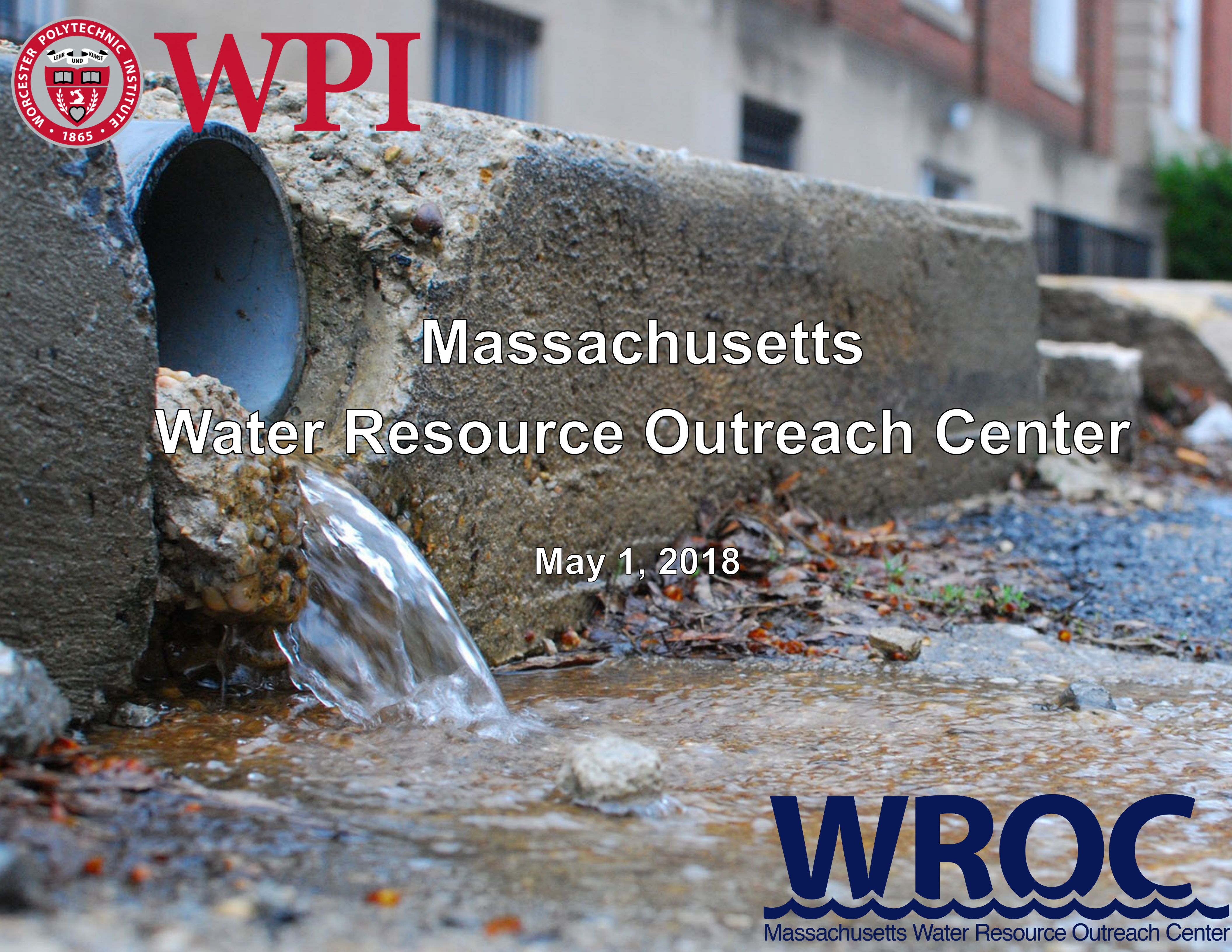

WPI

Massachusetts Water Resource Outreach Center

May 1, 2018

WROC

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Stormwater Runoff Awareness Through Youth Watershed Education

The 5th grade Watershed Curriculum Team spreading public awareness at a local Earth Day festival.

Abstract

Stormwater runoff carries pollutants from impervious surfaces and travels, untreated, to surface water bodies. The United States Environmental Protection Agency updated the Municipal Separate Storm Sewer Systems (MS4) Permit in 2016 including a more extensive public education and outreach requirement. The project goal was to spread public awareness and education by creating a 5th grade Watershed Curriculum for the Massachusetts towns of Shrewsbury and Holden that complies with both the Massachusetts Science Technology and Engineering Curriculum Frameworks and the new MS4 permit. We hope the *Watershed Curriculum* is a viable resource for the Massachusetts Department of Environmental Protection and Central Massachusetts Regional Stormwater Coalition and helps Massachusetts municipalities comply with these standards.

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An Interactive Qualifying Project submitted to the Faculty of Worcester Polytechnic Institute in partial fulfillment of the requirements for the Degree of Bachelor of Science.

WPI

Do You Know What Stormwater Is?

The United States has allocated hundreds of millions of dollars to keep the nation's surface water clean since the passage of the 1972 amendments to the Federal Water Pollution Control Act, effectively creating the Clean Water Act. In 2008 alone, the United States spent $42.3 billion for stormwater management. The United States Environmental Protection Agency (USEPA) recognizes stormwater runoff as a leading cause of water pollution in areas with high percentage of impervious surfaces (USEPA, 2017). Pollutants in stormwater runoff include litter, oil, animal droppings and runoff from building sites (Figure 1) (Heritage).

Figure 1: Stormwater Drain. This image is a depiction of pollutants going into a stormwater runoff drain. (Columbia River Keeper, n.d.).

These pollutants have impaired 42,728 bodies of water in the United States. This means that, as of 2014, all of the aforementioned bodies of water do not meet USEPA water quality standards (USEPA, 2014). While strict laws are important, in order to comprehensively tackle this problem, the general public needs to be made aware of the magnitude of the issue. Education can cause pro-environmental changes in behavior, causing an increase in youth civic engagement to better the quality of water and spread awareness (Figure 2) (Mitra & Serriere, 2012; Apple,2012).

Figure 2: Youth Civic Engagement. This image shows students cleaning polluted waters ("Bethel College Students Clean up Riverwalk", 2017).

The USEPA recognizes the importance of outreach and education on stormwater associated issues in its 2016 iteration of the Massachusetts Municipal Separate Storm Sewer Systems (MS4) Permit. The 2016 MS4 Permit includes six minimum control measures, each detailing a different set of requirements. The first minimum control measure—Public Education and Outreach—requires each municipality to create public outreach programs targeting four distinct audiences: residents, businesses, commercial facilities and industrial facilities (USEPA, 2016). It is through education that awareness will spread and facilitate behavior change (Ajaps & McLellan, 2015).

Awareness Through Education

When a population lacks awareness of an issue, such as stormwater runoff, there is no incentive to take action. The effects of runoff are magnified in areas with high amounts of rainfall such as New England (Douglas & Fairbank, 2010). One way to educate a population is to educate the youth, as interaction with parents, teachers, and the community can spread knowledge (Ajaps & McLellan, 2015). Children communicate school lessons with parents and teachers, who are active in the community (Cary, 2006). Therefore, it is important for school systems to educate younger generations on the water cycle, watershed, and stormwater runoff. Districts will engage communities with stormwater runoff issues through education and green infrastructure programs (USEPA, 2017). In this section we explain the water cycle and stormwater, introduce methods to mitigate stormwater runoff, and explore education techniques.

The Life Cycle of Stormwater

Stormwater is any precipitation that is part of the water cycle shown in Figure 3. Stormwater becomes runoff when it flows over impervious surfaces such as asphalt and cement. As a result, water cannot soak into the ground, be filtered by soil and end up in the water table (Barton & Pineo, 2009). Instead, runoff collects pollutants as it travels over impervious surfaces to a surface body of water.

Impacts of Stormwater Runoff

Pollution escalates as stormwater runoff flows. Earth and ocean researchers Douglas and Fairbank (2010) analyzed trends in annual maximum daily precipitation depth (MAXP), in New England from 1954 to 2008. Their research showed rises in MAXP and amount and length of storms, resulting in increased stormwater runoff and pollution (Douglas & Fairbank, 2010). Table 1 shows pollutants. (Barbosa, Fernandes, & David, 2012; May & Sivakumar, 2009; USEPA, 2015; Harvey, 1998). These pollutants are in water we drink, bathe in, swim in and cook with.

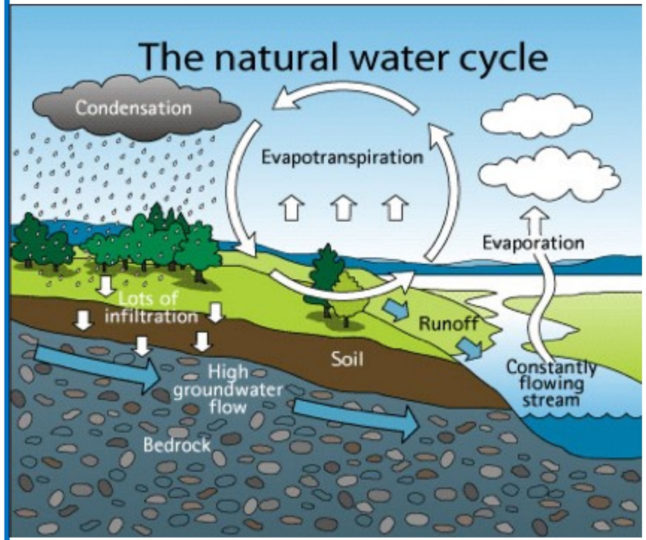


Figure 3: The Natural Water Cycle. This image is a depiction of the water cycle. (Stormwater Management-UCF LNR)

Stormwater runoff can also affect the environment. Effects include stream bank erosion, habitat destruction, infrastructure damage, increased turbidity, downstream flooding, and contaminated bodies of water (USEPA, 2015). The impact of impairment due to urban runoff is "approximately 5,000 square miles of estuaries, 1.4 million acres of lakes, and 30,000 miles of rivers", according to a 2015 USEPA report. The federal Clean Water Act requires states to rank waters by priority and calculate the Total Maximum Daily Loads (TMDLs) of allowable pollutants on the waters that meet water quality standards. If a body of water does not meet these standards, the USEPA considers it *impaired (U.S. Code: Title 33, 2011).*

The USEPA has deemed 63 of the 72 bodies of water in Central Massachusetts impaired. The USEPA has continuously updated the MS4 permit to combat the effects of stormwater runoff (My Waterway, EPA, 2017).

Methods to Mitigate

Stormwater runoff mitigation methods vary by region. Urban areas are a prime focus in stormwater runoff research due to the number of impervious surfaces (Figure 4). Education is an important factor in mitigating the impact of stormwater runoff, especially when coupled with tangible methods to combat stormwater.

Methods to Control Stormwater

The State of Washington Department of Ecology wrote that in urban areas, the percentage of impervious surfaces can range from 38% to 80% (Whiley, 2009). Any area over 10% impervious surfaces could result in a

Stormwater Runoff Pollutants and Their Impacts	
Pollutant	Impacts
Suspended Solids	Decrease in transmission of light through water, hides sources of food, habitat, and nesting sites, affects species respiration and digestion, increases water surface temperature, lowers oxygen levels at deeper levels, increases drinking water costs
Nutrients	Algal blooms that destroy vegetation, habitat, and food sources, kills fish species, reduced water quality, dissolved oxygen levels, lowered property value, interference with fishing
Heavy Metals	Bioaccumulation in animal tissues, and affect fishing, water supplies, aquatic species reproduction, and food chains.
Oxygen Demanding Substances	Deplete oxygen, kill fish, alter species composition, growth of anaerobic microorganisms, increase solubility of heavy metals
Oils, Greases, Hydrocarbons	Hinder photosynthesis, kill aquatic species and birds, bioaccumulation in species' tissues, cause cancer and mutations, reduces fishing, contaminates drinking water, surface films, taints fish and water taste
Pathogens	Diseases, reduces recreational usage, treatment costs

Table 1: Stormwater Runoff Pollutants and Their Impacts. (Barbosa et al., 2012; May & Sivakumar, 2009; USEPA, 2015; Harvey, 1998; Scholz, 2010).

decrease in water quality and efficiency of the water cycle (Gilbert & Clausen, 2006). Figure 5 illustrates the effects of different surfaces.

Methods to reduce quantity and improve quality of stormwater runoff include green roofs, rain gardens and permeable pavement (Whiley, 2009). The USEPA compiled a report titled “Green Roofs for Stormwater Runoff Control,” which concluded that green roofs retain over 50% of precipitation during observation periods. In

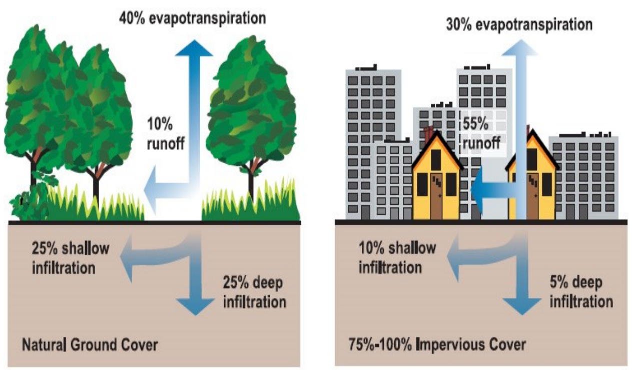


Figure 4: Urban vs. Rural Runoff. This is a depiction of the increase in stormwater runoff in an urban setting. (DeBaun, D. 2017).

addition, according to the USEPA rain gardens reduce peak water flow and help mitigate negative effects on bodies of water receiving stormwater outflow (Whiley, 2009). Permeable pavement is another method that allows precipitation to infiltrate pavement and seep through the surface back into the soil. Permeable pavement allows filtration of stormwater, resulting in a reduction of flooding and salt usage

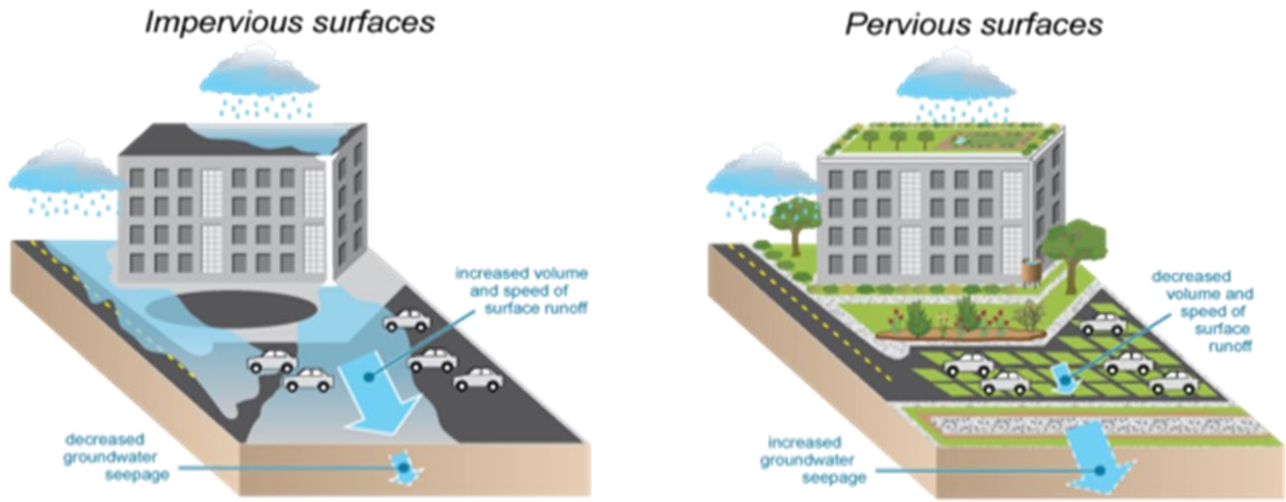


Figure 5: Impervious Vs. Pervious Surfaces. (Green Infrastructure Toolkit-Georgetown Climate Center)

(USEPA, 2015). The Fresno Metropolitan Flood Control District public awareness survey in 2013 84.75% of the 400 people surveyed were unaware of the threat stormwater has, despite methods to mitigate stormwater runoff as addressed in the MS4 Permit control measures (“Fresno metropolitan flood control district,” 2017).

Education as a Method

In 2002, Tufts University Professors found that pro-environmental behavior cannot be fostered by one framework. Rather, they found that you must connect knowledge to values, and that getting a person emotionally involved is the most effective method for facilitating a change in behavior (Kollmuss & Agyeman 2002). According to Dana Mitra and Stephanie Serriere of the American Education Research Journal there will be an increase in youth civic engagement through education by incorporating lessons that use pathos to connect to a students emotions (Mitra & Serriere, 2012). In addition, a social science project conducted by Worcester Polytechnic Institute students agree as they concluded that “children from 3rd to 5th grade are the best audience for educational programs because they are young enough to be taught about environment issues, but old enough to understand lessons” (Waters et al., 2016). Children aspire to influence and make changes when they are taught through public educational institutions about issues within their community. Education is directly related to developing pro-environmental behavior and contributes to mitigation of environmental problems (Figure 6) (Stoneman 2002; Apple 2012; Ajaps & McLellan, 2015). Educating the public through youth will help mitigate impacts of stormwater runoff by complying with the first minimum control measure of the MS4 Permit.

Role of Education

Between 1996 and 2016, the number of people enrolled in America's schools grew 9.9% with 36.6 million students in elementary and middle school. (United States Census Bureau, 2017). Therefore, goals of education are important to the population. One question in the *School Boards Circa 2010: Governance in the Accountability Era* asked board members to rank six goals for education. In a survey of 300 education experts, 42.6% believe the purpose is to "fulfill [students'] potential." In a close second, 31.7% find the purpose to "prepare students for a satisfying and productive life." (Figure 7)(Peifer, 2014).

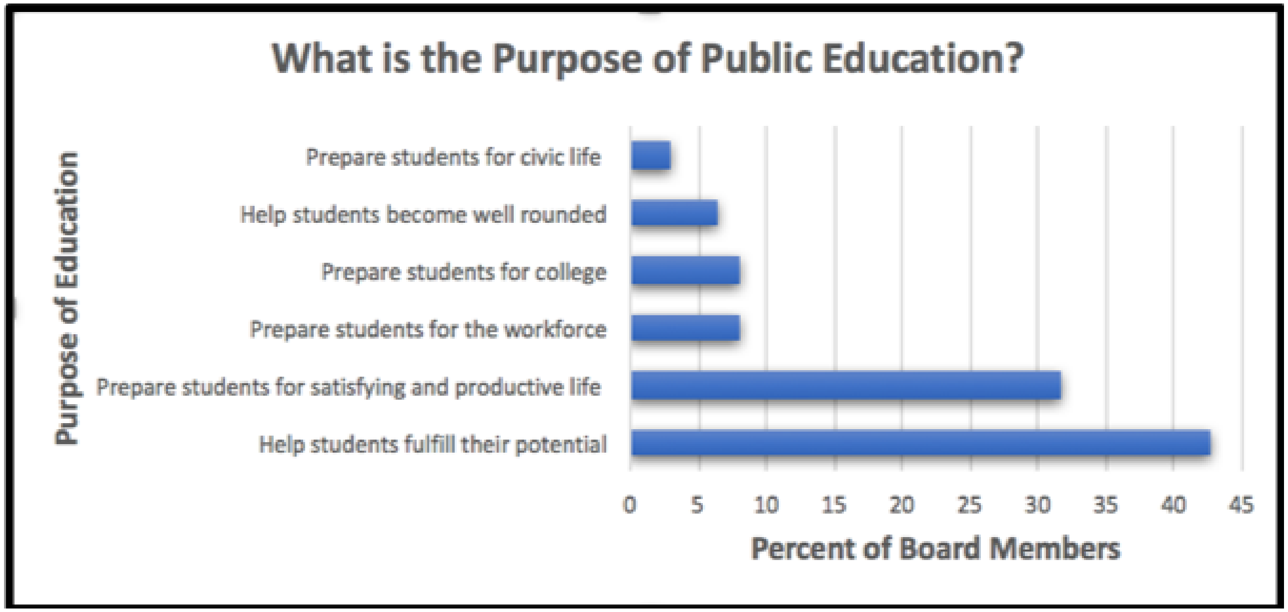


Figure 7: What is the Purpose of Public Education? This graph shows the percentage of board members who vot-

Methods of Education

Teachers must actively engage students in lessons to fulfill their potential and prepare them for their future. Three widely used teaching methods include: 1) teacher-centered with a script, student-centered approach, 2) student-centered where students create experiments, explore and make self-discoveries; and 3) collaboration-centered where students interact with peers and the teacher. Teachers make lesson plans backwards with the goal of the lesson plan as the starting point ("Elementary Teaching Methods," 2018). Teachers often use resources that pique the students' interest, such as Smokey the Bear and Lester the Lightbulb. These symbols are part of awareness campaigns that provide teachers with materials that allow students to interpret, evaluate, and comprehend lessons in a fun and memorable way (Ballard, Evans, Sturtevant, & Jakes 2012; Brown, 2011).

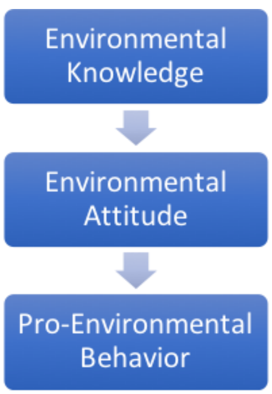


Figure 6: Pro-Environmental Behavior. This flowchart shows the relationship between knowledge and behavior

Another way to teach in a fun and interactive way is through technology. Technology can improve and support learning (MA Department of Education, 2018; The Office of Educational Technology 2016). Professors at North Carolina State University conducted a study that explored game-based learning technologies and indicated game-based learning positively impacts "science content learning and self-efficacy" (Liu, Tan & Chu, 2009; Zheng, Meluso, Spires & Lester, 2012). Moreover, integrating technology in K-12 curriculums is a national initiative in the United States (Brown & Warschauer, 2006). The Massachusetts Department of Education has illustrated support with the national initiative of integrating technology addressing this in the 2016 MA Science and Technology/Engineering (STE) standards focusing on "student engagement with science and technology/engineering" (Table 2) (MA Department of Education, 2018).

Massachusetts 5th Grade Science Curriculum

The Massachusetts Department of Education has a mission to help schools, districts, and organizational partners engage students in challenging, hands-on lessons. The Massachusetts Science Technology and Engineering Curriculum Frameworks (MA STE) provide science and technology/engineering lessons, adapted from the Next Generation Science Standards (NGSS), that are applicable to real-world scenarios (Next Generation Science Standards, 2017). The MA STE Curriculum Frameworks encourage students to engage in a deeper understanding of lessons and expand their understanding of scientific and engineering practices, disciplinary core ideas and crosscutting concepts. Students can utilize the concepts to solve real world problems, practice core concepts through engineering activities, and make connections with mathematics and literacy implemented in lessons on stormwater.

Watershed Curricula

Watershed Curricula should be tailored to specific needs of the area they are taught in (Chmielowiec, Coady, Bader & Noll, 2008). The demographics of a community is key when adapting a curriculum. In 2016, the towns of Shrewsbury and Holden have an average household income of over $100,000 dollars/year. This data is important because we found parent involvement, availability of resources, and funding to be greater than others, thus impacting the design of the *Watershed Curriculum* (US Census, 2016). Teachers have approached stormwater education in many ways. The Sudbury Assabet Concord River group created a “Stormwater Matters Lesson Plan for 5th and 6th grade” (Retrieved by Ms. Kerry Reed). These lessons teach students about stormwater, how storm drains transport stormwater runoff to water bodies without treatment, how people negatively affect quality of water and how students can help reduce water pollution. The teacher introduced topics of watershed, stormwater, impervious surfaces, storm drain systems and polluted stormwater. Then, teachers assess student comprehension of material covered. Another example is the “Stormwater Management Lesson Plan for Grades 3-12” that complies with the NGSS and Maryland Environmental Literacy Standards (Retrieved by Ms. Kerry Reed). Lesson plans consist of site inventories (mapping school grounds), site analysis (assessing school grounds) green roofs, rain barrels, rain gardens, rain garden plants,

Emphasis in STE Standards	Implication for Curriculum and Instruction
Relevance: Organized around core explanatory ideas that explain the world around us	The goal of teaching focuses on students analyzing and explaining phenomena and experience
Rigor: Central role for science and engineering practices *with* concepts	Inquiry- and design-based learning involves regular engagement with practices to build, use, and apply knowledge
Coherence: Ideas and practices build over time and among disciplines	Teaching involves building a coherent storyline over time and among disciplines

Table 2: STE Standards and Implications. (Massachusetts Department of Elementary and Secondary Education, 2016)

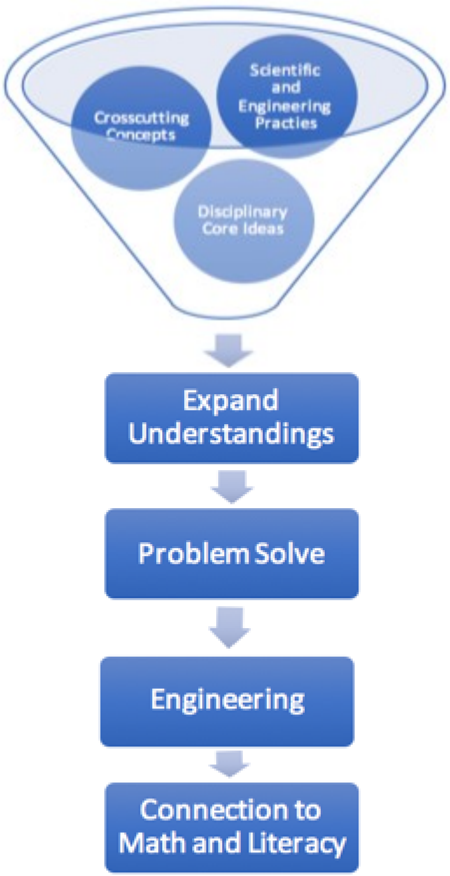


Figure 8: Next Generation Science Standards Core Values. (Next Generation Science Standards, 2017).

soils, permeable pavement, and hydrology. Each lesson gives instructions on science standards, objectives and procedures to perform the lesson.

Education is Key

Researchers conducted studies to discover methodologies that were successful. One solution is education of youth to help combat issues of stormwater runoff. A 2016 Worcester Polytechnic Institute student research project created a set of tools for Massachusetts elementary schools to use in an effort to comply with the MS4 Permit. The WPI students determined that one of the most effective ways to create public awareness is to begin by educating children who will in turn, go home and spread awareness to their families. The towns of Shrewsbury and Holden are Massachusetts municipalities, and thus must comply with the Massachusetts Science Technology and Engineering Curriculum Frameworks. (MA STE) (Waters et al., 2016). Still, researchers have not studied how to simultaneously comply with the 2016 MS4 Permit and the MA STE curriculum framework in an effective 5th grade curriculum. This was our task.

To do so, we worked with The Central Massachusetts Regional Stormwater Coalition (CMRSWC) which helps communities mitigate stormwater to meet requirements of the MS4 Permit in an efficient and cost-effective manner. We also worked with the Massachusetts Department of Environmental Protection (MassDEP) a state agency whose mission is to ensure clean air, water and preservation of wetlands and coastal resources within the state. **In collaboration with our sponsors, our goal was to create a new 5th grade *Watershed Curriculum*, a curriculum encompassing the water cycle, stormwater runoff and the watershed, for the towns of Shrewsbury and Holden that met the new Massachusetts Science Technology and Engineering Curriculum Framework and complies with the first minimum control measure in the MS4 Permit.**

Methodology: Spreading Public Awareness through the *Watershed Curriculum*

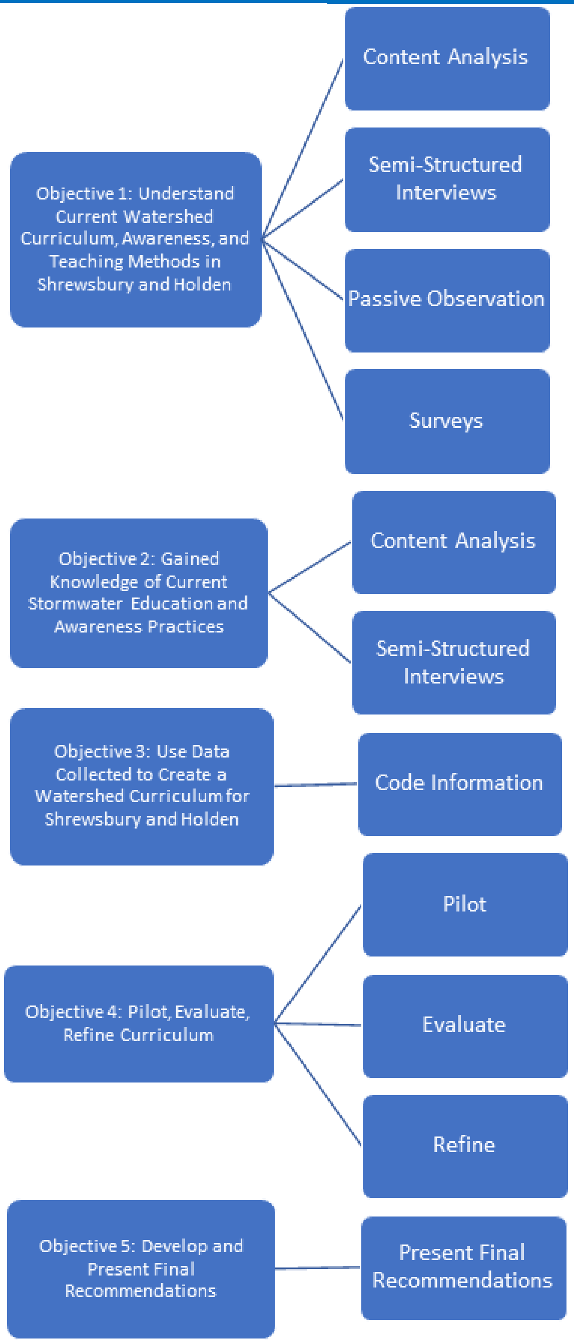
We created a *Watershed Curriculum* for the towns of Shrewsbury and Holden that meets the new Massachusetts Science Technology and Engineering Curriculum Frameworks. The *Watershed Curriculum* creates public stormwater runoff awareness by using elementary school students to reach a broader audience. We accomplished the following objectives to create the *Watershed Curriculum*

Objective one: Develop an understanding of current watershed curricula, awareness and teaching methods used in Holden and Shrewsbury elementary schools.

We used semi-structured interviews, content analysis and passive observation to understand current watershed curriculum, awareness, and teaching methods used in Holden and Shrewsbury elementary schools. Our team used content analysis to create a curriculum matrix with easily identifiable categories. We analyzed the Massachusetts Next Generation Science Standards (NGSS) and the 2016 Massachusetts Science and Technology/ Engineering Curriculum Framework before we developed the new *Watershed Curriculum*.

We interviewed Sarah Matthews, Tim Sweeten, Erin Anderson and Wendy Kallwarczyk, 5th grade science teacher from Shrewsbury, Holden and Charlton, respectively to understand what teachers needed from the *Watershed Curriculum*. We also interviewed Nicole Scola, Science Specialist, to understand how to develop a curriculum and to attempt to have the Department of Elementary and Secondary Education support widespread distribution of the curriculum (Elo & Kyngäs, 2008). We interviewed the creators of the “Living Lab Curriculum” town engineer Paul Starratt, K-5 Science and Social Studies Curriculum Coordinator in Westford

Figure 9: Passive Observation of a 5th grade science class at Sherwood Middle School, Shrewsbury Massachusetts. Student’s are conducting an experiment, and when passively observing we looked for three things specifically: students taking notes, eye contact, and the questions the students asked.



Elaine Santelmann, and Environmental Compliance Officer Mark Warren from Westford, Massachusetts. Westford has incorporated this interactive stormwater and water supply lab into their 5th grade science curriculum. We interviewed them to further understand how a town integrates MS4 requirements into schools.

We passively observed 5th grade science lessons in Shrewsbury, Wakefield and Holden. We observed seven one hour lessons, across six classrooms, with two being in Wakefield, two in Shrewsbury, and three in Holden over a two week period. Our observations helped gauge teaching methods and student engagement. We used an observation matrix to take detailed and comparable notes of 5th grade science classes to understand how lessons are taught, teaching techniques and student interactions (Kawulich, 2005). We sent consent forms home through backpack mail, early in the project so we would have the requisite consent forms prior to piloting our lessons. We also sent out surveys to parents of 5th grade students using Schoology and Dojo, parent-teacher interfaces, to grasp their current knowledge about stormwater, watershed, and stormwater pollution (Lune & Berg, 2017).

Objective two: Gain knowledge of current stormwater education and awareness practices.

We investigated stormwater curricula, activities and programs offered at non-profit organizations to learn about educational approaches and student engagement. We used content analysis and semi-structured interviews as research methods to achieve this objective (Lune & Berg, 2017).

We analyzed the content of pre-existing curricula provided to us by Ms. Kerry Reed, Framingham Senior Stormwater and Environmental Engineer. Specifically, we analyzed Maryland's statewide curriculum adaptations due to the Next Generation Science Standards and the Sudbury-Assabet-Concord River stormwater lesson plan. We analyzed pre-existing stormwater awareness programs including the Think Blue Maine Campaign and the University of New Hampshire Stormwater Center resources for MS4 Permit compliance (Rossi, Serralvo, & Joao, 2014). We focused our analysis on the techniques these programs used to disseminate information and the content of their messages and evaluated their appropriateness for inclusion. The content analysis enabled us to use pre-existing stormwater educational techniques and materials in the *Watershed Curriculum.*

We interviewed Stefanie Covino, a project coordinator from the Broadmeadow Brook Audubon. The interview consisted of topics on stormwater runoff, low impact development, and outreach programs.

Objective three: Use data collected from objectives one and two to create the *Watershed Curriculum* for use in Shrewsbury and Holden classrooms.

We compiled and analyzed the data on current watershed curricula, programs and teaching methods used in elementary schools and cataloged information in a detailed matrix on Microsoft Excel, after completing objectives one and two (Elo & Kyngäs, 2008). We summarized our data from our interview matrix, observation matrix and curriculum matrix for ease of analysis and identification of themes and trends that may be useful in creation of the *Watershed*

Figure 10: Piloting day 6 of the Watershed curriculum.

Curriculum. We developed goals for the *Watershed Curriculum* based on the detailed matrix and created 10 lesson plans and a series of educational videos to satisfy curriculum goals and enhance student engagement.

Objective four: Pilot, evaluate, and refine the *Watershed Curriculum* for Shrewsbury and Holden classrooms.

We completed three phases while implementing and evaluating the *Watershed Curriculum* for Shrewsbury and Holden. In Phase 1, we piloted the new *Watershed Curriculum* in Shrewsbury and Holden 5th grade classrooms.

In Phase 2, we evaluated the effectiveness of the *Watershed Curriculum,* since the MS4 Permit's first minimum control measure does not define effectiveness. We had a conference call with Newton Tedder, an environmental scientist at the USEPA, and drafter of the MS4 permit, to investigate the USEPA's interpretation of the word *effectiveness*. Our group made observations based on changes in parent involvement, student's opinions and beliefs before and after lessons, and implementation of active learning programs such as the enviroscape. Our group created lessons and activities that required collaboration between students and parents, helping to reach a broader audience.

In Phase 3 we refined the *Watershed Curriculum.* We asked teachers to fill out an observations survey. Our team used their feedback to gauge the effectiveness of the *Watershed Curriculum.* We revised and edited the teaching material based on the teacher's observations and feedback to develop a final iteration of the *Watershed Curriculum.*

Objective five: Develop and present final recommendations.

Our group developed final recommendations based on findings from previous objectives. We presented our recommendations to Shrewsbury and Holden school officials, our sponsors, and our advisor.

Findings

From our preliminary research and methodology, we created the *Watershed Curriculum,* lesson plans and educational videos based on three themes: teacher usability, standard compliance and student engagement. Through development of the *Watershed Curriculum,* we uncovered findings for the Massachusetts Department of Environmental Protection (MassDEP) and the Central Massachusetts Regional Stormwater Coalition (CMRSWC). In this section, we discuss how the *Watershed Curriculum,* videos, and lesson plans will assist municipalities in compliance with the first minimum control measure of the MS4 Permit and the Massachusetts Science Technology and Engineering Curriculum Frameworks. (MA STE).

Teacher Usability

For preliminary development of the *Watershed Curriculum,* lesson plans, and videos, our priority was to make it user friendly. Our goal was to create a *Watershed Curriculum* that could be picked and implemented with ease by any teaching professional.

Finding 1: Teachers find it difficult to find applicable and appropriate resources on how to teach about stormwater runoff.

Due to the lack of experience and variety of options out there, teachers have difficulty finding applicable and appropriate resources to teach about stormwater.

Our interviews with nine fifth grade science teachers in the towns of Shrewsbury, Holden, and Charlton revealed that physical resources, such as lesson plans and supplementary teaching materials are hard to find. Wendy Kalwarczyk and Erin Anderson, fifth grade science teachers from Charlton, explained that the resources they found were "cheesy, not realistic, and not effective." (W. Kalwarczyk and E. Anderson, Personal Communication, 4/5/2018).

In addition, these teachers are lacking time and money to teach about stormwater runoff. All nine teachers stated there was not enough time allotted to science. Teachers at Holden have a 45 minute time slot for science every other day and teachers in Shrewsbury and Charlton have 45 minutes of science everyday. Elaine Santelmann, K-5 Science and Social Studies Curriculum Coordinator in Westford, said that time constraints make it difficult to teach about stormwater in the classroom. Instead, it is taught as part of the district's Living Lab program. (E. Santelmann, Personal Communication, 3/21/2018). Teachers in Holden and Charlton also do not have funding to teach using the MA STE curriculum framework. The MA STE curriculum framework promotes the use of the science and engineering practices such as using models and conducting investigations, but these four teachers voiced that it is difficult to create these lessons if they do not have funding to buy supplies, resorting to them purchasing supplies out of pocket. We developed the *Watershed Curriculum,* lesson plans, and videos to help resolve this issue. The materials give applicable and appropriate lesson plans that do not require expensive materials or technology, but do offer options to use technology should schools have the supplies.

Finding 2: Teachers are more likely to implement curricula that are easy to use with clear objectives.

To teach lessons confidently and efficiently, teachers need to have an easy-to-use curriculum. Through interviews and content analysis, we discovered what four characteristics make it easy to use. **First, a curriculum that needs to be clear about which MA standards it meets and what questions students should be able to answer at the end of the unit**. Second, Nicole Scola, Science Specialist, explained that providing clear objectives and goals for each lesson would ensure teachers' competence in teaching material. She explained that a "**walk through of a lesson and tutorial of curriculum" would help make curriculum clear and easy to use.**" We used this information to develop lesson plans and videos to walk teachers through the curriculum. (N. Scola, Personal Communication, 3/16/2018).

Third, after sharing the first draft of the *Watershed Curriculum,* with teachers, **we learned the importance of incorporating one goal per day and essential and extended vocabulary into the material.** The essential vocabulary are terms that need to be covered for the day and extended terms are offered if they have additional time. Fourth, through content analysis of pre-existing curriculums that teachers use along with these interviews, it was evident that **color coding, clear objectives, goals and vocabulary are characteristics of an easy to use curriculum.** We incorporated these findings into the design of the *Watershed Curriculum*, shown in Figure 11.

Finding 3: A teacher's confidence in a subject has an impact on how they teach.

Elaine Santelmann of Westford Public School's Living Labs Curriculum, shared that teachers will perform differently in a classroom when they are confident in subjects than when they are not. Teachers are more likely to spend time on a subject, encourage questions, and engage students when they are comfortable guiding exploration on a topic. We developed the *Watershed Curriculum,* lesson plans, and videos to resolve this issue (E. Santelmann, Personal Communication, 3/21/2018).

Nicole Scola agrees and noted that "the watershed is a new concept and teachers are not confident." She also said that in 5th grade, teachers are more flexible on how they can choose to spend time on each subject, and if they are not confident in a subject, they are likely to spend less time teaching it. (N. Scola, Personal Communication, 3/16/2018). Ms. Kalwarczyk and Ms. Anderson, Charlton Public Schools, explain that since there is not enough time to teach every subject recommended, they must pick what subjects they teach and may have a preference for subjects they are confident teaching. (W. Kalwarczyk and E. Anderson, Personal Communication, 4/5/2018). Eight out of nine teachers said they were not confident in their ability to teach about watersheds and

5th Grade Watershed Unit

Massachusetts 2016 Standards Addressed:

5-ESS2-1 I can use models to describe the cycling of water through a watershed through evaporation, precipitation, absorption, surface runoff, and condensation.

5-ESS3-1 Obtain and combine information about ways communities reduce human impact on the Earth's resources and environment by changing an agricultural, industrial, or community practice or process.

5.3-5-ETS3-2 (MA) Use sketches or drawings to show how each part of a product or device relates to other parts in the product or device.

Grade 5 Unit Goals:

1. Students will be able to explain the process of the water cycle.
2. Students will be able to model the process in which pollutants reach bodies of water and how it impacts the water cycle/environment.
3. Students will be able to use maps and sketches to identify local watersheds and the bodies of water they flow to.
4. Students will be able to identify different materials and their effect on stormwater runoff
5. Students will be able to identify different designs that help protect Earth's resources and the environment.
6. Students will be able to explain the difference between sewer systems and stormwater systems.
7. Students will be able to model a catch basin system and explain its function.

Figure 11: The unit goals and state standards addressed by the Watershed Curriculum.

stormwater and agreed that an increase in confidence would help them to teach the subject. Ms. Scola offered that a way to help teachers is to create video tutorials to "teach the teacher," thus increasing confidence and teaching ability. We incorporated this advice in our development of "Dr. Drain the Rain Brain" videos for use in classrooms. (Dr. Drain Screenshot)

Adherence to Standards

While creating curriculum, we needed to make sure it complied with the first minimum control measure of the MS4 Permit and the Massachusetts Science Technology and Engineering Curriculum Frameworks. Through interviews, observations and feedback we found teachers are influenced by standardized tests. We also discovered that municipalities are unclear about what the MS4 Permit means by "effectiveness" of the educational message and educational programming. The permit states that "the permittee shall identify methods that it will use to evaluate the effectiveness of the educational messages… and shall be tied to the defined goals of the program and the overall objective of changes in behavior and knowledge." (USEPA, 2016)

Finding 4: There is a lack of a specific standard addressing stormwater in the Massachusetts STE Framework.

Standardized tests are used to assess students' knowledge, but can be used by schools to evaluate a teachers competencies. Through observations, interviews and Massachusetts Comprehensive Assessment System (MCAS) results, it was clear MCAS impacts teachers. In interviews with Holden science teachers, they agreed that it was difficult to prioritize teaching subjects that were not tested on MCAS. During observations of Tim Sweeten at Dawson Elementary School in Holden, MA, we observed that he had an MCAS review every day in class to ensure that students scored well. Charlton teachers said they struggle to teach all science curriculum in the allotted time for science and try not to "waste time on subjects that won't be covered on the MCAS." To facilitate change through youth education, it is imperative to force the educational systems' hand to teach stormwater by incorporating questions into the standardized tests (T. Sweeten, Personal Communication, 3/22/2018).

Through further investigation, we confirmed that MCAS does not have any questions about stormwater. In fact, over the past eight years, out of 21 questions, there have been a maximum of two questions regarding the water cycle on the MCAS, as shown in Table 3. The watershed is a new standard being addressed by the Massachusetts Science Technology and Engineering Curriculum Framework. If teachers do not identify that the

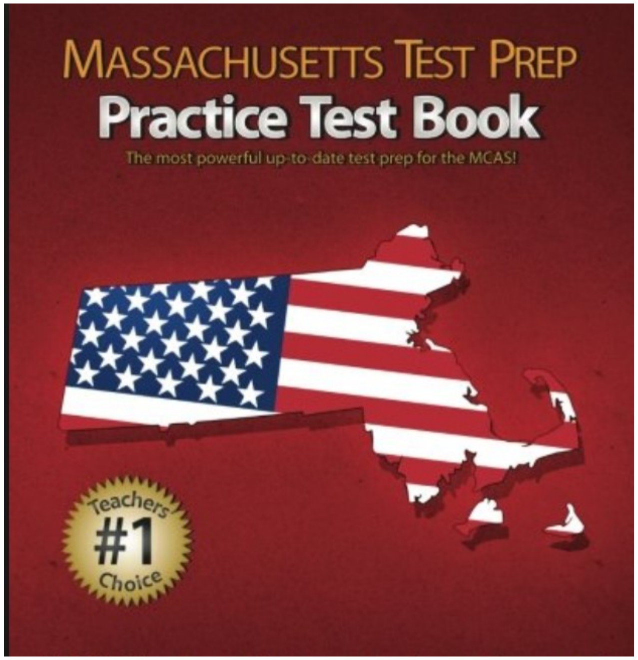


Figure 12: During our observations in Holden, we observed teachers using prep books like these to prepare for the standardized tests.

MCAS Tests	Questions		
Year	Water Cycle	Climate	Total Questions Asked
2017	0	2	21
2016	2	2	21
2015	2	3	21
2014	0	3	21
2013	2	3	21
2011	1	4	21
2010	1	2	21
2009	2	1	19
Water Questions/Total Questions	Percent		
30/166	17.96%		
Water Cycle Questions/Total Questions	Percent		
10/166	6%		

Table 3: Eight years of published MCAS test data showing the lack of questions regarding the water cycle.

new standard exits it may be overlooked based on the fact it has not been on an MCAS test yet. .

Finding 5: To comply with the first minimum control measure of the MS4 permit, materials must show an attempt to improve awareness and public outreach regarding stormwater runoff.

The *Watershed Curriculum,* lesson plans, and videos comply with the MS4 permit. The 2016 MS4 Permit definition of effectiveness in regards to the first minimum control measure, has not been clarified previously. Interviews with various Massachusetts Department of Public Works employees and town Engineers, including Isabel McCauley, Vincent Thai, and Brad Stone. Newton Tedder, USEPA employee and drafter of the permit, helped us understand the MS4 Permit Public Education and Outreach requirements (N. Tedder, Personal Communication, 3/21/2018).

Interviews with Isabel McCauley, Vincent Thai and Brad Stone addressed effectiveness, however, the three town engineer officials did not have a clear plan on how to comply with the first minimum control measure of the MS4 permit, due to the lack of transparency and ambiguity of the permit (B. Stone & V. Thai, Personal Communication, 3/15/2018).

We interviewed Newton Tedder, drafter of the permit who agreed that defining effective is difficult. However, he explained that the permit's goal is to have municipalities put in place a plan for a long term measurable goal that can be adapted year to year. This goal should measure behavior change and increases in knowledge, and should translate into municipalities adjusting their education and outreach program based on results. This type of long term effort would comply with the permits definition of effective. Mr. Tedder stated that having a successful outcome is not the initial goal, but having an adaptive plan satisfies the first minimum control measure. Mr. Tedder further explained that a parent survey (Figure 13) before and after a lesson is a measurable attempt at improving awareness, thus complying with the first minimum control measure of the MS4 permit. (N. Tedder, Personal Communication, 3/21/2018).

Elaine Santelmann and Paul Starratt from Westford Living Labs Curriculum created a program that follows this definition of effectiveness. Ms. Santelmann believes that effectiveness can be shown using pre and post-tests that give examples of what students have learned. **Therefore, an effective education produces a measurable increase in knowledge** (E. Santelmann & P. Starratt, Personal Communication, 3/21/2018).

Engagement

We developed materials that engaged students based on our findings and can be used to meet the MS4 permit effective education

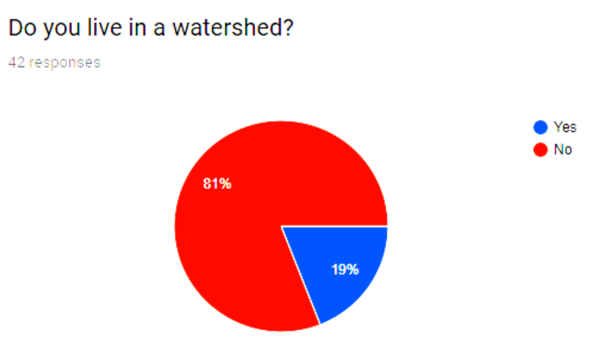


Figure 13: Results from our parent survey showing a lack of stormwater knowledge in the public

requirements. Because of the measurable outcomes and extent of student engagement, we believe the *Watershed Curriculum,* lesson plans and videos to be effective educational tools.

Finding 6: For education to be effective, students must be engaged.

An engaged classroom is essential for education to be effective. In interviews, Nicole Scola and Elaine Santelmann said that student engagement can be assessed by the ability of students to develop and ask questions on their own and to reiterate and explain the information taught. According to our primary teacher contacts, Tim Sweeten and Sarah Matthews, engagement is about how you display and teach lessons (S. Matthews, Personal Communication, 3/15/2018) (T. Sweeten, Personal Communication, 3/22/2018).

Ms. Scola, Science Specialist, and Ms. Ryan, a fifth grade science teacher from Shrewsbury agreed that students are not necessarily engaged just because a lesson is hands on , a common misconception (N. Scola, Personal Communication, 3/16/2018). Wendy Kalwarczyk, Erin Anderson and Elaine Santelmann informed us that a **key way to engage students is to invoke passion and emotion in them (**(W. Kalwarczyk & E. Anderson, Personal Communication, 4/5/2018) (E. Santelmann, Personal Communication, 3/21/2018)

When student emotions are involved, the level of engagement rises drastically because of how much they care. They also agreed projects and lessons that get children excited and connect to what children care about will engage students. **Through observations, we discovered that**

Observation Matrix							
Lesson	School	Date	Teaching Method	Technology	Student Engagement		
					Eye Contact	Note Taking	Asking Questions
Piloted Lesson	Sherwood Elementary	4/11	Lecture, hands on experiment	Smart Board, iPad	Yes	Yes	Yes
	Sherwood Elementary	4/12	Interactive presentation	Projector, iPad	Yes	Yes	Yes
	Sherwood Elementary	4/13	Hands on experiment	Projector, iPad	Yes	Yes	Yes

Table 4: A snapshot of our observation matrix from our piloted lessons looking at student engagement in particular.

student engagement can be shown in three ways; students asking questions, making eye contact with the teacher or primary speaker, and students taking notes, as shown in Table 4. We utilized this data to create effective *Watershed Curriculum, lesson plans, and videos.*

Finding 7: A measurable outcome can determine if education is effective.

We discovered that in the classroom, there are many ways to measure effective education. Ms. Scola said that engagement directly leads to a measurable outcome. **The students ability to develop, ask, and answer questions, as well as explain the taught lesson on their own are all effective ways to measure the outcome of a lesson** (N. Scola, Personal Communication, 3/16/2018).

According to Ms. Matthews, Mr. Sweeten and Ms. Santelmann, students need to be able to show that they have retained information through follow-up questions. Ms. Santelmann recommends children engineer solutions to problems related to lessons. This allows students to take a question and develop an answer using the scientific process. Ms. Santelmann also stated that students' retention should be measured by pre- and post-tests before and after the lesson, respectively. Tests will show improvement in students' ability to answer questions. Having students develop solutions to real world problems through written or spoken evaluations is a viable measurable outcome. We used this information to incorporate "Exit Tickets" (Figure 14), pre- and post-tests into the Watershed Curriculum and lesson plans to measure outcomes of lessons (S. Matthews, Personal Communication, 3/15/2018) (T. Sweeten, Personal Communication, 3/22/2018) (E. Santelmann, Personal Communication, 3/21/2018).

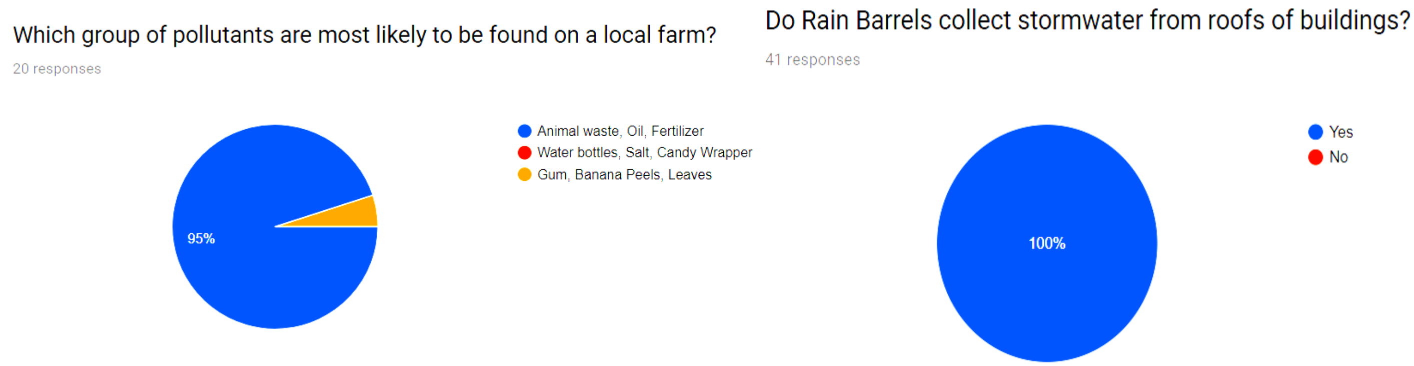


Figure 14: Two examples of questions to put on a quiz or exit ticket after a lesson to determine if the students are able to retain the information and provide a measurable outcome. .

Recommendations

Utilizing the seven findings, we developed recommendations for the Central Massachusetts Regional Stormwater Coalition (CMRSWC) and Massachusetts Department of Environmental Protection (MassDEP).

Recommendation 1: Send out pre-lesson and post-lesson surveys to parents to gauge how effective the curriculum is at satisfying the first minimum control measure of the MS4 permit.

In order to gauge how effective the *Watershed Curriculum,* lesson plans and videos are at spreading public awareness, we recommend utilizing a pre- and post-survey. The survey can be sent out to the parents of fifth grade students

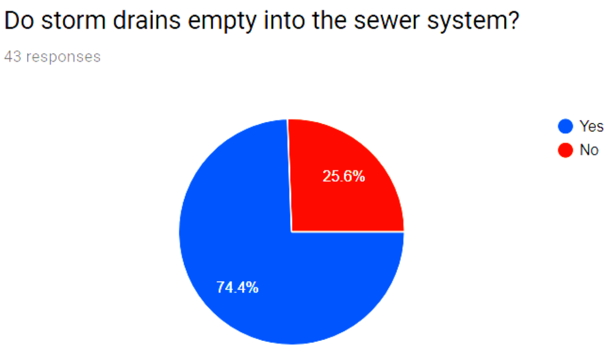


Figure 15: Results from our parent survey that could be redistributed to help show a positive change in storm-water awareness.

both before after the Watershed Curriculum is taught. The pre-survey with questions such as the one in Figure 15, will assess the parents' awareness of a watershed, stormwater and stormwater runoff without the potential influence of their children. Survey results could be used by town officials to gauge stormwater awareness within their community and use this data to create a long term plan to satisfy the first minimum control measure of the MS4 Permit.

Recommendation 2: Partner with the Massachusetts Department of Elementary and Secondary Education incorporate questions regarding stormwater in the MA STE standards.

For the *Watershed curriculum* to have the greatest impact, Massachusetts DESE must incorporate specific standards regarding stormwater in their framework. This would lead to questions about stormwater in the Massachusetts Comprehensive Assessment System (MCAS). In **Finding 4** we determined that teachers teach to standards of the STE Framework. Because of this, and the fact that the MCAS is developed directly based off of these standards; **We recommend the MassDEP and the CMRSWC advocate for the DESE to put a larger emphasis and specific standards that address stormwater in explicitly.**

Recommendation 3: When new curriculum is developed, provide teachers with a centralized database of resources and create teacher workshops to help "teach the teacher."

For teachers to teach confidently, they need to be knowledgeable about the subject and have resources to teach subjects effectively. Teachers have a difficult time finding appropriate resources to teach about stormwater runoff. Moreover, 5th grade teachers do not have specialized knowledge about stormwater runoff as their job requires them to be generalists. Who must have broad knowledge in math, science, english and history, compared to high school teachers, who teach one subject and therefore have specialized knowledge (Finding 3). This hinders 5th grade teachers' confidence in teaching about the subject.

We recommend that the CMRSWC and the MassDEP organize teacher workshops to teach teachers about stormwater runoff and the watershed. If teachers are more confident about a subject, they will spend more time teaching it. **We also recommend that the CMRSWC and MassDEP provide cities and towns with an enviroscape or similar tool, as well as, an instruction booklet accompanied by lessons.** The enviroscape is a great tool to use to teach about stormwater runoff, best management practices and human impact on the environment. If teachers were provided the resource, they would have a much easier time teaching the *Watershed Curriculum.* Finally, we recommend that the CMRSWC and the MassDEP centralize a place for ready to use teaching materials. This would not only encourage the relationship between teachers and state agencies, but would allow the coalition to identify which materials they have used and found to be effective.

Conclusion

In collaboration with the Massachusetts Department of Environmental Protection and Central Massachusetts Regional Stormwater Coalition, we created a new fifth grade *Watershed Curriculum* with lesson plans and videos for the towns of Shrewsbury and Holden. The *Watershed Curriculum,* lesson plans and videos will help these municipalities comply with the first minimum control measure of the MS4 permit and adhere with the Massachusetts Science Technology and Engineering Curriculum Framework. In our early research , we discovered that teacher usability, standard compliance and student engagement were the key to satisfying our goal. We designed the *Watershed Curriculum,* lesson plans and videos to be an effective fifth grade curriculum, tailored to the towns of Shrewsbury and Holden, but with aspects enabling it for broad use across any school system using the Massachusetts Science Technology and Engineering Curriculum Frameworks. In conclusion, we believe that the *Watershed Curriculum,* lesson plans and videos, should be recommended to any school system or municipality in need of a watershed curriculum. We hope our work will further prevent stormwater runoff, pollution, and help protect surface water quality in Massachusetts.

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