Appendix 18 – Elementary School Stormwater Education Proposal

Eastern Washington
Stormwater Effectiveness Studies

Detailed Study Design Proposal: Elementary School Stormwater Education

Study Classification:

☐ Structural BMP ☐ Operational BMP ☑ Education & Outreach

Study Objective(s):

☑ Evaluate Effectiveness ☑ Compare Effectiveness

June 30, 2017

Prepared For:

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Proposal Publication Information

This Detailed Study Design Proposal (Proposal) will be stored and accessible to the public at the following weblink: Add Weblink where the Proposal can be accessed by the Public

For questions regarding the Proposal, please contact First and Last Name of Lead Entity Contact by email add email address or phone (509)XXX-XXXX.

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Signature Page – QAPP Only

This section will be completed for the QAPP.

List each party responsible for the contents of the QAPP and the project along with their project title, and organization. Each party must sign and date this page before the study proceeds to the implementation phase (i.e. conduct the study).

Distribution List – Proposal

This section includes the distribution list for each party who will receive an Ecology approved copy of the Proposal.

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Distribution List - QAPP Only

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1.0 Table of Contents

The TOC should be updated during the QAPP development and auto generated using a word processing program.

2.0 Executive Summary – QAPP Only

This section will be completed for the QAPP.

3.0 Background

3.1 The Stormwater Education and Outreach (E&O) Program

The Eastern Washington (EWA) NPDES Phase II Municipal Stormwater (MS4) permit specifies that the cities and counties covered under the permit (permittees) implement public education and outreach (E&O) programs. The target audience for these programs is the general public, including school-aged children, living in the permitted jurisdictions or region. The goal of these programs is to inform the public about "*…the importance of improving water quality and protecting beneficial uses of waters of the state; potential impacts from stormwater discharges; methods for avoiding, minimizing, reducing and/or eliminating the adverse impacts of stormwater discharges; and actions individuals can take to improve water quality…*".

Some permittees meet this requirement by partnering with K-12 schools in their jurisdiction and providing educational workshops and presentations focused on stormwater as part of the regular school day for students. Other permittees partner with organizations, who specialize in educational training, to provide formal classroom instruction on their behalf. For example, several EWA permittees have an interlocal agreement (ILA) with the Franklin Conservation District (FCD) to provide this service. These jurisdictions include:

- City of Ellensburg
- City of Yakima
- Yakima County Stormwater Group (Selah, Union Gap, Sunnyside, Grandview)
- Quad Cities
- Asotin County
- City of Clarkston
- City of Asotin

The FCD has two stormwater education programs: *Water on Wheels and Drain Rangers*. *Water on Wheels* is for students in grades K-6th. The goal of this program is to increase the students' awareness of water and soil conservation issues. The *Drain Rangers* program is for students in grades 3rd-5th. The goal of Drain Rangers is to increase the student's awareness and understanding of stormwater pollution issues facing their community including the specific actions students can take to improve the quality of the waterways in their community.

This study focuses on the *Drain Rangers* educational program. *Drain Rangers* was developed with funds from an Ecology Grants of Regional or Statewide Significance (GROSS) Grant by educators, western Washington (WWA) permittees, and nonprofit organizations. *Drain Rangers* is a stormwater curricular unit with 10 lesson plans that are intended to be taught in classrooms and outdoors on the school site over a three to four-week period. The lesson plans focus on teaching students what stormwater is, how pollutants can get into waterways, and the actions students can take to keep waterways clean (i.e. prevent stormwater pollutants from entering waterways). Students also apply the engineering design process to develop solutions to stormwater runoff problems and then develop an educational campaign to share what they learned with others in their community. The curriculum was specifically developed to align with the MS4s NPDES goals for the E&O programs as well as elementary school learning standards including the Washington State common core for English Language Arts (ELA) and the Next Generation Science Standards (NGSS).

Drain Rangers was pilot tested during the 2016-2017 academic year at schools in WWA. The results from the pilot study will be released on June 30, 2017.

The FCD is one of the organizations involved in the *Drain Rangers* curriculum development. Their role was to adapt the curriculum to EWA and provide teacher training workshops in Spokane and Ellensburg. An overview of the EWA lesson plans is in Appendix A and a copy of the *Drain Rangers* curriculum is available on the FCD website: https://drive.google.com/file/d/0B5-jJRFUiir7OXVDWFV0Zng4LTQ/view

The focus of this study is to pilot test the *Drain Rangers* curriculum in up to three EWA elementary schools. If additional funding sources can be identified, the study will expand to include more schools in multiple jurisdictions.

3.2 Problem Description

Drain Rangers is a new educational program that has been implemented in a limited number of WWA schools. As such, there are many questions about this educational program including:

- What is the short-term impact of the Drain Rangers educational program for increasing student's awareness and understanding of stormwater pollution immediately following their participating in the program?
- Will the Drain Rangers educational program have a lasting impact on student's awareness and understanding of stormwater pollution one or more years after students participate in the program?
- What aspects (if any) of the Drain Rangers educational program will motivate students to take actions that will prevent stormwater pollution in their neighborhoods and communities?
- Will teachers incorporate the Drain Rangers educational program into their standard curriculum and make a long-term commitment to teach the program?

This study focuses on the first question and seeks to measure the short-term effectiveness of the *Drain Rangers* stormwater educational program. Answering the questions in the other bullets is beyond the scope and timeline of this Effectiveness Study. However, since the ultimate goal of stormwater education programs is to make a sustainable, positive impact on students, it is important to understand the variables that are more likely to yield this impact. This section provides a summary of findings from related research that have attempted to answer similar questions. These findings were all reported in a 2001 synthesis of literature written by Rickinson titled *Learners and Learning in Environmental Education: A critical review of the evide*nce (Rickinson, 2001).

It is evident from research reported on K12 environmental educational programs, similar to Drain Rangers, that these programs can have a positive effect on student's attitude and knowledge of the environment. Many studies have reported a significant positive impact in students immediately after the program. However the long-term impact of these programs on students is not as evident.

Some researchers have reported a measureable increase in student's awareness of the relationship between their actions and the environment years after the educational experience while other researchers have reported no measureable change in students' just weeks after they participated in the educational program.

The differences in the effectiveness of educational programs may relate to specific aspects of the educational program which have been reported by researchers to have the most significant influence on student's educational experience. These aspects include:

- Duration – longer duration educational programs appear to have more of an impact on students compared to shorter duration programs. A study that evaluated two versions of an outdoor ecology education program (1-day and 5-day) found that only students from the longer 5-day program reported a significant shift in their attitudes and behaviors toward the environment.
- Location - outdoor classroom experiences have been identified as the most significant aspects of an environmental program for motiving students. One justification is that students are more likely to relate environmental issues to their own community when they learn the information outdoors in their community.
- Community involvement – K-12 environmental education programs that include community involvement appear to enhance the students learning experience, specifically when students are able to share their new knowledge and experiences with their families and friends
- Preparatory and follow-up work - environmental educational programs that include teacher training workshops before the program is implemented and teachers that follow up with the students on the environmental program concepts (after the program has been implemented) appear to improve both the short-term and long-term impact on students.

Some of the key aspects reported are already part of the Drain Rangers curriculum. For example, the lesson plans are intended to be taught over a long duration (3-4 week period) with several lessons taught outdoors, and teacher training workshops are provided to teachers to support them in implementing the program in their own classroom. In addition, the final project includes students developing an educational campaign focused on stormwater awareness. This aspect of the program provides students with an opportunity to engage and share with the community what they have learned.

In summary, while this study focuses on evaluating the short-term effectiveness of Drain Rangers, the educational program includes aspects that have been identified by researchers as key for supporting the long-term impact of the program on students.

3.3 Results of Prior Studies

The WWA Drain Rangers educational program pilot testing included evaluating the effectiveness of the curriculum by comparing students before and after survey responses. A copy of the Drain Rangers student survey form is in Appendix B. Results from this evaluation are expected to be released by the City of Bothell after the June 30, 2017 deadline for this Proposal. During the development of the QAPP, this section should be updated with a summary of those results including any recommendations for future implementation of the Drain Rangers program.

3.4 Regulatory Requirements

The EWA Phase II MS4 Permit S5.B.1 requires permittees to implement a public education and outreach program, either locally or regionally. This study will focus on evaluating the effectiveness of a stormwater education program for elementary school aged children.

4.0 Project Overview

4.1 Study Goal

The goal of the study is to evaluate the short-term effectiveness of the Drain Rangers education program in EWA. Effectiveness will be measured based on changes in the students understanding of selected learning objectives immediately after participating in this program. The Drain Rangers curriculum includes 10 lesson plans each of which has different learning objectives as shown in Appendix B. This study will only evaluate those learning objectives that align with the EWA NPDES MS4 Phase II permit requirements for E&O. Specifically, increase student understanding and awareness of the following:

- Students will describe what stormwater is
- Students will describe how pollutants get into stormwater and pollute waterways
- Students will describe actions they can take to prevent pollutants for entering waterways and to keep waterways clean

4.2 Study Description and Objectives:

This study will pilot test the Drain Rangers Stormwater Education program in elementary schools in EWA. This will include using the Drain Rangers curriculum that was developed for EWA as part of a 2015-2017 GROSS Grant. Prior to the start of this study, the WWA Drain Rangers final report (due June 30, 2017) will be reviewed to determine if the findings or recommendation could improve the effectiveness of the EWA educational program. This may result in modification to the existing EWA Drain Ranger curriculum or the teacher training materials. Teacher training workshops will be offered to the teachers who participate in the pilot study. The purpose of the workshop is to provide teachers with background on the curriculum concepts as well as guidance for consistently implementing the curriculum in their classrooms. The curriculum will be implemented by the student's teachers during the regular school hours. Students will be given surveys designed to assess the students' knowledge of the learning objectives immediately before and after they participate in the educational program. The effectiveness of the Drain Rangers programs will be evaluated by comparing the differences in student's responses to the pre and post surveys.

The study goals will be achieved by meeting the objectives and subsequent tasks noted in Table 4.1.

4.3 Study Location and/or Target Population

The study will be pilot tested at up to three elementary schools within the lead entity city with the help of additional study participants. If additional funding sources can be identified before the QAPP is completed, the study may be expanded to include pilot testing at more schools in other Eastern Washington jurisdictions. The schools selected for this study will be identified by the lead entity with consultation from study participating agencies. Selection will focus on locating schools where both the administration and teachers are committed to participating in the study. A secondary consideration is to select schools with a balance of student demographics preferably representative of the lead entity demographics. This section will be updated during the QAPP development to include the actual criteria used to select the schools.

The target population for this study are students in grades 3-5. This population was pre-determined because it is the target age for the *Drain Rangers* curriculum.

4.4 Data Needed to Meet Objectives

Data will be collected using surveys administered to the students immediately before (pre) and after (post) they participate in the educational program. Since the survey (instruments) will be developed after the Proposal is submitted, this section will be updated when the QAPP is developed.

Demographic data about the students who attend the school will also be collected. This data is published on the school website and available to the general public. This information will be used to characterize the students participating in the study.

For this pilot study, the sample size will include students from one class in each grade (3-5) who participated in the educational program.

4.5 Tasks Required to Conduct Study

The primary task identified to complete this study along with a general description of the work are summarized in a table in section 4.2 along with the study objectives.

Table 4.1 Study Objectives and Tasks Required to Conduct Study

Objective	**Tasks**
Refine the Study Plan	
Prepare the EWA Drain Rangers Curricular materials and teacher training materials for this study	Prepare Materials for the Study – The materials for this study include the Drain Rangers curriculum and teacher training materials. This may include: Review the WWA Drain Rangers final report and incorporate applicable findings, recommendations, and/or lessons learned. If needed, modifying/revise the EWA Drain Ranger Curriculum and teacher training materials (previously implemented in Spokane and Ellensburg). Once the materials are finalized, the curricular materials will be assembled into 'kits' for the teachers use during the training workshops and to implement the curriculum in their classrooms.
Recruit school(s) and teachers to participate in the study	Recruit School(s) and Teachers Committed to Study – Contact schools in the lead entity for the purpose of locating schools/teachers willing to commit to being involved in the entire study. Specifically, teachers will be asked to attend the teacher training workshop, implement the curriculum in their classrooms, and administer the pre- and post-surveys to students.

Identify the available funding sources for this study, finalize the budget, and decide on the size of the study (i.e. number of schools, teachers, and students that will be included in the study).	Determine Funding Sources and Finalize Study Scope – The lead entity will determine all available funding sources: identify the available funds from their jurisdiction, request funding from Participating entities, and apply for a GROSS Grant (2017-2019). This may include locating other grant partners willing to commit their involvement in the study (i.e. the FCD, other organizations, educators, consultants, etc.). Based on the available resources (i.e. funding and partners), the lead entity will decide how many schools will be included in the pilot study.
QAPP Development	
Design an experiment that will evaluate the effectiveness of the EWA Drain Rangers program including how quality assurance and quality control plan will be applied to the study.	QAPP Development – Finalize the QAPP by developing the QAPP-Only sections of this document and updating the Proposal sections as needed. The primary work associated with this task is expected to include: • Finalize the sections of this document that were not completed during the Proposal development (because the scope of the study was not finalized). This may include modifying/revising the sections to address comments Ecology provides on the Proposal after the June 30, 2017 submittal. • Design and develop study instruments (i.e. surveys) that will measure changes in the students understanding of the learning objectives. This may include modifying the surveys from the WWA study or developing new surveys. • Define the Study Quality Assurance and Quality Control (QA/QC) Plan – This plan focuses on collecting quality data and minimizing errors including: developing *standard operating procedures (SOPs) for data collection*, developing a *data management plan* that defines how the data collected during the study will be managed and stored; and defining the *procedures for audits* that will be conducted during the study to verify the study conforms to the QAPP.
Prepare for Data Collection	
Prepare for and provide training workshops for the teachers who will participate in the study.	Teacher Training Workshops – this task includes preparing for and providing training workshops focused on providing teachers with guidance for implementing the Drain Rangers curriculum in the teacher's classrooms.
Assess the IRB requirements for the proposed study plan	IRB Requirements – Verify the study is exempt from an IRB. *See Section 4.5 for more information about IRBs*.
Data Collection	
Measure changes in students understanding of the learning objectives as a result of participating in the study.	Collect Data – This task focuses on collecting data immediately before and after students participate in the educational program (i.e. the curriculum has been implemented in the classroom). This is expected to include: obtain permission from parents for the students to participate in the study, administering pre-surveys to students prior to their participation in the educational program; administering the post-surveys to the students after they have participated in the educational program, and input data into excel spreadsheets or other data bases.

Pilot test the curriculum in the selected classrooms.	Implement Curriculum - Teachers will implement the Drain Rangers curriculum in their classroom during the regularly scheduled school day.
Verify the procedures defined in the QAPP are followed during the study.	Audits – Shortly after the study has started, conduct audits to verify procedures defined in the QAPP are followed. For example, visiting the classroom to verify the pre- and post-surveys are administered following the survey instructions and visiting the location where the data is stored to verify that data management procedures are followed.
Optional: Assess teacher opinions of the curriculum and students learning experiences.	Poll Teachers – After teachers have completed the *Drain Rangers* curricular unit, consider polling the teachers. The poll would focus on the teachers' opinions of curriculum (what went well and what could be improved) and the students learning experience. Polling the teachers is not necessary to meet the requirements for an Effectiveness Study but this information could be used to improve the curriculum and ultimately support the long-term success of the educational program.
Develop Technical Reports	
Evaluate and interpret the effectiveness of the curriculum for achieving the pilot study learning objectives.	Evaluate Effectiveness – The effectiveness evaluation focuses on comparing the differences in the student's response on the pre- and post-surveys. This is expected to include: analyzing the data collected during, interpreting the results, and summarizing the findings into a final report (S8.B.10) and annual reports (S8.B.8).

4.6 Potential Constraints

Potential constraints are conditions that may impact the project schedule, budget, or scope. The potential constraints identified in this section, along with the steps that will be taken to reduce the impact of these conditions (mitigation approach), are based on the information that was available at the time the Proposal was written. This section should be updated during the QAPP development.

Potential Constraint	Mitigation Approach
Unable to obtain parental consent to include the student's survey response in the study. For example, students forget to bring their signed parental consent forms back to school.	Instead of asking students to provide a parent signed permission slips to participate in the study; only collect signed forms from the students whose parents objected to their participation in the study.
Inconsistent data collection procedures. For example: not all the teachers had students complete both the pre- and post-survey or the instructions provided by teachers to the students were inconsistent.	Identify one person who will administer the pre-survey and post-survey for all classes; schedule times for administering the surveys prior to the start of the study; and develop SOP that define the teacher instructions for administering the surveys.
Unable to locate teachers who are able to attend the training workshops.	Offer a stipend so teachers can hire a substitute to teach their students while they attend the training workshop.

Uneven offering of the curriculum. Curriculum is offered over 4 weeks so there could be units that are skipped or covered by a substitute instead of the normal teacher.	During the teacher training workshops, stress importance of curriculum coverage and ask teachers to track when their participation in educational program.

5.0 Organization and Schedule

5.1 Key Project Team Members: Roles and Responsibilities

Key Team Members	Organization	Roles and Responsibility
Lead Entity Contact Name Phone Number Email	Lead entity	Responsible for the execution of this study
Matt Carlson 509.243.2074 mcarlson@co.asotin.wa.us	Asotin County, City of Asotin, City of Clarkston	Advisory Board Lead/Member; Auditor; Data Verifier
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Dan Ford 509.545.3445 fordd@pasco-wa.gov	City of Pasco	Participant w/out designated role
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Name Phone Number Email	Organization	QAPP Author: To be defined when the QAPP is developed
Name Phone Number Email	Organization	Key Team Member Project Role: Define when the QAPP is developed if applicable

5.2 Project Schedule

An overview of the project timeline as depicted during the public commentary period is shown in Figure 5.2. A task timeline based on quarterly activities is shown in Table 5.1.

Table 5.2 Proposed Study Timeline

	2017		2018				2019	
Task Name	**Q3: Jul - Sept**	**Q4: Oct - Dec**	**Q1: Jan - Mar**	**Q2: Apr - Jun**	**Q3: Jul - Sep**	**Q4: Oct - Dec**	**Q1: Jan - Mar**	**Q2: Apr - Jun**
Refine Study Plan *GROSS Grant Application[1]*	*July 31st*							
QAPP Development								
Ecology QAPP Review								
Prepare for Data Collection								
Data Collection								
Analysis and Reporting[2]								*June 30th*

1. Ecology GROSS Applications are typically due on July 31st
2. If the project receives GROSS grant funding, the final report will be due on June 30th. Otherwise the final report is due to Ecology 6-months after data collection is complete.

Figure 5.1: Overview of project schedule

Table 5.3.1 Estimate Study Budget

Task Name	Hours	Cost per Hour	Work Performed by (Consultant, Lead Entity or Participating Entity)	Total
Project Management[1]				$4,400-$7,200
Refine Study Plan[2]	40-120	$50	FCD	$2,000-$6,000
QAPP Development[3]	120-160	$150	Lead entity & Consultant	$18,000-$24,000
Prepare for Data Collection[4]	40	$50	FCD	$2,000
Data Collection[5]	80	$50	FCD	$4,000
Analysis and Reporting[6]	160-240	$150	Lead entity & Consultant	$18,000-$36,000
				$48,400-$79,200

1. Project Management is approximately 10% of the total project cost.
2. Range of hours is dependent upon the extent revisions are needed to the curriculum and teacher training materials as well as level of effort required to recruit teachers.
3. The QAPP cost includes developing and validating the survey instruments. The lower hours assumes the survey from WWA will be used in EWA and the results from the Drain Rangers final report can be used to validate the WWA survey with minor modifications. The higher range of hours are for modifying the instruments primarily based on lessons learned from the WWA study.
4. Hours for this task do not include the IRB review costs (if required); lower range of hours assume two instructors from the FCD will provide one 1-day teacher training workshop. Teacher stipends are not included.
5. Assumes 3 schools will participate in the study with data collected from only one class per grade (3rd, 4th, 5th) for a total of 9 classes. The cost assumes teachers will collect the data. The majority of the cost for this task is associated with data management: entering the data into spreadsheets or a data base.
6. Data analysis hours will vary depending on the type of survey questions: quantitative analysis (multiple choice responses) takes less time to analyze than qualitative data (open-ended and picture responses).

5.3 Budget and Funding Sources

There are two potential studies identified in this Proposal:

1. The Lead Entity Drain Rangers Educational Program Pilot Study – this study will occur at one or more schools in the lead entity's School District. This pilot study will be funded by the jurisdiction. The specific number of schools selected for this pilot study will depend on the lead entity's available funding. The budget developed for this study assumes that pilot testing will occur at three elementary schools. At each school, only one class from each grade (3-5) will be asked to participate in the study by completing the pre- and post-survey.
2. The EWA Drain Rangers Educational Program Pilot Study – If additional funding sources can be located, the lead entity's pilot study will be expanded to include schools in more jurisdictions in EWA.

The lead entity will investigate additional funding sources prior to the QAPP development. This may include asking the participating entities to provide some level of financial support and applying for a GROSS Grant. If additional funding is secured, the resources will be used to expand the pilot testing area to include additional schools in other jurisdictions.

The QAPP should be updated to include the final study budget and funding source.

6.0 Quality Objectives

This section will be completed for the QAPP.

7.0 Experimental Design

7.1 Study Design

This study will pilot test the Drain Rangers Stormwater Education Program in elementary schools in EWA. This will include using the Drain Rangers curriculum that was developed for EWA as part of a 2015-2017 GROSS Grant. The purpose of the pilot testing is to "try-out" the EWA version of the educational program and identify any problems or areas that need improvement. The results from the pilot study would include recommendations for modifying the educational program before it is broadly implemented in EWA schools.

Section 4.5 provided a detailed description of the tasks that are required to conduct this study. This section provides an overview of the study along with a justification for some aspects of the study design selected.

Prior to this study, the WWA Drain Rangers final report (due June 30, 2017) will be reviewed to determine if the findings or recommendation could improve the effectiveness of the EWA educational program. This may result in modification to the existing EWA Drain Ranger curriculum or the teacher training materials. For example, through discussion with the WWA Drain Rangers research team, one challenge they encountered was teachers who did not administer post-surveys to their students. Missing post-survey responses from entire classes could limit the understanding of the educational programs effectiveness. The EWA study could take steps to prevent similar situations by scheduling a time for students to take the surveys and/or selecting one person not affiliated with the school to administer the surveys. These steps should be included in the data collection SOPs for the study QAPP.

Teacher training workshops will be offered to the teachers who participate in the pilot study. The purpose of the workshop is to prepare teachers to implement the educational program in their classrooms by providing them with the background on the curriculum concepts as well as guidance for consistently implementing the curriculum in their classrooms. The specific format of the workshop will be defined in the QAPP but may include having the teachers actively participate as students would in the learning the lessons plans. Research has shown that teachers who participate in professional development workshops, particularly for engineering curriculum, are more confident about teaching engineering, more likely to integrate engineering into their regular curriculum, and improve their classroom instructional practices (Rockland, et al., 2010). As such, providing the teacher training workshops is important to the both the success of the study as well as the long term success of the Drain Rangers educational program.

The curriculum will be implemented by the student's teachers during the regular school hours. The implementation process is will be defined in the QAPP and is briefly described in Section 7.4.

The effectiveness of the educational program will be evaluated based on changes in the students understanding of the educational learning objectives before and after participating in the educational program. It is anticipated that the instruments that will be used to measure changes in the students understanding will be a survey with less than a dozen questions and the pre- and post-survey will be the same survey. Considering the target population is elementary age children, a multicomponent survey is recommended that includes: drawings, open-ended questions, and multiple-choice questions. This type of survey provides students with multiple options for responding to questions (written, drawn, or checking a box). Because elementary school aged-children are still mastering writing and reading skills, it is particularly important to use diverse methods for assessing the students understanding (Kana'iaupuni & Kawai'ae'a, 2008) as opposed to limitations in their academic skills. An example of a multicomponent survey based on the Drain Rangers curriculum is in Appendix C.

Section 13.0 provides a detailed description of the methods that will be used to analyze the data and determine the effectiveness of the Drain Rangers program.

This section should also describe how the applicable **DQIs** are addressed, specifically **Objectivity.** Include references to MPCs defined in Section 6.

7.2 Process for Selecting the Test-Site and Target Population

The study location is the lead entity. Up to three elementary schools will be selected. The criteria for how the schools are selected will be defined in the QAPP. The proposed criteria for selecting schools that will participate in the pilot study is described below:

- Both the school and administration is committed to having their teachers participate in the study.
- Teachers are committed to attending the training workshop; implementing the program in their classroom; and having students complete the pre and post surveys.
- Selecting schools within a jurisdiction to have a balance of student demographics representative of the lead entity demographics.

Recruiting schools and teachers willing to commit to participating in the study is essential to the success of this study. One way to improve the success of the recruitment process is to create a flyer containing details about the study and educational program, for the schools and teachers to review. Fliers should include the study of who, what, why, etc., what teachers who participate are being asked to do, how the school could benefit from participating in the study, and other FAQ.

The target population for this study is students in grades 3-5. This population was pre-determined because it is the target age for the *Drain Rangers* curriculum. This is an ideal age for students to participate in a program like *Drain Rangers* because the majority of elementary age students are still interested in math and science (Brickhouse, 2001). After elementary school, student's interest and attitudes toward these subjects declines as grade-level increases. Student interested and engagement in the curriculum is important to the successful implementation of the *Drain Rangers* program (Brophy, 2013; Demmert Jr, 2001; Herrington, 2014).

7.3 Type of Data to be Collected

The type of data required to meet the study objectives is described in Table 7.3.1. All data will be collected from students in their classroom immediately before and after they participate in the Drain Rangers educational program.

The specific timeline for when the surveys will be administered to the students will be defined in the QAPP.

Table 7.1 Types of Data Being Collected

Data Type	Purpose
Students Grade Level	The data will be organized, analyzed, and summarized by grade level.
Students Teacher	Since the students name will not be collected, having the teachers name will help track students responses by class including how many participated in the pre- and post-survey. This data maybe particularly helpful for classes with significantly different responses.
School Demographics	The primary purpose is to characterize the demographics of students responding. A secondary reason to collect this data is because some demographical information (i.e. low income schools) has been connected to student performance, this data may be used to understand why students at a particular school had different scores than those at other schools.
Survey Responses from Students	Multiple choice survey responses will be used to assess the students understanding of the learning objectives before and after students participate in the educational program. This data will be used to measure the effectiveness of the education program: effectiveness will be measured based on changes in the average frequency of student's responses.
Coded Responses from Open-Ended Questions	The purpose of open-ended questions is to provide students with another method for communicating their understanding of the learning objectives before and after participating in the educational program. The effectiveness of the educational program will be measured based on the change and frequency of themes/codes that emerge from the students responses.
Coded Responses from Drawing Responses	The purpose of drawing responses is to provide students with another method for communicating their understanding of the learning objectives before and after participating in the educational program. The effectiveness of the educational program will be measured based on the change and frequency of themes/codes that emerge from the students drawings.

7.4 Implementation of E&O Program Component during the Study

The Drain Rangers educational program will be implemented as part of this study. The program will commence after all the teachers have attended the training workshop. The implementation period will extend for 3 to 4 weeks which is the duration it typically takes to teach the curriculum. An overview of the curriculum is located in Appendix A. The specific details of the implementation plan will be included in the QAPP.

7.5 Other E&O Programs

This section will be completed for the QAPP.

8.0 Instrument Design and Development

This section will be completed for the QAPP.

8.1 Instrument Design

This section will be completed for the QAPP.

8.2 Procedures for Collecting Data

This section will be completed for the QAPP.

8.3 Instrument Validation

This section will be completed for the QAPP.

9.0 Quality Control

This section will be completed for the QAPP.

9.1 Study QC Procedures

This section will be completed for the QAPP.

9.2 Corrective Action

This section will be completed for the QAPP.

10.0 Data Management Plan Procedures

This section will be completed for the QAPP.

10.1 Data Identification

This section will be completed for the QAPP.

10.2 Data Recording & Reporting Requirements

This section will be completed for the QAPP.

10.3 Procedures for Missing Data

This section will be completed for the QAPP.

10.4 Acceptance Criteria for Existing Data

This section will be completed for the QAPP.

11.0 Audits

This section will be completed for the QAPP.

12.0 Data Verification and Usability Assessment

The instruments that will be used during this study will be developed as part of the QAPP. As such, this section will be updated when the QAPP is developed to include the specific types of data that will be collected along with the process for verifying and assessing the usability of the data.

The anticipated data that will be collected and verified include surveys completed by the students before (pre-survey) and after (post-survey) participating in the educational program. Depending on the final survey design, the types of responses provided by students may include:

- Students written responses to open-ended questions
- Students responses to multiple choice questions
- Students drawn responses to drawing questions

12.1 Data Verification

This section will be completed in the QAPP.

12.2 Data Usability Assessment

This section will be completed in the QAPP.

13.0 Data Analysis Methods

The survey instruments for this study will be designed to measure the students understanding of the educational program learning objectives immediately before (pre-survey) and after (post-survey) completing the Drain Rangers Curriculum. Since the instruments will be developed during the QAPP process, Section 13.0 will be refined when the survey is complete. This section provides a summary of the data analysis methods for a student survey that includes three components: drawings, multiple-choice questions, and open-ended questions. This section also provides examples for how the data will be presented in the final report.

13.1 Hypothesis Testing

Hypothesis testing will be conducted on quantitative data (i.e. response to multiple choice and true/false questions) for the purpose of comparing whether there is a statistically significant difference between the pre-survey and post-survey of the aggregate responses of the student group for each grade. The potential null (Ho) and alternative (Ha) hypothesis that may be tested are noted below. This section will be updated in the QAPP to reflect the specific survey questions.

Ho - The pre-survey and post-survey responses are the same
Ha - The pre-survey and post-survey responses are not the same

13.2 Quantitative Data Analysis Methods

Quantitative Data includes survey questions with multiple choice and true/false response choices. An example is provided in Appendix C part 2. This data may be analyzed by converting responses to a likert scale (Table 13.1) or by determining the average number of students who responded to each response choice option (Table 13.2). Pre and post data may also be graphed to provide a comparison of the students response choices.

Table 13.1 Multiple Choice Questions: Comparison of Responses to Ranked Choices

Question *(Response choices: Agree, Not Sure, Disagree)*	Likert Scale Mean[1] Pre	Likert Scale Mean[1] Post	p-value	Statistically Significant
1. Rainwater that does not soak into the ground is called stormwater.	0.46	0.90	0.01	Y
2. As stormwater flows over land, it can pick up pollution.	0.44	0.50	0.36	N
3. Washing a car on the lawn is one way to prevent pollutants in soap from entering a storm drain.	0.25	0.53	0.03	Y

1. Scores closer to 1 indicate a higher frequency of students who “agreed” with a question compared to -1 which indicates a higher frequency of students who “disagreed.”

Table 13.2 Multiple Choice Questions: Comparison of Responses (Un-Ranked Choices)

Question: What is stormwater runoff?				
Multiple Choice Options	Survey Response Pre (%)	Survey Response Post (%)	p-value	Statistically Significant (Y/N)
a. The rain that falls from the sky into local waterways	17%	21%	0.17	N
b. The rain that soaks into the ground and then goes to local waterways	12%	10%	0.15	N
c. The rain that runs off hard surfaces and goes to local waterways	16%	44%	0.01	Y
d. I don't know	53%	25%	0.02	Y
e. No response	2%	0%	0.20	N

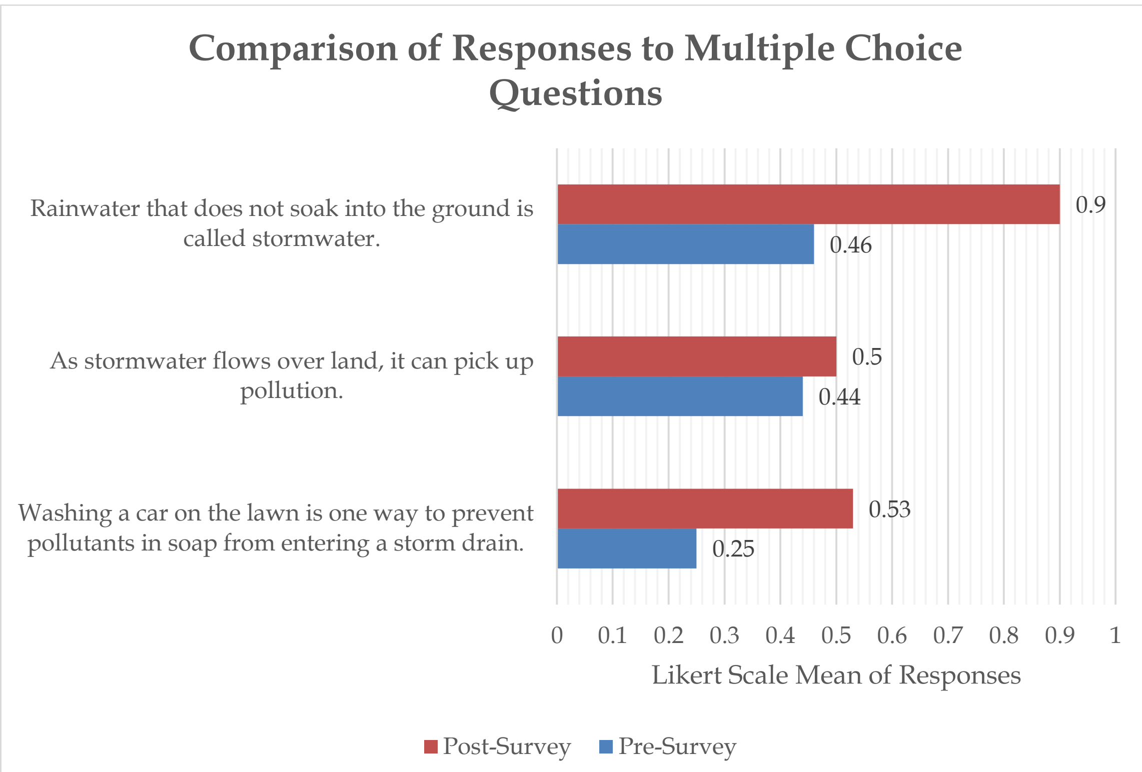

Figure 13.1 Example Graphs: Comparing Responses to Multiple Choice Questions

13.3 Qualitative Data Analysis Methods

Qualitative data includes survey questions with open-ended response choices and students drawings. Appendix C provides example of a drawing survey (Part 1) and open-ended response choices (Part 3).

Qualitative analysis for the open-ended questions typically follow these steps: 1) transcribing the data into Excel or other data base program (for the non-drawing questions), 2) compiling the student's responses by grade level and question, and then 3) reviewing and coding the responses into themes (Schutt, 2011).

13.3 Data Presentation Methods

The purpose of this section is to describe how the data will be presented (i.e. tables, charts, and/or graphs) in the final report. Section 13.1 and 13.2 included a description and examples for how the results could be presented in the final report.

In addition, the final report will include a summary of the number of students from each grade who completed the pre and post surveys as shown in Table 13.3.1. The student demographics for each school will also be summarize into a table similar to 13.3.

Table 13.3 Summary of Students who Completed Assessments

Grade	Pre-Survey	Post-Survey
	Number of Students (n)	Number of Students (n)
3rd	96	94
4th	88	84
5th	92	92
Total	276	270

14.0 Reporting

This section describes how the study findings will be reported and disseminated.

14.1 Final Reporting

This section will be completed for the QAPP.

14.2 Dissemination of Project Documents

The project documents (i.e. QAPP, final report, fact sheets/videos) will be available to the public on the lead entity webpage at the following link:

16.0 References

Brickhouse, N. W. (2001). Embodying science: A feminist perspective on learning. Journal of research in science teaching, 38(3), 282-295.

Brophy, J. E. (2013). Motivating students to learn. Routledge.

Demmert Jr, W. G. (2001). Improving Academic Performance among Native American Students: A Review of the Research Literature.

Herrington, J. B. (2014). Investigating the factors that motivate and engage Native American students in math and science on the Duck Valley Indian Reservation following participation in the NASA Summer of Innovation Program.

Kana'iaupuni, S. M., & Kawai'ae'a, K. K. (2008). E Lauhoe Mai Na Wa'a: Toward a Hawaiian Indigenous Education Teaching Framework. Online Submission, 5, 67-90.

Rickinson, M. (2001). Learners and learning in environmental education: A critical review of the evidence. Environmental Education Research, 7(3), 207-320.

Rockland, R., Bloom, D. S., Carpinelli, J., Burr-Alexander, L., Hirsch, L. S., & Kimmel, H. (2010). Advancing the “E” in K-12 STEM education.

Schutt, R.K., *Qualitative Data Analysis,* in *Investigating the social world: The process and practice of research*. 2011, Pine Forge Press.

15.0 Appendices

Appendix A – Drain Rangers Curriculum: Overview and Objectives

Lesson	Overview	Student Learning Objectives
Lesson 1: ELA Performance Task: Part 1	This lesson is designed to build background knowledge about stormwater pollution: what it is, why it is a problem, and what we can do to help keep the water clean. Students are introduced to the problem of stormwater runoff pollution by doing research using 3 different sources.	• Complete Part 1: Performance Task "Stormwater Pollution." • Compile research from 3 sources in "My Notes" (page 11) and answer 3 questions about stormwater pollution (pages 12-14).
Lesson 2: ELA Performance Task: Part 2	Students will work individually to compose an informative/explanatory essay on addressing polluted stormwater runoff, referring to their notes and answers from the 3 research questions.	• Organize their essay using the "Organizing My Essay: Stormwater Pollution" graphic organizer (page 26) using their notes and answers to the 3 research questions. • Write a 5 paragraph essay, citing sources as outlined in the graphic organizer.
Lesson 3: Watershed Model	Students develop a watershed model that shows the basic shape (geography) of a watershed, how water flows through it, and the impact people can have on both water quality and water quantity. Then students compare the similarities and difference between their physical watershed and the model they built.	• Define a watershed as the entire land area from which water drains into a particular water body. • Use their model to demonstrate that pollutants can cause water quality problems within a watershed. • Compare their model to the watershed they live in.
Lesson 4: Four Rain Drops	Students simulate the movement of water droplets in a forested (undeveloped) and an urbanized (developed) watershed and graph the results.	• Compare how water moves through a forested watershed (undeveloped) and an urbanized watershed (developed). • Learn that an equal amount of rainfall creates very different amounts of stormwater runoff depending on the amount of forest trees vs urban development. • Explore impacts to land and aquatic habitat caused by increased amounts of runoff. • Think of ways to control or reduce the amount of stormwater runoff in urban watersheds.
Lesson 5: Research the Problem: Schoolyard System	In this lesson students develop a model of the schoolyard system by drawing and labeling the parts of the schoolyard. Then students investigate (find evidence) of how water flows through their schoolyard including identifying pervious and impervious surfaces and possible quality and quantity stormwater runoff problems.	• Use drawings as a model of a system. • Identify the parts of the system and water inputs and outputs. • Identify features in their schoolyard system that impact water flow and the collection of pollution in that system. • Identify pervious and impervious surfaces in the schoolyard.

Lesson	Overview	Student Learning Objectives
Lesson 6: Engineering Design and Defining the Problem	Students will use all the information from the Performance Task: Part 1 reading, diagram, videos, and watershed model to define the stormwater runoff problem in their community.	• Be introduced to Engineering Design as described in the Next Generation Science Standards. • Come up with a statement about the stormwater pollution problem in their community. • Determine things they need to know and research to explore solutions to the stormwater pollution problem.
Lesson 7: Understanding Stakeholders	Students identify various people and groups (stakeholders) that are interested in stormwater. They will interview a stakeholder or analyze information from the web to understand this group's priorities and advice on what type of project they should do.	• Identify stakeholders. • Obtain information from a stakeholder (interview or website) to help plan and implement a stormwater project in their community.
Lesson 8: Explore and Compare Possible Solutions	Students explore and compare multiple possible solutions to the stormwater runoff problem in their community that will reduce pollution in stormwater runoff.	• Explore multiple solutions to the stormwater pollution problem in their community. • Evaluate multiple stormwater solutions in their community that will reduce pollution in stormwater.
Lesson 9: Develop, Implement and Test	Students develop the steps to their outreach plan including whom to contact, people who can help, how this helps solve the problem, and materials they will need. Before implementing their plan, students develop a method to measure if their solution was successful. Students implement their plan following the steps they outlined, and then test the effect of their outreach.	• Plan steps for their solution project. • Create outreach materials sharing a message of stormwater pollution prevention. • Plan how they will test their outreach solution using surveys or other feedback. • Implement the test of their solutions.
Lesson 10: Evaluate Solutions and Communicate	Students will evaluate their solutions by analyzing the data from surveys, personal action plans, or other tests they used. Students will then discuss improvements to their project (optimize), reflect on their accomplishments, and communicate their accomplishments in some way to the school or the community.	• Analyze data from surveys, personal action plans, or other tests to evaluate their solution. • Discuss ways to improve their stormwater pollution project. • Reflect on their accomplishment. • Communicate their project in some way; for example, put their project on a website.

Appendix B - WWA Drain Ranges Stormwater Student Assessment Form

Stormwater Student Assessment

~~**Student Name:** __________________________________ **Date:** ________________~~

Teacher Name: __________________________________ **Grade (4th or 5th):** ________

This is to help your teacher know what you do or don't know. If you do not know an answer it is okay to answer, "I don't know." It is not a test and won't be graded but will help us make this unit great!

1. **What is stormwater runoff? (select the best answer)**

   ☐ The rain that falls from the sky into local waterways

   ☐ The rain that soaks into the ground and then goes to local waterways

   ☐ The rain that runs off hard surfaces and goes to local waterways.

   ☐ I don't know

2. **Which of the following are usually hard or *impervious surfaces*? (Check all that apply)**

   ☐ Sidewalk ☐ Parking lot ☐ I don't know

   ☐ Roof ☐ Garden

   ☐ Forest ☐ Field

3. **What are three problems that could be caused by stormwater runoff?**

   1.____

   2.____

   3.____

4. Describe two possible solutions for stormwater runoff problems.

First solution to reduce stormwater runoff problem:

____

Describe how it would help with the problem:

____

____

____

Second solution to reduce stormwater runoff problem:

____

Describe how it would help with the problem:

____

____

____

5. **If you were an engineer designing a solution to a stormwater runoff problem, which of the following would be important if you wanted to have the best solution?** (check all that apply)

- ☐ Compare possible solutions to decide which one best fits the problem's criteria and constraints
- ☐ Define the criteria for success
- ☐ Choose the most expensive solution
- ☐ Research possible solutions
- ☐ Test the solution to see if it works
- ☐ Build a rain garden
- ☐ Talk to people about the problem and the solutions you are thinking about
- ☐ I don't know

Ver 1.23.17

Appendix C – Example Student Survey for EWA Drain Rangers Study

Teacher: ________________________________ **Grade:**___________ **Age:**_________

Part 1 – Draw A Picture

Draw a Picture of Your Neighborhood

Draw things that you and your neighbors do that can cause pollution to get into storm drains.

Label your picture and describe here what you drew:

Part 2 – Multiple Choice and True/False Questions

1. **What is stormwater runoff? (select the best answer)**

☐ The rain that falls from the sky into local waterways

☐ The rain that soaks into the ground and then goes to local waterways

☐ The rain that runs off hard surfaces and goes to local waterways.

☐ I don't know

2. **Rainwater that does not soak into the ground is called stormwater.**

☐ True

☐ False

☐ I don't know

3. **As stormwater flows over land, it can pick up pollution.**

☐ True

☐ False

☐ I don't know

4. **Washing a car on the lawn is one way to prevent pollutants from going into storm drains.**

☐ Agree

☐ Disagree

☐ I don't know

Part 3 – Open Ended Questions

5. What is stormwater?

____

____

____

____

6. What are three ways that stormwater becomes polluted?

a. ____

____

b. ____

____

c. ____

____

7. What are three ways that my community can help to keep stormwater clean?

a. ____

____

b. ____

____

c. ____

____

Appendix 19 – BMP Inspection and Maintenance Responsibilities Proposal

Eastern Washington
Stormwater Effectiveness Studies

Detailed Study Design Proposal:
BMP Inspection and Maintenance Responsibilities

Study Classification:

☐ Structural BMP ☑ Operational BMP ☑ Education & Outreach

Study Objective(s):

☐ Evaluate Effectiveness ☑ Compare Effectiveness

June 30, 2017

Prepared For:

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(248)763.4099

Proposal Publication Information

This Detailed Study Design Proposal (Proposal) will be stored and accessible to the public at the following weblink: Add Weblink where the Proposal can be accessed by the Public

For questions regarding the Proposal, please contact First and Last Name of Lead Entity Contact by email add email address or phone (509)XXX-XXXX.

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QAPP Publication Information

This item will be added for the QAPP.

QAPP Author and Contact Information

This item will be added for the QAPP.

Signature Page - Proposal

Approved by:

Date 6/22/17

Donald D. Carpenter, Primary Author, Drummond Carpenter PLLC

Date 6/30/2017

Aimee Navickis-Brasch, Peer Review, HDR, Inc.

Date

Name, Lead Entity, Jurisdiction

Date

Karen Dinicola, Ecology, Phase 2-3a Gross Grant Project Manager

Date

Abbey Stockwell, Ecology, Reviewer E&O Studies

Date

Doug Howie, Ecology, Reviewer Structural and Operational BMP Studies

Signature Page – QAPP Only

This section will be completed for the QAPP.

List each party responsible for the contents of the QAPP and the project along with their project title, and organization. Each party must sign and date this page before the study proceeds to the implementation phase (i.e. conduct the study).

Distribution List – Proposal

This section includes the distribution list for each party who will receive an Ecology approved copy of the Proposal.

Name, Title	Organization	Contact Information: Email, Telephone
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Distribution List - QAPP Only

During the QAPP development, this section should be updated to include a list of each party who will receive copies of the approved **QAPP** as well as any subsequent revisions along with their contact information. This may include those who is responsible for the QAPP development and project implementation including project managers, QA managers, representatives of other groups/agencies involved, field staff, etc.

1.0 Table of Contents

The TOC should be updated during the QAPP development and auto generated using a word processing program.

2.0 Executive Summary – QAPP Only

This section will be completed for the QAPP.

3.0 Background

3.1 Introduction to the Operation & Maintenance Program

In 2012, the Washington State (WA) Department of Ecology (Ecology), who has been delegated by Environmental Protection Agency (EPA) the responsibility of implementing and enforcing Clean Water Act (CWA) regulatory activities within WA, issued the Eastern Washington (EWA) Phase II Municipal Stormwater Permit program. This permit program, designed to regulate municipalities within WA who are currently under a Phase II permit, was created to support the goals of the National Pollutant Discharge Elimination System (NPDES) and State Waste Discharge General Permit for discharges from small Municipal Separate Storm Sewer Systems (MS4s) in EWA (Ecology 2014b).

According to the EWA Phase II Municipal Stormwater Permit (Ecology 2014b), permittees are required to implement procedures for site inspection and enforcement of post-construction control measures. This study will investigate procedures developed by other jurisdictions related to inspection and enforcement of operation and maintenance requirements for all structural best management practices (BMPs) installed on privately owned property including, but not limited to, detention ponds, tanks and vaults; infiltration facilities; detention facilities; stormwater treatment wetlands and wet ponds; and mechanical separators.

Stormwater management through the use of structural BMPs involves thoughtful application of site design principles, construction techniques and maintenance strategies to reduce the effect of altered hydrology and also prevent sediment and other pollutants from entering surface or groundwater. However, if they are not properly maintained, their performance can be compromised which could affect receiving waters. In fact, according to the EWA Stormwater Manual (Ecology 2004), "proper operation and maintenance of runoff treatment BMPs may be more significant than the actual volume of runoff treated in protecting receiving waters over the long term." This is expanded in Section 2.2.7 Core Element #7 Operation and Maintenance:

> *"Where structural BMPs are required, projects shall operate and maintain the facilities in accordance with an Operation and Maintenance (O&M) plan that is prepared in accordance with the provisions in Chapters 5 and 6 of this Manual. The O&M plan shall address all proposed stormwater facilities and BMPs, and identify the party (or parties) responsible for maintenance and operation; the O&M plan must also address the long-term funding mechanism that will support proper O&M. At private facilities, a copy of the plan shall be retained onsite or within reasonable access to the site, and shall be transferred with the property to the new owner. For public facilities, a copy of the plan shall be retained in the appropriate department. A log of maintenance activity that indicates what actions were taken shall be kept and be available for inspection by the local jurisdiction."*

In summary, the results from this study will assist in protecting water quality by informing municipalities of the best strategies for executing O&M plans in their jurisdictions to address the possible lack of maintenance on privately owned structural BMPs. Findings from the project could be used to inform an Education and Outreach (E&O) program that will reduce municipal O&M expenses.

3.2 Problem Description

Privately owned structural BMPs represent a unique problem for ensuring long-term design-based performance because of O&M issues. Complications can arise from lack of access for inspection (e.g., an inspector may not have permission to enter private property) and/or failure to maintain structural BMPs because of lack of understanding, unclear and/or changing ownership, lack of incentive, or limited funding. Commonly, the private party that owns the BMP is responsible for all maintenance; however, there may be other models or strategies which could support better long-term performance of BMPs.

It is clear from discussions with the EWA Stormwater Coordinators' Group, as well as guidance documents published by municipalities in other states, that the challenge of long-term BMP maintenance is not unique to EWA. The Environmental and Water Resources Institute of the American Society of Civil Engineers founded the Stormwater BMP Task Committee in 2010 "to further the current state of knowledge pertaining to operation and maintenance of structural stormwater BMPs. (http://www.ewri-swi.org/stormwater_bmp_task.html). The goals of the committee were to:

- Generate a detailed maintenance protocol for each BMP type.
- Generate region/physiographic province-specific guidance for BMP maintenance.
- Review literature to determine effects of proper maintenance on BMP efficacy.
- Complete case study reporting on BMP maintenance activities for various classes of asset managers (e.g., commercial, transportation, institutional, military, etc.)

In addition to reporting on a detailed literature review on the topic (Flynn et al 2012), they developed the web-based BMP Maintenance Survey, the purpose of which "is to collect information related to the maintenance of stormwater BMPs." The information collected focuses primarily on the scale of structural BMP operations including the number, type, and size of facilities managed; the age of facilities; the amount spent on O&M; and the staff assigned to the task. The survey does not explicitly address the issue of maintenance responsibility but the task committee has captured the complexity of the topic. Of additional interest is their use of the Zoomerang® online portal which is one web-based vehicle for data collection that could be employed by this project. Overall, Flynn et al (2012) reported a wide variety of strategies for addressing the challenge of O&M and there is no consensus on the best approach for designating responsibility for maintaining privately owned BMPs.

The State of North Carolina investigated structural BMP O&M through a survey of stormwater professionals (Bruce and Barnes 2008). The study sought to determine how local governments in North Carolina were "implementing, financing, managing, and enforcing post-construction, engineered, structural stormwater BMPs." Bruce and Barnes (2008) found that local municipalities had significant differences in the way they oversaw the planning, installation, and monitoring of BMPs, and a vast majority left maintenance responsibilities to the landowner – either private or public. The researchers utilized the Human Subjects Review Board at University of North Carolina – Chapel Hill to approve administration protocols, and cautioned on limited response rates from an electronic survey sent via email invitation. Researchers found they needed to personally contact (via phone) and recruit to get response rates of 36% (of 164 jurisdictional stormwater managers) of North Carolina jurisdictions ultimately participating.

3.3 Results of Prior Studies

This section will be completed for the QAPP.

3.4 Regulatory Requirements

The EWA Phase II Municipal Stormwater Permit issued to the lead entity by Ecology requires the Stormwater Management Program Effectiveness Studies. Each city and county permittee listed in the permit shall collaborate with other permittees to select, propose, develop, and conduct Ecology-approved studies to assess, on a regional or sub-regional basis, effectiveness of permit-required stormwater management program activities and best management practices. The lead entity is proposing to be the lead entity for the following effectiveness study: BMP Inspection and Maintenance Responsibilities Study. Section S5.B.6 of the permit (Ecology 2014b) is specifically addressed by this investigation.

- S5.B.6 Municipal Operations and Maintenance - According to the permit, “permittees shall implement an operation and maintenance program that includes a training component and has the ultimate goal of preventing or reducing pollutant runoff from municipal operations” (Ecology 2014b).

4.0 Project Overview

4.1 Study Goal

The purpose of this Effectiveness Study is to determine the best O&M strategy for privately owned stormwater BMPs in EWA. There are multiple strategies currently employed for inspection and maintenance of privately owned BMPs involving combinations of third-party inspectors, contractors, and municipal staff. Commonly, the private party that owns the BMP is responsible for all maintenance; however, there may be other strategies or models, such as public ownership and maintenance responsibility, which could support better long-term performance of BMPs. The following four potential strategies were identified during a preliminary investigation conducted by Yakima County:

1. City/County performs inspection of structural BMPs but requires the property owner to hire a qualified contractor to conduct necessary maintenance and provide proof that the maintenance has been completed.
2. City/County requires structural BMP owners to contract with a third-party inspector and provide an inspection certification letter to the City/County, as well as proof that any required maintenance has been completed.
3. City/County performs maintenance but the BMP remains under private ownership and the property owner pays the City/County for the service.
4. City/County assumes ownership, and responsibility for maintenance. Funding could be through existing stormwater fees and/or a onetime payment by the property owner or other means.

These four potential strategies will be evaluated during this Effectiveness Study and other strategies might be identified during the investigation.

Erickson et al. (2013) reported that maintenance of structural BMPs (primarily detention facilities and pipe networks) occurs too infrequently to ensure performance and that improved inspection protocols could lead to an overall reduction in maintenance costs. It is envisioned that more effective models for ensuring regular maintenance of privately owned BMPs may be identified through the proposed research effort. This could lead to the development of recommendations for a prototype O&M program or draft O&M manual that individual EWA jurisdictions could adopt when appropriate.

4.2 Study Description and Objectives:

This project will gather information from WA and similar semi-arid jurisdictions (when applicable) to learn novel and effective ways that municipalities are meeting the challenge of ensuring ongoing maintenance of structural BMPs on private property. The long-term aspiration is to develop a prototype E&O program or pilot for an O&M manual of privately owned structural BMPs for EWA jurisdictions. Both of which would improve decision-making of municipal stormwater operators and increase the effectiveness of their programs. The objectives of this investigation are:

- Gather information on how jurisdiction are meeting the challenge of ensuring ongoing operations and maintenance of privately owned structural BMPs.
- Synthesize and provide the information to municipal stormwater operators so they can compare their own programs to other jurisdictions.
- Identify which O&M BMP strategies are more commonly being implemented by jurisdictions.
- Identify which O&M BMP strategies are the best option for jurisdictions in EWA.

The goals and objectives of this study will be achieved by developing and implementing a survey of select MS4 jurisdictions in WA and other similar semi-arid regions in the Columbia Basin (Oregon and Idaho) to determine how they address the long-term needs of privately owned structural BMPs. As part of the recruitment process, it will be important to capture a range of opinions from various jurisdictions within the region. A subset of stormwater managers from these municipalities will then be interviewed to further discuss their perceptions of the advantages and shortcoming of their programs. Finally, focus groups may be used in lieu of, or in addition to, interviews to validate findings.

4.3 Study Location and/or Target Population

The study location is selected MS4 jurisdictions in WA and other similar semi-arid regions in the Columbia Basin (Oregon and Idaho) who have similar O&M requirements for owner-operators of privately owned structural BMPs. The target population is stormwater operators of privately owned structural BMPs identified through the US Environmental Protection Agency and Department of Ecology contacts.

4.4 Data Needed to Meet Objectives

The data required to meet the objectives are a list of jurisdictions to participate in the survey, survey responses from municipal stormwater managers in those jurisdictions, and interview transcripts and coded interview responses. Since the survey (instruments) will be developed after the Proposal is submitted, this section will be updated when the QAPP is developed.

4.5 Tasks Required to Conduct Study

The primary tasks required to conduct the study (including one optional task):

1. QAPP Development – develop and submit the QAPP to Ecology.
    a. Literature Review – conduct a literature review with a focus on O&M of privately owned structural BMPs. The literature review will include both journal articles as

well as documents published by government agencies. The purpose of the literature review is to develop the questionnaires for this study.

b. Survey Development - Develop a survey that addresses general strategies for structural BMP O&M including program management, inspection protocols, maintenance required, and financial information.
c. Determine whether an Institutional Review Board (IRB) review is required and, if necessary, obtain an IRB review.[1]

2. Participant Recruitment – Gather names of stormwater managers from jurisdictions with similar permit requirements as EWA to complete the survey.
3. Survey Deployment - deploy the survey using an online data gathering portal such as Zoomerang®; invite participants to complete the survey (email or phone communication).
4. Synthesize Survey Results – prepare an interim report on survey results which will be used to develop the interview protocol.
5. Interview Protocol Development – develop an interview based on survey results.
6. Interviews - conduct interviews with 10 to 15 of the survey respondents to gain additional insight on responses.
7. Synthesize Interview Results – prepare an interim report of interview results which will be used to develop the focus group interview.
8. Focus Group (optional) - conduct a focus group to validate survey and interview findings. One cost effective approach is to hold the focus group at a location where representatives

[1] ***A Note about IRB's:*** *A Institutional Review Board (IRB) is an independent ethics review committee that reviews and approves research involving human subjects. The purpose of the IRB is to assure proper steps are taken to protect the rights and welfare of individuals participating in the research study. For more information about IRBs consult the following document:* http://www.rcjournal.com/contents/10.08/10.08.1362.pdf. *Studies that are conducted through a university should consult the university about the IRB process. For studies not conducted at a university, consult the Western Institutional Review Board~~WIRB~~: (*http://www.wirb.com/Pages/Default.aspx*). The review process with the WIRB requires a nominal fee and includes submitting an application that defines the research plan prior to the start of the study. The WIRB will review the research plan and either give it an exempt determination, approve the plan, require modifications to the plan, or reject the plan. Effectiveness Studies involving human subjects maybe exempt from an IRB depending on the nature of the questions. Examples of research plans that maybe exempt include: when the data collected during the study is completely de-identified, when parents provide consent for their minor child to participate in the study, and when the study results will be not be published. Jurisdictions with Effectiveness Studies that intend to collect data through interactions with individuals should determine whether an IRB is required by contacting the WIRB.*

of the MS4s will already be in attendance such as the Washington Municipal Stormwater conference.

9. Develop a Final Report.

4.6 Potential Constraints

In the context of the proposal, constraints are any conditions that may impact the schedule, budget, and scope of the project. The potential constraints are:

- Survey response rate. Market researchers report an average response rate to an email survey invitation is approximately 25%[2] but it will vary depending on motivation. Motivated participants who are carefully recruited, such as the population being surveyed in this study, could be expected to respond at 40% or more[3]. However, it is hard to predict how many stormwater managers will complete the online survey and the amount of effort it will take to achieve meaningful results.
- Stormwater managers that are either unable or unwilling to provide insight or participate in the data gathering process; especially if the findings might make their programs look ineffective.
- Identification of BMP strategies may be difficult to determine without actually engaging citizens currently in possession of a privately owned stormwater facility.
- Identifying out-of-state jurisdictions with similar programs.
- Inconsistent responses could make it difficult to determine preferred strategy.
- Issues with electronic communication including emails not being delivered or ending up in a recipients SPAM folder.

Strategies for mitigating these constraints are discussed in Section 7.0 are part of the study design and implementation.

[2] http://fluidsurveys.com/university/response-rate-statistics-online-surveys-aiming/
[3] https://www.surveygizmo.com/survey-blog/survey-response-rates/

5.0 Organization and Schedule

5.1 Key Project Team Members: Roles and Responsibilities

Key Team Members	Role	Responsibility
Lead Entity Contact Name Phone Number Email	Lead Entity	Responsible for execution of study
Dan Ford 509.545.3445 fordd@pasco-wa.gov	City of Pasco	Participant W/Out Designated Role
Brad Daly 509.527.4363 bdaly@ci.walla-walla.wa.us	City of Walla Walla	Financial Support; Reviewer; Advisory Board Member; Data Collector
Ruby Irving 509.576.6781 Ruby.Irving-Hewey@yakimawa.gov	City of Yakima	Financial Support; Advisory Board Member
Karen Dinicola Ecology 360.407.6550 kdin461@ecy.wa.gov	Ecology Reviewer	Phase 2-3a GROSS Grant Project Manager
Abbey Stockwell Ecology 360.407.7221 abst461@ecy.wa.gov	Ecology Reviewer	Reviewer E&O Studies
Donald D. Carpenter Drummond Carpenter, PLLC 248.763.4099 dcarpenter@drummondcarpenter.com	Proposal Author	Primary author of Proposal
Aimee Navickis-Brasch HDR, Inc. 509.343.8515 aimee.navickis-brasch@hdrinc.com	Proposal Peer Review	Provided technical review of Proposal
Name Organization Phone Number Email	QAPP Author	To be defined when the QAPP is developed
Name Organization Phone Number Email	Key Team Member Project Role	Define when the QAPP is developed if applicable

5.2 Project Schedule

An overview of the project timeline as depicted during the public commentary period is shown in Figure 5.2.1. A task timeline based on quarterly activities is shown in Table 5.2.1.

Table 5.2.1 Proposed Study Timeline

	2017		**2018**				**2019**			
Task Name	**Q3: Jul - Sept**	**Q4: Oct - Dec**	**Q1: Jan - Mar**	**Q2: Apr - Jun**	**Q3: Jul - Sep**	**Q4: Oct - Dec**	**Q1: Jan - Mar**	**Q2: Apr - Jun**	**Q3: Jul - Sep**	**Q4: Oct - Dec**
1. QAPP Development										
2. Participant Recruitment										
3. Survey Deployment										
4. Synthesize Survey Results										
5. Interview Protocol Development										
6. Interviews										
7. Synthesize Interview Findings										
8. Focus Group										
9. Final Report										

Figure 5.2.1: Overview of project schedule

5.3 Budget and Funding Sources

Per the lead entity, funding for the project will come from all participating entities including Yakima County, Walla Walla County, City of Yakima, City of Wenatchee, and City of Pasco.

Table 5.3.1 Estimated Study Budget

Task	Hours	Cost Per Hour	Work Performed by	Total
QAPP Development	120	$150	Consultant	$18,000
Participant Recruitment	40[4]	$60[5]	Lead Entity	$2,400
Survey Deployment	40[6]	$60	Lead Entity	$2,400
Survey Results	40[7]	$60	Lead Entity	$2,400
Interview Development	24[8]	$150	Consultant	$3,600
Interviews	48[9]	$150	Consultant	$7,200
Interview Results	40[10]	$150	Consultant	$6,000
Focus Group (optional)	20	$150	Consultant	$3,000
Final Report	60[11]	$60	Lead Entity	$3,600
			Total	$48,600

[4] It is estimated the lead entity will spend 40 hours compiling the names and contact information for survey recipients.
[5] Estimated hourly rate for work performed by lead entity is $60/hour.
[6] It is estimated the lead entity will spend 40 hours recruiting participants to complete the survey including phone calls, targeted emails etc. as part of low response mitigation.
[7] It is estimated the lead entity will spend 40 hours generating an interim report and tables with survey results.
[8] It is estimated a consultant will spend 24 hours generating an interview based on survey results.
[9] It is estimated a consultant will spend approximately 48 hours (4 hours per interviewee) recruiting, conducting and summarizing individual interviewees.
[10] It is estimated a consultant will spend 40 hours generating a report based on interview results.
[11] It is estimated the lead entity will spend 60 hours compiling individual project components and generating a final report.

6.0 Quality Objectives – QAPP Only

This section will be completed for the QAPP.

7.0 Experimental Design

7.1 Study Design

To gather information, a survey will be developed and administered to jurisdictions in the State of Washington and Columbia River Basin to determine how they address the long-term needs of privately-_owned structural BMPs. The survey will cover the following information. A copy of the survey will be included in the QAPP.

- Position, role and responsibilities of respondent.
- Time spent by respondent and their staff on O&M activities.
- Estimated number of privately owned structural BMPs in the jurisdiction.
- Type, size, age, and area managed of those structural BMPs.
- Number of structural BMPs inspected each year.
- Number of enforcement actions taken as a result of those inspections.
- Funds spent on maintenance by jurisdiction.
- Process for tracking BMP O&M (paper forms, Excel or Access Database, GIS Database, other software package).
- Define the strategy that the jurisdiction currently uses for inspection and maintenance responsibility.
- Funding mechanisms (e.g., cost share or fee programs for implementing the selected strategy (if applicable).
- Potential inspection or enforcement cost savings through implementation of the selected strategy.
- Issues with access or other private property legalities.
- Issues of local traditions or "culture" that could affect O&M.
- Issues with enforcement or implementation strategies by different agency programs.

Poor response rates from initial online recruitment could cause the need for targeted subsequent communication including phone calls to potential respondents. The goal is to obtain at least 30 survey responses since 30 is considered a large sample size in quantitative research. However, there is no specific rule requiring a minimum of 30 responses.

There are several strategies that can be employed to improve response rate including survey design, value proposition, confidentiality, and targeted reminders. The survey should be designed in a matter that is clear and concise for those participating and should take respondents less than 10 minutes to complete. In addition, the value proposition for why they should participate should be clearly stated in the recruitment email since messaging can improve response rates. While the responses to the survey might not be considered sensitive to everyone, some respondents might not want their thoughts broadly disseminated. As such, confidentiality should improve response rates. Finally, for those not responding initially, reminder emails should be sent at a different day and time than the initial email recruitment or any previous email contact.

The purpose of interviews in this study is to validate the findings from the survey and explore themes that might emerge. The general rule when conducting qualitative research involving interviews is that once a researcher reaches "saturation" of responses (i.e. no additional themes are emerging and no new insight is being gained), than the researcher should stop interviewing participants. Guest, Bunce and Johnson (2006) reported that typically saturation occurs at about 15 to 20 respondents, but could be fewer than 10 depending on the questions being asked and the sample size. Jabbar (2015) indicated that 15 to 25 interviews should provide sufficient qualitative data. Galvin performed a review of 54 investigations in "six prominent building and energy journals" where interviews were conducted on people's beliefs, practices, and attitudes towards building energy consumption. He found that a majority of investigations reported between 6 and 15 interviews were used to make conclusions about the population. Based on the literature, it is recommended that ten to fifteen interviews be conducted.

To validate the findings of the survey responses, approximately ten to fifteen stormwater (managers) operators will be chosen from the survey participants and asked to participate in an interview. The interviews will represent a wide range of responses such that information is gathered from strategies and various program management demographics. As part of the recruitment process, it will be important to capture the opinions of jurisdictions that are and are not experiencing problems with their O&M protocols.

The reason for conducting interviews, and subsequently the types of questions that will be asked will focus on, gaining insight on why their O&M program is structured as it is, what are the perceived benefits and limitations of their O&M structure, and what, if anything, they would change about their programs or recommend to others. The interviews primarily provide a narrative for the descriptive statistics, but the responses will be coded into themes that can be reported. A copy of the interview questionnaire will included in the QAPP.

Interviews will be conducted over the phone and are targeted for 30 minutes. Recording the interview is recommended to capture the nuance of responses, but the interviewee must provide explicit permission and interviews should not be recorded without the interviewees' written consent. Interviews should begin with a brief introduction of the interviewer, project, and logistics of the interview. After the introduction, all interviewees should be asked the same questions about the O&M programs based on these initial responses to the survey. At the conclusion of the interview, interviewees should be given a chance to clarify any of their statements, provide any closing thoughts, and ask questions of the interviewer (mostly about the future of this project and sharing of project information). The actual interview responses will remain anonymous and all identifying information will be redacted.

Finally, focus groups may be used in lieu of or in addition to interviews. Organizing and facilitating a focus group takes effort and practice but can be a robust source of information. The individual participants can respectfully respond to each other and uncover information that might not be discovered during one-on-one interviews. To minimize costs, the focus group could be conducted at the Washington Municipal Stormwater Conference or at any regular meeting of the EWA permittees. A copy of the optional focus group questionnaire will be included in the QAPP.

7.2 Process for Selecting the Test-Site and Target Population

The study location is all jurisdictions from WA who have similar O&M requirements for owner-operators of privately owned structural BMPs. An effort will be made during QAPP development to identify participants from jurisdictions in the Columbia Basin (similar semi-arid climate and culture to EWA) to also complete the survey. Lists of contacts will be obtained through the EPA and Ecology. The target population is all stormwater (managers) operators of privately owned structural BMPs in the previously identified jurisdictions. Once a comprehensive list of stormwater operators is generated, they will be contacted to participate in the survey.

7.3 Operational BMP Function

Not Applicable

7.4 Type of Data to be Collected

The data required to meet the objectives are described in Table 1.

Table 1: Summary of data being collected.

Data Type	Purpose
List of Jurisdictions	A comprehensive list of all jurisdictions that could participate in the study will be used to track jurisdiction participation.
List of Stormwater Managers	A comprehensive list of all stormwater managers who will receive the survey will be used to track response rate and identify potential interviewees.
Survey Responses from Stormwater Managers	Survey responses will be used to gather information on how jurisdictions are meeting the challenge of ensuring ongoing O&M of structural BMPs. This information will be synthesized and provided to municipal stormwater operators so they can adjust their own programs to be more effective.
Interview Transcripts and Coded Interview Responses	The purpose of interviews is to validate the findings from the survey and explore themes that might emerge based on responses. This information will be synthesized and provided to municipal stormwater operators so they can adjust their own programs to be more effective.
Focus Group Summary (optional)	If there are any inconsistencies between the interview responses and the survey responses, a focus group could be conducted and results summarized to address those inconsistencies.

7.5 Implementation of E&O Program Component during the Study

Not Applicable.

7.6 Other E&O Programs

This section will be completed for the QAPP.

8.0 Instrument Design and Development – QAPP Only

This section will be completed for the QAPP.

8.1 Instrument Design

This section will be completed for the QAPP.

8.2 Procedures for Collecting Data

This section will be completed for the QAPP.

8.3 Instrument Validation

This section will be completed for the QAPP.

9.0 Quality Control – QAPP Only

This section will be completed for the QAPP.

9.1 Study QC Procedures

This section will be completed for the QAPP.

9.2 Corrective Action

This section will be completed for the QAPP.

10.0 Data Management Plan Procedures – QAPP Only

This section will be completed for the QAPP.

10.1 Data Identification

This section will be completed for the QAPP.

10.2 Data Recording & Reporting Requirements

This section will be completed for the QAPP.

10.3 Procedures for Missing Data

This section will be completed for the QAPP.

10.4 Acceptance Criteria for Existing Data

Not Applicable.

11.0 Audits – QAPP Only

This section will be completed for the QAPP.

12.0 Data Verification and Usability Assessment

Section 12.0 represents a general description of the data verification usability assessment process. These sections will be further refined during QAPP development.

12.1 Data Verification

The survey instrument will be verified by having several (approximately three to five) stormwater (managers) operators serve as beta-testers of both the instrument and the administration protocols. These individuals can be selected from participating jurisdictions in Yakima County. These individuals can suggest revisions of the questions and confirm the online data collection interface is functioning. Finally, the beta-testers can verify their online responses were accurate before broad survey administration. After the actual survey administration, responses will be analyzed for completeness and questions with “no response” accounted for in the descriptive statistics.

During the interviews, the survey responses of the interviewees can be verified to determine if there are any data anomalies between survey and interview responses. If the survey responses and the interview responses align, it can be assumed that all survey responses are valid and accurately reflect their opinions and/or understanding of the situation in their jurisdiction.

Finally, during the theme coding of the interviews, a minimum of two people should serve in a peer-review capacity and determine if the coded response themes and the recorded transcripts from the interview align. If the peer-reviews identify any discrepancies, they can confer with the original reviewer and collectively determine if the themes should be adjusted. This will remove any potential bias in the original coded responses.

12.2 Data Usability Assessment

If the data verification procedures are followed, the data will be usable for meeting the study objectives. However, section 12.2 cannot be finalized until the Data Quality Indicators (Section 6.0) are defined during QAPP development.

13.0 Data Analysis Methods

The survey being developed for this Effectiveness Study includes both open-ended and multiple choice questions. However, the survey instrument will be developed during the QAPP process and Section 13.0 will be refined after the survey is complete.

13.1 Hypothesis Testing

Not Applicable. There are no hypotheses formed that can be statistically compared.

13.2 Quantitative Data Analysis Methods

Section 7.1 provides a list of potential survey content that would include both open-ended and multiple-choice questions. For certain questions, it might be useful to compute a mean value (for example, the mean number of privately owned stormwater BMPs managed), but for most questions, the distribution of responses will be more informative based on the objectives of this Effectiveness Study.

Given the relatively small sample size, a robust statistical analysis of the data would not likely yield significant results. However, the descriptive data can provide insight necessary to meet the objectives of identifying the most commonly implemented O&M strategies and which of those strategies are the most successful at ensuring ongoing O&M of privately-owned structural BMPs.

Overall, the data will primarily be analyzed for trends based on survey responses. For example, one option is to parse the data based on O&M program management size. The responses to the four possible O&M strategies listed in Section 4.1 might vary depending on program management size. For example, did the jurisdictions with relatively few privately owned stormwater BMPs (<50) respond the same as those with numerous privately owned stormwater BMPs (>250). Another example would be to summarize the inspection or enforcement cost savings that jurisdictions have realized based on their approaches.

13.3 Qualitative Data Analysis Methods

To validate the findings of the survey responses, ten to fifteen stormwater (managers) operators will be chosen from the survey participants and asked to participate in an interview. The interviews will represent a wide range of survey responses such that information is gathered from a range of program management demographics. The reason for the interviews is to gain insight on why a respondents O&M program is structured as is, what are the benefits and limitations of their O&M structure, and what, if anything, they would change about their programs or recommend to others. Interview responses are inherently open-ended and need to be analyzed qualitatively. The interviews primarily provide a narrative for the survey descriptive statistics, but the responses will be analyzed by:

- Organizing the interview responses into spreadsheets and categorizing the data into themes.

- Summarizing the number of similar or dissimilar responses compared with survey responses.

13.4 Data Presentation Methods:

Data collected during this project will be presented primarily in tables of survey responses with select bar-chart style graphics to illustrate key findings. As described in Section 7.1 Study Design, the survey will have questions related to a wide range of BMP issues. All of this data will be reported in descriptive tables such as Table 1. The data could also be depicted in graphic bar charts if the responses to certain questions warrant visual representation.

Table 1: Responses to Q: Approximately how many stormwater BMPs are currently on located on private property on your jurisdiction?

Response	Responses	%
None	4	7%
1 to 10	13	22%
11 to 50	18	31%
51 to 100	3	5%
101 to 250	4	7%
250+	11	19%
Unknown	6	10%
Total	59	100%

Responses could also be depicted in tables based on jurisdictional response. For example, Figure 2 represents the responses from a pilot survey of Western Washington counties conducted in 2016 by Yakima County regarding which of the four management strategies they employ. Counties highlighted in green represent those that respondent to the survey request and the "X" represents the practice they use. In the case of King County, they use multiple strategies for O&M on privately owned BMPs, so each is listed. The counties highlighted in yellow did not respond to the initial survey request.

One of the reasons *not* to present data in this form is it highlights who did not participate in the study. There are many reasons a target participant might not participate in a survey including survey delivery to the wrong person, the electronic invitation being deliver to a SPAM folder, the invitation arriving during a busy timeframe so response in the open data collection window was not practical, etc. Since anonymity in response should yield more truthful answers, it is better to present the data in aggregate (Figure 3) rather than to explicitly list participant responses.

Responses to the remaining questions can be analyzed based on the size of the program. For example, responses from jurisdictions with relatively few privately owned stormwater BMPs

(<50) can be compared and contrasted to those from jurisdictions with numerous privately owned stormwater BMPs (>250).

WESTERN WASHINGTON COUNTIES	*Clallam*	*Clark*	*Cowlitz*	*Grays Harbor*	*Island*	*Jefferson*	*King*
County performs inspection of structural BMPs, but the property owner is required to hire a qualified contractor to conduct necessary maintenance and provides proof of completion.		X					X
County requires structural BMP owner to contract with a third party inspector and that provides maintenance services; certification letter demonstrating completion is sent to the County.							X
County performs maintenance but the BMP remains under private ownership and the property owner pays for the services.							
County assumes ownership, and responsibility for maintenance. Costs are paid through stormwater fees.							X

Figure 2: Example of survey responses from a pilot investigation.

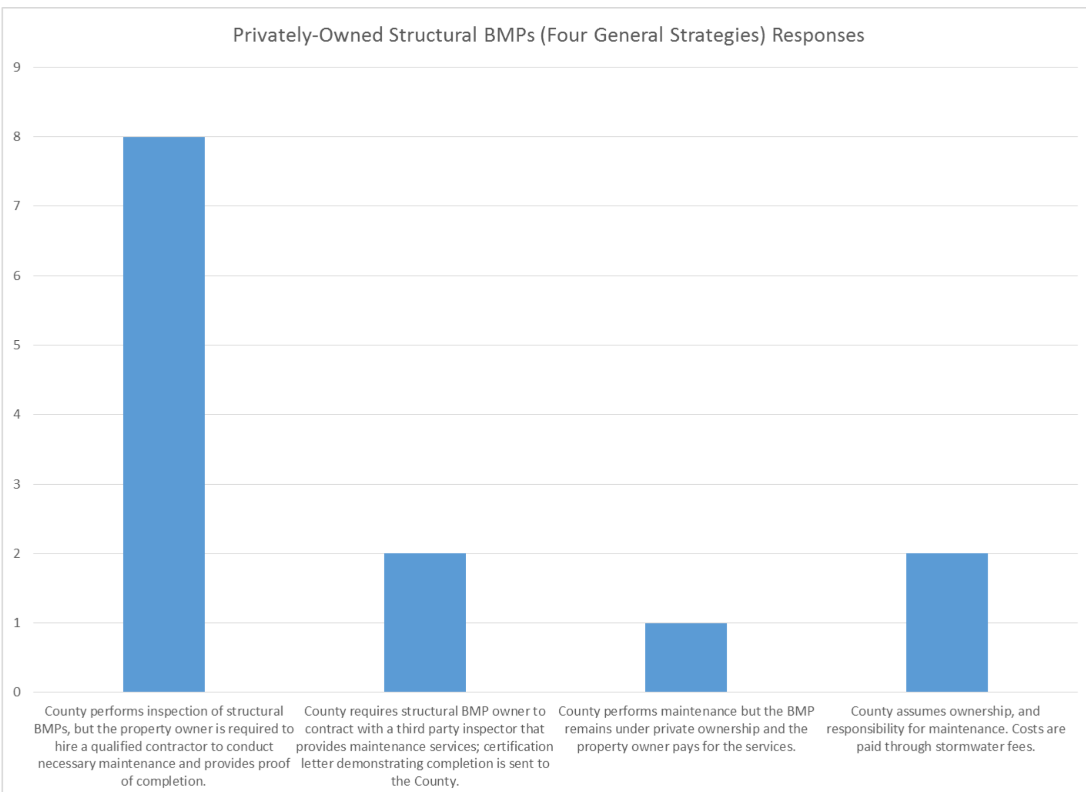


Figure 3: Example of survey responses from a pilot investigation.

14.0 Reporting

14.1 Final Reporting

This section will be completed for the QAPP.

14.2 Dissemination of Project Documents

Upon completion of the project, a final descriptive report and conclusion will be provided. Results will be shared with jurisdictions of EWA currently under the NPDES Phase II permit program and published in peer-reviewed literature. The final report will be posted to the lead entities webpage.

15.0 References

Bruce, S., and Barnes, G. (2008). *Survey of Local Government Post-Construction BMP Maintenance and Enforcement in North Carolina: Report Findings*, Best Management Practices (BMP) Maintenance & Enforcement Survey Report, State of North Carolina, Raleigh, NC.

Erickson, A., Weiss, P., and Gulliver, J. (2013). *Optimizing Stormwater Treatment Practices: A Handbook of Assessment and Maintenance*, Springer, New York, New York.

Flynn, K.M., Likous, B.W., Buechter, M.T. (2012). "Operation and Maintenance Assessment for Structural Stormwater BMPs", *Proceedings of the World Environmental and Water Resources Congress*, Albuquerque, NM.

Galvin, R. (2015). How many interviews are enough? Do qualitative interviews in building energy consumption research produce reliable knowledge? The Journal of Building Engineering.

Guest, Bunce, and Johnson (2006). "How many interviews are enough? An experiment with data saturation and variability." Field Methods 18 (1):59-82.

Jabbar, A. (2015). Sample Size for Qualitative Interviews. The Academic Triangle Website. https://researcholic.wordpress.com/2015/03/20/sample_size_interviews/. Accessed June 3, 2017.

State of Washington Department of Ecology, (2013). *Eastern Washington Low Impact Development Guidance Manual*, Olympia, WA, Ecology publication # 13-10-036.

State of Washington Department of Ecology, (2014). *Eastern Washington Phase II Municipal Stormwater Permit*, Olympia, WA.

State of Washington Department of Ecology, (2004). *Stormwater Management Manual for Eastern Washington*, Olympia, WA, Publication # 04-10-076.

State of Washington Department of Ecology, (2014. *Stormwater Management Manual for Western Washington*, Olympia, WA, Publication # 14-10-055.

State of Washington Department of Ecology, (2011). *Technical Guidance Manual for Evaluating Emerging Stormwater Treatment Technologies – Technology Assessment Protocol – Ecology (TAPE),* Olympia, WA, Publication # 11-10-061.

University of Minnesota, (2010). *Stormwater Treatment: Assessment and Maintenance - Field Data Sheet for Level 1 Assessment: Visual Inspection of Permeable Pavements*, Minneapolis, MN.

16.0 Appendices

To be developed in the QAPP.

Appendix 20 – Bioretention Soil Media Study Proposal

Eastern Washington
Stormwater Effectiveness Studies

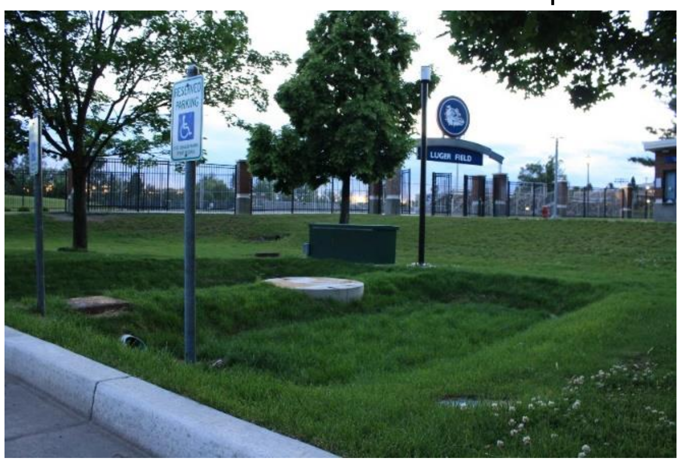
Detailed Study Design Proposal
Bioretention Soil Media Study

Study Classification:

☑ Structural BMP ☐ Operational BMP ☐ Education & Outreach

Study Objective(s):

☑ Evaluate Effectiveness ☑ Compare Effectiveness
☑ Develop Modified BMP ☐ Develop New BMP



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Proposal Publication Information

This Detailed Study Design Proposal (Proposal) will be stored and accessible to the public at the Spokane County's website: https://www.spokanecounty.org/918/Stormwater-Utility. For questions regarding the Proposal, please contact Matt Zarecor by email MZarecor@spokanecounty.org or phone (509)477-7255.

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QAPP Publication Information

Will be completed for the QAPP.

QAPP Author and Contact Information

Will be completed for the QAPP.

Signature Page - Proposal

Approved by:

______________________________________ Date______________
Matt Zarecor, Lead Entity, Spokane County

Aimee S. Navickis-Brasch Date 6/30/2017
Aimee Navickis-Brasch, Primary Author, HDR, Inc.

______________________________________ Date______________
Karen Dinicola, Ecology, Phase 2-3a Gross Grant Project Manager

______________________________________ Date______________
Doug Howie, Ecology, Reviewer Structural and Operational BMP Studies

______________________________________ Date______________
Brandi Lubliner, Ecology, Reviewer Monitoring System Designs

Signature Page – QAPP Only

This section will be completed for the QAPP.

List each party responsible for the contents of the QAPP and the project along with their project title, and organization. Each party must sign and date this page before the study proceeds to the implementation phase (i.e. conduct the study).

Distribution List – Proposal

This section includes the distribution list for each party who will receive an Ecology approved copy of the Proposal.

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Distribution List - QAPP Only

During the QAPP development, this section should be updated to include a list of each party who will receive copies of the approved **QAPP** as well as any subsequent revisions along with their contact information. This may include those who is responsible for the QAPP development and project implementation including project managers, QA managers, representatives of other groups/agencies involved, field staff, etc.

1.0 Table of Contents

2.0 Executive Summary

This section will be completed for the QAPP.

3.0 Introduction and Background

3.1 Introduction to the Structural BMP

Bioretention ponds are a common structural stormwater best management practice (BMP) in Spokane County (Figure 3.1). These BMPs are characterized as shallow landscaped depressions which are designed to capture stormwater runoff from small basin areas and provide treatment as stormwater infiltrates through engineered soils referred to as bioretention soil media (BSM) (Figure 3.2). Pollutant removal primarily occurs as stormwater infiltrates through the BSM. Stormwater then infiltrates into the existing soils beneath the pond or is collected in an underdrain and conveyed to a storm drain network. Flow control is provided when the volume of runoff infiltrates into the underlying soils beneath the bioretention area.

Figure 3-1. Example of a Bioretention area in the City of Spokane

The BSM specified in the eastern Washington (EWA) LID Manual is composed of 60% sand and 40% compost by volume (60:40) (AHBL & HDR, 2013). This mix is approved by Ecology to provide flow control and runoff treatment of total suspended solids (TSS) and dissolved metals, copper (Cu) and zinc (Zn), to the level specified in the EWA Phase II NPDES MS4 Permit. The primary treatment mechanism responsible for reducing pollutants include:

- sedimentation, as particles settle on the surface of the BMP
- filtration, runoff infiltrates into the BSM and particulates become physically trapped in the media pore spaces
- Sorption of dissolved metals onto the surface of organic materials amended in the BSM

This study proposes to evaluate the effectiveness of a modified bioretention BMP, specifically the runoff treatment (TSS and dissolved Cu and Zn) and flow control functions. This modified BMP is the same as the bioretetion BMP defined in the EWA LID Manual except without vegetation. At the time this proposal was written, the composition of the BSM had not been selected. The two options to be decided upon are the BSM specification under development in WWA, or, the default bioretention specification (60:40 mix). The process for selecting the BSM is defined in Section 4.1.

Note: The WWA study is one of the Regional Stormwater Monitoring Program Effectiveness Studies, The study goal is to identify blends of media for bioretention BMPs that may improve stormwater treatment. Results from this study will be used to recommend a new BMS specification. These results are expected to be released in 2019.

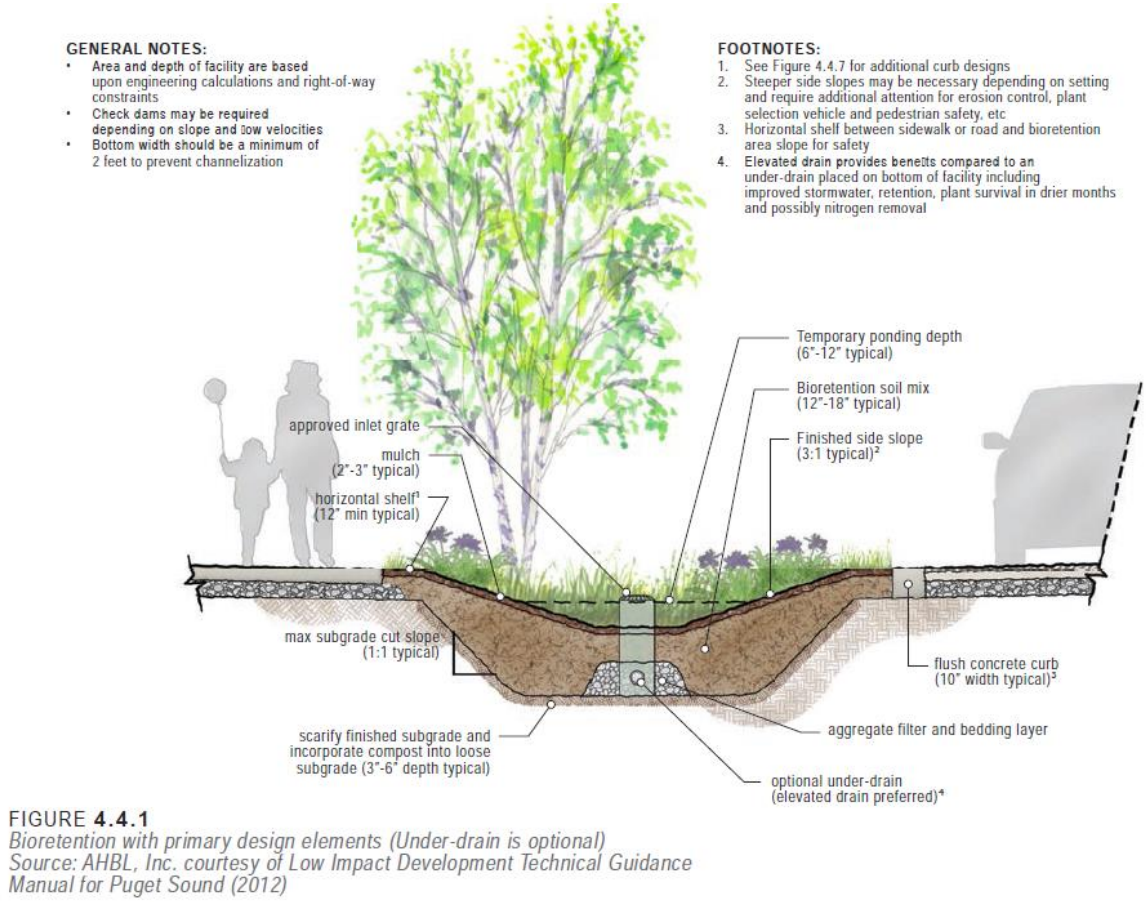

Figure 3.2: Typical bioretention cell design (AHBL & HDR, 2013)

3.2 Background and Problem Description

A number of BMP options in the Eastern Washington Stormwater Management Manual (Ecology, 2004), such as bioinfiltration swales and bioretention ponds, include the installation of plants as part of the design. While plants, and their root structure, are known to enhance pollutant removal and/or infiltration capacity and aesthetics (Kadec, 2008), there presence also creates extra maintenance needs, including watering and mowing. In semi-arid locations like eastern Washington, evaporation greatly exceeds rainfall during the dry season, creating conditions that make irrigation essential to sustain plants (Caraco, 2000). In the dryer parts of Eastern Washington, plant irrigation needs often exceed the average annual rainfall by tenfold. This problem is compounded during drought years when the availability of irrigation water is restricted. All too often the solution is to install the BMP with vegetation but not provide irrigation which results in BMPs with dead, brown vegetation similar to the one shown in Figure 3.3. Research on the pollutant removal performance of these type of BMPs is mixed (Caraco, 2001), which suggested they are not a reliable BMP for providing runoff treatment

A practical strategy for stormwater management in semi-arid regions is select BMPs that provide treatment without a supplemental water source. Common examples include BMPs without vegetation such as sand filters, infiltration trenches, evaporation ponds, and permeable pavements. Nonvegetated bioretention BMPs are not as common however the primary treatment mechanisms (filtration, sedimentation, and sorption) provided by the BMP are a function of the physiochemical properties of the engineered soils (BSM) not the plants. For example, TSS removal rates are dependent upon graduation and permeability rates: larger grain soils have more void spaces and a higher permeability resulting in lower TSS removal rates from stormwater compared to fine grained soils (Hunt & Lord, 2006; Hsieh & Davis, 2005). Whereas dissolved metals removal is associated with the sorptive properties of the soils such as cation exchange capacity (CEC): soils with a higher CEC have a larger capacity for removing dissolved metals from stormwater (Hunt & Lord, 2006; Hunt, 2003). Considering TSS and dissolved metals are the target pollutants in this study and that the engineered soils portion of bioretention BMPs provide the primary treatment functions for removing these pollutants, it is anticipated that bioretention BMPs without vegetation will still provide treatment of these pollutants.

It is well documented that vegetation contributes to the total pollutant reduction provided by bioretention BMPs (Henderson, 2009; Barrett, Limouzin, Lawler; 2013). A question of importance to this study is to what extent does vegetation contribute to pollutant reduction and is the treatment provided by the BSM alone sufficient for achieving Ecology treatment goals for basic and dissolved metals.

Figure 3.3 Biofiltration swale in EWA during the dry season

3.3 Results of Prior Studies

Section 3.3 is not required for the proposal (only for QAPP). This section will be completed for the QAPP.

3.4 Regulatory Requirements

The Eastern Washington Phase II Municipal Stormwater Permit issued to the Spokane County by the Department of Ecology Washington State requires the Stormwater Management Program Effectiveness Studies. Each city and county permittee listed in the permit shall collaborate with other permittees to select, propose, develop, and conduct Ecology-approved studies to assess, on a regional or sub-regional basis, effectiveness of permit-required stormwater management program activities and best management practices. Spokane County proposes to serve as the lead entity for the following effectiveness study: Bioretention Soil Media Study. Section S5.B.5 of the permit (Ecology, 2012) are specifically addressed by this investigation.

- S5.B.5 which requires permittees to implement and enforce a program to address post construction stormwater runoff to the MS4 from new development and redevelopment projects.

4.0 Project Overview

4.1 Study Goal

The purpose of this is study is to evaluate the influence of vegetation on the runoff treatment performance of bioretention ponds. In particular, determine whether a bioretention pond without vegetation can achieve Ecology's treatment goals for basic and dissolved metals, Copper (Cu) and Zinc (Zn). If some of these goals are met, the results will be used to justify the development of a modified BMP (i.e., Bioretention ponds without vegetation) that is approved for 'general use' on future projects (Ecology, 2011).

The selected BSM for this study will be either the bioretention media specification that is under development in WWA, or, the default bioretention specification (60:40 mix) defined in the EWA LID Manual. The process for selecting the BSM will depend primarily upon timing. Specifically, results from the WWA study need to be available and/or of sufficient detail to serve as a BSM specification that can be installed in the field prior to October 2019 (estimated start of data collection). Otherwise the default BSM mix (60:40) will be used.

Conducting this study is also dependent on locating a funding sources such as a 2019-2021 GROSS Grant or from participating entities.

Note: This study includes the goal of developing a modified BMP, as such the experiment design for this study will follow the modified BMP effectiveness requirements defines in Appendix A.

4.2 Study Description and Objectives:

This is a paired study with a dual-cell pond constructed at the test-site. Each cell contains the same type and configuration of BSM except one is vegetated with grass and the other is nonvegetated (Figure 4.1). A parking lot contributes runoff (influent) to the pond which is equally distributed to both cells. An impermeable liner, installed under both cells, captures infiltrated runoff (effluent) which is conveyed in underdrains to a manhole. The test-site is equipped with an automated monitoring system that collections composite samples (influent and effluent) and continuously records rainfall depth as well as flow measurements. Composite samples will be collected from 12 qualifying rainfall events this will include collecting one influent and two effluent samples from each storm. Samples will be tested for the required and screening parameters (see Table 4.1) as defined in TAPE for basic and dissolved metals. The study is expected to extend through 2 wet seasons. The infiltration performance of each pond will also be evaluated.

The data will be evaluated to determine whether there is a significant difference in the treatment performance between the two ponds and to determine if the nonvegetated pond meets Ecology's treatment performance requirements defined in TAPE. The scope of work for this study includes submitting a TAPE application that enters the modified BMP into the evaluation program, submitting the quality assurance project plan (QAPP), and a technical evaluation report (TER) to Ecology and the TAPE board of external reviewers (BER) as part of the process for approving a modified BMP.

The goal of this study will be achieved by meeting the following objectives:

- Determine the pollutant removal efficiency for each pond by measuring and comparing the pollutant concentrations in the influent and effluent
- Determine whether the pollutant removal efficiency of the nonvegetation pond is significantly different than the vegetated pond by comparing the effluent pollutant concentrations
- Determine infiltration performance of each pond over the duration of the study by measuring infiltration
- Determine whether the nonvegetated pond achieved the Ecology treatment performance goals
- Summarize study findings into a report and develop recommendations for next steps: if some or all of the treatment performance goals are achieved, the final report will recommend approval of the modified BMP and the report will be submitted through TAPE for review

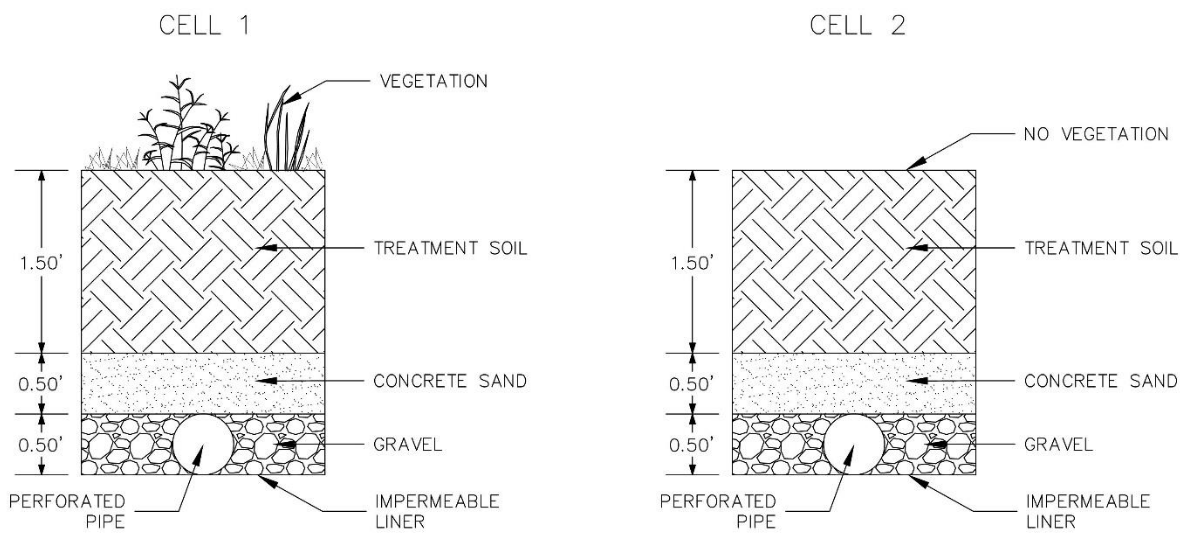

Figure 4.1 Typical section of pond cells: vegetated (left) and nonvegetated (right).

4.3 Study Location

The study location is on the campus of Gonzaga University in the City of Spokane. The location is shown in Figure 4.1, Gonzaga Biopond Monitoring Site. The contributing basin area is 0.42 acres of a paved parking lot and 0.08 acres from sidewalks and the access road to the parking lot. The basin area is delineated in Figure 4-2.

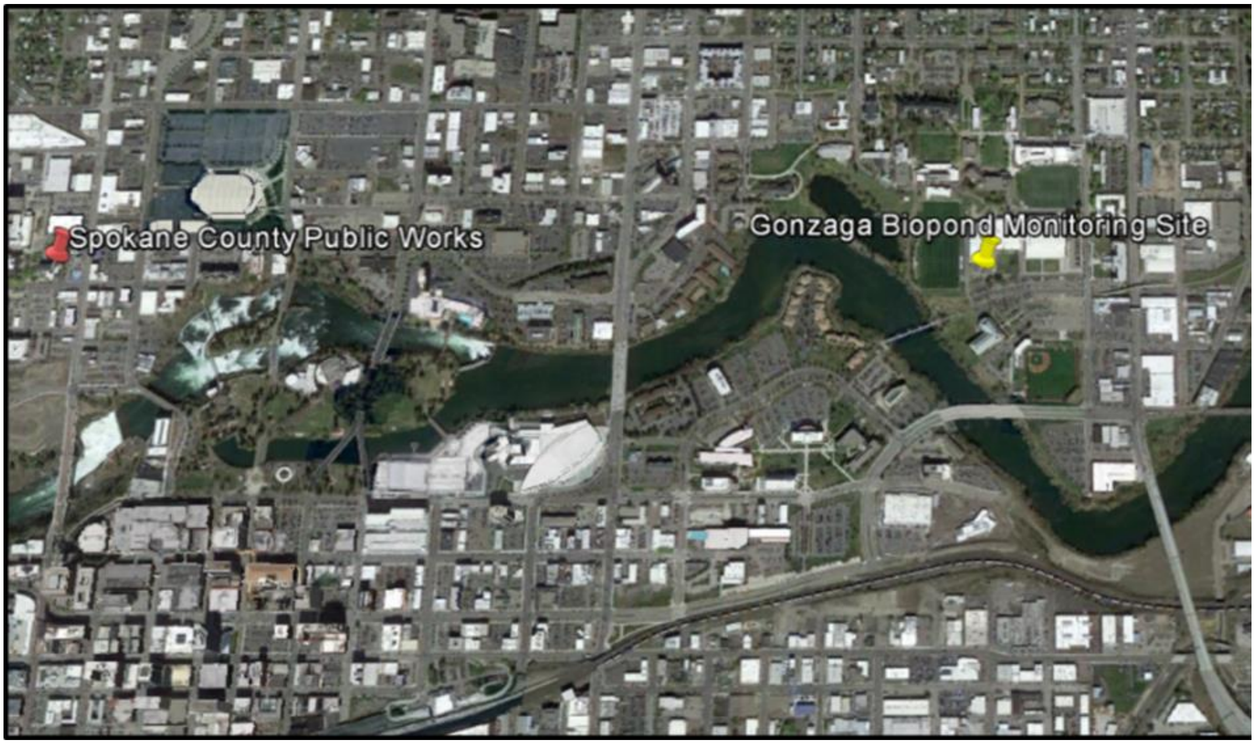

Figure 4.1 Study Location

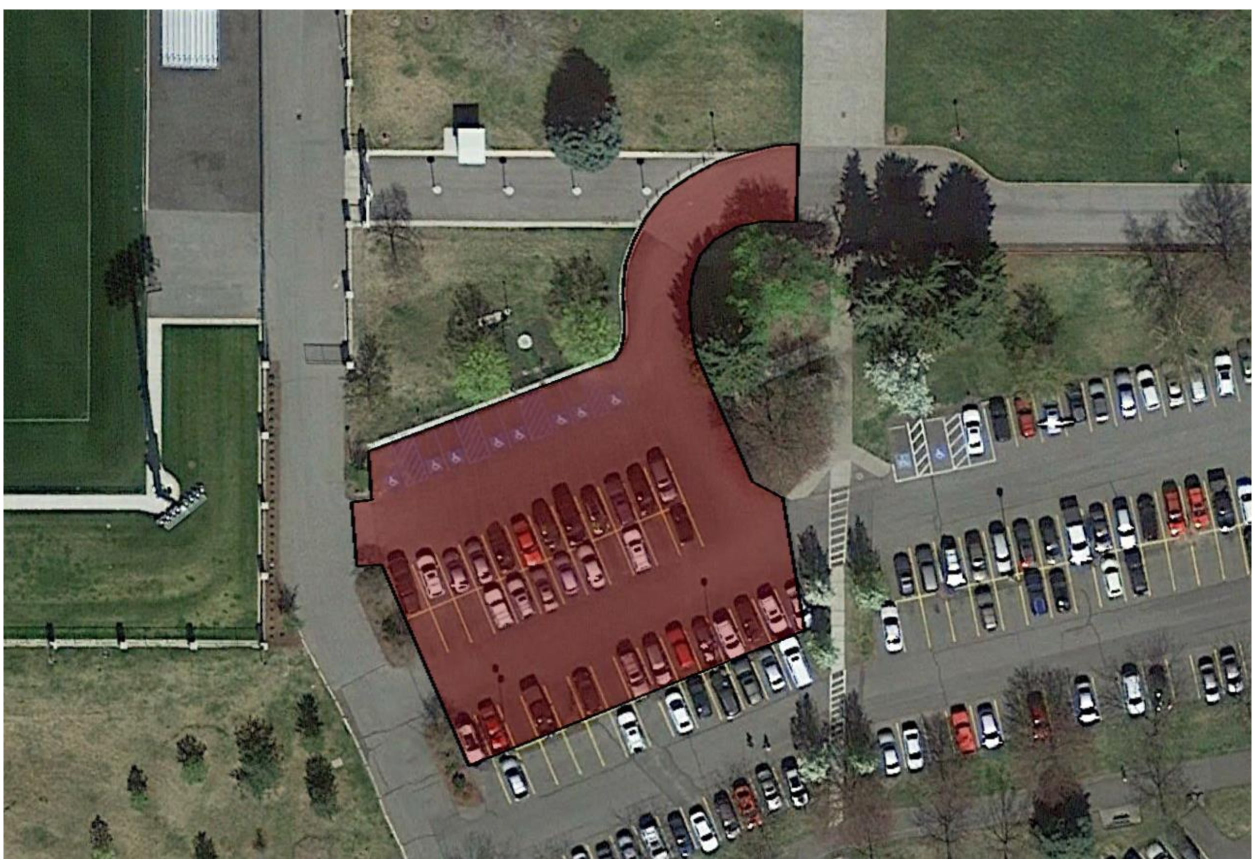
Figure 4.2 Contributing Basin Area

4.4 Data Needed to Meet Objectives

The data necessary to complete this study will be collected during field activities:

- BSM media physiochemical properties
- Flow measurements of influent and effluent
- Water Quality Samples: Influent and effluent pollutant concentrations during storm events (see table 4.1)
- Rainfall data collected from a rain gauge and data logger
- Infiltration measurements

Table 4.1 Summary of Water Quality Testing (per TAPE requirements)

Performance Goal	Required Parameters	Required Screening Parameters
Basic	TSS	PSD, pH, TP, orthophosphate, hardness, total and dissolved Cu and Zn
Dissolved metals	TSS, hardness, total and dissolved Cu and Zn	PSD, pH, TP, orthophosphate

4.5 Tasks Required to Conduct Study

Tasks required to conduct the study include:

- GROSS Grant Application
    - Apply for grant to fund study
- Enter BMP in the TAPE Evaluation Program
    - Develop and submit application
    - Convene a Board of External Reviewers (BER) from Ecology and (EWA) made up of stormwater experts/researchers
- Develop Quality Assurance Project Plan (QAPP)
    - Submit QAPP to Ecology and BER for review
- Prepare for Data Collection:
    - Program and install monitoring equipment
    - Remove existing BSM from ponds and replace with new BSM
    - BSM material testing
    - Maintain ponds including cleaning catch basins upstream of at test-site
- Data Collection:
    - Monitor weather daily
    - Collect influent and effluent samples from 12 rainfall events; test samples for required and screening parameters: basic, dissolved metals treatment goals
    - Measure infiltration rate quarterly

- Clean and prepare sampling equipment before sampling events
- After each sampling event, download from data logger: precipitation and flow rate
- Develop and manage a database that contains all the collected data
- Analyze data

- Develop Technical Report:
  - Write annual reports
  - Develop technical evaluation report
  - Respond to comments from Ecology and BER regarding report

4.6 Potential Constraints

Potential constraints are conditions that may impact the project schedule, budget, or scope. The potential constraints identified in this section, along with the steps that will be taken to reduce the impact of these conditions (mitigation approach), are based on the information that was available at the time the Proposal was written. This section will be updated during the QAPP development.

4.2 Summary of Potential Constraints and Mitigation Approaches

Potential Constraint	Mitigation Approach
Spills: oil or other chemicals	Large spills could impact the BMP treatment performance; Visually inspect the pond following each rainfall event; if a spill occurs conduct appropriate maintenance and note the incident in the data collection log
Uneven delivery of influent flows to each cell in the pond	Periodically measure flow and compare flows; balance flow rates at pond inlets as needed
Insufficient qualifying rainfall events	Extend monitoring period or collect data from lower depth (<0.15-inches) rainfall events
Campus facilities using fertilizer at test-site	Educate campus facilities about the study and adjust their maintenance practices
Monitoring equipment malfunctions	Frequent inspection of equipment and review system output variables after each storm for any anomalies. If problems are encounters, equipment will be fixed promptly.

5.0 Organization and Schedule

5.1 Key Project Team Members: Roles and Responsibilities

Key Team Members	Role	Responsibility
Matt Zarecor 509.477.7255 mzarecor@spokanecounty.org	Lead Entity	Responsible for execution of study
David Haws Yakima County 509.574.2277 David.Haws@co.yakima.wa.us	Financial Support (Potential)	Provide lead entity with financial contributions toward their cost of executing the study
Brad Daly Walla Walla County 509.524.4669 bdaly@wallawallawa.gov	Financial Support (Potential)	Provide lead entity with financial contributions toward their cost of executing the study
Art Jenkins* City of Spokane Valley 509.720.5018 ajenkins@spokanevalley.org	Advisory Board Lead/Member	The goal of a technical advisory group (TAG) is to provide insight, suggestions, and professional opinions over the course of the research study.
Danielle Mullins City of West Richland 509.967.5434 dmullins@westrichland.org	Advisory Board Lead/Member	The goal of a technical advisory group (TAG) is to provide insight, suggestions, and professional opinions over the course of the research study.
Brad Daly Walla Walla County 509.524.4669 bdaly@wallawallawa.gov	Advisory Board Lead/Member	The goal of a technical advisory group (TAG) is to provide insight, suggestions, and professional opinions over the course of the research study.
Art Jenkins* City of Spokane Valley (if needed) 509.720.5018 ajenkins@spokanevalley.org	Data Verifiers	Data verifiers will review the analyzed data and verify the analysis is correct.
Rob Buchert City of Pullman 509-338-3314 rob.buchert@pullman-wa.gov	Reviewer	Review and provide comments on the study documents.
Ruby Irving, Environmental Compliance Specialist City of Yakima 509.576.6781 Ruby.Irving-Hewey@YAKIMAWA.GOV	Reviewer	Review and provide comments on the study documents.
Bill Aukett City of Moses Lake 509.764.3792 baukett@cityofml.com	Reviewer	Review and provide comments on the study documents.

David Haws Yakima County 509.574.2277 David.Haws@co.yakima.wa.us	Reviewer	Review and provide comments on the study documents.
Brad Daly Stormwater Coordinator Walla Walla County 509.524.4669 bdaly@wallawallawa.gov	Reviewer	Review and provide comments on the study documents.
Dan Ford, City Engineer City of Pasco 509.545.3445 fordd@pasco-wa.gov	Participant	Participant w/out designated role
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Karen Dinicola Ecology 360.407.6550 kdin461@ecy.wa.gov	Ecology Reviewer	Phase 2-3a GROSS Grant Project Manager
Doug Howie Ecology 360.407.6444 doho461@ecy.wa.gov	Ecology Reviewer	Responsible for the technical review and approval of this Proposal
Aimee Navickis-Brasch HDR, Inc. (509)343-8515 aimee.navickis-brasch@hdrinc.com	Proposal Primary Author	Responsible developing the detailed study design proposal
Zack Holt, D&H Technology Solutions, LLC (360)509-0996 holt.zackary@gmail.com	Proposal Author	Responsible for the development of the monitoring system
Name Organization Phone Number Email	QAPP Author	To be defined when the QAPP is developed
Name Organization Phone Number Email	Key Team Member Project Role	Define when the QAPP is developed if applicable

5.2 *Project Schedule*

A task timeline based on quarterly activities is shown in Table 5.1.

	2017		2018				2019				2020				2021		
Task Name	Q3: Jul - Sept	Q4: Oct - Dec	Q1: Jan - Mar	Q2: Apr - Jun	Q3: Jul - Sep	Q4: Oct - Dec	Q1: Jan - Mar	Q2: Apr - Jun	Q3: Jul - Sep	Q4: Oct - Dec	Q1: Jan - Mar	Q2: Apr - Jun	Q3: Jul - Sep	Q4: Oct - Dec	Q1: Jan - Mar	Q2: Apr - Jun	Q3: Jul - Sep
Ecology Proposal Review Period																	
Submit GROSS Grant Application[1]									July 31st								
Submit TAPE Application																	
QAPP Development																	
QAPP Review Ecology & BER																	
Prepare for Data Collection • Monitoring System • Replace BSM • BSM testing																	
Data Collection[3]																	
Reporting • Annual Reports • Final Report (TER)			Annual Report				Annual Report				Annual Report				Annual Report		
TER Review Period Ecology & BER																	

1. Ecology GROSS Applications are typically due on July 31st. Project timeline assumes study will receive grant funding.
2. If the project receives GROSS grant funding, the final report will be due on June 30th. Otherwise the final report is due to Ecology 6-months after data collection is complete.
3. Project will begin 15 months after QAPP approval.
4. If the project receives GROSS grant funding, the final report will be due on June 30th. Otherwise the final report is due to Ecology 6-months after data collection is complete.
5. Data collection will begin 15 months following QAPP approval.

5.3 Budget and Funding Sources

The funding source for this study has not been identified. Spokane County intends to apply seek funding through grants as well as contributions from participating entities.

Table 5.2: Study Budget

Task	Hours	Cost Per Hour	Equipment Fees[3]	Total
Project Management				$18,250
QAPP Development[1]	200	$150	0	$30,000
Prepare for Data Collection[2] • Monitoring Equipment • Remove & replace BSM • BSM material testing	180	$150	$15,000	$42,000
Data Collection[4]	360	$150	$14,500	$68,500
Reporting • Technical Evaluation Report • Annual Reporting	340	$150		$51,000
			Total	$210,650

1. Budget assumes the jurisdiction staff with maintain the test-site. Hours for this task have not been included.
2. Task includes cost for programming and installing equipment, removing and replacing BSM in ponds, and testing BSM material properties; the equipment cost included are replacement parts and consumable items that will need to be replace during the testing period.
3. Monitoring equipment has already been purchased for this site
4. Task includes hours for sample collection and processing, field Ksat testing, maintaining equipment, data management and analysis, audits, and laboratory fees for analytical testing

6.0 Quality Objectives

This section will be completed for the QAPP.

7.0 Experimental Design

7.1 Study Design Overview

This is a paired study with a dual-cell pond constructed at the test-site. Each cell contains the same type and configuration of BSM except one is vegetated with grass (control) and the other is nonvegetated (test). The site also includes 2 catch basins, an influent sampling sump, a manhole (effluent sampling), and equipment storage vault (Figure 7.1). Runoff from a parking lot is collected in a catch basin located on the south end of the pond which overflows into a covered sump (influent sampling) that discharges to a second a covered catch basin located between the pond cells. Runoff is distributed equally to each cell through stormdrains located on opposite sides of the catch basin. Runoff infiltrates through the BSM in each cell and is captured by the impermeable liner and conveyed to a manhole through underdrain pipes where effluent samples are collected (Figure 7.2 and 7.3).

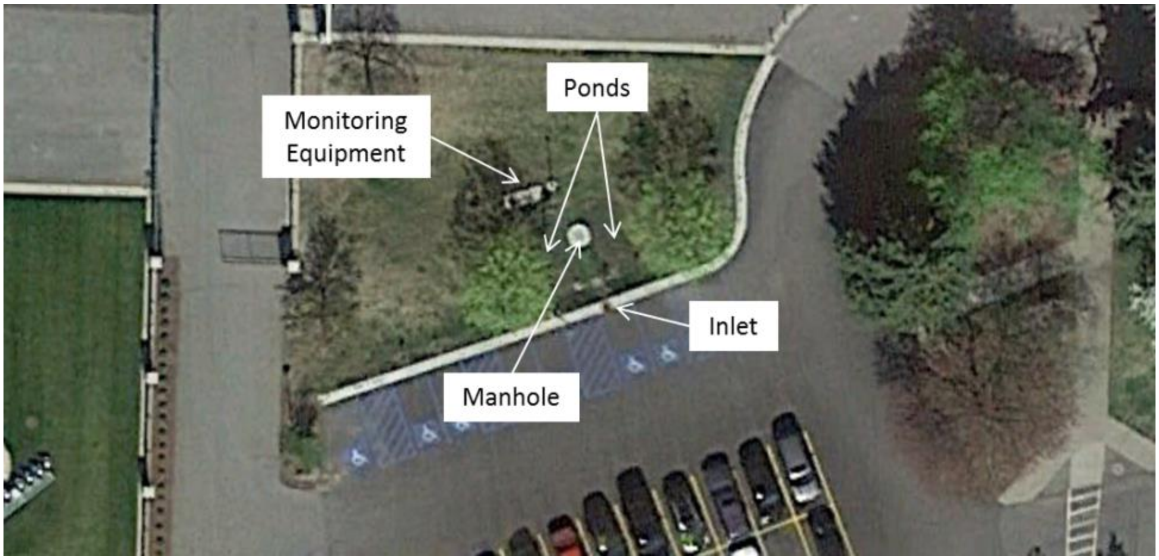


Figure 7.1 Aerial View of Test Site

Figure 7.2 Influent sampling sump (left) and manhole-effluent sampling (right)

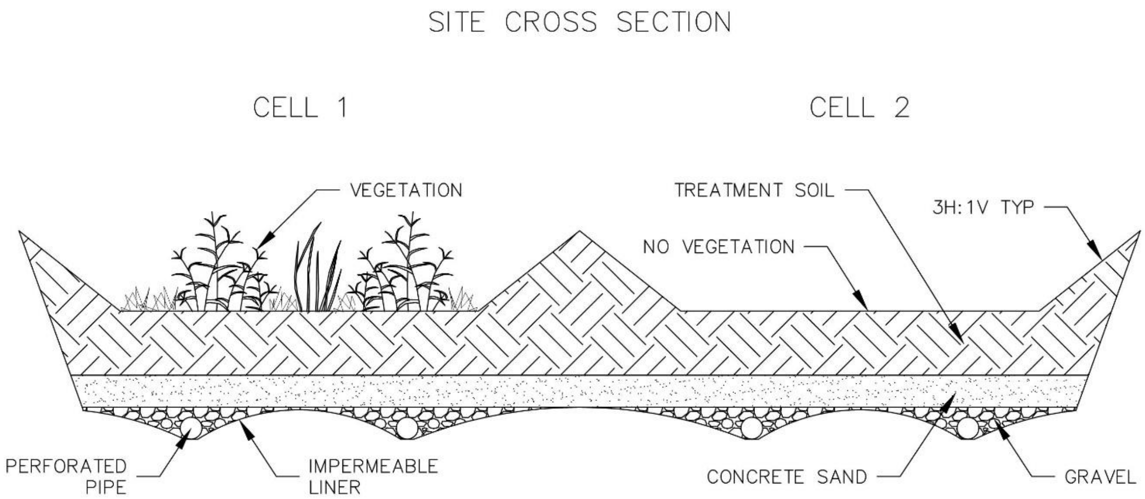


Figure 7.3 Cross section of pond with underdrains.

The monitoring system includes a rain gauge, three automated samplers, one data logger, and three pressure transducers. One composite influent sample is collected in the stormdrain pipe that runs through the sump and two composite effluent samples (one from each pond) are collected in the manhole from stormdrain pipes that discharge from each pond cell. Samples are pumped to the automated samplers which are stored in the equipment vault. The flow rate of the influent and effluent is continuously measured using a combination of a pressures transducer (stage) and an upstream weir which are also located in the sump and the manhole pipes.

Composite samples will be collected from qualifying rainfall events (see Section 7.5 for details on qualifying events). A minimum of 12 storms will be sampled and up to a maximum of 36 (dependent on the number of samples needed to achieve a 95% confidence interval for TAPE treatment goals). This will include collecting one influent and two effluent samples from each storm. Samples will be tested for the required parameters (each sampling event) and screening parameters (minimum 3 sampling events) in order to demonstrate treatment performance goals for basic and dissolved metals (Table 14.1). Testing is expected to occur over a minimum of 2 wet seasons.

Samples of the BSM will be collected when the new media is installed in the pond cells. The material physiochemical properties of the samples will be tested (at an Ecology certified lab) to verify that media meets the specification for the selected BSM mix. Section 7.9 provides more details on material testing. Infiltration testing will occur quarterly (2 locations in each cell) using a constant head test to assess any changes in the infiltration rate during the study.

The focus of the study is to evaluate the influence of vegetation on the runoff treatment performance of the cells. This will include statistically comparing the effluent concentrations from each cell to determine whether the treatment performance of the nonvegetated pond is significantly different than that of the vegetated pond for reducing TSS and dissolved metals (Cu and Zn). In addition the removal efficiency from the nonvegetated soil will be compared to the TAPE treatment goals to determine whether the nonvegetated cell achieved Ecology’s treatment goals for basic and dissolved metals.

The final report will be submitted to Ecology at the end of the study and the annual reports will be included in Spokane County’s annual stormwater report. For the pollutants in which the treatment goals are met, the final study report (TER) will be submitted to Ecology and the BER requesting a ‘*general use*’ designation for nonvegetated bioretention ponds.

7.2 Test-Site(s) Selection Process

In 2014, the test-site was constructed for the purpose of conducting an effectiveness study focused on bioretention. A copy of the construction plan sheets is located in Appendix B. This site was selected because the contributing basin area is a parking lot near the university soccer field, basketball center, and a recreation facility. During a typical day the parking stalls are all occupied and there is a frequent turnover of vehicles. This type of land use is associated with a buildup of pollutants such as metals, TSS, and oils (Minton, 2013). As such, it is anticipated these pollutants will be of measurable quantity in the stormwater runoff and have the potential to meet the TAPE influent concentration range (see Table 7.1),

7.3 The Structural BMP System Sizing

The ponds were designed following the bioretention design guidance from the EWA LID Manual (AHBL & HDR, 2013). The following is a summary of the pond design methods, assumptions, and results.

- Pond sizing: size to contain the water quality event (6-month 24-hour event) to a depth of 6-inches and provide 1-foot of freeboards above the 25-year 24-hour ponded depth
- Model: use single event model and the Type 1A hyetograph
- Rainfall depths: 6-month 24-hour (1”) and 25-year 24-hour (2.20”)
- Infiltration rate = 2.4-inches/hour
- Final pond dimensions: 2.5-feet depth, 7-feet wide, and 18-feet long

The test-site was constructed in 2014 and 2015. Plan sheets and details from both construction years are located in Appendix B.

7.4 Type of Data Being Collected

Sampling process design has been developed based on monitoring requirements identified in the Eastern Washington NPDES Phase II Permit and in TAPE. This section addresses the steps and processes taken to develop these monitoring sites and sampling strategies and to ensure the data collection and monitoring methods satisfy the requirements of TAPE and the permit.

Table 7.1 Overview of Monitoring Variables

Parameters	Frequency	Sampling Method and sampling location	Telemetered Data
Rainfall	Continuous, year-round	Rain Gage, on-site	Yes
Stage (Discharge)	Continuous, year-round. Discharge calculation activated per-storm	Pressure Transducer, influent and effluent	Yes
Temperature	Continuous, year-round	In Situ Probe at influent and effluent	Yes
Water Quality, except grab samples	Discrete storm events (min. of 12 samples)	Autosampler, Influent and effluent	No
Infiltration	Quarterly	Single ring infiltrometer; middle of each cell	No
Maintenance	Twice/year	-	No
BSM materials	Once, prior to start of study	TBD; each pond cell	No

Rainfall, temperature, and stage will be continuously monitored at the station locations. A data collection platform (DCP) will be located at each monitoring location. The DCP will consist of a data logger, autosampler, and attached peripheral probes for water temperature, rain gage, and stage. Time is measured by the data logger to ensure antecedent dry period criteria are met. Data loggers will be programmed to record measurements at a minimum every 15 minutes, per TAPE guidance. When a storm begins, stage measurements will increase their frequency to five minute increments during the storm. Stage measurements will be used by the data logger to calculate storm discharge. From these calculations, samples will be collected by the autosampler at even flow weighted intervals when triggered by the data logger. The data logger will monitor storm duration based upon rainfall and antecedent criteria. Data logger will continue storm event sampling until 6 hour antecedent criteria are met, then the station will end sampling and wait to be reset for the next storm.

The monitoring system includes three automated samplers and one data logger (located in the equipment vault), and a rain gauge. The samplers collect flow weighted composite water quality samples at three locations: one influent sample at the influent sampling catch basin and two effluent samples from the discharge of each pipe in the manhole at the most downstream inverted Tee. The manhole that houses both discharge pipes is shown in Figure 7.2. Discharge is measured by measuring water level using a pressure transducer which is then converted to discharge using a weir equation for the installed Thel-Mar weirs. Thel-Mar weirs tend to be preferred over flumes in lower-flow “flashy” systems in order to more accurately characterize small-scale hydrological features (Rantz at al, 1982; USEPA, 2002c), though weirs tend to be more influenced by debris than flumes (Church et al., 2003). Equations for Thel-Mar weirs are derived specifically for each size of weir and are provided by the manufacturer. Stage and temperature data will be collected for influent and effluent stormwater within an inverted tee that is located upstream of the control weir. Autosamplers will collect stormwater from another tee located just downstream of the control weir.

Note: The experimental design for this study has been developed based on monitoring requirements identified in the Eastern Washington NPDES Phase II Permit and in TAPE This study is being conducted for two reasons: develop a modified BMP and meet the permit requirements defined in section S8.B for evaluating the effectiveness of permit required stormwater management programs and activities. As such, the experimental design for this study will follow a modified version of TAPE for studies which is summarized in a table located in Appendix A under the column titled Develop Modified BMP.

The data logger will be equipped with a satellite antenna to telemeter monitoring data. Data will be saved to the internal logger memory and transmitted via telemetry at one-hour intervals. Hydrographs and hyetographs will be created from the collected rain gage and discharge data to accurately compare and relate the two parameters.

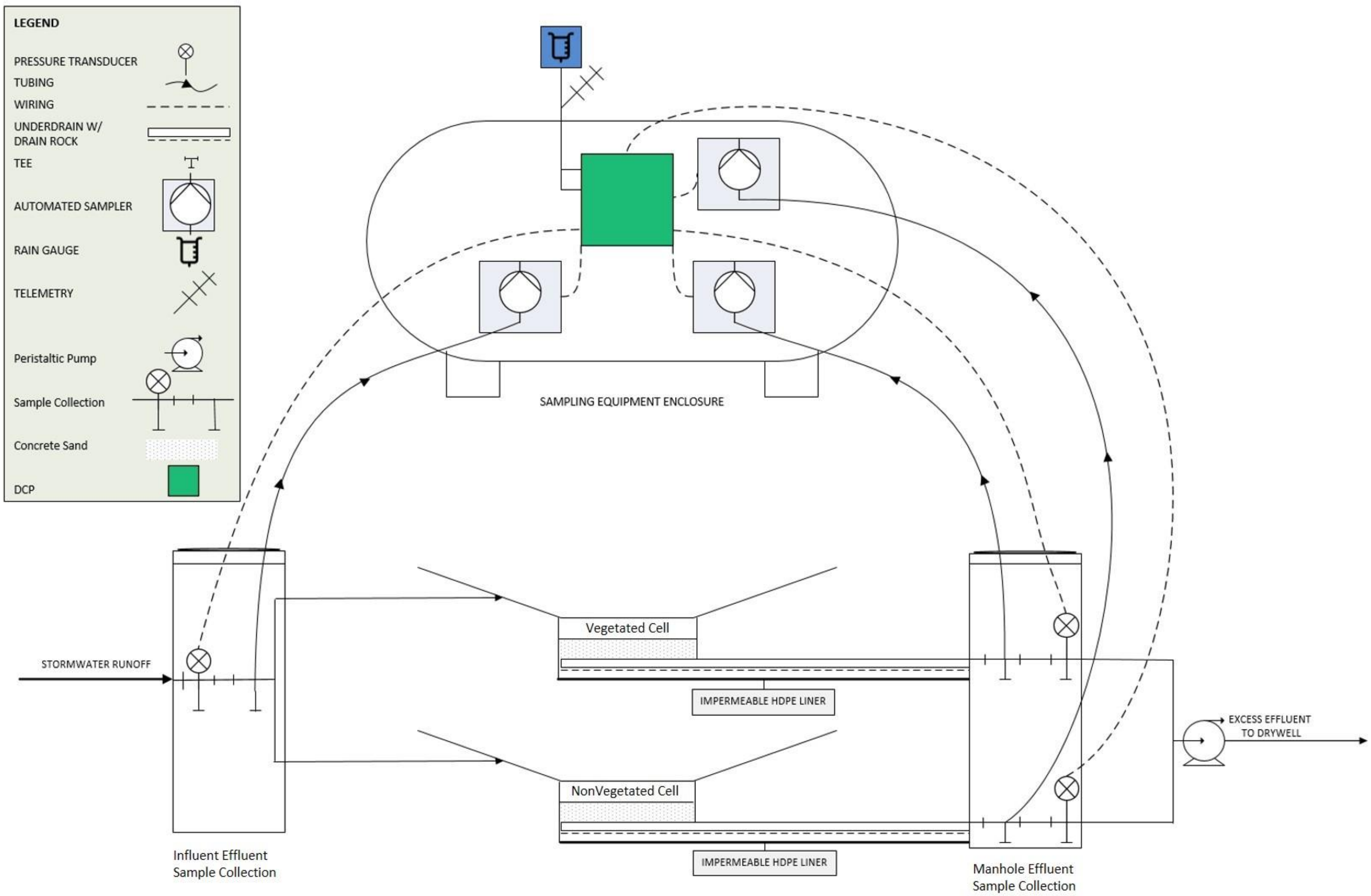


Figure 7.4 Process Diagram of Monitoring System

7.5 Precipitation Monitoring

Precipitation monitoring consists of two parts: storm event prediction and rainfall measurements. This section describes the methods for both.

Storm Event Prediction

Sampling should be attempted for storms that are predicted to meet the storm event guidelines defined in TAPE (Ecology, 2011 p. 14). These events are referred to as 'qualifying rainfall events' in this Proposal which have the following characteristics:

- A minimum of 0.15-inch depth
- Storm start (antecedent dry-period): 6 hours minimum with less than 0.04-inches of rainfall
- Storm end (post storm dry period: 6 hours minimum with less than 0.04-inches of rainfall
- Minimum storm duration: 1-hour
- Average storm intensity: range of rainfall intensities (to assess performance on an annual average basis and performance at the system's peak design rate, proponents should collect samples over a range of rainfall intensities)

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service, Spokane forecast office website will be monitored daily for storm forecasts. (http://graphical.weather.gov/sectors/otx.php). These observations will determine if a predicted storm will meet the qualifying event criteria in which sample collection will occur.

Rainfall Measurements

Precipitation monitoring will be conducted to quantify rainfall during storm events and to measure the duration, intensity and distribution of rainfall throughout a discrete storm event. Precipitation will be monitored in 15 minute increments by the data logger. The precipitation monitoring device used for this study is a jeweled bearing tipping bucket rain gage. The tipping bucket rain gage has a data resolution of 0.01 inches.

The tipping bucket rain gage is located on-site within the drainage basin for the facility to accurately represent on-site rainfall characteristics. Rain gages was installed in a secure, level fashion in a location where no buildings, trees, overpasses, or other objects obstruct or divert rainfall prior to entering the rain gage. Rain gage placement followed the National Weather Service specifications (http://www.weather.gov/om/coop/standard.htm) for the site.

If a deviation from NWS specification are needed, a notation will be made regarding the alteration and included in the TER. Rain gages will be mounted to the antenna mast approximately 6-8 feet from the ground unless otherwise specified. The rain gage will be calibrated prior to installation and maintained in accordance with the manufacturers' specifications.

The data collected from the rain gage will be logged every 15 minutes and will be broadcast hourly via telemetry to remotely identify on-site weather characteristics and determine when sampling crew need to deploy for sample collection. During each station visit, the rain gage will be inspected, cleared of debris, and maintained in accordance with the manufacturers' specifications. Rain gage data will also be downloaded from the logger for each storm event or during the maintenance schedule.

7.6 Water Quality Sampling

Two methods will be used for water quality sampling methods depending on the analyte that will be tested: grab sampling and composite sampling. This section describes the methods for both. Figure 7.4 includes a process drawing of the monitoring system.

Grab Sampling

TAPE states that grab samples should be collected on the rising limb of the hydrograph. Sampling staff are to collect grab samples as early in the runoff event as practical to ensure representativeness of the sample. A minimum of twelve samples will be collected for statistical comparison following TAPE guidelines.

If grab samples are not collected or are missed during qualifying storm events, allowable non-qualifying sized storm events may be sampled to ensure statistical requirements are met. An allowable non-qualifying storm means that only the stormwater rainfall depth can be the reason the storm is non-qualifying. Samples collected from non-qualifying storms will be noted and flagged in the dataset.

Grab samples are typically those collected manually in jars or measured in situ with a probe. For pH, temperature, and visible sheen are required grab samples.

Composite Sampling

TAPE specifies that stormwater runoff must be collected by in-situ flow-weighted composite sampling. Autosamplers such as an ISCO or a similar product will be used at each of the monitoring stations to collect stormwater samples during a qualifying storm event. Autosamplers will be programmed to begin sampling when initiated by the data logger. Autosamplers are programmed to begin sampling at the predetermined rates required for the collection of at least 75 percent of the event hydrograph. Sample collection into autosampler bottles will be triggered by a four-step threshold system. Four thresholds (i.e., water temperature, rainfall, discharge, and time) are necessary to determine whether the antecedent criteria and rainfall criteria was met, stormwater runoff is occurring and the water is not frozen. Water temperature, rainfall, and discharge will be measured using external probes connected to the data logger. Time will be measured by the data logger itself. If these four thresholds are not met during the storm, samples will not be collected. Each monitoring station will be equipped with an autosampler and a 2.5-gallon glass bottle for sample containment.

7.7 Infiltration Testing

The infiltration rate of the bioretention ponds will be measured quarterly using a single ring infiltrometer in the middle of the cell. The test method that will be used for this study is defined in the 2008 Spokane Regional Stormwater Manual. This is the same method used in the Spokane County to verify the infiltration rate of bioinfiltration swales, a BMP that is similar to the bioretention ponds in regards to requirements for sizing and infiltration rates. A copy of the test method is located in Appendix C.

7.8 Sediment Sampling

The amount of sediment that accumulates in the BMP will be sent to the laboratory for determination of the particle size distribution (PSD) and dry weight. Composition of sediments will be noted on field forms as well to assist with characterization and corroborate the laboratory findings. This section will be further developed in the QAPP.

7.9 BSM Material Testing

The BSM will be tested once prior to the start of data collection. Samples will be collected from each at the time the BSM is installed in the cells.

The purpose of the testing is to verify that materials properties are consistent with the properties defined in the selected BSM specification. The physiochemical properties to be tested will include those that are known to influence treatment and flow control performance. The testing anticipated for this study is summarized in Table 7.2. This section will be updated when the QAPP is developed.

Table 7.2 Summary of Anticipated BSM Media Material Testing

Parameter	Test Methods
pH	S-2.20[3]
Cation Exchange Capacity (CEC)	S-10.10 (or equivalent other)
Maximum Dry Density	ASTM D1557, Proctor Method C
Saturated Hydraulic Conductivity (K_{sat}) @ 85% compaction rate	ASTM D2434
Particle Size Distribution for the following sieve sizes: 4, 8, 16, 30, 50, 100, 200	ASTM D422
Total Elements Zn, Cu, Pb, Fe, Al, P, Mg, Ca	EPA 3050A/6010B

8.0 Sampling Procedures

This section will be completed for the QAPP.

8.1 Standard Operating Procedures

This section will be completed for the QAPP.

8.2 Containers, Preservation Methods, Holding Times

This section will be completed for the QAPP.

8.3 Equipment Decontamination

This section will be completed for the QAPP.

8.4 Sample Identification

This section will be completed for the QAPP.

8.5 Chain of Custody

This section will be completed for the QAPP.

8.6 Field Log Requirements

This section will be completed for the QAPP.

9.0 Measurement Procedures

This section will be completed for the QAPP.

9.1 Procedures for Collecting Field Measurements

This section will be completed for the QAPP.

9.2 Laboratory Procedures

This section will be completed for the QAPP.

9.3 Sample Preparation Methods

This section will be completed for the QAPP.

9.4 Special Method Requirements

This section will be completed for the QAPP.

9.5 Lab(s) Accredited for Methods

This section will be completed for the QAPP.

10.0 Quality Control

This section will be completed for the QAPP.

10.1 Field QC Required

This section will be completed for the QAPP.

10.2 Laboratory QC Required

This section will be completed for the QAPP.

10.3 Corrective Action

This section will be completed for the QAPP.

11.0 Data Management Plan Procedures

This section will be completed for the QAPP.

11.1 Data Recording & Reporting Requirements

This section will be completed for the QAPP.

11.2 Electronic Transfer Requirements

This section will be completed for the QAPP.

11.3 Laboratory Data Package Requirements

This section will be completed for the QAPP.

11.4 Procedures for Missing Data

This section will be completed for the QAPP.

11.5 Acceptance Criteria for Existing Data

This section will be completed for the QAPP.

11.6 Environmental Information Management (EIM) Data Upload Procedures

This section will be completed for the QAPP.

12.0 Audits

This section will be completed for the QAPP.

12.1 Technical System Audits

This section will be completed for the QAPP.

12.2 Proficiency Testing

This section will be completed for the QAPP.

13.0 Data Verification and Usability Assessment

The section will define the process that the project will employ to evaluate the quality of the data and the usability of the data for meeting the project objectives. This section will be fully developed in the QAPP.

The following includes a list of the data that will be verified:

- Water quality data
- Infiltration measurements
- Flow measurements
- Rainfall data
- BSM material properties

13.1 Field Data Verification

This section will be completed for the QAPP.

13.2 Laboratory Data Verification

This section will be completed for the QAPP.

13.3 Data Usability Assessment

This section will be completed for the QAPP.

14.0 Data Analysis Methods

14.1 Data Analysis Methods

Flow Control Performance

The following information will be compiled for each sampling event that occurred during the data collection period to evaluate the flow control performance of the BSM:

- Influent, effluent, and bypass volume of water
- Storm precipitation depth
- Storm duration
- Storm average precipitation intensity
- Storm peak precipitation intensity
- Storm antecedent dry period
- Peak discharge at the Influent and Effluent Monitoring Station
- Runoff volume at the Influent and Effluent Monitoring Station
- Flow duration at the Influent and Effluent Monitoring Station

Once this information is compiled, additional analyses will be performed to identify a subset of storms that had sufficient precipitation totals and/or intensities to produce measurable runoff into the sand filter. Specifically, any storm event that produced a measurable flow volume at the Influent Monitoring Station will be flagged as runoff-producing.

Water Quality Treatment Performance

The water quality data will be evaluated against the Ecology performance goals for basic and dissolved metals (Zn and Cu). This included comparing the average removal efficiency at the 95% confidence interval and influent concentration from all rainfall events to the Ecology information noted in Table 14.1. If the removal efficiency is equal to or greater than the treatment performance criteria and if the average influent concentration falls within the range specified by Ecology, the conclusion will be made that the treatment performance criteria was met for pollutant of concern.

Table 14.1 Ecology Treatment Performance Goals

Performance Goal	Pollutant	Influent Concentration Range	Treatment Performance Criteria
Basic Treatment	Total Suspended Solids (TSS)	100-200 mg/L	80% Reduction
Dissolved Metals Treatment	Dissolved Copper (Cu)	5.0-20.0 μg/L	30% Reduction
	Dissolved Zinc (Zn)	20-300 μg/L	60% Reduction

Statistical Comparisons of Pollutant Concentrations

A statistical comparison will be conducted to determine whether there was a significant difference in the analytical results between influent and effluent pollutant concentrations, and between the cell datasets.. This is expected to include evaluating whether the data was normally distributed using the Ryan-Joiner test (similar to Shapiro-Wilk test) (Helsel & Hirsch, 2002). Normality will be assumed if the tests produced a p-value greater than 0.05 (Ecology, 2008). If the data is normally distributed, a two-sample t-test was used to determine if there was a significant difference between the influent and effluent concentrations. If the data was non-normally distributed, a Wilcoxon rank sum test (a nonparametric analogue to the paired t-test) was used instead. The specific null hypothesis (H_o) and alternative hypothesis (H_a) were evaluated as defined below. The statistical comparison was based on a confidence level of 95% (α=0.05).

Statistical comparison for each parameter between the influent concentration and the effluent concentration for each pond.

- H_o: Effluent pollutant concentration is equal to the influent concentration
- H_a: Effluent concentrations are less or greater than influent concentrations

The treatment performance of the two ponds will evaluated to determine if there is a significant differences between the vegetated pond and the nonvegetated pond.

Statistical comparison for each parameter between the effluent concentration of cell 1 and the effluent concentration of cell 2.

- H_o: Effluent concentrations from the vegetated cell are equal to the effluent concentrations of the nonvegetated cell
- H_a: Effluent concentrations from the 12-inch are less or greater than effluent concentrations of the 18-inch pond

Calculation and Evaluation of Pollutant Reduction Efficiencies

The effectiveness of the BMP will be evaluated based on the average removal efficiency and mean concentration for each parameter over at least the 12 qualifying rainfall events. This will include calculating the removal efficiency for each pollutant from each individual rainfall events using the equation below. Then the bootstrapping method will used to compute the 95% confidence interval for the average removal efficiency from all rainfall events for each pollutant. The boot strapping method is the Ecology recommended method which assumes the dataset is non-normally distributed (Ecology, 2011). If analytical results provided by the lab included values that are non-detectable, the reporting limit for the respective pollutant will be used as defined by the standard testing method.

$$\Delta C = 100x\frac{C_{in}-C_{eff}}{C_{in}}$$

Where:
C_{in} = influent concentration (mg/L)
C_{eff} = effluent concentration (mg/L)

Infiltration Measurements

Infiltration measurements for each pond will be taken quarterly and analyzed in a spreadsheet using standard statistical techniques and graphical representation of BMP performance over time. Descriptive statistics (mean, minimum, maximum, and standard deviation) will be computed for each set of infiltration measurements (see Table 14.2 for an example). A summary table of all tests for each pond can be presented together (see Table 14.3 for example).

Table 14.2: Infiltration rate (inches per hour) statistics of Segment B pervious concrete north (04/15/2018).

Mean	205.10
Std Dev	2.79
Min	199.10
Max	214.00

Table 14.3: Infiltration rate statistics for 04/15/2018.

		Infiltration Rate (in/hr.)	
	Total # Tests	Mean	Standard Deviation
Vegetated Cell	2	2.4	0.5
Nonvegetated Cell	2	2.0	0.7

The effectiveness will be determined by comparing the infiltration rates against time using graphical representation.

14.2 Data Presentation

The data will be presented (i.e., tables, charts, and/or graphs) in the final reports to illustrate trends, relationships, and anomalies. Examples of how the data may be presented is shown in Figures 14.1, 14.2, and Table 14.1 and briefly described below:

- Figure 14.1 - Box and Whisker Plots display the distribution of data collected during the study. This will include the average and range of influent and effluent concentrations and any outliers. When applicable, the concentration representing the Ecology treatment performance goal will be graphed (red dashed line) to illustrate the relationship to the influent and effluent average concentrations.

- Figure 14.2 - Log-Normal Graphs are line graphs of the removal efficiency (C_{eff}/C_{in}) for each sampling event. These graphs illustrate the trend in the treatment performance over the duration of the study.

- Table 14.2 – a summary of the water quality results will be include in a table. This will include the average influent and effluent concentrations, sample size, results from the hypothesis testing, and the removal efficiency corresponding to the 95% confidence interval.

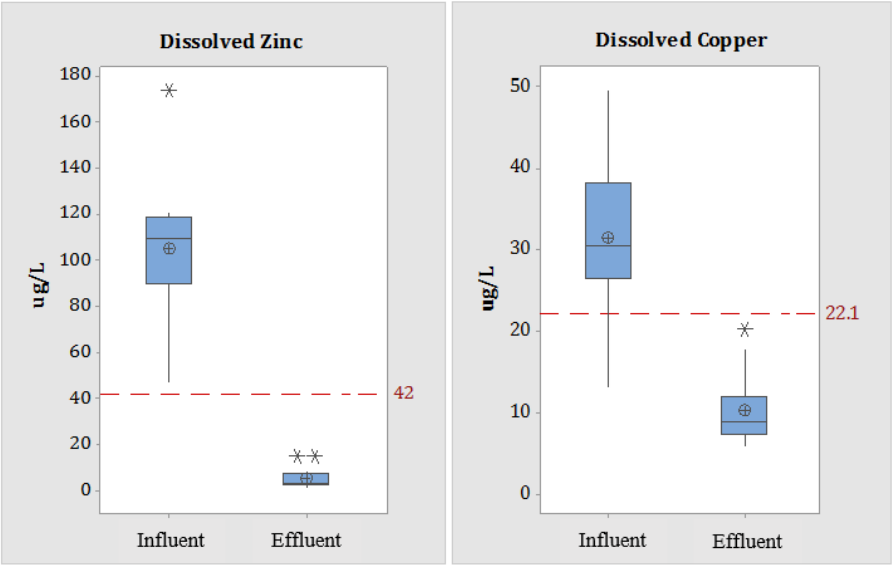


Figure 14.1 Example of Box Plots

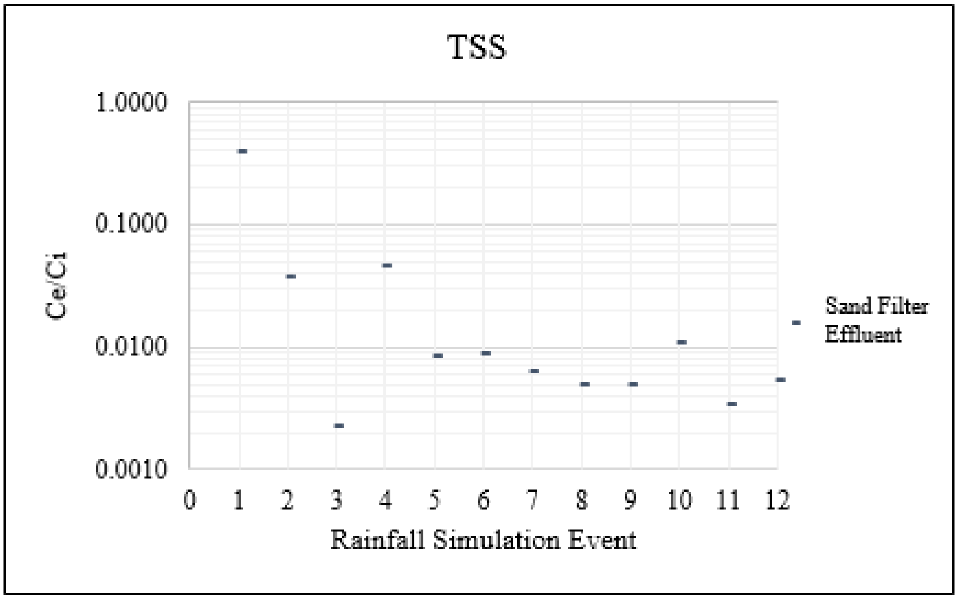


Figure 14.2 Example of Log-Normal Graphs line graphs: the removal efficiency (C_{eff}/C_{in})

Table 14.1 Summary of Water Quality Results (Example)

Column ID	Average Influent Concentration	Average Effluent Concentration	Sample Size (n)	Statistically Significant (Y/N)	95% CI Removal Efficiency	Performance Criteria	Pass Or Fail
TSS (mg/L)							
Pond 1	171.0	2.640	12	Y	92.0%	80%	Pass
Pond 2	126.4	2.390	12	Y	89.3%	80%	Pass

15.0 Reporting

This section describes how the study findings will be reported and disseminated.

15.1 Final Reporting

This section will be completed for the QAPP.

15.2 Dissemination of Project Documents

The final report will be shared with the participating agencies and will be posted to the Spokane County webpage: https://www.spokanecounty.org

16.0 References

AHBL and HDR, *Eastern Washington Low Impact Development Guidance Manual*. 2013, Washington State Department of Ecology: Puyallup, WA.

Barrett, M. E., Limouzin, M., & Lawler, D. F. (2013). Effects of media and plant selection on biofiltration performance. Journal of Environmental Engineering (United States), 139(4), 462-470. DOI: 10.1061

Davis, A.P., et al., Laboratory study of biological retention for urban stormwater management. Water Environment Research, 2001: p. 5-14.

Ecology, Guidance for Evaluating Emerging Stormwater Treatment Technologies, DRAFT. 2008, Ecology: Olympia.

Hatt, B.E., Hydraulic and Pollutant Removal Performance of Fine Media Stormwater Filtration Systems. Environmental Science and Technology, 2008: p. 2535-2541.

Helsel, D.R., Hirsch, R.M., Statistical Methods in Water Resources, Chapter A3, in Techniques of Water-Resources Investigations of the United States Geological Survey. 2002, USGS.

Henderson, C.F.K. 2009. The Chemical and Biological Mechanisms of Nutrient Removal from Stormwater in Bioretention Systems. Thesis. Griffith School of Engineering, Griffith University.

Hunt, W.F. and W.G. Lord, *Bioretention performance, design, construction, and maintenance*. 2006: NC Cooperative Extension Service.

Li, H. and A.P. Davis, *Urban particle capture in bioretention media. I: Laboratory and field studies.* Journal of Environmental Engineering, 2008. **134**(6): p. 409-418.

Kadlec, R. H., & Wallace, S. (2008). *Treatment wetlands*. CRC press.

Technical Guidance Manual for Evaluationg Emerging Stormwater Treatment Technologies. 2011, Washington State Department of Ecology: Olympia.

Appendices

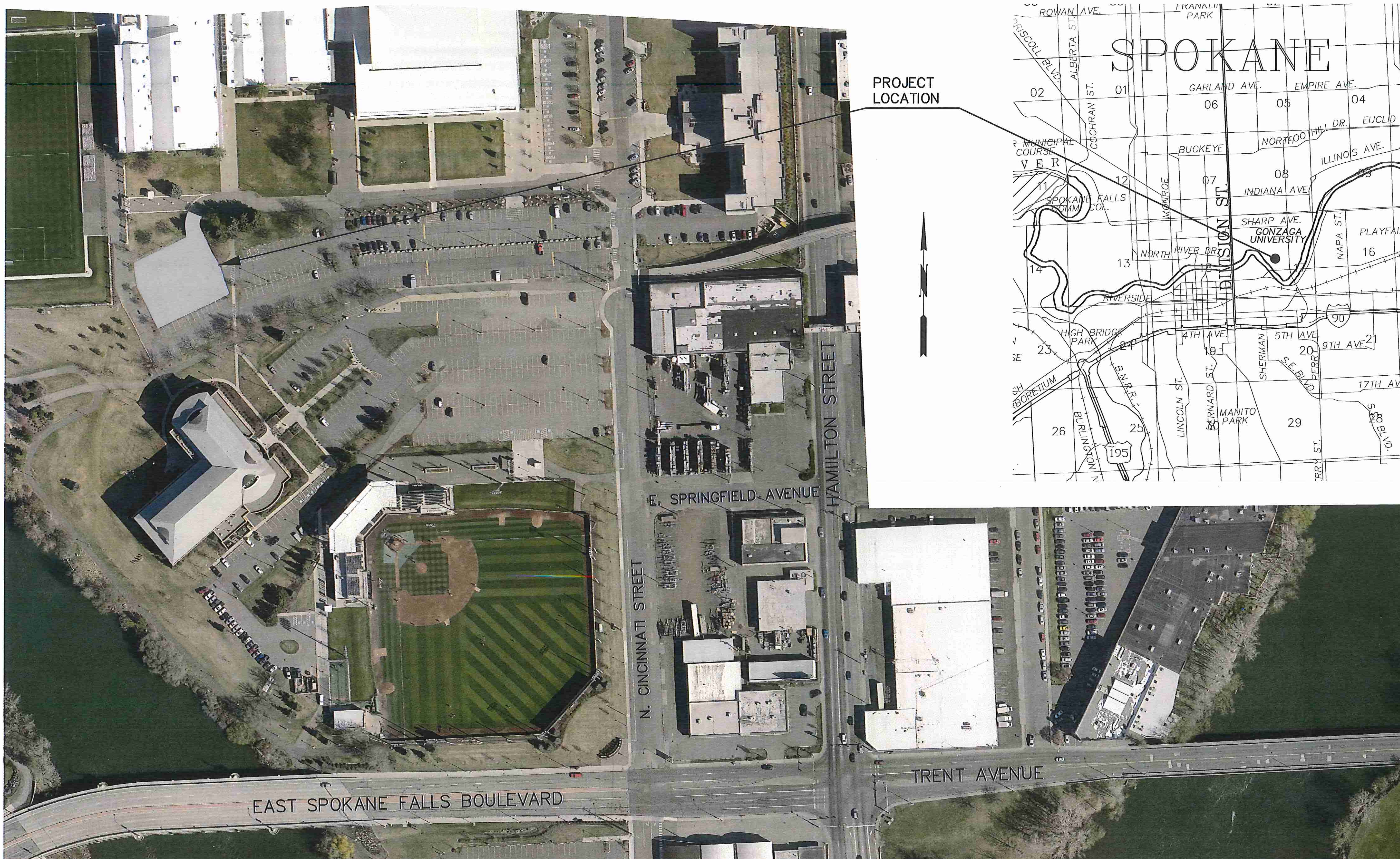
Appendix A – Summary of Modified TAPE Process Requirements

Study Elements	Evaluate Practice Effectiveness	Develop Modified BMP	Develop New BMP
TAPE Application	No application required	No application required	Application required - Jurisdictions are exempt from TAPE fees
Define BMP Materials[1]	• Verify BMP material properties and quantities are consistent with the BMP design guidance. • Determine BMP material properties using manufacturer provided specifications or through material testing • For BMPs that contain compost, define material source. • For BMPs that contain topsoil, define material source.	Same as Effectiveness plus: • Define BMP design criteria material modifications	Same as Effectiveness plus: • Define BMP material properties and quantities proposed for new BMP design criteria
Study Duration	1.5 maintenance cycles or 2 wet seasons	Same as Effectiveness Study	Same as Effectiveness Study
Water Quality Testing[1]	Test influent & effluent for the pollutants concentrations the BMP is approved to provide runoff treatment for.	Test influent & effluent for the following: • Pollutants BMP is approved to provide runoff treatment for plus the additional required parameters[2] • Test for the required screening parameters 3 times during the study[2]	Same as Modified BMP plus: • Evaluate the treatment performance at the peak and average flow rate using field monitoring information only
Sample Size	Collect samples from a minimum of 12 natural rainfall events (maximum of 35) that meet the qualifying conditions[3].	Collect samples from a minimum of 12 and maximum of 35 natural rainfall events that meet the qualifying conditions[3].	Same as Modified BMP plus: • Collect samples from 50% to 125% of the design flow rate using field monitoring information only
Design Flow Rate	• Define Design Flow Rate specified in the BMP design criteria • Measure the influent and effluent flow rate as defined in the TAPE requirements	Same as Effectiveness Study	• Define design flow rate for proposed BMP design criteria • Measure initial flow rate using standard methods (i.e. Modified ASTM D2434) • Measure the influent and effluent flow rate as defined in the TAPE requirements
Audits	• Technical system audits and proficiency audits <u>are recommended</u> • Audits maybe conducted by the Project Manager	• Technical system audits and proficiency audits <u>are required</u> • Audits maybe conducted by the Project Manager	Same as Modified BMP except: • Audits shall be conducted by a 3rd party

Study Elements	Evaluate Practice Effectiveness	Develop Modified BMP	Develop New BMP
Data Analysis	• Evaluate if difference between influent and effluent pollutant concentrations is statically significant and indicate the confidence interval. • Determine average pollutant removal efficiency. • Bootstrap Method is recommended to determine efficiency and associated confidence interval.	• Hypothesis testing: statistically significant difference between influent and effluent pollutant concentrations to a 95% confidence interval and 80% power • Evaluate BMP using Ecology treatment performance goal[4]: 95% confidence interval for removal of pollutants the BMP is approved and/or proposed to provide runoff treatment for. • Use Bootstrap Method to determine removal efficiency at 95% confidence interval.	Same as Modified BMPs
Final Report	• Final report should contains elements defined in S8.B10 of the NPDES permit • Use TAPE TER requirements as a guide for developing report[5] • QAPP may substitute for relevant sections including: introduction, technology description, and sample procedures	• Use TAPE TER requirements as a guide for developing report[5] • QAPP may substitute for relevant sections including: introduction, technology description, and sample procedures	Follow TAPE TER requirements [5]
Document Review Process	• Ecology reviews/approves QAPP • Ecology reviews final report (*no requirements for Ecology approval defined in permit*)	Jurisdiction must convene a Board of External Reviewers (BER): 3-5 individuals (2 from Ecology) with technical skills necessary to provide a peer review of the QAPP and TER.	QAPP & TER Review by Board of External Reviewers (BER)

1. All water quality and material testing should be conducted at an Ecology Accredited Laboratory. Reference the following link for a full list of laboratories: https://fortress.wa.gov/ecy/laboratorysearch/
2. See TAPE Guidance document, Table 8 for a list of the required parameters and required screening parameters
3. Qualifying conditions include but are not limited to: minimum rainfall depth and duration, minimum time between rainfall events, and range of influent pollutant concentration. See TAPE guidance document for more details, specifically Tables 2, 5-7.
4. The Ecology treatment performance goals define the pollutant removal efficiency for the BMP: 80% TSS, 60% dissolved Zinc, 30% dissolved Copper, 50% Total Phosphorus, and < 10mg/L of Total Petroleum Hydrocarbons (TPH). The specific requirements are in Table 2 of the TAPE guidance document.
5. TAPE Technical Evaluation Report (TER) guidance is define on page 35 of the **TAPE Guidance Document**.

Appendix B – Monitoring Site Plan Sheets



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NO.	DATE	BY	CKD.	APPR.	REVISION DESCRIPTION

NOT TO SCALE

DRAWN BY:	FARNSWORTH	SEPT., 2014
DESIGNED BY:	GONZAGA	SEPT., 2014
CHECKED BY:	ZARECOR	SEPT. 18, 2014

SPOKANE COUNTY

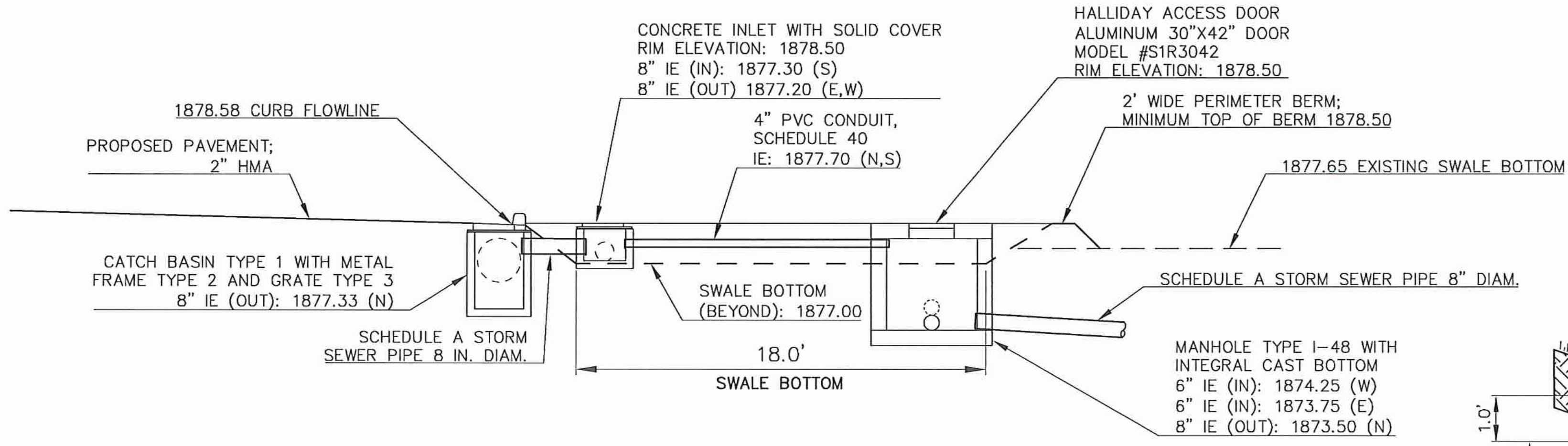
Spokane County Department of Public Works
1026 W. Broadway Ave. SPOKANE, WA
99260-0170
(509) 477-3600

APPROVED: ______
STORMWATER ENGINEER
ENGINEER
Date: ______

MATTHEW B. ZARECOR, STATE OF WASHINGTON, 36216, REGISTERED PROFESSIONAL ENGINEER

COUNTY STORMWATER PROJECT No: SWR 80-14
GONZAGA SWALE PROJECT
VICINITY MAP
PROJECT VICINITY

SHEET 1 of 3



SECTION B–B
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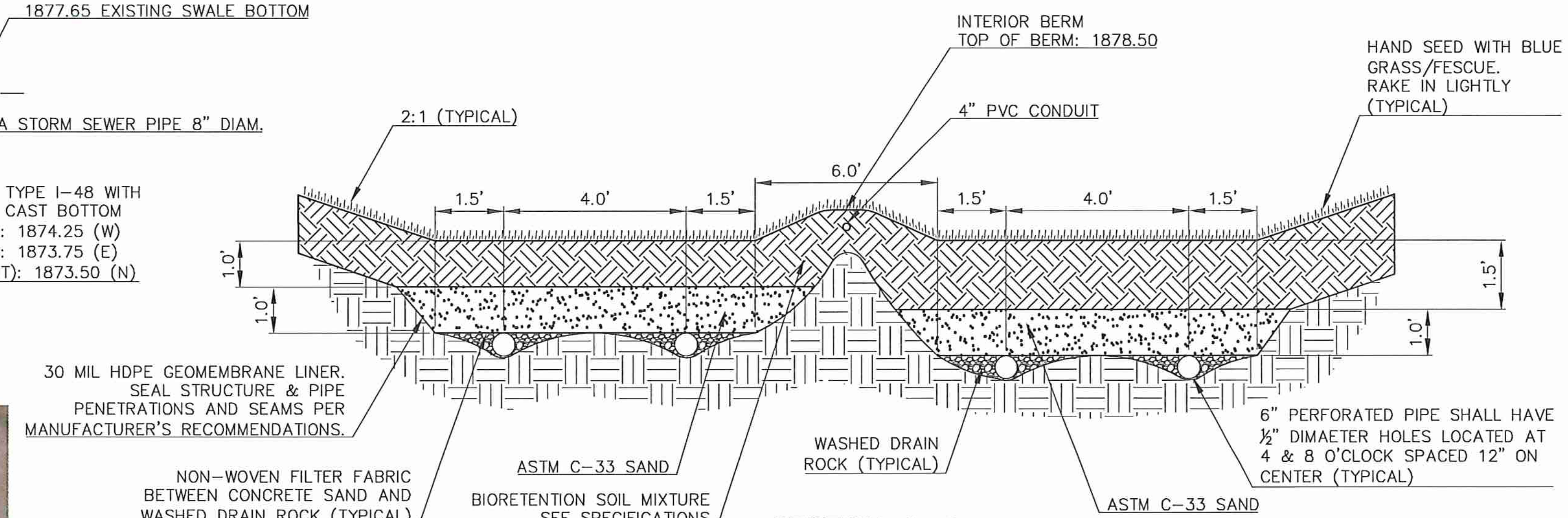

SECTION A–A
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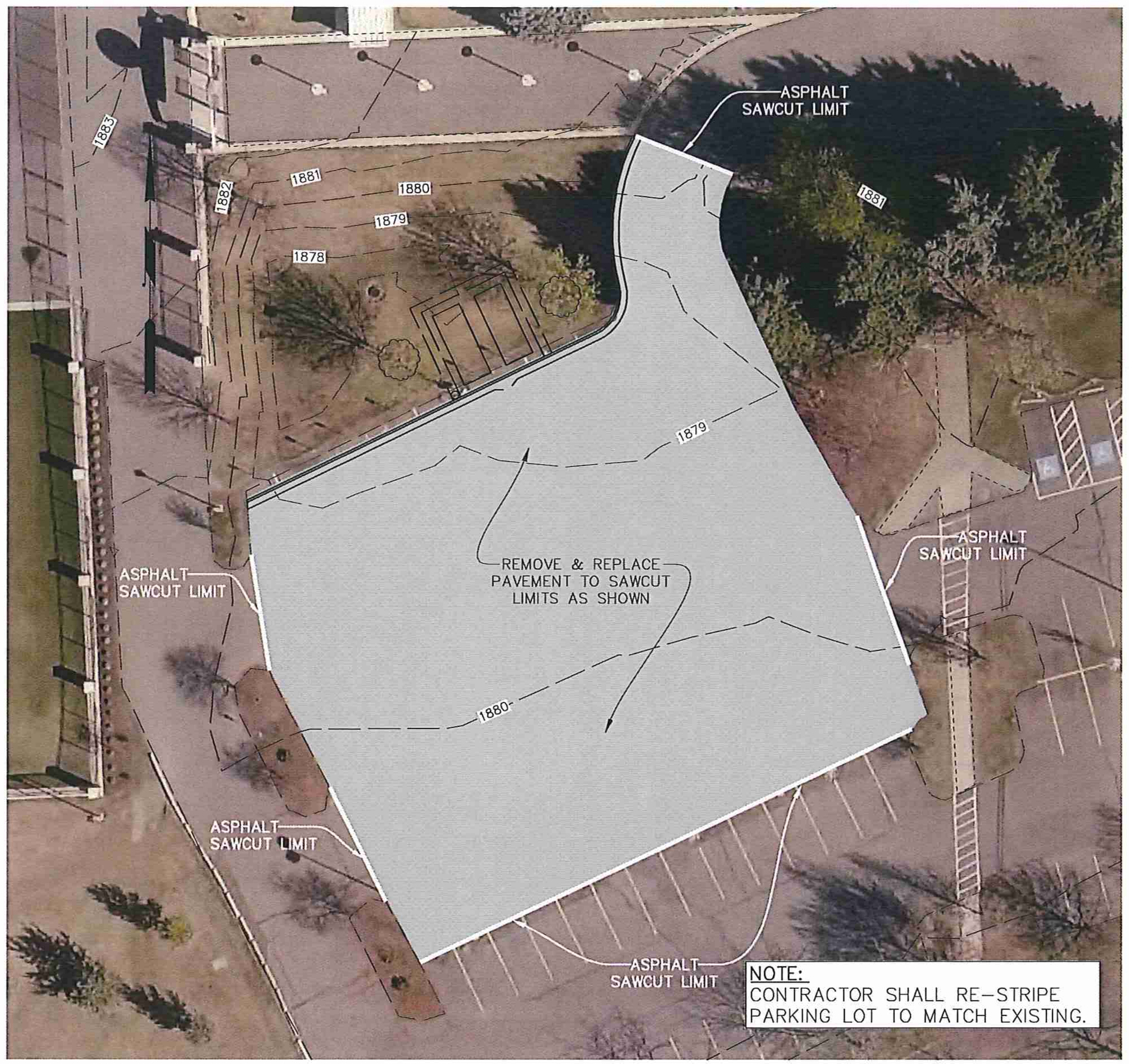
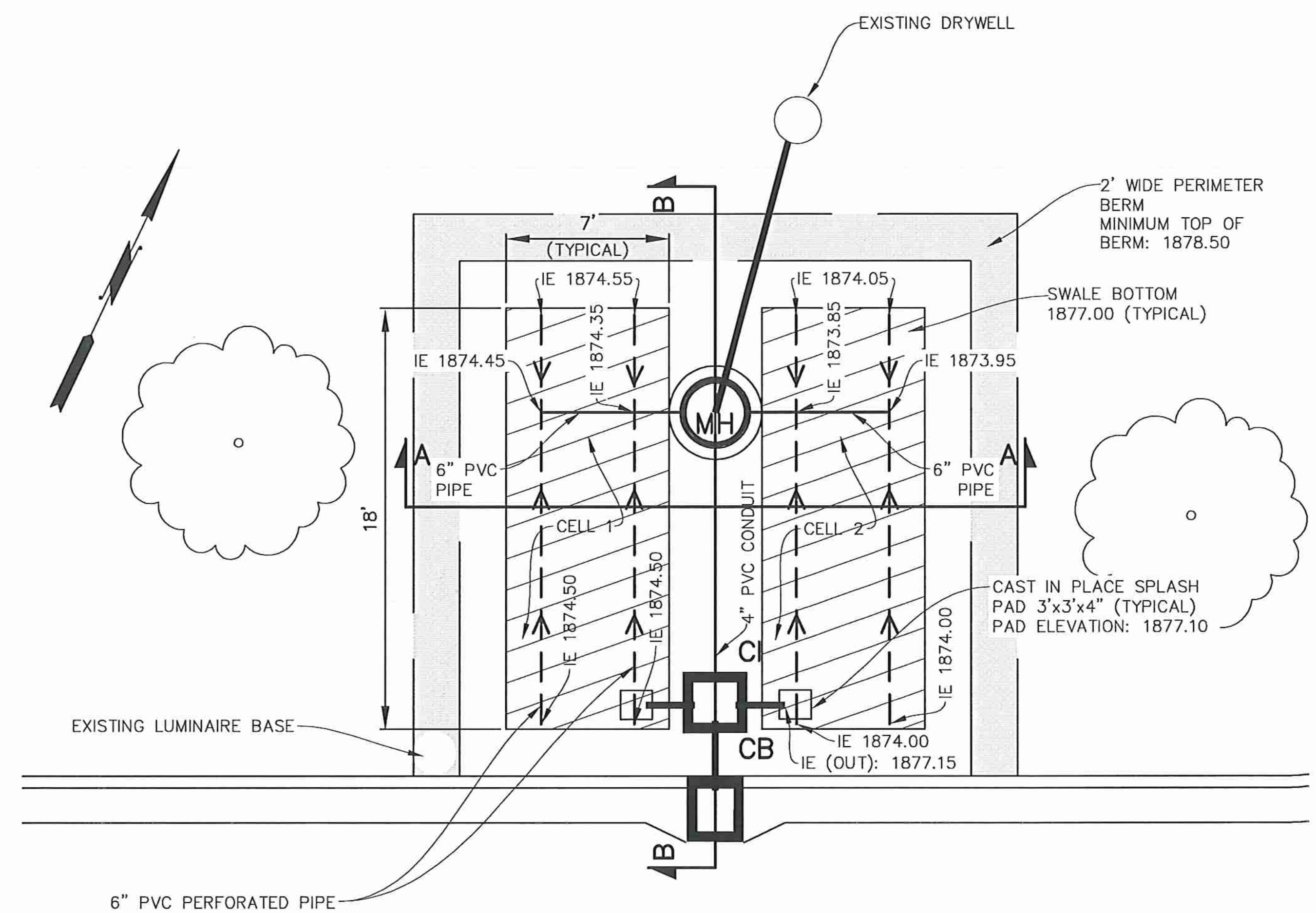


PAVEMENT REMOVAL
SCALE: 1"=40'



SWALE PLAN VIEW
SCALE: 1"=8'

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NO.	DATE	BY	CKD.	APPR.	REVISION DESCRIPTION

SCALE: AS NOTED

DRAWN BY:	FARNSWORTH	SEPT., 2014
DESIGNED BY:	GONZAGA	SEPT., 2014
CHECKED BY:	ZARECOR	SEPT. 22, 2014

SPOKANE COUNTY

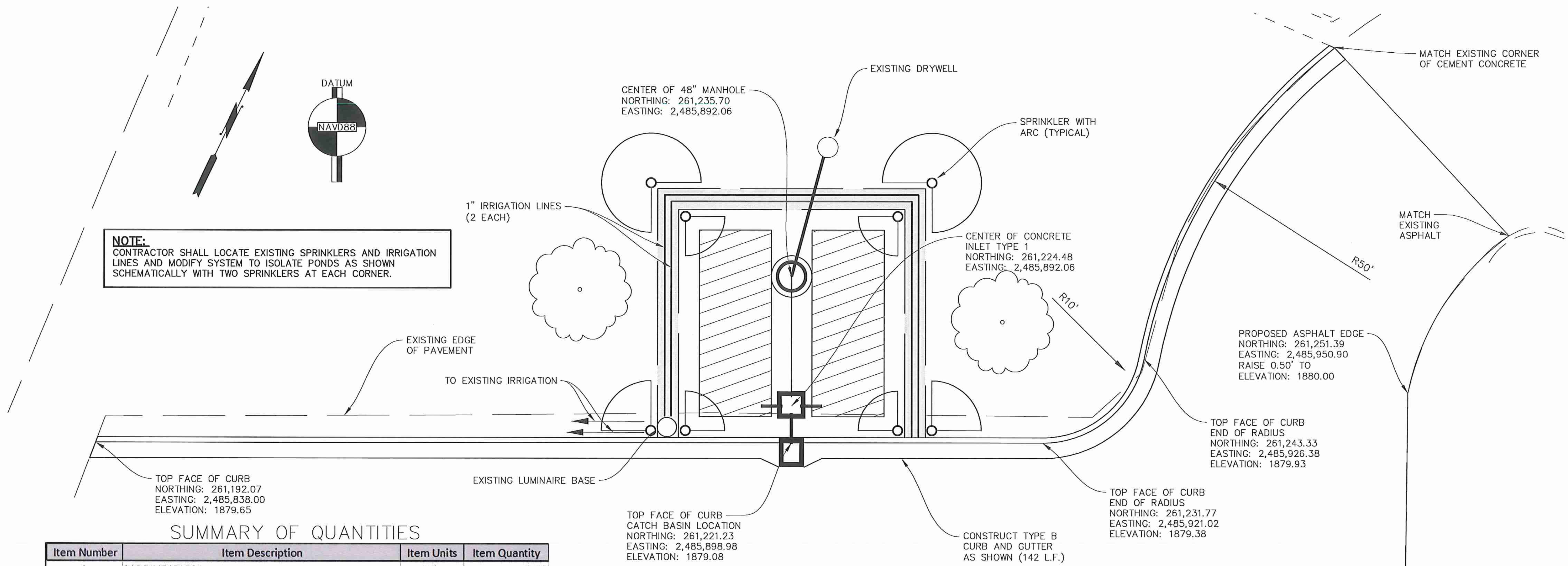
Spokane County Department of Public Works
1026 W. Broadway Ave. SPOKANE, WA
99260-0170
(509) 477-3600

APPROVED:
STORMWATER ENGINEER
ENGINEER
Date:

MATTHEW B. ZARECOR
STATE OF WASHINGTON
36216
REGISTERED
PROFESSIONAL ENGINEER

COUNTY STORMWATER PROJECT No: SWR 80-14
GONZAGA SWALE PROJECT
PAVEMENT REMOVAL
SWALE LAYOUT AND CROSS SECTIONS

SHEET
2 of 3



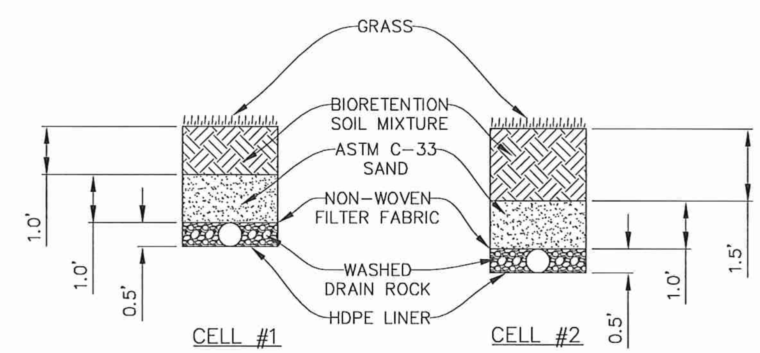
NOTE:
RE-GRADE AS NEEDED BY ADDING CRUSHED SURFACING TOP COURSE TO PROVIDE CONTINUOUS GRADE FROM ALL POINTS TO INLET.

EXISTING EDGE OF PAVEMENT

PROPOSED ASPHALT EDGE
NORTHING: 261,213.86
EASTING: 2,485,968.28
RAISE 0.45' TO
ELEVATION: 1879.70

SUMMARY OF QUANTITIES

Item Number	Item Description	Item Units	Item Quantity
1	MOBILIZATION	L.S.	1.00
2	SAWCUTTING ASPHALT CONC. PAVEMENT	L.F.	236.00
3	ASPHALT PAVEMENT REMOVAL INCL. HAUL	S.Y.	1,867.00
4	GRADING AND SHAPING	S.Y.	1,867.00
5	SWALE EXCAVATION INCL. HAUL	C.Y.	52.00
6	METAL FRAME TYPE 2 AND GRATE TYPE 3	EACH	1.00
7	HALLIDAY ACCESS DOOR MODEL #S1R3042	EACH	1.00
8	CATCH BASIN TYPE 1	EACH	1.00
9	CONCRETE INLET TYPE 1 INCL. FRAME & SOLID COVER	EACH	1.00
10	MANHOLE TYPE I-48	EACH	1.00
11	48" TOP SLAB	EACH	1.00
12	4" PVC CONDUIT, SCHEDULE 40	L.F.	12.00
13	SCHEDULE A STORM SEWER PIPE 8 IN. DIAM.	L.F.	35.00
14	6" PVC PIPE	L.F.	15.00
15	6" PVC PERFORATED PIPE	L.F.	72.00
16	CRUSHED SURFACING TOP COURSE	C.Y.	20.00
17	CRACK SEALING	L.F.	236.00
18	HMA CL. 1/2 IN. PG 64-28, 0.17 FT. DEPTH	S.Y.	1,865.00
19	BIORETENTION SOIL MIXTURE	C.Y.	22.00
20	ASTM C-33 SAND	C.Y.	14.00
21	WASHED DRAIN ROCK; 1"-2"	C.Y.	6.00
22	NON-WOVEN FILTER FABRIC	C.Y.	35.00
23	30 MIL HDPE GEOMEMBRANE LINER	S.Y.	130.00
24	GRASS SEED INSTALLATION	S.Y.	150.00
25	CEMENT CONCRETE CURB TYPE B	L.F.	142.00
26	IRRIGATION SYSTEM MODIFICATION	L.S.	1.00



CELL MATERIAL DETAILS
NOT TO SCALE

NO.	DATE	BY	CKD.	APPR.	REVISION DESCRIPTION

SCALE: 1"=10'

DRAWN BY:	FARNSWORTH	SEPT., 2014
DESIGNED BY:	GONZAGA	SEPT., 2014
CHECKED BY:	ZARECOR	SEPT. 22, 2014

SPOKANE COUNTY

Spokane County Department of Public Works
1026 W. Broadway Ave. SPOKANE, WA
99260-0170
(509) 477-3600

APPROVED: ______
STORMWATER ENGINEER
ENGINEER
Date: ______

MATTHEW B. ZARECOR
STATE OF WASHINGTON
38216
REGISTERED
PROFESSIONAL ENGINEER

COUNTY STORMWATER PROJECT No: SWR 80-14
GONZAGA SWALE PROJECT
CURB CONSTRUCTION & GRADING INFORMATION
QUANTITIES AND IRRIGATION DETAILS

SHEET 3 of 3

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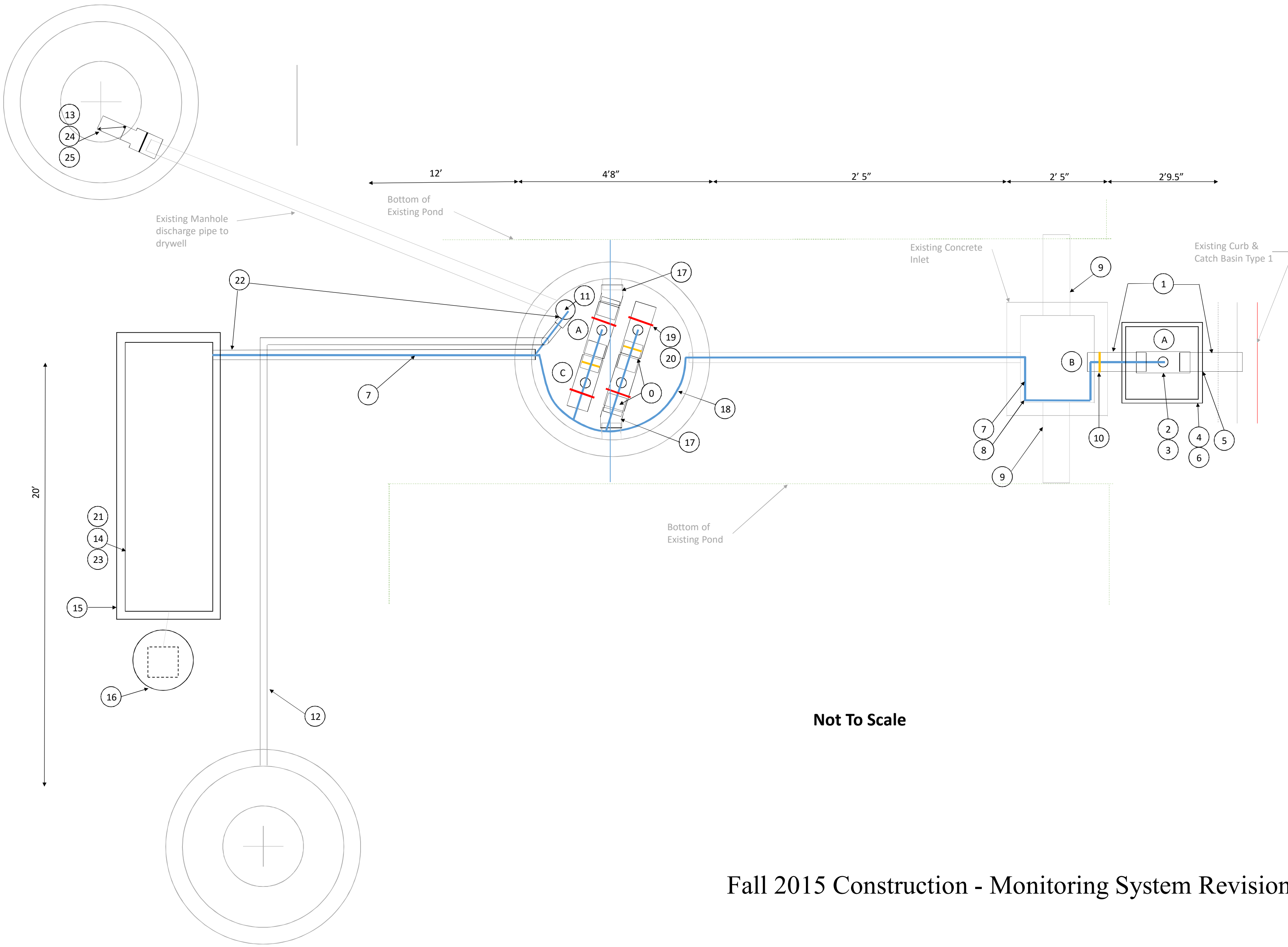

Not To Scale

Fall 2015 Construction - Monitoring System Revisions

Item Number	Item Description	Item Units	Total Item Quantity	Construction Notes
0	6" Storm Sewer Pipe, SDR35	LF	20	Install as part of item 1 and as part of effluent sample collection Tees in the existing 48" manhole
1	Replace Existing 8" Pipe with 6" Storm Sewer Pipe SDR35 (cut pipe in half and connect to Tee, item 2)	LS		Locate 6" pipe outside crown elevation to match existing 8" outside crown elevations at each catch basin & concrete inlet
2	6x6x6 Sewer Tee, solvent weld	EA	5	Prior to Installation Gonzaga will: cut 4"x5" opening into top of Tee (PT access & maintenance)
3	6" cap H; for SDR35 pipe	EA	5	Prior to Installation Gonzaga will: installed the PT support onto the inside of cap
4	NDS 24-inch square two opening catch basin (#2400)	EA	1	route 6" storm sewer through outlets with water tight seal around pipes; drill four 1/8" weep holes in bottom of basin , place basin on top of 4" gravel base (prevent standing water)
5	NDS 6-inch Universal Locking Outlet (#1266)	EA	2	
6	24" square, solid & lockable lid	EA	1	lid need to fit on NDS 24" catch basin; vendor reps have not responded and/or I have gotten the wrong lid. This lid needs to be solid (not a grate) because it will cover an open sample location
7	1-1/4" PVC conduit	LF	40	route sample tubing and PT cord in 1.5" PVC conduit from each sample collection point, through existing 4" PVC, to each ISCO sampler; also need a way to support 1.5" (zip ties to stormdrain?)
8	1-1/4" PVC 90 degree elbows and Tee	EA	12	use elbows and some Tees to connect length of 1.25" PVC pipe
9	Remove & reinstall two 8" storm sewer pipe (from concrete inlet to each pond) for flow equilizer weir installation	LS		Gonzaga will install flow equilizer weir and metal adjustment plates (water tight seal around weir).
10	Install Thel-Mar Weir	EA	3	Gonzaga will Install weirs ~12" downstream of connection to Tee (w/ PT) and after weir, allow a minimum 1" between the weir and another fitting.
11	Install Sump pump with float valve	LS	1	locate in bottom of manhole; needs power connection and connect to 2" discharge pipe from pump to dry well
12	1-1/4" PVC discharge pipe from sump pump to dry well (+ vent)	LF	40	install connection through existing manhole for pipe, locate pipe underground between manhole and dry well. Additional pipe bedding maybe required. Will also need vent in discharge line.

13	6" valve backwater PVC IPS (see Harrington Quote from 08/14/2015)	EA	1	Locate adapter, eccetric reducer, and backwater valve on the existing 8" SDR35 storm sewer pipe inside the drywell. During installation, slope valve down 1/4" so flapper valve is installed in the normally clossed position.
14	Fiberglass Expanded Equipment Enclosure; Tracom Model 200-060-80; 8"Wx23"Dx29"H; Cost includes optional adders including; green color, shelf, as well as breaker box and panel.	EA	1	Locate north and immediately adjacent to monitoring pond in the bottom of the existing pond. Enclosure shall be green and capable of locking. Additional equipment also needs to be installed to adapt enclsure for monitoring equipment setup including; part shelf (for data logger) as well as breaker box and panel. Install per manufacturers recommendations.
15	cast in place concrete pad for enclosure	LS	1	
16	Rain gauge stand/installation			Locate gauge near equipment enclosure and connect to data logger. Aime is still working on this item and will coordinate with Gonzaga Facilities and machine shop about making something that will work at the site.
17	11.5 degree couplings for 6" SDR pipe	EA	2	Connect to existing 6" effluent discharge pipe to adjust sampling and flow monitoring collection setup (double Tee configuration)
18	1.5" flexible PVC (sprinkler pipe?)	LF	15	Locate sample tube and PT cord inside flexible tubing and install 2 suports along inside of manhole. Constractor will also install
19	Pipe supports (constructed from Hayden	LF	20	Construct 4 pipe supports using channels and install into base of existing manhole. Secure 2 supports to each effluent discharge sample/flow monitoring collection setup using 6" strut clamps (2 per pipe).
20	FNW 7873 strut clamps for 6" SDR35 pipe	EA	4	see item 19 notes
21	Trickle Charger (any type that will support two 100AH 12V battery)	EA	2	Locate in equipment enclosure and connect to power supply. Chargers will connect to each of the 2 batteries
22	Power Supply/installation	LS		Gonzaga will provide power; contractor will coordinate with Gonzaga and locate power from source to equipment enclosure and manhole.
23	Install/connect monitoring equipment			Gonzaga will connect batteries to ISCO equipment and data logger. As well as mount Logger inside equipment enclosure.
24	8" adapter SPIGxH for PVC to SDR 35 (See Harrington Quote 08142015)	EA	1	see item 13
25	8"x6" couplling eccentric reducer for PVC Schedule 40 (See Harrington Quote 08142015)	EA	1	see item 14

Appendix C Single Ring Infiltrometer Test Method

APPENDIX 4D – SINGLE-RING INFILTROMETER TEST METHOD

PURPOSE

The single-ring infiltrometer test method is applicable for estimating infiltration and permeability rates of surficial soils to verify drawdown times in bio-infiltration swales and detention ponds.

PROCEDURE

1. Drive, jack, or hand advance a short section of steel or PVC pipe, at least 20 inches long and with a minimum inside diameter of 12 inches and a beveled leading edge, (referred to as a "ring" in this test method) into the soil surface to a depth of about 8 inches, leaving approximately 12 inches of pipe exposed above the ground surface. If after installation the surface of the soil surrounding the wall of the ring shows signs of excessive disturbance such as extensive cracking or heaving, reset the ring at another location using methods that will minimize the disturbance. If the surface of the soil is only slightly disturbed, tamp the soil surrounding the inside and outside wall of the ring until it is as firm as it was prior to disturbance.

2. Introduce clean water into the ring. Use some form of splash guard such as a sheet of thin aluminum or a diffuser apparatus such as a highly porous, non woven, geotextile fabric to prevent erosion at the surface of the soil during filling and testing. Monitor flow using an in-line flow meter. Before beginning the test, field check the accuracy of the flow meter by filling up a suitable container of known volume, such as a 5-gallon bucket or a 55-gallon barrel.

3. Raise the water level in the ring until a head level of at least 6 inches above the soil surface is achieved.

4. Monitor and record the flow rate required to maintain the constant head level at appropriate intervals. In no case shall the interval exceed 10 minutes in length.

5. Maintain the water level in the ring, by adjusting the flow rate, for a minimum of 2 hours or until a stabilized flow rate has been achieved, whichever is longer. Test time begins after the water level in the ring has reached 6 inches above the soil surface. The flow rate is considered stable when the water level in the ring is maintained and the incremental flow rate does not vary by more than 10%.

6. Upon completion of the constant-head period, discontinue flow, and monitor and record the water level in the ring at intervals of no longer than 5 minutes, for a 30-minute period.

7. One single-ring infiltrometer test shall be performed for every 2,500 square feet of bio-infiltration swale/pond bottom area or detention pond bottom area, with a minimum of one per swale or pond or as required by the local jurisdiction.

CALCULATIONS

1. Calculate the surface infiltration rate (I)

$$I = \frac{Q}{A} \qquad \text{(feet/second)}$$

Where: Q = stabilized flow rate observed near the end of the constant-head portion of the test (cfs); and,

A = area of soil inside the ring (square feet).

2. Compute the permeability rate (K)

$$K = \frac{(Q * L)}{(A * H)} \qquad \text{(feet/second)}$$

Where: L = depth of soil contained within the ring (inches);

A = area of soil inside the ring (square feet); and,

H = constant level of water within the ring, measured from the base of the ring to the free water surface (inches).