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Stormwater Management Rule Implementation Process

FINAL REPORT
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16. Abstract

The N. J. Department of Environmental Protection's Stormwater Management Rules (N.J.A.C. 7:8), adopted on February 2, 2004, has created more stringent storm water management standards for land developments in the state, including roadway and other transportation projects. These Rules include requirements for groundwater recharge and both stormwater quality and quantity control. A Stormwater Best Management Practices (BMP) Manual was developed by the NJDEP to assist regulated agencies such as the NJDOT with Rule compliance. However, the BMP Manual lacks sufficient guidance to properly lead engineers to identify applicable regulations and select appropriate storm water management measures for transportation projects.

As a result, NJDOT planners, designers, and maintenance personnel need a simplified process to navigate the Stormwater Management Rules and facilitate the selection of appropriate stormwater management measures. This report documents the development of an electronic decision-making program in Microsoft Excel that provides such a process. This program also assists NJDOT personnel in determining during early project stages whether all of the requirements of the Rules can be met for a specific project or whether hardship waivers will be necessary.

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EXECUTIVE SUMMARY

This report describes a comprehensive study and computer programming effort to implement the Stormwater Management Rules (NJAC 7:8) promulgated by the New Jersey Department of Environmental Protection (NJDEP) in February 2004 at roadway and other transportation projects by the New Jersey Department of Transportation (NJDOT). The project has resulted in a Microsoft Excel-based computer program that assists NJDOT planners, designers, and managers in the development of roadway projects that meet the Stormwater Management Rules.

Development of the computer program began with an exhaustive literature search of stormwater management standards and Best Management Practices (BMPs), with specific emphasis on how they are being applied to roadway and other linear transportation projects. This search included various state regulations, books, and research papers on these topics, including the New Jersey Best Management Practices (BMP) Manual. The results of this search indicate:

1) While technically sound, the New Jersey BMP Manual does not provide adequate guidance in the selection of appropriate BMPs for roadway projects.
2) The California Best Management Practice Handbook provides a good decision tree and check lists that could be used as the basis for the computer software.
3) The Washington Highway Runoff Manual provides helpful guidance in the selection and planning of BMPs.
4) The Western Washington Stormwater Management Manual gives a step-by-step procedure for developing stormwater pollution prevention plans.
5) The Georgia Stormwater, Vol. 2 provides a BMP maintenance checklist.
6) Other documents of interest included the Maryland, Missouri, and Idaho BMP Manuals.

From these results, it was recommended that the New Jersey BMP Manual be used as both the technical and regulatory basis of the new computer program, with additional technical guidance derived from other search documents, particularly the Maryland BMP Manual.

Following the literature search, a questionnaire was sent out to 8 regulators and 10 consultants to collect expert input. From the questionnaire responses, it was determined that the two biggest problems design were a shallow depth to Seasonal High Water Table (SHWT) and limited Right-of-Way (ROW) in which to locate required BMPs. With relatively high annual rainfall and with large percentages of the state either close to sea level and/or underlain by aquifers, bedrock, or dense soils, the chance of encountering a high groundwater table at a roadway project site is common. A high water table makes it very difficult to utilize BMPs that rely on runoff infiltration. Most BMPs require relative large areas of land to be effective, which creates particularly acute planning and design problems for projects with limited ROW. Lack of adequate soil permeability in many areas of the state creates additional BMP selection difficulties, along with areas of soil contamination.

Other problems identified in the questionnaires include limited space in urbanized areas, lack of adequate BMP maintenance, a need for multiple BMPs in areas that discharge to C1 waters, and potential safety hazards with BMPs in highway clear zones.

An electronic decision-making program was developed using Microsoft Excel. Excel was selected since it is widely available to most users. The electronic decision-making program was tested on selected roadway projects that had already been completed. The final result is an easy to use computer program that will help planners, engineers, and managers comply with the NJDEP Stormwater Management Rules at roadway and other linear transportation projects. Finally, since the Rules are expected to change over time, the program was written to easily incorporate these changes.

BACKGROUND

The NJDEP implemented the Stormwater Management Rules N.J.A.C. 7:8 in February 2004 in order to protect the waters of the State from adverse impacts of stormwater runoff. The regulations require projects that disturb one or more acres of land or create at least 0.25 acres of impervious surface to comply with stringent stormwater management standards. These regulations are general in nature and are difficult to implement within a transportation project. The Stormwater Best Management Practices (BMP) Manual developed by the NJDEP provides examples of techniques and various methods to meet the standards, however it requires the designer to be aware of all the applicable NJDEP regulations and select the appropriate stormwater management technique.

A typical NJDOT roadway project consists of primarily linear development through an urban corridor with limited Right of Way (R.O.W.). Impervious surfaces accumulate pollutants deposited from the atmosphere, leaked from vehicles, or windblown from adjacent areas. During storm events, these pollutants quickly wash off and are discharged to the downstream waters. Some common pollutants found in urban stormwater runoff include: nutrients, suspended solids, organic carbon, bacteria, hydrocarbons, trace metals, pesticides, chlorides from salts that are applied in the winter months and trash and debris.

Stormwater Management Rule N.J.A.C. 7:8 requires stormwater treatment. The use of manufactured treatment devices has been the most common method of addressing water quality. However the new Stormwater Rules assign removal rates to the treatment techniques and the total removal rate for the stormwater treatment system must exceed 80%. As a result treatment techniques will now have to be combined in a treatment train to create a cumulative total removal of more than 80%.

Stormwater Management Rule N.J.A.C. 7:8 also requires groundwater recharge. The recharge system must include non-structural and/or structural stormwater management measures that prevent the loss of groundwater recharge at the project site.

The NJDOT planners, designers and maintenance personnel realize the need for a simplified process to navigate the regulations and to narrow down the selection of the most appropriate BMP techniques. A clear understanding and proper selection of the appropriate BMP is extremely critical at the planning and design stages of the project. The selected BMP technique identifies the impact to environmentally sensitive areas, determines the need for additional R.O.W., facilitates a formal agreement with the NJDEP as part of the project development and allows the project manager to estimate the potential cost to the project.

RESEARCH OBJECTIVES

The objectives of this study were to:

Develop an electronic decision process to assist planners, designers and maintenance staff to

- Determine applicable stormwater rules.
- Identify the appropriate treatment train of non-structural and structural stormwater strategies and measures including manufactured treatment devices to comply with the Stormwater Rules.
- Consider treatment capacity, footprint (Right of Way requirements), cost, frequency of maintenance and operating cost.

INTRODUCTION

It was realized from the beginning that this project would be difficult because there were no “black and white” issues involved. The demands of the rule implementation invariably require manufactured treated devices, which are maintenance intensive and costly. In addition, the use of “hardship” waivers are discouraged and are not accepted without detailed justification that some manufactured device could not be implemented, regardless of the cost.

The research effort started with a detailed literature search, a request for input from those doing practical work in the field, and many discussions on a decision tree matrix that would capture the regulatory requirements.

Finally, an EXCEL spreadsheet program detailing the decision process was set up and tested on real projects that had already been built. The results of this effort are detailed below.

The NJDEP BMP Manual is used in guiding the beginning of the storm water process. The users are asked what type of pollutant(s) is present, and what is in excess. The effects of the pollutants will be given to the user, and the process is used to help narrow down which technique will fit the specific pollutant needs. All the important regulations that are needed are incorporated and all the methods and formulas that are required for the calculations in each of the BMP techniques is incorporated in the electronic process. Lastly, the general guidelines for each of the BMP techniques are included in the computer program. In addition, information from other manuals and case studies were considered.

The NJDEP BMP manual alone could not be used to make this computer program because it is primarily a technical guide. First, one method needs to be selected to calculate stormwater runoff rates and treatment volumes. Second, the BMP techniques are very general. They are not adapted to the specific uses: residential, construction, industrial or municipal. Each technique needs to change for the different uses and the NJ BMP manual does not spell this out. Since this project is mainly concerned with construction of roads and highways, only BMPs applicable to lineal development were considered. Evaluation of the process was accomplished by using projects already designed.

A stormwater best management practice (BMP) is a technique, measure or structural control that is used for a given set of conditions to manage the quantity and improve the quality of stormwater runoff in the most cost-effective manner. The American Society of Civil Engineers (ASCE) National Stormwater BMP Database has grouped and defined structural BMPs as follows:

- Infiltration systems capture a volume of runoff and infiltrate it into the ground.
- Detention systems capture a volume of runoff and temporarily retain that volume for subsequent release. Detention systems do not retain a significant permanent pool of water between runoff events.
- Retention systems capture a volume of runoff and retain that volume until it is displaced in part or in total by the next runoff event. Retention systems therefore maintain a significant permanent pool volume of water between runoff events.
- Constructed wetland systems are similar to retention and detention systems, except that a major portion of the BMP water surface area (in pond systems) or bottom (in meadow-type systems) contains wetland vegetation. This group includes wetland channels
- Filtration systems use some combination of granular filtration media such as sand, soil, organic material, carbon or a membrane to remove constituents found in the runoff.
- Vegetated systems (biofilters) such as swales and filter strips are designed to convey and treat either shallow flow (swales) or sheet flow (filter strips) runoff.
- Minimize directly connected impervious surfaces describes a variety of practices that can be used to reduce the amount of surface area directly connected to the storm drainage system by minimizing or eliminating traditional curb and gutter.

No single BMP can address all stormwater problems. Each type has certain limitations based on drainage area served, available land space, cost, pollutant removal efficiency, as well as a variety of site-specific factors such as soil types, slopes, depth of groundwater table, etc. Careful consideration of these factors is necessary in order to select the appropriate BMP or group of BMPs for a particular location.

BMPs used by the various states in summarized in Appendix A. Several states do not have a BMP manual. While New Jersey does not use every available BMPs used, it does allow a significant number of BMPs.

SUMMARY OF WORK PERFORMED

Literature Survey

An exhaustive search was made of stormwater management BMP rules and their implementation, and specifically, how they are being implemented in regard to linear development projects for roads and highways. This included the various state regulations, books, and papers on this topic. Outputs of literature search indicate: 1) The NJ BMP Manual is good technically, but provides no decision tree for selecting BMPs. 2) The California BMP Handbook provided a good decision tree and check list that was used as a starting point. 3) The Washington Highway Runoff Manual was helpful in detailing planning and choosing BMPs. 4) The Western Washington Stormwater Management Manual gave a step-by-step procedure for developing a plan on pollution prevention. 5) The Georgia Stormwater, Vol. 2 provided a checklist for maintenance. 6) The Maryland, Missouri and Idaho BMP documents provided some valuable input.

There were only a few relevant papers or books found to be of benefit to the development of the decision process. The State of California process provided the most relevant guidance, which although a bit complicated, was a good starting point.

Literature of Interest

<u>NJDEP Best Management Practices Manual (BMP)</u>

<u>Impacts of Development on Runoff</u>
Development can cause major changes to the hydrologic response of an area and its entire watershed. During development, beneficial native vegetation is disturbed and replaced with impervious surfaces or lawns and therefore disturbing the hydrologic cycle. There is no more filtration of the water, and there is less groundwater recharge since most of the water is going too quickly into the gutters and into the closest waterway. The water quality of the runoff is also harmful to the waterways as it increases the amount of suspended solids, nitrogen, phosphorous, chlorides, and other chemicals in the waterways (each having different effects on the waterway).

Solid pollutants such as bottles, cans, paper bags, and any debris are transported to waterways where they can be washed ashore or settle onto the bottom of the waterway. These first can cause clogging in drains, create aesthetic and recreational problems at local beaches, and create problems for sea life. Sediment that is soil material is one of the most significant problems. Sediments also have a tendency of clogging drains. It creates increased turbidity in waterways, reduced light, and clogged fish gills.

Nutrient deposits especially inorganic nitrogen and inorganic phosphorous are of major concern to New Jersey. These chemicals can cause excessive plant growth in aquatic systems, eutrophication, algae growth, and extra pollutants in drinking water.

The mentioned pollutants and other nonpoint sources such as pesticides, herbicides, pathogens, road salt, and fertilizers all need to be taken into consideration during new or redevelopment. It is important to know how the natural system works with all these chemicals and how it filters these chemicals, in order to build a system that will closely replicate the natural processes. In the electronic program, the user must know what is present at the site currently and what pollutants need to be removed and what are the desired levels of the different chemicals in order to select the BMP technique that will fit the specific needs.

Stormwater Pollutant Removal Criteria

The U.S. EPA and the NJDEP set removal standards for these pollutants. By N.J.A.C 7:8, any project that creates at least 0.25 acres of impervious surface must meet an annual total suspended solids (TSS) removal rate of at least 80%. This chapter also sets the first design considerations for all projects. In order to achieve all the reduction requirements, all designs must be made to treat the runoff from the stormwater quality design storm, a 1.25 inch/2 hour rainfall rate. This will be very important in calculate runoff rates.

The TSS removal rates and nutrient removal rates are important. The removal rates given for the different BMP techniques are outlined in Table-1.

Table 1. TSS Removal Rates for BMPs[*]

Best Management Practice (BMP)	Adopted TSS Removal Rate (%)
Bioretention System	90
Constructed Stormwater Wetland	90
Dry Well	Volume Reduction Only[1]
Extended Detention Basin	40 to 60[2]
Infiltration Structure	80
Manufactured Treatment Device	See N.J.A.C. 7:8-5.7(d)[3]
Pervious Paving System	Volume Reduction Or 80[4]
Sand Filter	80
Vegetative Filter	60-80
Wet Pond	50-90[5]

[*]Taken from Table 4-2, Ch. 9, of NJDEP manual.
[1]See NJDEP manual.
[2] Final rate based upon detention time. See Chapter 9 of NJDEP manual.
[3]To be determined through testing on a case-by-case basis.
[4]If system includes a runoff storage bed that functions as an infiltration basin.
[5]Final rate based upon pool volume and detention time.

Table 2 from NJDEP's document gives the phosphorous and nitrogen removal rates.

Table 2. Typical Phosphorous and Nitrogen Removal Rates for BMPs

Best Management Practice (BMP)	Total Phosphorous Removal Rate (%)	Total Nitrogen Removal Rate (%)
Bioretention Basin	60	30
Constructed Stormwater Wetland	50	30
Extended Detention Basin	20	20
Infiltration Basin	60	50
Manufactured Treatment Device	See N.J.A.C. 7:8-5.7(d)	See N.J.A.C. 7:8-5.7(d)
Pervious Paving	60	50
Sand Filter	50	35
Vegetative Filter	30	30
Wet Pond	50	30

These two tables were valuable in creating the electronic decision process as the users can input desired removal rates and narrow down their selection of BMP techniques.

For the TSS removal rates, not all techniques meet the 80% standard. BMPs in series can be evaluated and applied to meet the required removal rate. These guidelines are also presented in the computer program as the user will need it if they decide to design a series.

Computing Stormwater Runoff Rates and Volumes

The fundamentals of computing stormwater runoff rates and volumes from rainfall use two main methods – the Rational Method, and the Natural Resources Conservation Service (NRCS) methods. The rational method has been used for many years. It is best used to estimate peak runoff rates and is generally not used to predict the total volume of runoff. There are other methods that can be used to predict the total volume of the runoff. However, the NRCS method can predict the total volume of runoff, the peak rates and hydrographs for runoff. To use both of these methods, the drainage area has to be 20 acres or less. The design calculations must be done for at least the water quality storm (1.25 inch rainfall non-uniformly distributed over 2 hours) and the 100-year storm (8.6 inch rainfall non-uniformly distributed over 24 hours in Middlesex County). The water quality storm will determine the water quality design and the 100-year storm will help determine the flood control design. This chapter outlines how to do the calculations for the Rational Method (and the associated Modified Rational Method) and the NRCS Method and it gives examples of each. Table 3, as taken from the NJDEP manual outlines what method to use under what conditions.

Table 3. Summary of Modeling Guidance for Various Site Conditions Rational, Modified Rational and NRCS Methods

Site Condition or Parameter	Rational Method	Modified Rational Method	NRCS-Based Methods
Mixture of pervious and directly connected impervious surface	Use Standard procedures	Use standard procedures	Use weighted average runoff volume
Unconnected impervious surface	Use not recommended	Use not recommended	TR-55 or Two-Step Technique
Groundwater recharge areas	Reduce effective size of recharge area	Reduce effective size of recharge area	Reduce runoff volume by recharge volume
Time of concentration	Maximum sheet flow length =150 feet Maximum sheet flow n = 0.40 Include effects of storage and ponding areas.		

Note: Table presents summaries only.

Using the two different methods can result in two different answers in peak rates. Therefore, it is important to establish which method should be used. This needed to be considered when making the electronic program so that there would be no confusion on what peak rate to use and to ensure uniformity.

Journal Articles and Research Papers

Managing Stormwater, Parris, T.M.
This article is helpful in that it lists other resources for stormwater management. First it provides states that have active stormwater management programs: California, Florida, New York, Vermont, Virginia, and Washington. Other important resources included the Stormwater Manager's Resource Center (http://www.stormwatercenter.net) the International Stormwater Best Management Practices Database (http://www.bmpdatabase.org). Many other sources are listed; however, they are directed towards community involvement in stormwater management.

Stormwater Under the Bridge, Price, S.V.
The Woodrow Wilson Bridge (WWB) project presented unique challenges in stormwater management. This project created 350 acres of impervious surfaces and therefore needed many BMP techniques to manage all the stormwater. This article identified Highway Stormwater Runoff Pollutants and their origins. This project was considered in

the electronic program to help designers understand the key pollutants from highway runoff and their origination. The WWB Project uses stormwater basin reservoirs to manage stormwater runoff. The project would have been a useful case study to help in the development of the electronic program, but was not used.

Best Management Practices for Post-Construction Soils (M. Musick and H. Stenn)
Washington is the first state to include soil quality and depth BMPs in its stormwater management program. When new construction occurs, native soil is replaced with fill or topsoil. This can destroy natural functions and causes soil erosion. The soil erosion was a source for killing salmon. In order to prevent this, Washington developed soil control BMPs to protect the native soil and make sure that in new construction sites, soil that was taken out is being replaced with native soil. This article clearly defined one of the severe impacts of construction and inadequate stormwater management. There is not much from this article that was used in the electronic program other than being aware to control soil quality.

Online Resources
The two online resources that are listed by the *Managing Stormwater* article were investigated and proved to be useful. The database is broken down by country, state, BMP type, structural group, etc.

Stormwater Manager's Resource Center
This website was created by the Center for Watershed Protection. It contains a library with 150 articles that deal with different aspects of watershed management and protection. A number of these articles deal with stormwater pollution and stormwater BMPs. The articles on Stormwater BMPs are studies of different BMP techniques such as ponds, infiltration, filters, wetlands and a few others.

The website also has eight different slide shows related to stormwater. Four of the slide shows are on designing certain BMPs. One of the slide shows can be very useful in choosing the right stormwater treatment practice. It presents a series of matrices that can be used to select the best stormwater treatment practice. This is also one of the many sources served as a guideline in creating the electronic design matrix.

International Stormwater BMP Database
This database was created by the ASCE. The most useful source on this website is the database itself. There are 204 cases listed so far in the database. Users can search by state, country, structural group, non-structural type, watershed area range, storm volume, etc. The database then finds test sites that match best what the user is searching for. The results include the basic site information, the analytical parameters for the BMP, key characteristics of the study, statistical analysis of the BMP performance and a summary of precipitation and the flow data for the BMP.

Another important feature is that this website contains information about sizing and performance criteria, selection matrices and construction and maintenance checklist. The latter two were of importance to this project. The selection matrices have a few tables that by filling in what a project site requires can help in the narrowing down of BMP techniques. The construction checklist contains checklist for different BMP techniques. This is to ensure that the designer has dealt with every aspect of the BMP design.

This website is very useful and was looked at to supplement the process for the electronic process.

Other Stormwater BMP Manuals

The *Managing Stormwater* article mentioned a few states that have good active stormwater management programs. All states manuals can be found under the following web site:
http://www.stormwaterauthority.org/regulatory_data/state.aspx?id=167
Of those reviewed, California and Washington seem to be the most useful.

Washington Highway Runoff Manual

This manual is geared toward highway runoff control and transportation project, which is exactly what the NJDOT was looking for. One of the best features of the manual is that it provided descriptions of each chapter since it is a very lengthy book. It also provides the user with a section on how to use the manual. First, the user must start off with Chapter 2. Chapter 2 lists the minimum stormwater treatment requirements. It also tells how to determine which of the requirements must be met for given transportation projects. Then the WSDOT design process is given in Chapter 3. After this, the user can go to Chapter 5, which guides the designer through the selection of BMPs and permanent stormwater treatment. Chapter 5 is important as it gives a BMP selection process and design criteria. This manual is specifically for WSDOT and therefore this project only benefited by using this as guideline to creating the electronic program.

Stormwater Management Manual for Western Washington

Stormwater Management Manual for Western Washington is more like the NJDEP Stormwater Management Manual. It gives a general overview of stormwater pollution prevention plans (SWPPP) and then delves into the different BMP techniques. One of the key features of this manual is that it provides a checklist for construction stormwater pollution prevention plans. It also gives a few different BMPs than the NJDEP manual and these BMPs can be considered for integrated into the new computer program.

California BMP Handbooks

The first asset of the California BMP Handbooks is that it is separated by the type of use: new development and redevelopment, construction, industrial and municipal. Only the Construction Handbook was studied since it dealt with roadway construction. Again this manual gave the general introduction to stormwater and the requirements for stormwater control. After this, the manual presented the BMPs by sediment control BMPs, erosion control BMPs, non-stormwater management BMPs and Material Management BMPs. This breakdown was very useful as it targeted specific pollutant problems and how to tackle them. The style of writing in each of the California BMPs is different than the NJDEP manual. All the necessary information, design criteria and maintenance are presented in bullet form. The user can quickly go through each BMP, pick out the necessary design criteria, maintenance requirements and other necessary information for each technique. This handbook was definitely helpful for developing the New Jersey electronic program.

California also has Stormwater Quality Handbooks and in this it provides a manual on project planning and design guide. This handbook has many decision trees and tables that will be highly useful. It provides insight on the BMP selection process, the plans, specifications, and estimates process, the BMP design selection process, and summaries and design criteria's of some of the more widely used BMPs such as infiltration basins, biofiltration, and detention basins. One of its best features is its in-depth checklist. The checklist includes checking for all the necessary documentation, data reports, site data sources, water quality test, design for pollution prevention and a treatment decision tree. The checklist served as a basic guideline for making the decision matrix in the computer program for NJDOT.

Technical Panel

The NJDOT assembled a technical panel composed of representatives from various NJDOT units and other agencies such as the New Jersey Department of Environmental Protection.

The New Jersey Department of Transportation had the responsibility of identifying and inviting these representatives to participate during the project development and review. A presentation was made to the panel to outline the project work plan. Comments from the panel were recorded. NJDOT had the opportunity to modify the work plan based on the outcomes of the presentation. The workplan changed very little and everyone realized the difficulty of this project because no issue was clear cut. In particular, the issue of "hardship waivers" was not taken lightly and every effort was made to eliminate the need to request hardship waivers in the electronic decision making process.

Interview Key Personnel

NJDOT identified key personnel in the Planning, Design and Maintenance departments. The personnel were interviewed to identify available treatment techniques, history of use within the department, costs and environmental constraints that effect design, and maintenance considerations.

A questionnaire (Appendix B) was sent out to 8 regulators and 11 consultants (Appendix C). A total of 5 consultant and 3 regulators responded, with a few saying their answers were given by another respondent. The responses were subjective and appeared to have bias relating to the respondents experience with BMPs used, The Interview of Key Personnel was however quite informative. As noted a total of eight personnel volunteered their time to answer questions about Stormwater BMP techniques and the problems that exist with their implementation.

The two biggest problems that were noted with stormwater BMP design are the Seasonal High Water Tables (SHWT) and Limited Right-of-Way (ROW). Almost half of the land in New Jersey is at or close to sea level, and along with large aquifers and high precipitation the chance of an area having a high water table is common. High water tables make it very difficult to create BMPs without altering the natural hydrology of the surrounding area. High water table limits BMPs to basically constructed wetlands and storage ponds, which may be the worst BMPs for the surrounding areas and conditions. Most BMPs require many acres of land to be effective, limited ROW will affect large BMPs, especially Infiltration Basins. Another problem that is encountered is soil characteristics. Due to high pollution levels in New Jersey, many areas have contaminated soil that will restrict any additional infiltration in that area. Also some soils are not conducive for certain BMPs that require high permeability rates.

Other problems that were brought up are: limited space in urbanized areas, lack of DOT maintenance, a need for multiple BMPs for C1 waters, the developed area is not large enough to accommodate BMPs, and possible safety hazards with BMPs in highway clear zones. Many areas in New Jersey no longer have enough space for development or any other structures including BMPs that may need to be implemented due to road rehabilitation or expansion.

These key problematic factors had to be clearly studied. Examples were looked at to help decide ways to limit difficult steps in BMP design process.

The details of this questionnaire approach were detailed in a report to NJDOT as a part of this project. While the results of this input did not directly affect the electronic decision making process designed it did provide “food for thought” in completing the process correctly.

BMP Techniques Table and Regulatory Breakdown

Stormwater Management is focused on the concept that surface water runoff from any project site discharges to a receiving water body or channel. Runoff must be controlled to protect the public health and safety. Standard convention within the industry is to refer to the downstream-most discharge point from a site as an *Outfall* or *Point of Interest*. Any change in the land use or watershed characteristics within the contributing runoff area could affect the water quality, groundwater recharge, and discharge volume and peak. The Stormwater Management (SWM) Rules in New Jersey are designed to minimize the potential impacts of a project by establishing design controls for flows from outfalls.

In a typical linear development transportation project in the State of New Jersey, the adjacent land uses are developed properties, environmentally constrained areas with competing environmental resources, and neighborhoods with limited available right-of-way property. Acquiring sufficient space to install stormwater management components to meet the regulations can be expensive and time consuming. Identifying the stormwater management needs in the early phases of a project would allow designers to develop cost effective solutions, incorporate any changes into the overall project design, and maintain the overall project delivery schedule. Documenting any project constraints, which may impede strict compliance with the regulations, would help develop more realistic cost estimates. Attempting to resolve stormwater management conflicts in the later phases of a project can have significant impacts on the design, deliverables schedule and cost.

This Electronic Decision Process (EDP) guides the user through a series of systematic decision processes to determine the applicability of the SWM rules. Based on the user-supplied information, the program evaluates design constraints that could restrict or influence the selection of an appropriate best management practice (BMP). It asks the user to assess the availability of existing space within the right-of-way (R.O.W.) already obtained, and consider the feasibility of purchasing adjacent properties to increase the amount of space available for BMPs. It will calculate the amount of additional space required to meet the SWM rules. The program will also assist the user in recognizing and documenting any regulatory, environmental, or physical constraints, which may prohibit strict adherence to the SWM rules.

In order to establish if the proposed project must comply with the SWM or if an exemption is warranted, a comprehensive decision process has been developed. The user begins by providing specific information about the amount of new and disturbed impervious areas and total surface disturbance anticipated. If the project is within the quarter acre threshold for new impervious surfaces, and disturbs less than one acre, it may be exempt from the SWM requirements. This information is critical for small projects where the areas associated with several activities such as modification to the drainage system or replacement of existing impervious areas could cumulatively exceed the threshold limits. This program will standardize the process used to determine if SWM compliance is required.

It is the intention of this project to provide a clear and consistent methodology for use when evaluating the stormwater management components of a proposed linear development project. The program will distinguish potential design solutions from the pool of available technologies. The outputs generated will help the designer and reviewer to determine the extents to which compliance with the regulations may be achieved, and assist in documenting conditions pertinent to a hardship waiver.

<u>Water Quality</u>

The accumulation of surface pollutants in runoff can degrade the quality of the receiving waters and impact the environment for marine life. The SWM rules attempt to improve the quality of runoff volumes by restricting pollutant discharges. In this subroutine, the program calculates the required removal rate for total suspended solids (TSS), storage volumes required to achieve pollutant removal rates, and eligible and practical BMPs for the project. If sufficient surface area is not available within the R.O.W. to satisfy the water quality volume, this routine will indicate any additional surface area, which may need to be obtained in order to meet the regulations.

Chapter 9 of the NJDEP BMP manual lists a number of technologies available for pollutant removal. Not all of these methods are applicable to transportation projects. In developing the BMP matrix table used in the program, we eliminated dry wells and rooftop vegetation from consideration. Dry wells are more appropriate for small volumes such as may be generated by roofs. The size and configuration of most BMPs in the manual are volume based. Exceptions to this are vegetative filters and manufactured treatment devices. The program relies on a user entered value for Water Quality Design Storm Peak Runoff rate to determine if a manufactured treatment device is applicable as a stand alone BMP.

While the regulations focus on TSS removal as an indicator of water quality treatment, the secondary requirement is to reduce nutrient loading. Ground cover, which does not require fertilization, is preferred over lawn areas, which do require periodic fertilization. Required removal rates for nitrogen and phosphorus are not included in the regulations at this time. However, nutrient removal rates have been established for various BMPs. While this program does not evaluate the effectiveness of BMPs in removing nutrients, the user should review Chapter 4 of the BMP manual to determine how to maximize nutrient removal using the eligible and practical BMPs.

The Natural Resources Conservation Service (NRCS) methodology for calculating runoff from a site is the basis for this subroutine. The rational method for calculating runoff has been proven to be of limited applicability. Specifically, the rational method is best applied to smaller drainage areas with uniform ground cover and topography. It also provides the peak runoff rate, but not the cumulative runoff volume. The NRCS methodology is one common application for generating runoff rates, runoff volumes, and creating hydrographs. The NRCS methodology is used in the program to compute runoff volumes where required.

The user is asked to provide curve numbers, drainage areas, and time of concentration values for the pre- and post-construction conditions. The required TSS removal rate is computed based on the new impervious surface area and the reconstructed pavement area according to the equation

$$TSS = \frac{(Anew * 0.8) + (Arepl * 0.5)}{(Anew + Arepl)}$$

A TSS removal rate of 80 percent is required for new impervious surfaces, while 50 percent removal is required for reconstructed or replacement impervious areas. If an outfall discharge to a Category 1 receiving water, the project must demonstrate 95 percent TSS removal. The program allows the user to override the calculated TSS removal rate and manually enter a TSS goal. The higher of the computer generated and user supplied TSS rates is used to evaluate potential BMPs.

Based on the NRCS method, the program generates the volume required to provide the necessary TSS removal. The program follows the guidelines recommended in Chapter 5 of the BMP manual for sites with pervious and directly connected impervious cover. If applicable, the weighed average volume technique is used as permitted by NJDEP. The program does not address disconnected impervious surfaces.

Selection of an eligible and practical BMP is dependent upon the required TSS removal rate, the drainage area, flow rate to the BMP, depth to seasonal high water table, hydrologic soil group where the BMP is proposed, and available depth of the BMP. After determining if a BMP is "eligible" based on the above parameters, the program evaluates if a BMP is "practical" based on the available surface area within the R.O.W.

The numerical values for the parameters in the BMP evaluation matrix were obtained from the NJDEP BMP manual. Design criteria for each potential BMP are clearly specified. If a particular design parameter is not specified in the NJDEP manual, the design criteria have been supplemented from the Maryland BMP manual. The NJDEP will need to evaluate and agree to the use of these parameters before implementation of the program.

Groundwater Recharge

The loss of groundwater recharge at a project site can lead to increased incidents of flooding in the state. It can also lead to decreased recharge of aquifers and lower the available safe yield to groundwater wells. The groundwater recharge component of the SWM regulations may be demonstrated by one of the following two methods:

1. 100 percent of the average annual pre-developed groundwater recharge volume at a project site be maintained after development; or
2. 100 percent of the difference between the pre- and post-development 2-year runoff volumes at a project site be infiltrated.

Per the regulations, the designer has the option of selecting which requirement the design will satisfy. The decision logic in the program has been modeled to allow flexibility in using either the New Jersey Groundwater Recharge Spreadsheet (NJGRS) to compute a recharge volume, or allowing the computer to calculate the difference in the 2 year storm runoff volume based on information previously entered. The NJGRS used methodologies, database information, and algorithms developed in the *1993 Geologic Survey Report GSR-32: A Method for Evaluating Ground Water Recharge Areas in New Jersey*. This report was developed by the New Jersey Geologic Survey. Additional information about the NJGRS may be found in Chapter 6 of the NJ BMP manual. Within the program, the user has the option of either linking to the NJGRS or using the volume generated by that spreadsheet, or allowing the program to calculate a recharge volume based on the difference between the 2 yr runoff volumes. Information about the anticipated 2 year storm rainfall intensities per county is included in the program.

The program will compare the depth to the seasonal high water table (SHWT) and depth to bottom of the BMP supplied by the user during the initial outfall definition. In order to satisfy the NJDEP SWM regulations, vertical clearance of 3 feet must be provided between the SHWT and bottom of the BMP. The user can elect to use either a surface recharge BMP or an underground recharge BMP.

In comparing the volumes generated using the NJGRS and difference in the 2 year storm runoff methodologies, we found that the required recharge volumes varied significantly. In each of the 21 counties in New Jersey, we identified the single municipality with the highest anticipated rainfall each year. We evaluated the recharge volumes for four potential pre-construction land use land cover types: woods, meadows, brush, and open space. It was assumed that the post-developed condition consisted of converting the existing area to 60 percent impervious cover and the remaining 40 percent to open space.

We selected two soil types in each of the hydrologic soil groups A, B, and C. Soil group D was not investigated due to its low recharge potential. Within each of the soil groups, we examined the recharge potential for

- Type A: Fort Mott and Hooksan
- Type B: Nixon and Klej
- Type C: Venango and Adelphia

For each scenario simulated, the groundwater recharge deficit and BMP volume were calculated using a 12-inch effective depth for the BMP.

The NRCS TR-55 algorithm was used to calculate the 2 year storm runoff volume for pre- and post-development conditions with the assumptions listed above. When we compared the volumes for each scenario, the results obtained from the NJGRS program were significantly smaller than the 2 year storm runoff volumes. The NJGRS recharge volumes calculated varied between 7 percent and 20 percent of the 2 year storm runoff difference. The variation between the volumes calculated by the different methods has not previously been studied and further investigation is suggested.

Within each municipality, the percent of variation in the computed recharge volumes was fairly consistent. In order to make the required recharge volumes more consistent between the two optional recharge calculation methods, we selected a conservative factor of 0.2 to apply to the difference in 2 yr storm runoff volume. This means that if the user elects to use the difference between the runoff volumes, the number calculated will be multiplied by 0.2 yielding 20 percent of the original calculated volume. This reduced volume more closely approximates the value found when using the GSR-32 method.

Again, this observation has not been closely studied to date, and approval from the NJDEP is required before implementation.

Water Quantity

The design storms for water quantity analysis calculations are the 2, 10, and 100 year storm events. The design guidelines promulgated under N.J.A.C. 7:8-5.4 for water quality analysis require that:

- There is no change in runoff hydrographs for the 2, 10, and 100 year storm events for the entire contributing site, OR
- There is no increase from pre-construction to post-construction peak runoff rates from the 2, 10, and 100 year storms for the entire site, and that any increase in volume or change in timing of runoff will not result in downstream flooding, OR
- There are reductions in the post-construction peak runoff rates for the 2, 10, and 100 year storms for the runoff attributed to the portion of the site in the proposed project.
- If the proposed project is located in a tidal flood hazard area, the runoff quantity analysis is only applicable if the increased discharge volume could increase flood damages downstream.

Local county stormwater management regulations may be more stringent than N.J.A.C. 7:8. This EDP generates the storage volumes required to meet the state quantity requirements. It verifies if sufficient space is available within the basin configuration entered by the user, and permits the user to explore the feasibility of surface or subsurface storage, based on available area.

This program focuses on maintaining the peak discharge rates from pre- to post-development conditions. The program analyzes the 100-year storm event and generates a storage volume required to attenuate the peak runoff. It uses information previously entered by the user to calculate a volume using the NRCS TR-55 methodology, outlined within Chapter 6 of the old TR-55 manual. Although this method is not recommended under the new release of the TR-55 computer program, since this program lacks the ability to handle hydrograph routing, we elected to implement this method to determine the flood storage volume requirement. The scope of this project was to develop the decision logic using a widely accepted commercial software product such as Microsoft's EXCEL program. The TR-55 method to compute required flood storage volumes has been acceptable in the past.

The results obtained from using TR-55 should be compared with hydraulic software capable of hydrograph routing. That study is beyond the scope of this project.

The storm attenuation volumes generated in this subroutine are used to determine the availability of adequate BMP surface area and volume within the existing R.O.W. If sufficient area is not available, the program will identify the amount of deficiency, which will assist the user in calculating the amount of additional property, which may be required to satisfy the regulations.

Constraints

The decision matrix used in this subroutine verifies the presence or absence of environmental, physical, or regulatory constraints, which may affect the implementation of a BMP. A waiver from strict compliance with the SWM rules may be appropriate, or the NJDEP may require encroachment upon the conflicting areas for the provision of a BMP facility. If a site is found to be clear of any potential design constraints, the program will investigate the feasibility of combining all three required volumes into one large single BMP volume. However, if constraints are found to restrict provision of a particular BMP previously determined to be eligible and practical, the program will guide the user through a systematic approach to evaluating alternatives for compliance. If the requirements cannot be satisfied at another outfall within the watershed or mitigated at an offsite location, the program output will document the situation for discussions with the NJDEP about a waiver from strict compliance.

The decisions matrix is built on the premise that the designer will honestly and thoroughly evaluate and document appropriate measures to address the regulatory requirements. However, for projects where a waiver may be justified, this program is intended to guide the designers and reviewers through a clear and standardized evaluation of alternatives. This evaluation process is a necessary step in qualifying for a hardship waiver.

Select Case Studies

In order to test the capabilities of this electronic decision process, two transportation projects were selected by NJDOT. The proposed designs were evaluated against the output generated by the program. These projects were designed by other consultants and are compliant with the SWM rules. The two projects were Route I-78, Diamond Hill Road (DHR) Interchange Improvements located in the Township of Berkeley Heights, Union County, and Route 1 Section 6V located in the Township of North Brunswick, Middlesex County. Information available in the Engineer's Reports for each project was reviewed for existing and proposed site conditions and any pertinent design parameters.

Route I-78, Diamond Hill Road Interchange Improvements

Project Description
This project involves improvements to Interstate 78 at the Diamond Hill Road (DHR) interchange in the Township of Berkeley Heights in Union County. Included in the scope of improvements is the construction of two new ramps, relocation of an existing ramp, modifications to both Route I-78 acceleration lanes, and widening of the westbound bridge over DHR.

The project included the creation of approximately 4.2 acres of new impervious and the reconstruction of approximately 2 acres of previously paved surfaces. The design approach selected by the consultant required evaluating the entire site (including the new impervious, reconstruction, and existing surface areas) for compliance with the water quality requirements. Therefore, the design was additionally required to treat approximately 6.6 acres of existing surface areas for a 50 percent total suspended solids (TSS) removal. A net TSS removal of 7.69 acre rate was calculated to demonstrate compliance with the water quality component of the requirements. (4.2 acres x 80% rate + 2 acres x 50% rate + 6.6 acres x 50% rate = 7.7 acre rate)

Consultant Design Solution

Water Quality – A total of seven manufactured treatment devices dispersed throughout the site, and an extended detention basin, were required to provide a sufficient level of treatment. The overall level of TSS removal provided by the treatment train was 7.82 acre rate.

Ground Water Recharge – the project area is entirely located within the Buried Valley Aquifer. Based on the geotechnical investigation, the area was not considered likely to be a substantial recharge area. An exemption was requested by the design team.

Runoff Quantity – Including an extended detention basin in the project design addressed the stormwater quantity requirements. The proposed design affected existing watershed runoff patterns. In order to demonstrate compliance with the SWM rules, the existing and proposed hydrographs were routed through the proposed basin design. By demonstrating no change in runoff hydrographs for the 2, 10, and 100 year storm events, the design satisfies the quantity component.

Electronic Design Process Solution

Water Quality

In evaluating the quality component of the SWM rules, the decision logic selects potential best management practice (BMP) components based on the higher value between a program generated TSS removal rate and a user supplied rate. As discussed above, the program will automatically generate a minimum required removal rate based on 80 percent removal for new impervious and 50 TSS removal for replacement impervious. The NJDEP accepted TSS removal rate for many of the BMPs is already included in the decision program. If the TSS removal rate is dependent upon a variable such as time or length, the user is asked to enter a removal rate based on the design parameters for the BMP, within the guidelines established by the NJDEP.

In this project, new impervious and replacement impervious drain to each outfall. The weighted required TSS rate is over 50 percent at each outfall. The decision program did not return manufactured treatment devices as potential BMPs for this project. The NJDEP maximum TSS removal rate for treatment devices varies based on the removal technology. A hydrodynamic separator treatment device has a maximum removal rate of 50 percent in the program logic. Since a manufactured treatment device (MTD) would not be capable of producing the required level of treatment, it is not identified as an eligible BMP for this project.

The decision logic developed requires the program to select only those BMPs, which satisfy the required removal rate at each outfall. However, the approach taken by the project design consultant was to achieve the required composite removal rate over the entire site. Areas within the project limits not actually requiring treatment were treated, in addition to those areas requiring treatment under the regulations. This approach is reasonable based on the site design constraints.

In order to simulate the design approach by the consultant, we increased the user assigned TSS removal rate for MTDs to 80 percent. This change forced the program to identify MTDs as an eligible and practical BMP. At one outfall location, an extended detention basin was identified as an eligible and qualified BMP. This is consistent with the design of the consultant. The TSS removal rate at the extended detention basin calculated by the program was 55 percent as compared to a 56 percent removal calculated by the consultant. Due to the changes to contributing areas and curve numbers, the overall TSS for the site determined by the program was 8.84 acre rate. This is greater than the required removal rate of 7.69 calculated based on existing and proposed conditions. It is also greater than the 7.82 acre rate level of TSS removal provided by the consultant's design.

Groundwater Recharge

Based on the geotechnical information available, and the exemption waiver requested by the consultant, the recharge component was not evaluated.

Runoff Quantity

The watershed draining to the proposed extended detention basin is the revised watershed pattern. The existing area draining to the outfall was assumed to be zero. A curve number of 82 (pre-development) and 84 (post-development) were used to be consistent with the design by the consultant. The program computed a required runoff attenuation volume of 137,139 cubic feet. The consultant's design provided approximately 67,779 cubic feet of storage volume. The volume computed by the program was approximately twice as large as the volume provided under the design.

In order to correct the variance between the program output and the consultant design, it was necessary to revise the existing conditions input values in the program. The areas and curve numbers used in the program were altered to reflect the actual net increase in impervious surfaces within the project corridor. The approach used by the consultant was to compare runoff patterns using hydrograph routing software. Since there was no change in runoff hydrographs, the input values were not consistent with the information required by the program. It was necessary for us to revise the input to reflect an existing contributing area of 4 acres and a new impervious contributing area of 4.2 acres. The net is consistent with the 4.2 acre differential identified by the consultant.

The design by the consultant included weighted CN values. The consultant identified an existing runoff coefficient of 82 and a proposed CN of 84. It was necessary for us to redefine the contributing area as impervious and pervious, and assign a CN of 98 to new impervious. A value of 98 would indicate full development or impervious surface. The resultant attenuation volume generated by the program was 84,237 cubic feet. This is about 24 percent higher than the volume provided in the design. This is conservative, but within the acceptable limits for the program.

We were able to revise the input values to correct the variance between the program and actual design. The revised program output was conservative, but within acceptable program parameters. In order to further reduce potential variations, we recommend incorporating hydraulic and hydrologic software with hydrograph routing capabilities into the program.

Summary

The overall water quality total suspended solids removal rate determined by the program was 8.84 or 15 percent higher than the required rate based on site conditions, and 13 percent higher than the rate provided in the consultant's design. The increased TSS acre rate removal is due to the increased TSS removal rate of 60 percent computed by the program as compared to a removal rate of 55 percent calculated by the consultant. The groundwater recharge component was not evaluated due to site constraints prohibiting effective recharge.

The runoff attenuation volume determined by the program was conservative, but within the acceptable limits of deviation for the program. The input values used had to be modified to reflect the proposed improvements. A thorough knowledge of the decision logic used in the program was necessary to allow us to evaluate which parameters to modify to effectuate changes, which mimic the consultant's design logic.

This program is intended to standardize the design of stormwater compliance BMPs, but should not be viewed as limiting potential designs. It must be recognized that this program responds within limitations based on assumptions including BMP parameters, calculation methodologies, and software limits. For this case study, the program responded within the acceptable limits noted in the design scope. A suggestion, which should be considered to improve the response of the program, includes using a software program, which would allow hydrograph routing.

One of the goals of this project is to standardize the design approach to satisfying the SWM regulations. The initial deviation between the computer and human outputs was due to a lack of understanding of the required program inputs. The information available from the Engineer's Report was not presented in such a way as to be readily used as input data. It was not necessary to change the design solution developed by the consultant, but rather to present and extract different information for use in the EDP.

Standardizing the outputs will not in any way limit the available design approaches. Each designer will retain the freedom to accept an approach specific to the site conditions. However, the information generated to meet the SWM rules may be presented in a more consistent manner. This will enable regulatory agencies to be more consistent in their reviews of project

Route 1 Section 6V

Project Description
The scope of this contract includes widening of Route 1, Section 6V, from approximately 0.45 miles south of the Route 1 / Railroad crossing bridge to a point approximately 0.86 miles north of the Route 1 / Railroad crossing bridge. The project is located in the Township of North Brunswick, Middlesex County, New Jersey. The project includes creating approximately 3.9 acres of new impervious area and the reconstruction of approximately 4.7 acres of impervious surfaces.

Consultant Design Solution

Water Quality – The proposed design included two (2) bio-retention basins and an extended detention basin. An overall total suspended solids removal of 9.75 acre rate was calculated based on the proposed design.

Groundwater Recharge – The consultant used the New Jersey Groundwater Recharge Spreadsheet (NJGRS) to calculate a required recharge volume of 2,789 cubic feet. Based on a geotechnical investigation of the site, the bio-retention basins were designed to recharge the entire water quality volume. The total volume of recharge under the proposed design is approximately 31,500 cubic feet.

Runoff Quantity – The proposed design uses the bio-retention basins and extended detention basins to address all the requirements of the SWM rules. The increased runoff volume is attenuated in the proposed storage BMPs.

Electronic Decision Process Solution

Water Quality

The program did not identify bio-retention basin or the extended detention basin as eligible and practical BMPs for this project. The decision logic evaluates potential BMPs based on several design constraints including contributing drainage area, required total suspended solids (TSS) removal rate, and the user assigned removal rate for that specific outfall. For this project, a bio-retention basin was not applicable because the contributing drainage area exceeds the maximum allowable limit of five (5) acres. An extended detention basin should have been applicable. The program is designed to allow extended detention basins as practical BMPs when the contributing drainage area exceeds five acres.

In order to match the consultant's design, it was necessary to alter the design constraints in the decision logic of the EDP. Based on the revised evaluation criteria, the program accepted the extended detention basin as an eligible and practical BMP. This allowed us to continue our evaluation of the computer generated and user generated designs.

The discrepancy in qualified BMPs between the consultant's design and the program output is due to assumptions built into the program. The NJDEP BMP manual does not specify limits for these two individual types of BMP. In order to develop criteria to evaluate the BMP, we adapted limits from the Maryland BMP manual. Concurrence from the NJDEP will be required to finalize the constraints necessary for the evaluation criteria.

The program calculated a volume for water quality at each of the three (3) outfall locations. A comparison of computer generated and user designed volumes is presented below in Table 4.

Table 4. Volumes for water quality.

Outfall Location No.	Program Generated Volume (cubic feet)	Consultant Designed Volume (cubic feet)	Variance
1	12,723	11,825	8%
2	21,105	19,624	8%
3	12,572	10,598	19%

The variance between the cumulative computer-generated water quality volume and user designed water quality volumes was 10 percent. This is within the permitted variance for the program design guides.

Groundwater Recharge

The cumulative recharge volume calculated by the program as the difference in 2 year storm runoff volumes was 6,349 cubic feet. This is based on the difference between pre- and post-construction conditions as required by the SMW regulations. It is significantly higher than the volume calculated using the NJGRS. The volume suggested by the NJGRS is about 9 percent of the volume calculated by the program. This is consistent with the findings discussed above under "BMP Techniques Table and Regulatory Breakdown." Our preliminary study indicates that the difference in Middlesex County for hydrologic soil group B would be about 10 percent.

Runoff Quantity

The program calculated the required runoff attenuated volume at each of the three outfalls. A comparison of quantities is presented in Table 5.

Table 5. Runoff attenuated volume

Outfall Location No.	Program Generated Volume (cubic feet)	Consultant Designed Volume (cubic feet)	Variance
1	18,023	15,619	15%
2	29,240	28,433	3%
3	13,594	11,479	18%

The cumulative flood attenuation volume computed by the program within the corridor where a BMP was implemented was approximately 9 percent higher than the volume designed by the consultant. The discrepancy between the program and user-generated volumes may be attributed to the different calculation methodologies. The program uses the NRCS TR-55 methodology as discussed above under "BMP Techniques Table and Regulatory Breakdown." The consultant used the modified rational method for flood routing.

Summary

The volume of water required to satisfy the water quantity component of the regulations was calculated as 42,047 cubic feet while the program generated a required volume of 46,400 cubic feet. The program output is conservative and provides approximately 10 percent more storage than is required. This is acceptable within the limits developed for evaluating the success of the program.

The program calculated the required recharge volume based on the difference in runoff volumes for pre- and post-developed conditions for the 2-year storm. The consultant's design used the NJGRS. As discussed above under "BMP Techniques Table and Regulatory Breakdown," the output generated by NJGRS is a fraction of the output from the 2 yr storm method. In this example, the NJGRS calculated a recharge volume, which was 9 percent of the difference in 2 year storm runoff. This is consistent with our predictions for Middlesex County, which yield a comparison factor of 10 percent.

In order to address the runoff attenuation requirement, the consultant's design included 55,531 cubic feet of combined storage while the program calculated a required volume of 60,857 cubic feet. As with the water quality volumes, the output generated by the program was conservative by approximately 10 percent. This is within the acceptable limits for evaluating the program. Though minor modifications of the assumptions designed in the program logic were required, this case study should be viewed as a successful application of the BMP. Evaluation and concurrence by the NJDEP of the assumptions and design criteria is required before full implementation of this EDP.

Decision Process Development

The stormwater decision matrix or SWD was created, discussed during project meeting with NJDOT, and accepted. The program used Microsoft's Excel as the program of choice. It has turned out that because of the sophistication of the program that Excel has been pushed to its limits.

Electronic Decision Process

The electronic decision process was discussed a number of times with the project oversight committee and DOT. Appendix D provides a schematic of the final version of this process.

Conclusions and Recommendations

Rutgers University, Gannett Fleming, and Stormwater Management have provided an electronic decision making process that should be of great benefit to New Jersey engineers in designing lineal roadway systems.

This SWD process should greatly aid the NJDOT in its efforts to comply with NJDEP stormwater regulations, which are applicable to NJDOT projects. The sophistication of this product will have to be increased in the future after it is utilized by designers and engineers, and NJDEP has provided more input to the process based on field experience. State of Maryland input used for parts of the program will have to be either accepted by NJDEP or new input provided. The Gannett Fleming programmers have pushed the Excel program to its limits in providing this product, and any future updates may have to consider switching to another program platform.

Implementation and Training

The electronic decision making process program is ready to be implemented. Training will be scheduled by the NJDOT.

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APPENDICES

Appendix A: BMPs used in various states.

Note: All BMPs are within State BMP Manual.

	Stormwater BMPs															
	Storm-water Ponds	Storm-water Wet-lands	Infiltration Practices	**Sand Filter**	Bio-retention	Water Quality Swales	Dry Detent-ion Ponds	Catch Basin	Oil / Particle Separa-tors	Under-ground Detention Facilities	Permeable Pave ment	Dry Wells	Vegetated Filter Strips	Grass Drainage Channels	Level Spread-ers	Alum Treat-ment
AL	X	X	X	X	X	X	X	X		X	X	X	X	X	X	
AK	X		X	X	X	X		X					X	X	X	
AZ																
AR	X		X	X	X	X		X	X		X		X	X	X	
CA			X		X								X	X		
CO																
CT	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X
DE	X	X	X	X	X	X	X		X				X	X		
FL	X	X	X	X	X	X		X	X	X	X		X	X	X	
GA	X	X	X	X	X	X	X		X	X	X		X	X		X
HI																
ID	X	X	X	X	X	X	X	X	X				X	X	X	
IL		X	X	X	X	X		X		X	X		X	X	X	
IN			X			X		X					X	X	X	
IA																
KS																
KY	X		X	X	X	X	X	X					X	X	X	
LA			X			X		X					X	X	X	
ME	X	X	X	X	X	X				X			X	X		
MD	X	X	X	X	X	X							X	X		
MA	X	X	X	X	X	X	X	X		X		X	X	X		
MI	X	X	X	X	X		X	X	X	X	X		X	X		
MN	X	X	X	X	X	X	X	X		X	X	X	X	X	X	
MS																
MO	X	X	X		X	X	X	X			X		X	X	X	
MT																
NE																
NV	X	X	X	X	X	X	X	X	X		X		X	X	X	
NH	X	X	X	X	X	X	X				X	X	X	X		
NJ	X	X	X	X	X		X	X		X	X	X	X	X		
NM																
NY	X	X	X	X	X	X	X	X	X		X	X	X	X		
NC	X	X	X	X	X	X	X						X			
ND				X									X	X	X	
OH	X	X	X	X	X	X	X	X					X	X		

Appendix A (cont'd) - State by State Comparison of Accepted United States Stormwater BMPs

Note: All BMPs are within State BMP Manual

Stormwater BMPs

	Storm-water Ponds	Storm-water Wet-lands	Infiltration Practices	**Sand Filter**	Bio-retention	Water Quality Swales	Dry Detent-ion Ponds	Catch Basins	Oil / Particle Separators	Under-ground Detention Facilities	Permeable Pavement	Dry Wells	Vegetated Filter Strips	Grass Drainage Channels	Level Spreaders	Alum Treat-ment
OK																
OR				**X**									**X**		**X**	
PA*																
RI	**X**	**X**	**X**	**X**	**X**	**X**			**X**				**X**	**X**		
SC	**X**	**X**	**X**	**X**	**X**		**X**						**X**	**X**		
SD																
TN	**X**	**X**	**X**		**X**	**X**	**X**	**X**	**X**	**X**			**X**	**X**	**X**	
TX	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**		**X**	**X**	**X**		
UT																
VT																
VA	**X**	**X**	**X**	**X**	**X**	**X**		**X**					**X**			
WA	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**				**X**	**X**		
WV																
WI	**X**		**X**		**X**			**X**					**X**	**X**		
WY	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**	**X**		**X**		**X**	**X**		

Appendix B: Questionnaire sent to regulators.

Stormwater Management Rule Implementation Process
Interview Questions
November 16, 2005

Interview Questionnaire for Key Regulatory Personnel

NJDOT has identified you as a key person in the review and approval of the stormwater management aspects of road and highway projects. We need to know your knowledge of the design, review, construction, and maintenance of the various stormwater BMPs that are used to comply with the N.J. Stormwater Management Rules.

Please enter your responses below and return it to: jstencel@rci.rutgers.edu.

Interview Questions:

1. Name:

2. Department and Division/Program Unit:

3. Telephone Number:

4. Email Address:

5. Are you familiar with the goals of the project?

6. Are you familiar with the new NJDEP Stormwater Management Rules? (NJAC 7:8)

7. Which of the following types of NJDOT transportation projects have you reviewed?

NJDOT Transportation Project Type	Have Reviewed
Roadway Reconstruction	
Roadway Widening/Dualization	
Intersection Improvements	
New Roadway Construction	
Park and Ride Facility	
Interchange Improvements	
Drainage Improvements	
Other:	
Other:	

8. List the stormwater BMPs you feel are most applicable to NJDOT transportation projects. From question 7 above, indicate what types of NJDOT transportation projects they are most applicable to.

Stormwater BMP Name	Applicable Transportation Projects	Have You Designed?

9. Indicate which of the BMP design considerations or constraints listed below influence your approval of a Stormwater BMP for an NJDOT transportation project? Indicate the order of influence of the items selected below with 1 being the most influential.

Check Below:	Consideration/Constraint	Order of Influence
	Design Difficulty	
	Required Area	
	Required Depth or Height	
	Soil Permeability	
	Depth of seasonal high water Table or bedrock	
	Construction Effort or Cost	
	Maintenance Effort or Cost	
	Safety	
	Aesthetics	
	R.O.W. acquisition	
	Acceptable to NJDEP	
	Other:	
	Other:	

10. Based upon your review experience, please rank the following N.J. Stormwater Management Rule requirements by their difficulty to meet in NJDOT transportation projects. Indicate the order of difficulty of the items selected below with 1 being the most difficult.

SWM Rule Requirement	Difficulty Meeting
Nonstructural Stormwater Management	
Groundwater Recharge	
Stormwater Quality, excluding category 1 watershed	
Stormwater Quality, within category 1 watershed	
Stormwater Quantity	
Safety	
Structural	

11. Describe the reasons why the four most difficult requirements listed in the above table are problematic.

12. Describe other problems or obstacles to selecting appropriate stormwater BMPs for NJDOT transportation projects.

13. How many stormwater management waivers have been granted for NJDOT transportation projects you have reviewed?

14. Do you think the use of regional stormwater BMPs to meet the requirements of the NJDEP Stormwater Management Rules is feasible? What obstacles or problems (e.g., current regulations, planning, scheduling, funding, land acquisition) would prevent or discourage the use of such facilities?

15. Please list below any additional comments/suggestions:

Appendix C: Questionnaire sent to consultants

Stormwater Management Rule Implementation Process
Interview Questions
November 16, 2005

Interview Questionnaire for Key Personnel

NJDOT has identified you as a key person in the Planning, Design and/or Maintenance related project with regards to roads and highways. We need to know your knowledge in the treatment techniques, history of use within the department, costs and environmental constraints that effect design, and maintenance considerations in regard to BMPs for stormwater management. **Please type in a response and return it to: jstencel@rci.rutgers.edu.**

Interview Questions:

1. Name

2. Company Name

3. Telephone Number

4. Email Address

5. Are you familiar with the goals of the project?

6. Are you familiar with the new NJDEP Stormwater Management Rules? (NJAC 7:8)

7. What types of transportation projects have you worked on for the NJDOT?

8. List the Stormwater BMPs you feel are most applicable to NJDOT transportation projects. From question 7 above, indicate what types of NJDOT transportation projects they are most applicable to. Also indicate which ones you have previously designed.

Stormwater BMP Name	Applicable Transportation Projects	Have You Designed?

9. From the list below, indicate which items you feel are major design considerations or constraints that influence your selection of a Stormwater BMP for an NJDOT transportation project? Indicate the order of influence of the items selected below with 1 being the most influential.

Check Below:	Consideration/Constraint	Order of Influence
	Design Difficulty	
	Required Area	
	Required Depth or Height	
	Soil Permeability	
	Depth of seasonal high water Table or bedrock	
	Construction Effort or Cost	
	Maintenance Effort or Cost	
	Safety	
	Aesthetics	
	R.O.W. acquisition	
	Acceptable to NJDEP	
	Other:	
	Other:	

10. Please rank the following Stormwater Management Rule requirements by their difficulty to meet in NJDOT transportation projects. Use 1 for the most difficult, etc.

SWM Rule Requirement	Difficulty Meeting
Nonstructural Stormwater Management	
Groundwater Recharge	
Stormwater Quality, excluding category 1 watershed	
Stormwater Quality, within category 1 watershed	
Stormwater Quantity	
Safety	
Structural	

11. Describe the reasons why the four most difficult requirements listed in the above table are problematic.

12. Describe other obstacles to selecting Stormwater BMPs or fully complying with the NJDEP Stormwater Management Rules.

13. Describe the measures (e.g., hardship waiver) that you have taken to resolve unmet Stormwater Management Rule requirements with the NJDEP.

14. Do you think the use of regional stormwater BMPs to meet the requirements of the NJDEP Stormwater Management Rules is feasible? What obstacles or problems (e.g., current regulations, planning, scheduling, funding, land acquisition) would prevent or discourage the use of such facilities?

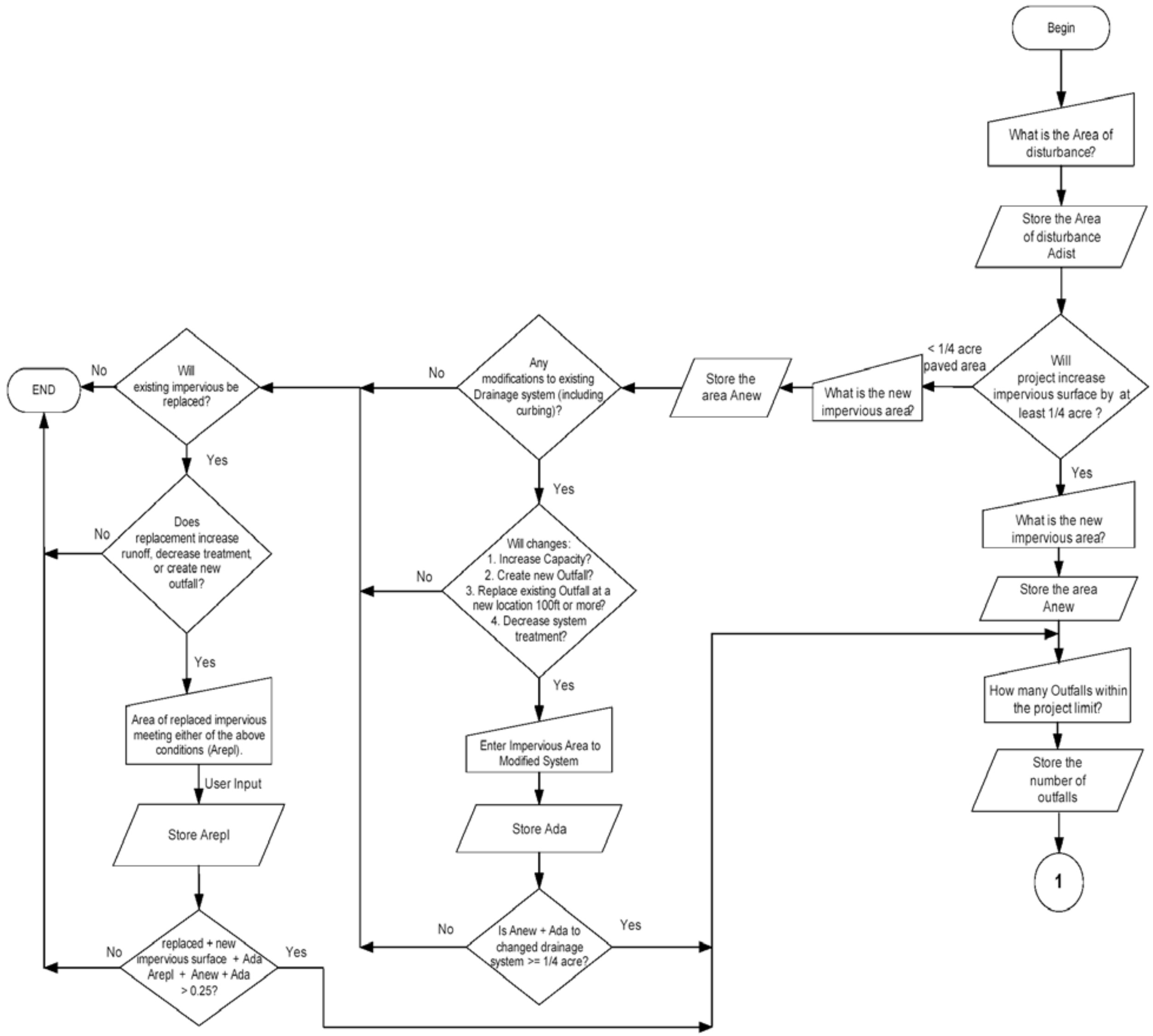
15. Do you obtain guidance and /or recommendations from NJDOT Maintenance Division as part of the Stormwater BMP selection for NJDOT transportation projects?

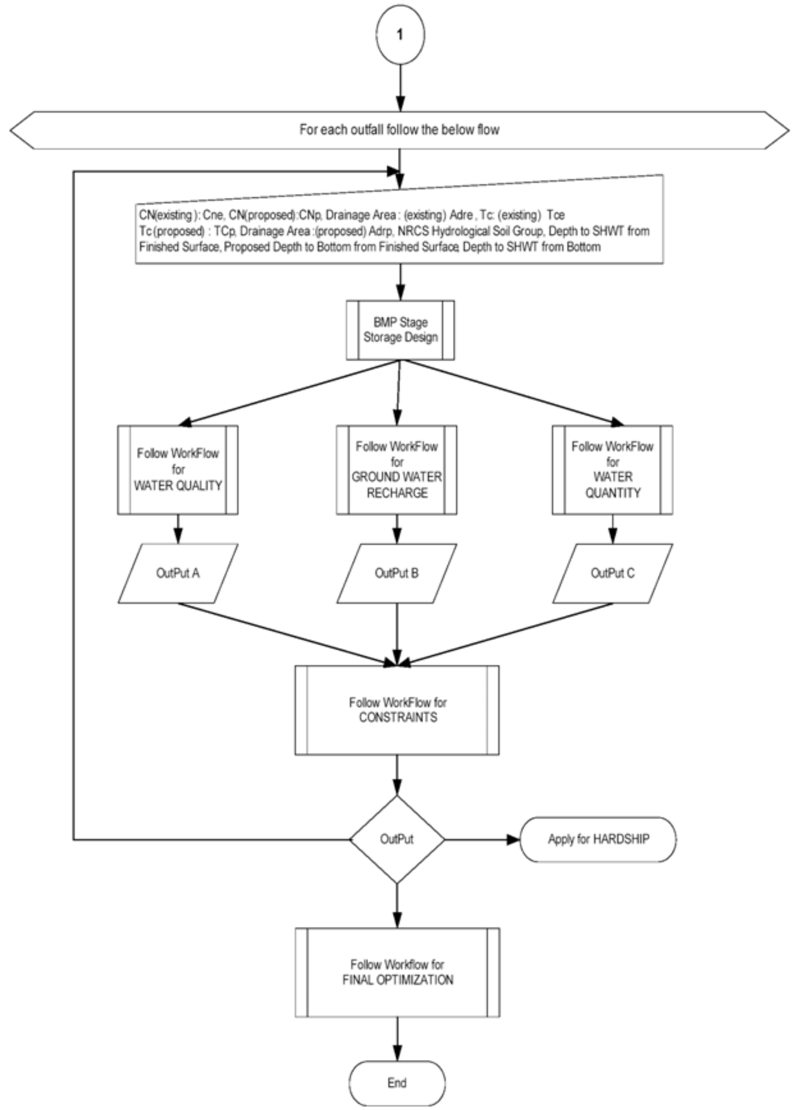
16. Please list below any comments / suggestion.

Appendix D. SWD Matrix

See the next eight pages.

Process Flow For BMP Selection :





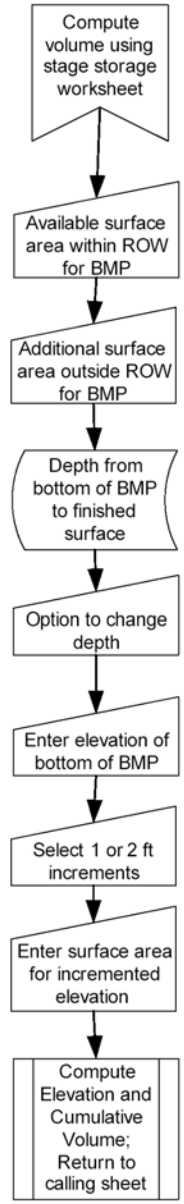
Output will include the following:

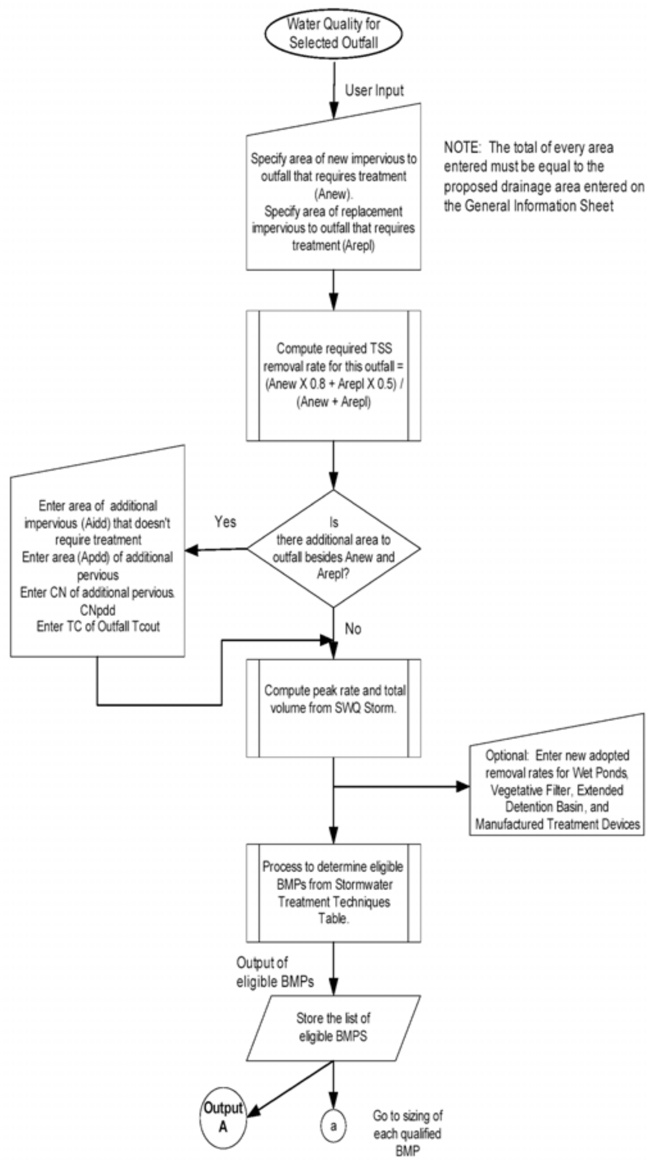
Hardship qualifying criteria
Appropriate BMP selection
Approximate area and volume for selected BMPs
Approximate R.O.W. and Construction cost

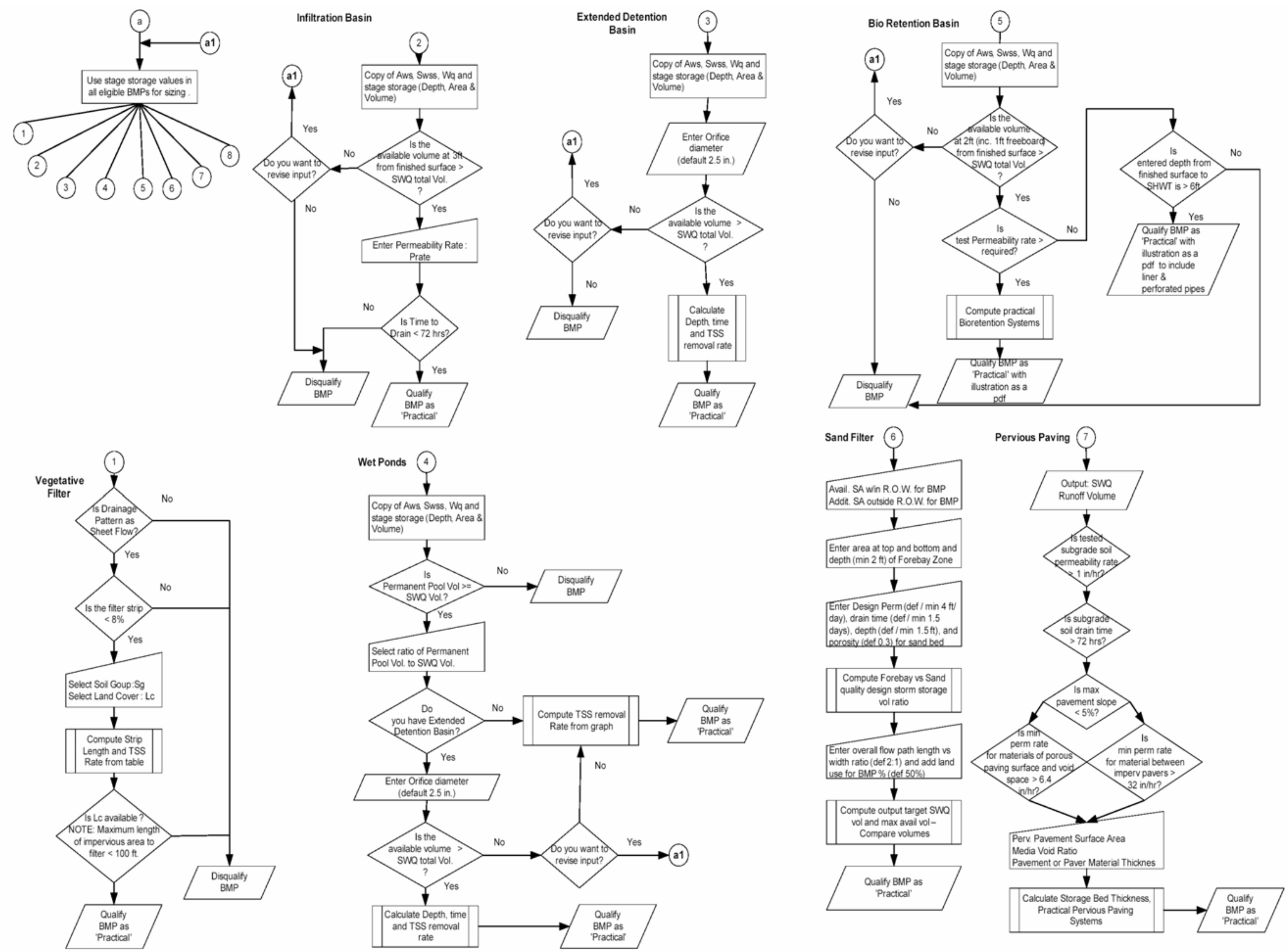
Assumptions:

Alignment is set.
Underground BMP below travel lanes is not an option

Stage Storage

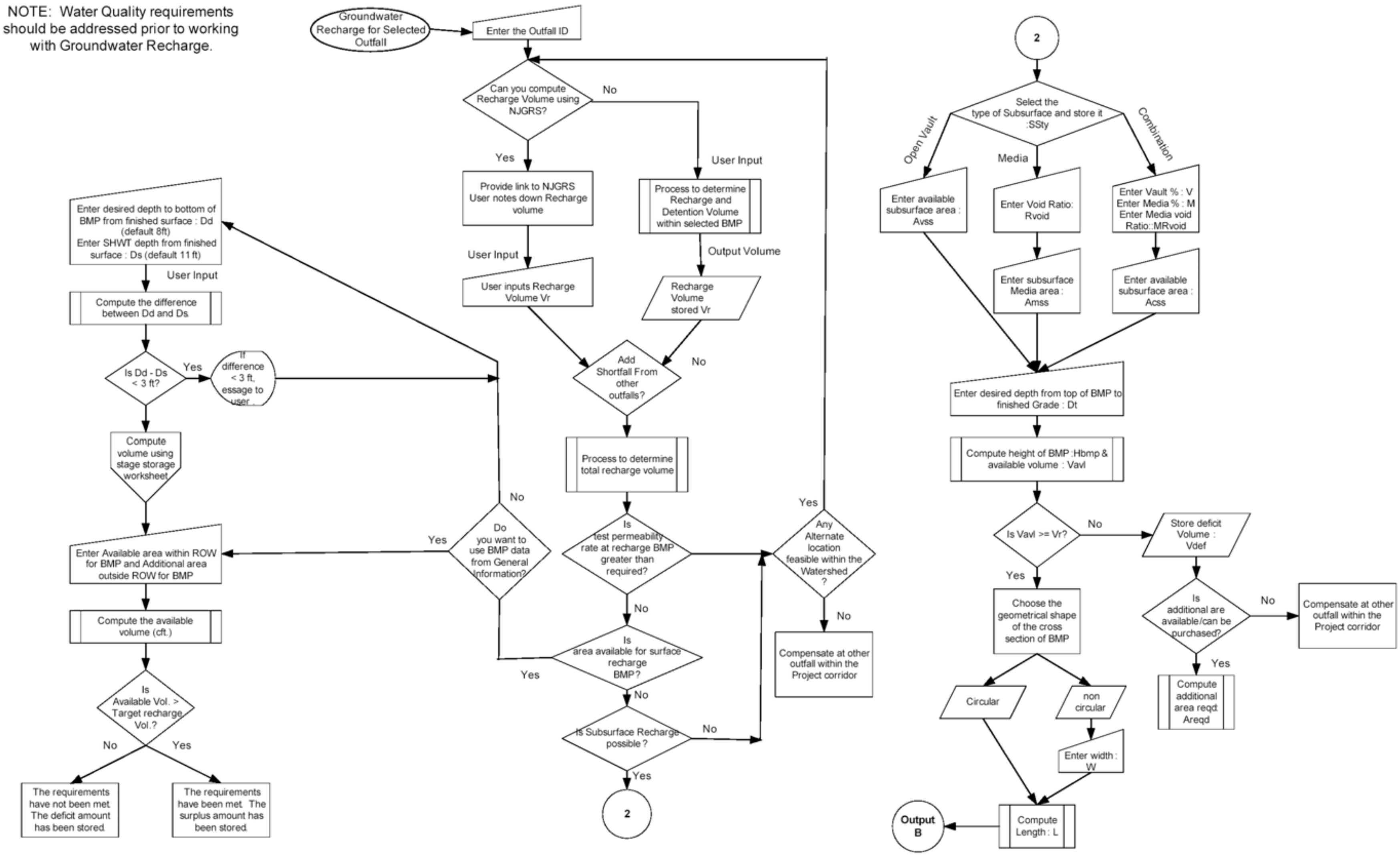


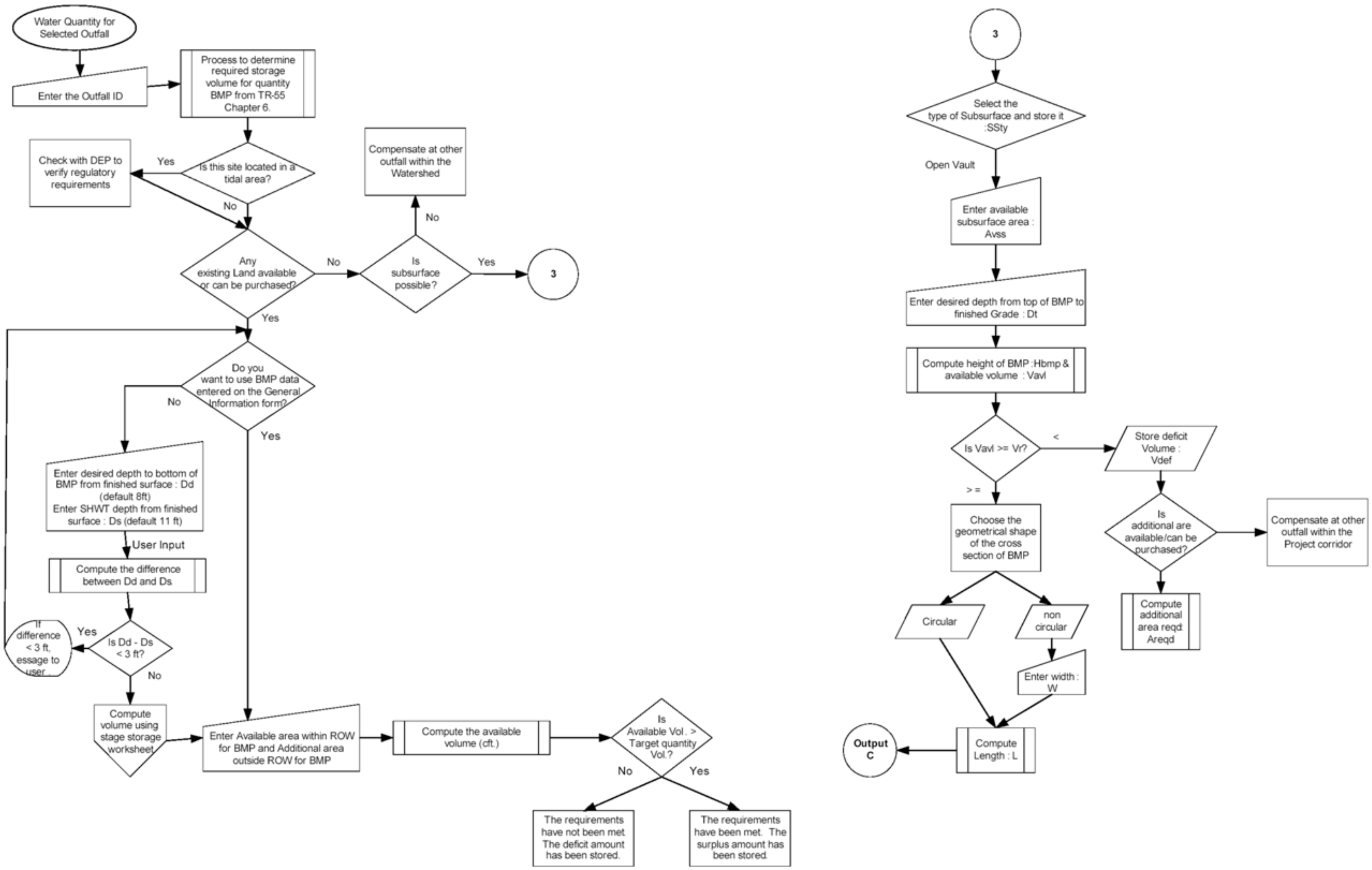

Water Quality for Selected Outfall
User Input
Specify area of new impervious to outfall that requires treatment (Anew).
Specify area of replacement impervious to outfall that requires treatment (Arepl)
NOTE: The total of every area entered must be equal to the proposed drainage area entered on the General Information Sheet
Compute required TSS removal rate for this outfall = (Anew X 0.8 + Arepl X 0.5) / (Anew + Arepl)
Is there additional area to outfall besides Anew and Arepl?
Yes
Enter area of additional impervious (Aidd) that doesn't require treatment
Enter area (Apdd) of additional pervious
Enter CN of additional pervious. CNpdd
Enter TC of Outfall Tcout
No
Compute peak rate and total volume from SWQ Storm.
Optional: Enter new adopted removal rates for Wet Ponds, Vegetative Filter, Extended Detention Basin, and Manufactured Treatment Devices
Process to determine eligible BMPs from Stormwater Treatment Techniques Table.
Output of eligible BMPs
Store the list of eligible BMPS
Output A
a
Go to sizing of each qualified BMP

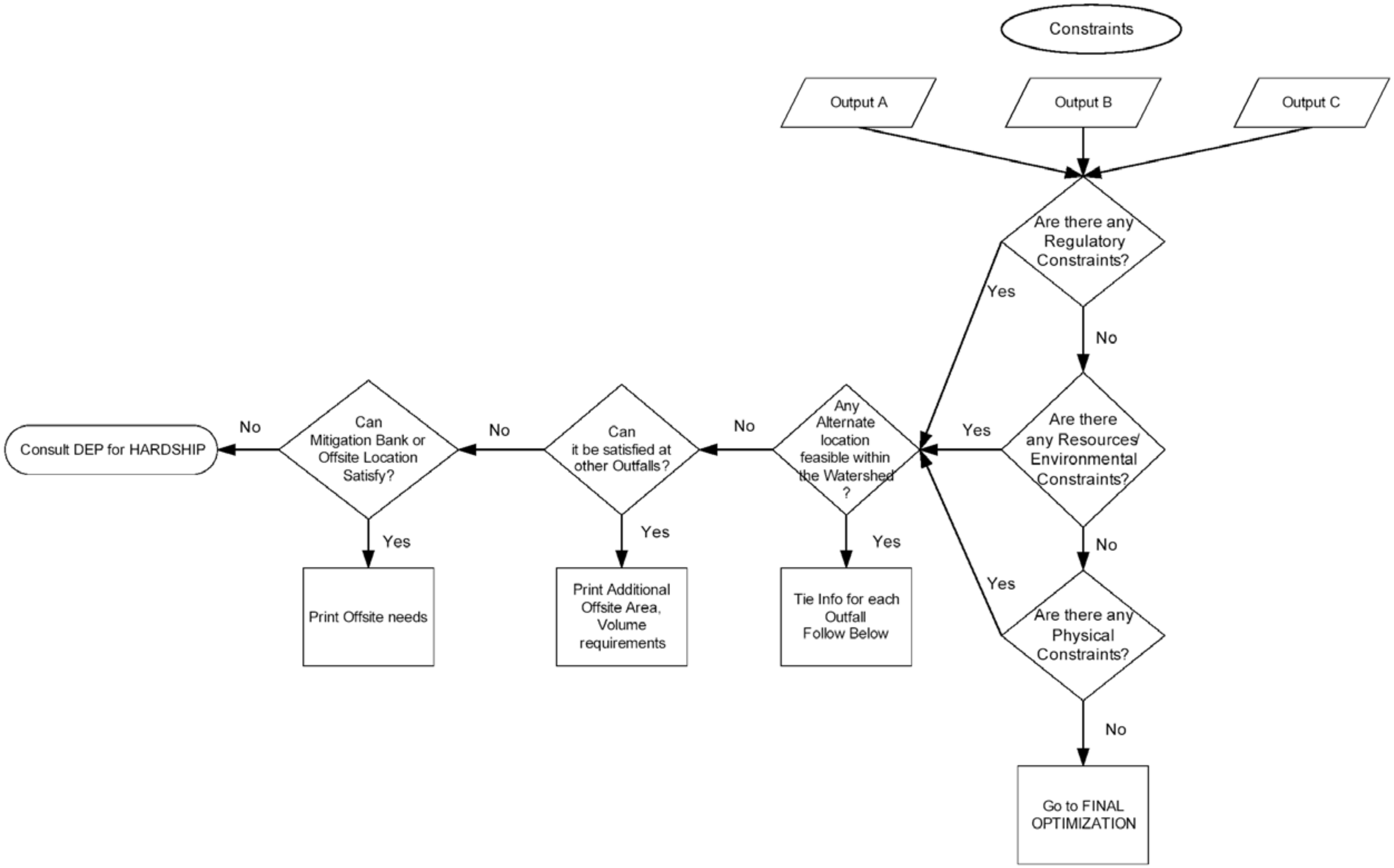


a
a1
Use stage storage values in all eligible BMPs for sizing .
1
2
3
4
5
6
7
8
Infiltration Basin
2
Copy of Aws, Swss, Wq and stage storage (Depth, Area & Volume)
Is the available volume at 3ft from finished surface > SWQ total Vol. ?
No
Yes
Do you want to revise input?
Yes
a1
No
Enter Permeability Rate : Prate
Is Time to Drain < 72 hrs?
No
Yes
Disqualify BMP
Qualify BMP as 'Practical'
Extended Detention Basin
3
Copy of Aws, Swss, Wq and stage storage (Depth, Area & Volume)
Enter Orifice diameter (default 2.5 in.)
Is the available volume > SWQ total Vol. ?
No
Do you want to revise input?
Yes
a1
No
Disqualify BMP
Yes
Calculate Depth, time and TSS removal rate
Qualify BMP as 'Practical'
Bio Retention Basin
5
Copy of Aws, Swss, Wq and stage storage (Depth, Area & Volume)
Is the available volume at 2ft (inc. 1ft freeboard) from finished surface > SWQ total Vol. ?
No
Do you want to revise input?
Yes
a1
No
Disqualify BMP
Yes
Is test Permeability rate > required?
No
Is entered depth from finished surface to SHWT is > 6ft
No
Yes
Qualify BMP as 'Practical' with illustration as a pdf to include liner & perforated pipes
Yes
Compute practical Bioretention Systems
Qualify BMP as 'Practical' with illustration as a pdf
Vegetative Filter
1
Is Drainage Pattern as Sheet Flow?
No
Yes
Is the filter strip < 8%
No
Yes
Select Soil Goup:Sg
Select Land Cover : Lc
Compute Strip Length and TSS Rate from table
Is Lc available ? NOTE: Maximum length of impervious area to filter < 100 ft.
Disqualify BMP
Qualify BMP as 'Practical'
Wet Ponds
4
Copy of Aws, Swss, Wq and stage storage (Depth, Area & Volume)
Is Permanent Pool Vol >= SWQ Vol.?
No
Disqualify BMP
Yes
Select ratio of Permanent Pool Vol. to SWQ Vol.
Do you have Extended Detention Basin?
No
Compute TSS removal Rate from graph
Qualify BMP as 'Practical'
Yes
Enter Orifice diameter (default 2.5 in.)
Is the available volume > SWQ total Vol. ?
No
Do you want to revise input?
Yes
a1
No
Yes
Calculate Depth, time and TSS removal rate
Qualify BMP as 'Practical'
Sand Filter
6
Avail. SA w/in R.O.W. for BMP
Addit. SA outside R.O.W. for BMP
Enter area at top and bottom and depth (min 2 ft) of Forebay Zone
Enter Design Perm (def / min 4 ft/ day), drain time (def / min 1.5 days), depth (def / min 1.5 ft), and porosity (def 0.3) for sand bed
Compute Forebay vs Sand quality design storm storage vol ratio
Enter overall flow path length vs width ratio (def 2:1) and add land use for BMP % (def 50%)
Compute output target SWQ vol and max avail vol – Compare volumes
Qualify BMP as 'Practical'
Pervious Paving
7
Output: SWQ Runoff Volume
Is tested subgrade soil permeability rate > 1 in/hr?
Is subgrade soil drain time > 72 hrs?
Is max pavement slope < 5%?
Is min perm rate for materials of porous paving surface and void space > 6.4 in/hr?
Is min perm rate for material between imperv pavers > 32 in/hr?
Perv. Pavement Surface Area
Media Void Ratio
Pavement or Paver Material Thicknes
Calculate Storage Bed Thickness, Practical Pervious Paving Systems
Qualify BMP as 'Practical'

NOTE: Water Quality requirements should be addressed prior to working with Groundwater Recharge.




Water Quantity for Selected Outfall
Enter the Outfall ID
Process to determine required storage volume for quantity BMP from TR-55 Chapter 6.
Check with DEP to verify regulatory requirements
Yes
Is this site located in a tidal area?
No
Compensate at other outfall within the Watershed
No
Any existing Land available or can be purchased?
No
Is subsurface possible?
Yes
3
Yes
Do you want to use BMP data entered on the General Information form?
No
Yes
Enter desired depth to bottom of BMP from finished surface : Dd (default 8ft)
Enter SHWT depth from finished surface : Ds (default 11 ft)
User Input
Compute the difference between Dd and Ds
Yes
Is Dd - Ds < 3 ft?
No
Compute volume using stage storage worksheet
Enter Available area within ROW for BMP and Additional area outside ROW for BMP
Compute the available volume (cft.)
Is Available Vol. > Target quantity Vol.?
No
Yes
The requirements have not been met. The deficit amount has been stored.
The requirements have been met. The surplus amount has been stored.
3
Select the type of Subsurface and store it :SSty
Open Vault
Enter available subsurface area : Avss
Enter desired depth from top of BMP to finished Grade : Dt
Compute height of BMP :Hbmp & available volume : Vavl
Is Vavl >= Vr?
<
Store deficit Volume : Vdef
> =
Choose the geometrical shape of the cross section of BMP
Is additional are available/can be purchased?
Compensate at other outfall within the Project corridor
Circular
non circular
Compute additional area reqd: Areqd
Enter width : W
Output C
Compute Length : L


Constraints
Output A
Output B
Output C
Are there any Regulatory Constraints?
Yes
No
Are there any Resources/ Environmental Constraints?
Yes
No
Are there any Physical Constraints?
Yes
No
Go to FINAL OPTIMIZATION
Any Alternate location feasible within the Watershed ?
Yes
Tie Info for each Outfall Follow Below
No
Can it be satisfied at other Outfalls?
Yes
Print Additional Offsite Area, Volume requirements
No
Can Mitigation Bank or Offsite Location Satisfy?
Yes
Print Offsite needs
No
Consult DEP for HARDSHIP