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A DECISION SUPPORT SYSTEM (DSS) FOR STORMWATER MANAGEMENT SYSTEM SELECTION

Angie Shelley Miles
University of New Hampshire

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BY

ANGIE SHELLEY MILES
B.S. Environmental Science, Saint Joseph's College, 1998

THESIS

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This thesis has been examined and approved.

Thesis Director, Dr. Thomas P. Ballestero
Associate Professor of Civil Engineering

Dr David Fluharty, P.E.
Director, University of New Hampshire
Technology Transfer Center

Ridgely Mauck, P.E.
NHDES

Date

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On a personal note I would like to thank; John, for encouraging me to continue my education and his ongoing support; Michelle, for always being there; and Mindy for just putting up with me through the ups and downs of research.

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LIST OF ABBREVIATIONS

BMPs	Best Management Practices
DSS	Decision Support System
MS4	Municipal Separate Storm Sewer System
NH	New Hampshire
US EPA	United Stated Environmental Protection Agency

ABSTRACT

A DECISION SUPPORT SYSTEM (DSS) FOR STORMWATER MANAGEMENT SYSTEM SELECTION

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On December 9, 1999 the US EPA published Phase II of the Clean Water Act. Under Phase II all existing municipal separate storm sewer systems (MS4s) located in "urbanized areas" (as defined by the Bureau of the Census) and construction activities that disturb more than or equal to one acre but less than five acres are required to attain a NPDES permit. The MS4 entities are obligated by Phase II to develop, institute and enforce stormwater management programs. These programs must include the selection and implementation of stormwater best management practices (BMPs) to reduce the pollutant load to receiving waters. The objective of this research was to develop a technically based DSS, which can assist in this compliance of the new NPDES Phase II stormwater regulations.

Keywords: Stormwater, Decision Support System (DSS), Best Management Practices (BMP)

CHAPTER 1

INTRODUCTION

1.1 History of Stormwater Regulations

Stormwater occurs when precipitation falls to the ground and flows over the surface rather than infiltrating. Land development can lead to increased stormwater due to the decreased infiltration from the construction of impervious surfaces. In between storm events, impervious surfaces collect a variety of contaminants. With the ensuing stormwater flow, the runoff washes the contaminants and directs them to surface water. The type and concentration of this contamination is often related to local land-uses. Left unchecked stormwater from urbanized areas may lead to changes in the hydraulic characteristics of the receiving water and result in increased peak flows and downstream flooding. Stormwater may also result in increased sediment transport rates and shoreline erosion. Public health could be jeopardized through the consumption of contaminated fish or drinking water supplies, or recreating on a contaminated water body *(US EPA, 1999)*. According to a report released by the US EPA, stormwater runoff from urban and agricultural land is the leading source of impairment to our nation's surface waters *(US EPA, 1996a)*. The degradation of surface water is therefore an environmental and public health concern.

The Federal Water Pollution Control Act (FWPCA), commonly know as the Clean Water Act (CWA), was first adopted in 1948. Amendments to the CWA in 1972 led to the establishment of the National Pollutant Discharge Elimination System (NPDES) program. The intent of NPDES was to prohibit non-permitted discharges to U.S. waters

(US EPA, 1996b). In 1978 the US EPA established the National Urban Runoff Program (NURP). The overall goal of which was to gain a clear understanding of the nature of urban runoff. This program had three main objectives: to examine and compare the quality of urban runoff at several locations, to determine the role of urban runoff in the water quality issues of the nation, and to examine the efficiency of BMPs to control and treat urban runoff *(US EPA, 1983)*.

US surface water protection programs are based on both regulatory and non-regulatory portions of the CWA. The CWA was initially focused on point sources of water pollution. However, as the point source issues became largely addressed, the focus expanded to include nonpoint source pollution *(US EPA, 2002a)*. Since 1972 the CWA has gone through several revisions and amendments. Congress enacted Section 319 of CWA in 1987, which established a program to control the pollution of waters by nonpoint sources *(US EPA, 2003)*. The CWA was expanded again in 1990 to include Phase I of the NPDES stormwater program. Phase I requires discharge permits from: municipal separate storm sewer systems (MS4s) that serve populations greater than or equal to 100,000; various listed industrial activities; and construction sites which disturb five or more acres *(US EPA, 2002b)*. The purpose of Phase I was to identify and decrease illicit discharges to receiving waters. It is estimated by the US EPA that 220 MS4s and over 123,000 industrial facilities, including construction activities, are subject to Phase I permitting *(APWA, 2000)*.

The first Phase of the NPDES stormwater program is considered to be an effective tool in the prevention of water pollution. However, according to the 1996 National Water Quality Inventory, 13 percent of impaired rivers, 21 percent of impaired lake acres and 45 percent of impaired estuaries are affected by urban/suburban stormwater runoff *(US EPA, 1996a)*. On October 29, 1999, EPA Administrator Browner signed Phase II of the NPDES stormwater program; it was then published in the Federal Register on December

8, 1999 *(US EPA, 2000a)*. According to *Stormwater Phase II Fact Sheet 1.0* released by the US EPA, Phase II is intended to further reduce adverse impacts to water quality and aquatic habitat by instituting the use of controls on the unregulated sources of stormwater discharges that have the greatest likelihood of causing continued environmental degradation *(US EPA, 2000b)*. Phase II of the NPDES stormwater program greatly expanded stormwater discharge regulations. Under Phase II all existing MS4s located in "urbanized areas" (as defined by the Bureau of the Census), and construction activities that disturb more than or equal to one acre but less than five acres are required to attain NPDES permit coverage. The Phase II rule will affect approximately 3,500 cities and 110,000 construction sites a year *(Copeland, 1998)*. Phase II MS4 communities are required to implement the following six minimum control measures: (1) public outreach and education, (2) public participation, (3) identify and eliminate illicit discharges, (4) construction site erosion control, (5) post-construction stormwater management, and (6) pollution prevention and "good house keeping" *(Hunter, 2002)*. Phase II compliance is a daunting task for small communities, where technical and financial resources are often limited. The MS4 communities are obligated by Phase II to develop, institute, and enforce stormwater management programs. The programs must include the selection and implementation of stormwater BMPs to reduce the pollutant load to receiving waters, and fulfillment of the six minimum control measures *(US EPA, 2000b)*.

BMP selection can be very time consuming and costly for communities that do not have past experience in stormwater management. This is mainly due to the vast options available for stormwater treatment *(Esterberg, 2000)*. The purpose of this research is to provide the user with a tool to aid in the BMP selection process. The goal of the project is to organize BMP options based on device specifications. This project will be directly applicable to the requirements of 4, 5, and 6 of the six Phase II minimum control measures.

1.2 Decision Support System (DSS)

An expert system, sometimes also known as a DSS, assists in solution development based on expert data and user input. Decision support systems first started to gain recognition in the 1960s. Initially DSS were focused on business management and only began to expand into other fields in the late 1980s *(Power, 2003)*. A DSS is an interface between the user and expert knowledge and understanding. The goal of a DSS is to enhance the decision-making ability and efficiency of the user *(Sprague and Carlson, 1982)*. The knowledge base of a DSS should be designed in such a way to allow for easy modification. This is extremely important in the areas of engineering, specifically stormwater management, due to the continuous advancement in these fields. It is vital to the success of a DSS that the knowledge base be current with the technologies of the day *(Maher, 1987)*. There are many examples of tools to aid in the management of stormwater. These tools vary widely, from state issued BMP manuals to databases of manufactured devices. The databases are usually limited to the companies that pay for advertising, and state manuals often do not include manufactured devices. The following are examples of three different types of stormwater management tools.

The NH Innovative Stormwater Treatment Technologies Best Management Practices (ISTTBMP) Manual is a textual resource, which walks the reader through the BMP selection process. This manual is geared toward nontraditional innovative stormwater treatment technologies. Innovative technologies are often employed due to site limitations and/or political pressures. The ISTTBMP manual consists of five chapters: Chapters 1 and 2 provide an introduction to stormwater and its related issues; and address the issues to be considered when selecting BMPs. Chapter 3 explains the seasonal affects on BMP effectiveness and maintenance requirements. The importance of implementing effective operation and maintenance plans is outlined in Chapter 4. Chapter 5 provides details on several stormwater BMPs (NH DES, 2002).

The National Stormwater Best Management Practices (BMP) Database (http://www.bmpdatabase .org) provides the results of research into the effectiveness of specific BMPs. There is a vast amount of data at this web site, a total of 199 BMPs are evaluated. The database can be searched by several parameters: state, county, watershed size, general BMP type, BMP group, specific BMP type, and water quality. These parameters may be queried individually or in combination. The database of the site is limited to BMPs that have been researched and submitted for listing (UWRRC, 2002).

In the November/December 2002 issue of Stormwater Magazine, Stuart Patton Echols wrote an article titled `A Community Framework for Ranking Stormwater Strategies' which detailed a decision support system to assist in the ranking of local priorities. This DSS is a series of ranking tools for evaluating, BMP types based on site conditions and limitations, the benefits and efficiency of each BMP type, and the overall environmental and community benefit. As stated by the author of this ranking system, it is both complex and time intensive.

Each of the decision support tools previously described the initial framework for stormwater management and the selection of stormwater treatment devices. However, all are limited in the area of specific device selection. The BMP database website addresses only the effectiveness of each site-specific device. The NH ISTTBMP manual aids in the identification of specific devices, however only 21 options are currently included in the manual. The ranking system by Stuart Patton Echols assists in the determination of BMP type but does not address specific devices. Many of the existing tools could nicely compliment the Stormwater DSS. The Stormwater DSS does not aid in the initial determination of the appropriate BMP type for a site but rather gives the user the appropriate technologies to use when the DSS is given input (site) characteristics.

1.3 Research Objectives

The objective of this research was to develop a technically-based DSS, which can assist in the selection of stormwater management systems. The DSS was designed to organize and simplify the abundant information on stormwater treatment devices. The goal of this Stormwater DSS is to function as both a database of stormwater treatment devices and technologies, and to produce stormwater treatment options based on site-specific information. The user is able to access detailed product information via either the encyclopedic database, organized by device name, or through queries that result in a list of appropriate devices. The DSS provides specifications on both traditional and innovative technologies. Non-manufactured or traditional devices may be accessed as any other device. However, the database fields for manufacturer and contact information instruct the user to consult their local or state issued stormwater BMP manual. Due to the fact that the field of stormwater management is continually advancing, this DSS was created to be easily updated and modified in response to the latest developments. The Stormwater DSS is applicable to most stormwater assessments.

CHAPTER 2

METHODS

2.1 Stormwater DSS Development

The Stormwater DSS was developed following the seven basic steps for creating a DSS outlined in Building Effective Decision Support Systems *(Sprague and Carlson, 1982)*. The first is to interview potential users to determine needs and what type of decision support tool would be useful. Second, prepare an outline and the overall objective of the DSS based on user input. Third, select a software platform for development of the DSS. Fourth, code the initial version of the DSS. Fifth, distribute the initial version of the software for beta testing. Sixth, make alterations to the software based on beta testing results. Finally, publicize and distribute the DSS.

The first step in model development was to interview individuals affected by NPDES Phase II regulations to determine their needs and what, if any, type of decision support might be useful, see Figure 1. A wide variety of individuals were interviewed: a private environmental consultant, a public works director and a city chief sanitary engineer are three examples of the individuals interviewed, for a complete list see Appendix C. As described in the results section, the format of the DSS was designed on input from this first series of interviews. Based on these results, the Stormwater DSS, needed to consist of two major components: a database of stormwater treatment devices and a decision support structure to recommend stormwater treatment devices based on site-specific information.

Interview Questions Outline

1. What information would be useful from such a program?
   a. What should be included in the database?
2. What are typical input parameters?
3. What information should be included in the results?
   a. How should the results be formatted?
4. Other ideas for effort.
5. What types of stormwater controls and treatments are you currently implementing?

Figure 1. Interview Outline

The DSS knowledge base consists of a compilation of information and data relevant to stormwater treatment. The device database includes: manufacturer contact information, pollutants, type of BMPs, installation and special requirements, and images of each device. The database information was acquired through interviews of experts in the field of stormwater management and the compilation of manufacturers' specifications. Device specific information was obtained from several sources: the World Wide Web, stormwater workshops, manufacturer publications, and direct contact with manufacturers. This information was then organized into the database. The content and format of the database was determined by the initial interviews. Prior to distribution, all database material was sent to the manufacturers for final approval. This verification process ensures the accuracy of the Stormwater DSS database.

A variety of software platform options were researched for the development of the DSS. Microsoft Visual Basic 6.0 (MS VB6.0) was selected as the platform. Visual Basic 6.0 was chosen due to its orientation with the Windows environment and ease of use. MS VB6.0 allows the programmer to compile the software code during the construction phase, which enables simple testing and troubleshooting. In addition, MS VB6.0 was a cost effective software option with a well-established technical support through Microsoft. MS VB6.0 also offered many database options. A Windows-based platform was selected under the assumption that most users would have prior exposure to Windows applications and therefore familiarity around Windows screens and logic structure. Microsoft (MS) Access was selected as the database. MS Access is easily linked to MS VB6.0, and many of the same Window's benefits of MS VB6.0 apply to MS Access. The database is accessed by the Stormwater DSS through either the alphabetic encyclopedia of devices or a series of decision support queries; the decision support structure of the Stormwater DSS is outlined in Figure 2. The premise is that the MS Access database is easily updated with technological advances in stormwater management and devices/manufacturers. However, precaution will have to be taken if the database is updated to a newer version of MS Access. As discussed in the results section, there was some unforeseen difficulty in liking MS Access XP to MS VB6.0.

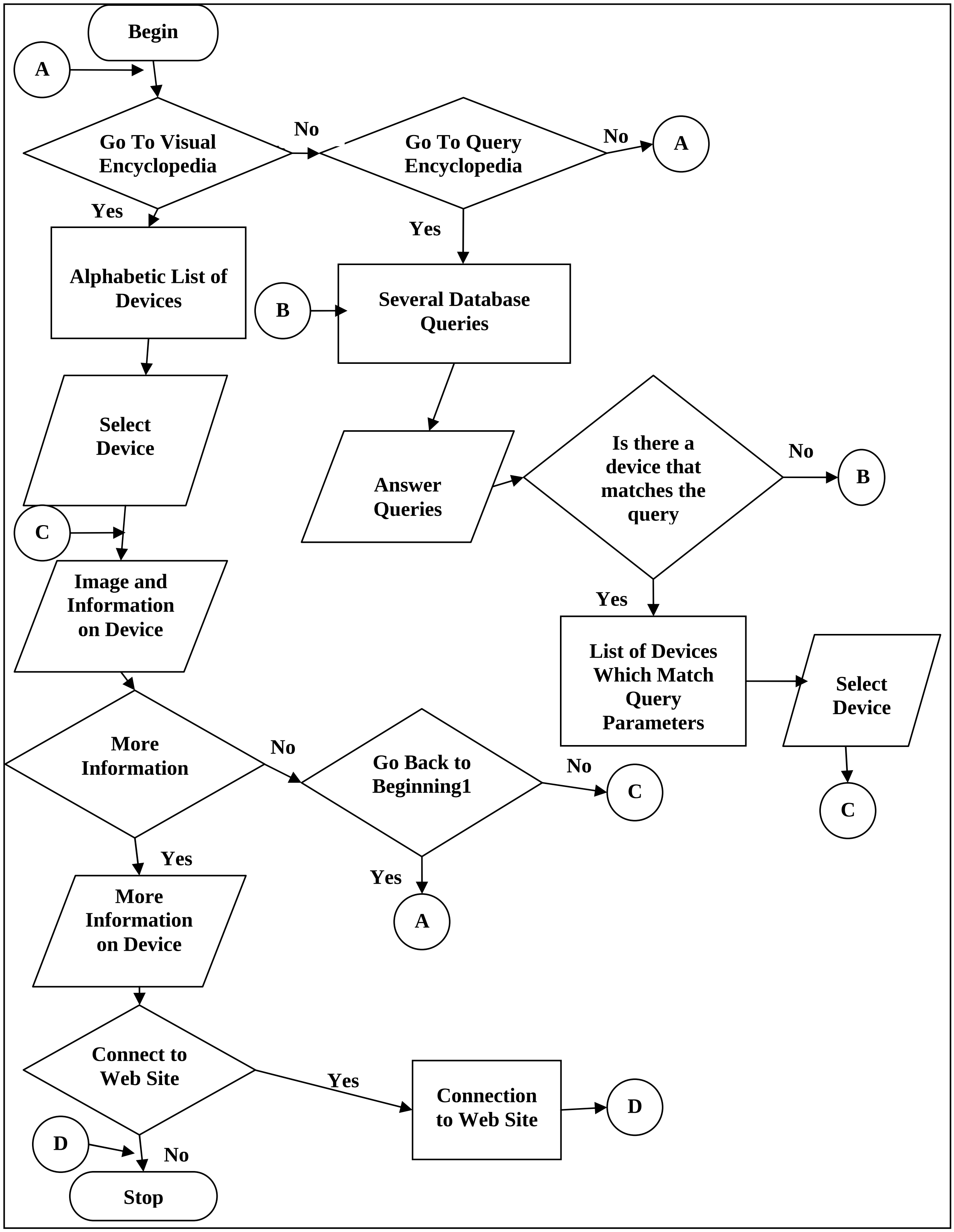

Figure 2. Flow Chart of the Stormwater DSS Structure

The Stormwater DSS was distributed to four individuals in the water resources division of the civil engineering program at the University of New Hampshire for testing. The goal of the "in-house" testing was to identify any bugs and glitches in the software prior to beta testing. This initial phase of testing was not geared toward verifying the applicability of the software. The intent was to confirm the software would function, without conflicts, on most if not all windows based environments. Upon completion of this first step, the DSS was then sent to five individuals in the field of stormwater management. The beta testing group (Appendix D) consisted of city engineers, consultants and state regulatory officials. The five were asked to comment on usability, quirks in the software, applicability, and what is lacking in the software. The DSS was then updated and modified based on testing results. The most significant issue identified through the testing was the lack of an adequate help document. The help file was then expanded to include a definition of terms section.

Prior to software distribution, the database information was sent to manufacturers for verification and final approval. This was a key step in confirming the accuracy of the information contained within the Stormwater DSS. The DSS is available for download from www.STEVC.unh.edu as well as on CD.

CHAPTER 3

RESULTS

3.1 Initial Interviews

It was determined through the initial interviews that a tool to aid in the BMP selection process would be useful, due to the vast amount of data and technologies available. There was clear agreement from all interviewed that a visual encyclopedia of stormwater treatment devices would be valuable. It was expressed that a DSS would have to be both simple to apply and non-time intensive.

3.2 Software/Database Development

Microsoft Access and Visual Basic 6.0 were selected as the software platforms. These selections were made based on the user-friendliness of the windows environment for both the programmer and the Stormwater DSS user. However, there was some difficulty in updating the database from MS Access 98 to MS Access XP. The MS VB6.0 programming code had to be altered to link to the newer version of MS Access. This should be taken into consideration before any version updates are made to the database.

Manufacturer input has been difficult to obtain throughout the project. In order to distribute the Stormwater DSS, permission was first sought from manufacturers to reproduce copy write-protected material and design specifications. After 18 months of contact only fifteen of the seventy manufacturers responded.

3.3 Beta Testing

Through testing, it was determined that the DSS was a useful tool in narrowing the range of BMP device options. One significant comment was that the Beta version of the Stormwater DSS would be more useful if the queries were refined. In the original code, the query structure was very broad. Figure 3 is a capture of the Stormwater DSS query screen. The Stormwater DSS was applied to aid in the selection of manhole and catch basin retrofits. In one beta test, using the Stormwater DSS in this case, the user was able to quickly locate many technologies that fit within specified parameters. Once the device was selected the user was able to proceed directly from the DSS to the manufacturer's web site and request more detailed product specifications. Beta testing also resulted in the identification of an error in compatibility with some versions of the Windows operating system. This was resolved with software patches available for download from the Microsoft web site.

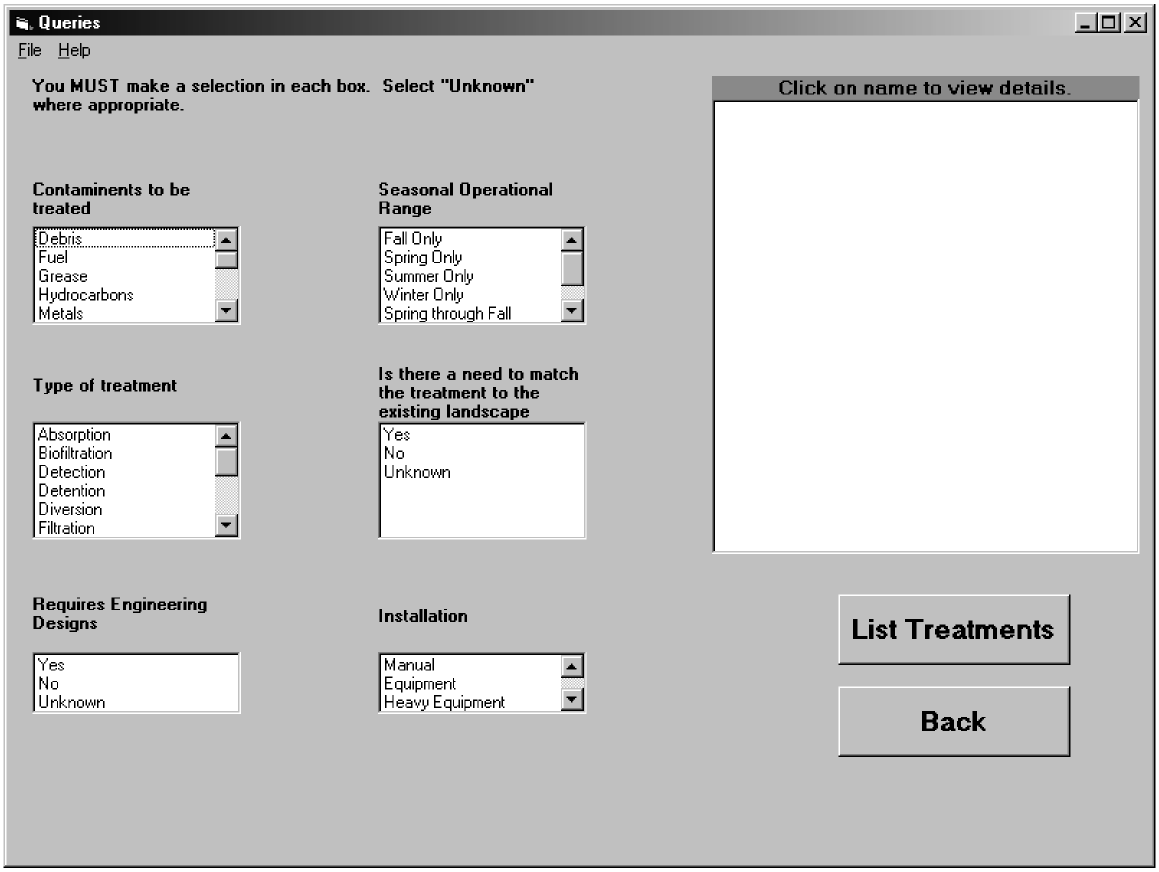

Figure 3. Stormwater DSS Screen Capture

3.4 Application

The user initially has the ability to select either the encyclopedic database of stormwater treatments or the queries to narrow the treatment options based on user selection. The query structure and output was developed based on the results of the initial interviews. The following is an example application of an application of the DSS.

1. The query option was selected from the initial user interface screen, Figure 4.

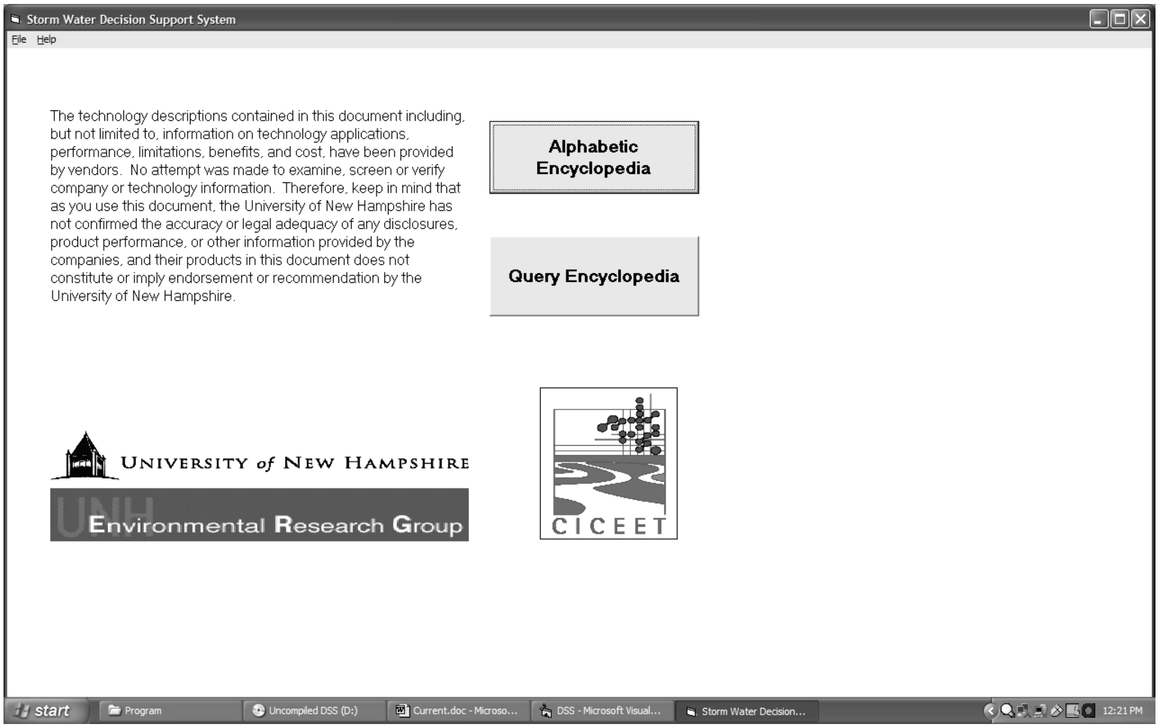

Figure 4. Stormwater DSS Initial User Interface Screen Capture

2. Two selections were made from the six query options. The user has the ability to make detailed selections in any number of the query boxes. However, if the user does select for site specific requirements then "Unknown" must be selected, Figure 5. "List treatments" is selected to populate a list of the treatments which match the query selections.

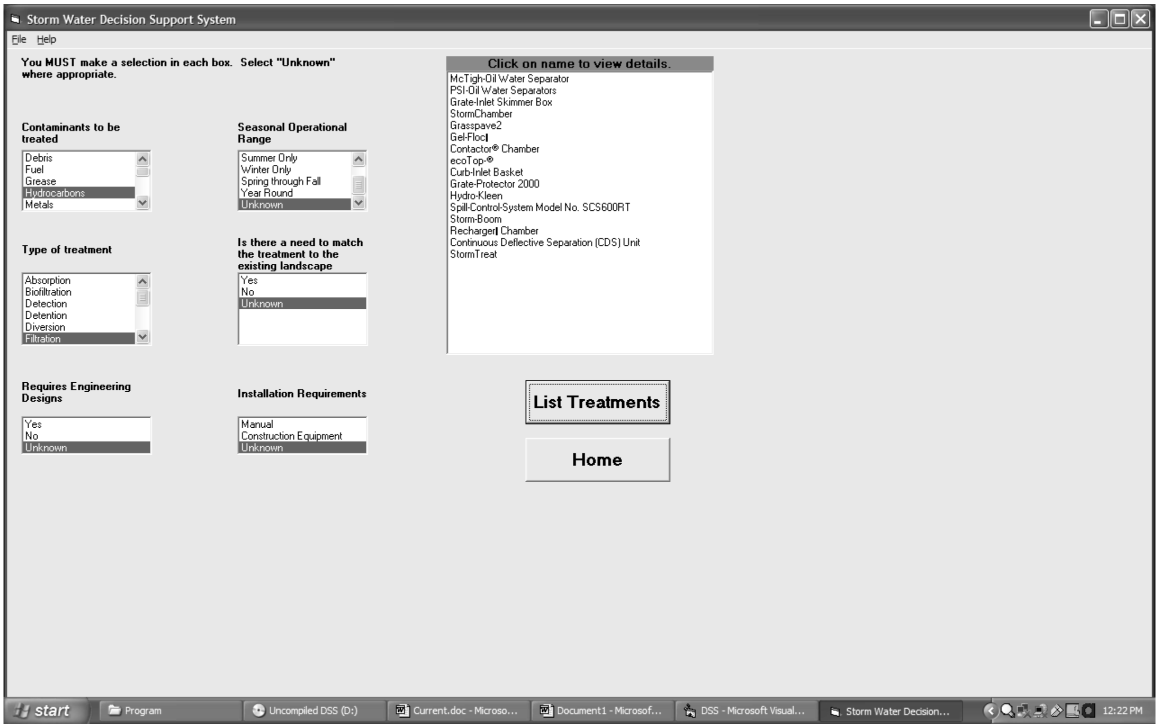

Figure 5. Stormwater DSS "Query" Screen Capture

3. A treatment is selected from the list box to view more detailed information on the treatment, Figure 6. From this screen an image of the device may be viewed by selecting the "View Image" option. The user also has the ability to view more detail and a link to the manufacturer's web site by clicking on the manufacturer's name.

Figure 6. Stormwater DSS "Treatment Selection" Screen Capture

Once the user has narrowed the field of treatment options they should contact either the manufacturers or refer to their local stormwater BMP manual for detailed specifications.

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

4.1 Discussion and Conclusions

As discussed in the Results section, the Beta testers reflected that the Stormwater DSS was a useful tool.

The Stormwater DSS database is limited by the cooperation of manufacturers, and their willingness to participate. The database only includes devices and technologies for which information was readily available and whose permission was granted by manufacturers. The Stormwater DSS does not rank the BMPs based on performance, it only lists the appropriate options applicable to the user input. The Stormwater DSS relies on manufacturer's specifications and publications; the accuracy of this information was not verified in this research. The goal of this project was not to identify the effectiveness of various treatment options but rather to organize the options based on intended function.

As discussed in the Introduction, many of the existing tools for stormwater treatment are either nonspecific or very time intensive. The NH ISTTBMP manual does address specific devices; however there are very few devices to select from within the manual. One of the goals of the Stormwater DSS was to include as many devices as possible. The Stormwater DSS was also designed to be simple and non-time intensive to operate. The NH ISTTBMP manual provides a solid background on stormwater management, however application of the manual is time intensive. This is also true for the DSS by Stuart Patton

Echols. The Stormwater DSS has achieved the original goal of being a user-friendly tool to aid in the BMP selection process.

4.2 Recommendations for Future Research

There are several areas where the Stormwater DSS could be expanded to provide a more comprehensive stormwater management tool. For example, expansion of the query structure and database to include more detailed device specifications, such as: installation unit costs, specific contaminant removal effectiveness, maximum device flow, etc.

The Stormwater DSS uses a Microsoft Access database, which can be individually tailored with minimal effort. It would also be useful in the future to provide the user with the ability to update a global Stormwater DSS database. For instance, if there were means for the user to submit information on new technologies via the world-wide-web. There are problems with this process however, there would either be an assumption that the information submitted was correct or there would have to be an established verification process. This would require a fair amount of man-hours, which may not be an option.

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APPENDIX A

STORMWATER DSS SOFTWARE INSTALLATION INSTRUCTIONS

1. Insert and open the Stormwater DSS disk. The contents of the disk may be viewed through windows explorer.

2. Double click the SetUp.exe file and follow the installation instructions.

APPENDIX B

DATABASE USER/PROGRAMMERS MANUAL

Note: Use caution if updating the version of Microsoft Access. Newer versions may not link to Visual Basic in the same manor as the current version.

It is very simple to add new technologies to the database. First, using MS Access, open the Stormwater DSS database, treatment.mdb, and then select the table named technology. The information on the new device may then be added to the existing table format. It is very important to maintain the names of the existing columns as the queries in the Stormwater DSS code are based on these column names. The order of the columns is not relevant and may be changed for easier viewing. Columns may also be added to the database as long as the name of the new column does not duplicate any of the existing column names. These new columns can be the basis for expanded queries or just additional information. After the database has been modified the software batch file must be updated. This is done by going to the DSS location on the hard drive. Open the DSS folder and the sub folder Support. Double Click the only file in the folder with the file extension, ".BAT". This will update the DSS software cabinet file and tell the software to use the new version of the database.

APPENDIX C

LIST OF INITIAL INTERVIEWEES

David Fluharty	University of NH Technology Transfer Center
Jerry Dexter	Pease Development District
Joanne McLaughin	NH Office of State Planning
Melodie Esterberg	City of Rochester
Thomas Siegle	City of Manchester
William R. Arcieri	Great Bay Environmental Consulting

APPENDIX D

LIST OF BETA TESTERS

David Fluharty	University of NH Technology Transfer Center
Melinda Bubier	University of NH
Ridgely Mauck	NH Department of Environmental Services
Robert Roseen	University of NH
Thomas Ballestero	University of NH