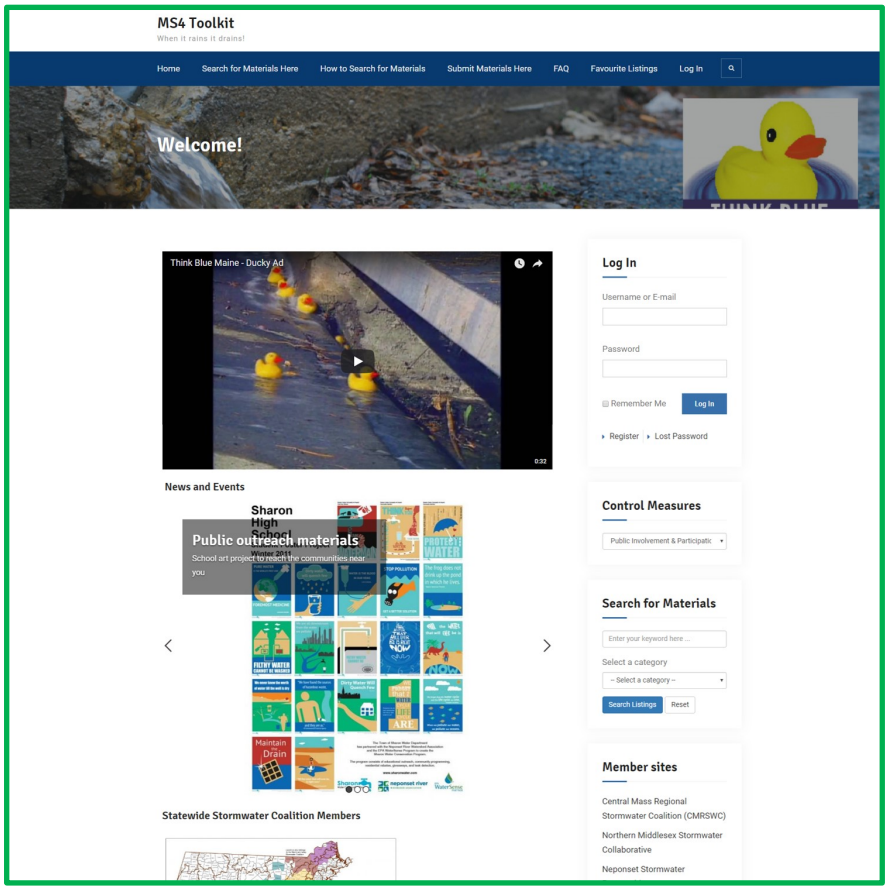
WROC
Massachusetts Water Resource Outreach Center

Development of a Centralized Stromwater Materials Repository



Abstract

Stormwater pollution is the largest contributor to water pollution in Massachusetts. To more efficiently manage stormwater pollution, our sponsors, the Massachusetts Statewide Municipal Stormwater Coalition, worked with us to design and develop an online centralized repository to hold vetted stormwater management materials, which, prior to this, were diffuse and variable in terms of content. Through our semi-structured interviews and research, we identified the most important criteria that were required for the success of the repository. Additionally, we identified the top possible housing and hosting locations that were credible and sustainable. Lastly, we developed a working template of the repository for actual use and further development for the Statewide Coalition.

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Massachusetts Statewide Municipal Stormwater Coalition (MSMSC)

An Interactive Qualifying Project submitted to the faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements o for the degree of Bachelor of Science

WPI

Centralized Stormwater Materials for Massachusetts Municipalities

As of 2017, two billion people in the world, 28% percent of the worldwide population, do not have access to clean water (Vang le, 2017). As the years go on, this number will continue to increase unless something is done to prevent it. Although water is the most abundant resource, only 1.2% is freshwater and can be used for human needs (Howard, 2016). Unfortunately, our water sources are constantly being polluted and contaminated through the dumping of industrial wastes, sewage disposals, and stormwater pollution. Consumption of these contaminated waters, filled with pathogens, garbage, chemicals, and other pollutants, attribute to 80% of all deaths in the developing world (Annan, 2003). Even in the developed world, such as the United States, individuals still suffer from the consequences of water pollution. Our project revolved around developing a centralized repository to hold materials that can be used in the state of Massachusetts to properly and efficiently manage stormwater pollution, one of the major contributors to water pollution in the United States (Gaffield, 2011).

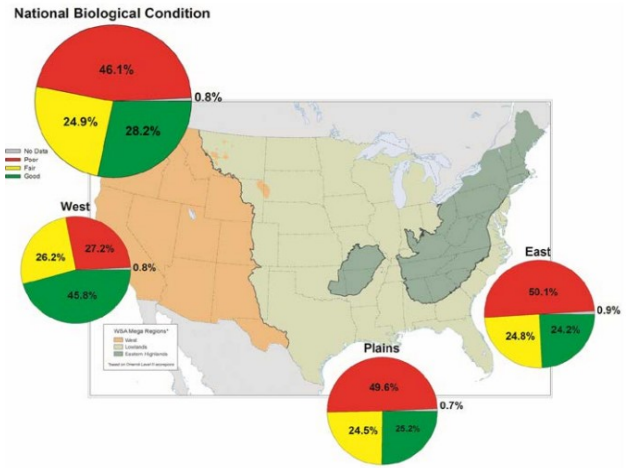

Figure 1: Map showing percentage of impaired waters in the United States (US EPA, 2017)

Stormwater Pollution in the United States

The 2017 United States Environmental Protection Agency (US EPA) Report to Congress reported that 46% of tested rivers and streams, as well as 21% of randomly selected lakes and reservoirs, were impaired, or unfit for public consumption and use, as seen in Figure 1 (US EPA, 2017). A member of the US EPA at the time, Gaffield explained in his published paper that stormwater runoff is one of the major contributors to water pollution in the United States (Gaffield, 2011). Stormwater runoff is the natural precipitation from either rain showers or melted snow that flows over impervious surfaces, such as roof tops and paved roadways, surfaces that have been expanding due to urbanization. As runoff flows across the impervious surfaces, it picks up and carries garbage, chemicals, bacteria, sediments, and other pollutants to different surface waters and water bodies (Gaffield, 2011). Spread of these hazardous materials damage the natural environment and contaminate water reservoirs used for public drinking water and recreation (Bioclean, 2012).

Stormwater Regulation

To minimize the effects of water pollution in the United States, The United States Congress passed amendments to the 1948 Federal Water Pollution Control Act and created what is currently known as the Clean Water Act (CWA). The CWA prohibits any discharge of pollutants into bodies of water without a permit (US EPA, 2013). An extension of the CWA is the Municipal Separate Storm Sewer System (MS4) Permit, used to regulate pollutants within MS4s.

A MS4 is a means of transportation of stormwater to avoid it running over impervious surfaces. The system consists of a series of catch basins, storm drains, pipes, ditches and outfalls, which serve to collect, move, and discharge stormwater into a local surface water body. This design decreases the amount of pollutants collected while moving along ground surfaces. It should be noted that MS4s are separate from local sewage systems, which, unlike MS4s, send collected water to a treatment plant, as seen in Figure 2 (US EPA, 2015b, 2018). Therefore, in MS4s, all water discharged into lakes, rivers and streams are untreated, dumping any pollutants picked up along the way to these surface water bodies.

Municipal Separate Storm Sewer System Permit in Massachusetts

The US EPA implemented the MS4 Permit in 2003 with the goal to improve the quality of surface water bodies by reducing the amount of pollutants that enter into MS4s (US EPA, 2005). To reach this goal, the US EPA developed six minimum control measures that local governments must comply with through incorporating them into their stormwater management practices:

1. Public Education & Outreach
2. Public Participation/Involvement
3. Illicit Discharge Detection & Elimination
4. Construction Site Runoff Control
5. Post-Construction Runoff Control
6. Pollution Prevention/Good Housekeeping

Municipalities must meet all of the requirements of the MS4 permit or they may be subjected to a fine. In 2008, the 2003 MS4 Permit expired, but remained active until the start of the 2016 permit. The US EPA revised the 2003 MS4 permit to create the 2016 MS4 permit and planned to make it effective on July 1, 2017. However, after seeing the revised permit, affected municipalities voiced their opinions, worries, and concerns regarding the increased specificity and rigid requirements, as it has about 8 times as many requirements (F. Civian, Personal Communication, March 15, 2018). Due to these concerns and lawsuits, the US EPA pushed the implementation date of the revised MS4 Permit to July 1, 2018.

Figure 2: Diagram of MS4 and Sanitary Sewer (US EPA 2018)

Public Education and Outreach Control Measure

Due to the vastness of the MS4 Permit, our project focused specifically on the first minimum control measure of Public Education and Outreach. The purpose of the first minimum control measure is to spread awareness and educate four specific audiences within the local community: residents, commercial businesses, developers and industry (US EPA, 2005). The goal of this requirement is to facilitate pro-environmental behaviors and encourage a more environmentally favorable lifestyle due to the awareness and knowledge of how societal actions affect the surrounding environment. Through this, the MS4 Permit hopes to have all community stakeholders make conscious and informed decisions to reduce stormwater pollution. One of the biggest and most worrisome additions to the revised permit is the requirement to evaluate educative and outreach materials (I. Cooke and N. Fyler, Personal Communication, March 16, 2018). To comply with the first minimum control measure of the 2003 MS4 permit, municipalities could simply distribute flyers, pamphlets, newspaper advertisements, and education materials, but did not need to evaluation the effectiveness of these materials. The revised permit states that municipalities must "evaluate" their materials, however does not directly specify what it means to evaluate and by what standards (K. Reed, Personal Communication, March ,2018). This lack of clarification has made municipalities unsure of what exactly to do to meet the first minimum control measure (I. Cooke and N. Fyler, Personal Communication, March 16, 2018).

Massachusetts Statewide Municipal Stormwater Coalition

For this project, we worked directly with the Massachusetts Statewide Municipal Stormwater Coalition (MSMSC), commonly referred to as the Statewide Coalition. The Statewide Coalition, established in 2016, is a statewide collaborative effort to bring together various coalitions and watershed associations across Massachusetts to help municipalities comply with the 2016 MS4 Permit. Participating coalitions include the Central Massachusetts Regional Stormwater Coalition, the Connecticut River Stormwater Collaborative, the Northern Middlesex Stormwater Collaborative, the Neponset Stormwater Partnership, the Merrimack Valley Planning Commission, and the Southeast Regional Services Collaborative's Stormwater Group as seen in Figure 3.

These coalitions share their stormwater resources and materials to help each other more effectively manage stormwater in their respective regions. In addition to the coalitions, there are six watershed associations that are also helping out in this collaborative effort. Combined, the

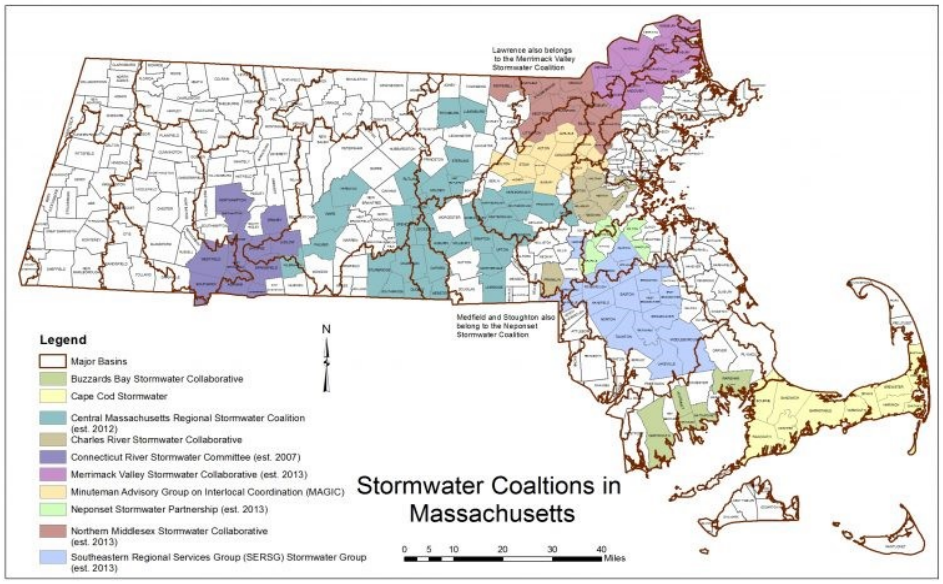

Figure 3: Map of Stormwater Coalitions (A. Briggs, Personal Communication, April 6, 2018)

Statewide Coalition represents 90 different municipalities in Massachusetts that are all affected by the MS4 permit and are working together to manage stormwater in a more efficient and cost-effective manner (Central Massachusetts Regional Stormwater Coalition, 2018a).

The Need for a Centralized Repository

At the time of writing, coalitions and municipalities were preparing themselves to meet the new requirements of the 2016 MS4 permit. Prior to the issuance of the 2016 Massachusetts MS4 Permit, municipalities grew concerned anticipating the potential vastness of the new requirements after the US EPA completed a comparative analysis between the revised New Hampshire MS4 Permit in 2013 with the initial New Hampshire MS4 Permit in 2003 (US EPA, 2013a). There were growing concerns regarding the challenges of implementing and complying with the new and more rigid stormwater regulations (Able, 2017). This is especially true for smaller municipalities who may not have the financial, technical, and physical resources to meet the newer and stricter requirements (Barat, Chin, & Feraco, 2012). Additionally, the ambiguous descriptions for some requirements, such as the evaluation component of the first control measure, has caused concern for the municipalities (Barat, Chin, & Feraco, 2012).

The Massachusetts Department of Environmental Protection (MassDEP) has taken up the role of MS4 educational liaison to help municipalities understand the MS4 permit requirements (Botelho, Gorton, & Pai, 2013) (Figure 4). They work to communicate with municipalities and provide additional resources to assist them in their MS4 compliance efforts. However, many municipalities are hesitant to fully disclose their current stormwater management systems as they can be subjected to a fine up to $60,000 due to lack of compliance (Spencer, 2012).

To circumvent these issues, the Statewide Coalition hopes to help municipalities across Massachusetts with compliance. As a result, the Statewide Coalition recognized the need for a centralized repository of information and materials for use by Massachusetts municipalities. Given the lack of a centralized repository and a Statewide Coalition Website, regional coalitions have been using their coalition websites to house resources for stormwater management, but these are diffuse and variable in their content (F. Civian, Personal Communication, March 15, 2018). This scattered information made it difficult for members of local municipalities to locate and identify relevant materials that fit their current situation and needs. A centralized repository would allow all participating members of the Statewide Coalition to easily access and distribute relevant vetted stormwater materials and resources.

What is a Centralized Repository

A repository can come in various forms such as an online database, a binder filled with relevant materials, a handbook, and other similar receptacles (Oxford Dictionary, 2018). The Statewide Coalition aimed to design and develop an online centralized repository, allowing all participating municipalities could access, upload, and download materials, as demonstrated in Figure 4. A centralized repository is an online resource that acts like a container to hold materials that can be accessed through the internet on any device (Andrews & Shiman,

2002). The Statewide Coalition hoped to design a repository that allows municipalities to quickly search for relevant and vetted stormwater materials.

An online repository can be split into two aspects: back-end and front-end. Back-end refers to the infrastructure and administrative side of a website that keeps the website running. (Harvard, 2018). of a website database as a whole including online servers, coding and data management. The one aspect of back-end we considered in our project was housing. Housing entails where exactly and on what server the Centralized Repository will be located online and made available to users. Front-end refers to the overall aesthetic and organizational layout of the pages on the repository. For the purposes of our project, we primarily focused on front-end criteria for the design and development of the Centralized Repository.

As there is a lot of psychology behind front-end designs, various professionals in the field have evaluated and examined the best designs for websites and repositories (Galitz, 2007). User interface is the primary component of front-end development and is therefore essential for the success of a website (User Interface Design, 2017). If an online resource is not user friendly, it will have no users. User interface design begins with anticipating what potential users may use the online resource for and developing an organized flow to avoid any possible confusion and frustration. Various components make up user interface, such as input controls (e.g. drop-down menus, buttons, etc.) and navigational components (e.g. sliders, search fields, etc.) that users directly interact with on the website. Designers must determine their primary audience and organize these components to ensure their product is user friendly (User Interface Design, 2017).

Figure 4: The Idea of a Centralized Repository for Stormwater Coalitions

All of these different aspects of a repository must be considered when designing an online repository. Although there are often commonly used themes, each website and repository are unique to satisfy their specific target audience. With the members of the stormwater coalitions as our primary users, we designed the Centralized Repository to fit their specific needs.

Six Steps of Repository Development

We identified six objectives that were necessary to designing a successful repository for the Statewide Coalition. For the purposes of our project, we classified a successful repository as one that met all the needs of the Statewide Coalition and all the criteria identified in Objectives 1 and 2.

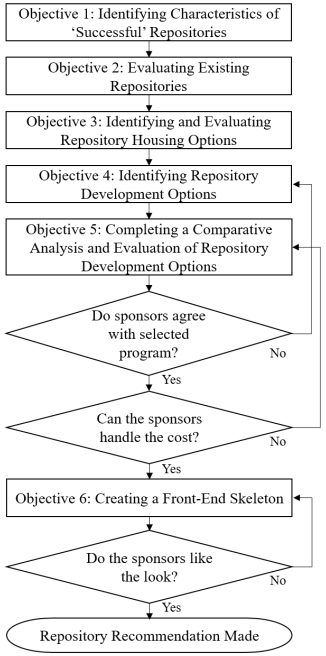

Figure 5: Project Flowchart of objectives

The overall workflow of the project was not completely linear, as seen in Figure 5. Instead, we met with our sponsors on a weekly basis and presented our current works to refine our results and matrices. Their feedback ensured that our recommendations could meet all their needs.

Figure 5: Project Flowchart of Objectives

Objective 1: Identifying Characteristics of 'Successful' Repositories

We began by selecting 18 online resources, seven were guides provided by

businesses that help with website or repository development, five guides from freelance developers who have worked in the field for over ten years, four academic text books and guides, and two posts on a technical and software forum. These sources provided different point of views of the field of what should be included in a repository. We recorded all of the criteria brought up in all 18 sources, for example content organization, advanced search options, and easy to use user interfaces, in a matrix to keep track of times referenced. In addition to these online resources, we conducted three semi-structured interviews with professors, specifically Professors Lane Harrison, Dmitry Korkin, and Michael Ciaraldi, in the Worcester Polytechnic Institute (WPI) Computer Science Department, as they all have a focus in web design and repository development. We collected all criteria mentioned from the interviews in the recording matrix.

After compiling all the criteria, we condensed the matrix to identify which criteria were the most common and brought up the most by using a filter of $n \geq 4$, with n being the number of sources that cited the criteria, to create a preliminary list of criteria for the Centralized Repository. Additionally, to triangulate our research, we conducted semi-structured interviews with 18 Statewide Coalition members, Massachusetts Department of Environmental Protection (MassDEP) employees, and an employee of the USEPA to discuss the MS4 Permit and the Centralized Repository. Some of these individuals included Fred Civian, the Massachusetts Stormwater Coordinator (shown in Figure 6); Robin Craver, Town Administrator for the Town of Charlton and the Chair of the Statewide Coalition; and Newton Tedder, the primary author of the MS4 Permit. We interviewed these individuals as they are directly impacted by or involved in working with MS4 Permit compliance. We designed our questions to gauge the current state of preparedness and thoughts on the revised MS4 permit, specifically focusing on the Public Education and Outreach minimum control measure. We transitioned the discussion to the design and development of the repository, seeking interviewee feedback on desired criteria for the repository. We compiled all criteria into a spreadsheet for ease of analysis. Our team analyzed all interview information by identifying the most mentioned criteria. It should be noted that we did not consider topics regarding editable template documents or a vetting process as repository criteria, as although they are important, they are not directly related to the development of the repository.

To organize the data in an efficient fashion, we followed the metrics established by Duqia et. al and combined both matrices together and reorganized all the criteria into different categories for easy analysis (2014). We created a weighted matrix and totaled the scores of each criteria, category, and theme. Using this weighting system, we then ranked the criteria based on importance. From this, we condensed our matrix to develop a list of the top ten essential criteria.

Figure 6: The team meeting with Stormwater Expert Fred Civian

Following these initial steps, we designed a Criteria Survey that we asked all interviewees to complete. Additionally, we sent the Criteria Survey to all members of the Statewide Coalition. We received 17 responses from 30 of the most active coalition members. Our team used these surveys to explore the opinions of the municipal employees who would be using the repository and to refine the list of essential repository criteria.

Objective 2: Evaluating Existing Repositories

To evaluate existing repositories, we designed an Evaluation Rubric, which was similar in design to the survey we used to accomplish Objective 1. We used the Evaluation Rubric (shown in Figure 7) to

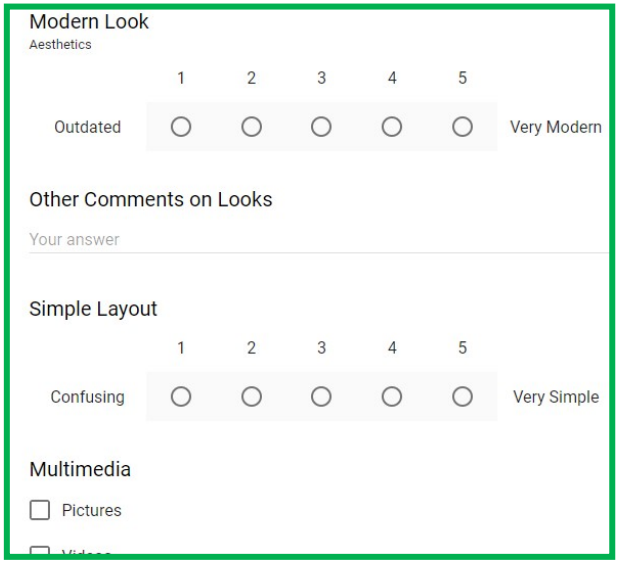

Figure 7:Screenshot of Evaluation Rubric,

systematically score websites and repositories based on how well they met the essential criteria identified in Objective 1. We evaluated eleven repositories, some of which were suggested by interviewees, such as the New York City Environmental Protection Information Center and the National Service Center for Environmental Publications. We also evaluated the websites of the coalitions in the Statewide Coalition. This process helped us identify the strengths and weaknesses of these websites and repositories. The Evaluation Rubric consisted of 17 grading criteria based on the criteria identified in Objective 1 and criteria mentioned by our sponsors. Two of the 17, Aesthetics and Layout, were subjective. Our team calculated the average of the scores of our evaluations of the criteria to produce a 'final' score. We analyzed the results of this evaluation to further refine the list of criteria developed in Objective 1 to ensure that it is capable of meeting the needs of our primary audience - members of the Statewide Coalition and participating municipalities. Using all the data from Objectives 1 and 2, we revised and further refined our list of criteria, resulting in a final ranking of essential criteria.

Objective 3: Identifying and Evaluating Repository Housing Options

For our project, we defined a 'housing option' as where a repository is located online, such as a university website or government website. After identifying criteria from Objectives 1 and 2 specific to repository housing, such as credibility and maintenance, we identified housing options to evaluate. From our 18 coalition member interviews and sponsor meetings, we obtained numerous possible housing options, such as the MassDEP website and the WPI website. We compiled a list of the twelve housing options to further analyze in a weighted comparative analysis matrix. A comparative analysis matrix is a principal tool of analysis used to evaluate different sets of data or items (Collier, 1993).

Our analysis consisted of evaluating cost and which options were capable of meeting most, if not all, of our stakeholders' primary criteria. Our Housing Matrix started by providing qualitative data, such as the level of credibility, but to compare the housing options in a bar chart format, we gave each option a total score through quantizing. Quantizing is the conversion of qualitative data into quantitative data, to further analyze and present in a numerical format (Tashakkori and Teddlie, 1998). We gave each housing option criteria a qualitative score, as shown in Table 1 for an example housing option. For objective criteria, such as a commenting system, we scored a "yes"/"no". Subjective criteria, such as the cost or level of customizability, scored on a scale. Through quantizing, a numerical value was given for each qualitative score. We amplified this score by a weight factor, which was given based on the amount of times the respective criteria appeared in our interviews and the weight of the interviewee. We calculated the total score of each housing option as the sum of all individual criteria scores multiplied by the weight factor and then presented the results in a bar chart. This allowed us to identify the best possible housing option for the Centralized Repository.

Objective 4: Identifying Repository Development Options

With a potential housing option in mind, we began identifying numerous development options capable of creating an online repository. A development option is a program or tool capable of designing and implementing an online repository (Palmer, Teffeau, and Newton, 2008). We used two methods to identify the development options - research of scholarly work and interviews. We first used research of online journals and studies on IEEE Xplore Digital Library, which contains scholarly technical literature related to engineering and technology,

Table 1: Housing Option Criteria Scoring System Example

Criteria	Weight Factor	Qualitative Score	Base Quantitative Score	Amplified Quantitative Score
Website Support	38	High	10	380
Credibility	5	High	10	50

to identify the development options ("IEEE - The IEEE Xplore Digital Library", 2018). Professionals published multiple comparisons of online repository development options on IEEE, such as an article comparing Dspace, Eprints and Greenstone (Adewumi, Fernandez, Misra, & Omoregbe, 2013). We also used University libraries, including Cornell University, Virginia Commonwealth University and Northeastern University, which published evaluations and comparisons of repository development options that their respective institutions had used (Corbett, Ghapery, Work, & Byrd, 2016).

The second method we used to identify development options was conducting semi-structured interviews with the three previously mentioned WPI Computer Science Professors, two Gordon Library repository developers, and an industry professional. Our interviews with WPI library repository managers, Anna Newman and Emily O'Brian, provided our team with six development options to further investigate (Personal Communication, March 2018). In addition, they explained the development option WPI currently employed to create a new repository resource for student use. We also conducted a semi-structured interview with an industry professional, Jennifer McCann, a database supervisor and former principal network engineer at General Dynamics Electric Boat. She explained various development options capable of creating an online repository ranging from simple to advanced implementation difficulty (Personal Communication, April 2018). The three WPI Computer Science Professors, Dmitry Korkin, Lane Harrison, and Michael Ciaraldi identified and explained development options which they have used or have knowledge of. Two of the professors were helpful in providing additional information regarding developmental options, however one instead left us overwhelmed from the immense technical knowledge and information he provided (Personal Communication, March 2018).

We discussed the technical information provided by this interview with our sponsors and determined the information was outside the scope of our project. After conducting the interviews and online research we then compiled the results into one list that we evaluated in Objective 5.

Objective 5: Completing a Comparative Analysis and Evaluation of Repository Development Options

We evaluated the 14 development options identified in Objective 4 to determine the top options capable of meeting the needs of our sponsors. To create the first comparative matrix, we used the criteria identified in Objectives 1 and 2. In addition, we condensed some criteria for the matrix, for example all front-end design components such as the ability to have drop down menus, search bars, and overall page aesthetics combined into one criteria labeled as front-end customizability. We scored each development option to allow us to quickly compare and assess the 14 development options. We gave each criteria a weight factor due to certain criteria appearing more frequently during our research and interviews. We took the given weight factor for each criteria as the total score for each criteria identified in Objectives 1 and 2, as shown in Table 2 for an example development option.

For each criteria we evaluated and scored the 14 development options. Similarly, to Objective 3, we gave each criteria a qualitative score, which we then converted to a quantitative score. We evaluated objective criteria, such as a commenting system or user profile feature, as “yes/no” and subjective criteria on a scale. An example numerical score for each qualitative score, both are shown in Table 2. After we gave each criteria a score for all development options, we multiplied each by their respective weight

factor, and then summed them to yield a total score for each development option. We presented the total scores for each development option in a single bar chart, allowing us to present and eliminate obvious negative choices.

Table 2 Development Option Scoring System Example

To evaluate each development option and assign accurate scores for the criteria, we conducted research through various methods, including contacting the primary correspondent or sales associate of each option, examining the website and demo of each option, and speaking with current users of the development options. Specifically, we interviewed Anna Newman and Emily O'Brian, who are implementing Samvera as the new WPI Library database and have knowledge of numerous repository development options; Laura Roberts, webmaster of the WPI Water Resource Outreach Center and Worcester Community Project Center Wordpress websites; Fabio Carrera, creator of various Interactive Qualifying Project Google Sites and the Venpedia Mediawiki site; and Two sales associates from Bepress and Figshare. These six interviews provided useful insight into various aspects of each development option. In addition, for criteria such as *functionality* and *user interface*, we examined reviews and previous online analyses of each option, whereas for *cost* we contacted representatives from Bepress and Figshare.

Next, we created a condensed matrix which, using the results from the first matrix, included the top five development options. We developed prototypes of the Central Repository using these remaining development options and evaluated their feasibility and usability of each. We created three of the options using a local Windows or Linux server, and two using tools available within a web browser. This led to a finalized matrix presenting our top five development options in an easy to format of qualitative scores. The finalized matrix also had more accurate scores of feasibilities due to the piloting. We presented the top five options to our sponsors and collaboratively decided to further develop the top three options.

Objective 6: Creating a Front-End Skeleton

Having decided on a housing location and developmental option, our team began designing a front-end skeleton, or wireframe of what the Central Repository would look like in terms of layout and organization. We designed a draft layout based on the stakeholder feedback. We also incorporated some designs identified in Objective 2, where we took note on the layout of all evaluated repositories. From our development options identified in Objective 5, we created skeletons from the top 3 results: WordPress, MediaWiki, and Classic Google Sites. Although we designed on all three development options, we primarily focused on WordPress to design the skeleton as it is having a large range of customizability and allows for the implementation of various widgets to emulate the repository functions desired. Furthermore, WordPress has an easily accessible and user-friendly development interface to allow for easy editing, making it the most widely used platform for website development, with 30% of all websites being constructed on WordPress (W3Techs, 2018). We presented the different versions and drafts of the skeleton at our sponsor meetings to seek feedback.

Table 2: Development Option grading example

Specific Criteria	Weight Factor	Qualitative Score	Base Quantitative Score	Amplified Quantitative Score
Front End Customizability	160	Low	2.5	400
Different View for Users	25	Yes	10	250

Findings

Through the course of our seven-week project, we found that there are various challenges municipalities face in compliance with the 2016 MS4 Permit. Through our 29 semi-structured interviews, we identified that a Centralized Repository would help to these municipalities. We reviewed and analyzed data from our 29 interviews and numerous scholarly sources to produce recommendations and a starting point for the Statewide Coalition Centralized Repository. Through our process, we identified five findings that we believe will help guide the Statewide Coalition in finalizing the Centralized Repository development process.

Finding 1 - Stormwater Materials are Difficult to Identify and Locate Online

When conducting our 18 semi-structured interviews with coalition members, we found that stormwater materials are difficult to identify and locate. Coalitions and municipalities have been uploading their materials to their respective websites to share them with other individuals. However, nine of our interviews stated that this method is not the most effective method of sharing materials. When questioned about the topic, seven of our semi-structured interviews agreed in that the two primary reasons causing this difficulty was varying levels of technical expertise and the lack of time to navigate the breadth of information online.

As identified in our interview with Robin Craver, there is a vast difference in technical abilities among participating towns (Personal Communications, March 21, 2018). Due to this range of technical knowledge, some towns have difficulties identifying materials online both on their respective sites as well as other coalition or municipal sites. Furthermore, as all coalition members are volunteers, do not have the time to spend large amounts of time on a website to find materials (K. Reed, Personal Communications, March 2018). In combination, municipality employees struggle to find effective and relevant stormwater materials online as they are spread out throughout different sites. With these difficulties, all 18 interviewees agreed that a Centralized Repository would benefit all coalitions and municipalities.

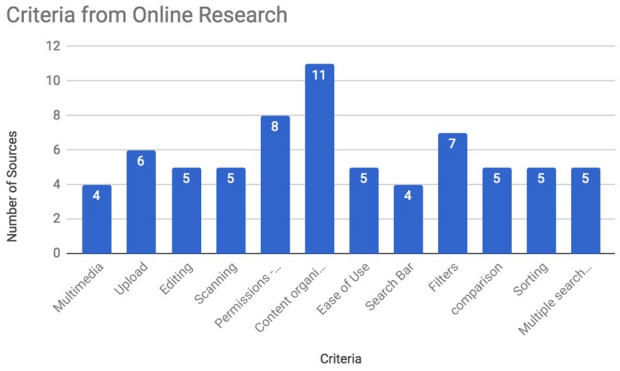

Figure 8: Criteria from Online Research

Finding 2 - A Repository Should be Organized in a User-Friendly Manner

Over the course of our project we identified that how a repository is organized is one of the most important factors in the design and development process. We found this through our research of 18 online guides from website businesses, professional web developers, and scholarly textbooks and from our 18 semi-structured interviews with our primary stakeholders - coalition members. User-friendly content organization prevents confusion on the repository, making it easier to use for its primary users.

From our 18 online resources, 11 of them mentioned the importance of content organization, as shown in Figure 8. Stratecomm, a professional web design and digital marketing company established in 1999, stated in its web design guide that developers must design their site in a user-friendly fashion as "a site that is difficult to navigate will only frustrate visitors" (Stratecomm, 2018). This aligned with the views of all 18 of our semi-structured interviews with the primary users. As identified in Finding 1, coalition members come from various technical backgrounds and therefore some have difficulties navigating currently used sites. All interviewees desired the Centralized Repository to be designed in a user-friendly fashion, making it simple and easy enough for all members to use it. These interviewees believed that this design would allow municipalities to easily find relevant materials to help comply with the MS4 permit.

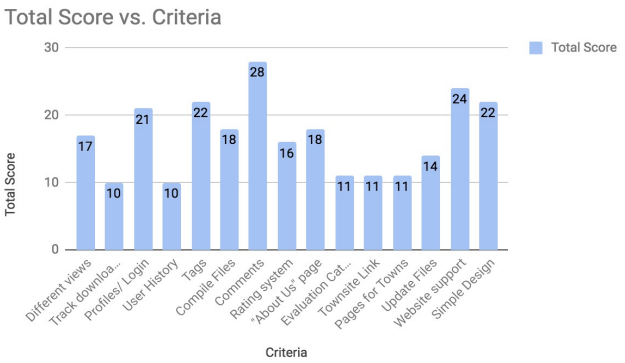

Figure 9: Criteria from Weighted Interview Analysis

Finding 3 - Coalition members desired various user interactions, such as a commenting system, on the centralized repository

After interviewing the coalition members, we completed a weighted analysis and found that

Table 3: Comparative analysis of housing Options

Criteria/Housing Option	WPI WROC	Custom Website	Coalition Site	Pre-Developed Tool	WPI Main Site	USEPA	Mass DEP	Google Sites
Customizability	Low	High	Low	Low	High	Low	Low	Limited
Credibility	High	Low	Limited	Low	High	High	High	Low
Cost	Free	High	Free	High	Free	Free	Free	Free

our stakeholders desired various user interactions on the centralized repository. 15 of the 18 interviews brought up the interest of different user interactions. When analyzed, we found that of the user interactions, the most desired user interaction coalition members wanted on the centralized repository was a commenting system, with a score of 28 as seen in Figure 9. Two interviewees, Eli Goldman and Trish Settles, envisioned that the commenting system in combination with a rating system would create a Yelp or Amazon-like environment where coalition members can provide feedback and opinions on the materials on the Centralized Repository (Personal Communication, March 16, 2018).

This desire for a commenting system aligned with the suggestions identified in our online research. Four of our resources, three professional freelance developer blogs and one from a web design guide from a business, mentioned implementing a commenting system to increase user interactions (Stratecomm, 2018). Including user interactions will increase user engagements to make user's experiences more appealing and satisfactory (O'Brien & Toms, 2008).

Finding 4 - A repository for widespread use should be housed on credible and sustainable location

Identifying a suitable housing option was the first step of the development process of the Centralized Repository. We identified a housing option prior to development options as different housing options have varying software limitations and may not be compatible with some development options. Using our 18 semi-structured interviews with coalition members, we reached the conclusion that the repository should be housed on a credible and sustainable location. The location should also be capable of allowing the customizability of the repository to fit the requirements of the primary users. A credible housing option will validate the repository and make users more likely to trust the materials contained within it. If the housing option is sustainable, users do not have to worry about the repository malfunctioning or becoming outdated and obsolete.

Table 3 shows a simplified view of the comparative analysis matrix of the housing options. In connection we developed a bar chart comparison, shown in Figure 10, to identify the top possible housing options. Upon sharing this information with our sponsors, we eliminated the Pre-developed tool, and custom website options due to high cost. Therefore, we began considering the remaining housing options and underwent a process of elimination to identify the best possible location.

At the beginning of our project, the MassDEP was immediately identified as the most potential housing option as it would be very credible coming from the regulator. However, through our interviews with coalition members and members of the MassDEP, it became apparent that it was not an ideal housing location. The primary data point that concluded the

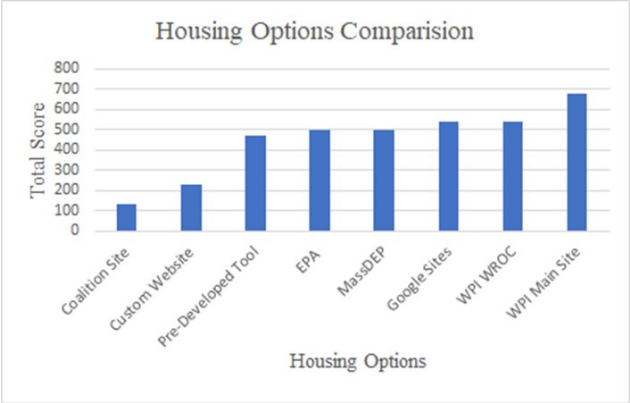

Figure 10: Comparison of All Evaluated Housing Options

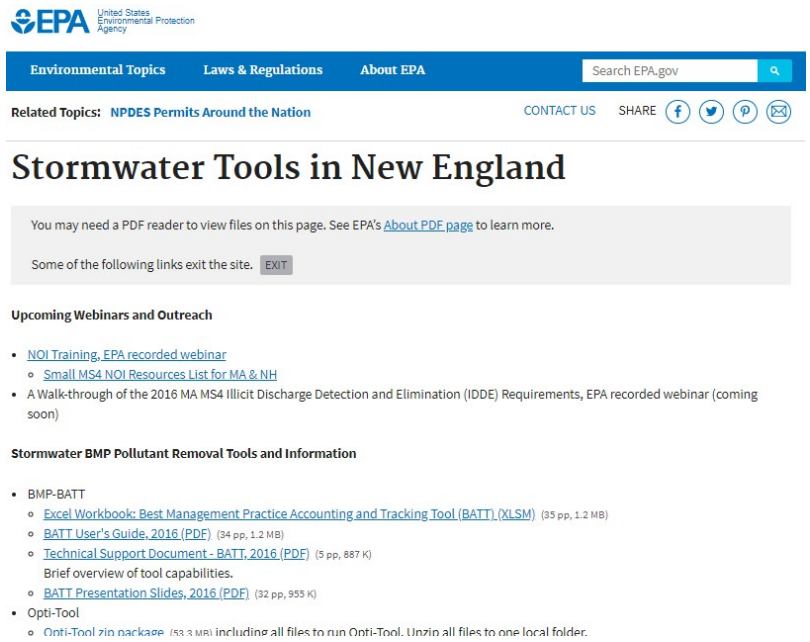

Figure 11: Example of the US EPA website

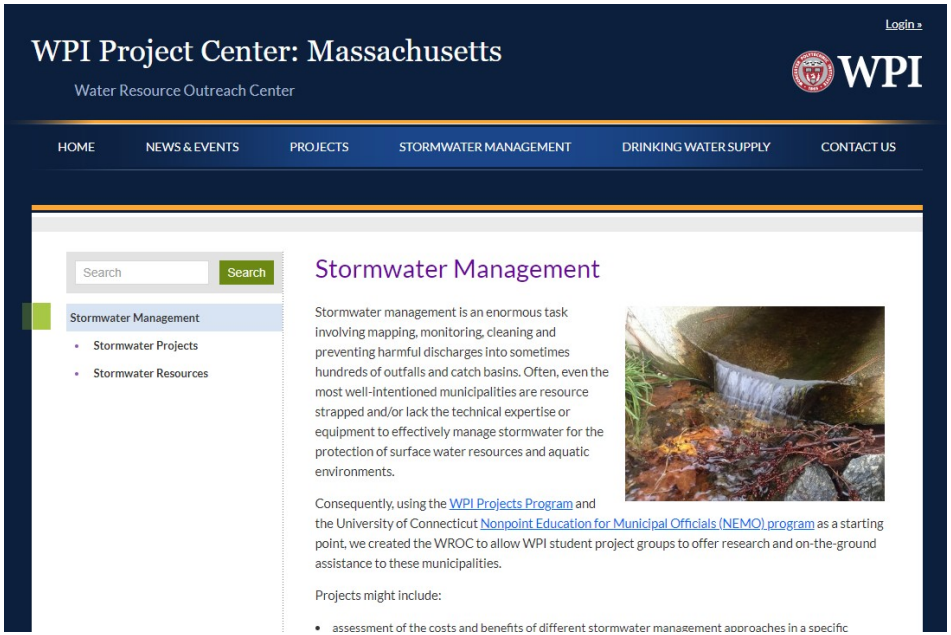

Figure 12: Example of the WPI WROC website

exclusion of the MassDEP as a housing option was through a semi-structured interview with Julianne Ture the maintainer of the MassDEP website. In our semi-structured interview, she stated that the "MassDEP does not currently have the resources to house and maintain the repository" (Personal Communication, March 26, 2018). When asked if the MassDEP could simply house the repository but the maintenance and actual updating of materials would fall under the responsibility of another party, she replied stating that if the repository is housed on the MassDEP, "only authorized state-agency staff have access to upload to, and maintain content on, mass.gov websites" (Personal Communication, March 26, 2018). With the exclusion of the MassDEP, we began identifying different possible housing options.

Another possible housing option considered was the EPA main website, suggested by Newton Tedder during our semi-structured interview. However, we were very quick to exclude it as a possible housing option as it did not meet the requirements of our sponsors. If housed on the US EPA main site, instead of a searchable and engaging repository, it would be a page of links with limited user interactions, as shown in Figure 11 (Personal Communication, March 23, 2018). We confirmed with our sponsors that although the EPA main website would have immense credibility, it was not the best housing option due to its organizational and user-interface limitations.

After eliminating the MassDEP and EPA as housing options we looked at housing the repository on a coalition website. Through our semi-structured interviews, it became apparent that the repository should not be housed under one specific coalition website. All interviewees agreed that instead of being associated with a specific coalition, for the success of the repository, it should be housed on relatively neutral grounds. Based off the aforementioned criteria, we began considering the WPI WROC website as a potential housing option. The WPI WROC website contains all projects completed at the Massachusetts water outreach center project

center, as well as some additional information on stormwater education. However, through our semi-structured interview with Laura Roberts, co-director of the WROC and primary WROC Webmaster, it became apparent that there were multiple limitations to housing on the WROC. She stated that "any front-end customization would be limited as we must use the WROC Template", which is shown in Figure 12. Furthermore, any searches that are done through the repository will search the entire WROC Website (Personal Communication, April 4, 2018). Both major limitations eliminated the WROC as a potential housing option.

Instead of focusing on the WROC, we broadened our scope and began to consider housing the repository as an extension of the WPI website. Upon contacting WPI IT, we were referred to Ermal Toto, a research data scientist at WPI, who had previous experience in developing a research database for the university. After speaking with him, he provided us server space on WPI's servers to test further development of our project as many of our housing criteria were met using a WPI extension.

Finding 5 - The Centralized Repository Must be Regularly Updated and Maintained

Through our semi-structured interviews with coalition members and housing analysis, we found that in order for the Centralized Repository to be successful, it must be regularly updated and maintained. One of the largest reasons we eliminated several housing options, was due to the fact of the lack of proper maintenance and updating on those respective sites. All 18 interviewees were concerned with the maintenance of the Centralized Repository. They feared that even with its creation, due to its vastness, the responsibility of maintaining and updating it would be too great that it eventually becomes outdated and obsolete. This fear stems from past experiences with coalition sites. For example, in our semi-structured interview with Robin Craver, she explained that the Central Massachusetts Regional Stormwater Coalition previously hired an individual to maintain their website, however upon leaving the position, coalition members had difficulty maintaining and updating the site (Personal Communication, March 21, 2018).

Table 4 :Top Five Development Options Comparative Analysis

Criteria Category	Specific Criteria	Dspace	Classic Google Sites	Hyrax (Samvera Ext.)	Media Wiki	Wordpress
User Features	Profiles	X	X	X	X	X
	Compile for Annual Submission	X	X	X	X	X
	Track User Downloads				X	X
	Track User History				X	X
User Engagement	Comment System		X	X	X	X
	Rating System		X		X	X
	Chat Room		X			X
	Blogs		X		X	X

Finding 6: Wordpress has the customizability, searchability and ease of use that the Centralized Repository requires.

Through evaluation of criteria identified in Objectives 1 and 2, as well as testing of the development options, we found Wordpress to have the customizability, searchability, and ease of use that the Centralized Repository requires. We started to identify these options by creating a comparative analysis matrix of specific criteria that the repository needed to meet. As detailed in Objective 5, we created a scoring system and then a bar chart, shown in Figure 13, to evaluate the 14 development options. As shown in Figure 13, development options which have a higher bar meet most of the identified criteria, whereas those with lower bars meet less criteria.

We chose the top five development options by excluding ones that were missing most of the desired repository criteria and had a high cost. The top five development options consisted of Wordpress, Hyrax (Samvera Ext.), Dspace, Mediawiki, and Classic Google Sites. A simplified comparative analysis of the top five development options is shown in Table 4.

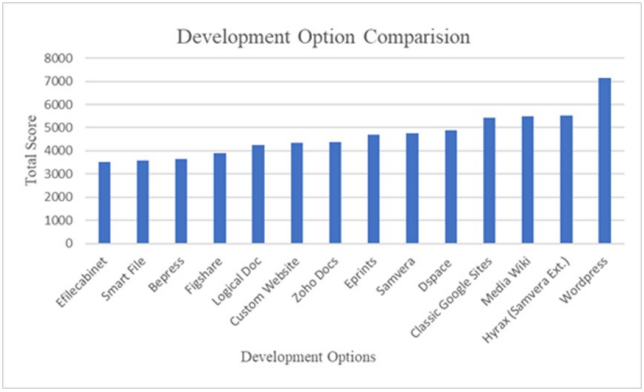

Figure 13: Bar Chart Comparison of Development Options

From our testing and official Wordpress documentation, we found Wordpress to be a simple tool for creating websites, and it also allows for plugins that give it the capability to function as a searchable repository (WordPress, 2018). Hyrax is an all in one, front end and back end, open source repository system (Hyrax, 2018). Open source meaning that the software or program is free to use, and community developed. Dspace is like Hyrax, functioning as an all in one system open source system developed by Massachusetts Institute of Technology (DuraSpace, 2018). Google Sites is a simple website building tool, which allows for Google Gadgets that provide added features (Google, 2018). MediaWiki is an open source platform that is built upon the Wikipedia structure, allowing for many extensions which boost its multi-function capability as a repository (MediaWiki.org, 2018). All these development options could be used to develop a repository that would meet the needs of the stakeholders, as they support the requested repository criteria and are low cost.

This led to implementation difficulty and continuing support being the main concerns. Mr. Toto, the data scientist identified in Finding 3, stated he had no knowledge of Dspace or Hyrax, and that they must be developed and tested extensively on a local machine before being implemented onto a WPI server (Personal Communication, April 11, 2018). We attempted to set up a local machine with Hyrax and Dspace, but due to limited computer science knowledge we were unable to fully create a working system. Interviews with Anna Newman and Emily O'Brian of the library repository staff at WPI who planned to implement a Samvera repository stated that they are hiring a full-time developer to work and implement the system (Personal Communication, March 30, 2018). The WPI Gordon library shows how hard it is to implement this system as they need to hire a full-time web developer to do it.

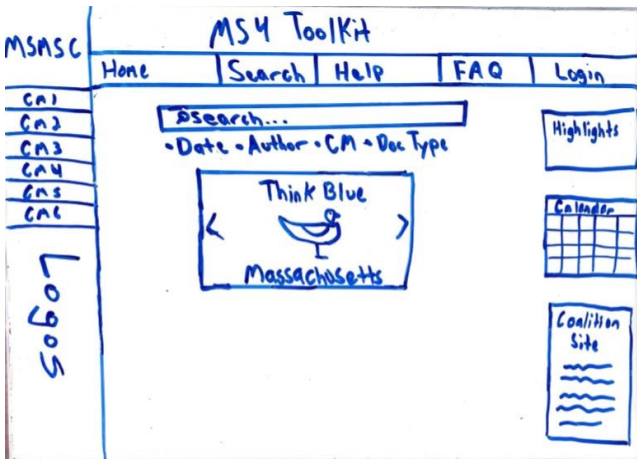

Figure 14: Draft of Initial Layout of The Repository

Based on our experience and coalition members experience it was not feasible to learn such a complicated system, nor was it feasible to outsource a full-time web developer due to cost. This eliminated Dspace and Hyrax from our possible development options, leading us to Classic Google Sites, MediaWiki and Wordpress being the top three development options for the skeleton of the Centralized Repository.

To further evaluate MediaWiki, Wordpress, and Classic Google Sites we created working models of each to present to our sponsors. However, when creating the MediaWiki site we found front end customizability to be much harder than expected, especially when trying to meet the specific criteria our sponsors wanted, such as drop-down menus and search bar locations. This eliminated MediaWiki from our top three choices and left us with Classic Google Sites and Wordpress. Classic Google Sites had more limited searching ability and customization than originally anticipated. In addition, Google has discussed ending support for Classic Google Sites, and in a few years the site might not even be supported, thus we eliminated from our choices (Google, 2017). This left us with Wordpress which we found to have the customizability, searchability, and ease of use that the Centralized Repository requires.

Finding 7 - An online repository should have consistent layouts between pages and various user engagements

Staying consistent with Finding 1, we identified that in order for online repositories to

have a user-friendly design, they should have consistent layouts between pages and contain various user engagements. Consistent layouts between pages help users with navigation and provides a sense of familiarity, ultimately increasing ease of use of the repository. Furthermore, various user engagements, such as calendars, newsfeeds, and comment sections keep users involved with the site. In addition to these engagements, interactive menus and search bars can provide users with different methods to identify information. Collectively, these components increase repository usability and user friendliness.

This conclusion was obtained through the comparison and analysis of our criteria matrices similarly to Finding 1. The most important theme identified through our analysis was Repository Organization, which included page layout and page organization. In addition to this conclusion, we began identifying possible layouts to use or obtain inspiration from, as Professor Lane Harrison, a Computer Science Professor who teaches Web Design, recommended that the best way to build a website is to "find a layout you like and start from there" (Personal Communication, March 29, 2018). Using his advice, we began evaluating various websites and repositories. As part of the evaluation, our team ranked the layouts and organization of each source. Using the repositories that obtained the highest layout and organization scores, we compared and analyzed to identify common themes and layouts. We identified that five of six sources had consistent top header with drop down menus throughout all pages on the site. Additionally, four of six sources had a sidebar containing advanced search options and additional filters on the home page. Furthermore, our sponsors played a major role in the design process, explaining to us very early on how they envisioned the repository having user interactions and menu bars for users (A. Briggs and K. Reed, Personal Communication, March 2018). Using their guidance and the information from our evaluations as a starting point, we drafted an initial layout of the Centralized Repository shown in Figure 14.

At our sponsor meetings, we shared the initial draft with our sponsors to receive their feedback on the layout. The attending members approved of the layout and suggested looking at the thinkbluemaine.org theme and incorporate it into the repository design. Additionally, at the sponsor meetings, our sponsors stressed the desire of user interactions, specifically a commenting system and an up-to-date calendar or newsfeed. We included these criteria in our future designs that we developed on various developmental platforms, as seen in in Figure 15, to help with actual visualization of an online product. Using our drafts, we began to identify housing and developmental options that were capable of creating our desired layouts with most if not all of our criteria.

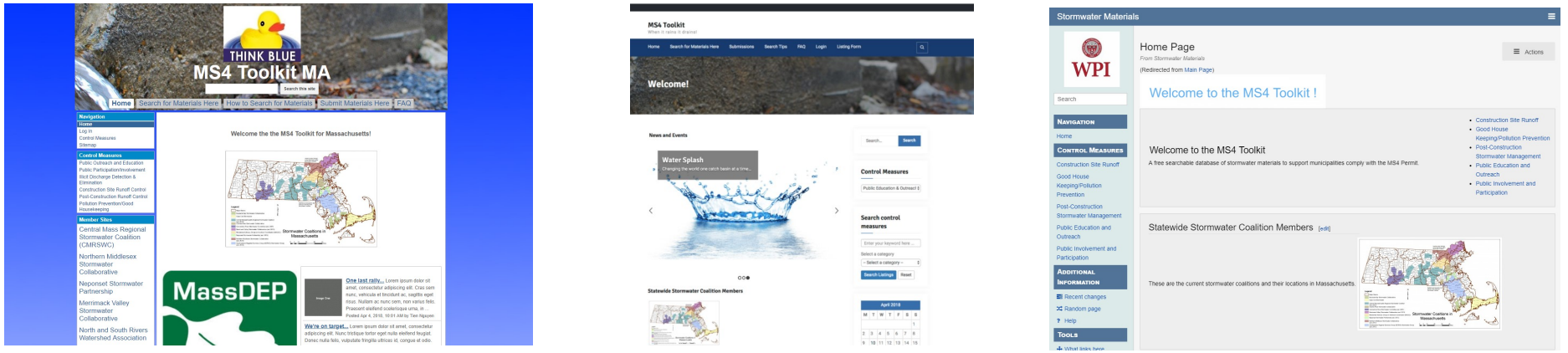

Figure 15: Online Template Draft of The Repository on Google Sites, Wordpress, Mediawiki

Our Final Recommendations

In order to meet the needs of the primary stakeholders, **we recommend developing the Centralized Repository on WordPress using our skeleton as a model**. WordPress is a low cost, easy to use development option where individuals with very little technical knowledge can create a professional website. Its user interface is simple to use but still allows for addition of pre-coded programs, to make a website more technically advanced. These pre-coded programs can be implemented into a site to create a repository with all of the essential criteria identified in our 18 semi-structured interviews with Statewide Coalition members. Furthermore, due to its extensive usage, WordPress can be housed at any location, making it compatible with most housing options.

From our housing analysis, **we recommend selecting a Worcester Polytechnic Institute (WPI) extension as the housing location for the Centralized Repository.** Housing on WPI servers will ensure that the Centralized Repository will rarely malfunction. In the case it does, the technical services at WPI will work to resolve any issues. We also recommend WPI as the university, coalitions, and MassDEP have been working together for over six years, creating a positive and trustworthy working relationship. From this relationship, coalitions are already familiar of WPI's involvement in the stormwater field and therefore may be more inclined to use the Centralized Repository. In addition, as a university, WPI brings a sense of credibility that would be not present with a standalone website. To further increase this credibility, the MassDEP has agreed to endorse the Centralized Repository should it be housed on WPI servers, showing users that it can be trusted and used to find helpful materials. It should be noted that if desired, the Centralized Repository can be housed at any university and still have a high level of sustainability and credibility compared to other housing options. However, its credibility will not be as high as WPI due to the aforementioned existing relationship between the coalitions and the university.

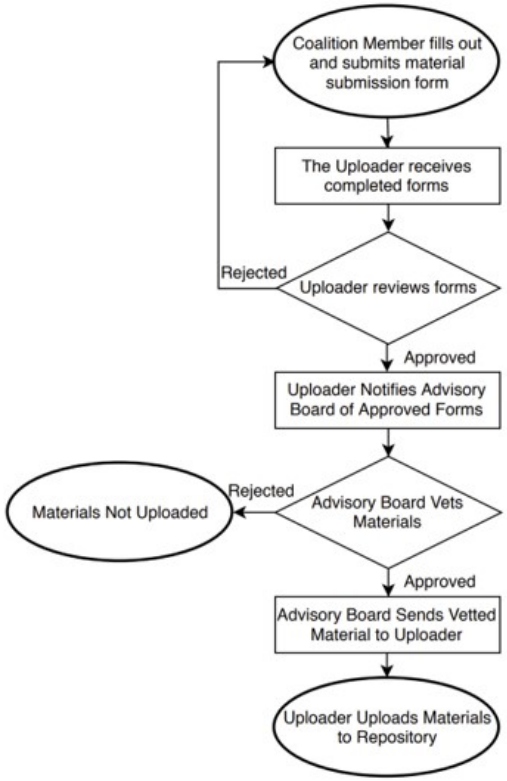

Figure 16: Workflow of the Uploading Process

The Centralized Repository will require consistent maintenance and updating to ensure its usage by municipalities and coalition members. Although the overall task of maintenance and uploading materials is immense, **we recommend splitting up the responsibilities to prevent any one coalition or organization from being overwhelmed with work**. Through our discussions with our sponsors and coalition members, separating responsibilities will not only share the burden, but will make the maintenance and uploading process more efficient. We identified two major roles that will take control of the responsibilities: The Uploader and The Advisory Board. With these two roles identified, we developed a preliminary workflow shown in Figure 16. The Uploader will be responsible for reviewing submission forms completed by coalition members, making sure they are filled our accurately and with enough detail to be sent to The Advisory Board. The Advisory Board will vet materials and send all approved stormwater materials to The Uploader to be uploaded to the Centralized Repository for statewide usage. In terms of who will make up these roles, The Advisory Board has a few individuals that have expressed interest in being part of The Advisory Board such as Newton Tedder of the US EPA (Personal Communication, March 23, 2018) as well as members of the Statewide Coalition public education sub-committee (K. Reed, Personal

Communication, April 2018). However, for the role of The Uploader we have identified three possible options: a work study student, a coalition member, or a third-party individual, although further analysis and consideration is required for each potential option.

When developing the repository, we recommend designing it in a similar fashion to the skeleton shown in Figure 17. The skeleton incorporates most of the essential criteria we identified through our 18 semi-structured interviews with the Statewide Coalition members. The skeleton includes essential criteria such as efficient content organization, a commenting system, advanced searching, and multiple user interactions to increase users' experiences as they use the repository. Furthermore, to help with usage, we implemented a consistent layout to reduce the complexity of the site to allow users from all technical backgrounds to use the Centralized Repository with relative ease. This layout will increase user familiarity to make the Centralized Repository easily navigable. In addition to the consistent layout, we have incorporated large tabs at the very top to further help with navigation and usage of the Centralized Repository. The skeleton also incorporates two search features, one for advanced searches and another for quick searches. Both search tools will allow users to locate relevant materials through inputting specific information or through result filters to only show specific materials. However, the skeleton requires further development to fully incorporate all essential criteria.

Conclusion

Municipalities have struggled to find stormwater materials to comply with the MS4 permit, by developing the Centralized Repository we hope to greatly reduce these struggles. Over the course of this project we identified criteria, evaluated housing options, evaluated development options, and developed a working skeleton of the repository. Once the Centralized Repository is fully implemented it will greatly reduce the time and effort municipalities face when trying to find stormwater materials to comply with the MS4 permit. In order for the repository to be successful the Centralized Repository should be modeled after the skeleton or utilize the skeleton to further develop it into a fully populated repository. We hope that our project will provide relief to municipalities struggling to comply with the MS4 permit, and in turn reduce stormwater pollution in Massachusetts.

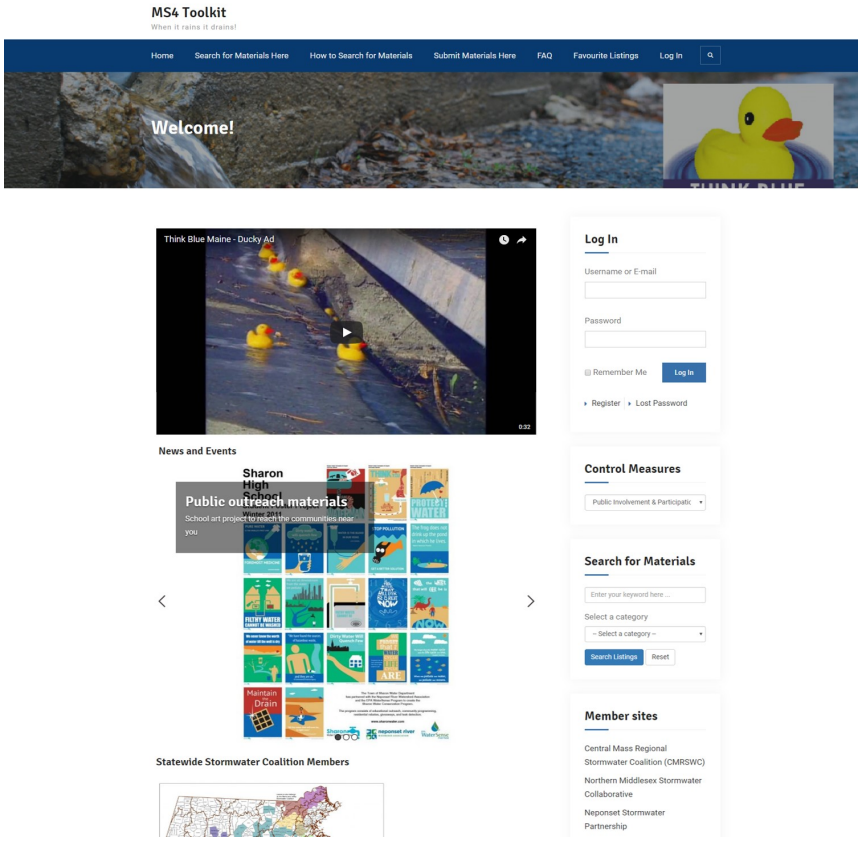

Figure 17: Final Skeleton made in WordPress

Acknowledgements

We would like to first thank our sponsors, the Massachusetts Stormwater Municipal Stormwater Coalition, and our sponsor correspondents, Kerry Reed and Andrea Briggs, for allowing us to work on this intriguing and impactful project. Throughout the 7 weeks, they have been immensely helpful and quintessential in the design and development process of the repository. The same can be said about Corey Dehner, our project advisor, who, despite our confusion at times, was always there to support and help us move forward with our project. Our team is also very grateful for the Massachusetts Department of Environmental Protection for allowing us to use their Worcester Facilities and for Fred Civian, the MassDEP Stormwater Coordinator, who his knowledge and persistence to help us in any way possible. Additionally, we would like to thank all of our participants in our project for taking the time out of their busy schedules to meet with us to help us obtain the necessary information regarding the MS4 Permit and the centralized repository.

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