New Jersey Department of Environmental Protection
Water Resource Management
Division of Water Supply and Geoscience
New Jersey Geological and Water Survey

GUIDANCE MANUAL

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ESTIMATING THE SAFE YIELD OF SURFACE WATER SUPPLY RESERVOIR SYSTEMS

Governor Chris Christie
Commissioner Bob Martin

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SECTION 1 PURPOSE

This manual provides guidance for the preparation and submittal of safe yield estimates. This applies to surface water supply reservoir systems that are regulated under the New Jersey Water Supply Management Act by the New Jersey Department of Environmental Protection (Department). The Department's intent is to: (1) establish a cooperative process with clear expectations between the Department and purveyors to ensure that all relevant aspects of each safe yield estimate are considered to the extent feasible; (2) ensure that the methods, assumptions and logic used to estimate safe yield are appropriate and are clearly and plainly documented in the engineer's report; and (3) ensure that sufficient information is available to enable the Department's final decision document to adequately address public concerns.

By clearly listing what data and analysis should be included the Department's approval process becomes more open and transparent. This helps purveyors prepare quality submissions and fosters predictable agency actions.

The guidance in this manual applies from the date of the manual until it is superseded by either future guidance from the Department or applicable statutory/regulatory requirements. The guidance applies regardless of any previous approvals of safe yield estimates by the Department. Purveyors should use this guidance manual whenever they initiate a request for approval of a safe yield estimate and whenever they respond to a Department requirement to submit a safe yield estimate. Also, this guidance is for the preparation and submittal of safe yield estimates for existing surface water supply reservoir systems, proposed new and modified surface water supply reservoir systems, and potential alternative surface water supply reservoir systems.

Purveyors are strongly encouraged to review this guidance manual *prior* to preparing safe yield estimates. In part, the guidance manual identifies statutory and regulatory authority and requirements regarding safe yield estimates for surface water supply reservoir systems. Beyond statutory and regulatory requirements, the manual provides only general guidance as it would be impractical to describe complete step-by-step instructions to prepare safe yield estimates for every surface water supply reservoir system in New Jersey. In part, this is because each system has its own unique characteristics, thus each submittal may consider unique alternatives. Each safe yield estimate may also be affected in unique ways by various human activities, natural features and natural processes. Some surface water supply reservoir systems and safe yield estimates may be simple while others may be very complex. Also, there are limits to the present scientific understanding of the land phase of the hydrologic cycle. As a result, safe yield estimates may require case-by-case judgments made by the qualified technical personnel of the purveyor and the Department. There will be situations for which alternative methods are appropriate and additional methods needed. Such methods may be used when approved by the Department. Consequently, purveyors are also strongly encouraged to confer with the Department *prior* to preparing safe yield estimates in order to reach tentative consensus regarding the scope of the estimate, the applicability of the various portions of the guidance manual, and any additional methods and requirements that are unique to the particular submittal. In many cases, purveyors should also find it helpful to collaborate with the Department as safe yield estimates are being prepared.

For consistency, the Department will refer to the general guidance in this manual when independently estimating the safe yield of surface water supply reservoir systems, as well as when reviewing safe yield estimates prepared and submitted by purveyors. The Department will provide an explanation and justification for any methods that vary from the guidance provided in this manual, if it determines that they should be used to estimate the safe yield of surface water supply reservoir systems.

If purveyors have questions regarding this manual, they should contact the New Jersey Geological and Water Survey, Water Supply Modeling and Planning Section at (609) 984-6587.

SECTION 2 AUTHORITY

The Department's authority with regard to the subject of this guidance manual is based on the following:

2.1 Statutory Authority

Title: 58 New Jersey Statutes for Waters and Water Supply, and more specifically the Water Supply Management Act, P.L. 1981, C. 262, (N.J.S.A. 58:1A), declares that:

> "the water resources of the State are public assets of the State held in trust for its citizens and are essential to the health, safety, economic welfare, recreational and aesthetic enjoyment, and general welfare, of the people of New Jersey; that ownership of these assets is in the State as trustee of the people; that because some areas within the State do not have enough water to meet their current needs and provide an adequate margin of safety, the water resources of the State and any water brought into the State must be planned for and managed as a common resource from which the requirements of the several regions and localities in the State shall be met; ... that it is necessary to insure that within each basin there exist adequate water supplies to accommodate present and future needs; that to ensure an adequate supply and quality of water for citizens of the State, both present and future, and to protect the natural environment of the waterways of the State, it is necessary that the State, through its Department of Environmental Protection, have the power to manage the water supply by adopting a uniform water diversion permit system and fee schedule, a monitoring, inspection and enforcement program, a program to study and manage the State's water resources and plan for emergencies and future water needs, and regulations to manage the waters of the State during water supply and water quality emergencies."

The Act defines "safe or dependable yield" or "safe yield" as that maintainable yield of water from a surface or ground water source or sources which is available continuously during projected future conditions, including a repetition of the most severe drought of record, without creating undesirable effects, as determined by the Department.

2.2 Regulatory Authority

The Water Supply Allocation Permit Rules at N.J.A.C. 7:19-1.1 et seq. establish the information required in applications for water supply allocation permits (N.J.A.C. 7:19-2.2) and for determination of safe or dependable yield (N.J.A.C. 7:19-6.3). These rules are currently under review for proposal with amendments that will establish and clarify the technical requirements and administration procedure for submitting safe yield estimates. In water supply allocation permits, the Department often imposes passing flows or other operational requirements on permittees diverting water to ensure there are no undesirable effects on water quality, downstream users, and natural resources.

Currently the rules cited below require the following:

N.J.A.C. 7:19-6.3(a) Each purveyor shall either accept an estimate of safe yield from surface supplies or of dependable yield of subsurface sources previously made by the Department or submit its own evaluation and estimate for the approval of the Department within one year after a written request for such an estimate by the Department.

N.J.A.C. 7:19-6.3(b) A purveyor is required to provide a safe or dependable yield of water from its own sources, which, when added to water supplies available by contract and after subtraction of water obliged to be delivered by the purveyor by contract, shall be sufficient to provide for the normal demand of its own customers.

N.J.A.C. 7:19-6.3(b) 4	Increased safe yield or dependable yield of individual water supply systems may be allowed, to take advantage of system diversity and interconnections, but only in conformance with regional arrangements approved by the Department, under which coordinated systems of operation will assure system-safe yields greater than that which could be provided by the individual water systems.
N.J.A.C. 7:19-6.3(c)	If a determination of yield in accordance with (a) above shows that a purveyor has insufficient capacity to meet the normal demand of its customers, the purveyor shall revise existing contract arrangements to reduce system demands, as necessary, or shall immediately obtain additional water supply to increase its safe or dependable yield.

SECTION 3 DEFINITIONS

The following words and terms, as used in this document, have the following meanings unless the context clearly indicates otherwise:

Calibration process means the process of attempting to obtain agreement between simulated outputs of a safe yield simulation model and actual field measurements or observations and, if necessary, adjusting selected computer model input data, calculations and logical functions in reasonable and defensible ways to minimize the differences between the simulated outputs and actual field measurements or observations.

Control point means a key location for a surface water supply reservoir system or any other relevant human activity, natural feature, hydrologic process or hydraulic process that is important for computing and simulating the flow and storage of water in a safe yield simulation model, for the purpose(s) of estimating the system's safe yield or assessing the impacts associated with the other activity, feature or process. These key locations are also often referred to as "spatial control points", "computational control points" or "model control points". Although these locations are traditionally referred to as "points", which technically have no spatial dimensions, they may also be conceptualized as "objects" with one, two or three spatial dimensions. For example, a control point for a reservoir may be conceptualized either as a dimensionless point located at the spillway weir or as a one-dimensional space with separate inlet and outlet locations along a stream flow network. Similarly, a stream control point may be conceptualized either as a dimensionless point located somewhere along a stream or as a one-dimensional stream reach with separate inlet and outlet locations along the stream flow network. Relevant human activities, natural features, hydrologic processes and hydraulic processes should be identified on a case-by-case basis through the process described in Section 5.1 of this manual.

Critical drawdown period means the time from the onset of drawdown of the reservoir(s) of a surface water supply reservoir system from full storage volume to the time when the least water is being stored, before the system refills to full storage volume once again. Critical drawdown periods may be actual, calculated, projected or simulated.

Daily natural surface water flow data means observed daily surface water flow data from which the impacts, if any, of the surface water supply reservoir system for which safe yield is being estimated, and any other relevant human activities are removed; or an estimate of such for particular locations and times made using synchronous observed daily surface water flow data from a surface water gage or gages at other appropriate locations. Observed daily surface water flow data are usually derived by calculating the arithmetic mean of observed time-series surface water flow data for each calendar day. The observed time-series surface water flow data may be collected as often as every minute. Daily natural surface water flow data should be expressed in consistent units of Million Gallons per Day (MGD). Relevant human activities should be identified on a case-by-case basis through the process described in Section 5.1 of this manual.

Dead storage means water in storage or a zone of storage capacity in one or more reservoirs of a surface water supply reservoir system that is not generally accessible to serve water supply needs and is not included in usable storage. Generally, dead storage in each reservoir includes: water below the lowest withdrawal elevation if water is withdrawn from the reservoir to serve water supply needs; water below the lowest release elevation if water is released from the reservoir so that it can be withdrawn downstream to serve water supply needs; water that cannot be conveyed from the reservoir to the applicable potable treatment plant(s) due to hydraulic constraints; and water that cannot meet the drinking water quality standards after treatment at the applicable potable treatment plant(s).

Demand means water required to satisfy the needs of water supply system customers, unless otherwise indicated by the context.

Diversion or **divert** or **diverted** means the taking or withdrawal of surface or ground waters from a river, stream, lake, pond, aquifer, other underground source, or other water body, whether or not the water is returned thereto, consumed, made to flow into another aquifer, stream or basin, or discharged elsewhere. For the purpose of estimating safe yield under the Water Supply Management Act, diversions include the taking or withdrawal of any and all surface and ground waters that are important for this purpose, whether they be waters of the State or other surface and ground waters (such as those in adjacent states). Diversions may be actual, calculated, projected or simulated.

Diversion source means a location where surface or ground waters are diverted.

Drought means weather conditions in a particular area over a time period of months or more that are drier than the long-term average. For the purposes of this manual, repeats of past drought periods are simulated based upon the their effects upon the observed water flow and storage data used in safe yield simulation models.

Drought warning means the non-emergency administrative status designated by the Department, pursuant to N.J.A.C. 7:19-10.1(c), in response to significant drought conditions based on an assessment of drought indicators and other relevant water supply criteria, which are determined to be of a magnitude that warrants action by the Department and water purveyors to augment or balance water supplies and otherwise act to avert or lessen the severity of a water emergency.

Finished water means potable water which does not require treatment in order to meet the requirements of the State primary and secondary drinking water regulations.

Flood control void space means a zone of storage capacity in one or more reservoirs of a surface water supply reservoir system that is reserved as empty volume, all or some of the time, for storage of water during flood events to reduce downstream and/or upstream flooding. Flood control void space is not included in usable storage, except to the extent that it can also be used for safe yield.

Full pool elevation means the water surface elevation of a reservoir when filled to the crest of the lowest uncontrolled spillway or, if the spillway(s) are controlled by crest gates, to the highest elevation where there is no spillage with the crest gates in their normal position. Case-by-case judgments with regard to identifying the normal position of the crest gates should be made through the process described in Section 5.1 of this manual.

Full storage volume means the total amount of water in one or more reservoirs of a surface water supply reservoir system when they are filled to their full pool elevation(s). Full storage volume includes any volumes designated as flood control void space, usable storage (for water supply), reserve storage and dead storage.

Interconnection means a water supply connection with another water supply system or systems.

Interdependent system source means, with respect to a water supply system under review, a separately-operated water supply system with a separate supply of raw water that is not considered to be a part of the water supply system under review. The interdependent system source is capable of transferring water to the system under review to an extent limited by applicable purveyor agreements, physical constraints and/or the safe yield of the separately-operated water supply system based on its separate supply of raw water. In general, finished water transfers are not considered when estimating safe yield.

Local inflow means water that flows into surface waters from a drainage area delimited by upstream and downstream surface water flow control points, Local inflow may be actual, calculated, projected or simulated.

Margin of safety means the increased reliability of water supply from a surface water supply reservoir system resulting from one or more conservative assumptions, features or factors of a safe yield estimate for the system that are intended to compensate for uncertainties of the estimate.

Passing flow monitoring point means the location where the stream flow is measured for compliance with passing flow requirements including a determination if there is sufficient flow to allow for the diversion.

Passing flow requirement means the volumetric rate of water required to be maintained at a selected passing flow monitoring point in order to divert water under a water supply allocation permit, while maintaining or improving water quantity and quality conditions after consideration of the needs of downstream users and protection of ecological health, as established by the Department. The Department may establish instantaneous, hourly, daily, weekly, monthly, seasonal, annual or any other frequency for measuring, monitoring and reporting passing flow volumetric rates.

Period of record means the time interval(s) for which daily natural surface water flow data are compiled and developed for a surface water supply reservoir system. The period of record should be based on the period(s) of existence and operation of the surface water flow and storage gages that are to be used to compile and develop the daily natural surface water flow data. The period of record should encompass the longest, reasonable time period and, to the extent possible, should be continuous.

Person means any individual, corporation, company, partnership, firm, association, owner or operator of a water supply facility, political subdivision of the State and any state, or interstate agency or Federal Agency.

Pump-storage reservoir system means any surface water supply reservoir system that includes a surface water diversion source with associated pumping equipment that is intended to convey water and discharge it back to the system's source waters, so that the water may be stored in one or more of the system's raw surface water reservoirs and thereby retained within the system for a period of time.

Purveyor or **water purveyor** means any person who owns or operates a water supply system.

Raw water means untreated ground or surface water.

Reserve storage means a selected portion of usable storage that is not simulated to be diverted as system draft when estimating safe yield, so as to provide or contribute to a margin of safety.

Rule curve means any set of sequential water storage volumes or levels for a surface water supply reservoir system over a temporal scale of one year, that is a part of past, existing, alternative or proposed operating plans and procedures for the system. Storage declines below a specific rule curve are usually linked to system operational actions that should be taken. For example, because the safe yields of pump-storage reservoir systems are based solely or partially on pumping, these systems generally have prescribed rule curves that help determine when to pump. There may be a number of different rule curves for any particular system, each triggering different, additive or sequential actions or sets of actions, as conditions decline below the respective curve. Rule curves may be either for normal operations or for operations during drought conditions. Drought rule curves are generally used to help determine when to recommend and mandate actions intended to reduce system draft.

Run-of-river surface water system means a surface water supply system that does not include any raw surface water reservoirs. Surface water supply reservoir systems are not run-of-river surface water systems.

Semi-confined aquifer means an aquifer that is fully saturated and bounded on the top by a less-permeable unit that impedes the vertical movement of water through it.

Significant figures means those digits in a numeral that denote the accuracy of measurement or calculation.

Source waters means: surface waters within the gravity drainage areas of one or more surface water diversion sources (including any areas of hydraulic backwater effects), associated passing flow monitoring points, and other locations where the water is important with regard to avoiding the creation of undesirable effects, as determined by the Department in accordance with the Water Supply Management Act; and ground waters that are or may be diverted at one or more ground water diversion sources or are important with regard to avoiding the creation of undesirable effects, as determined by the Department in accordance with the Water Supply Management Act. The flow and storage of source waters may be actual, calculated, projected or simulated.

Storage recovery period means the time from the end of a critical drawdown period until the reservoir(s) of the surface water supply reservoir system refill to full storage volume. A storage recovery period may be actual, calculated, projected or simulated.

Surface water means water on the surface of the earth. It does not include water in the atmosphere or in the saturated and unsaturated ground water zones.

Surface water supply system means a water supply system that includes one or more raw surface water intake structures and diverts predominantly surface water rather than ground water. Surface water supply reservoir systems and run-of-river surface water systems are surface water supply systems.

Surface water supply reservoir system means a surface water supply system that includes one or more raw surface water reservoirs. Surface water supply reservoir systems include all applicable infrastructure and related features that are used to estimate their safe yield. Run-of-river surface water systems are not surface water supply reservoir systems.

System draft means the average rate that water is taken or withdrawn from any particular water supply system during a specific time interval. System drafts are normally made to serve the short-term water supply needs of end users such as households and businesses but the water may also be conveyed to other water supply systems for longer-term storage. System drafts do not include the rate that source waters are diverted from the diversion source(s) of a system but are retained within the same system by being discharged back to the system's source waters as a part of system operations (such as in pump-storage reservoir systems). System drafts should be expressed in consistent units of MGD. System drafts may be actual, calculated, projected or simulated. System draft is sometimes referred to as demand from a water supply system.

System draft pattern means the result obtained when the values of a unit draft pattern are multiplied by a trial annual average system draft. System draft pattern is sometimes referred to as seasonal demand pattern.

Unconfined aquifer means an aquifer in which the water table is the upper boundary. Above this boundary the soil or rock is unsaturated, below it is saturated.

Unit draft pattern means a sequence of daily system drafts over a calendar year, each divided by an average annual system draft (see Section 5.6). Unit draft patterns are normally based on a number of years of recent data. Unit draft pattern is sometimes referred to as unit demand pattern.

Usable storage means water in storage or a zone of storage capacity in one or more reservoirs of a surface water supply reservoir system that is generally accessible to serve water supply needs and is designated by the purveyor to serve those needs. For the estimation of a surface water supply reservoir system's safe yield, usable storage does not include dead storage. Water or void space reserved for other purposes such as flood control, recreational use, or maintenance of surface water quality is only included in usable storage to the extent that it can also be used for safe yield.

Verification process means a process similar to the calibration process except *that periods other than that used in the calibration* are analyzed to assess and improve confidence in the usefulness of the computational predictions of the safe yield simulation model. If model input data, calculations and logical functions are adjusted during a particular verification process to improve the agreement between the simulated and measured/observed data, it then becomes a part of the calibration process and a new, independent verification process is then used to assess the performance of the model.

Water emergency means a declaration by the Governor, upon a finding by the Commissioner, that there exists or impends a water supply shortage, water quality emergency, or other hydrologic condition, whether naturally induced or otherwise, of a dimension which significantly impacts water supply and, thereby, endangers the public health, safety or welfare in all or part of the State.

Water supply allocation permit or **water allocation permit** means the document issued by the Department pursuant to N.J.A.C. 7:19-1 et seq. to a person granting that person the privilege, so long as the person complies with the conditions of the document, to divert more than 100,000 gallons of water per day and more than 3.1 million gallons per month for more than 30 days in a consecutive 365 day period, for a specific flow rate, use, location, and duration for any purpose other than agricultural or horticultural purposes. This term does not include a dewatering permit issued under N.J.A.C. 7:19-2.3, a short term water use or dewatering permit-by-rule authorized under N.J.A.C. 7:19-2.17, a water use registration issued under N.J.A.C. 7:19-2.18, or a water usage certification issued for agricultural, aquacultural, or horticultural water uses under N.J.A.C. 7:20A.

Water supply system means a system of physical infrastructure and associated source waters that are for the purpose of serving public water supply needs. Water within a water supply system that is received from an interdependent system source is also considered to be a part of the water supply system. For the purposes of this manual, water supply systems do not include any finished water aqueducts or distribution piping. Water supply systems may include past, existing, alternative and proposed new and modified systems.

Waters of the State means all surface waters and ground waters in the State.

SECTION 4 SAFE YIELD PRACTICES AND PRINCIPLES

4.1 Application of the Concept of Safe Yield

The Department applies the concept of safe yield to water taken or withdrawn (drafted) from surface water supply reservoir systems. In order to be succinct this is often referred to as simply the safe yield of surface water supply reservoir systems. Surface water supply reservoir systems have these characteristics:

- Each system includes physical infrastructure and associated source waters;
- Each system serves public water supply needs;
- Each system includes one or more raw surface water intake structures;
- Each system includes one or more raw surface water reservoirs;
- Each system diverts predominantly surface water rather than ground water;
- They may receive water from interdependent system sources, which by definition are outside the scope of the safe yield estimation process; and
- They do not include any finished water aqueducts or distribution piping.

The definition of "safe or dependable yield" and "safe yield" in the Water Supply Management Act refers to "yield of water from a surface or ground water source or sources" and indicates that it must not create undesirable effects. This implies that rather than being a characteristic of source waters themselves, "safe or dependable yield" and "safe yield" are a characteristic of water taken or withdrawn (diverted) at a diversion source or sources. The definition also indicates that "safe or dependable yield" and "safe yield" are "maintainable" and "available continuously during projected future conditions, including a repetition of the most severe drought of record". Further, the Act indicates that water supplies are to provide adequate margins of safety. The Department interprets this to mean that it must ensure that water supplies are sufficiently reliable. The reliability of water supplies depends not only upon the diversion of source waters, but also upon other characteristics of water supply systems including their physical infrastructure, their operating logic and criteria (including regulatory restrictions), their system draft patterns, and any interdependent system sources that they may have. For surface water supply reservoir systems, the reliability of water supplies is usually very dependent upon the storage capacity of their raw surface water reservoir(s). Based on this and for practical purposes, the Department interprets "safe or dependable yield" and "safe yield" to be a characteristic of water taken or withdrawn (drafted) from water supply systems. This is further explained below.

Because "safe or dependable yield" and "safe yield" are defined as being available continuously, individual diversion sources that are required to cease to meet passing flow requirements or because water is not available during certain time periods do not have a "safe or dependable yield" or "safe yield" by themselves. Such sources often need to cease diverting simultaneously, usually under drought conditions. Thus, even multiple diversion sources, by themselves, may not have a "safe or dependable yield" or "safe yield". Most stream diversion sources have very limited water available during drought conditions even if they are not required to cease diverting. In order to supply larger quantities of water continuously, with sufficient reliability to protect the welfare of end users, diversion sources are often operated as a part of water supply systems that store water and/or have interdependent system sources. Surface water supply reservoir systems, store water in one or more raw water reservoirs so that it may be drafted to satisfy customer demands at later times when sufficient water may not otherwise be obtained from the system's diversion sources. Similarly, water transferred from interdependent system sources (usually with their own raw water storage capability) to a particular water supply system may be drafted from the particular system to satisfy customer demands when sufficient water may not otherwise be obtained from the particular system's diversion sources. Water transferred from interdependent system sources to surface water supply reservoir systems may also be stored in the receiving systems before it is drafted. In all of these cases, the rate at which drafted water is available continuously depends upon the water supply systems, including the reservoirs and/or water transferred from interdependent system sources, rather than just the system diversion sources and source waters.

Although both "safe or dependable yield" and "safe yield" are referenced in their Water Supply Management Act definition, the remainder of this manual uses only the term "safe yield".

The Department does not apply the concept of "safe yield" to reliability issues associated with finished water aqueducts and distribution piping because it would complicate the estimation of safe yield to do so and because the Department has traditionally addressed these issues through separate means.

The definition of "safe yield" in the Water Supply Management Act refers to a yield of water from a surface or ground water source or sources and may be interpreted to be applicable to all water supply systems regulated under the Act. However, at the present time the Department does not normally apply the definition to water supply systems that divert solely or predominantly ground water. This is because major ground water sources tend to be less affected by drought than surface-water supplies. Thus yields from systems that divert solely or predominantly ground water can normally be considered to be secure supplies as long as they have been approved in accordance with the Department's hydrogeologic testing and reporting procedures. Also, the surface water flow and storage accounting computations and computer models that have traditionally been used to estimate "safe yield" are more uncertain when they are applied to ground water. The Department does use the definition of safe yield in the Water Supply Management Act as it applies to surface water supply reservoir systems that divert relatively small quantities of ground water in relation to their surface water diversions. However, this is only done if the uncertainty associated with estimating the availability of the small quantities of ground water is acceptably small in relation to the surface water supply reservoir system's overall safe yield. Case-by-case judgments regarding whether the uncertainty is acceptably small should be made through the process described in Section 5.1 of this manual.

Also, the Department has generally not found it necessary to apply the concept of "safe yield" to run-of-river surface water systems.

4.2 Current Practices

The Department limits actual system drafts from regulated surface water supply reservoir systems to each system's approved safe yield estimate. The Department does this by limiting system diversions through conditions in water allocation permits and/or by limiting contractual obligations of water allocation permittees. In accordance with the intent of the Water Supply Management Act, this is done to ensure sufficiently reliable water supplies with margins of safety that are adequate to meet current water supply needs, insure adequate future water supplies, and protect the health, safety, economic welfare, recreational and aesthetic enjoyment, and general welfare of the people of New Jersey.

The Department considers the physical components, operating logic and criteria, system draft patterns, and any interdependent system sources of surface water supply reservoir systems when estimating their safe yields because these factors affect the reliability of the systems' water supplies. The operating logic and criteria that are considered include regulatory restrictions but exclude the water demand reduction components of operating plans (see Section 4.3). The adequacies of margins of safety of safe yield estimates are established by including conservative assumptions, features and/or factors in order to compensate for uncertainties of the estimate.

4.3 Basic Conservative Assumptions for Establishing the Adequacies of Margins of Safety

The definition of safe yield in the Water Supply Management Act requires the use of several conservative assumptions when estimating safe yield in order to establish an adequate margin of safety. This is explained in the paragraphs below.

First, safe yield is to be based on projected future conditions that include a repeat of the most severe drought of record. Because the definition refers to projected future conditions, safe yield is inherently an estimated characteristic of future conditions that can not currently be observed or measured. Thus any safe yield is only theoretically available at the time of the estimate. However, the reference to a repeat of the most severe drought of record indicates that past conditions are to be used to project future conditions. The definition does not limit projected future conditions to a repeat of the most severe drought of record and does not identify a particular drought as the most severe drought of record. The Department interprets the definition to mean that the projected future conditions should be based on a repeat of past conditions during the period of record for the surface water supply reservoir system under review. Further, the Department interprets the repeat of the most severe drought of record to be within that repeat of the period of record and to be the drought during which the most restrictive conditions that limit the safe yield occur. In this way, the most severe drought of record is determined on a case-by-case basis for each safe yield estimate of each surface water supply reservoir system. The safe yield estimate for each system must be based on this drought, which results in the most conservative estimate for the system. This is in accordance with the intent of the Water Supply Management Act to provide adequate margins of safety to meet current water supply needs and insure adequate future water supplies.

Although projected future conditions are to be based on past conditions, it is clear that they are distinct from those past conditions. The Department interprets projected future conditions to be modifications of past conditions with the superimposition of the effects of current and projected future hydrologic modifications. In general, this includes:

- The effects of the operations of the system under review and the estimated safe yield's associated repeating system draft pattern;
- The effects of other water supply systems and diversion sources for which operations are simulated at the maximum limit(s) allowed in accordance with approved safe yield estimates, effective water allocation permits and physical capacities; and
- The current effects of other hydrologic modifications.

To the extent that approved safe yield estimates or permitted diversions have not been fully utilized, they may be thought of as projected future conditions that are superimposed back over the period of record.

Second, the definition of safe yield indicates that it must be a maintainable yield of water which is available continuously during the projected future conditions that include a repeat of the most severe drought of record. The Department interprets this to mean that water demand reduction components of operating plans and procedures for surface water supply reservoir systems (such as drought rule curves) are always reserved to provide or contribute to the margin of safety for each safe yield estimate This is, in part, to compensate for the uncertainty associated with the possibility that a drought more severe than the most severe drought of record might occur. Similarly, any unusually high system water demands that could be expected at the beginning of a drought are also not considered in estimating safe yield. The Department interprets the terms "maintainable" and "continuous" to mean without cessation and without variance from the repeating system draft pattern(s) used to estimate safe yield as defined in Section 3 (and based on the unit draft pattern(s) characterized as described in Section 5.6) rather than to mean constant or unchanging in value.

Third, the definition of safe yield indicates that during the projected future conditions that include a repeat of the most severe drought of record, safe yield must not create undesirable effects, as determined by the Department. In general, the Department has determined undesirable effects may include any projected or potential lack of compliance with New Jersey Statutes for Waters and Water Supply and associated Department permit requirements such as passing flow requirements in water allocation permits, as well as analogous requirements that apply to the waters of other states. However, it is not always practical to quantify such lack of compliance and its relationship to safe yield. Therefore, the Department will generally determine whether each specific lack of compliance is an undesirable effect on a case-by-case basis, as a part of determining the scope of the safe yield estimate as described in Section 5.1. It is acknowledged that, as a characteristic of water drafted from surface water supply reservoir systems, safe yield does not by itself create undesirable affects. Therefore, to prevent lack of compliance with the statutes, the Department interprets the definition to mean that each safe yield must be projected to be able to be drafted from its water supply system without creating undesirable effects. Overall, the Department interprets the definition to mean that relaxation of any regulatory requirements by the Department and by other states that would result in undesirable effects are always reserved to provide or contribute to margins of safety in safe yield estimates, in part to compensate for the uncertainty associated with the possibility that a drought more severe than the most severe drought of record might occur.

Because these three aspects of the definition of safe yield in the Water Supply Management Act and their contributions to each margin of safety are statutory requirements, they are mandatory for all safe yield estimates that are approved by the Department regardless of what other conservative assumptions, features or factors and what uncertainties are or may be present.

These aspects of the definition of safe yield were created with knowledge of, and to offset, uncertainties that were typically inherent in the water accounting computations and data used to estimate the safe yields of surface water supply reservoir systems at the time that the Act was promulgated in 1981. These uncertainties include:

- The possibility that a drought more severe than the most severe drought of record might occur;
- Inaccuracies and errors in surface water flow and storage gage measurements;
- Inaccuracies and errors in the synthesis of surface water flow values;
- Inaccuracies and errors in reservoir volume estimates;
- Inaccuracies and errors in diversion and discharge measurements;
- The variance of actual system drafts from the system draft pattern(s) used to estimate safe yield; and
- The variance of actual wastewater discharge flows from the existing wastewater discharge flow patterns used to estimate safe yield.

To summarize, the margin of safety associated with basing each safe yield estimate on a maintainable yield of water which is available continuously during projected future conditions, including a repetition of the most severe drought of record, without creating undesirable effects as determined by the Department, generally precludes the need to include any other conservative assumptions, features or factors in the estimate in order to offset these typically inherent uncertainties.

4.4 Addressing Other Significant Uncertainties of Safe Yield Estimates

Beyond the typically inherent uncertainties identified in Section 4.3 above, safe yield estimates may also have other significant uncertainties. As previously indicated, each surface water supply reservoir system and safe yield estimate is unique and some may be very complex. For example, with regard to uncertainties associated with superimposing the effects of current and projected future hydrologic modifications back over a system's period of record, traditional water accounting computations and data have normally only addressed a narrow scope of such hydrologic modifications. This narrow scope generally only included relatively large surface water diversions and discharges of water supply and wastewater systems, and storage changes of relatively large surface water reservoirs and impounded lakes. There are many other types of hydrologic modifications that can affect surface water flows by altering surface water runoff and ground water recharge. This wider scope includes hydrologic modifications such as:

- Storage changes in smaller lakes and reservoirs;
- Smaller surface and ground water diversions and discharges;
- Changes in evapotranspiration associated with changes in vegetation and other land cover resulting from both anthropogenic activities such as land development and from natural succession of field, shrub and forest land types. Evapotranspiration normally accounts for approximately one-half of the water budget of the land phase of the hydrologic cycle in the State of New Jersey;
- Changes in impervious cover (usually increases), soil structure and void space;
- Changes in storm water collection and conveyance systems (usually new and expanded systems);
- Changes in exfiltration from water supply distribution systems; and
- Changes in inflow/infiltration (I/I) to sanitary sewer systems.

Many of the hydrologic modifications in this wider scope are associated with land use changes. Land use changes are an indicator of the significance of the effects of this wider scope of hydrologic modifications. The source watersheds of some surface water supply reservoir systems' serving the State of New Jersey have extensive land use changes over the systems periods of record. The Department believes that these changes are likely to have created significant hydrologic modifications that need to be addressed when estimating safe yields.

Past efforts to estimate safe yields have generally not been successful at directly addressing the effects of this wider scope of hydrologic modifications using traditional water accounting computations. In part, this is because there are limits to the present scientific understanding of the land phase of the hydrologic cycle. It may be possible to address these effects by using computer models that simulate all important hydraulic and hydrologic physical processes of the land phase of the hydrologic cycle in a fully integrated manner, at high spatial and temporal resolutions. At the present time, this approach it is an area of scientific research and its practicality is limited by the large amounts of data needed, by heavy computational requirements and by the capabilities of current hydrologic modeling software and hardware.

Adding one or more conservative assumptions, features or factors in addition to those inherent in the definition of safe yield may compensate for not addressing directly the impacts of this wider scope of hydrologic modifications. However, it is now difficult to accurately calculate the sizes of effects of these modifications, as well as the sizes of the increases in the margin of safety provided by additional conservative assumptions, features or factors. As a result, it is not possible to lay out a well-defined sequence of steps to determine when to use this indirect approach and what additional conservative assumptions, features or factors to use. The only feasible way for the Department to address this is on a case-by-case basis using the best professional judgment of qualified technical personnel of the purveyor and the Department. Case-by-case judgments should be made using the process described in Section 5.1.

This paragraph is provided as general guidance when judgments are made to indirectly address the effects of this wider scope of hydrologic modifications. In each such case, the Department will usually favorably consider establishing a conservative balance between the magnitudes of the individual wastewater discharge facilities and individual diversion sources considered in the safe yield estimate. This is because wastewater discharges usually increase safe yield estimates while diversions, other than those of the surface water supply reservoir system that the safe yield is being estimated for, usually decrease safe yield estimates. This applies to upstream diversions and discharges. In general, when such diversion sources and discharge facilities have a significant effect on a safe yield estimate, the combined effects of the wider scope of hydrologic modifications also have the potential to be significant. The intent of such a conservative balance is to prevent excessive emphasis on hydrologic modifications that increase safe yield when there is significant uncertainty in the estimate due to omission of the effects of other hydrologic modifications. In general this means that wastewater discharge facilities that are smaller than the smallest diversion source should not be included in the safe yield estimate and all existing discharge facilities and diversion sources that are larger than this value should be included. The conservative balance should generally be applied separately to surface water discharge facilities and diversion sources and then to ground water discharge facilities and diversion sources. This also means that projected future increases of wastewater discharge volumes should not be included whereas the operation of diversion sources and water supply systems, other than the system that the safe yield is being estimated for, should be included at the maximum limit(s) allowed in accordance with their approved safe yield estimates, effective water allocation permits, and physical capacities.

Judgments regarding other uncertainties of safe yield estimates and other means to address such uncertainties, such as the use of reserve storage as an additional conservative assumption, feature or factor, should be made on a case-by-case basis through the process described in Section 5.1.

4.5 Additional Practices and Principles

Each safe yield estimate should be based on maintaining the system draft pattern of the applicable surface water supply reservoir system during the entire projected repeat of the period of record. However, for each estimate, the limiting conditions always occur during the critical drawdown period of the projected repeat of the most severe drought of record, from the onset of drawdown of the system's reservoir(s) to the minimum storage volume. Because it is impossible to predict when another equivalent or more severe drought may occur for any system in the future, actual system drafts from each surface water supply reservoir system with a Department approved safe yield estimate need to be limited to that estimate whenever actual combined storage in the system's reservoirs falls below full storage volume to ensure sufficient reliability in accordance with the Water Supply Management Act. In general, the Department limits actual system drafts to the Department approved safe yield estimate at all times in order to avoid the need to mandate system draft reductions that might adversely affect system end users.

Because safe yield is defined as continuous, there should not be more than one Department approved safe yield estimate for each surface water reservoir system regulated under the Water Supply Management Act.

It is important to express safe yield numeric values on a consistent basis to avoid confusion and to avoid the need to normalize the values when comparing or summing them. Actual end-user demands, and therefore actual system drafts, usually vary in a repeating pattern on an annual cycle, normally with the lowest drafts during winter and the highest drafts during summer. The safe yield of surface water supply reservoir systems is usually estimated using a repeating system draft pattern that varies over a temporal scale of one year and that mimics the typical repeating annual pattern of end-user demands. As indicated above, the limiting conditions that determine safe yield estimates always occur during the critical drawdown period of the projected repeat of the most severe drought of record, from the onset of drawdown of the system's reservoir(s) to the minimum storage volume. Because the critical drawdown periods of different safe yield estimates for different surface water supply reservoir systems are usually for different durations and usually begin and end at different times during the repeating annual cycles of the varying system draft patterns, expressing safe yield estimates as average rates over the critical drawdown periods would result in numeric values with inconsistent temporal bases. To express safe yield estimates on a consistent temporal basis, the annual duration of system draft patterns should be used. Although a single safe yield estimate could be expressed as a sequential series of values similar to the system draft pattern itself, the traditional approach is to express each safe yield estimate as a single average annual rate. Because this is the simplest consistent approach, the Department will continue to use it. Since each safe yield is expressed as an single annual average rate, associated limitations on diversions in water allocation permits and on contractual obligations of water allocation permittees should also be on an annual average basis.

Because of the uncertainties inherent in safe yield estimates, they should be rounded in accordance with standard mathematical practice to no more than three significant figures.

SECTION 5 METHODS TO ESTIMATE THE SAFE YIELD OF SURFACE WATER SUPPLY RESERVOIR SYSTEMS

This section describes the general methods and iterative steps that should be used to estimate the safe yield of surface water supply reservoir systems. For each particular surface water supply reservoir system, safe yield should be estimated through the use of a deterministic computer model that computes and simulates the flow of water through the system and its watershed(s), and the storage of water in the system's reservoir(s) during the system's period of record, using a daily time step. In this guidance manual, when this type of computer model is used to estimate safe yield, it is referred to as a "safe yield simulation model". In this context, "deterministic" means that the model should estimate safe yield based on the most severe drought of record for the surface water supply reservoir system and should not identify a yield as the safe yield based on its probability of occurrence or recurrence interval.

The Department will verify purveyor simulation models through the use of RiverWare™ software, which is supported and maintained by the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado.

Traditionally, in New Jersey, most safe yield simulation model computations have been based on a simple accounting (addition and subtraction) of surface water flow and storage gage data and have not simulated most of the major hydrologic and hydraulic processes of the land phase of the hydrologic cycle. These traditional models are sometimes referred to as water accounting or mass balance models. This guidance manual is based on the premise that safe yield simulation models will continue to use the traditional approach in large part, with some modifications such as the use of hydraulic relationships to model reservoir spills and releases and the potential inclusion of some natural features, hydrologic processes and other hydraulic processes that can not be adequately simulated by water accounting computations.

Model calculations and logical functions should be focused on simulating the flow and storage of water at key locations, known as control points. Typically, the control points of safe yield simulation models consist predominantly of reservoirs and stream reaches. The control points should characterize:

- The surface water supply reservoir system;
- Any other relevant human activities that significantly impact, or are significantly impacted by, the system and its safe yield; and
- Any relevant natural features, hydrologic processes and/or hydraulic processes that significantly impact the surface water supply reservoir system and its safe yield.

Relevant human activities, natural features, hydrologic processes, hydraulic processes and associated significant impacts should be identified on a case-by-case basis through the process described in Section 5.1 of this manual.

Safe yield simulation models should perform calculations and logical functions in a predominantly sequential manner. In this context, from a temporal perspective, "sequential" means that the calculations and logical functions normally begin using values from the first day of the period of record and are repeated for every day until the end of the period of record, with each day beginning with the previous day's ending storage values. From a spatial perspective, "sequential" means that the calculations and logical functions of each daily time step normally progress, in order, from the most upstream control points to the most downstream control points. The calculations and logical functions are not always absolutely sequential because they may include spatial and/or temporal looping from downstream to upstream control points and/or later to earlier time steps. When the topology of a model includes spatial and/or temporal looping, it should be noted that the calculations and logical functions involved may need to be performed for a number of iterations to satisfy the numeric requirements and constraints of the model before converging on a sufficiently precise solution.

Development of a safe yield simulation model for a surface water supply reservoir system requires a substantial amount of data to: 1) determine the scope of the model; 2) characterize physical components; 3) characterize operating logic and criteria; 4) identify and select key spatial control points; 5) compile and develop daily "natural" surface water flow data for key surface water locations during the period of record of the surface water supply reservoir system; 6) characterize unit draft pattern(s); 7) characterize any existing wastewater discharge flow pattern(s); and 8) calibrate and verify the model.

The daily natural surface water flow data for the period of record of the surface water supply reservoir system should normally be a primary part of the input data that drives the model. However, model runs should, in general, simulate the hydrologic effects of current and projected future relevant human activities (see Section 5.1) over the entire period of record. In this way, the effects of current and projected future human activities are superimposed on natural flows over the period of record in order to estimate what daily surface water flows would occur now or in the future if there were a repeat of past climactic conditions, including past droughts.

Due to the relatively close proximity of the control points and relatively short travel times of flows for most surface water supply reservoir systems in New Jersey, the timing of daily high and low stream flows at the control points usually correlate relatively well with each other. As a result, it is not usually necessary to model lag time or storage of stream reaches and simple mass balance calculations can be used instead. For example, a simple mass balance calculation for a stream reach with a diversion source may calculate daily downstream outflow from the reach by adding daily inflows from upstream control points (if any) to daily local inflow and then subtracting the daily diversion from the reach. A related calculation may compute the daily diversion request as the previous day's unfilled storage volume of the reservoir that the diversion is conveyed to, minus some portion of the reservoir's full storage volume that will reduce the probability of the daily diversion being wasted by refill and spillage. A second related calculation and logical function may limit the maximum daily diversion to the smaller of: 1) the capacity of the diversion pumping facilities with the largest pump not in service (firm capacity) ; and 2) the sum of daily inflows to the stream reach from upstream control points (if any) and daily local inflow, minus the minimum daily passing flow requirement. Decisions to model lag time or storage of stream reaches for any specific surface water supply reservoir system should be made as case-by-case judgments through the process described in Section 5.1.

For reservoirs, model calculations should use the storage equation concept. The basic mass balance storage equation that should be used for a reservoir control point is:

$$I - O = \Delta S \qquad \text{(equation 1)}$$

Where:

I = total inflow to the reservoir control point during a specified time period, in units of volume (Billion Gallons, abbreviated BG)

O = total outflow from the reservoir control point during the same specified time period, in units of volume (BG)

ΔS = change in storage of the reservoir control point during the specified time period, in units of volume (BG)

As indicated above, safe yield simulation models should perform calculations and logical functions on a daily time step. The above mass balance equation can be converted to a form that can analyze the cumulative effects of inflows and outflows over consecutive time steps as follows:

$$\Delta S_t = S_t - S_{t-1} \qquad \text{(equation 2)}$$

Where:

ΔS_t = change in storage (BG) of the reservoir control point during time step t

S_t = storage of the reservoir control point in volume (BG) at the end of time step t

S_{t-1} = storage of the reservoir control point in volume (BG) at the end of time step t - 1

By substituting this relationship, equation 2 is converted to:

$$I_t - O_t = S_t - S_{t-1} \qquad \text{(equation 3)}$$

Where:

I_t = the total inflow (BG) to the reservoir control point during time step t.

O_t = the total outflow (BG) from the reservoir control point during time step t.

Equation 3 can be further transformed to a more useful form by rearranging terms:

$$S_t = S_{t-1} + I_t - O_t \qquad \text{(equation 4)}$$

The storage of the reservoir control point is repetitively calculated on a daily basis by adding total daily inflows and subtracting total daily outflows. The total daily inflows to reservoir control points are typically calculated by summing daily flows from sources such as upstream control points (if any), local inflows, and water diverted and conveyed to the reservoir from other rivers, reservoirs and ground water. The total daily outflows from reservoir control points are typically calculated by summing daily flows such as withdrawals or releases from the reservoir to serve customer demands, releases from the reservoir to satisfy minimum passing flow requirements, and spillage.

System draft patterns of water supply systems should be calculated in safe yield simulation models by multiplying the daily values of unit draft patterns by trial annual average system drafts.

Safe yield simulation models may be used to successively evaluate various specific physical, operational, or unit draft pattern alternatives to optimize the safe yield of the surface water supply reservoir system and to balance the safe yield in relation to other relevant human activities (see Section 5.1), such as those associated with the needs of other water users.

Physical alternatives may include such things as new reservoirs, increased storage capacity of existing reservoirs, new diversion sources, increased pumping capacity of existing diversion sources, new aqueducts from interdependent system sources, or increased physical capacity of reservoir release facilities. Operational alternatives may include such things as modified storage rule curves for reservoir release requirements, pumping station operations and transfers from interdependent system sources; modified operation of bascule gates; and modified minimum passing flow requirements in water allocation permits. Unit draft pattern alternatives may include modifications that may be achieved through end-user demand-side management. Various combinations of physical, operational, and unit draft pattern alternatives may be evaluated together in a specific configuration or scenario of a safe yield simulation model.

Each specific alternative, configuration or scenario of a safe yield simulation model should be run iteratively, for the period of record, with various trial annual average system drafts to determine the annual average system draft that would divert all usable storage (to the extent possible within the mathematical rounding limitations of the safe yield estimate) volumes of water from the system's reservoir(s), except for any reserve storage volumes that are set aside to provide or contribute to a margin of safety, and that would continuously satisfy the repeating system draft pattern. That annual average system draft, in units of MGD, is the safe yield estimate of the particular alternative, configuration or scenario of the applicable surface water supply reservoir system. Department approval of any safe yield estimate only applies to the particular alternative, configuration or scenario of the applicable surface water supply reservoir system that it was estimated for and is limited by any conditions made a part of the approval.

For each specific alternative, configuration or scenario of a safe yield simulation model, simulated usable storage volumes of water normally vary over the period of record and the restrictive condition that limits the safe yield estimate is the diversion of all usable storage volumes of water as described in the paragraph above during any one day of the period of record. The drought during which this restrictive condition occurs is the most severe drought of record.

The safe yield, as estimated using the simulation model, may not make use of any volumes of water or reservoir void space: 1) set aside for reserve storage; 2) in dead storage; 3) reserved for other purposes such as flood control, recreational use, or maintenance of surface water quality, except to the extent that such volumes or void space can also be used for safe yield; 4) if such use results in a lack of compliance with passing flow requirements in an effective water allocation permit; or 5) that are derived by accounting for negative storage in the model.

Estimating the safe yield of surface water supply reservoir systems using safe yield simulation models is an iterative process in many ways. Examples of this iterative nature include:

- Considering various combinations of physical, operational and unit draft pattern alternatives using variations of a particular simulation model;
- Running various trial annual average system drafts for specific alternatives, configurations or scenarios; and
- Executing the calculations and logical functions of individual model runs that incorporate spatial and temporal looping.

It is important to realize that these iterations can not be completely described as a set of sequential procedures or linear steps that address all potential situations. Rather, it should be understood that various portions of the iterative steps described below may have to be repeated to estimate the safe yield of a particular surface water supply reservoir system.

5.1 Determination of the Scope of the Safe Yield Estimation Process

The scope of the safe yield estimation process, including the safe yield simulation model and related methods, should be determined as follows:

5.1.1 The purveyor should initially identify the scope of the safe yield estimate based on the best professional judgment of their qualified technical personnel and the guidance provided in this manual. The Department will make the final decision regarding the scope and will provide the purveyor with an explanation and justification of the final decision as a part of the Department's staff report. In order to help ensure that work performed in preparing the estimate will be for a scope that will be approved, the Department and the purveyor should convene a pre-application meeting prior to preparing the estimate to discuss the scope. The Department recommends that the purveyor present the proposed scope of the safe yield estimate to the Department, in writing, prior to the meeting in order to make the meeting as productive as possible. Following the meeting, the Department will provide written comments regarding the scope of the safe yield estimate to the purveyor based on the best professional judgment of the Department's qualified technical personnel and the guidance provided in this manual. Because safe yield estimates may be complex and there are limits to the present scientific understanding of the land phase of the hydrologic cycle, the Department recognizes that in many cases it will not be practical to completely define the scope prior to preparing the safe yield estimate. The scope may be affected by new issues that arise, by new alternatives that are developed, and by case-by-case judgments that are made by qualified technical personnel during preparation of the safe yield estimate. In such cases, the purveyor should continue to collaborate with the Department during preparation of the estimate to further ensure that work performed in preparing the estimate will be for a scope that will be approved by the Department.

5.1.2 The scope of the safe yield estimate should address the following:

5.1.2.1 The major physical components of the surface water supply reservoir system for which safe yield will be estimated, including: the surface and ground source waters; the raw surface water intake structure(s); any other raw water diversion facilities; the raw surface water reservoir(s); any raw water canals; any other engineered raw water open channels; any raw water aqueducts; any raw water pumping stations and force mains; any other raw water conveyance piping; the water treatment plant(s); and their locations;

5.1.2.2 Any interdependent system source(s) from which the transfer of water to the surface water supply reservoir system will be simulated;

5.1.2.3 Any relevant human activities that will be simulated, other than the existence and operation of the surface water supply reservoir system facilities, because the activities significantly impact, or are significantly impacted by, the surface water supply reservoir system and its safe yield. The location of each relevant human activity should be identified;

5.1.2.4 Any relevant natural features and/or processes that can not be adequately simulated by a simple accounting (addition and subtraction) of surface water flow and storage gage data and that will be simulated based on mathematical representations of the hydraulic and/or hydrologic processes of the land phase of the hydrologic cycle because they significantly impact the surface water supply reservoir system and its safe yield. The location of each natural feature should be identified;

5.1.2.5 Undesirable effects that will be addressed as a part of the safe yield estimate, including any projected or potential lack of compliance with New Jersey Statutes for Waters and Water Supply and associated Department permit requirements such as passing flow requirements in water allocation permits, as well as analogous requirements that apply to the waters of other states;

5.1.2.6 The period of record of the surface water supply reservoir system. The period of record should be based on the period(s) of existence and operation of the surface water flow and storage gages that are to be used to compile and develop the daily natural surface water flow data. The period of record should encompass the longest, reasonable time period and, to the extent possible, should be continuous. The drought years 1929-1933, 1949-1951, 1961-1967, 1980-1983, 1984-1986, 1991-1996, 1998-2000, 2001-2002 as well as any subsequent drought periods should be included to the extent possible;

5.1.2.7 For each surface water flow control point, the portions of the period of record for which daily flows were and were not impacted by the surface water supply reservoir system and/or any other relevant human activities. The basis for these determinations should be characterized for each surface water flow control point;

5.1.2.8 The physical, operational, and unit draft pattern alternatives, configurations and scenarios that will be evaluated to optimize the safe yield of the surface water supply reservoir system and to balance the safe yield in relation to other relevant human activities, such as those associated with the needs of other water users. If an alternative to an existing surface water supply reservoir system is being proposed or considered, the existing configuration of the system should always be evaluated as one scenario;

5.1.2.9 Whether sedimentation in each raw surface water reservoir, lake and other similar water body that will be simulated may have affected the pool elevation and storage volume (stage-storage) relationship and pool elevation and water surface area relationship of that water body since the time(s) that those relationships were last determined. If this is the case, these relationships and their associated information and analyses should be updated as a part of the safe yield estimate. Any decision to update the information and analyses for a particular relationship should consider the time that passed since the previous determination, the potential of the upstream watershed to generate sediments, the potential for upstream impoundments to capture sediment that would otherwise be captured by the water body that will be simulated, whether there have been recent floods that have deposited large amounts of sediment, signs of high sediment deposition such as the forming of a delta at the inlet of the water body, and the volume of the water body in relation to potential rate of sedimentation;

5.1.2.10 Any other case-by-case judgments that are made with regard to estimating safe yield, including the use of any methods that vary from or are in addition to the guidance provided in this manual; and

5.1.2.11 Any other information that the purveyor's qualified technical personnel believe is appropriate.

5.1.3 The relevant human activities to be simulated, other than the existence and operation of the surface water supply reservoir system facilities, should generally be limited to the following:

5.1.3.1 The storage, diversion, draft, conveyance, spill and release of water associated with other water supply systems that, in whole or in part, are upstream or downstream of the subject surface water supply reservoir system;

5.1.3.2 The diversion of other surface waters or unconfined or semi-confined aquifer ground waters at locations that are upstream or downstream of the subject surface water supply reservoir system;

5.1.3.3 The storage, spill and release of water associated with dams that form lakes, or other similar water bodies that are upstream or downstream of the subject surface water supply reservoir system; and

5.1.3.4 The discharge of existing wastewater flows at locations that are upstream or downstream of the subject surface water supply reservoir system.

5.1.4 The relevant human activities associated with other water supply systems and other surface water diversion sources or unconfined or semi-confined aquifer diversion sources that significantly impact the subject surface water supply reservoir system and its safe yield and are to be simulated should generally be limited to those for which the potential impacts are significant enough to justify simulation of their operations. The intent of this is to limit these activities to a practical number of relatively large systems and diversion sources for which operations can reasonably be simulated. The operation of these other systems and diversion sources should be simulated at the maximum limit(s) allowed in accordance with the applicable approved safe yield estimates and effective water allocation permits, except that simulations should not exceed the physical capacities of the diversion facilities.

5.1.5 The facilities discharging wastewater to surface waters that significantly impact the surface water supply reservoir system and its safe yield and are to be simulated should generally be limited to those with existing annual average flows greater than or equal to the smaller of the following:

5.1.5.1 The smallest annual diversion of the surface water diversion sources that are represented by control points and for which operations are simulated in the model, allowed in accordance with the applicable water allocation permits; or

5.1.5.2 The smallest peak diversion rate of the surface water diversion sources that are represented by control points and for which operations are simulated in the model, based on the physical capacities of the diversion facilities.

5.1.6 The facilities discharging wastewater to ground waters that significantly impact the surface water supply reservoir system and its safe yield and are to be simulated should generally be limited to those with existing annual average flows greater than or equal to the smaller of the following:

5.1.6.1 The smallest annual diversion of the ground water diversion sources for which operations are simulated in the model, allowed in accordance with the applicable water allocation permits; or

5.1.6.2 The smallest peak diversion rate of the ground water diversion sources for which operations are simulated in the model, based on the physical capacities of the diversion facilities.

5.2 Characterization of Physical Components

The purveyor should characterize the existing, alternative, and/or proposed physical infrastructure, source waters, hydrologic features and other physical components of: 1) the surface water supply reservoir system that are integral to sustaining the system's safe yield; and 2) any other relevant human activities and natural features identified on a case-by-case basis through the process described in Section 5.1 of this manual. Any additional physical components that are needed to calibrate and verify the safe yield simulation model should also be characterized. Include, where applicable, the following:

5.2.1 The watersheds, water bodies, raw surface water reservoirs, dams, stream reaches, stream gages, raw surface water intake structures, other raw surface water diversion facilities, raw water canals, other engineered raw water open channels, raw water aqueducts, raw water pumping stations and force mains, other raw water conveyance piping, interdependent system source facilities, ground water diversion facilities, and water treatment plants;

5.2.2 The physical connections that control the flow of water between the components identified in Section 5.2.1 above and the direction(s) of flow between the components;

5.2.3 The date(s) of construction and modification of each component of the existing physical infrastructure, facilities and structures**;**

5.2.4 The drainage areas of each raw surface water reservoir at the spillway, each raw surface water intake structure, each raw surface water diversion facility, and each surface water gage or other location where water flow or storage is or would be used to regulate the operation of a surface water supply reservoir system. Where a diversion facility, intake structure or gage is or would be designed or operated to divert or monitor water downstream of its actual location through a hydraulic backwater effect, both the entire drainage area including that of the backwater effect and the smaller drainage area upstream of the actual location should be characterized;

5.2.5 The pool elevation and storage volume (stage-storage) relationship(s) and pool elevation and water surface area relationship(s) for each raw surface water reservoir, as well as the information and analyses used to determine these relationships such as bathymetric contour data, other geometric/topographic analyses, and/or storage and flow gage data. These relationships should be characterized in the forms of tables, graphs, and mathematical equations. In addition to being needed by the purveyor to determine usable storage, dead storage, and possibly evaporation from the water surface, this data will be needed by the Department to verify the purveyor's safe yield simulation model results using RiverWare software. These relationships should be accurate from the bottom elevation (zero dead storage and water surface area) to at least the elevation of the top of the lowest dam. If needed to simulate reservoir hydraulic and evaporative processes in RiverWare software, these relationships should be extended to higher elevations;

5.2.6 The spillway weir(s) for each raw surface water reservoir including the pool elevation and spill relationship(s), and the information used to determine this relationship(s) such as: weir type(s); elevation(s); length(s); the existence and position(s) of any bascule gates, flashboards or superboards that control full pool elevation(s) and the applicable weir equation(s) and calculation(s). All spillways that are a part of a surface water supply reservoir system or that may affect the safe yield of a system should be addressed, including emergency spillways. The pool elevation and spill relationship(s) should be characterized in the forms of tables, graphs, and mathematical equations. This data may be used by the purveyor to model reservoir hydraulic processes and will be needed by the Department to verify the purveyor's safe yield simulation model results using RiverWare software. These relationships should be accurate from the lowest spill elevation to at least the elevation of the top of the lowest dam. If needed to simulate reservoir hydraulic processes in RiverWare software, these relationships should be extended to higher elevations;

5.2.7 The outlet works for each raw surface water reservoir including the pool elevation and maximum release relationship(s), and the information used to determine this relationship(s) such as physical dimensions, cross-sectional area, pipe materials and frictional coefficients, lowest release elevation, inlet and outlet invert elevations, and the applicable equation(s) and calculation(s). The pool elevation and maximum release relationship(s) should be characterized in the forms of tables, graphs, and mathematical equations. This data may be used by the purveyor to model reservoir hydraulic processes and will be needed by the Department to verify the purveyor's safe yield simulation model results using RiverWare software. This relationship(s) should be accurate from the lowest release elevation to at least the elevation of the top of the lowest dam. If needed to simulate reservoir hydraulic processes in RiverWare software, this relationship(s) should be extended to higher elevations;

5.2.8 The types of information identified in Sections 5.2.5, 5.2.6, and 5.2.7 above for each lake, or other similar water body, that is identified as a relevant human activity through the process described in Section 5.1;

5.2.9 The water surface elevation and maximum withdrawal/diversion relationship(s) for each raw surface water intake structure and raw surface water diversion facility and the information used to determine this relationship(s) such as physical dimensions, cross-sectional area, pipe materials and frictional coefficients, lowest withdrawal elevation, inlet and outlet invert elevations, and the applicable equation(s) and calculation(s). Water surface elevation and maximum withdrawal/diversion relationships should be characterized in the forms of tables, graphs, and mathematical equations. This data may be used by the purveyor to model the hydraulic processes associated with the withdrawal and may be used by the Department to verify the purveyor's safe yield simulation model results using RiverWare software. For raw surface water reservoirs, these relationships should be accurate from the lowest withdrawal elevation to at least the elevation of the top of the lowest dam. If needed to simulate reservoir hydraulic processes in RiverWare software, these relationships should be extended to higher elevations. Where the withdrawal/diversion is from a stream reach, the purveyor is encouraged to consult with the Department through the process described in Section 5.1 for additional guidance and to determine how the Department may utilize this relationship prior to undertaking the safe yield analysis;

5.2.10 The hydraulic capacity of each raw water canal and each other engineered raw water open channel, and the information, equations and calculations used to determine that capacity;

5.2.11 The hydraulic capacity of each raw water aqueduct and the information, equations and calculations used to determine that capacity;

5.2.12 The minimum and maximum capacities of each pump in each raw water pumping station, the total capacity of the pumping station, the capacity of the pumping station with the largest pump out of service, the maximum hydraulic capacity of each force main, and the information, equations and calculations used to determine force main capacity;

5.2.13 The pumping capacity of each well or other ground water diversion facility;

5.2.14 The hydraulic capacity of each water treatment plant, as limited by its design treatment requirements;

5.2.15 Ground water infiltration or exfiltration, bank storage, seepage and/or leakage, as applicable, for each component of water supply systems, whenever these factors may significantly affect the safe yield of the surface water supply reservoir system. Case-by-case judgments regarding the significance of these factors should be made through the process described in Section 5.1; and

5.2.16 Any other physical components that are integral to sustaining the surface water supply reservoir system's safe yield.

5.3 Characterization of Operating Logic and Criteria

The purveyor should characterize the existing, alternative and/or proposed operating logic and criteria for: 1) the surface water supply reservoir system that are integral to sustaining the system's safe yield; and 2) any other relevant human activities identified on a case-by-case basis through the process described in Section 5.1 of this manual. Any additional operating logic and criteria that are needed to calibrate and verify the safe yield simulation model should also be characterized. Include, where applicable, the following:

5.3.1 Currently effective, alternative and/or proposed water allocation permit requirements, conditions, stipulations and related information for each diversion source. Any past water allocation permit requirements that are needed to calibrate and verify the safe yield simulation model should also be characterized. New Jersey water allocation permits as well as equivalent approvals from other states or interstate agencies should be addressed. Include, where applicable, the following:

5.3.1.1 The permit or approval number, issuing agency, name and address of applicant, issuance date, effective date, and expiration date;

5.3.1.2 The maximum annual diversion;

5.3.1.3 The maximum monthly diversion;

5.3.1.4 The maximum daily diversion;

5.3.1.5 The maximum instantaneous diversion rate;

5.3.1.6 The passing flow requirements. Safe yield simulation models for surface water supply reservoir systems should be based on the assumption that all passing flow requirements for the systems, as well as upstream and downstream of the systems, will be maintained, except for purposes of calibrating and verifying the models;

5.3.1.7 The surface water quality limits and any contingency plans that would be implemented to minimize the effects of such limits on the surface water supply reservoir system's safe yield; and

5.3.1.8 Any other diversion limitations.

5.3.2 The elements of the purveyor's existing, alternative and/or proposed operating plans and procedures that are integral to sustaining the surface water supply reservoir system's safe yield. Any of the purveyor's past operating plans or procedures that are needed to calibrate and verify the safe yield simulation model should also be characterized. Include, where applicable, the following:

5.3.2.1 Other purposes, in addition to public water supply, that the surface water supply reservoir system is or would be operated for such as flood control, recreational use, or maintenance of surface water quality and the associated reservoir levels and/or release rates used to satisfy these other purposes;

5.3.2.2 Water quality constraints, other than those specified in water allocation permits and equivalent approvals, including constraints at lower reservoir storage levels if water quality is not expected to comply with the Department's Primary drinking water regulations after treatment at the applicable water treatment plant(s). The applicability of water treatment plants and associated water quality constraints should be determined on a case-by-case basis through the process described in Section 5.1 of this manual. Any contingency plans that would be implemented to minimize the effects of water quality constraints on the surface water supply reservoir system's safe yield should also be characterized;

5.3.2.3 Criteria related to the margin of safety of the safe yield estimate, such as reserve storage, or the reliability of various components of the surface water supply reservoir system, such as basing a safe yield estimate on the capacity of a pumping station with the largest pump out of service.

5.3.2.4 Procedures for operating reservoir outlet works, bascule gates, flashboards, superboards, raw surface water intake structures, other raw surface water diversion facilities, raw water canals, raw water aqueducts, raw water pumping stations and force mains, ground water diversion facilities, water treatment plants, and any other physical components of the surface water supply reservoir system identified as described in Section 5.2 or that may affect the safe yield of the system;

5.3.2.5 Procedures for operating interdependent system source facilities including copies of applicable purveyor agreements specifying the maximum annual average transfer or supply and all overdraft allowances;

5.3.2.6 Surface water supply reservoir system storage level, volume and/or zone operation triggers and rule curves. Rule curves should be characterized graphically and in tabular form. Rule curve graphs should illustrate applicable storage volumes and/or zones such as full storage volume, flood control void space, usable storage, reserve storage, and dead storage. Zones should generally be defined and labeled as top-of-zone curves; and

5.3.2.7 The logical progression(s) of decision alternatives and criteria used to identify, select, prioritize, initiate and regulate operational actions such as initiating operation of various raw surface water diversion facilities and regulating releases at upstream reservoirs to balance storage with downstream reservoirs. These should characterized in text as well as illustrated graphically in operating design logic flow chart(s), using symbols interconnected by lines, to summarize the basis for operating the surface water supply reservoir system.

5.3.3 The existing, alternative and/or proposed operating logic and criteria of any other water supply systems that are addressed in the safe yield simulation model, including any assumptions. Any past operating logic, criteria, or assumptions that are needed to calibrate and verify the safe yield simulation model should also be characterized.

5.3.4 Any other operating logic or criteria that are integral to sustaining the surface water supply reservoir system's safe yield or for any other relevant human activities identified through the process described in Section 5.1.

5.4 Identification and Selection of Key Spatial Control Points

The purveyor should identify and select key spatial control points for the safe yield simulation model based on: the scope of the model; the existing, alternative and/or proposed physical components; the existing, alternative and/or proposed operating logic and criteria; and other factors identified in this section. Include, where applicable, the following:

5.4.1 A separate control point for the location of each surface water supply reservoir that is a component of the surface water supply reservoir system. A surface water supply reservoir control point is usually located at the spillway weir because it should represent, together with any upstream control points, the reservoir's entire gravity drainage area. A surface water supply reservoir control point may also be conceptualized as a reservoir object with separate inlet and outlet locations;

5.4.2 A separate control point for each additional location where surface water is or would be diverted by facilities and/or structures that are a component(s) of the surface water supply reservoir system. Each of these control points should represent, together with any upstream control points, the entire gravity drainage area of the diversion source, including that of any backwater effect;

5.4.3 A separate control point for each additional location where flow and/or storage of water are or would be used to identify, select, prioritize, initiate or regulate the surface water supply reservoir system's operational actions that are integral to sustaining the system's safe yield;

5.4.4 Any control point or control points that is/are important for computing and simulating locations where ground water is or would be diverted by facilities that are a component(s) of the surface water supply reservoir system. It is sometimes appropriate to compute and simulate these ground water diversions as a part of another control point or to lump multiple ground water diversion sources together as a single control point;

5.4.5 Any control point or control points for locations that are important for simulating the flow and/or storage of water in raw water canals, raw water aqueducts, raw water pumping stations, raw water force mains, other raw water conveyance piping, interdependent system source facilities, or other similar physical facilities or structures, for the purpose(s) of estimating the surface water supply reservoir system's safe yield and/or assessing the impacts associated with other relevant human activities, natural features, hydrologic processes and hydraulic processes. Relevant human activities, natural features, hydrologic processes and hydraulic processes should be identified on a case-by-case basis through the process described in Section 5.1 of this manual.

5.4.6 A separate control point for the location of each water treatment plant that is a component of the surface water supply reservoir system;

5.4.7 Any control point or control points for locations that is/are important for computing and simulating the flow and/or storage of water associated with the other relevant human activities, natural features, hydrologic processes and hydraulic processes that are identified as described in Section 5.1 of this manual. It is not usually necessary to include separate control points just to represent the discharge of quantities of wastewater at locations that are upstream of all surface water supply reservoir systems.

5.4.8 A separate control point for each additional location that is important for calibrating and/or verifying the safe yield simulation model;

5.4.9 Any other control point or control points that is/are required or appropriate for the particular software being used to create the safe yield simulation model; and

5.4.10 Any other control point or control points that is/are important for the purpose of estimating the surface water supply reservoir system's safe yield.

5.5 Compilation and Development of Daily Natural Surface Water Flow Data

The purveyor should compile and/or develop daily "natural" surface water flow data for the surface water supply reservoir system. The period(s) of time for which daily natural surface water flow data are compiled and/or developed should be based on the period(s) of existence and operation of the surface water flow and storage gages that are to be used for this purpose. This period of time is known as the period of record of the surface water supply reservoir system for which safe yield is being estimated. The period of record should encompass the longest, reasonable time period and, to the extent possible, should be continuous. The drought years 1929-1933, 1949-1951, 1961-1967, 1980-1983, 1984-1986, 1991-1996, 1998-2000, 2001-2002 as well as any subsequent drought periods should be included to the extent possible

Daily natural surface water flow data should be compiled and/or developed for each of the spatial control points of the safe yield simulation model that represent a surface water location that receives inflows or local inflows from its own drainage area(s), exclusive of the drainage area(s) of any upstream control points. A control point that meets this criteria will be referred to as a "surface water flow control point" in this guidance manual.

In this context, "natural" means that the impacts, if any, of the surface water supply reservoir system, and any other relevant human activities identified on a case-by-case basis through the process described in Section 5.1 of this manual, on observed daily surface water flow data are removed from the data; or that daily surface water flow data without the impacts, if any, are estimated for particular surface water control points and times using synchronous observed daily surface water flow data from a surface water gage or gages at other appropriate locations in each particular case. Case-by-case judgments regarding the appropriateness of the other locations should be made through the process described in Section 5.1. Similarly, case-by-case judgments regarding the acceptability and sufficiency of the raw data that is used to compile and/or develop daily natural surface water flow data should also be made through the process described in Section 5.1.

The process of removing the impacts from observed daily surface water flow data is referred to as "surface water flow reconstruction" in this guidance manual. The process of estimating daily natural flows as referenced in the paragraph above is referred to as "surface water flow synthesis" in this guidance manual.

The daily natural surface water flow data should be compiled and/or developed as follows:

5.5.1 For each surface water flow control point, for portions of the period of record during which daily flows were not impacted by the surface water supply reservoir system or any other relevant human activities identified through the process described in Section 5.1, daily natural surface water flow data should be compiled and developed as follows:

> **5.5.1.1** For portions of the period of record when a surface water flow gage recorded observed daily flow data at the surface water flow control point, the observed daily flows should normally be used as the daily natural surface water flow data; and
>
> **5.5.1.2** For other portions of the period of record, the daily natural surface water flow data should normally be estimated using surface water flow synthesis methods as described in Section 5.5.3.

5.5.2 For each surface water flow control point, for portions of the period of record during which daily flows were impacted by the surface water supply reservoir system or any other relevant human activities identified through the process described in Section 5.1, daily natural surface water flow data should be developed as follows:

5.5.2.1 For portions of the period of record: when a surface water flow gage recorded observed daily flow data at the surface water flow control point; and for which a sufficient quantity and quality of other flow and storage data are readily available that can be used to adequately quantify the impacts of the surface water supply reservoir system and any other relevant human activities identified through the process described in Section 5.1; the daily natural surface water flow data should normally be developed using the surface water flow reconstruction method described in Section 5.5.4; and

5.5.2.2 For other portions of the period of record, the daily natural surface water flow data should normally be estimated using surface water flow synthesis methods as described in Section 5.5.3.

5.5.3 Surface water flow synthesis methods generally considered to be acceptable to the Department include drainage area ratio, regression analyses and Maintenance-Of-Variance-Extension (MOVE), or variations of these methods. It is important, however, that each selected method be appropriate to the watersheds of the surface water flow control point and the other surface water flow gage(s) for which it is being used. In each case, the watershed(s) of the gage(s) from which the synchronous observed daily flow data are obtained should be demonstrated to have daily flows sufficiently similar to the watershed of the surface water flow control point. The use of gages at nearby locations upstream or downstream of the control point, with similar drainage areas, should generally be considered first. Case-by-case judgments regarding the guidance in this paragraph should be made through the process described in Section 5.1. Synchronous observed daily flow data that are used for surface water flow synthesis should generally either be from index gages at locations, and during times, with limited human impacts or should have the impacts of the surface water supply reservoir system, and any other relevant human activities identified through the process described in Section 5.1, removed using the surface water flow reconstruction method described in Section 5.5.4.

5.5.4 A daily natural surface water flow value may be reconstructed from an observed daily surface water flow value that is impacted by the surface water supply reservoir system and/or any other relevant human activities identified through the process described in Section 5.1. This requires a sufficient quantity and quality of other flow and storage data that can be used to adequately quantify the impacts. Surface water diversions, discharges, and storage changes as well as ground water diversions and discharges should be assumed to impact observed daily surface water flow values on a one-to-one proportionate basis. Each surface water diversion, discharge, and storage change should be assumed to impact the observed daily surface water flow value for the day that the diversion, discharge or storage change occurred. If any surface water flow and storage data need to be interpolated to a daily basis from longer time periods, the Department recommends that the purveyor should collaborate with the Department regarding this procedure on a case-by-case basis through the process described in Section 5.1. Annual average ground water diversion and discharge values should generally be used to reconstruct daily natural surface water flow values and each annual average value should be assumed to impact all observed daily flow values during the applicable year. In general, the reconstruction should be performed, starting with the observed daily flow value (in MGD), by either adding or subtracting, as indicated, all of the following quantities:

5.5.4.1 Add all diversions (in MGD) of surface waters or unconfined or semi-confined aquifer ground waters by the surface water supply reservoir system and any other relevant human activities identified through the process described in Section 5.1, that are upstream of the surface water flow gage that recorded the observed daily flow value;

5.5.4.2 Add all positive (increases) and negative (decreases) changes in storage (in MGD) of all reservoirs, lakes, or other similar water bodies that are a part of the surface water supply reservoir system or any other relevant human activities identified through the process described in Section 5.1, that are upstream of the surface water flow gage that recorded the observed daily flow value; and

5.5.4.3 Subtract all discharges (in MGD) from relevant human activities identified through the process described in Section 5.1 to surface waters and unconfined or semi-confined aquifer ground waters, that are upstream of the surface water flow gage that recorded the observed daily flow value. Discharges from relevant human activities include discharges of raw water from surface water supply reservoir systems (such as discharges from pump-storage reservoir system operations), as well as wastewater discharges.

5.5.5 Daily natural surface water flow data may be compiled and/or developed using other methods when approved by the Department. The purveyor is encouraged to consult with the Department through the process described in section 5.1 regarding the use of other methods.

5.6 Characterization of Unit Draft Patterns

The purveyor should characterize existing and alternative unit draft patterns for each water supply system included in the safe yield simulation model as follows:

5.6.1 For each water supply system, compile monthly system draft data for the five most recent calendar years during which no water emergency or drought warning that affected the system was declared and for which the data are available. The number of calendar years of such data may be reduced to four or three when the data for the additional years are not available. Monthly data are usually available from the Department's water diversion report records and these records should generally be used to compile monthly system draft data because they are certified by representatives of the permitted entities as being accurate and are periodically checked by the Department for accuracy. Use the monthly system draft data as follows:

5.6.1.1 Calculate the average system draft for each of the twelve calendar months by summing the system drafts for each calendar month and dividing each sum by the number of calendar years of data used; and

5.6.1.2 Calculate the average annual system draft by summing the average system drafts for each of the twelve calendar months and dividing that sum by twelve.

5.6.2 For each water supply system for which the data referenced in Section 5.6.1 above are not available:

5.6.2.1 Identify an average system draft for each of the twelve calendar months and provide justification for these values for review and approval by the Department. The purveyor is encouraged to consult with the Department through the process described in section 5.1 regarding the guidance in this paragraph; and

5.6.2.2 Calculate the average annual system draft by summing the average system drafts for each of the twelve calendar months and dividing that sum by twelve.

5.6.3 The unit draft pattern for each water supply system should be on a temporal scale of one calendar year and should normally be calculated as follows:

5.6.3.1 Assign the average system draft for each of the twelve calendar months to the temporal mid-point of the month;

5.6.3.2 Linearly interpolate between the average calendar month values to calculate the average daily system draft for each day over the calendar year; and

5.6.3.3 Divide the average daily system draft for each day over the calendar year by the average annual system draft .

5.6.4 Unit draft patterns developed using other methods may be simulated for each water supply system, when approved by the Department. For example, this may occur in situations such as when a major water user has been added or permanently lost and is expected to significantly affect the unit draft pattern. The purveyor is encouraged to consult with the Department through the process described in section 5.1 regarding the use of other methods. Case-by-case judgments regarding the significance of effects on unit draft patterns should also be made through the process described in Section 5.1.

5.7 Characterization of Existing Wastewater Discharge Flow Patterns

An existing wastewater discharge flow pattern represents the sequence of wastewater flows discharged during each day of an average calendar year at a specific location, normally based on a number of years of recent data. The purveyor should characterize existing wastewater discharge flow patterns as follows:

5.7.1 For each location where the discharge of wastewater flows to surface waters has been identified as a relevant human activity through the process described in Section 5.1 of this manual, the purveyor should characterize the existing wastewater discharge flow pattern as follows:

5.7.1.1 For each discharge location, compile monthly wastewater flow data for the five most recent calendar years for which the data are available. The number of calendar years of such data may be reduced to four or three when the data for the additional years are not available. Use this data as follows:

5.7.1.1.1 Calculate the average wastewater flow for each of the twelve calendar months by summing the flows for each calendar month and dividing each sum by the number of calendar years of data used; and

5.7.1.1.2 Calculate the average annual wastewater flow by summing the average flows for each of the twelve calendar months and dividing that sum by twelve.

5.7.1.2 For each discharge location where the data referenced in Section 5.7.1.1 above are not available:

5.7.1.2.1 Identify an average wastewater flow for each of the twelve calendar months and provide justification for these values for review and approval by the Department. The purveyor is encouraged to consult with the Department through the process described in section 5.1 regarding the guidance in this paragraph; and

5.7.1.2.2 Calculate the average annual wastewater flow by summing the average wastewater flows for each of the twelve calendar months and dividing that sum by twelve.

5.7.1.3 The existing wastewater discharge flow pattern for each location should be on a temporal scale of one calendar year and should normally be calculated as follows:

5.7.1.3.1 Assign the average wastewater flow for each of the twelve calendar months to the temporal mid-point of the month; and

5.7.1.3.2 Linearly interpolate between the average calendar month values to calculate the average daily wastewater flow for each day over the calendar year.

5.7.2 For each location where the discharge of wastewater flows to ground waters has been identified as a relevant human activity through the process described in Section 5.1, the purveyor should characterize the existing wastewater discharge flow pattern as a constant value in units of MGD representing the average flow for the five most recent calendar years that data are available. The number of calendar years of such data may be reduced to four or three when the data for the additional years are not available. If less than three years of data are available, the purveyor should identify a constant flow value and provide justification for this value for review and approval by the Department. In this case, the purveyor is encouraged to consult with the Department through the process described in section 5.1 regarding this guidance.

5.7.3 Existing wastewater discharge flow patterns developed using other methods may be simulated for each location, when approved by the Department. The purveyor is encouraged to consult with the Department through the process described in section 5.1 regarding the use of other methods.

5.8 Building and Running the Safe Yield Simulation Model

In general, the Department recommends that the purveyor develop and use the safe yield simulation model as described in this manual when preparing and submitting a safe yield estimate for their surface water supply reservoir system. The daily natural surface water flow data for the period of record of the surface water supply reservoir system should normally be a primary part of the input data that drives the model. However, model runs should, in general, simulate the hydrologic effects of current and projected future relevant human activities (see Section 5.1) over the entire period of record. In this way, the effects of current and projected future human activities are superimposed on natural flows over the period of record in order to estimate what daily surface water flows would occur now or in the future if there were a repeat of past climactic conditions, including past droughts. When attempting to calibrate and verify the model, the relevant human activities that actually existed or occurred during the drought period(s) that are being analyzed should be simulated.

More specifically, the model should be built and run as follows:

5.8.1 For each key spatial control point (see Section 5.4), the calculations and logical functions that will be used to simulate the flow and, where applicable, storage of water should be identified and programmed into the simulation model. The calculations and logical functions should reflect the criteria associated with selecting the control point and should be based on the nature of: the physical components; the operating logic and criteria; the daily natural surface water flow data; any unit draft patterns or other system draft data; any existing wastewater discharge flow patterns or other wastewater discharge data; any hydraulic processes; and any hydrologic processes associated with the control point. The topology of the control point, including the physical connections that control flow to and from the control point, should also be reflected in the calculations and logical functions. The calculations and logical functions should include variations that are needed to evaluate the alternatives, configurations and scenarios identified as described in Section 5.1 of this manual, as well as to calibrate and verify the model. These variations should either be able to be turned on and off in the model or be contained within separate copies of the model. If separate copies of the model are used, the guidance in Sections 5.8.2 below applies to each copy of the model.

5.8.2 The data identified as described in this manual that is needed to run, calibrate, and verify the safe yield simulation model should be input into the model. Some of the data may be hard-coded into the model calculations and logical functions. The data should normally be input into the model as follows:

5.8.2.1 The daily natural surface water flow data for each surface water flow control point should be input into the safe yield simulation model for the period of record of the surface water supply reservoir system. The data in their raw form represent flows from the entire gravity drainage area of each surface water flow control point. However, in the model, at each surface water flow control point that is downstream of any other surface water flow control point(s), flows from the drainage areas of the upstream point(s) are already accounted for by the data, calculations and logical functions of the upstream points and the topological connections of the model. As a result, only the daily local inflows between the downstream surface water flow control point and the next upstream surface water flow control point(s) should be added to the downstream control point as additional daily natural surface water flows. In this situation, either the daily local inflows should be calculated from the raw daily natural surface water flow data and input into the model or the raw daily natural surface water flow data should be input and the daily local inflows should be calculated by the model;

5.8.2.2 The physical capacities of the physical components should be input into the safe yield simulation model. Pool elevation and storage volume relationship data may be substituted for the storage volumes of reservoirs, lakes, and other similar water bodies if hydraulic and/or evaporative processes are simulated as indicated in Section 5.8.2.6 below;

5.8.2.3 The water allocation permit diversion limitations and passing flow requirement(s) should be input into the safe yield simulation model. Safe yield simulation models for surface water supply reservoir systems should be based on the assumption that all passing flow requirements of the systems, as well as upstream and downstream of the systems, will be maintained, except for purposes of calibrating and verifying the models;

5.8.2.4 The unit draft pattern(s), as well as any system draft data that are needed to calibrate or verify the safe yield simulation model, should be input into the model;

5.8.2.5 Any applicable operation trigger and/or rule curve data should be input into the safe yield simulation model;

5.8.2.6 Any applicable pool elevation and storage volume relationship data, pool elevation and water surface area relationship data, pool elevation and spill relationship data, pool elevation and maximum release relationship data, and pool elevation and maximum withdrawal relationship data should be input into the safe yield simulation model. These types of data may be needed if hydraulic and/or evaporative processes of reservoirs, lakes, and other similar water bodies are to be simulated;

5.8.2.7 The safe yields of any other water supply systems that are to be simulated should be input into the safe yield simulation model;

5.8.2.8 Any applicable existing wastewater discharge flow pattern data should be input into the safe yield simulation model. Each existing wastewater discharge flow pattern represents the sequence of wastewater flows discharged during each day of an average calendar year at a specific location, based on recent data. The remainder of this paragraph applies to most situations, except when the model is being calibrated or verified. At each control point that is not downstream of any other control point(s), the calculations and logical functions of the safe yield simulation model should add the average daily wastewater flows of the existing wastewater discharge flow patterns for which the discharge locations are upstream of that control point to the inflows to that control point on a daily basis. At each control point that is downstream of any other control point(s), the average daily wastewater flows discharged above the upstream point(s) are already accounted for by the data, calculations and logical functions of the upstream points and the topological connections of the model. As a result, only average daily wastewater flows discharged between the downstream control point and the next upstream control point(s) should be added to the downstream control point as additional daily inflows. The applicable average wastewater flows discharged during each day of the calendar year should be added to the inflows of each applicable control point on the synchronous days over the period of record of the surface water supply reservoir system on a repeating annual periodic basis. For each control point, the applicable average wastewater flows for each day may be summed either before or after they are input to the model;

5.8.2.9 Any wastewater discharge flow data that are needed to calibrate or verify the safe yield simulation model should be input into the model. The remainder of this paragraph applies when the model is being calibrated or verified. At each control point that is not downstream of any other control point(s), the calculations and logical functions of the safe yield simulation model should add the average daily wastewater flows of the wastewater discharge locations that are upstream of that control point to the inflows to that control point on a daily basis. At each control point that is downstream of any other control point(s), the average daily wastewater flows discharged above the upstream point(s) are already accounted for by the data, calculations and logical functions of the upstream points and the topological connections of the model. As a result, only average daily wastewater flows discharged between the downstream control point and the next upstream control point(s) should be added to the downstream control point as additional daily inflows. For each control point, the applicable wastewater flows for each day may be summed either before or after they are input to the model;

5.8.2.10 Any other applicable data required to simulate natural features, hydraulic processes and/or hydrologic processes identified as described in Section 5.1 of this manual should be input into the safe yield simulation model; and

5.8.2.11 Any other applicable data that are needed to run, calibrate, or verify the safe yield simulation model should be input into the model.

5.8.3 The purveyor should attempt to calibrate and verify the safe yield simulation model as a means of assessing the performance of the model and evaluating the model input data, calculations and logical functions. The calibration and verification processes should be performed as follows:

5.8.3.1 The calibration process should be focused on attempting to obtain agreement during one or more drought periods between (1) simulated surface water flows and storage volumes and (2) observed data from surface water flow and storage gages within the watershed(s) of the surface water supply reservoir system(s). Observed storage volume data from each reservoir, lake and other similar water body and observed surface water flow data from locations that are downstream of each diversion source, if available, should be compared with the simulated outputs. When attempting to calibrate the model, the calculations, logical functions and input data that are used should reflect the physical components, operating logic and criteria, diversions, releases and wastewater discharge flows that actually existed or occurred during the drought period(s) that are being analyzed. System drafts that were observed during the drought period(s) that are being analyzed should be used rather than a system draft pattern. Because, in many cases, the reliable data needed for the calibration process are only available for relatively recent times, recent drought periods are usually selected for calibration. The agreement, or lack thereof, between the simulated and observed data should be evaluated. If any significant lack of agreement is found, an analysis should be performed to identify and prioritize the model input data, calculations and logical functions that have the greatest influence on the calibration process and potential explanations for the lack of agreement should be hypothesized. Model input data, calculations and logical functions should then be adjusted in reasonable and defensible ways to improve the agreement between the simulated and observed data. Case-by-case judgments regarding the guidance in this paragraph should be made through the process described in Section 5.1;

5.8.3.2 The verification process should be performed as described for the calibration process above but for one or more other drought periods. If model input data, calculations and logical functions are adjusted during a particular verification process to improve the agreement between the simulated and observed data, it then becomes a part of the calibration process and a new, independent verification process should be used to assess the performance of the model; and

5.8.3.3 If applicable, the performance of the safe yield simulation model should also be assessed by attempting to replicate any previously approved safe yields. When attempting to replicate a previously approved safe yield, the calculations, logical functions and input data that are used should reflect the same period of record, physical components, operating logic and criteria, system draft pattern(s), and wastewater discharge flows that were used in the assessment that forms the basis for the previous approval, to the extent that the applicable data are available. To the extent that these data are not available, the calculations, logical functions and input data that are used should reflect the period of record, physical components, operating logic and criteria, system draft pattern(s), and wastewater discharge flow pattern(s) that actually existed or occurred at or near the time of the previous assessment, if such data are available. If daily natural surface water flow data are available from the previous assessment and differ from the daily natural surface water flow data being used for the current assessment, an additional model run or runs using the previous data to attempt to replicate the previously approved safe yield should be performed.

5.8.4 The safe yield simulation model should be run to evaluate the alternatives, configurations and scenarios identified as described in Section 5.1 of this manual. Initial storage volumes of the reservoirs, lakes and other similar water bodies that are simulated should be set to full storage volume for each model run. Where an alternative to an existing surface water supply reservoir system is being proposed or considered, the existing configuration of the surface water supply reservoir system should always be evaluated as one scenario. Each specific alternative, configuration or scenario of a safe yield simulation model should be run iteratively, for the period of record, with various trial annual average system drafts to determine the annual average system draft that would divert all usable storage (to the extent possible within the mathematical rounding limitations of the safe yield estimate) volumes of water from the system's reservoir(s), except for any reserve storage volumes that are set aside to provide or contribute to a margin of safety, and that would continuously satisfy the repeating system draft pattern. That annual average system draft, in units of MGD, is the safe yield estimate of the particular alternative, configuration or scenario of the applicable surface water supply reservoir system. Department approval of any safe yield estimate only applies to the particular alternative, configuration or scenario of the applicable surface water supply reservoir system that it was estimated for and is limited by any conditions made a part of the approval.

SECTION 6 SAFE YIELD ENGINEER'S REPORT

The purveyor should summarize the results of the safe yield estimate for their surface water supply reservoir system in a safe yield engineer's report and submit copies of the report to the Department for review. The introduction to the report should identify the name of the surface water supply reservoir system for which a safe yield is being estimated, as well as the names and addresses of the owners(s) and operator(s) of the system. A general description and map(s) showing the location and areal extent of the surface water supply reservoir system and its source waters should be included. Map(s) showing the boundaries of the surface water supply reservoir system's service areas and franchise areas should also be included and any wholesale customers should be identified. The introduction should discuss the reason(s) why a safe yield estimate was made and identify any previously approved safe yield(s) for the surface water supply reservoir system and the associated date(s) of approval.

The introduction to the safe yield engineer's report should identify and describe the safe yield simulation model software that the purveyor is using to estimate the safe yield of their surface water supply reservoir system. Provided that methods described in this manual or specifically approved by the Department are followed, purveyors may use safe yield simulation model software of their choosing.

The remainder of this section details additional information that should be included in the safe yield engineer's report.

6.1 Safe Yield Simulation Model Scope

The safe yield engineer's report should include a description of the scope of the safe yield estimate, and any related communication(s) as detailed in Section 5.1 of this manual. Maps, schematics and figures that facilitate understanding of the scope should be included.

Any methods that the purveyor is using to estimate safe yield that vary from or are in addition to the guidance provided in this manual should be identified and described. Other methods of estimating the safe yield of surface water supply reservoir systems should only be used if they are specifically approved by the Department.

6.2 Physical Components

The safe yield engineer's report should include the information resulting from characterization of the existing, alternative, and/or proposed physical components as described in Section 5.2 of this manual. Information from characterization of any additional physical components that are needed to calibrate and verify the safe yield simulation model should also be included. Estimated reservoir elevation (level) data should be described in feet above mean sea level and be relative to the North American Vertical Datum of 1988 (NAVD 88). Maps, schematics, figures, tables and graphs that facilitate understanding of the physical components should be included.

6.3 Operating Logic and Criteria

The safe yield engineer's report should include the information resulting from characterization of the existing, alternative, and/or proposed operating logic and criteria as described in Section 5.3 of this manual. Information from characterization of any additional operating logic and criteria that are needed to calibrate and verify the safe yield simulation model should also be included. Maps, schematics, figures, tables, graphs and charts that facilitate understanding of the operating logic and criteria should be included.

For each interdependent system source, the safe yield engineer's report should identify their currently effective water allocation permit number(s) and, if applicable, approved safe yield.

6.4 Key Spatial Control Points

The safe yield engineer's report should include the information resulting from identification and selection of key spatial control points as described in Section 5.4 of this manual. This should include the name and location of each control point; the rationale for selecting each control point; and a description of how the calculations and logical functions of the safe yield simulation model will represent the spatial dimensions (or lack thereof) of each control point. Maps and schematics that show the name and location of each control point, the physical connections that control the flow of water between the control points, and the direction(s) of flow should also be included.

6.5 Daily Natural Surface Water Flow Data

The safe yield engineer's report should include the information resulting from compilation and development of daily natural surface water flow data as described in Section 5.5 of this manual. For each surface water flow control point, the engineer's report should document and record the observed daily flow data; any other raw data; available information about the quality of the data; the rationale for the determination regarding the portions of the period of record for which daily flows were and were not impacted by the surface water supply reservoir system or any other relevant human activities identified through the process described in Section 5.1 of this manual; any surface water flow synthesis and reconstruction method(s); any methods used to address the effects of evaporation; and the calculations used to produce the daily natural surface water flow data. Large datasets such as time-series data and associated formulas and calculations should be recorded in standard read-only Microsoft Excel™ spreadsheets that are capable of being copied by the Department for input into RiverWare software as part of its verification of purveyor's safe yield estimates. The Excel files should be copied onto standard electronic media and attached to the safe yield engineer's report.

6.6 Unit Draft Patterns

The safe yield engineer's report should include the information resulting from characterization of existing and alternative unit draft patterns as described in Section 5.6 of this manual. Raw data and the results of step-by-step calculations should be included. Tables and graphs of the daily data that constitute each unit draft pattern should also be included.

6.7 Existing Wastewater Discharge Flow Patterns

The safe yield engineer's report should include the information resulting from characterization of existing wastewater discharge flow patterns as described in Section 5.7 of this manual. Raw data and the results of step-by-step calculations should be included. Tables and graphs of the daily data that constitute each existing wastewater discharge flow pattern should also be included.

6.8 Model Calculations and Logical Functions

The safe yield engineer's report should identify and describe the calculations and logical functions that are being used to simulate the flow and, where applicable, storage of water for each key spatial control point of the safe yield simulation model as described in Section 5.8.1 of this manual. The rationale for the calculations and logical functions of each control point should be explained.

6.9 Safe Yield Simulation Model Data

The safe yield engineer's report should identify the data that is input into the safe yield simulation model and describe how the data is entered in relation to the guidance provided in Section 5.8.2 this manual.

6.10 Model Calibration and Verification

The safe yield engineer's report should include the information resulting from the attempt(s) to calibrate and verify the safe yield simulation model, and to replicate any previously approved safe yield(s), as described in Section 5.8.3 of this manual. All documentation of any previously approved safe yield(s) that is available to the purveyor, including any associated computer model(s) and electronic dataset(s), should be included in or attached to the safe yield engineer's report. Tables and graphs that facilitate understanding of the attempt(s) to calibrate and verify the safe yield simulation model and replicate any previously approved safe yield(s) should be included.

6.11 Safe Yield Simulation Model Results

The safe yield engineer's report should include the information that results from running the safe yield simulation model as described in Section 5.8.4 of this manual. If an existing or proposed new surface water supply reservoir system is the only system evaluated, the estimated safe yield for that system should be identified. If modification of an existing surface water supply reservoir system is being proposed, then the estimated safe yields for both the existing and proposed modified systems should be identified. If additional alternatives, configurations, and scenarios are evaluated, the safe yield engineer's report should include a description of each alternative, configuration, or scenario, its estimated safe yield, and its advantages and disadvantages. Justification for rejecting each of the alternatives, configurations and scenarios not chosen should be provided. A selected alternative, configuration, or scenario and its estimated safe yield should be identified.

The safe yield engineer's report should include a discussion regarding the various trial annual average system drafts that were run in the safe yield simulation model in order to estimate the safe yield that the purveyor has identified for their surface water supply reservoir system. The critical drawdown period of the most severe drought of record for this safe yield should be identified in the report. A graph relative to this safe yield showing the daily volumes of water held in the usable storage of all the system's reservoirs combined during the critical drawdown period and the storage recovery period should be included. Any reserve storage and/or dead storage should be shown or noted on the graph. The engineer's report should include similar graphs for next two most severe droughts for the surface water supply reservoir system during the period of record. A tabulation summarizing the daily inflow, outflow and storage volume data associated with all three graphs should be included to assist with public review of the safe yield estimate. An example tabulation summary form is shown in Appendix A.

If the surface water supply reservoir system has any previously approved safe yields, and the safe yield that the purveyor has identified for their surface water supply reservoir system in the current engineer's report is different than the most recent previously approved safe yield, the major factors that resulted in this difference should be identified and explained in the report to the extent possible.

If the surface water supply reservoir system that the safe yield is being estimated for is a pump-storage reservoir system and if the purveyor intends to adjust operation of the system in response to incremental changes in system draft, the engineer's report should include the general operating plans and procedures that will be used for each level of system draft. A complete explanation of the basis for all of the general operating plans and procedures should be included. It should be demonstrated that all levels of system draft up to the estimated safe yield could be supplied continuously using the applicable operating plans and procedures, during future conditions projected in accordance with the definition of safe yield in the Water Supply Management Act that include a repeat of the most severe drought of record based on the system's period of record data. Because the operation of a pump-storage reservoir system may be very complex, the general operating plans and procedures may not be able to incorporate all factors that significantly affect actual operations and may only be able to be used as a general guide to help make actual day-to-day operational decisions. The Department will not enforce the general operating plans and procedures on a real-time day-to day basis. The Department will assess the sufficiency of the general operating plans and procedures to help maintain the reliability of the water supply by evaluating them over longer periods of time, such as the reservoir drawdown periods of future drought events. The Department and purveyors should work cooperatively to adjust general operating plans and procedures as needed to maintain the reliability of pump-storage reservoir systems.

Any other maps, schematics, figures, tables, graphs and charts that facilitate understanding of the information identified in this section should also be included in the engineer's report.

SECTION 7 SUBMITTING THE SAFE YIELD ESTIMATE

Purveyors may submit estimates of the safe yields of their surface water supply reservoir systems to the Department for review at any time. The Department may also require purveyors to submit estimates of the safe yields of their surface water supply reservoir systems in accordance with the Department's regulatory authority as described in Section 2.2 of this manual.

Whenever purveyors submit safe yield estimates for their existing or modified surface water supply reservoir systems to the Department, each submission should include copies of the safe yield engineer's report as described in Section 6 above. The purveyor should submit three (3) complete copies of the safe yield engineer's report and all associated information, data and appendices to the Department (Division of Water Supply and Geoscience - Bureau of Water Allocation and Wells). Safe yield engineer's reports that are submitted to the Department should be signed and sealed by a New Jersey licensed professional engineer. Purveyors proposing to divert water from new diversion sources or to modify diversion limitations to permit increased diversions from existing diversion sources to increase the safe yields of their surface water supply reservoir systems should submit the applicable information required at N.J.A.C. 7:19-2.2 as a part of the application.

Purveyors with surface water supply reservoir systems in the Highlands Region should also consult with the New Jersey Highlands Council regarding new diversion sources and increased diversion allocations for existing diversion sources. Other Federal, State and local government consent must be obtained as required by law.

Purveyors that submit safe yield simulation models may assert proprietary and/or confidentially claims on the models and related technical applications. Among the claims that could be asserted is that information, if made public, would divulge methods and processes entitled to protection as trade secrets, or potentially cause danger to public health, safety or the environment. In these cases, the purveyor must formally submit to the Department the reason(s) why such information should not be disclosed. If the Department's decision is to grant the proprietary and/or confidentially claim, the three (3) copies of the safe yield engineer's report described above should be submitted by the purveyor to the Department in two different versions. One copy of the report should be submitted with all associated information, data and appendices, including all information which the purveyor has claimed is proprietary and/or confidential. The two remaining copies of the safe yield engineer's report should be submitted in identical form to the first except that they should not include the information that the Department has determined to be proprietary and/or confidential. These two copies are for public review during public notice of the safe yield estimate of the surface water supply reservoir system. In order to provide the public notice that information has been omitted from the two remaining copies due to its proprietary or confidential nature, they should indicate where deletions have been made and the reason(s) for the deletions. Where a proprietary and/or confidentially claim has been approved, the Department will, within its authority, protect from disclosure all information included in that approval. In cases where a proprietary and/or confidentially claim is instituted, the purveyor should submit all information that is needed for input into the RiverWare software that the Department will utilize to verify the purveyor's safe yield simulation model results.

APPENDIX A

EXAMPLE TABULATION SUMMARY FORM

	INFLOWS TO COMBINED STORAGE		OUTFLOWS FROM COMBINED STORAGE			COMBINED STORAGE
DAY-MONTH-YEAR	GRAVITY INFLOW (MGD)	PUMPED INFLOW (MGD)	RELEASE (MGD)	SYSTEM DRAFT (MGD)	SPILL (MGD)	USABLE STORAGE (BG)

This is an example tabulation summary form for a hypothetical surface water supply reservoir system with inflows to combined usable storage from both surface waters by gravity and pumped diversion sources. This is an example only and the columns in the form will likely need to be customized for actual safe yield engineer's reports. In the example form, spills from combined usable storage could be calculated either with or without considering hydraulic pool elevation and spill relationships. If hydraulic relationships are not considered, spills might be calculated as the non-negative values obtained for each day by starting with the previous day's combined usable storage and: adding daily gravity inflow from surface waters; adding daily pumped inflow from diversion sources; subtracting daily release; subtracting daily system draft; and subtracting the maximum usable storage volume. Note that spills cannot be less than zero, so that any negative values would represent zero spill. Note also that this calculation may not be adequate in all circumstances because, for instance, a downstream reservoir of a multi-reservoir system may spill even when the combined usable storage including upstream reservoirs is less than the maximum volume. Combined usable storage would be calculated for each day by starting with the previous day's combined usable storage and: adding daily gravity inflow from surface waters; adding daily pumped inflow from diversion sources; subtracting daily release; subtracting daily system draft; and subtracting daily spill. Appropriate conversions between units of flow (MGD) and volume (BG) on a daily time step are necessary in the calculations.