FHWA-NJ-2017-001

DRAINAGE IDENTIFICATION ANALYSIS AND MAPPING, PHASE 2

FINAL REPORT
January 2017

Submitted by:

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In cooperation with

New Jersey
Department of Transportation
Division of Research and Technology
and
U.S. Department of Transportation
Federal Highway Administration

DISCLAIMER STATEMENT

1. **Report No.** FHWA-NJ-2017-001	2. **Government Accession No.**	3. **Recipient's Catalog No.**

4. **Title and Subtitle** Drainage Identification Analysis And Mapping, Phase 2	5. **Report Date** January 2017
	6. **Performing Organization Code**
7. **Author(s)** J. N. Meegoda, C. Tang, T. M. Juliano, L. Potts, M. Agbakpe and S. D. Aluthgun-Hewage	8. **Performing Organization Report No.**
9. **Performing Organization Name and Address** Department of Civil and Environmental Engineering, New Jersey Institute of Technology, University Heights, Newark, NJ 07102-1982	10. **Work Unit No.**
	11. **Contract or Grant No.** NJDOT Contract ID: 16-60107
12. **Sponsoring Agency Name and Address** N.J. Department of Transportation, 1035 Parkway Avenue, P.O. Box 600, Trenton, NJ 08625-0600; Federal Highway Administration (SPR), U.S. Department of Transportation, 1200 New Jersey Avenue, SE, Washington, DC 20590	13. **Type of Report and Period Covered** Final Report, August 2015 – January 2017
	14. **Sponsoring Agency Code**

15. **Supplementary Notes**

The project was administered through the Region 2 University Transportation Research Center (UTRC), at the City College of the City University of New York, under the leadership of Director Camille Kamga, Marshak Hall, Room 910, 160 Convent Avenue, New York, New York 10031

16. **Abstract**

Drainage Identification, Analysis and Mapping System (DIAMS) is a computerized database that captures and stores relevant information associated with all aboveground and underground hydraulic structures belonging to the New Jersey Department of Transportation (NJDOT). DIAMS retrieves relevant performance and financial information so that NJDOT can remain compliant with Phase II of the Government Accounting Standards Board Statement 34, which is NJDOT's sole means of reporting all financial transactions, namely the value of infrastructure drainage assets on an accrual accounting basis. DIAMS also retrieves all relevant environmental information to comply with the Clean Water Act and reporting requirements of the NJDEP. The DIAMS capabilities include identifying drainage infrastructure, maintaining inspection history, mapping locations, predicting service life based on the current condition states, and assessing present asset value. The DIAMS also contains several different repair, rehabilitation and replacement options to remedy the drainage infrastructure. In addition, the DIAMS can analyze asset information and determine decisions to inspect, rehabilitate, replace or do nothing at the project and network levels. Furthermore, the financial analysis module will output data into categories including inspection, cleaning, repair, and condition states. The process will direct users and decision makers to evaluate work orders, which will be reported in summaries, allowing the best choice for asset performance implementation for each asset type. Thus, making DIAMS an indispensable asset management and environmental information management tool. Possible improvements to DIAMS includes the system wide design improvements to accommodate impacts of climate change.

17. **Key Words** Financial Analysis, Pipes, Condition Assessment, Data Collection, Inspection, Inventory	18. **Distribution Statement** No Restrictions.

19. **Security Classification (of this report)** Unclassified	20. **Security Classification (of this page)** Unclassified	21. **No of Pages** 25	22. **Price**

Form DOT F 1700.7 (8-72)

ACKNOWLEDGMENTS
The authors wish to acknowledge the efforts of UTRC Director Dr. Camille Kamga, the NJDOT customer Sim Liu and the NJDOT Research Bureau Manager Camille Crichton-Sumners, Project Manager (Section Chief) Amanda Gendek and contract manager Stefanie Potapa.

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EXECUTIVE SUMMARY

Drainage Identification, Analysis and Mapping System (DIAMS) is a computerized database that captures and stores relevant information associated with all aboveground and underground hydraulic structures belonging to NJDOT. DIAMS retrieves relevant financial information for management so that NJDOT can remain compliant with Phase II of the Government Accounting Standards Board Statement 34, which is NJDOT's sole means of reporting all financial transactions, namely the value of infrastructure drainage assets on an accrual accounting basis. DIAMS also retrieves all relevant environmental information to comply with the Clean Water Act and reporting requirements of the NJDEP.

DIAMS, as is the case with any critical computational tool, required enhancements and updates. Phase II consisted of two objectives: to rectify the compatibility issues related to the recent upgrades of NJDOT vendor software updates and to update all collected data to make DIAMS current.

In addition, the DIAMS was also updated to include the Best Management Practices (BMP) data entry form containing detention basin asset data and inspection records.

OBJECTIVES

The specific tasks supporting the objectives of the DIAMS Phase II research included:

i) TASK 1: Upgrading the DIAMS to rectify the identified compatibility issues related to the recent upgrades of NJDOT vendor software updates. The upgrade made the DIAMS compatible with both WinCAN7 and WinCAN8 and other pipeline inspection software packages (Granite XP, PipeLogix, etc.), which allows for a seamless transition as contractors continue to update their inspection software packages. In addition, this upgrade also allows access to archival data and ensures that there is consistency with the installation and training at NJDOT.

ii) TASK 2: Uploading all collected data to update the Current Inspection Data Inventory at NJDOT to make DIAMS current. Although the task of manually uploading inspection data and videos into DIAMS is not extremely difficult, it is time consuming. The three and a half year backlog was large, that is over 1,000 DVDs with inspection data were uploaded. In addition, inconsistencies in the milepost data were continually a reoccurring problem. The NJIT Research team checked and updated the current inventory of inspection data at NJDOT by uploading it into the DIAMS.

INTRODUCTION

Adequate drainage is essential in the design of highways since it affects the serviceability and usable life of highways, including the pavement's structural strength. If ponding on the traveled way occurs, hydroplaning becomes an important safety concern. Drainage design involves providing facilities that collect, transport and remove stormwater from highways. The design must also consider the stormwater reaching the roadway embankment through natural stream flow or manmade ditches. The regulatory environment related to drainage design is ever changing and continues to grow in complexity. Engineers responsible for the planning and design of drainage facilities must be familiar with federal, state, county and local regulations, laws, and ordinances that may impact the design of storm drain systems (DelDOT, 2008).

Various maintenance treatments are employed by highway agencies to slow deterioration and restore condition of drainage infrastructure. However, budget constraints and other factors have often led to delaying or eliminating the application of these treatments. Such actions are expected to adversely influence the condition and performance and lead to a reduced level of service, to early deterioration, and eventually to the need for costly rehabilitation or replacement. Analytical tools are currently available to quantify the consequences of delayed application of maintenance treatments for drainage infrastructure. However, processes for using these tools to demonstrate the potential savings and performance enhancement resulting from applying maintenance treatments at the right time are not readily available. This research has attempted to address such processes. This information will help highway agencies better assess the economic benefits of maintenance actions and their role in enhancing the level of service of the highway system. In addition, incorporating these processes in asset management systems would provide a means for optimizing the allocation of resources.

DRAINAGE IDENTIFICATION ANALYSIS AND MAPPING SYSTEM (DIAMS)

Drainage Identification, Analysis and Mapping System (DIAMS) is a computerized database that captures and stores relevant information associated with all aboveground and underground hydraulic structures belonging to the New Jersey Department of Transportation (NJDOT). DIAMS retrieves relevant performance and financial information so that NJDOT can remain compliant with Phase II of the Government Accounting Standards Board Statement 34, which is NJDOT's sole means of reporting all financial transactions, namely the value of infrastructure drainage assets on an accrual accounting basis. DIAMS also retrieves all relevant environmental information to comply with the Clean Water Act and reporting requirements of the New Jersey Department of Environmental Protection (NJDEP).

DIAMS has a two-layer (front-end) database for information management of Pipes, Structures, Outfalls, and Stormwater Manufactured Treatment Devices that is the entry point for DIAMS. The first layer (data review application) is an Access 2003 application with user-interfaces and queries as well as data manipulation procedures. The second layer is the database that stores performance and financial data of drainage infrastructure, as well as related photo/movie files and report documents, with all of the above components integrated into an effective data management system. Please note that Access 2003 has data capacity limitations and hence DIAMS consists of three separate databases. However, these databases are linked and streamlined in such a way that the user is unable to notice the existence of three separate databases.

Users can review, modify, save and delete database records in DIAMS to keep the system data up-to-date and display them conveniently by forms and reports as well as by photos and videos. The DIAMS program has four main modules consisting of: asset identification, financial analysis, data uploading, and system administration as shown in Figure 1. The functionality of each of the main modules and their submodules are elaborated upon in the following sections.

Asset Data Module

The Asset Module interfaces consists of a main switchboard, and four sets of data review/edit forms as shown in Figure 2. In addition to the main switchboard, the Asset Module interfaces contain several functional submodules, each of which are discussed below.

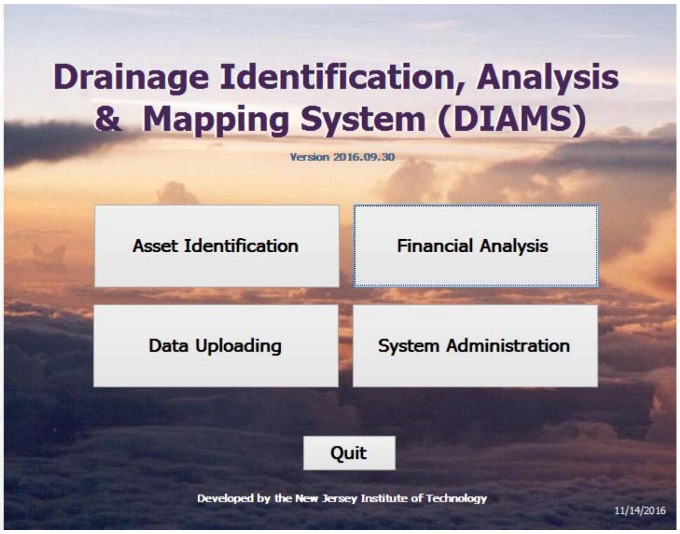


Figure 1. Main Form

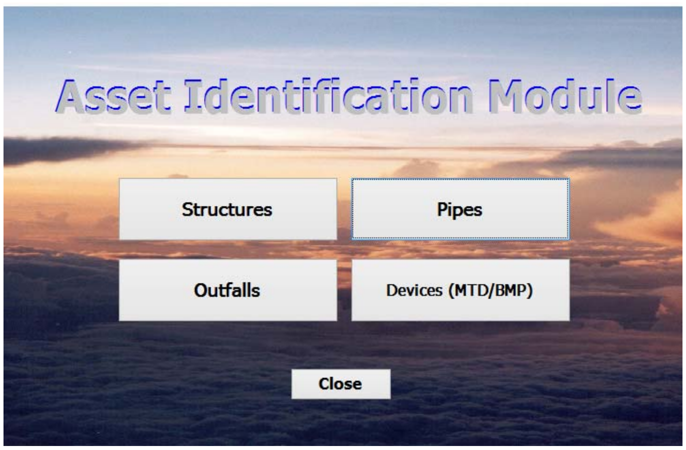


Figure 2. Asset Identification Switchboard Form

Inlet/Outlet Structures Data Module

The state's inlet-outlet structures are inspected by contractors who are tasked to identify and report their conditions so that decisions can be made regarding options of cleaning and repair as necessary. This task involves handling and deciphering an enormous amount of inspection data, both on the part of the inspectors and the state in managing the drainage system. The Inlet/Outlet Structures Data Module in DIAMS lightens this burden by giving searchable information about the locations of culvert endpoints, the inlet/outlet structures, and their conditions. In this module, digital photos of the culvert inlet and outlet structures are displayed. The Inlet/Outlet Structure Data form displays structure IDs and their attributes, as shown in Figure 3, as well as their inspection results. There are three combination boxes: (1) location by road name, (2) location by milepost, and (3) the expected inlet/outlet identification number that can be used to narrow the scope of search for a particular structure record. The structural asset information of the selected record is displayed on the upper selected box and the lower portion of the form will display related inspection information of the structure. The user can edit data fields on this form and add a new inspection record for a current structure. Photos can also be embedded into the structure records too. However, in order to keep data integrity, critical key fields, such as ‘Structure ID’, ‘SRI’, ‘Latitude’ and ‘Longitude’ are to be downloaded from the source database only, with no asset record addition and deletion. Please note that Standard Route Identification (SRI) system was developed to identify all NJ highways.

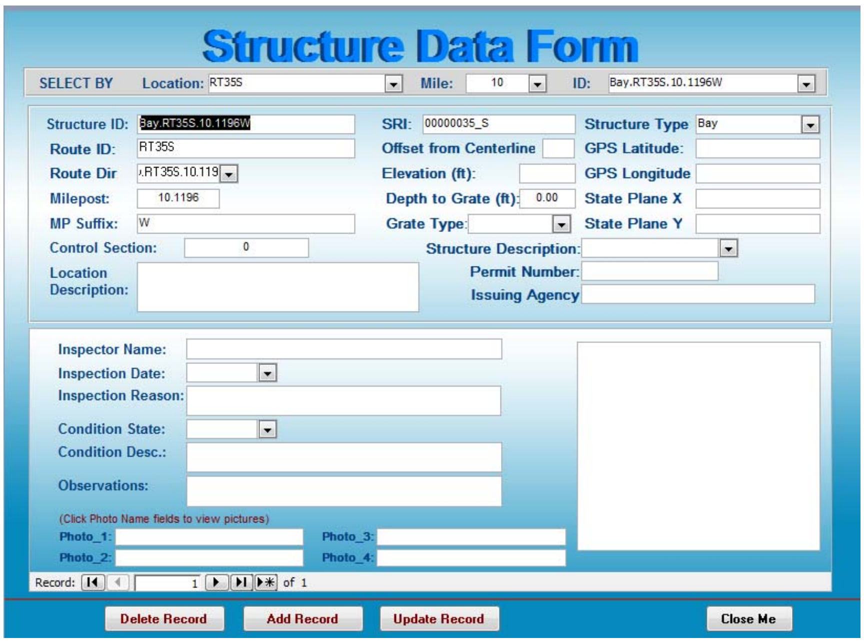


Figure 3. Inlet/Outlet Structure Data Form

Pipes Module

This module includes the pipe material type, current condition, treatment cost, and relevant date information for users to make operational decisions such as if the pipe needs inspection or rehabilitation treatment. There are three combination boxes: (1) location (Road, City, State…), (2) the start-manhole, (3) the end-manhole. This information will narrow down the selection range of a particular pipe record in order to access the details of the pipe asset, and also for record editing of data. This record includes all related inspection information of the selected pipe section record, including comments, photo file names, and movie file names, etc. However, in order to keep data integrity, critical key fields, such as Report ID and Video ID are not allowed to be modified. They are supposed to be downloaded from the source database only, with no asset record addition and deletion.

The decision-making process for pipe treatment starts with a treatment cost estimation. Based upon the pipe age, condition state, segment length and diameter, as well as, pipe material type, DIAMS will automatically calculate the standardized pipe treatment costs for the current pipe segment under review (e.g., the Installation cost, the Inspection/Cleaning cost, the Rehabilitation cost and the Replacement cost). If the treatment costs are not set yet for the pipe, they will be replaced by these auto-calculated standard costs. On the other hand, the pipe treatment costs will remain set at any existing values until they have been changed. The standardized costs are calculated based on a treatment unit cost table that was created based on common practice reported in the literature. The unit cost table is in fact used as a unit price template only, and users can modify the table's contents from DIAMS several Cost Estimation Forms, based on their working experiences. They can also add new items as data records into the table or delete those not usable.

By entering the cost items and quantities related to the pipe's installation, DIAMS will automatically calculate the total estimated installation cost for the pipe construction job. This total installation cost will be transferred back to the installation cost field on the Cost Estimation form as well as on the Pipe Assessment form. Based on all the estimated treatment costs, users can make a decision if certain treatment action should be performed. DIAMS can help users to justify if the chosen decision is worth performing by analyzing all suitable treatment techniques that the user can select and compare their corresponding expenses against their improved values. Based on the comparison, DIAMS will recommend or deny the user chosen techniques and remind the user to check existing data sets for accuracy.

DIAMS will also automatically compare the treatment technique costs (Action Costs) to 'Do Nothing' cost (i.e., the User Failure Cost) and notify the user if the selected action is justified or not. The user can make a choice to either accept the system recommendation or not.

Stormwater Device / Detention Basin Data Module

Stormwater detention basins and manufactured treatment devices (MTDs) are constructed to protect against flooding and, in some cases, downstream erosion by storing water for a limited period of time, in particular, MTDs act as stormwater treatment devices before discharge. Please note that the MTDs are approved as off-line water quality devices that are installed in urban settings to treat the stormwater before discharge. For Best Management Practices (BMPs), it essential to collect and maintain relevant data to enhance their overall performance and, for that matter, the performance of the drainage system.

The DIAMS system contains two stormwater data modules and one detention basin data module in the system. The modules are enumerated as: (1) Device Data Entry module is designed for entering major MTD data sets quickly; (2) MTD Data Review module is designed for registering/editing all related MTD information in details; and (3) BMP (Detention Basin) data entry module is for entering/reviewing detention basin information. These modules can be assessed from MTD/BMP Data Entry/Review Modules form which is a sub-switchboard form of the Devices (MTD/BMP) on Asset Identification Switchboard, as shown in Figure 2. The following sections will discuss each of the submodules.

Stormwater Device Data Entry
This module contains searchable records of stormwater device asset data, inspection data and major maintenance records, which are contained in a subforms under the following tabs: Device General Information, Inspection Information, and Maintenance Information. In locating a device record, the user can make use of two search methods: (1) by either specifying Location (Route/Street) or Milepost, or (2) by selecting the Device ID, Type and Model Number. Key fields to linking the device record to other related factual and dimensional data tables are Device ID, Type and the Model Number. For each device record, these three fields must be filled first in order to save the record into the system databases. In addition, there are five function control buttons on the bottom of the form for: adding of new records; deleting of error records; updating of modified records, and previewing of a maintenance report for the current record.

MTD Device Asset Data

This module contains stormwater device asset data, such as device IDs, Names, Types and Model numbers. Additional information is contained in a tabular format under the following tabs: location; project; attribute; watershed; and device-network spatial relationship information. There are three combination boxes, for users to search or specify the device ID, Type, and Model No. These three key fields will define the device category and attribute characters so as to link the device record to other related factual and dimensional data tables. For each device record, these three fields must be filled in first in order to save the record into the system databases. The rest of the device asset information has been organized into groups and displayed by five tab-forms. The following sections discuss the details of these tab-forms.

- Location Information
  This tab-form displays the geographic information of the current device asset. Users can edit data fields on this form. Optionally, a watershed picture should be provided to illustrate the watershed area of the device location with respect to its drainage network.
- Spatial Relationship Information
  In this tab-form the device is specified as either ‘online’ or ‘offline’ with respect to its existing proximity to the drainage network. The ‘Y/N’ textbox is use to alter the selections between ‘Yes’ (offline) and ‘No’ (online). Here one can record information of device related structures, pipes, and outfalls, and in addition, information on previously inspected and recorded relevant structures, pipes, and outfalls can be retrieved from the DIAMS database for use.

MTD Device Inspection Data Review

The Inspection Data Review form contains six tabs that display all the information of a single inspection record related to the device currently under consideration on the device asset form. Users can go through the six inspection data tabs to review or edit an inspection record of the device as well as its embedded photos. Also, users can browse through all the device’s inspection records. The following sections will discuss each tab:

- Routine Inspection
  This tab is used to record device routine inspection data in standardized data item entries.

- Measurements
  This tab defines the measurements of sediment/trash/debris/oil thickness deposited in device. The measured results will be compared with device trigger values to automatically determine if cleanout action is necessary. There is also a provision for recording data for a second chamber if the device demands.
- Inspection Decision
  This is a decision-making module based upon the field measurements and device manufacturers' recommended trigger values. Various cleanout action necessities are automatically calculated and represented as either 'Yes' or 'No'.
- Inspection Observation
  Device inspection observation data can be recorded on this form by altering the content of any 'Yes/No' textboxes.
- Structure Inspection
  Device related structure inspection data can be recorded on this form by using the combination boxes to fill in standardized data item entries.
- Inspection Photos
  Up to five inspection photos can be embedded into a single device inspection record.

MTD Device Maintenance Data

This module contains maintenance data records relevant to the selected device asset and its inspection records. It has four tabs that display all the information of device maintenance records related to the device under consideration from device asset/inspection forms. Users can go through all the four maintenance data forms to review or edit a single maintenance record of the device as well as its embedded photos. They can also browse through all the device's maintenance records. The functionalities of the tabs are listed below:

- General Info./Cleanout Planning
  This tab displays general information about the device maintenance as well as planned cleanout activities.
- Cleanout Records, Repair/Replacement Records, Maintenance Photos
  This tab records cleanout/repair/replacement action results as well as device photos taken before or after these activities.

BMP (Detention) Data Module

This form contains detention basin asset data and inspection records, contained under the following tabs: BMP General Information, Inspection Information (Part 1), and Inspection Information (Part 2) which are detailed below.

- BMP (Detention) General Information
  This sub-form displays the detention basin asset data such as ID, location, shape (Type) as well as its latitude and longitude. New data records can be added into system, through system prompts and commands. The key fields found here define the asset category and attribute characters so as to link the BMP records to other related factual and dimensional data tables. For each BMP record, these key fields must be filled in order to save the record into system databases.
- Inspection Information

The detention basin inspection result information will be entered into its Part 1 and Part 2 subforms, respectively. Figure 4 shows a sample inspection result report which can be generated by the user. Also, the diagram allows the user to generate and print an empty inspection data form when needed.

Outfalls (Stormwater Discharge) Data Module

Since an outfall is the point of release of the collected stormwater into the environment, such facilities are regulated by the U.S. EPA or the state Department of Environmental Protection, making their routine inspection, monitoring and maintenance not only vital for facility performance but also very crucial for regulatory compliance. The Outfalls Data Module contains information of outfall records.

There are three combination boxes for users to narrow down the searching scope for an outfall record. A location (Road) is selected at first, followed by a rounded Milepost (one mile per interval), and finally the expected outfall that is close to the selected round-up milepost value to display the outfall record. The data that are displayed will contain information on both outfall asset records and all related inspection information of the selected outfall. Users can edit data fields on this form. However, in order to keep data integrity, critical key fields such as ‘Outfall ID’, ‘Route ID’, “Route_Direction’ and ‘Milepost’, GPS coordinates, etc., should not be edited, but rather be downloaded from a source database. Any entered GPS data in the corresponding text fields can be converted into decimal numbers through the GPS Latitude or GPS Longitude data field.

The program also allows the user to browse through all existing outfall records, but presently can’t add and delete asset records. However, users can add a new inspection record for the current outfall, in addition to embedding of photos into the records.

Furthermore, the program allows the user to generate the current outfall inspection record report, shown in Figure 5, which summarizes the relevant stormwater discharge information of the outfall. Please note the physical observations, which are essential reporting data to the NJDEP to comply with Clean Water Act.

Monday, February 15, 2016

Stormwater BMP Basin Inspection and Maintenance Report

BMP - Basin General Information:

Inspection Date:	Inspector Name:	Weather:

Basin ID	Basin #	NJDOT Route	Nearest Milepost
Basin_384		RT78W	31.52

Municipality	County	Nearest Intersection

GPS Latitude:	GPS Longitude:
40.6481	-74.5211

Basin Location: Jug handle ramp ☐ Road side ☐ Stream side ☐ Off road ☐ Other ☐

Shape: Rectangular ☐ Round ☐ Oval ☐ Semicircle ☐ Elongated ☐ Other ☐

Inspection Information:

Basin Protection: None ☐ Guiderail ☐ Chain link fence ☐ Gate (Locked/Unlocked) ☐

Entered basin area? ☐ Access ramp to basin floor (Y/N) ☐

Basin size (Acres / sq. mi.): Side Slopes: Steep (<3:1) ☐ Mild (>3: ☐ Surveyed Slo...

Length Bottom: Width Bottom: Length Top: Width Top:

Basin Type According to Field Observation

1. Detention: (Detains stormwater. Has outlet device that empties basin)
2. Retention: (Temp. stores stormwater to be infiltrated. Has outlet device above basin floor)
3. Infiltration ___ (Infiltrates stormwater. No outlet device. Do/Doesn't have emerg. spillway
4. Wet Pond: ____ (Permanent pool of water due to groundwater elev. Has outlet device above floor)
5. Constructed Wetland: (Wetland vegetation on standing shallow water. Has outlet device)
6. Vegetated Channel: 7. Other:

Basin Condition: Dry ☐ Pool of water covers basin floor ☐ Est. water depth

Standing water: Floor low areas Inflow pipes area Outlet device area

Debris (Trash, leaves, litter, other): Basin walls Basin floor Outlet device Inflow pipe

Other:

Basin Walls Cover: Riprap Grass Dry Reeds Stumps Bare earth

Basin Bottom Cover: Sand Grass Overgrown veg. Trees Bare earth

Low Flow Channel: None Concrete Grass Bare earth Condition

Wetland Veg. Cover: #### % Basin floor #### % Basin walls ____ Dry Reeds

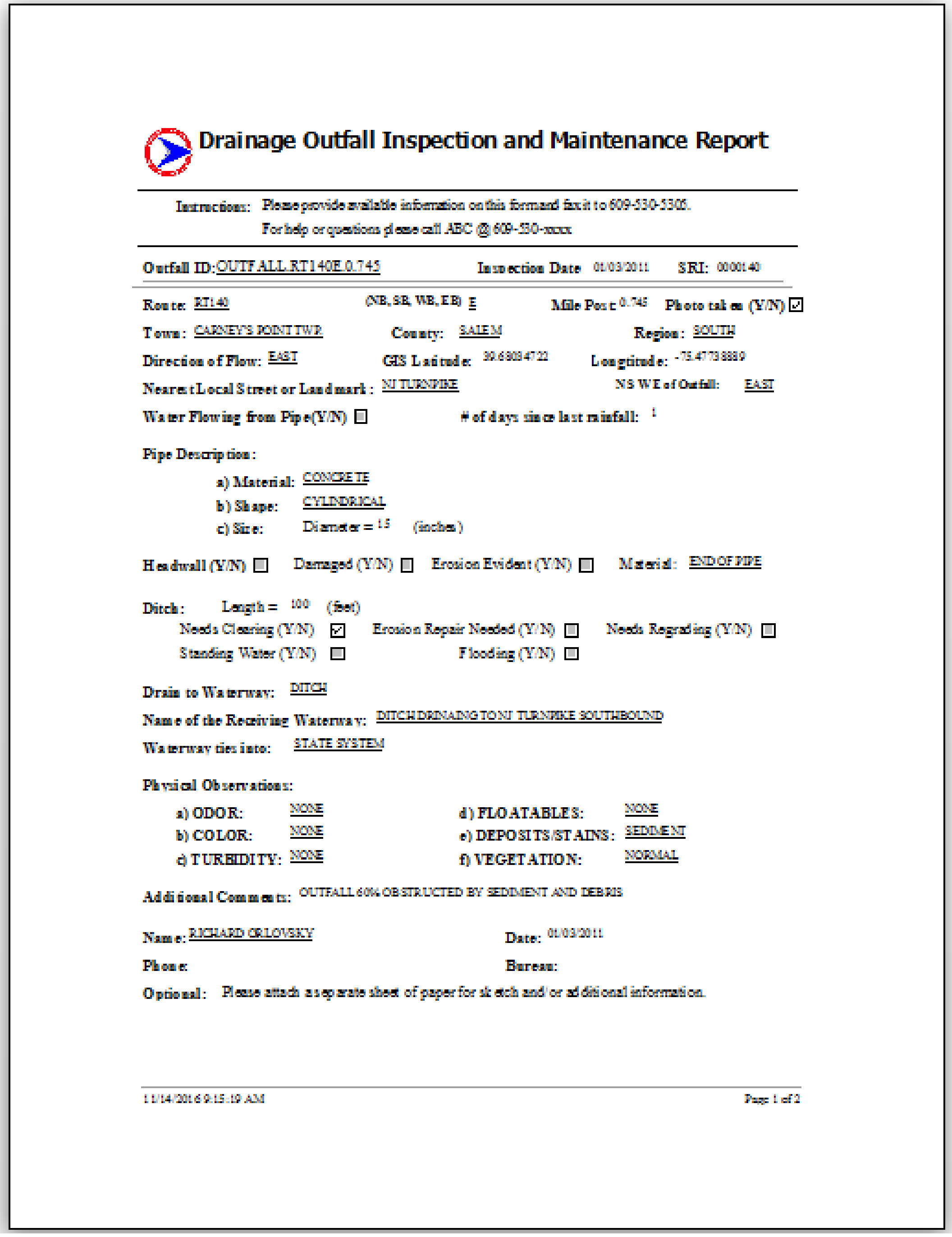
Basin is maintained or mowed: ☐

Erosion / Scour / Gullies: Basin bottom Basin walls In / Out Pipe

Siltation / Sedimentation: Heavy ____ Light ____ Basin floor ____ In / Out Pipe ____ Blocks pipe ____

Additional Comments on Inspection

Figure 4. BMP (Detention Basin) Inspection Report



Drainage Outfall Inspection and Maintenance Report

Instructions: Please provide available information on this form and fax it to 609-530-5305.
For help or questions please call ABC @ 609-530-xxxx

Outfall ID: OUTFALL.RT140E.0.745 Inspection Date 01/03/2011 SRI: 00000140

Route: RT140 (NB, SB, WB, EB) E Mile Post 0.745 Photo taken (Y/N) ☑
Town: CARNEY'S POINT TWP. County: SALEM Region: SOUTH
Direction of Flow: EAST GIS Latitude: 39.69084722 Longitude: -75.47738889
Nearest Local Street or Landmark: NJ TURNPIKE NS WE of Outfall: EAST
Water Flowing from Pipe(Y/N) ☐ # of days since last rainfall: 1

Pipe Description:
a) Material: CONCRETE
b) Shape: CYLINDRICAL
c) Size: Diameter = 15 (inches)

Headwall (Y/N) ☐ Damaged (Y/N) ☐ Erosion Evident (Y/N) ☐ Material: END OF PIPE

Ditch: Length = 100 (feet)
Needs Clearing (Y/N) ☑ Erosion Repair Needed (Y/N) ☐ Needs Regrading (Y/N) ☐
Standing Water (Y/N) ☐ Flooding (Y/N) ☐

Drain to Waterway: DITCH
Name of the Receiving Waterway: DITCH DRINAING TO NJ TURNPIKE SOUTHBOUND
Waterway ties into: STATE SYSTEM

Physical Observations:
a) ODOR: NONE d) FLOATABLES: NONE
b) COLOR: NONE e) DEPOSITS/STAINS: SEDIMENT
c) TURBIDITY: NONE f) VEGETATION: NORMAL

Additional Comments: OUTFALL 60% OBSTRUCTED BY SEDIMENT AND DEBRIS

Name: RICHARD ORLOVSKY Date: 01/03/2011
Phone: Bureau:
Optional: Please attach a separate sheet of paper for sketch and/or additional information.

11/14/2016 9:15:19 AM Page 1 of 2

Figure 5. Outfall Inspection Record Report

Data Uploading Module

This is a unique feature of DIAMS, where data generated by the maintenance contractors are automatically uploaded to the system. Data Uploading Module provides the functionality for users to upload various vendor data databases into DIAMS data database. The module contains a single uploading form that is used in a sequential order process that will allow the user to see which specific data have been uploaded, as shown in Figure 6.

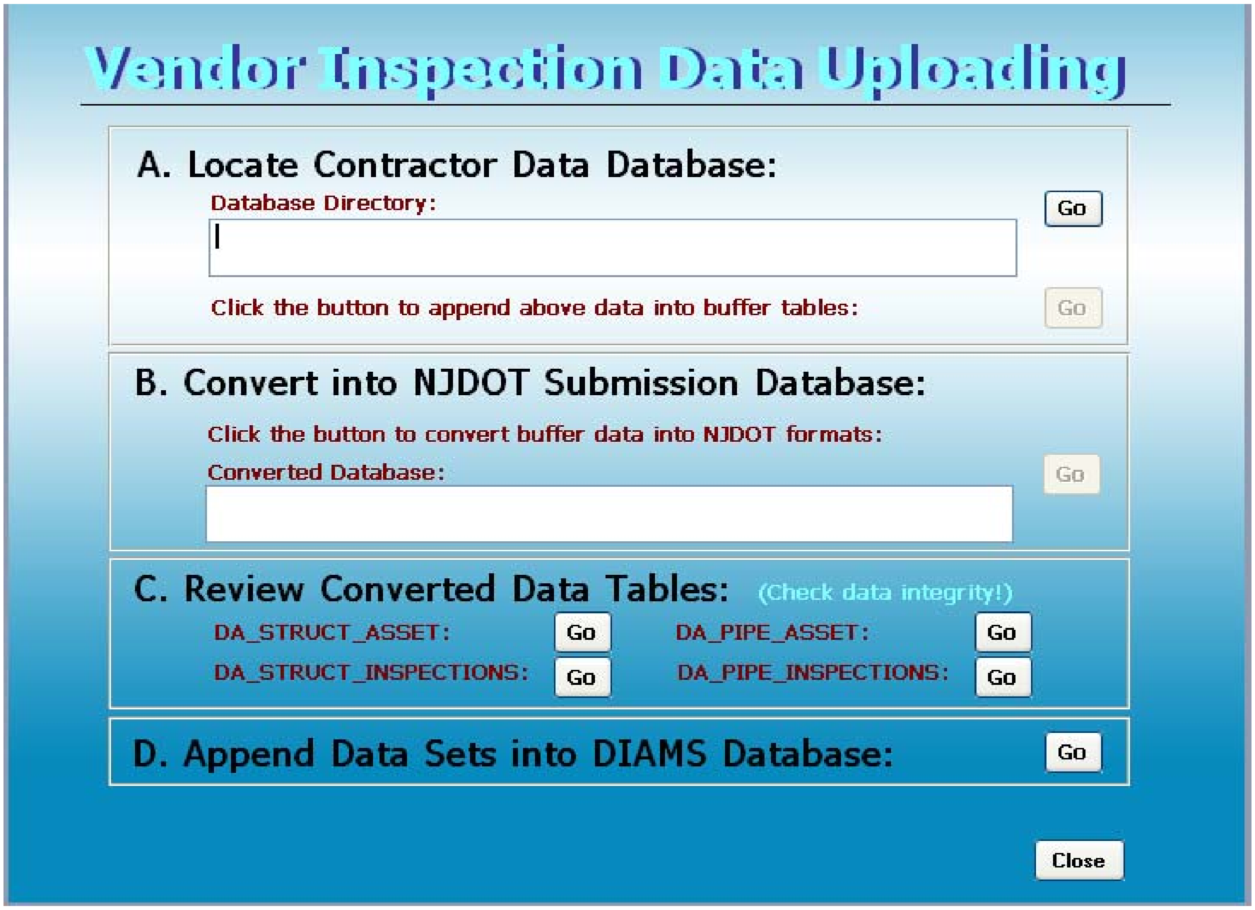


Figure 6. Vendor Inspection Data Uploading Form

Financial Analysis Module

The objectives of this financial analysis module are to (1) determine the optimum allocation of the current maintenance budget, by identifying the assets that are to be inspected, replaced, or repaired, (2) to estimate the minimum annual total budget needed over a given planning horizon, and (3) to make project level decisions to replace, rehabilitate or do nothing for a given state of assets. After the treatment techniques for the drainage infrastructure assets have been determined, the user can define maintenance projects. Here, a project is defined as a group of treatment jobs for drainage infrastructure assets to be considered for a given total budget.

With DIAMS, the user can search the optimal or near optimal solutions for the budget allocation among these treatment jobs of drainage infrastructure assets. The drainage infrastructure assets assessment and optimization process are the core components of the DIAMS pipe financial analysis module. The system evaluates the input data set and summarizes its major attributions, such as how many drainage infrastructure assets are in the project, what is the total capital required by their treatment jobs, and how many are pre-fixed jobs as well as the minimum required capital investments for these pre-fixed jobs. Figure 7 shows the budget optimization form.

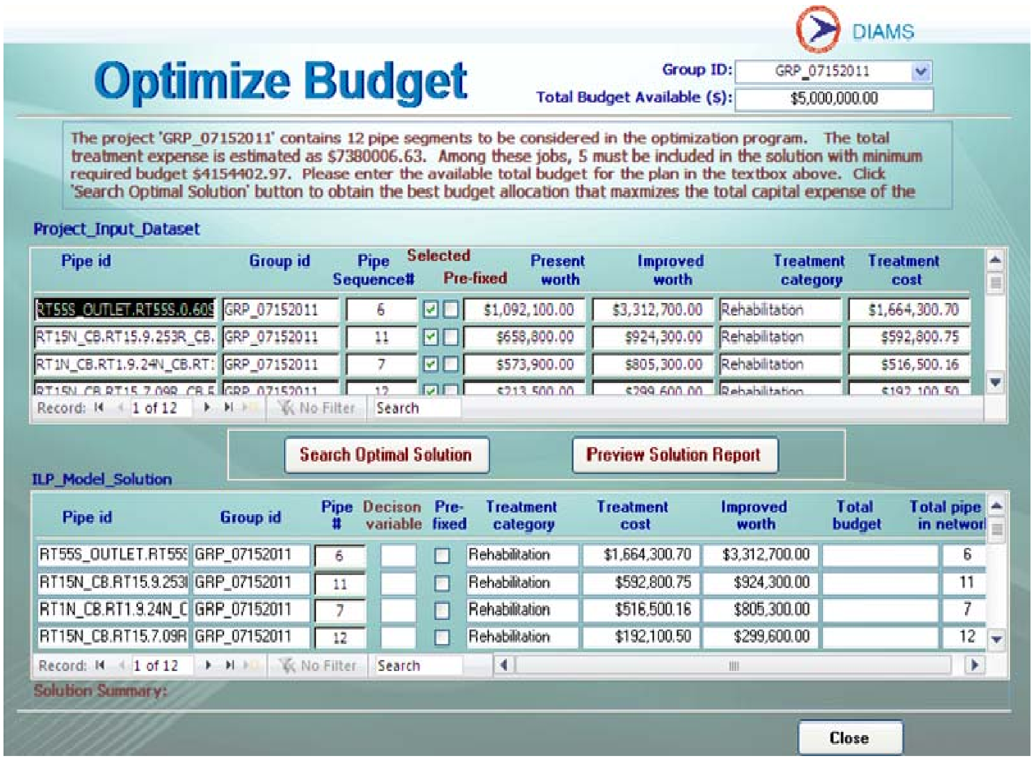


Figure 7. Optimize Budget Form

The system is setup to provide a solution for two algorithms, namely: (1) '0-1 Implicit Enumeration algorithm' to find real optimal solution or, (2) A heuristic procedure, named as 'Catch-the-big-fish', to obtain near-optimal solution. The 0-1 Implicit Enumeration algorithm enumerates all possible combinations of the decision variables and compares their resulting objective function values to determine the real optimal solution. On the other hand, the heuristic procedure sorts the selected treatments of the drainage infrastructure assets by their capital requirements then tries to capture the most costly ones without breaking the budget limit. The reason for two algorithms is that the real optimal solution for the integer program problem has 2^N computational complexity. When N>15, the enumeration will exceed 32,768 combinations. Although, the objective function and budget constraint are both simple linear additions, it may take a long time to evaluate all possible combinations when N gets too big. Therefore, it is recommended to use the heuristic when N>25. The heuristic covers the more costly segments first then the smaller ones until the available budget is consumed.

System Administration Module

The program's System Administration Module provides a place for users to edit, add, delete, and save keywords. These keywords, as depicted in Figure 8, are provided here as standard data entry values for some fields in asset and inspection forms of system entities. This form holds all the list table records designed for the DIAMS application. Users can modify these records to meet their individual needs.

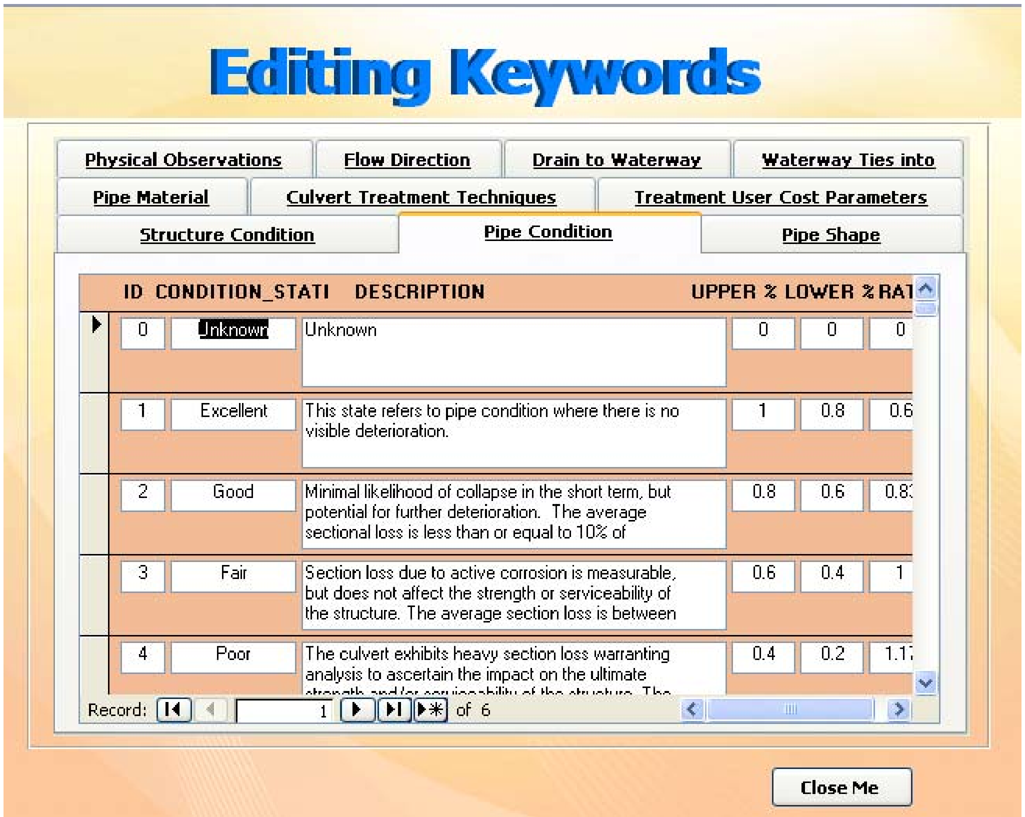


Figure 8. Standard Data Item Edition Forms

Please note that the Treatment User Cost Parameters should be updated on June 30th of each year. At that time, the user needs to visit Federal Reserve Bank of Minneapolis web site for Consumer Price Index (CPI) calculator to compute the escalation factor for that year to be used as well as to modify other parameters when necessary.

SPECIFIC OUTPUTS FROM TASK 1

According to DIAMS phase II specified tasks, the DIAMS data database and application database have been updated since August 2015.

- The Phase II task 1 required that the DIAMS application adapt several new data formats used by contracted companies such as the National Water Main Cleaning Company (NWMCC) and Mount Construction Company (MOUNT). The new data formats needed to be analyzed and mapped to existing data structures in the DIAMS application.

  The MOUNT databases have significant changes between their new and old formats. Also, the software used by contractors, e.g., WinCaN7 and WinCaN8, have different field names for the corresponding information in the DIAMS systems. Based on the limited database copies available, the NJIT team carefully compared new and previous data formats and found the following general issues need to be considered:

  (a) As in the previous version, there are missing manhole inspection information records. There is a need to derive or create the manhole inspection information from the related pipe inspection records.

(b) Typing errors exist. Many manhole ID entries did not follow the specification formats. Should these data CDs be rejected? Or is it the job of the data downloading staff to make corrections. These factors indicate a need to develop more data format auto-correction programs to ensure data quality control.

(c) Companies use different dimensional tables to guide data entries in data input. It is suggested that all companies use the same sets of dimensional tables as standard data entry templates and incorporate these dimensional tables into DIAMS so that the data records in the tables will display unified data definitions of the data entries, not numerical codes with different meanings.

(d) Contractors' databases were created by previous Access versions. Access 2013 may have problems opening databases and compatibility will need to be checked. Also, Upgrading Access 2007 to 2013 will require a modification of the DIAMS application codes. (e.g., 32 bit machines upgraded to 64 bit, such as, mouse wheel function, etc.)

(e) Check existing records for MH/Pipe ID errors. For example,
RT22_INLET.RT22.650RT650_UNKNOWN.RT22.650RT650; (INDUSTRIAL AVE RAMP, KEASBEY, NJ)
_RT22_INLET.RT22.650RT650_UNKNOWN.RT22.650RT650

(f) Offset_From_CL data source is missing from new formatted databases. How to define the Offset_From_CL by MH names - MH.RT28E.3.83; OF.RT28E.3.75#2; MH.RT28.6.15R; MH.RT28.6.15R1; MH.RT28W.4.195PL; CB.RT17S.19.480W; MH.RT35S.13.567SM; MH.RT35S.12.914SA, xxxN, xxxS, xxxW, xxxE, etc.

- The application programming has been modified based on the detailed data analysis of these new data formats. Separate sets of new queries and procedures have been developed to deal with both new and old data formats for each company, so that the application can identify and manipulate different version data in downloading/uploading processes automatically.

  Also, the VBA codes are modified so as to let the application run on either 32 bit or 64 bit machines. These modifications have been tested and used in the new data downloading/uploading process successfully.

- The DIAMS data database has nearly reached the Access database capacity limit (2GB). In order to improve the performance of the application, the DIAMS data database has been split into three separate data databases:
  (a) D**IAMS_DATASOURCE_Pipe_Struct_Outfall** – includes all Pipe, Structure, Outfall related data sets;
  (b) **DIAMS_DATASOURCE_MTD** – includes all MTD related data sets;
  (c) **DIAMS_DATASOURCE_Dimensional** – includes all dimensional tables; error checking list tables; etc.

  All three data databases are linked to the DIAMS application (Access version) by linked table manager.

- Based on the improvements mentioned above, DIAMS user manual has been edited to reflect the changes made.

- Specified Folder Structure for Installation:
  (a) Main folder: C:\DIAMS SQL APPLICATION\ - copy the following files:
    - Data database - **DIAMS_DATASOURCE_Pipe_Struct_Outfall; DIAMS_DATASOURCE_MTD; DIAMS_DATASOURCE_Dimensional**
    - Application database - **DIAMS_Application_mmddyyyy_access; DIAMS_Application_mmddyyyy_sql**
    - Working databases - NJDOT_Submission_DB; NJDOT_Submission_DB_BK; CIMS_UploadingDB; CIMS_UploadingDB_BK; All_Projects_Pipe_MH_Links; Current_Project_Pipe_MH_Links
    - .dll file - MouseHook.dll

  (b) Sub-folders: (Some files in the folders can be copied into user machines if needed.)
    (i) .\ ImageFiles
      .. \Manholes\Photos*.jpg … (Photos for manholes if any)
      .. \MTD\Photos*.jpg… (Photos for MTD if any)
      .. \OutFall\Photos*.jpg… (Photos for Outfall if any)
      .. \Pipe
        …\Movies*.mpg … (Movies for pipes if any)
        …\Photos*.jpg … (Photos for pipes if any)
    (ii) .\User Manual
    (iii) .\DIAMS_BK\ *… (Any application database backups)

- Remarks:
  The MS Photo Editor used by the application to display image files needs to be re-installed when MS Access has been updated to 2007 or higher version (See user manual for details). There has been an issue pertaining to the image files – the size (i.e., dimensions) of image files for the MS Photo Editor is limited. Photos must be pre-justified in their sizes and dimensions before being saved into image folders. If the size or dimension is too big, the photo editor will not be able to read the file and an error message will be displayed. A substitution of MS Photo Editor should be considered.

  The MediaFiles folder and its sub-folders contain video material of asset inspection results. When the user searches an inspection record on a form, the system will automatically match the recorded image file names with the image files in these folders. If a matched image file is found, the system will link the image file to an OLE object on form and display it. The question is whether or not all of the image files should be saved into a centralized storage space so that all users could share the same information source, or should these files be duplicated into individual user machines separately?

  Currently, each user machine should make a full copy of these folders and image files. If centralized later, the application's coding must be modified so that the system can automatically search corresponding image files from the centralized storage server space, e.g., usually a network server space.

SPECIFIC OUTPUTS FROM TASK 2

The NJIT team uploaded NJDOT DVD data into a DIAMS server installed in the NJIT computer lab. The uploaded data sets were normalized. By July 30, 2016, two basic data tables were loaded with new inspection records as follows:

Table Name	(New) NJIT
• dbo_DA_PIPE_ASSET :	4078
• dbo_DA_PIPE_INSPECTIONS:	4313

A total of 466 DVDs were uploaded and the inspection company breakdown is given below:

- Cook project - 6
- Mount project - 25
- NWMCC – 435

The numbers above increased because NJIT uploaded more NJDOT DVDs up until the DIAMS server was installed at NJDOT in December 2016.

DISCUSSION AND FUTURE RECOMMENDATIONS

DIAMS addresses the problems of archiving, accessing, analyzing and optimizing drainage infrastructure asset data for a highly efficient reporting system. The Asset Identification module stores all the receiving stormwater data such as the quality/quantity of water and discharge to watersheds, while also being able to develop general property reports. Analysis ratings are used for the asset locations relative to the NJ roadway centerlines. Users can locate assets needing immediate repair by road/milepost based upon their condition state. NJDOT's drainage infrastructure asset management is analyzed from historical records and condition states of all assets in the system.

The DIAMS capabilities include identifying drainage infrastructure, maintaining inspection history, mapping locations, predicting service life based on the current condition states, and assessing present asset value. In addition, the DIAMS contains several different repair, rehabilitation and replacement options to remedy the drainage infrastructure.

The DIAMS can analyze asset information and determine decisions to inspect, rehabilitate, replace or do nothing at the project and network levels. At the project level, it compares costs with risks and failures. This is achieved by comparing inspection, cleaning or repair costs with risks and costs associated with failure. At the network level, the associated costs are optimized to meet annual maintenance budget allocations by prioritizing drainage infrastructure needing inspection, cleaning and repair.

In addition, the financial analysis module will output data into categories including inspection, cleaning, repair, and condition states. The process will direct users and decision makers to calculated work orders, which will be reported in summaries, allowing the best choice for asset performance implementation for each asset type.

Changes in weather patterns and their associated climatic variability affect hydrologic conditions and the hydrologic responses of watersheds (Arisz and Burrell 2006). As corroborated by various studies, climatic changes have brought about increases in rainfall intensities, which is one of the main dynamics responsible for the presently observed increased frequency of flooding in cities (Arnbjerg-Nielsen and Fleischer 2009, Kleidorfer et al. 2014). The cumulative effects of these changes in hydrology due to climatic change are expected to alter the magnitude and frequency of peak flows over the service life of drainage infrastructure. Potential future changes in rainfall intensity are expected to alter the level of service of drainage infrastructure, with likely increased rainfall intensity resulting in more frequent flooding of storm sewers and surcharging of culverts (Arisz and Burrell 2006). Consequently, higher runoffs have impacted sewer and drainage system performance in terms of higher risk of flooding and sudden failure of drainage infrastructure due to increased flow rate, increasing the vulnerability of the country's drainage infrastructure (USGAO 2013, Neumann et al. 2015) and subsequent decrease of stormwater treatment performance.

Hence, city planners have to take into consideration all of these climatic changes and their effects in drainage system design, maintenance and replacement (Ashley et al. 2005). Consequently, once all NJDOT drainage infrastructure is identified and catalogued, it is proposed to incorporate a module to mitigate the climate change. With known rainfall and duration, as well as, known impact area and carrying capacity of drainage infrastructure, it is proposed to simulate the impact of climate change to update or eliminate bottlenecks and improve pump capacities to handle increased flow rates and to eliminate flooding and sudden failures of drainage infrastructure.

SUMMARY AND CONCLUSIONS

The DIAMS consists of three major computer software components: databases, user interfaces and functionality modules. Among the significant performance features of DIAMS is its proactive nature, which affords decision makers the means of conducting a comprehensive financial analysis to determine the optimal proactive schedule for the proper maintenance actions and to prioritize them accordingly. The DIAMS structure is laid out to simplify the process of using the system to allow efficient and productive sequential flow of the information performance system. It includes four separate modules: asset identification, vendor upload, financial analysis and system administration.

The vendor upload module has various sub-nodes to ensure that the contractor-supplied field collection data uploaded to the database is unified and consistent. The asset identification module performs key attribution of the various physical components, and assigns functionality attributes of the huge inventory of a drainage infrastructure. The system administration module supports low-level data reviews and editing. The final module is the financial analysis for maintenance and repair costs, in addition to design and extension of drainage network. The pipe condition state from inspection records and stored unit cost information are used for cost analysis.

Financial analyses of assets are performed by comparing inspection and/or rehabilitation costs with associated risks of failure. Benefits of DIAMS include long-term savings that accrue by adopting optimized preventive maintenance strategies and facilitating compliance with governmental accounting standards bureau (GASB-34) and federal stormwater regulations. Possible improvements to DIAMS includes the system wide design improvements to accommodate impacts of climate change.

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