EFFECTIVENESS STUDY & SOURCE IDENTIFICATION PROJECT

Effect of Particle Size Distribution on Stormwater Characterization and BMP Effectiveness

PROPOSAL | MAY 15, 2020






Prepared by the Washington Stormwater Center – Washington State University

In partnership with Osborn Consulting, Inc. (OCI)

WSU is committed to completing the proposed scope of work on budget and on time.

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Dan Nordquist – Associate VP Research

Washington State University

May 12, 2020

1. PROJECT PURPOSE

Selecting a suitable stormwater BMP for a specific site is typically based on site constraints, receiving water body conditions, pollution generating surfaces, approved BMP functions, and regulatory requirements for runoff treatment and flow control. However, not all pollutant sources are the same with respect to pollutant types and loads, and not all BMPs are as effective across a range of conditions. In particular, particle size distribution (PSD) may vary, affecting the chemistry of stormwater runoff (e.g., ratio of particulate to dissolved contaminants, etc.), and subsequently the treatment mechanisms needed to reduce and/or control the total pollutant load. For instance, brush street sweepers are more effective at removing coarse sediment compared to fine particles that contain highly adsorbed contaminants like phosphorus and metals. **The purpose of this study is evaluate how pollutant types and loads vary with particle size, and summarize the pollutant removal mechanisms and effectiveness of a range of BMP types to develop a guide that will assist permittees towards selecting the most effective BMP for their site based on the anticipated particle size distribution.** Our approach to achieve this goal is as follows:

1. **Conduct a systematic review of available literature, databases, and regional reports to investigate and summarize available information on the following topics:**

    A. **Appropriate methods for measuring PSD**. Recommended sampling practices in the literature for PSD and suspended sediment will be researched and summarized. The information will be used to assess the quality and comparability of the data before including it in this study.

    B. **Influence of PSD on stormwater chemistry.** Stormwater chemistry will be evaluated as a function of PSD to aid in the estimation of more accurate pollutant loads. Weighting factors for land-use based loads will be assessed and developed. These load weighting factors could potentially be used in watershed plans, total daily maximum load (TMDL) studies, and for estimating BMP credits.

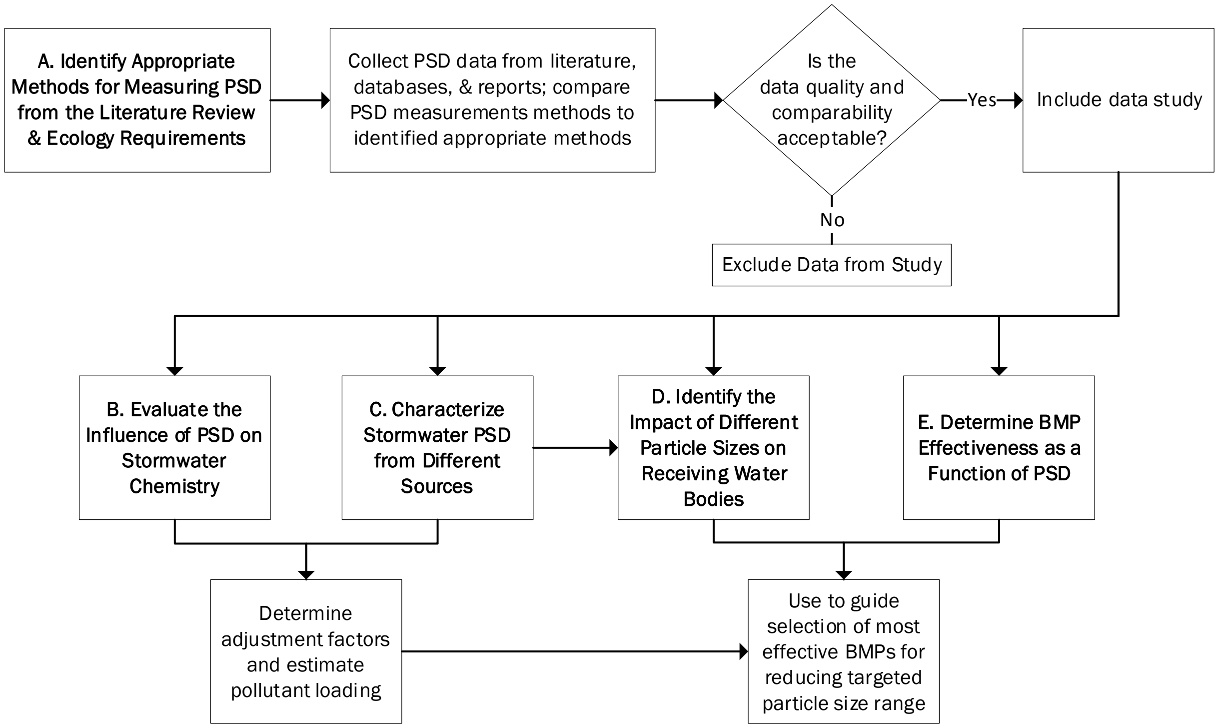
    C. **Characterization of stormwater PSD from different sources.** Building upon the jurisdictional conditions identified in the Structural Stormwater Control (SSC) project (led by the City of Tacoma and Osborn Consulting team), we will identify how site-specific conditions (e.g., land use, zoning, etc.) could influence particle size distribution. This information will be used to guide the estimation of the pollutant loads (Topic B) and the selection of BMPs (Topic E).

    D. **Impacts of different particle sizes to receiving water bodies**. We will identify stormwater related impacts on receiving water bodies based on specific ranges of particle sizes. This information will also be used to guide the selection of BMPs based on discharge locations (e.g. infiltration vs. surface water bodies).

    E. **BMP effectiveness as a function of PSD.** For structural, maintenance, and source control BMPs, we will report on BMP effectiveness based on the range of particle sizes. This information will be used to identify BMPs that are more effective at removing specific ranges of particles.

2. **Recommend how to incorporate the study findings into the current BMP selection process outlined in the Ecology Stormwater Manuals**. Specifically, we will provide guidance for selecting the most effective BMP for the respective PSD based on the contributing basin area (source) and discharge location (e.g. water body vs. infiltration).

Figure 1. Project Workflow



2. PROJECT DESCRIPTION & SCOPE OF WORK

TASK 1.0: PROJECT ADMINISTRATION AND MANAGEMENT

Task 1 focuses on providing project administration and management, which is expected to include tracking and reporting project costs; developing, managing, and adjusting the project schedule as needed; preparing quarterly progress reports and invoices; and general project communications and coordination. As noted in Figure 2 (Proposed Project Schedule) on Page 10, the expected duration of this proposed project is nine months from date funds are available. *A more detailed description of the work anticipated for this task is included in the Project Management Strategy Section of this proposal on Page 9.*

Table 1. Task 1 Deliverables and Schedule

Deliverable	Costs	Target Date
D1.1. Project Schedule	$2,900	2 weeks after contract execution
D1.2. 1st Status Report	$4,738	2 weeks after quarter end
D1.3. 2nd Status Report	$4,738	2 weeks after quarter end
D1.4. 3rd Status Report	$4,738	2 weeks after quarter end
TASK TOTAL:	**$17,114**	

TASK 2.0: LITERATURE SEARCH & SYNTHESIS OF LITERATURE

In Task 2, we will conduct a systematic review of available literature, databases, and regional reports to develop tables that summarize the data collected. Sources of data for this work will include the following: journal articles, the National Urban Runoff Program (NURP), the Highway Runoff Database (HRDB), the International BMP Database, local reports from completed effectiveness studies (e.g., Ecology, WSDOT studies) and studies conducted following Ecology's TAPE guidelines, the National Stormwater Quality

Database (NSQD), data files in the P8 model (http://www.wwwalker.net/p8) that provide summary tables of PSD data from many previous studies, and any reports or articles that support these databases. A draft list of potential sources has been compiled and is provided in Attachment 1. The specific areas of the literature search along with our approach are expected to:

A. Identify appropriate methods for measuring PSD.

The comparability and quality of data is a function of the methods utilized to collect, split, and measure PSD. If different monitoring, splitting, or laboratory methods were used, the datasets may be less reliable or might not be comparable. We will research and summarize recommended sampling practices in the literature for PSD and suspended sediment. Appropriate analysis methods will be identified by comparing and contrasting the reported methods to recommended methods like the PSD method defined in TAPE (ASTM 2007 Method D3977-97 modified Suspended Sediment Concentration using wet sieve filtration (Method C) and glass fiber filtration (Method B)). Next, we will rank the methods used in the available data sources and only data measured using highly ranked methods will be included in the study.

B. Identify the influence of PSD on stormwater chemistry.

The size of particles in stormwater is known to influence the chemistry of stormwater runoff. Typically, about half of the pollutants in stormwater runoff are transported in the particulate/sediment phase. Much of the particulate pollutant load is typically associated with the finer particles (<250 µm) but reported values vary by pollutant (e.g. lead, zinc phosphorus, PAHs on smaller particles with copper, and chromium on larger particles). We will identify how PSD affects the speciation and mass of different stormwater pollutants and identify the treatment mechanism needed to remove the respective pollutant. Next, we will determine the PSD effects on land-based pollutant loads to develop load weighting factors and use the PSD effects on BMP performance to develop potential performance adjustment factors.

C. Characterize stormwater PSD from different sources.

Understanding sources of pollutants is useful for predicting pollutant loading and selecting an appropriate BMP for a site. Common sources of suspended sediment particles will be identified by size range (e.g., atmospheric, windblown, runoff, etc.). We will also attempt to characterize PSD for these conditions and/or note variables that can influence PSD using common Western Washington jurisdictional conditions (identified from interviews during the SSC project).

D. Identify detrimental impacts of different particle sizes to receiving water bodies.

The stormwater related impacts on receiving water bodies will be identified for specific range of particle sizes. This information will be used to guide the selection of BMPs based on discharge locations (e.g., infiltration vs. discharge to water bodies). The information collected will also be used to assess the threshold for whether/when there is an environmental benefit to measuring the PSD for TSS and selecting BMPs based on effectiveness for PSD.

E. Determine BMP effectiveness as a function of PSD.

We will identify the specific types BMPs that will be included in this study which will be confirmed at the first TAC meeting. We envision including structural, maintenance, and source control types BMPs. For each BMP identified, we will develop a permit-related definition that includes the physical characteristics, treatment mechanisms, and stormwater related function. For BMPs included in the SSC Project, we will use that definition. We will also collect and synthesize BMP effectiveness data for a range of particle sizes.

Finally, we will develop tables that summarize BMP effectiveness as a function of PSD, sources, and discharge locations. This is expected to include consolidating the data/information in the table using basic statistics. A list of data sources will also be developed that summarizes the source related to how it was applied in this study, similar to Attachment 1.

Table 2. Deliverables and Schedule for Task 2

Deliverable	Costs	Target Date
D2.1 Synthesis of Literature	$16,097	Q2
D2.2 List of Data Sources	$4,467	Q2
D2.3 Data Summary Tables	6,208	Q2
TASK TOTAL:	**$26,772**	

TASK 3.0: SUMMARIZE, REPORT, AND COMMUNICATE FINDINGS

Findings from this study will be summarized into a white paper, factsheet, tables, and flow charts. The data tables developed (Task 2 D2.2 deliverable) will be summarized in a spreadsheet that documents all available information. Flow charts will be developed that can be integrated into the BMP selection process defined in the Ecology Stormwater Management Manual for Western Washington. The flow charts will assist permittees with select the most effective BMP based on site specific conditions and discharge locations. A white paper and factsheet will be developed to provide an overview of the work completed and report the study findings. Table 4 provides a proposed outline of the white paper.

Table 3. Task 3 Deliverables and Schedule

Deliverable	Costs	Target Date
D3.1 Draft Summary Spreadsheet with Flowcharts	$12,375	Q2
D3.2 Final Summary Spreadsheet with Flowcharts w/ TAC comments addressed	$3,055	Q3
D3.3 Draft White Paper	$17,243	Q2
D3.4 Final White Paper w/ TAC Comments Addressed	$3,625	Q3
D3.5 Draft Fact Sheet	$6,483	Q2
D3.6 Final Fact Sheet w/ TAC Comments Addressed	$2,152	Q3
D3.7 Draft/Final SAM Presentation; w/ TAC Comments Addressed	$5,529	Q3
TASK TOTAL:	**$50,462**	

Table 4. Proposed White paper Organization

Chapter Title and Description
Executive Summary Purpose: Provide an overview of the project, recommendations for applying results, and recommendations for future work. The Factsheet developed will serve as the Executive Summary.
Chapter 1. Introduction Purpose: Introduce the project and provide an overview of the White Paper contents.
Chapter 2. Why does PSD matter for stormwater? Purpose: Introduce particle size distribution (PSD), why it matters, recommend methods for sampling, splitting, and analyzing PSD.
Chapter 3. Data Sources for PSD Purpose: Summarize information on available PSD data sources (expansion of deliverable D2.3) and rate the quality of the data.
Chapter 4. PSD: Characterization from sources and impacts on receiving water bodies Purpose: Summarize sources of suspended sediment particles by size and/or note variables that can influence PSD. This section will also summarize the impacts of particle sizes on receiving water bodies and identify thresholds when consideration of particle size on BMP selection will provide benefits.
Chapter 4. Influence of PSD on pollutant loading Purpose: Summarize the effect of particle size on pollutant speciation, mass, and the potential effect of particle size distribution on pollutant loads.
Chapter 5. BMP effectiveness as a function of PSD Purpose: Define BMPs in the study and summarize how BMP effectiveness is affected by particle size distribution.
Chapter 6. How to apply study results Purpose: Describe how to apply study results utilizing the information provided in flow charts and tables.
Chapter 5. Conclusion Purpose: Provide a summary of the work completed and recommendations for future work/research.
Appendix • TAC Meeting Agendas, Minutes, and Responses to Comments • Tables and Flow charts

TASK 4.0: TAC COORDINATION

The goal of Task 4 is to form, coordinate with, and collect feedback from the TAC throughout the project. At the start of the project, we will finalize a committee of five to six TAC members. Potential TAC members have been identified and are listed in the box below. Nigel Pickering (PI) (WSU) will be the primary point of contact for the project and Aimee Navickis-Brasch (Osborn Consulting) will coordinate with the TAC.

Nigel and Aimee will attend all TAC meetings to support communication and coordination of project concepts. We envision three formal meetings with the TAC: 1) project kick-off meeting (see Project Management Strategy), 2) present and discuss Task 2 findings from the literature search, and 3) present and discuss the Task 3 draft deliverables prior to finalizing the documents. Prior to each meeting, draft deliverables will be submitted to the TAC for their review and comment, then we will meet with the TAC to discuss and ask questions about their comments. This process provides an opportunity to confirm our understanding of the intent of TAC comments before they are incorporated into the final deliverables. Preparation and follow up work for meetings includes developing and distributing a meeting agenda and meeting minutes to Ecology and the TAC and developing a table of responses to comments on the task deliverables.

Potential TAC Members:

- Melissa Ivanevich, City of Shoreline
- Abbey Barnes, Department of Natural Resources
- Dana Deleon, City of Tacoma
- Brandon Stone/Alex Nguyen, WSDOT

Table 5. Deliverables and Schedule for Task 4

Deliverable	Costs	Target Date
D4.1 Confirmed List of TAC Committee Members	$2,782	1st Month of Project
D4.2 Meeting Agenda & Minutes; Comment Responses	$6,380	Q1
D4.3 Meeting Agenda & Minutes; Comment Responses	$6,380	Q2
D4.4 Meeting Agenda & Minutes; Comment Responses	$6,380	Q3
TASK TOTAL:	**$21,922**	

3. PROJECT TEAM DESCRIPTION

The project team combines extensive experience studying stormwater problems and developing solutions. Nigel Pickering (PhD, PE) has a vast background in conducting and managing water quality and stormwater projects and research rom in the non-profit, consulting, and research sectors. Aimee Navickis-Brasch (PhD, PE) has extensive experience in stormwater research, design, planning, and policy development, which she utilizes as an applied researcher to develop solutions that can be applied to meet permit requirements.

The project team includes staff from Washington Stormwater Center and Osborn Consulting, Inc (OCI). Brief descriptions of their relevant expertise are included in this section.

The Washington Stormwater Center (WSC), as the designated stormwater center for the State of Washington (RCW.90.48.545), has built an integrated stormwater program over the past nine years. As a partnership between Washington State University and the University of Washington, the WSC's primary mission is to provide stormwater leadership through research, education, and training. The WSC works with a diverse array of partners from federal agencies like the National Oceanographic and Atmospheric Administration and the US Department of Fish and Wildlife; state agencies like the Department of Ecology and the Division of National Resources; to local entities like Cities of Tacoma and Puyallup, local schools, and non-profit agencies.

Faculty at WSC have conducted award-winning research in stormwater runoff toxicology, and effective stormwater treatment practices that is widely published and accessed internationally. In addition, WSC staff work closely with several municipalities and have become the central point for stormwater research, technical and educational information to ensure these stormwater permittees successfully comply with stormwater permits. WSC prides itself in providing information that meets the rigorous academic and peer-review standards of a large-research university.

In addition, WSU's land grant mission ensures that WSC's primary responsibility is the community and the people of the state of Washington. This land grant mission was recently articulated in the university's strategic plan as:

- Educating all people regardless of means or background;
- Performing scholarly activities that benefit the public and Washington residents; and
- Sharing our expertise and positively impacting people and communities.

WSC's role in this project will be to ensure that the same rigor and peer review standards that we currently use are applied to this project. As an independent entity, we can provide a level of transparency and independence in how the information for this project is analyzed and synthesized. In combination with our sub-consultant, we have the requisite skills and staff to complete this project satisfactorily and inform the State of Washington's future stormwater permits and design manuals.

OSBORN CONSULTING INCORPORATED

Osborn Consulting, Inc. (OCI) has extensive stormwater management experience, ranging from sizing stormwater BMPs to developing large stormwater capital improvement projects and planning efforts for local permittees. We consistently provide BMP effectiveness evaluation as part of this work, as well as the creative design and retrofits of detention, infiltration, and water quality treatment facilities. OCI provides stormwater research services for public agencies, which includes evaluating the effectiveness of stormwater management programs and specific BMPs, as well as the development of new treatment technologies.

Professionalism is a core value at OCI and making sure we provide a quality product to our clients is the foundation of that value. Quality control begins with the individual and every team member is responsible for the quality of his or her work. We have processes in place to verify procedures and results at every step, resulting in a final product that meets clients' expected value outcome.

KEY TEAM MEMBERS

Within the abbreviated resumes on the following pages, roles for the project key team members indicate the Tasks they will be leading. The project team is organized with the intent of providing collaboration and support across project team members and tasks to ensure a continuity of the project work.

NIGEL PICKERING, PhD, PE | WSU Principal Investigator & Project Manager for WSU; Task Lead for Task 2 items A, B, and part of C as well as write up for these items in Task 3 and overall Task 3 Lead Author

Education: PhD & MS Agricultural Engineering, Cornell University, Ithaca, NY. BS Agricultural Engineering, University of Natal, South Africa.

Licenses/Registrations: Agricultural Engineer, FL #51473; WA license held up at NCEES by COVID-19. Associate Civil and Environmental Engineering Professor, WSU.

Qualifications: Nigel Pickering has 33 years of experience in hydrologic/hydraulic modeling and land-based nutrient management. In Florida, he was involved with water quality modeling and monitoring projects and co-developed the Watershed Assessment Model (WAM). While in Massachusetts, he was a major contributor to watershed-scale projects including the statewide Water Budgets project and the Upper/Middle Charles River Total Maximum Daily Load (TMDL). Work in the last decade has focused on stormwater design, modeling, and research. He is currently an Associate Research Professor with WSC at WSU Pullman. He is effective at brainstorming innovative approaches to complex problems and experienced in leading, coordinating, and administering technical teams.

Past Project Performance:

- **Development of WSC-East (ongoing).** Lead regional representative for the WSC branch in eastern Washington. Developed a business plan for WSC-East. Developing future joint research projects with stormwater permittees.
- **Evaluation of Biofiltration Swale Media Mixes for Maximizing Phosphorus Removal (July 2019-Jun 2021).** Funded by WSDOT, this two-year research project is researching how to improve phosphorus removal from roadside swales. The study will investigate metal-based additives, peat materials, wood-based products, and shell-based products. Phosphorus adsorption will be evaluated using batch soil isotherms, laboratory soil columns and mesoscale roadside bioswales.
- **Design and Construction of Stormwater Wetlands, Medford and Milford, MA (2017).** Managed two state grants and a design team to create stormwater wetland practices to reduce phosphorus loads in Medford and Milford, Massachusetts.
- **Watershed Restorations to Meet Flow-Based TMDLs, VT (2012-2016).** Lead Scientist and Watershed Modeler to develop flow restoration plans (FRPs) for the watersheds of Centennial, Monroe, and Englesby Brooks. Efforts included field identification, conceptual design, and modeling of structural stormwater practices to meet the flow restoration targets using the Vermont BMP Decision Support System (VT-BMPDSS) model.
- **Promoting Green Infrastructure in the City of Chelsea, MA (2012).** Project Manager to assist US-EPA Region 1 in promoting the use of green infrastructure (GI) in the Chelsea. Reviewed existing City and State codes relative to the use of GI practices and suggested code improvements. Educated City staff members on benefits, limitations, and costs of GI and presented technical material at a targeted workshop.
- **Upper/Middle Charles Total Maximum Daily Load (TMDL) Project (2001).** Developed an HSPF water quality model for the Upper/Middle Charles River watershed for a nutrient TMDL. Provided full project oversight: management; sampling design/QAPP; streamflow monitoring; reach cross-sectional surveys, pond bathymetric/sediment surveys, aquatic plant assessment, HSPF model calibration/scenarios; public meetings, and final report.

AIMEE NAVICKIS-BRASCH, PhD, PE | Project Manager for OCI Team; Task Lead for Task 2 items D, E, and part of C as well as write up for these items in Task 3; Task 3 Supporting Author; Lead for TAC

Education: PhD, Civil Engineering, University of Idaho; MS, Civil Engineering, Washington State University; BS, Mechanical Engineering, Gonzaga University

Licenses/Registrations: Civil Engineer, WA #45258; Adjunct Civil Engineering Professor at Gonzaga University

Qualifications: Aimee has 27 years of experience in water resources and environmental engineering specializing in stormwater management including research, design, planning, policy development, and technical training. She has a comprehensive understanding of both regional and national stormwater regulations and practices and is the author of several stormwater publications, including the Washington State Department of Transportation (WSDOT) Hydraulics Manual and the Highway Runoff Manual. Her approach to research incorporates Community-Based Participatory Research, where researchers, permittees, and regulatory agencies collaborate to produce findings that comply with policy requirements and inform practical applications. Aimee combines a mixture of solid project management understanding and a deep technical vision while balancing stakeholder needs to meet schedules and budgets.

Past Project Performance:

- **Eastern Washington Effectiveness Study Development, City of Spokane Valley & Ecology.** Aimee, as PM/PI for this project, assisted EWA permittees in meeting the Phase II NPDES Municipal Stormwater S8 Monitoring & Assessment requirements. Her work included developing QAPP templates for structural, operational, and educational effectiveness studies.
- **Street Sweeping vs. Catch Basin Cleaning Effectiveness Study, City of Ellensburg.** Aimee, as PM/PI, developed the Ecology-approved QAPP, designed the test site, developed data collection SOPs, analyzed data, and developed the final technical evaluation report (TER).
- **Development of New Sand Filter Sidewalk Vault BMP, Spokane County.** Aimee, as the PM/PI for this project focused on developing a new treatment technology following TAPE developed the Ecology-approved QAPP; designed, operated, and maintained automated monitoring equipment; field data collection and analysis; led/coordinated with the TAC; and is developing the TER.
- **SSC Project Science Review and Synthesis Project, City of Tacoma & Ecology.** Aimee, as the PM for this recently awarded project, will lead a team of stormwater specialist and coordinate with Ecology and a TAC, to develop an objective science approach and white paper that will be used to inform NPDES MS4 permit requirements for SSCs.
- **Development and Evaluation of a Bioretention Soil Media for Reducing Stormwater Pollutants. City of Spokane.** Aimee, as the PM/PI, developed a bioretention soil media (BSM) amended with biochar for reducing regulated municipal and TMDL pollutants. This work included developing a QAPP, conducting flow-through column testing, final technical evaluation report, and a specification for the BSM that has been used for field construction of bioretention areas.
- **Evaluation of Constructed Stormwater Wetland (CSW) Design in Western Washington, WSDOT.** Aimee, as PM/PI, conducted a root cause analysis on CSW not complaint with the WSDOT High Runoff Manual (HRM). Results from the analysis were used to justify modifications to the HRM design guidance for CSW.

4. PROJECT MANAGEMENT STRATEGY

Nigel Pickering (PhD, PE) will serve as the Principle Investigator (PI) for the project, the Project Manager for the WSU tasks, and the primary point of contact. Aimee Navickis-Brasch (PhD, PE) will be the Project Manager for the OCI team. There will be monthly project check-in meetings via webinar with the Ecology Project Manager and internally between members of the project team. The project will begin with an initial two-hour kick-off workshop with the team leads, Ecology, and the TAC in order to:

- Confirm the vision and goals for this study
- Overview of the project tasks and deliverables
- Identify studies/reports to include in the project literature search
- Define communication protocols and process for reviewing deliverables
- Schedule project milestone deadlines and future meetings
- Confirm plan for coordination with the TAC (Task 4)

The team will utilize proven internal controls to ensure a streamlined delivery of on-budget and on-schedule tasks throughout the duration of this project. Nigel/WSU will use its accounting software to keep track of staff expenses and sub-contractor billing. WSU has many years of experience successfully working with large, data-related projects.

Aimee/OCI will utilize Deltek's Ajera software at OCI for project accounting and management. Aimee will employ OCI's established and proven QA/QC policy and manual that are used on every project, for every deliverable. OCI has extensive experience managing large data sets across multi-disciplinary teams.

The team will utilize standardized templates and tools for collecting and managing data to ensure consistency across all team members. We will develop a project folder on a secure shared WSU site that provides our team, Ecology, and the TAC access to the collected information and project deliverables. We will use a comment/response table that outlines a consistent format for comments and tracking responses.

5. PROJECT BUDGET & SCHEDULE

The following includes our proposed schedule and budget for this project. Estimated costs for each deliverable can be found within the Scope of Work section, Pages 2-6, and a budget summary by task is provided in Table 6 below.

Figure 2. Proposed Project Schedule

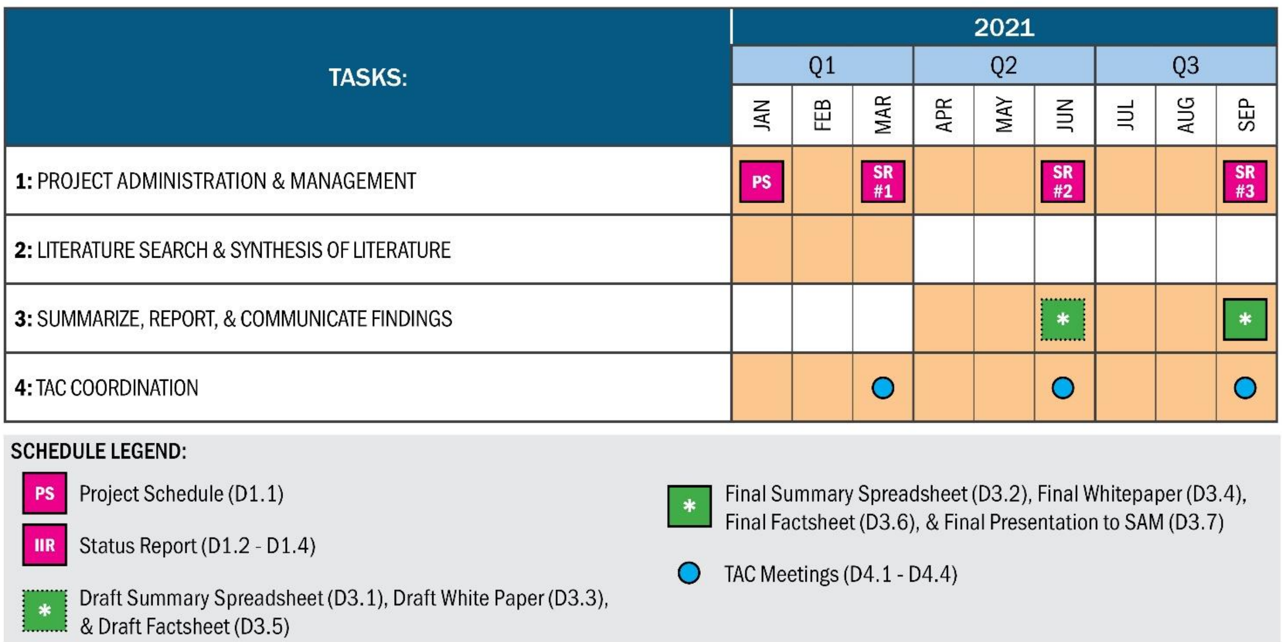


Table 6. Proposed Project Budget – Task Summary

Task #	Task Name & Deliverables	OCI Cost	WSU Cost	Total Cost
1	Project Administration and Management	$5,514	$11,600	$17,114
2	Literature Search & Synthesis of Literature	$14,602	$12,170	$26,772
3	Summarize, Report, and Communicate Findings	$27,681	$22,781	$50,462
4	TAC Coordination	$12,302	$9,620	$17,114
Total Estimated Cost		**$60,099**	**$56,171**	**$116,270**

ATTACHMENT 1 - POTENTIAL SOURCES FOR LITERATURE SEARCH

Reference	Methods for Measuring PSD	PSD Influence Stormwater Chemistry	Characterize PSD from Sources	PSD Impact on Water Bodies	BMP PSD Reduction Effectiveness
Anta, J., Peña, E., Suárez, J., & Cagiao, J. (2006). BMP selection process based on granulometry of runoff solids in urban catchments. Water Sa, 32(3), 419-428.			X		
Barrett, M. E. (2005). Performance comparison of structural stormwater best management practices. Water Environment Research, 77(1), 78-86.					X
Blott, S. J., & Pye, K. (2012). Particle size scales/classification of sediment types based on PSD: Review/recommended/procedures. Sedimentology.	X				
Brodie, I. M., & Dunn, P. K. (2009). Suspended particle characteristics in storm runoff from urban impervious surfaces in Australia. Urban Water Journal.		X		X	
Carbone, M., Garofalo, G., Malomo, S., & Piro, P. (2014). Stormwater Suspended Solids Reduction in Sand-Zelbrite Filter Media. Advanced Materials Research.					X
CDOT. (2008). Treatment BMP Tech. Report (Issue April). CALTrans.					X
Cha, S. M., Lee, S. W., Park, Y., & Kim, J. H. (2013). Characterizing particle size distribution of nonpoint source pollutants in an agricultural area. Desalination and Water Treatment.			X		
Clark, S. E., & Siu, C. Y. S. (2008). Measuring solids concentration in stormwater runoff: Comparison of analytical methods. Environmental Science & Tech.	X				
Deletic, A. (1999). Sediment behavior in grass filter strips. Water Science & Tech., 39(9), 129-136.		X			X
Ferreira, M., & Stenstrom, M. K. (2013). The importance of particle characterization in SW runoff. Water environment research, 85(9), 833-842.		X		X	
Ferreira, M., Lau, S.-L., & Stenstrom, M. K. (2013). Size Fractionation of Metals Present in Highway Runoff: Beyond the Six Commonly Reported Species. Water Environment Research.			X		
Fletcher, T. D., Duncan, H., Poelsma, P., & Lloyd, S. (2004). Stormwater flow and quality, and the effectiveness of non-proprietary stormwater treatment measures: a review and gap analysis. Technical Report, December, 1–171.					X
German, J., & Svensson, G. (2002). Metal content and PSD of street sediments and street sweeping waste. Water Science and Technology, 46(6–7), 191–198.			X		X
Gharabaghi, B., Rudra, R. P., & Goel, P. K. (2006). Effectiveness of VFS removal of sediments from overland flow. WQ Research Journal, 41(3), 275-282.					X
Guo, Q. (2006). Correlation of Total Suspended Solids (TSS) and Suspended Sediment Concentration (SSC) Test Methods. In Final Report, New Jersey Department of Environmental Protection (Issue November).	X	X			
Hall, K. J., Kiffney, P., Macdonald, R., Mccallum, D., Larkin, G., Richardson, J., Schreier, H., Smith, J., Zandbergen, P., Keen, P., Belzer, W., Brewer, R., Sekela, M., & Thomson, B. (1999). Non-Point Source Contamination in Urban Environment of Greater Vancouver: A Case Study of the Brunette River Watershed. Health of the Fraser River Aquatic Ecosystem, 109–134.		X	X	X	
Highway Runoff Database: https://www.usgs.gov/software/hrdb-highway-runoff-database-software-page			X		X
Hong, Y., Bonhomme, C., Le, M. H., & Chebbo, G. (2016). A new approach of monitoring and physically-based modelling to investigate urban wash-off process on a road catchment near Paris. Water Research.	X	X	X		
International BMP Database: http://bmpdatabase.org/					X
Karamalegos, A. M., Barrett, M. E., Lawler, D. F., & Malina, J. F. (2005). Particle size distribution of highway runoff and modification through SW treatment. Center for Research in Water Resources, University of Texas at Austin.			X		X

Reference	Methods for Measuring PSD	PSD Influence Stormwater Chemistry	Characterize PSD from Sources	PSD Impact on Water Bodies	BMP PSD Reduction Effectiveness
Kayhanian, M., Fruchtman, B. D., Gulliver, J. S., Montanaro, C., Ranieri, E., & Wuertz, S. (2012). Review of highway runoff characteristics: Comparative analysis and universal implications. Water Research, 46(20), 6609–6624.		X	X	X	
Kayhanian, M., McKenzie, E. R., Leatherbarrow, J. E., & Young, T. M. (2012). Characteristics of road sediment fractionated particles captured from paved surfaces, surface run-off and detention basins. Science of the Total Environment, 439, 172–186.			X		X
Kim, J. Y., & Sansalone, J. (2008). Particulate matter particle size distributions transported in urban runoff. Proceedings of the World Environmental and Water Resources Congress 2008.			X		
Lau, S.-L., Han, Y., Kang, J.-H., Kayhanian, M., & Stenstrom, M. K. (2009). Characteristics of Highway SW Runoff in Los Angeles: Metals and Polycyclic Aromatic Hydrocarbons. Water Environment Research, 81(3), 308–318.			X		
Lee, D., Min, K., & Kang, J., (2014). Performance evaluation; sizing method for hydrodynamic separators treating urban SW runoff. Water Science & Tech.					X
Leisenring, M., Pankani, D., Strecker, E., Clary, J., Earles, A., & Jones, J. (2015). Transferability of Post-Construction SW BMP Effectiveness Studies. July.					X
Li, H., & Davis, A. P. (2008). Urban particle capture in bioretention media. In Lab/field studies. Journal of Environmental Engineering, 134(6), 409-418.			X		X
Li, Y., Deletic, A., & Fletcher, T. D. (2007). Modelling wet weather sediment removal by SW wetlands: Insights from a lab study. Journal of Hydrology.					X
Li, Y., Lau, S. L., Kayhanian, M., & Stenstrom, M. K. (2006). Dynamic characteristics of particle size distribution in highway runoff: Implications for settling tank design. Journal of Environmental Engineering, 132(8), 852-861.			X		X
Li, Y., Lau, S.-L., Kayhanian, M., & Stenstrom, M. K. (2005). Particle Size Distribution in HWY Runoff. Journal of Environmental Eng, 131(9), 1267–1276.			X		
Liebens, J. (2001). Heavy metal contamination of sediments in stormwater management systems: the effect of land use, particle size, age. Environmental Geology, 41(3-4), 341-351.		X	X	X	
Markiewicz, A., Strömvall, A., Björklund, K., & Eriksson, E. (2019). Generation of nano/micro-sized organic pollutant emulsions road runoff. Environment Int.		X	X	X	
Marsalek, J., Watt, W. E., Anderson, B. C., & Jaskot, C. (1997). Physical and chemical characteristics of sediments from a stormwater management pond. Water Quality Research Journal of Canada, 32(1), 89–100.			X		X
Monrabal-Martinez, C., Muthanna, T., & Meyn, T. (2016). Seasonal variation in pollutant concentrations and PSDn in urban stormwater-design implications for BMPs.		X		X	
Nara, Y., & Pitt, R. (2005). Alabama Highway Drainage Conservation Design Practices-Particulate Transport in Grass Swales/Filters (UTCA Report 04117).					X
NAS (2006). Evaluation of BMPs for Highway Runoff Control. In NCHRP Report (Vol. 565). National Academies of Sciences, Engineering, and Medicine.					X
National Stormwater Quality Database (NSQD)			X		
National Urban Runoff Program (NURP)			X		X
P8 model - PSD data files: http://www.wwwalker.net/p8					X
Pitt, R. E., Bannerman, R., Clark, S., & Williamson, D. (2005). Sources of Pollutants in Urban Areas (Part 1) - Older Monitoring Projects. Journal of Water Management Modeling, 6062(Part 1).					X
Pitt, R. E., Bannerman, R., Clark, S., & Williamson, D. (2005). Sources of Pollutants in Urban Areas (Part 2) - Recent Sheetflow Monitoring. Journal of Water Management Modeling, 485–506.		X	X		

Reference	Methods for Measuring PSD	PSD Influence Stormwater Chemistry	Characterize PSD from Sources	PSD Impact on Water Bodies	BMP PSD Reduction Effectiveness
Pitt, R., Clark, S., Eppakay, V., & Sileshi, R. (2017). Don't Throw the Baby Out with the Bathwater—Sample Collection/Processing Issues Associated with Particulate Solids in SW. Journal of Water Management Modeling, January.	X				
Revitt, D. M., Lundy, L., Coulon, F., & Fairley, M. (2014). The sources, impact and management car park runoff pollution. Journal of Enviro Management Vol. 146		X	X	X	
River, M., & Richardson, C. J. (2018). Particle size distribution predicts particulate phosphorus removal. Ambio, 47(1), 124-133.		X			
Roger, S., Montrejaud-Vignoles, M., Andral, M., Herremans, L., & Fortune, J. (1998). Mineral, physical, chemical analysis solid matter motorway runoff. Water Research. 32(4). 1119–1125.			X		
Sansalone, J. J., & Kim, J. Y. (2008). Suspended particle destabilization in retained urban SW as a function of coagulant dosage and redox conditions. Water Research, 42(4-5), 909-922.		X	X	X	
Sansalone, J., Benty, J., Carrasco, E., Gulliver, J., Hathaway, J., Hunt, B., Kayhanian, M., Khambhammettu, U., Roseen, R., Rushton, B., & Williams, T. (2009). Field testing guidelines for certification of manufactured SW BMPs: Part II. Proceedings of World Environmental/Water Resources Congress 2009.	X				X
Selbig, W. R. (2015). Characterizing the distribution of particles in urban stormwater: advancements through improved sampling tech. Urban Water Journal, 12(2), 111-119.	X		X		
Selbig, W. R., Bannerman, R., & Corsi, S. R. (2013). From streets to streams: Assessing the toxicity potential of urban sediment by particle size. Science of the Total Environment.		X	X	X	
Selbig, W. R., Fienen, M. N., Horwatich, J. A., & Bannerman, R. T. (2016). The effect of PSD on the design of urban SW control measures. Water (Switzerland).					X
Smith, K., Sorenson, J., & Granato, G. E. (2018). Characterization of SW Runoff from Bridge Decks E. Massachusetts, 2014–16. USGS Scientific Investigations Report, 5033, 92.			X		
Stagge, J. H., Davis, A. P., Jamil, E., & Kim, H. (2012). Performance of grass swales improving WQ from HWY runoff. Water research, 46(20), 6731-6742.					X
TAPE Technical Evaluation Reports					X
Thompson, J., Sattar, A. M. A., Gharabaghi, B., & Warner, R. C. (2016). Event-based TSS particle size distribution model. Journal of Hydrology.			X		
Wang, Q., Zhang, Q., Dzakpasu, M., Chang, N., & Wang, X. (2019). Transferral of HMs pollution from road-deposited sediments to SW runoff during transport.		X	X	X	
Wang, Q., Zhang, Q., Dzakpasu, M., Lian, B., Wu, Y., & Wang, X. C. (2018). Development of an indicator for characterizing particle size distribution and quality of stormwater runoff. Environmental Science and Pollution Research.		X	X	X	
WA State Depart. of Ecology Completed Effectiveness Studies - NPDES MS4 permit requirements			X	X	X
Winston, R. J., & Hunt, W. F. (2013). Monitoring of representative PSD gross solids from roadways application to SCM design. World Environmental & Water Resources Congress 2013: Showcasing the Future - Proceedings			X		X
Winston, R. J., & Hunt, W. F. (2017). Characterizing runoff from roads: PSD, nutrients, gross solids. Journal of Environmental Engineering (United States).	X	X	X		
WSDOT Stormwater Monitoring and Effectiveness Studies: www.wsdot.wa.gov/environment/technical/disciplines/watererosion/reports-research			X		X
Ying, G., & Sansalone, J. (2008). Granulometric relationships for urban source area runoff function of hydrologic event class. & sedimentation. Water, Air, Soil Pollution, 193(1–4), 229–246.		x	X		
Yun, Y., Park, H., Kim, L., & Ko, S. (2010). Size distributions & settling velocities of suspended particles from road/highway. KSCE Journal of Civil Engineering.		x	x		

OSBORN
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DATE May 15, 2020

TO Dan Nordquist, Associate VP of Research, Washington State University

FROM Tarelle Osborn, PE, Principal, Osborn Consulting, Inc.

SUBJECT Letter of Commitment Regarding Stormwater Action Monitoring (SAM) Effectiveness Study & Source Identification Project

Dear Mr. Nordquist,

Osborn Consulting, Inc. (OCI) is committed to supporting the Washington Stormwater Center (WSC) to deliver the **Effect of Particle Size Distribution on Stormwater Characterization and BMP Effectiveness** study, funded by Stormwater Action Monitoring (SAM). We understand and are committed to meeting the schedule and budget of the project as described in the Request for Study Proposals and demonstrated in our team's proposal.

OCI's role on the consultant team includes the following, as described in the proposal:

- Task Lead for literature search regarding detrimental impacts of different particle sizes to receiving water bodies as well as the writeup for these items in the white paper.
- Task Lead for literature search regarding determination of BMP effectiveness as a function of PSD as well as the writeup for these items in the white paper.
- Task Support for literature search regarding characteristics of stormwater PSD from different sources as well as the writeup for these items in the white paper.
- Lead for development of flow charts.
- White paper and factsheet supporting author.
- TAC Coordination Lead.

Civil engineering for stormwater-driven projects is the core expertise provided by OCI. We have worked closely with permittees statewide for 15 years to develop innovative yet practical and cost-effective stormwater solutions. This experience allows us to efficiently evaluate site conditions, identify alternatives, and develop customized solutions to our clients' drainage issues, while also meeting Ecology's grant and stormwater management requirements.

Since 2004, OCI has successfully delivered innovative projects for our clients, including local cities, counties, ports, tribal districts, and neighborhood groups, as well as federal government agencies. We work collaboratively with our clients and project stakeholders to deliver high quality solutions to exciting design challenges in our region. Our locations in downtown Bellevue, Seattle, and Spokane allow us to provide our clients with quick response time and immediate accessibility to our experienced staff.

Sincerely,

Tarelle Osborn

Tarelle Osborn, PE
Principal
Osborn Consulting, Inc.