	29	24	24	22	31	35	53
31	42		65		35		22	22		24		52



Appendix D -

Summary of Screened-Out Potential Projects

Appendix D - Summary of Screened-Out Projects

The purpose of this appendix is to explain why certain projects were rejected from full evaluation. This information may be useful if these projects are further considered because of new information or changing criteria.

New Dams

Twenty previously studied sites were found in historical reports, as shown in Table 3.2-1 in the main report. Sixteen of the sites were in PA, three in NJ and one in DE. All reservoirs would provide large volumes, ranging from 5 BG to 140 BG. Fourteen sites were rated low (poor or 1), usually due to impacts from flooding to infrastructure, residences or to preserved areas as indicated in the ratings and reasons in the table below. Accordingly, these sites were not evaluated further. The sites and their overall ratings are mapped in Figure 3.2-1.

Table D-1 Previously studied sites for new dams screened from full evaluation

									Rating (1= poor, 2=fair, 3=good, NR = not rated)									
Map key (see Figure 3.2-1)	**Project Name**	**State**	**County**	**Sub watershed**	**Stream**	**New Capacity, BG**	**Pool Elevation, ft**	**Flooded Area, ac**	**Road Flooding**	**Building Flooding**	**Utility Conflicts**	**Recreational**	**Wetland Impacts**	**Stream Impacts**	**Position in basin**	**Distance from Del. River**	**Overall rating**	**Reasons for disconsideration.**
6	Newark	DE	New Castle	Brandywine	White Clay Creek	10	156	1060	3	3	3	1	1	2	1	2	1	Floods White Clay Creek State Park. Low in basin – reduced potential to control salt front.
7	Evansburg	PA	Montgomery	Schuylkill	Skippack Creek	8	166	1120	2	3	2	1	1	2	2	2	1	Floods Evansburg State Park.
8	Irish Creek	PA	Berks	Schuylkill	Schuylkill River	23	420		2	1	2	1	2	2	2	1	1	Floods several housing subdivisions.
9	Blacks Creek	NJ	Burlington	Crosswicks	Blacks Creek	7	70	1790	2	1	2	2	1	2	2	3	1	Major commercial facility would be flooded, while providing modest volume.
10	French Creek	PA	Berks	Schuylkill	French Creek	8	289	1250	1	1	2	2	2	1	2	2	1	Floods dozens of homes. French Creek is a PA scenic river here. Provides only modest volume.
11	Icedale	PA	Chester	Brandywine	W. Br. Brandywine	5	?		2	2	2	2	1	2	1	2	1	Low in basin – reduced potential to control salt front. Pool elevation not identified but could have major infrastructure impacts.
12	Pidcock Creek	PA	Bucks	Middle DR	Pidcock Creek	49	?	4160		1	3	1	1	2	3	3	1	Could flood Washington Crossing State Park and Bowman's Hill.
13	Flat Brook	NJ	Sussex	Middle DR	Flat Brook	81	?	2940	2	1	3	1	1	1	3	3	1	Would flood trout stream and protected land within the Delaware Water Gap National Recreation Area.
14	Mill Creek	PA	Bucks	Schuylkill	Mill Creek	21	470	1810	1	1	2	3	1	2	2	1	1	Mostly farmland but would flood dozens of homes.
15	Aquashicola	PA	Carbon	Lehigh	Aquashicola Creek	8	503	1230	1	1	1	2	2	2	3	2	1	Floods about 20 buildings in Little Gap, PA and Blue Mountain Ski Resort, while providing only modest storage volume.
16	Cherry Creek	PA	Monroe	Middle DR	Cherry Creek	140	590	3750	1	1	1	2	1	2	3	3	1	Per 1976 report, "Cherry Creek appears to have very serious environmental problems…It is recommended that Cherry Creek be dropped from consideration." Would flood dozens of homes.
17	McMichael	PA	Monroe	Middle DR	McMichael Creek	15	?	?	1	1	1	2	1	2	3	3	1	Flood several rural homes and a highway.
18	Tobyhanna	PA	Monroe	Lehigh	Tobyhanna Creek	28	?	?	1	1	1	2	2	2	3	1	1	Flat area. Will flood lots of infrastructure. Upstream of FE Walter Dam.
19	Girard	PA	Northampton	Middle DR	Bushkill Creek	14	?	?	1	1	1	NR	NR	2	3	3	1	Highly developed. Major impacts to infrastructure and homes.
20	Hackettstown	NJ	Warren	Muscenotcong	Musconetcong River	10	?	?	NR	NR	NR	NR	NR	1	NR	NR	1	Several dams have been/will be removed on Musconetcong River; installing new dam not feasible.

Existing Dams

The pre-screening cutoff for existing dams was current maximum storage volume of greater than 2 BG. According to the National Inventory of Dams, 34 dams in the Basin met this criterion. The ratings for all dams are presented in Table 3.3-1 and mapped in Figure 3.3-2. Each option received a separate overall rating for a dam raise and for an operational change, i.e., purchase/lease of existing storage. Four projects were evaluated for a storage increase as listed in Table 5.3.1: Wild Creek, Cannonsville, Blue Marsh and Prompton. Four were evaluated for a transfer of ownership: Merrill Creek, Rio, Lake Ontelaunee and Penn Forest/Wild Creek.

The remaining 28 dam/reservoirs were rated poor regarding feasibility of storage increase and transfer and were eliminated from further evaluation. The reasons, as listed in the table below, were primarily that, for dams on recreational lakes, their shorelines are densely populated or providing other high-value uses; for other dams, because their small surface area would require a large elevation/area increase to provide sufficient extra storage or having a small drainage area that makes capture of additional inflow unreliable. The FE Walter dam was excluded within the RFP because of its involvement in another active study. Crystal Lake dam (#29) was excluded because of its position just outside the Basin. DRBC also excluded the USACE's Jadwin (a dry dam) and Beltzville from further consideration. Several dams raise could not be evaluated for a raise because no drawings were available to use in design and costing, namely Lake Ontelaunee, Rio, Swinging Bridge and Toronto.

Table D-2: Existing dams/reservoirs screen from full evaluation, sorted by maximum existing storage

							USES								Ratings on specific criteria								Overall Ratings		
Map ID	Name	State	County	River	Owner	Owner Type	Water Supply	Flood control	Recreation	Hydropower	Max storage, BG	Normal Storage, BG	Surface area, ac	Drainage Area, sq mi	Storage Volume	Sufficiency of Inflow	Proximity to Delaware River	Position in Basin	Land Use Setting	Institutional Ease --raise	Institutional Ease--op change		Water level Raise	Purchase/Lease	Reasons for rejection
20	PEPACTON	NY	DELAWARE	E Br Delaware R	NYCDEP	Pub Util	X				199	137	5,763	372	3	3	2	3	3	2	1		3	1	RFP specified no op change considered at NYC dams; Raise could not be evaluated because no drawings were available to use in design and costing;
1	WALLENPAUPACK	PA	Pike	Wallenpaupack Cr	Brookfield	Pwr Co			X	X	88	43	5,700	228	3	2	2	3	2	3	3		3	3	Owner stated no extra storage was available for transfer. Raise impractical because of unacceptable flooding of lakefront property.
34	FE WALTER	PA	LUZERNE	Lehigh River	USACE	Fed		X	X		52	1	80	288	3	3							1	1	Ruled out in RFP
22	NEVERSINK	NY	SULLIVAN	Neversink River	NYCDEP	Pub Util	X				46	35	1,472	90	3	2	1	3	3	2	1		3	1	RFP specified no op change considered at NYC dams; Raise could not be evaluated because no drawings were available to use in design and costing;
6	BELTZVILLE	PA	Carbon	Pohopoco Creek	USACE	Fed	X	X	X		34	13	947	96	3	3	2	3	3	2	2		3	1	Bethlehem's water supply reservoirs (Penn Forest and Wild Creek) sit just upstream so capturing additional volume in Beltzville would difficult, especially after a release.
7	NOCKAMIXON	PA	Bucks	Tohickon Creek	PADCNR	State		X	X		23	13	1,450	73	3	2	1	3	3	2	2		3	1	Raise would flood existing infrastructure that supports recreation; owner not interested in pursuing
31	HOPATCONG	NJ	MORRIS	Musconetcong R	NJDEP	State		X			16	16	2,474	25	1	1	1	3	1	1	1		1	1	Heavily developed shoreline; another dam before Delaware R, which would trap release
18	JADWIN	PA	WAYNE	Dyberry Creek	USACE	Fed		X			15	<1	1	65	3	1	2	3	3	1	1		1	3	Similar to Prompton project so no need to duplicate. Plus, no permanent pool makes it hard to expand.
2	SWINGING BRIDGE	NY	Sullivan	Mongaup River	Eagle Creek	Pwr Co			X	X	12	12	1,000	118	3	3	1	3	3	3	3		3	1	Raise could not be evaluated because no drawings were available to use in design and costing; complicated operation because of downstream reservoirs. (Transfer was evaluated at Rio)

Table D-2 (continued): Existing dams/reservoirs screen from full evaluation, sorted by maximum existing storage

Map ID	Name	State	County	River	Owner	Owner Type	Water Supply	Flood control	Recreation	Hydropower	Max storage, BG	Normal Storage, BG	Surface area, ac	Drainage Area, sq mi	Storage Volume	Sufficiency of Inflow	Proximity to Delaware River	Position in Basin	Land Use Setting	Institutional Ease -- raise	Institutional Ease--op change		Water level Raise	Purchase/Lease	Reasons for rejection
9	SHOHOLA MARSH	PA	Pike	Shohola Creek	PA GAME	State			X		9	4	1,130	54	2	1	1	3	3	2	2		3	1	Raise would flood existing infrastructure with complicated administrative effects (i.e., paid for by federal grants); owner not interested in pursuing. Might require raising of I84 bridge.
3	TORONTO	NY	Sullivan	Mongaup River	Eagle Creek	Pwr Co				X	8	8	860	23	3	3	2	3	3	3	3		3	1	Raise could not be evaluated because no drawings were available to use in design and costing; complicated operation because of downstream reservoirs. (Transfer was evaluated at Rio)
10	GREEN LANE RES	PA	Montgomery	Perkiomen Creek	Aqua PA	Priv Wtr	X		X		8	4	814	71	2	2	2	2	2	3	1		3	1	Some development along upper reaches
19	MARSH CREEK RES	PA	CHESTER	Marsh Creek	PADCNR	State	X	X	X		8	2	535	20	2	1	2	1	3	2	2		2	1	Small drainage area; low in basin reduces effectiveness at repelling salt front.
11	LAKE ONTELAUNEE	PA	Berks	Maiden Creek	Reading	Pub Util	X				7	4	1,037	192	2	2	1	2	3	3	1		3	1	Raise could not be evaluated because no drawings were available to use in design and costing
13	PEACE VALLEY (GALENA)	PA	Bucks	Neshaminy Creek	Bucks County	Pub Util	X	X	X		6	2	365	16	2	2	2	2	3	3	1		3	1	Very small normal volume; would require large raise for substantial volume increase
4	RIO	NY	SULLIVAN	Mongaup River	Eagle Creek	Pwr Co			X	X	5	5	460	195	2	2	1	3	3	3	3		3	1	Raise could not be evaluated because no drawings were available to use in design and costing
32	LAKE MERCER	NJ	MERCER	Assunpink Creek	Mercer County	County		X	X		5	1	275	30	1	1	3	3	1	2	1		1	1	Small surface area; would require a large raise for substantial volume increase, which would flood active recreation
14	STILL CREEK	PA	Schuylkill	Still Creek	Tamaqua Water	Pub Util	X				4	3	332	7	2	1	3	2	2	3	1		3	1	Small normal volume; would require large raise for substantial volume increase; high in Schuylkill basin; Exelon purchased storage so no more available. Raise could not be evaluated because no drawings were available for design and costing
23	GEIST (SPRINGTON)	PA	DELAWARE	Crum Creek	Aqua Pa	Priv Wtr	X				4	3	391	22	1	1	3	1	1	3	3		1	1	Heavily developed shoreline; raise would flood private property and houses
24	VAN SCIVER LAKE	PA	BUCKS	Scotts Creek	Warner Co	Private			X		4	3	700	2	1	1	3	2	1	1	1		1	1	Not really a dam. More like a levee/polder. Raise not feasible.
25	HOOPES	DE	NEW CASTLE	Red Clay Creek	Wilming-ton	Pub Util	X				4	<1	194	2	1	1	3	1	2	2	1		1	1	Small surface area; would have to raise by >20 ft to get 1 BG, which would flood much land; position low in Basin reduces effectiveness at repelling salt front
33	ASSUNPINK LAKE	NJ	MERCER	Assunpink Creek	NJDEP	State		X			4	<1	225	22	1	1	2	3	3	2	2		1	1	Small normal volume and surface area; would have to raise by a lot for substantial volume increase
15	CRYSTAL LAKE	PA	Luzerne	Wapwallopen Cr	PA Am Water	Priv Wtr	X				3	2	494	3	1	1	1	3	3	3	1		3	1	Outside the boundary of the basin.
26	MAUCH CHUNK	PA	CARBON	Mauch Chunk Cr	PA Fish & Boat	State	X	X	X		3	1	320	6	1	2	1	3	3	2	2		1	1	Small normal volume, surface area and drainage area; would have to raise by a lot for substantial volume increase
27	LOCUST CREEK (TUSCARORA)	PA	SCHUYLKILL	Locust Creek	PADCNR	State		X	X		2	2	96	13	1	1	1	2	3	3	3		1	1	Small area and normal volume; requires large raise (30') to get 1 BG; far from Delaware River
28	YANKEE LAKE	NY	SULLIVAN	Pine Kill	Yankee Lake Assoc.	Private			X		2	1	415	4	3	2	2	3	1	1	1		1	1	Small normal volume; private lake -- owners not likely to cooperate; raise would flood private property and houses
29	WANAKSINK (LORDS)	NY	SULLIVAN	Fowlwood Brook	Wanaksink Lake Club	Private			X		2	1	325	2	1	2	2	3	1	1	1		1	1	Small normal volume; private lake -- owners not likely to cooperate; raise would flood private property and houses
30	LAKE HAUTO	PA	CARBON	Nesquehoning Cr	Lake Hauto Club	Private			X		2	1	290	9	1	2	1	3	1	1	1		1	1	Small normal volume; private lake -- owners not likely to cooperate; raise would flood private property and houses

QUARRIES

Sixty-five quarries passed the prescreening criteria of area >25 acres, as presented in Table 3.4-1 and Figure 3.4-1. After applying the screening criteria, 33 quarries (30 in PA, 2 in NJ and 1 in NY) were rated good and were passed forward for further evaluation as listed in Table 3.4-1 and mapped in Figure 3.4-1. Because time and budget would not allow full evaluation of 33 quarries, a supplemental screening was performed, primarily based on the availability of a reliable water supply near the quarry. Several additional quarries were rejected because their volume was small (i.e., 1 BG or less), which was unattractive because several quarries that were evaluated could supply > 2 BG. The 49 rejected quarries are listed in the table below along with the reason for the rejection.

Table D-3 Quarries excluded from full evaluation

Site ID in Figure 3.4-1	Owner	State	County	SubBasin (HUC8)	Dist. To closest stream, approx. (ft)	Closest stream	Nominal area, ac	Nominal Rim Elev	Nominal Bottom Elev	Nominal Depth	**Est. Vol, BG**	Pool Area, ac		Storage Volume	Access to Water	Water Retention	Proximity to Del R	Position in Basin	Land Use Setting	Overall Rating	Reasons
9	MARTIN STONE QUARRIES	PA	Berks	Schuylkill River	1,500	Swamp Creek	130	395	242	153	**3.2**	0		3	2	1	2	2	3	3	Far from major stream.
10	GLASGOW INC	PA	Chester	Schuylkill	9,600	Valley Cr	92	307	122	185	**2.8**	0		3	1	1	2	2	2	3	Not near major stream.
11	H & K GROUP INC	PA	Berks	Schuylkill	1,415	Limekiln Cr	52	380	60	320	**2.7**	50		3	2	3	2	2	3	3	Not near major stream.
13	Woodbourne Lawn and Garden	NY	Sullivan	Middle Del	100	Neversink River	57	1155	?	?	**?**	40		2	3	3	2	3	2	3	In a developed area. Could not accurately determine depth because its full of water. Presumed to be shallow. Surroundings not conducive to project development.
15	LEHIGH CEMENT CO LLC	PA	Berks	Schuylkill	6,600	Manatawny Creek	56	304	?	?	**?**	56		2	2	3	1	2	3	3	Two filled quarries separated by a road. Both water filled since 1990s. Small area; presumed small volume
17	NEW ENTERPRISE STONE	PA	Northampton	Middle Del	50	Delaware River	29	215	?	?	**?**	29		2	3	3	3	3	3	3	Water filled since 1990s. Small area. Presumed small volume.
18	DELAWARE VALLEY LANDSCAPE	PA	Bucks	Middle Del	500	Delaware River	35	115	?	?	**?**	35		2	3	3	3	3	3	3	Water filled; small area. Presumed small volume.
20	Weldon Quarry, L.L.C.	NJ	Sussex	Middle Del	2,256	Lubbers Run	200	990	932	58	**1.9**	0		2	3	1	1	3	2	3	Next to Lake Hopatcong, but pumping from the Lake would face serious opposition. No major stream nearby.
24	KEYSTONE CEMENT CO	PA	Wayne	Lackawaxen	2,300	Middle Cr	36	1480	1300	180	**1.0**	4		2	1	3	2	3	3	3	Small volume. No major stream nearby.
26	LEHIGH CEMENT CO LLC	PA	Northampton	Middle Del	1,100	Delaware River	62	320	245	100	**1.0**	0		2	3	1	3	3	3	3	Major earthwork required to raise low area on rim. Small volume
28	H & K GROUP INC	PA	Montgomery	Schuylkill River	500	Schuylkill River	25	130	10.0	120	**.5**	0		2	3	1	2	2	3	3	Small volume
29	NEW ENTERPRISE STONE	PA	Lehigh	Lehigh	97	Coplay Cr	39	470	350	120	**.8**	12		1	3	3	3	3	3	3	Small volume
30	COPLAY AGGREGATES INC	PA	Bucks	Middle Del	120	Rapp Cr	50	360	280	80	.7	2		1	3	2	3	3	3	3	Small volume
31	HOLCIM (US) INC	PA	Lehigh	Lehigh	1,176	Coplay Cr	34	400	290	110	.6	6		1	3	3	3	3	3	3	Small volume

Table D-3(continued): Quarries excluded from full evaluation

Site ID in Figure 3.4-1.	Owner	State	County	SubBasin (HUC8)	Dist. To closest stream, approx. (ft)	Closest stream	Nominal area, ac	Nominal Rim Elev	Nominal Bottom Elev	Nominal Depth	Est. Vol, BG	Pool Area, ac		Storage Volume	Access to Water	Water Retention	Proximity to Del R	Position in Basin	Land Use Setting	Overall Rating	Reasons
32	HOLCIM (US) INC	PA	Bucks	Crosswicks-Neshaminy	417	Mill Cr	24	160	40	120	.5	1		1	3	1	2	2	3	3	Small volume
33	NACEVILLE MATERIALS	PA	Lehigh	Lehigh	3,197	Lehigh River	33	380	300	80	.4	20		1	3	3	3	3	3	3	Small volume
34	LEHIGH CEMENT CO LLC	PA	Delaware	Lower Del	300	Chester Cr	86	200	-180	380	5.3	2		3	1	2	3	1	3	2	No large stream nearby.
35	PENNSY SUPPLY INC	PA	Schuylkill	Lehigh	1,267	Lizard Cr	179	760	600	160	4.7	0		3	1	1	2	3	3	2	Nearby stream, Lizard Creek, is small. 4 mi from Jordan Cr but have to pump over big hill.
36	HANSON AGGREGATES BMC INC	PA	Chester	Brandywine-Christina	754	Valley Cr	104	260	20	240	4.1	23		3	2	3	1	1	2	2	Very low in basin. Limited value to repel salt front.
37	NEW ENTERPRISE STONE	PA	Northampton	Lehigh	248	Hokendauqua Cr	53	330	20	310	2.7	6		3	2	3	1	3	3	2	Hokendauqua Cr is a not a large stream. Other quarries in area more attractive options.
38	NEW HOPE CRUSHED STONE	PA	Bucks	Crosswicks-Neshaminy	150	Mill Cr	135	260	160	100	2.2	24		3	1	3	3	2	2	2	No large stream nearby.
39	GF EDWARDS INC	PA	Northampton	Lehigh	3,800	Monocacy Cr	96	430	290	140	2.2	25		3	1	3	3	3	3	2	No large stream nearby.
40	HIGHWAY MATERIALS	PA	Chester	Schuylkill	5,307	Pickering Cr	49	350	120	230	1.8	0		2	1	1	3	2	3	2	No large stream nearby.
41	Limecrest Quarry Developer	NJ	Sussex	Middle Del	12,500	Paulins Kill	130	670	600	70	1.5	24		2	2	3	2	3	3	2	Modest volume; suspect water supply
42	ALLAN MYERS MATERIALS	PA	Luzerne	Lehigh	765	Lehigh River	67	1360	1260	100	1.1	0		2	3	1	1	3	3	2	Small volume; long way from main stem.
43	M & M STONE CO	PA	Berks	Schuylkill	1,300	Schuylkill River	54	260	140	120	1.0	28		2	3	3	1	2	3	2	Small volume; long way from main stem.
44	LEHIGH CEMENT	PA	Bucks	Crosswicks-Neshaminy	5,947	N Br Neshaminy Cr	51	520	420	100	.8	1		1	2	1	2	2	3	2	Small volume; no large stream nearby
45	NEW ENTERPRISE STONE	PA	Berks	Schuylkill	4,700	not named	38	200	80	120	.8	1		1	2	1	2	2	2	2	Small volume; no good water source.
46	EUREKA STONE QUARRY	PA	Berks	Schuylkill	758	Seidel Cr	93	310	265	45	.7	0		1	2	1	2	2	3	2	Small volume;
47	H & K GROUP INC	PA	Wayne	Lackawaxen	384	Wallenpaupack Cr	57	1460	1400	60	.6	10		1	2	3	1	3	3	2	Small volume;
48	HIGHWAY MATERIALS	PA	Schuylkill	Schuylkill	200	Bear Cr	17	660	520	140	.4	7		1	1	3	1	2	3	2	Small volume;

Table D-3(continued): Quarries excluded from full evaluation

Site ID in Figure 3.4-1.	Owner	State	County	SubBasin (HUC8)	Dist. To closest stream, approx. (ft)	Closest stream	Nominal area, ac	Nominal Rim Elev	Nominal Bottom Elev	Nominal Depth	Est. Vol, BG	Pool Area, ac		Storage Volume	Access to Water	Water Retention	Proximity to Del R	Position in Basin	Land Use Setting	Overall Rating	Reasons
49	Callanan Industries Inc	NY	Sullivan	Middle Del	500	Neversink	43	1187	1140	47	.3	30		1	3	3	2	3	3	2	Pool covers entire bottom. Bottom depth uncertain. Small area. Presumed small volume.
50	H & K GROUP INC	PA	Lebanon	Schuylkill	2,363	Tulpehocken Cr	96	480	280	200	3.1	0		3	1	1	1	2	3	1	Poor water availability; at edge of basin.
51	DELAWARE VALLEY CONCRETE	PA	Bucks	Middle Del	1,400	Delaware River	59	113	?	?	?	59		2	3	3	3	3	1	1	Now Giving Pond. Part of Delaware Canal State Park. Owned by State.
52	WARNER CO	PA	Chester	Schuylkill	1,000	Valley Cr	52	NA	?	?	?	52		2	1	3	2	2	1	1	Now a full pond by office building; Owner not likely to cooperate. Not near major stream.
53	HANSON AGGREGATES PA LLC	PA	Bucks	Crosswicks-Neshaminy	157	N Br Neshaminy Cr	70	420	300	120	1.4	0		2	1	1	1	2	3	1	Poor water availability
54	H & K GROUP	PA	Bucks	Schuylkill	2,121	Morris Run	32	460	300	160	.8	1		1	1	1	1	2	3	1	Small volume; Small stream;
55	EUREKA STONE QUARRY INC	PA	Montgomery	Schuylkill	3,100	Ridge Valley Cr	50	480	380	100	.8	0		1	1	1	2	2	3	1	Small volume;
56	HANSON AGGREGATES	PA	Berks	Schuylkill	4,000	Sacony Cr	92	440	390	50	.8	0		1	1	1	2	2	2	1	Small volume; poor water availability
57	E Tetz & Sons Inc	NY	Sullivan	Middle Del	3,100	Mongaup	100	1300	1250	50	.8	1		1	3	1	2	3	3	2	Small volume; Lots of interior hills; low on one side; not too deep.
58	Trap Rock Industries, Inc.	NJ	Mercer	Middle Del	26,000	Jacobs Cr	48	260	200	60	.5	0		1	1	2	3	3	3	1	Small volume; no stream nearby.
59	Inversand Company	NJ	Gloucester	Lower Del	1,758	Mantua Cr	251	150	140	10	.4	0		1	2	3	2	1	3	1	Small volume; Not deep.
60	NACEVILLE MATERIALS	PA	Lehigh	Lehigh	1,903	Coplay Cr	29	420	370	50	.2	0		1	3	1	3	3	3	1	Small volume;
61	Trap Rock Industries, Inc.	NJ	Mercer	Middle Del	846	Delaware River	31	60	20	40	.2	0		1	3	1	3	3	3	1	Good option but slated to become a park.
62	Harmony Sand and Gravel Inc.	NJ	Warren	Middle Del	1,005	Delaware R.	13	290	250	40	.1	0		1	3	1	3	3	3	1	Adjacent to Del R but low on one side and not deep. Small volume.
63	Baer Aggregates	NJ	Warren	Middle Del	1,485	Delaware R.	18	180	160	20	.1	1		1	2	3	3	3	3	1	Adjacent to Del R but low on one side and not deep. Small volume.
64	NEW ENTERPRISE STONE	PA	Bucks	Crosswicks-Neshaminy	3,728	Neshaminy Cr	32	240	220	20	.1	0		0	2	1	3	2	2	1	Too shallow; low volume.
65	JML Quarries Inc	NY	Sullivan	Middle Del	800	South Brook	15	1190	1188	2	.0	9		0	3	3	2	3	3	1	Very low on one side; very low storage.
66	Cobleskill Stone Products Inc	NY	Delaware	East Branch Delaware	1,000	E Br Delaware R	26	1225	1220	NA	.0	0		0	3	0	3	3	3	1	Low opening on one side; but narrow: could be dammed; up 300' from river.

MINES

Thirty-one mine pools were identified in the Basin, listed Table 3.5-1. Five mines (all abandoned) passed the prescreen criteria of providing approximately >2 BG of storage. All five were evaluated. Table 3.5-1 is reproduced below with the five evaluated mines struck through. All rejected mines have volumes less than 1 BG.

Table D-4 Mines excluded from full evaluation (non-struck-through entries)

South Anthracite Field

Key	Pool	Vol. (gal)	
1	Tamaqua Lands (S)	800,000,000	
2	Tamaqua Lands (N)	312,000,000	
3	Mary D	400,000,000	
4	Kaska	600,000,000	
~~5~~	~~Silver Creek~~	~~1,774,000,000~~	X
6	Eagle Hill	727,000,000	
7	Palmer Vein	400,000,000	
8	Bear Ridge	40,000,000	
9	Pine Fores	419,000,000	
~~10~~	~~Wadesville~~	~~3,582,000,000~~	X
11	Pottsville East	125,000,000	
12	Pine Knot #1	600,000,000	
13	Thomaston	784,000,000	
14	Richardson	625,000,000	
15	Glendower	403,000,000	
16	Buck Run (old)	477,000,000	
17	Buck Run (dam basin)	53,000,000	
18	Lytle	795,000,000	
~~19~~	~~Phoenix Park~~	~~2,054,000,000~~	X
~~20~~	~~Otto~~	~~2,265,000,000~~	X
21	Middle Creek	700,000,000	
	Total	**17,935,000,000**	

Eastern Middle Anthracite Field

Key	Pool	Vol. (gal)
24	Audenreid	241,844,000
25	Spring Brook	5,880,000
26	Tresckow	17,280,000
27	Tresckow #21	84,240,000
29	Coleraine	67,860,000
29	Evans	20,160,000
31	Silver Brook	683,000,000
	Total	**1,120,264,000**

Western Middle Anthracite Field

Key	Pool	Vol. (gal)	
~~32~~	~~Morea~~	~~2,679,000,000~~ #	X
NA	**Total**	**2,679,000,000** #	

Note: Volumes taken from USBM TP #727-1949; # denotes value from USGS SIR 2010-5261.

Appendix E

Table of All Project Scores, sorted by project type, then by overall weighted score

Appendix E: Table of All Project Scores, sorted by project type, then by overall weighted score

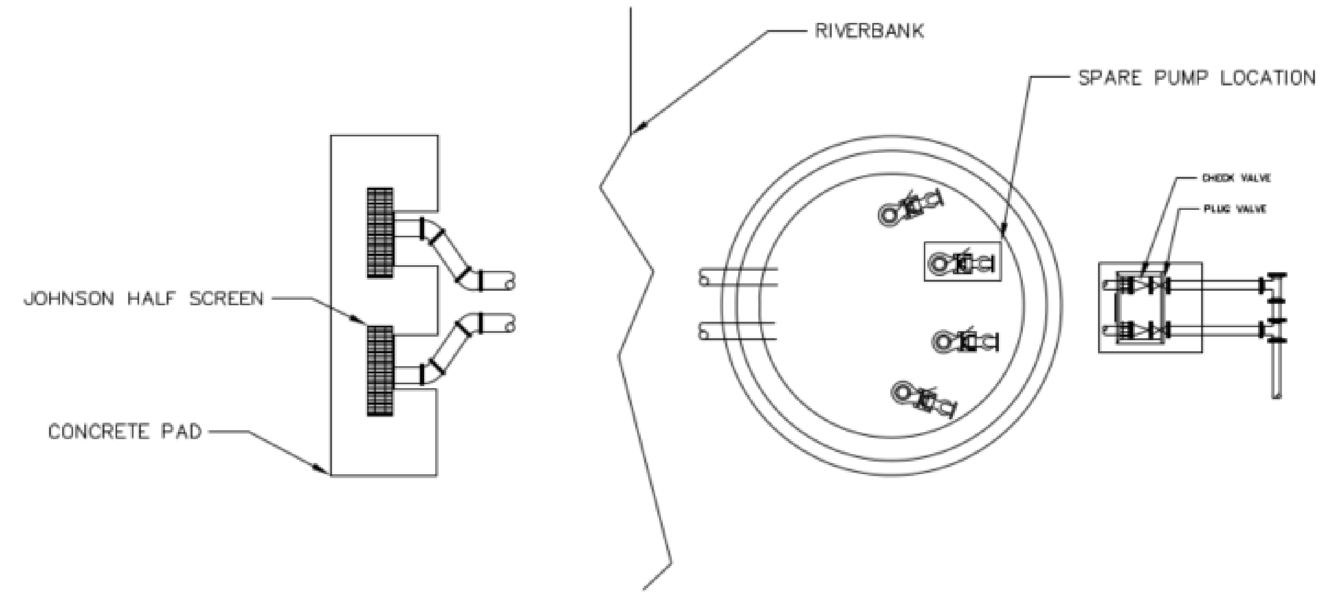
		New Dams							Existing Dam-- water level increase				Transfer of storage ownership			
		N4	N5	N2	N1	N6	N3	N7	E4	E2	E1	E3	T2	T4	T1	T3
		Rattling Run	Equinunk	Milan-ville	Red Creek	Hawley	Little Martins Creek	Silver/ Big Creek	Prompton	Cannons-ville	Wild Creek	Blue Marsh	Rio	Lake Onte-launee	Merrill Creek	Penn Forest/ Wild
County (PA if not indicated)		Berks	Wayne	Wayne	Schuylkill	Wayne	Northha mpton	Schuylkill	Wayne	Delaware , NY	Carbon/ Monroe	Berks	Sullivan, NY	Berks	Warren, NJ	Carbon/ Monroe
Volume (BG)		1.3	42	42	13.3	1.3	7.1	11.3	2	13	1	5	2	1	2	3
Overall Cost (Present Value, M$)		293	1150	950	366	182	353	921	2	77	135	65	27	27	110	162
Cost effectiveness (M$/BG)		225	27	23	28	140	50	81	1	6	135	13	14	27	55	54
Pump in or Gravity		G	G	G	P	G	P	P	G	G	G	G	NA	NA	NA	NA
Average Score		2.79	2.78	2.69	3.04	2.81	2.69	2.86	3.72	3.59	3.11	3.01	3.93	3.85	3.79	3.80
WEIGHTED SCORE		3.05	3.03	2.95	2.90	2.87	2.87	2.77	4.04	3.99	3.29	3.19	4.16	4.01	3.91	3.87
Six primary criteria	Weight				Score											
1. Water quantity and quality	30%	3.83	4.50	4.17	3.67	4.17	4.17	3.50	4.17	4.67	4.00	3.83	4.17	3.33	4.50	3.83
o Volume of storage provided (BG)		2	5	5	4	2	3	4	2	4	2	3	2	2	2	2.5
o Hydrologic reliability of supply (months to fill)		4	3	2	4	5	4	2	5	5	5	5	5	5	5	5
o Release rate (cfs)		5	5	5	5	5	5	5	5	5	5	5	5	3	5	3.5
o Promptness of delivery to mainstem (days)		4	5	5	3	5	5	3	5	5	3	4	5	3	5	3
o Geographic benefit		3	4	4	3	4	5	3	4	4	5	3	4	4	5	5
o Quality of stored water		5	5	4	3	4	3	4	4	5	4	3	4	3	5	4
2. Infrastructure design, construction and operation	10%	3.40	2.60	2.60	2.20	2.80	2.20	1.80	3.80	3.60	2.80	2.20	4.60	4.60	4.60	4.60
o Site/Civil, Land & Easements		5	1	1	1	2	1	4	5	5	5	1	5	5	5	5
o Subsurface conditions		3	3	3	3	3	3	2	5	5	2	3	5	5	5	5
o Infrastructure Complexity		3	3	3	2	3	2	1	4	3	3	1	5	5	5	5
o Construction complexity		3	3	3	3	3	3	1	4	3	1	1	5	5	5	5
o Operational complexity		3	3	3	2	3	2	1	1	2	3	5	3	3	3	3
3. Environmental impacts	15%	3.36	2.00	2.16	2.93	2.18	1.96	2.68	3.25	3.21	3.50	3.43	5.00	5.00	5.00	5.00
o protected species		3	2	2	3	3	3	3	2	2	2	3	5	5	5	5
o Water quality degradation of downstream waters		5	4	4	3	3	2	4	5	5	5	5	5	5	5	5
o obstruction to passage of aquatic animals		3	1	1	3	1	1	3	5	5	5	5	5	5	5	5
o hydromodification		4	4	4	3	4	3	4	5	5	5	5	5	5	5	5
Habitat type																
o wetlands inundated or filled		5	1	1.25	3.5	1.25	1.75	1.75	1.75	2.5	4	1	5	5	5	5
o streams inundated		1	1	1.5	2	1.5	1	2	2	1.5	1.5	3	5	5	5	5
o uplands inundated or developed		2.5	1	1.375	3	1.5	2	1	2	1.5	2	2	5	5	5	5
4. Social and Economic Impacts	10%	4.22	3.00	3.00	3.22	3.33	3.44	4.33	4.78	4.89	4.89	4.11	5.00	5.00	5.00	5.00
o Disruption/displacement		5	1	1	1	2	1	5	5	5	5	2	5	5	5	5
o Safety and health		3	3	3	3	3	3	4	3	5	5	4	5	5	5	5
o Social equity/environmental justice		5	4	4	4	4	4	5	5	5	5	4	5	5	5	5
o Recreational loss		3	4	4	4	3	4	4	5	5	5	5	5	5	5	5
o Cultural/historical resources		5	4	4	4	3	4	5	5	5	5	5	5	5	5	5
o Aesthetic		4	4	4	4	4	4	5	5	5	5	5	5	5	5	5
o Loss of tax revenue		5	3	3	3	4	4	5	5	5	5	4	5	5	5	5
o Loss of production from farmland, timberland, quarries		5	3	3	3	4	4	5	5	5	5	4	5	5	5	5
o Emissions of greenhouse gasses		3	1	1	3	3	3	1	5	4	4	4	5	5	5	5
5. Project Costs & Schedule	30%	1.83	2.33	2.33	2.33	2.00	2.17	1.83	4.50	4.00	2.50	2.67	3.83	4.17	2.67	3.17
o Overall Cost (Present value, $)		1.5	1	1	1.5	2	1.5	1	5	3	2.5	3.5	3	4.5	1	2.5
o Cost effectiveness ($/BG)		1	3	3	2.5	1	2	1.5	5	5	1	3.5	3.5	3	2	2
o Schedule (Time to make Operational, years)		3	3	3	3	3	3	3	3	4	4	1	5	5	5	5
6. Ancillary Benefits	5%	1.60	2.40	2.40	2.40	1.60	2.20	3.00	1.80	1.20	1.00	1.80	1.00	1.00	1.00	1.20
o Flood control		1	3	3	2	2	2	1	1	2	1	2	1	1	1	1
o Recreation/tourism		3	4	4	5	2	4	5	3	1	1	2	1	1	1	1
o Habitat/fishery enhancement		2	3	3	3	2	3	3	3	1	1	2	1	1	1	1
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)		1	1	1	1	1	1	3	1	1	1	1	1	1	1	2
o Ability to leverage funding from other programs		1	1	1	1	1	1	3	1	1	1	2	1	1	1	1

	Quarries																	
	Q19	Q02	Q04	Q12	Q25	Q07	Q22	Q21	Q23	Q01	Q08	Q27	Q03	Q14	Q07	Q16	Q05	Q06
	Eureka Rush Valley	Dyer Glasgow	Hanson Penns Peak	Solebury	Tilcon Oxford	Glasgow (Delaware)	NESL Whitehall	NESL Ormrod	Lehigh Perkio-menvile	Pottsville	Holcim Evans-ville	NESL Nazareth	Plymouth Meeting	M&M Telford	Glagow (Bushkill)	Berks Temple	Glasgow Nazareth	Lehigh Imperial
County (PA if not indicated)	Bucks	Montgom ery	Bucks	Bucks	Warren, NJ	Northampton	Lehigh	Lehigh	Montgomery	Schuylkill	Berks	Northampt on	Montgomer y	Bucks	Northampto n	Berks	Northampt on	Northampt on
Volume (BG)	1.7	6.2	3.3	2.3	1.2	4.6	1.2	1.3	1.0	6.9	3.1	1.0	3.5	1.0	4.6	1.0	4.2	3.8
Overall Cost (Present Value, M$)	24	30	31	38	28	26	34	45	26	39	44	25	39	25	26	30	48	51
Cost effectiveness (M$/BG)	14	5	10	16	23	6	28	35	26	5	14	25	11	25	6	30	12	13
Pump in or Gravity	P	G	P	P	P	P	P	P	G	P	G	P	P	P	P	P	P	P
Average Score	4.10	4.01	4.07	4.09	3.95	3.94	4.04	4.03	3.95	3.97	3.91	3.82	3.81	3.33	3.35	3.17	3.23	3.22
WEIGHTED SCORE	4.07	4.06	4.04	4.03	4.02	4.01	3.96	3.92	3.91	3.91	3.91	3.86	3.76	3.50	3.47	3.42	3.37	3.34
1. Water quantity and quality	3.75	3.50	3.58	3.75	4.00	4.08	3.83	3.83	3.58	3.42	3.75	3.67	3.50	3.17	3.42	3.25	3.25	3.25
o Volume of storage provided (BG)	2	3	2.5	1.5	2	3.5	2	2	2	3	2.5	2	2.5	1.5	3.5	1.5	2.5	2.5
o Hydrologic reliability of supply (months to fill)	5	5	5	5	5	5	5	5	5	4.5	5	5	4.5	5	3	5	4	3
o Release rate (cfs)	5	3	3	5	5	3	5	5	4.5	3	5	3	3	2.5	3	3	2	3
o Promptness of delivery to mainstem (days)	4.5	3	5	5	5	5	5	5	4	3	4	5	5	4	5	4	5	5
o Geographic benefit	3	3	3	3	4	5	3	3	3	3	3	4	3	3	3	3	3	3
o Quality of stored water	3	4	3	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3
2. Infrastructure design, construction and operation	3.60	3.10	3.60	3.20	3.60	3.70	3.00	3.10	3.80	3.40	3.20	3.40	3.10	2.90	2.50	2.20	2.30	2.30
o Site/Civil, Land & Easements	4	2	3.5	4	4	4	2.5	3	4	4	3	3	2.5	4	3	2	2.5	2.5
o Subsurface conditions	3	3	3	3	4	2.5	2.5	2.5	3	3	2.5	4	3	2	2.5	2	2.5	2.5
o Infrastructure Complexity	4	4	4	3	3	4	3	3	4	4	3.5	3	4	3	2	2	2	2
o Construction complexity	4	3	4	3	3	4	3	3	4	3	3	4	3	3	3	2	2.5	2.5
o Operational complexity	3	3.5	3.5	3	4	4	4	4	4	3	4	3	3	2.5	2	3	2	2
3. Environmental impacts	4.79	4.61	4.57	4.57	4.57	4.93	4.86	4.93	4.79	4.21	4.79	4.21	3.89	4.07	3.43	4.64	3.00	3.14
o protected species	5	5	5	5	5	5	5	5	5	4	4.5	5	5	5	4	4	4	4
o Water quality degradation of downstream waters	5	5	5	4	5	5	5	5	4.5	5	5	3	4	4	3	5	3	3
o obstruction to passage of aquatic animals	5	5	5	5	5	5	5	5	5	5	5	5	4.5	5	3.5	5	3	3
o hydromodification	4	4	4	5	4.5	5	5	5	4	3	5	2	2	1	2	4	1	2
Habitat type																		
o wetlands inundated or filled	5	4.75	3.5	3.75	5	5	5	5	5	5	4.5	5	4.5	5	5	4.5	3.5	3.5
o streams inundated	4.5	4	4.5	4.5	4	4.5	4.5	4.5	5	3.5	4.5	4.5	3	3.5	3	5	3	3
o uplands inundated or developed	5	4.5	5	4.75	3.5	5	4.5	5	5	4	5	5	4.25	5	3.5	5	3.5	3.5
4. Social and Economic Impacts	4.88	4.75	4.88	5.00	4.88	4.25	4.69	4.63	4.88	4.63	4.00	5.00	4.75	4.75	4.50	3.25	4.38	4.38
o Disruption/displacement	5	4	5	5	5	4	5	5	5	4	5	5	4	5	5	3	4	4
o Safety and health	5	5	5	5	5	3	4.5	5	5	5	5	5	5	3	3	3	3	3
o Social equity/environmental justice	5	5	5	5	5	5	5	5	5	5	3	5	5	5	5	3	5	5
o Recreational loss	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	2	5	5
o Cultural/historical resources	5	5	5	5	5	4	4	4	5	5	4	5	5	5	5	3	5	5
o Aesthetic	5	5	5	5	5	5	5	5	5	5	4	5	5	5	5	3	5	5
o Loss of tax revenue	4.5	4	4.5	5	4.5	4	4.5	4	4.5	4	3	5	4.5	5	4	4	4	4
o Loss of production from farmland, timberland, quarries	4.5	5	4.5	5	4.5	4	4.5	4	4.5	4	3	5	4.5	5	4	5	4	4
o Emissions of greenhouse gasses	3	3	3	3	3			3	3	3	3	3	3	3	3	3	3	3
5. Project Costs & Schedule	4.00	4.50	4.17	4.00	3.83	3.67	3.67	3.50	3.67	4.17	3.83	3.83	3.83	3.67	3.67	3.67	3.83	3.67
o Overall Cost (Present value, $)	4.5	4.5	4.5	4.5	4.5	3.5	4.5	4	4.5	4	4	4.5	4	4.5	4.5	4.5	4	3.5
o Cost effectiveness ($/BG)	3.5	5	4	3.5	3	3.5	2.5	2.5	2.5	4.5	3.5	3	3.5	2.5	4.5	2.5	3.5	3.5
o Schedule (Time to make Operational, years)	4	4	4	4	4	4	4	4	4	4	4	4	4	4	2	4	4	4
6. Ancillary Benefits	3.60	3.60	3.60	4.00	2.80	3.00	4.20	4.20	3.00	4.00	3.90	2.80	3.80	1.40	2.60	2.00	2.60	2.60
o Flood control	3	3	3	3	2	3	3	3	1	4	3.5	1	4	1	3	1	3	3
o Recreation/tourism	4	4	4	5	3	3	5	5	4	4	4	3	4	1	3	3	3	3
o Habitat/fishery enhancement	4	4	4	4	3	3	5	5	4	4	4	3	4	1	2	1	2	2
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)	4	3	4	4	3	3	4	4	3	4	4	3	4	1	2	2	2	2
o Ability to leverage funding from other programs	3	4	3	4	3	3	4	4	3	4	4	4	3	3	3	3	3	3

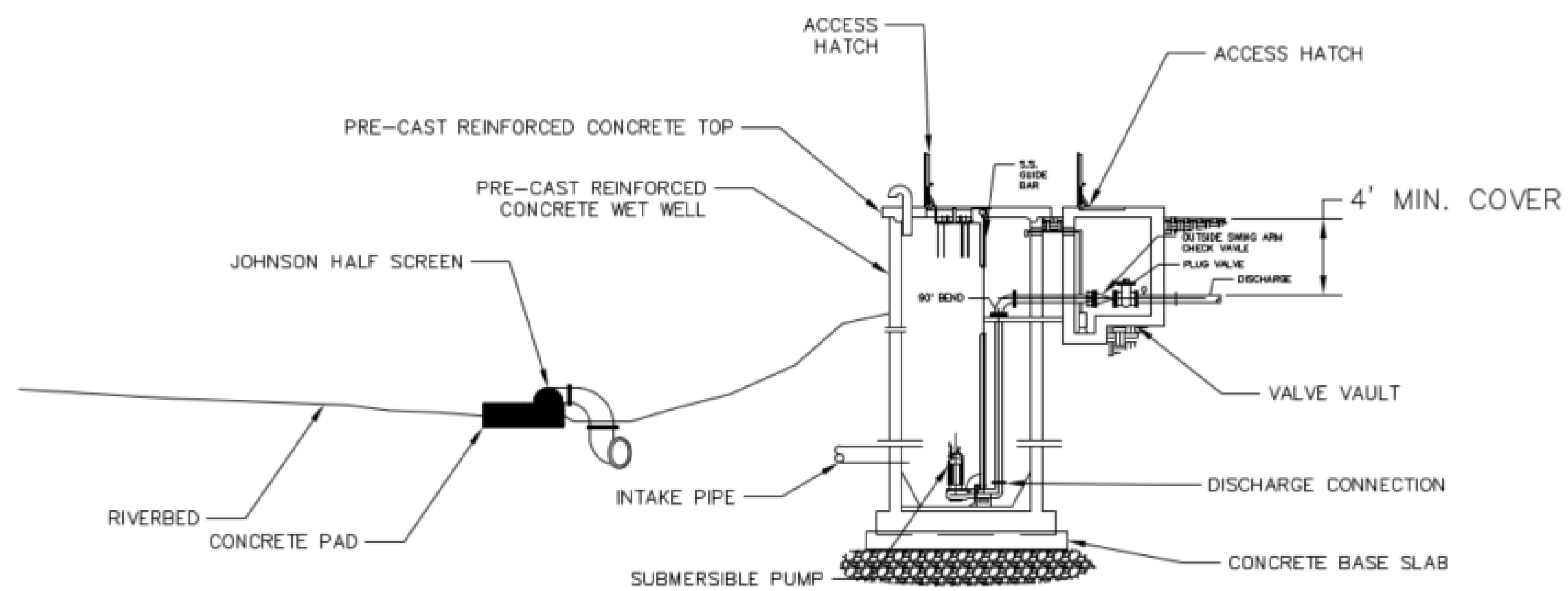
	Mines				
	M32	M20	M5	M19	M10
	Morea Basin	Otto	Silver Creek	Phoenix Park	Wades-ville
County (PA if not indicated)	Schuylkill	Schuylkill	Schuylkill	Schuylkill	Schuylkill
Volume (BG)	2.7	2.3	1.7	2.1	3.6
Overall Cost (Present Value, M$)	65	65	65	65	65
Cost effectiveness (M$/BG)	24	28	38	31	18
Pump in or Gravity	P	P	P	P	P
Average Score	3.60	3.55	3.35	3.22	NA
WEIGHTED SCORE	3.58	3.53	3.12	2.99	NA
1. Water quantity and quality	3.08	3.17	3.00	2.83	
o Volume of storage provided (BG)	2.5	2	2	1	
o Hydrologic reliability of supply (months to fill)	4	4	4	4	
o Release rate (cfs)	2	2	2	2	
o Promptness of delivery to mainstem (days)	3	3	3	3	
o Geographic benefit	3	4	3	3	
o Quality of stored water	4	4	4	4	
2. Infrastructure design, construction and operation	3.20	3.00	3.20	2.90	
o Site/Civil, Land & Easements	4	3	4	3	
o Subsurface conditions	2	2	2	2	
o Infrastructure Complexity	4	4	4	4	
o Construction complexity	4	4	4	3.5	
o Operational complexity	2	2	2	2	
3. Environmental impacts	4.43	4.43	4.50	4.21	
o protected species	5	5	5	4	
o Water quality degradation of downstream waters	5	5	5	5	
o obstruction to passage of aquatic animals	5	5	5	5	
o hydromodification	1	1	2	1	
Habitat type					
o wetlands inundated or filled	5	5	5	5	
o streams inundated	5	5	5	5	
o uplands inundated or developed	5	5	4.5	4.5	
4. Social and Economic Impacts	5.00	5.00	5.00	5.00	
o Disruption/displacement	5	5	5	5	
o Safety and health	5	5	5	5	
o Social equity/environmental justice	5	5	5	5	
o Recreational loss	5	5	5	5	
o Cultural/historical resources	5	5	5	5	
o Aesthetic	5	5	5	5	
o Loss of tax revenue	5	5	5	5	
o Loss of production from farmland, timberland, quarries	5	5	5	5	
o Emissions of greenhouse gasses	3	3	3	3	
5. Project Costs & Schedule	3.50	3.33	2.00	2.00	
o Overall Cost (Present value, $)	4	4	2	2	
o Cost effectiveness ($/BG)	3.5	3	1	1	
o Schedule (Time to make Operational, years)	3	3	3	3	
6. Ancillary Benefits	2.40	2.40	2.40	2.40	
o Flood control	1	1	1	1	
o Recreation/tourism	1	1	1	1	
o Habitat/fishery enhancement	1	1	1	1	
o water quality improvement/environmental remediation (i.e. acid mine discharge; quarry reclamation)	4	4	4	4	
o Ability to leverage funding from other programs	5	5	5	5	

APPENDIX F

Pumping Station Schematic Drawings & Supporting Data



PLAN – WETWELL
NOT TO SCALE



TYPICAL SECTION – LOW FLOW WETWELL
NOT TO SCALE

SMALL SOURCE PUMP STATION

MOTT MACDONALD

325 CHESTNUT STREET
SUITE 300
PHILADELPHIA PA,19106
Certificate No. 24GA28016600

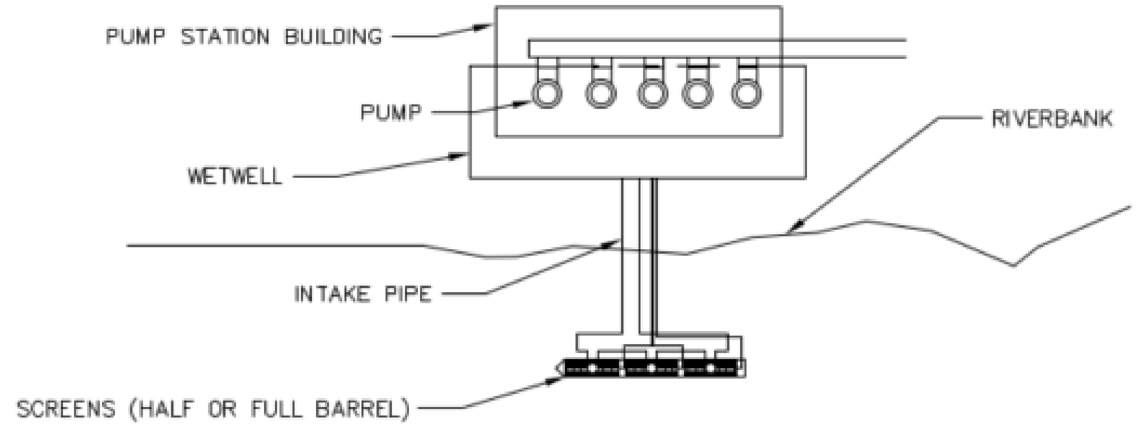
T +1 (800) 627 2277
F +1 (215) 627 2278
www.mottmacamericas.com

Client: DELAWARE RIVER BASIN COMITTEE

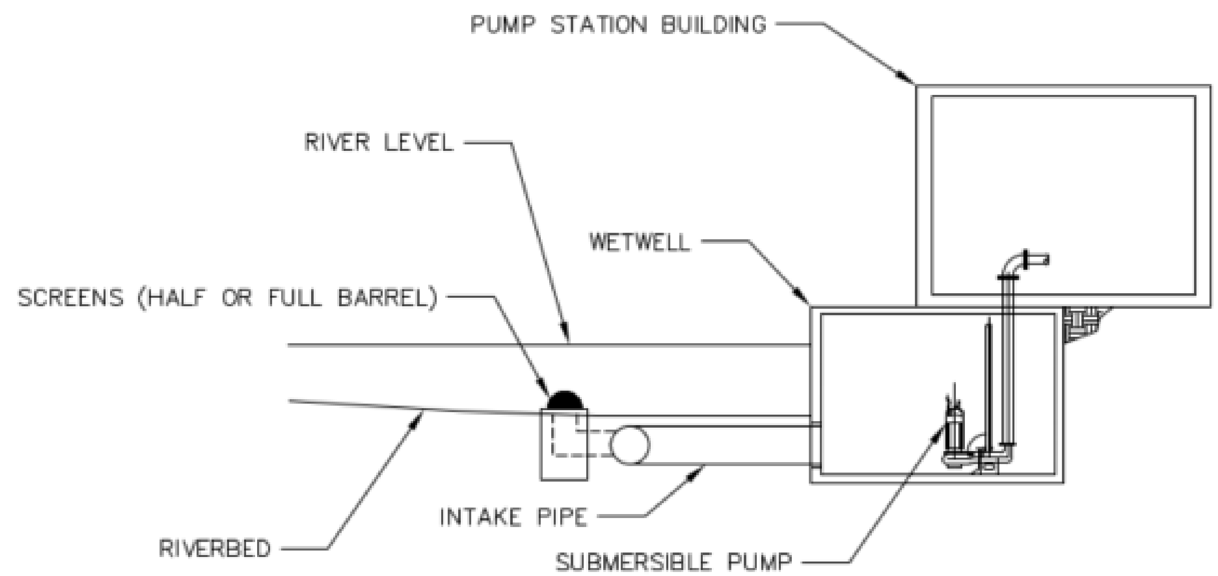
Rev	Date	Drawn	Description	Ch'k'd	App'd

Title: SMALL SOURCE PUMP STATION

Drawn	S. D'ORTONE	8/8/2022
Checked		
Approved		
NOT TO SCALE		
Security: STD	Status: PRE	Rev



PLAN – PUMPING STATION
NOT TO SCALE



TYPICAL SECTION – PUMPING STATION
NOT TO SCALE

LARGE SOURCE PUMP STATION

MOTT MACDONALD
325 CHESTNUT STREET
SUITE 300
PHILADELPHIA PA,19106
Certificate No. 24GA28016600

T +1 (800) 627 2277
F +1 (215) 627 2278
www.mottmacamericas.com

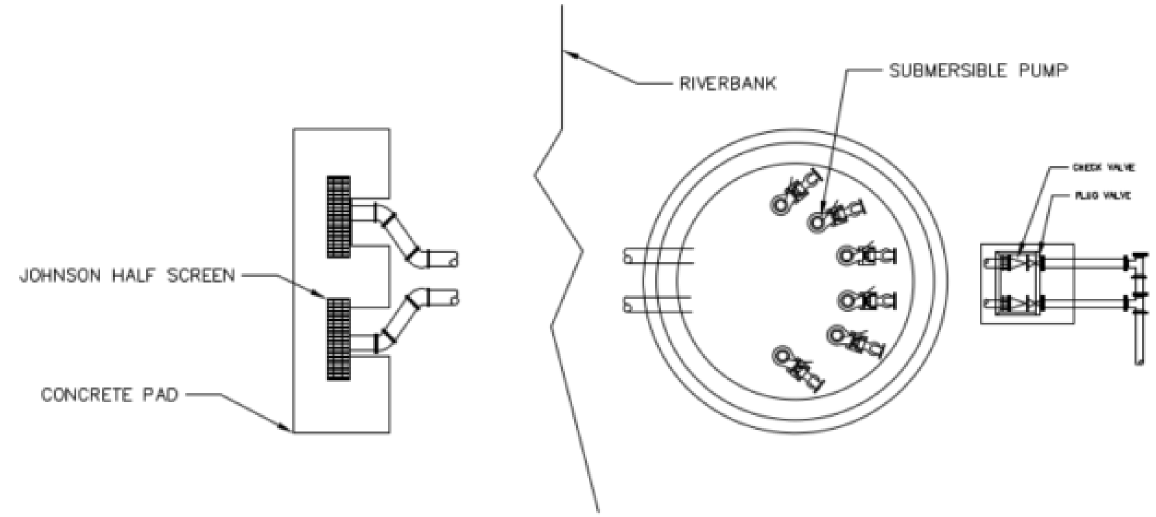
Client: DELAWARE RIVER BASIN COMITTEE

Rev	Date	Drawn	Description	Ch'k'd	App'd

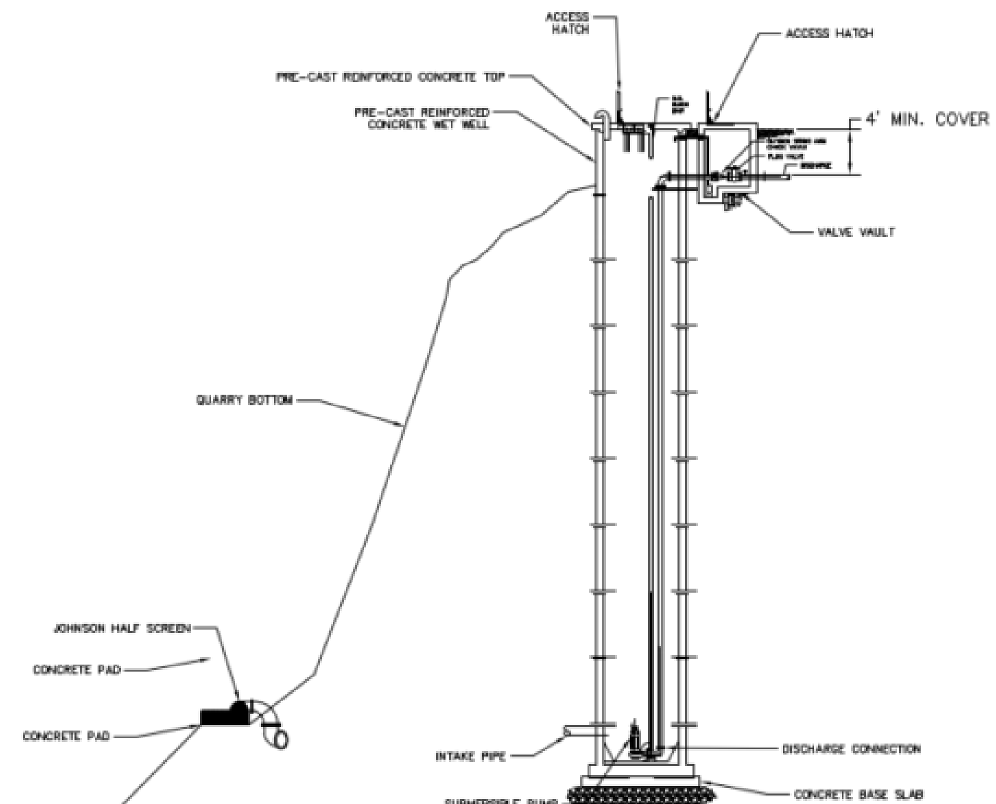
Title: LARGE SOURCE PUMP STATION

Drawn	S. D'ORTONE	8/8/2022
Checked		
Approved		
NOT TO SCALE		

Security	Status	Rev
STD	PRE	



PLAN — WETWELL
NOT TO SCALE



TYPICAL SECTION — WETWELL
NOT TO SCALE

QUARRY DISCHARGE PUMP STATION

MOTT MACDONALD

325 CHESTNUT STREET
SUITE 300
PHILADELPHIA PA,19106
Certificate No. 24GA28016600

T +1 (800) 627 2277
F +1 (215) 627 2278
www.mottmacamericas.com

Client: DELAWARE RIVER BASIN COMITTEE

Rev	Date	Drawn	Description	Ch'k'd	App'd

Title: QUARRY DISCHARGE PUMP STATION

Drawn	S. D'ORTONE	8/8/2022
Checked		
Approved		
NOT TO SCALE		
Security: STD	Status: PRE	Rev

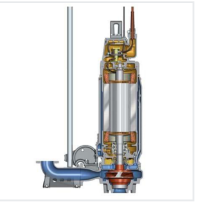
APPENDIX G

Manufacturer's brochure for typical pump for quarry discharge

Appendix G – Manufacturer's brochure for typical pump for quarry discharge

Flygt Channel Impeller Pumps

Flygt C 3240



Specifications

Overview

PRODUCT FEATURES

- High efficiency
- Excellent flow passing properties
- Motors with high power density
- Robust and reliable

WASTEWATER CHANNEL IMPELLER PUMP

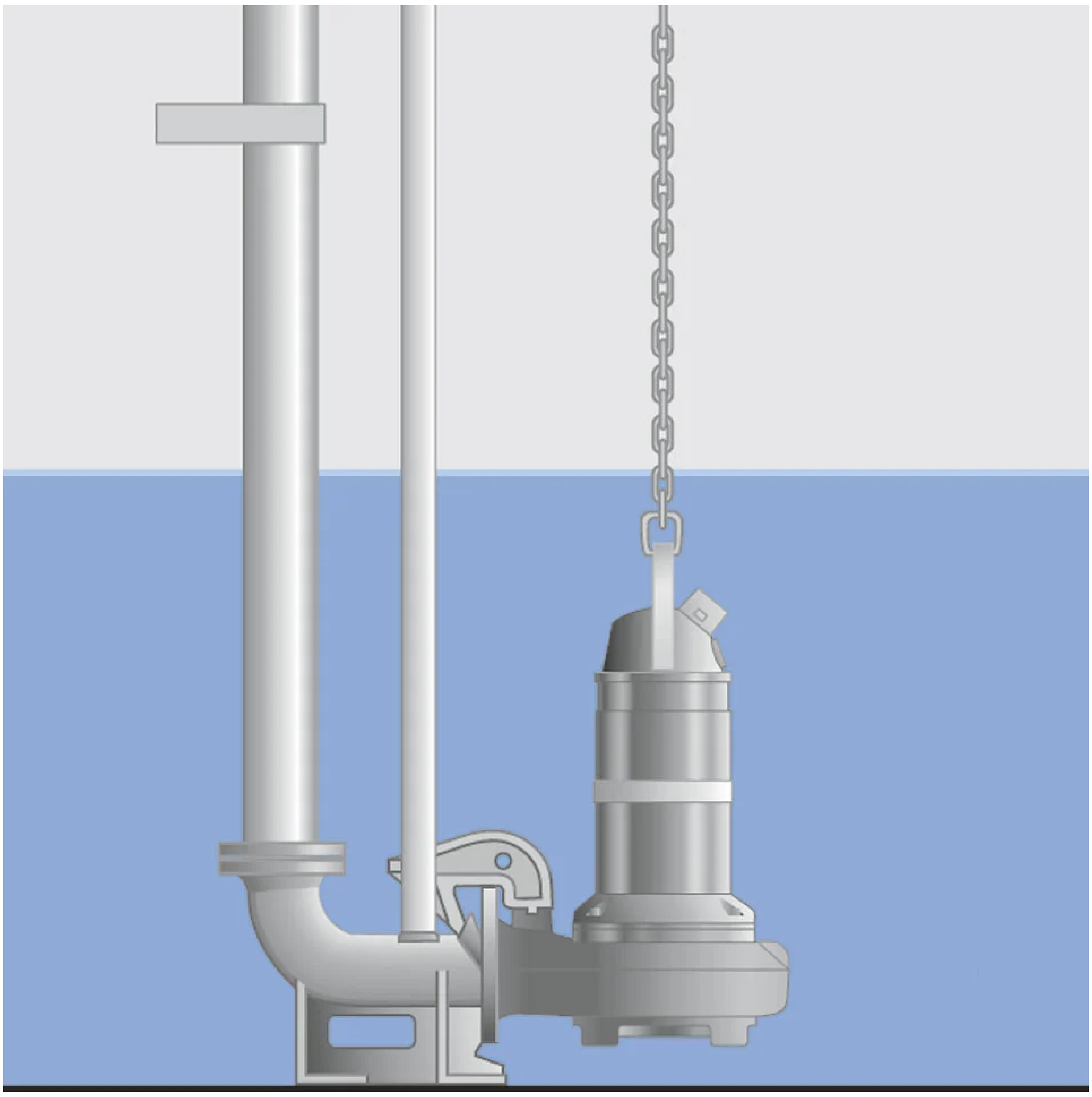
The classic C-pumps with shrouded impellers have proven themselves over the years and are designed to handle different types of media.

The C 3240 two-channel impeller has excellent flow passing properties that reduce clogging in the impeller channel. A narrow gap between the interchangeable wear rings ensures high efficiency.

ROBUST AND RELIABLE DESIGN

- The short shaft overhang reduces shaft deflection and increases seal and bearing life
- Motor designed for submersible use. Heat is concentrated to the stator core for improved cooling properties.
- Martensitic stainless steel shaft for maximum strength and corrosive resistance
- Optional duplex stainless steel shaft for superior corrosive resistance
- Double mechanical seal system. Two sets of mechanical shaft seals work independently to provide double security. They are available in Tungsten carbide (WCCR) or Silicone carbide (SiC) depending on pumped media.
- Motor cable SUBCAB ® specially developed for submersible use

Wet Pit (P)



Semi permanent, submersible pump installation. Wet pit arrangement with the pump installed on twin guide bars with automatic connection to the discharge pipe.

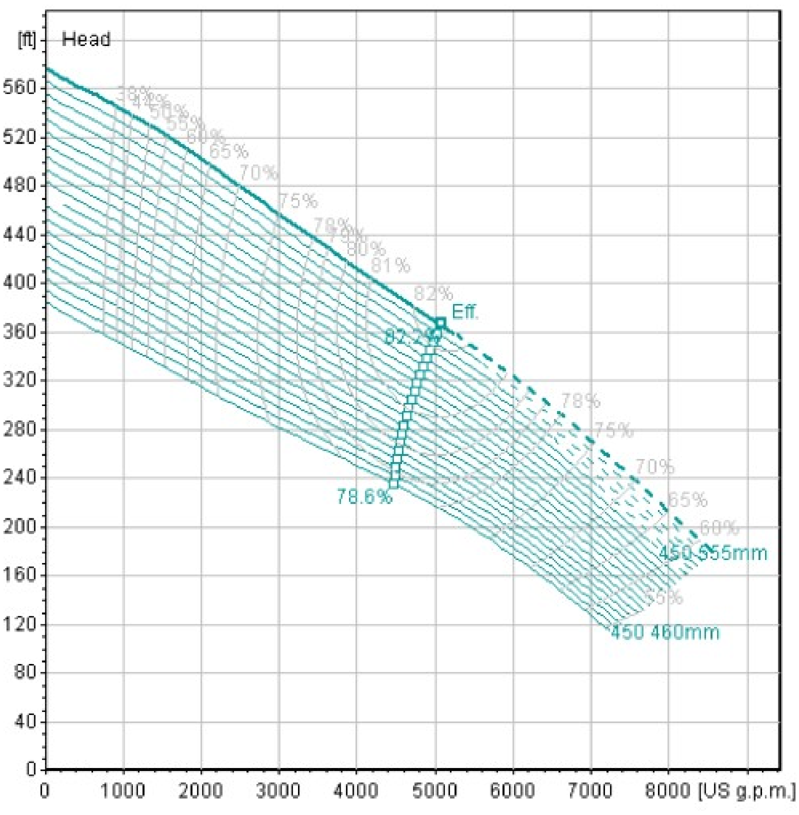
PUMP	C 3240 3 PHASE 4 POLES 450 60HZ US	C 3240 3 PHASE 4 POLES 451 60HZ US
f) Frequency	60 hz	60 hz
g) Number of poles	4	4
h) Phase	3~	3~
d) Discharge outlet diameter	7 7/8 inch	7 7/8 inch
i) Rated power	335 hp - 580 hp	335 hp - 580 hp
a) Impeller material	Grey cast iron	Stainless steel
	Standard	Standard

Performance Curves

Performance Curves

50 hz 60 hz Metric US

C 3240 3 phase 4 poles 450 60hz US



APPENDIX H

Relevant Permit Program Summary

Appendix H Relevant Permit Program Summary

FEDERAL

Regulations/Policies	Agency	Regulated Area	Regulated Activity
Rivers and Harbors Act of 1899, Sections 9, 10, 408	US Army Corps of Engineers, New England District (USACE)	Navigable Waters of the US and Tidal Waters	Deposition or dredging or construction of a structure in a navigable water; effect on a USACE civil works project in a navigable water (408)
Clean Water Act of 1972, Section 401, 404	USACE/USEPA	Waters of the US including Wetlands	Deposition of dredged or fill material in a water of the US; subject to the 404b(1) Guidelines
Endangered Species Act	US Fish and Wildlife Service (USFWS); NOAA National Marine Fisheries Service (NMFS)	Listed species, Critical Habitat	...must not take (includes harm, harass, pursue, hunt, shoot, wound, kill, trap, capture, or collect) any listed plant fish or wildlife within the United States
Migratory Bird Treaty Act	USFWS	Native, migratory birds listed and their nesting habitat	prohibits the take (including killing, capturing, selling, trading, and transport) of protected migratory bird species, including breeding habitat, without prior authorization
Bald and Golden Eagle Protection Act	USFWS	Bald and Golden Eagles	protects eagles from commercial exploitation and safeguards their continued survival in the United States
Marine Mammal Protection Act	NOAA National Marine Fisheries Service (NMFS)	Marine Mammals	Prohibits the "take" of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products into the U.S.
Chapter 106 National Historic Preservation Act	PA Historical and Museum Commission, State Historic Preservation Office	Listed or potentially listed historic/archaeological/cultural resources, on land or submerged	Clearly defined process for historic preservation of individual buildings and structures, but also of districts, objects, and archeological sites that are important due to their connection with the past to determine if federally funded or permitted work would harm a site and if so, avoid or minimize harm
National Pollutant Discharge Elimination System (NPDES)	Delegated to the State of PA by USEPA	Uplands greater than 1 acre in size	Direct or indirect discharge of pollutants to water
National Environmental Policy Act (NEPA)	US Environmental Protection Agency (USEPA)	Applies to any federally funded, executed or permitted actions	Federal action cause significant harm to the environment
Magnusen Stevens Act	NMFS	Commercially viable fisheries in tidally influenced waters	Primary law governing marine fisheries management in U.S. federal waters, including migratory species in navigable waterways
National Flood Control Act	Delegated to the Commonwealth of PA by FEMA (see below)		Regulates work in the floodplain
Federal Coastal Management Act of 1972, PA Coastal Resources Management Program, June 2021	Delegated by NOAA to the Commonwealth of Pennsylvania Pennsylvania Department of Environmental Protection, Compacts and Commissions Office, Coastal Resources Management Program June 2021	A program that evaluates any proposed federal cation conducted in the Coastal Zone of PA. Must be conducted in a manner consistent with the enforceable policies of a coastal state's federally approved coastal management program-In PA this include the Delaware Estuary or Lake Erie Coastal Zones.	Federal actions that have reasonably foreseeable effects on any land or water use or natural resource of the coastal zone (also referred to as coastal uses or resources, or coastal effects)

COMMONWEALTH OF PENNSYLVANIA

Regulations/Policies	Agency	Regulated Area	Regulated Activity
Chapter 166 Floodplain Management Act (October 4, 1978, P.L. 851, No. 166 32 P.S. §679.101 et seq)	PADEP, Regional Bureaus Waterways Engineering and Wetlands; Pennsylvania Emergency Management Agency, Pennsylvania Department of Community & Economic Development	The floodway, the 100 year floodplain (1% annual risk of flood)	Restricts storage of certain substances in the flood prone zone; limits construction in the floodway. All structures in floodplain must be designed to avoid increasing flooding or releasing listed pollutants
Chapter 105 Dam Safety and Encroachments Act (Act 325 of 1978)	PADEP Office of Water Management, Bureau of Watershed Management, Bureau of Waterways Engineering and Wetlands; County Conservation Districts	Provide for the comprehensive regulation and supervision of dams, reservoirs, water obstructions and encroachments in the Commonwealth in order to protect the health, safety, welfare and property of the people • Dams on a natural or artificial watercourse with a drainage area of 100 acres or more with maximum storage capacity of 15 ft Protect the natural resources, environmental rights and values secured by PA Constitution, and conserve and protect the water quality, natural regime and carrying capacity of watercourses • Regulation of the watercourses, wetlands and floodway • Erosion and Sediment Control • Submerged Lands of the Commonwealth	Construct, operate, maintain, modify, enlarge or abandon a dam; or other obstructions or encroachments along or across, or projecting into a watercourse, floodway or body of water, whether temporary or permanent. Any change in the cross-sectional area of a watercourse or wetland
PA Clean Streams Law Act 394 of 1937	PADEP	To preserve and improve the purity of the waters of the Commonwealth for the protection of public health, animal and aquatic life, and for industrial consumption, and recreation	Prohibition of discharge of “wastes” as determined by the PADEP into streams
401 State Water Quality Certification (SWQC) (51 Pa.B. 238)	PADEP	Grants concurrence that an issued USACE permit does not violate state water quality standards	The above-referenced State statutes and regulations included as condition to the SWQC as they comprise the Commonwealth's water quality standards and the environmental regulatory programs, which the Department has determined are necessary to achieve and maintain those standards
PA Stormwater Management Act. (1978, P.L. 864, No. 167)	PADEP Clean Water Program, Division of Stormwater Management and Sediment Control	Regulation of land and water use for flood control and storm water management purposes	Commercial, Industrial activities, MS-4 and Wastewater during Construction dewatering

APPENDIX I

One-page Summaries for

Top Ten Ranking Projects

RECOMMENDED STORAGE PROJECT – ONE PAGE SUMMARY *(Refer to the Storage Project Summary located in Appendix A for more detailed information.)*			PROJECT NUMBER Q19
PROJECT NAME AND LOCATION *(City and State)*			
Rush Valley Quarry *Furlong (Bucks County), Pennsylvania*		STORAGE TYPE Quarry	ESTIMATED VOLUME 1.7 BG

KEY PROJECT INFORMATION

PROJECT OVERVIEW	PROJECT SCORE & RANK	PROJECT COST
Quarry Storage; Neshaminy Creek source; Pump fill/discharge	SCORE: 4.07 RANK: 1	CAPITAL COST: $ 17.0M (2022) CAPITAL+O&M: $ 26.05M (Present Value)

DESCRIPTION OF PROJECT AND RELEVANCE TO THIS STUDY

The Eureka Rush Valley Quarry is an active quarry located in Furlong, PA in Bucks County, Pennsylvania. The site lies within Buckingham Township and borders Wrightstown Township, Doylestown Township, and Warwick Township. The quarry has a maximum volume of 1.7 billion gallons. This quarry is approximately 97 acres in area and has an estimated fillable rim elevation of 160 ft. At the quarry's deepest point, it has an elevation of 50 ft, giving the quarry a nominal depth of 110 feet. The nearest pumpable stream to the quarry is the Neshaminy Creek. The quarry is composed primarily of siltstone and mined for various aggregate products.

The intended design is to fill the quarry from the Neshaminy Creek located only about 250 ft away from the quarry interior. The flow of the source stream is substantial and should not affect the planned pumping rate and project target to replenish the storage with a 6-month period. The planned average withdrawal is approximately 29 mgd. The discharge of quarry storage to augment stream flow in times of need is governed by the limitations of the quarry pumping station and protection of the receiving stream from erosion. The discharge rate back into the stream has been established at 50 cfs (31 mgd).

The infrastructure required includes the quarry, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. Withdrawal will be accomplished with an arrangement of 3 x 10 mgd pumps in the wetwell. Discharge from the quarry back to the source stream is approximately 50 cfs (32 mgd) using 4 x 8.6 mgd pumps. The proposed pipeline route is schematically above and is approximately 250 feet of 30-inch diameter ductile iron pipe (DIP).

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. Capital costs have a contingency (+50%) commensurate with the concept development level of detail. Capital construction cost is $17.0M. $2M was carried for land costs associated with this project. Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1.4 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $26.05M. The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 9 years.

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented below, with individual scores sub-criteria provided in the Storage Project Scoring sheet.

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.75	30%	1.13
Infrastructure Design, Construction & Operation	3.60	10%	0.36
Environmental Impacts	4.79	15%	0.72
Social & Economic Impacts	4.88	10%	0.49
Project Cost & Schedule	4.00	30%	1.20
Ancillary Benefits	3.60	5%	0.18
AVERAGE	**4.10**		**4.07**

TITLE

FIRM NAME	STUDY	CLIENT NAME
MOTT MACDONALD M M Mott MacDonald	*Evaluation of Additional Storage in the Delaware River Basin*	**Delaware River Basin Commission** Delaware River Basin Commission DELAWARE • NEW JERSEY PENNSYLVANIA • NEW YORK UNITED STATES OF AMERICA
		DATE: 11/15/22

RECOMMENDED STORAGE PROJECT – ONE PAGE SUMMARY

(Refer to the Storage Project Summary located in Appendix A for more detailed information.)

PROJECT NUMBER

Q2

PROJECT NAME AND LOCATION *(City and State)*

McCoy Quarry
King of Prussia (Montgomery County), Pennsylvania

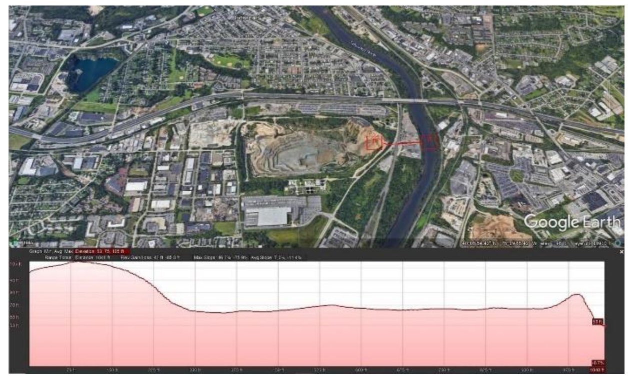
STORAGE TYPE	ESTIMATED VOLUME
Quarry	6.2 BG

KEY PROJECT INFORMATION

PROJECT OVERIVEW	PROJECT SCORE & RANK	PROJECT COST
Quarry Storage; Schuylkill River source; Pump fill/discharge with possible gravity	SCORE: 4.06 RANK: 2	CAPITAL COST: $ 21.7M (2022) CAPITAL+O&M: $ 31.05M (Present Value)

DESCRIPTION OF PROJECT AND RELEVANCE TO THIS STUDY

The McCoy Quarry is located in King of Prussia within Upper Merion Township and is adjacent to Plymouth Township, Pennsylvania. The quarry has a maximum estimated volume of 6.2 billion gallons. This quarry is approximately 123 acres in area and has an estimated fillable rim elevation of 70 ft. At the quarry's deepest point, it has an elevation of -237 ft, giving the quarry a nominal depth of 307 ft. The Schuylkill River is about 1040 ft away. The quarry is composed of quartz sand and gravel and generally mined for aggregate products. Water would be extracted during times of high flows (possibly by gravity) from the Schuylkill River, stored in the quarry, then discharged back to the River to augment flow during low flow.



The infrastructure required includes the quarry, stream withdrawal facilities, quarry discharge pumping facilities and interconnecting pipeline. The elevation of the Schuylkill River is approximately 53 ft, the quarry rim is 70 ft (90 ft highpoint shown in the above profile). This geometry may allow for gravity "skimming" of the river. Even if pumping is used to fill the quarry storage, the geometry is advantageous relative to others in that the distance is minimal and the static head to overcome for filling the quarry is low.

Mott MacDonald prepared a feasibility-level cost estimate consistent with the general approach described in the main report. The costs are based on the project assumptions and the developed infrastructure concepts as outlined above. Capital costs have a contingency (+50%) commensurate with the concept development level of detail. Land costs are assumed to be approximately $4M based on comparable quarry values in the region. Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 5.5 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $31.05. The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 7 years.

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are summarized in below.

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.50	30%	1.05
Infrastructure Design, Construction & Operation	3.10	10%	0.31
Environmental Impacts	4.61	15%	0.69
Social & Economic Impacts	4.75	10%	0.48
Project Cost & Schedule	4.50	30%	1.35
Ancillary Benefits	3.60	5%	0.18
AVERAGE	**4.01**		**4.06**

Individual scores for the criteria and sub-criteria are provided in the Storage Project Scoring sheet.

TITLE

FIRM NAME	STUDY	CLIENT NAME
MOTT MACDONALD M M Mott MacDonald	*Evaluation of Additional Storage for the Delaware River Basin*	**Delaware River Basin Commission** Delaware River Basin Commission DELAWARE • NEW JERSEY PENNSYLVANIA • NEW YORK UNITED STATES OF AMERICA
		DATE: 11/15/22

RECOMMENDED STORAGE PROJECT – ONE PAGE SUMMARY
(Refer to the Storage Project Summary located in Appendix A for more detailed information.)

PROJECT NUMBER
E4

PROJECT NAME AND LOCATION *(City and State)*

PROJECT NAME AND LOCATION	STORAGE TYPE	ESTIMATED VOLUME
Prompton Dam Modification *Near Honesdale (Wayne County), Pennsylvania*	Dam Modification	2.0 BG

KEY PROJECT INFORMATION

PROJECT OVERIVEW	PROJECT SCORE & RANK	PROJECT COST
Existing dam modification; new inlet and gate	SCORE: 4.04 RANK: 3	CAPITAL COST: $ 2.0M (2022) CAPITAL+O&M: $ 2.0M (Present Value)

DESCRIPTION OF PROJECT AND RELEVANCE TO THIS STUDY

Prompton Dam is a flood-control dam on the West Branch of the Lackawaxen River in Wayne County, PA, constructed and managed by the US Army Corps of Engineers (USACE). Currently, a low-level inlet water level is kept far below the spillway elevation to reserve a large volume for flood storage. In a drought emergency in the 1980s, the USACE built a temporary structure around the low-level inlet in the reservoir that raised the permanent pool to provide water for flow augmentation. This structure was later removed and has not been replaced. A new, uncontrolled inlet is proposed creating higher elevation than the existing inlet, which would provide about 2 BG of additional water storage. The movable gate on the existing inlet would be opened when a flood is forecast to quickly evacuate this additional water. No modifications to the dam proper, the spillway or the downstream channel are proposed. An advantage for this project is that no buildings would be flooded so socioeconomic impacts are minor. Significant challenges are navigating USACE and other Federal regulations regarding modifying the dam purpose to include flow augmentation/water supply and forecast-informed operation. The existing inlet at elevation 1125 ft would be equipped with a sliding gate or some other type of device that would normally be kept closed, increasing the permanent water level and providing additional 2 BG of storage. A new inlet would be constructed and connected to existing outlet pipe running through the bottom of the dam.

Mott MacDonald prepared a feasibility-level cost estimate for construction costs. Construction cost plus land costs and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) were estimated. Capital costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail. The capital cost is $2M, the lowest cost of any project by $20M, and the cost effectiveness is $1M/BG, which is the best of any project. The estimated schedule for the project is approximately 10 years. The schedule could be extended for many years if complications are encountered like complex dam regulatory delays, endangered species, mitigation of environmental impacts, or political opposition. Costs associated with compliance with USACE regulations, mitigation of environmental impacts and replacement costs of recreational facilities were not assessed but could be significant.

This site was scored as described below and provided in more detail in the Storage Project Scoring sheet.

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.17	30%	1.25
Infrastructure Design, Construction & Operation	3.80	10%	0.38
Environmental & Regulatory Considerations	3.25	15%	0.49
Stakeholder and Social Considerations	4.78	10%	0.48
Project Cost & Schedule	4.50	30%	1.35
Potential Ancillary Benefits	1.80	5%	0.09
TOTAL	**3.72**		**4.04**

TITLE

FIRM NAME	STUDY	CLIENT NAME
MOTT MACDONALD M M Mott MacDonald	*Evaluation of Additional Storage for the Delaware River Basin*	**Delaware River Basin Commission**
		DATE: 11/15/22

RECOMMENDED STORAGE PROJECT – ONE PAGE SUMMARY

(Refer to the Storage Project Summary located in Appendix A for more detailed information.)

PROJECT NUMBER: Q4

PROJECT NAME AND LOCATION *(City and State)*	STORAGE TYPE	ESTIMATED VOLUME
Penns Park Quarry *Wrightstown (Bucks County), Pennsylvania*	Quarry	3.3 BG

KEY PROJECT INFORMATION

PROJECT OVERIVEW	PROJECT SCORE & RANK	PROJECT COST
Quarry Storage; Neshaminy Creek source; Pump fill/discharge with possible gravity	SCORE: 4.04 RANK: 4	CAPITAL COST: $ 23.9M (2022) CAPITAL+O&M: $ 34.2M (Present Value)

DESCRIPTION OF PROJECT AND RELEVANCE TO THIS STUDY

The Penn Park Quarry is located in Wrightstown, PA within Bucks County. The quarry has a maximum volume of 3.3 billion gallons and an area of 87 acres. It has an estimated fillable rim elevation of 180 and at the deepest point the elevation is –138. This gives the quarry a nominal depth of 318 feet. The nearest significant stream to this quarry is the Neshaminy Creek, located about 2500 feet away.

The intended design is to fill the quarry from the Neshaminy Creek located approximately 0.5 miles away. The average expected withdrawal is approximately 29 mgd. The rate of quarry discharge to the stream has been established at 50 cfs (32 mgd).

The infrastructure required includes the quarry, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. The quarry fill/stream withdrawal pumping station will be 3 x 9.6 mgd pumps in the wetwell. The proposed pipeline is projected to be 2500 lf of 30 inch diameter ductile iron pipe (DIP).

Mott MacDonald prepared a feasibility-level cost estimate. Capital costs have a contingency (+50%) commensurate with the concept development level of detail. The market value of the quarry was approximated at $3M so this was carried forward as the land cost. Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 2.6 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $34.25M. The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 8 years.

This site was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are summarized in below.

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.58	30%	1.08
Infrastructure Design, Construction & Operation	3.60	10%	0.36
Environmental Impacts	4.57	15%	0.69
Social & Economic Impacts	4.88	10%	0.49
Project Cost & Schedule	4.17	30%	1.25
Ancillary Benefits	3.60	5%	0.18
AVERAGE	**4.07**		**4.04**

Individual scores for the criteria and sub-criteria are provided in the attached Storage Project Scoring sheet.

TITLE

FIRM NAME	STUDY	CLIENT NAME
MOTT MACDONALD M M Mott MacDonald	*Evaluation of Additional Storage for the Delaware River Basin*	**Delaware River Basin Commission** Delaware River Basin Commission DELAWARE • NEW JERSEY PENNSYLVANIA • NEW YORK UNITED STATES OF AMERICA
		DATE: 11/15/22

RECOMMENDED STORAGE PROJECT – ONE PAGE SUMMARY
(Refer to the Storage Project Summary located in Appendix A for more detailed information.)

PROJECT NUMBER: Q12

PROJECT NAME AND LOCATION *(City and State)*

Solebury Quarry
Solebury Twp (Bucks County), Pennsylvania

STORAGE TYPE	ESTIMATED VOLUME
Quarry	2.3 BG

KEY PROJECT INFORMATION

PROJECT OVERIVEW	PROJECT SCORE & RANK	PROJECT COST
Quarry Storage; Delaware River source; Pump fill/discharge with possible gravity	SCORE: 4.03 RANK: 5	CAPITAL COST: $ 24.3M (2022) CAPITAL+O&M: $ 40.9M (Present Value)

DESCRIPTION OF PROJECT AND RELEVANCE TO THIS STUDY

This storage project would store water pumped from the nearby Delaware River in the Solebury Quarry and subsequently release back to the Delaware River when needed. The quarry has a maximum volume of 2.3 billion gallons. This quarry is approximately 82 acres in area and has an estimated fillable rim elevation 100 ft. At the quarry's deepest point, it has an elevation of -100 ft, giving the quarry a nominal depth of 200 feet. The quarry is composed primarily of limestone and was mined for related construction materials. The quarry is closed and undergoing maintenance and phased reclamation led by PADEP

The nearby Delaware River provides ample supply, particularly during high flow periods. This allows for unencumbered withdrawal for the project targeted 50 cfs flow. The size of the Delaware does not restrict the discharge rate and the project design pumping rate is 50 cfs (31.64 mgd). Gravity discharge from the quarry to the river is possible, but limited.

The infrastructure required includes the quarry, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. The intake is a wedgewire screen on the river bottom, but supports different intake options. The pumping station will have multiple submersible pumps (3 x 10 mgd). The stored quarry water will be withdrawn with submersible pumps (4 x 8.6 mgd) at a high, constant rate. The connecting pipeline is projected to be 6,100 lf of 30 inch diameter ductile iron pipe (DIP).

Mott MacDonald prepared a feasibility-level cost estimate for this storage project. Capital costs have a contingency (+50%) commensurate with the concept development level of detail.
Land costs were assigned a market value of approximately $9.2M. Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1.8 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $40.87M.
The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 11 years.

Scores for the criteria are provided below and detailed in the available Storage Project Scoring sheet.

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.75	30%	1.13
Infrastructure Design, Construction & Operation	3.20	10%	0.32
Environmental Impacts	4.57	15%	0.69
Social & Economic Impacts	5.00	10%	0.50
Project Cost & Schedule	4.00	30%	1.20
Ancillary Benefits	4.00	5%	0.20
AVERAGE	**4.09**		**4.03**

TITLE

FIRM NAME	STUDY	CLIENT NAME
MOTT MACDONALD Mott MacDonald	*Evaluation of Additional Storage for the Delaware River Basin*	**Delaware River Basin Commission**
		DATE: 11/15/22

RECOMMENDED STORAGE PROJECT – ONE PAGE SUMMARY
(Refer to the Storage Project Summary located in Appendix A for more detailed information.)

PROJECT NUMBER
Q25

PROJECT NAME AND LOCATION *(City and State)*

Tilcon Oxford Quarry
Oxford (Warren County), New Jersey

STORAGE TYPE	ESTIMATED VOLUME
Quarry	1.2 BG

KEY PROJECT INFORMATION

PROJECT OVERIVEW	PROJECT SCORE & RANK	PROJECT COST
Quarry Storage; Pequest River source; Pump fill/discharge with possible gravity	SCORE: 4.02 RANK: 6	CAPITAL COST: $ 19.2M (2022) CAPITAL+O&M: $ 25.4M (Present Value)

DESCRIPTION OF PROJECT AND RELEVANCE TO THIS STUDY

This storage project will use the Tilcon Oxford quarry to store water pumped from the adjacent Pequest River and discharge to the Pequest River, which flows to the Delaware River. The Tilcon Oxford Quarry is an active quarry located in Oxford Township Warren County in west central New Jersey. The quarry has a maximum volume of 1.2 billion gallons. This quarry is approximately 64 acres in area and has an estimated fillable rim elevation 530 ft. The quarry's deepest point, has an elevation of 360 ft, giving the quarry a nominal depth of 160 feet. The nearest pumpable stream is the Pequest River, located about 3,000 feet away. The Delaware River is 3 miles away, offering higher flows.

Given the small quarry volume, this inflow pumping rate is not considered stream limited; pumping at the targeted average 31 mgd is assumed. The discharge pumping from quarry storage back to the Pequest River has a target discharge rate of 50 cfs (31.64 mgd), which is much less than the mean annual stream flow. The infrastructure required includes the quarry, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. The quarry fill/stream withdrawal pumping station is wedgewire halfscreens and onshore wetwell, fitted with submersible pumps (4 x 9 mgd pumps). Stored water will be pumped from the quarry shaft/wetwell using 4 x 8.6 mgd submersible pumps. The pipeline is approximately 3000 lf to the Pequest River and typical 30 inch diameter ductile iron pipe (DIP).

Mott MacDonald estimated capital costs, assigning a contingency (+50%) commensurate with the concept development level of detail. $4M was used for the land cost. Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $25.44M. The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 9 years.

This project was scored relative to the criteria as presented below and detailed in the available Storage Project Scoring sheet.

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.00	30%	1.20
Infrastructure Design, Construction & Operation	3.60	10%	0.36
Environmental Impacts	4.57	15%	0.69
Social & Economic Impacts	4.88	10%	0.49
Project Cost & Schedule	3.83	30%	1.15
Ancillary Benefits	2.80	5%	0.14
AVERAGE	**3.95**		**4.02**

TITLE

FIRM NAME	STUDY	CLIENT NAME
MOTT MACDONALD M M Mott MacDonald	*Evaluation of Additional Storage for the Delaware River Basin*	**Delaware River Basin Commission** Delaware River Basin Commission DELAWARE • NEW JERSEY PENNSYLVANIA • NEW YORK UNITED STATES OF AMERICA
		DATE: 11/15/22

RECOMMENDED STORAGE PROJECT – ONE PAGE SUMMARY
(Refer to the Storage Project Summary located in Appendix A for more detailed information.)

PROJECT NUMBER
Q07D

PROJECT NAME AND LOCATION *(City and State)*

Stockertown Quarry (Delaware River Source)
Stockertown (Northampton County), Pennsylvania

STORAGE TYPE
Quarry

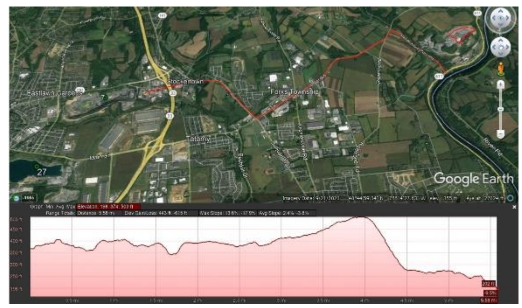
ESTIMATED VOLUME
4.6 BG

KEY PROJECT INFORMATION

PROJECT OVERIVEW	PROJECT SCORE & RANK	PROJECT COST
Quarry Storage; Delaware River source; Pump fill/discharge with possible gravity	SCORE: 4.01 RANK: 7	CAPITAL COST: $ 54.5M (2022) CAPITAL+O&M: $ 64.9M (Present Value)

DESCRIPTION OF PROJECT AND RELEVANCE TO THIS STUDY

This storage project stores water in the Stockertown Quarry using the Delaware River for the source and discharge. The Stockertown Quarry is an active quarry located in Stockertown, PA in Northampton County just east of the Nazareth Borough, Pennsylvania. The quarry is composed of shale and limestone and mined for construction materials. The quarry has a maximum volume of 4.6 billion gallons, the third largest quarry storage reviewed. This quarry is approximately 120 acres in area and has an estimated fillable rim elevation of 300 ft. At the quarry's deepest point, it has an elevation of 65 ft, giving the quarry a nominal depth of 235 ft. The closest pumpable stream to the quarry is the Bushkill Creek, located only about 150 feet away. However, the larger Delaware River is a better source and discharge point. This allows for unencumbered withdrawal and subsequent discharge of the design pump station flow of 50 cfs.



The infrastructure required includes the quarry, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. The intake will be wedgewire screens on the river bottom, pumping station wetwell with a connecting pipe section. Withdrawn water will be pumped at a high constant rate, sufficient to reasonably fill the quarry. Similarly, the quarry discharge station will consist of a shaft and pumping facilities. The pipeline is approximately 3.91 miles of 30 inch diameter ductile iron pipe (DIP).

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. The cost of the pipeline is a significant cost to the project. Capital costs have a contingency (+50%) commensurate with the concept development level of detail. Land costs are estimated to be $3M. Operating costs for this project are estimated to be approximately $0.375M/year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $64.88M. The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 9 years.

Categories, descriptions and individual scores are presented below and provided in detail on Storage Project Scoring sheet.

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.5	30%	1.23
Infrastructure Design, Construction & Operation	3.70	10%	0.37
Environmental Impacts	4.93	15%	0.74
Social & Economic Impacts	4.25	10%	0.43
Project Cost & Schedule	3.67	30%	1.10
Ancillary Benefits	3.00	5%	0.15
AVERAGE	**3.94**		**4.01**

TITLE

FIRM NAME	STUDY	CLIENT NAME
Mott MacDonald	*Evaluation of Additional Storage for the Delaware River Basin*	**Delaware River Basin Commission**
		DATE: 11/15/22

RECOMMENDED STORAGE PROJECT – ONE PAGE SUMMARY
(Refer to the Storage Project Summary located in Appendix A for more detailed information.)

PROJECT NUMBER
E2

PROJECT NAME AND LOCATION *(City and State)*

Cannonsville Reservoir Water-Level Increase
Delaware County), New York

STORAGE TYPE	ESTIMATED VOLUME
Dam Modification	13.0 BG

KEY PROJECT INFORMATION

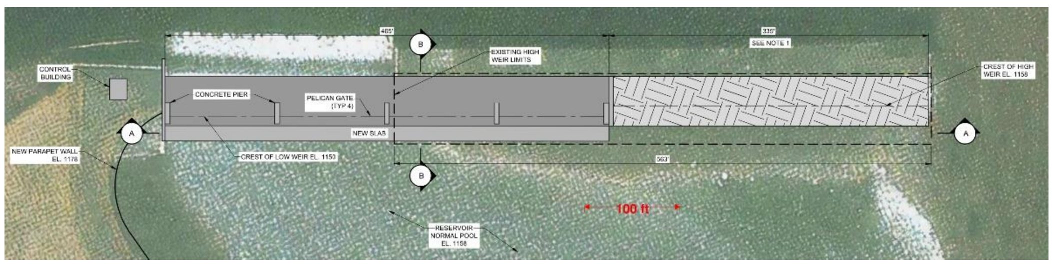
PROJECT OVERIVEW	PROJECT SCORE & RANK	PROJECT COST
Reservoir increase by installation of gates atop the spillway	SCORE: 3.99 RANK: 8	CAPITAL COST: $ 67.0M (2022) CAPITAL+O&M: $ 77.0M (Present Value)

DESCRIPTION OF PROJECT AND RELEVANCE TO THIS STUDY

The Cannonsville Reservoir and Dam are located on the West Branch of the Delaware River in Delaware County, NY. It is owned by and serves as a water supply reservoir for New York City. The potential project is to increase its storage volume by 13 BG by raising the water level 8 ft from elevation 1150 ft to elevation 1158 ft. This would be accomplished by installing movable gates on the existing spillway. The dam crest elevation would remain at 1175 feet, but a 3-ft parapet wall would be constructed on top of the dam to prevent wind-caused overflow. The raise would enlarge the pool footprint by about 760 acres. No buildings would be inundated but road sections would need to be elevated or relocated.

The reservoir currently holds 95.7 billion gallons (BG) when full. The dam raise adds 13 BG (13,500 ac-ft) of storage through 8 ft of additional reservoir height. No modifications to the existing dam are proposed.

A portion of the existing concrete spillway would be removed and replaced with a modified spillway to accommodate four 8-foot-high pelican type gates, each 110 foot-long with downstream operators and five-foot wide supporting piers. A total of 465-feet of existing spillway would be modified.



Mott MacDonald prepared a feasibility-level cost estimate for construction costs. Costs have a 25% design contingency and a 20% construction contingency commensurate with the concept development level of detail. Construction cost and annual operation and maintenance cost (0.2% of the construction costs converted to present value assuming 30-year life and 3% interest rate) and cost effectiveness (million dollars per billion gallons of storage) were estimated. Total cost (present value) was estimated at $77M. Land acquisitions costs were assumed negligible. The cost effectiveness of $6M/BG is by far the best of all the new dam, dam raise or storage reallocation projects and the highest for any project providing over 5 BG. The schedule for the project is estimated at 10 years.

The Cannonsville Reservoir expansion project was scored relative to the criteria as presented below and further detailed in the Storage Project Scoring sheet.

Criteria	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	4.67	30%	1.40
Infrastructure Design, Construction & Operation	3.60	10%	0.36
Environmental Impacts	3.21	15%	0.48
Social & Economic Impacts	4.89	10%	0.49
Project Cost & Schedule	4.00	30%	1.20
Ancillary Benefits	1.20	5%	0.06
AVERAGE	**3.59**		**3.99**

TITLE

FIRM NAME	STUDY	CLIENT NAME
MOTT MACDONALD Mott MacDonald	*Evaluation of Additional Storage for the Delaware River Basin*	**Delaware River Basin Commission**
		DATE: 11/15/22

RECOMMENDED STORAGE PROJECT – ONE PAGE SUMMARY
(Refer to the Storage Project Summary located in Appendix A for more detailed information.)

PROJECT NUMBER
Q22

PROJECT NAME AND LOCATION *(City and State)*

Whitehall Quarry
Whitehall (Lehigh County), Pennsylvania

STORAGE TYPE
Quarry

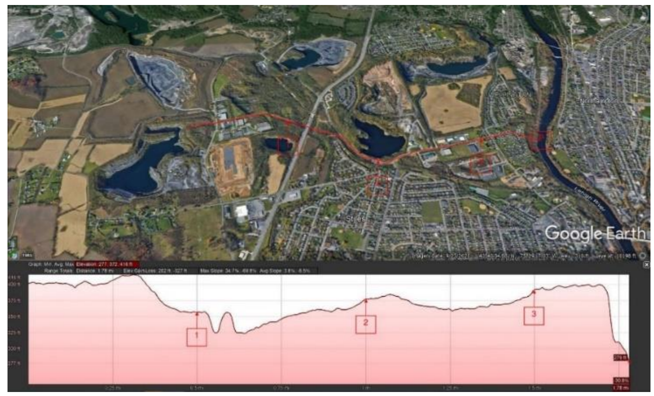
ESTIMATED VOLUME
1.2 BG

KEY PROJECT INFORMATION

PROJECT OVERIVEW	PROJECT SCORE & RANK	PROJECT COST
Quarry Storage; Lehigh River source; Pump fill/discharge with possible gravity	SCORE: 3.97 RANK: 9	CAPITAL COST: $ 26.1M (2022) CAPITAL+O&M: $ 33.6M (Present Value)

DESCRIPTION OF PROJECT AND RELEVANCE TO THIS STUDY

This storage project pumps from the Lehigh River, stores in the Whitehall Quarry and later discharges to the Lehigh. This project is part of the Coplay Cluster of quarries and may offer opportunity to combine storage projects. The quarry has a maximum volume of 1.2 billion gallons. This quarry is approximately 62 acres in area and has an estimated fillable rim elevation 360 ft. At the quarry's deepest point, it has an elevation of 240 ft, giving the quarry a nominal depth of 120 feet. Coplay Creek is located immediately adjacent to the site but has low flows. The nearest significant stream is the Lehigh River (2 miles away). The quarry is composed primarily of limestone and was mined for related construction products.



The intended design is similar to other projects, particularly Q21, located 1.2 miles away. The quarry fill and discharge approach utilizes the flows of the Lehigh River. The filling of the quarry is not stream-limited; the Lehigh will sustain pumping at a practical pumping station flow rate, established at 50 cfs. The stored water in the quarry will be released back to the Lehigh at the target rate of 50 cfs.

The infrastructure required includes the quarry, stream withdrawal pumping facilities, quarry discharge pumping facilities and interconnecting pipeline. This includes a submerged wedgewire screen on the river bottom, a wetwell and submersible pumps (3x 10 mgd) for lifting and transferring river water to the quarry. The quarry discharge/stream augmentation pumping station is similar with 4 x 8.6 mgd pumps for discharge. The pipeline is estimated to be 9,400 lf of 30- inch diameter ductile iron pipe (DIP).

Mott MacDonald prepared a cost estimate for this storage project consistent with the general approach described in the main report. Capital costs have a contingency (+50%) commensurate with the concept development level of detail. The total capital cost is shown above. The land cost assigned a value of $3.66M. Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $33.6M
The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 11 years.

This project was scored relative to the criteria as presented in the main report. Categories, descriptions and individual scores are presented below and in more detail in the Storage Project Scoring sheet.

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.83	25%	0.96
Infrastructure Design, Construction & Operation	3.00	20%	0.60
Environmental Impacts	4.86	20%	0.97
Social & Economic Impacts	4.69	15%	0.47
Project Cost & Schedule	3.67	15%	0.55
Ancillary Benefits	4.20	5%	0.42
AVERAGE	**4.04**		**3.97**

TITLE

FIRM NAME	STUDY	CLIENT NAME
MOTT MACDONALD M M Mott MacDonald	*Evaluation of Additional Storage for the Delaware River Basin*	**Delaware River Basin Commission** Delaware River Basin Commission DELAWARE • NEW JERSEY PENNSYLVANIA • NEW YORK UNITED STATES OF AMERICA
		DATE: 11/15/22

RECOMMENDED STORAGE PROJECT – ONE PAGE SUMMARY

(Refer to the Storage Project Summary located in Appendix A for more detailed information.)

PROJECT NUMBER

Q21

PROJECT NAME AND LOCATION *(City and State)*

PROJECT NAME AND LOCATION	STORAGE TYPE	ESTIMATED VOLUME
Ormrod Quarry *Coplay (Lehigh County), Pennsylvania*	Quarry	1.3 BG

KEY PROJECT INFORMATION

PROJECT OVERIVEW	PROJECT SCORE & RANK	PROJECT COST
Quarry Storage; Lehigh River source; Pump fill/discharge with possible gravity	SCORE: 3.92 RANK: 10	CAPITAL COST: $ 33.4M (2022) CAPITAL+O&M: $ 45.0M (Present Value)

DESCRIPTION OF PROJECT AND RELEVANCE TO THIS STUDY

This storage project would extract water from the Lehigh River, store it in the Ormrod Quarry and release it when needed for flow augmentation. This active quarry is located in Coplay within North Whitehall Township of Lehigh County, Pennsylvania. The quarry has a maximum volume of 1.3 billion gallons. This quarry is approximately 87 acres in area and has an estimated fillable rim elevation 350 ft. At the quarry's deepest point, it has an elevation of 240 ft, giving the quarry a nominal depth of 110 feet. Coplay Creek is located adjacent to the site but has low flows. The nearest significant stream to the quarry is the Lehigh River, located about 3 miles away.

The filling of the quarry is not stream-limited since the Lehigh River will sustain pumping at a practical pumping station flow rate, established at 50 cfs. The discharge of stored water in the quarry will be released back to the Lehigh at the target rate of 50 cfs. The infrastructure required includes the quarry, stream withdrawal pumping facilities, quarry-discharge pumping facilities and interconnecting pipeline. The stream pumping involves submerged wedgewire screens connected to a wetwell that houses submersible pumps (3 x 10 mgd). The quarry discharge/stream augmentation pumping station will be as typical with 4 x 8.6 mgd pumps. The pipeline measures approximately 3 miles of 30 inch diameter ductile iron pipe (DIP).

Mott MacDonald prepared feasibility level cost estimate that have a contingency (+50%) commensurate with the concept development level of detail. The land cost was estimated at $8.75M. Operating costs for this project are estimated to be approximately $0.375M/year. This assumes annual discharge of 1 BG and subsequent filling for the following year. Assuming a 30-year operating horizon and ignoring routine maintenance costs, the present value (PV) of the operating cost is $7.35M. This brings the combined total of capital and PV of operating cost to a project total of $45M. The schedule for putting this project in service after general concurrence of all major parties is expected to be approximately 9 years.

Categories, descriptions and individual scores are presented below and in more detail in the Storage Project Scoring sheet.

CATEGORY	Assigned Score	Assigned Weight	Weighted Score
Water Quantity & Quality	3.83	30%	1.15
Infrastructure Design, Construction & Operation	3.10	10%	0.31
Environmental Impacts	4.93	15%	0.74
Social & Economic Impacts	4.63	10%	0.46
Project Cost & Schedule	3.50	30%	1.05
Ancillary Benefits	4.20	5%	0.21
AVERAGE	**4.03**		**3.92**

TITLE

FIRM NAME	STUDY	CLIENT NAME
Mott MacDonald	*Evaluation of Additional Storage in the Delaware River Basin*	**Delaware River Basin Commission**
		DATE: 11/15/22

mottmac.com