Quality Assurance Project Plan: Sharp Avenue Permeable Pavement Pollutant Removal Efficacy –SWMP Effectiveness Study

March 2019

City of Spokane, Washington
Wastewater Management Department
909 East Sprague Avenue
Spokane, Washington 99203

Quality Assurance Project Plan: Sharp Avenue Permeable Pavement Pollutant Removal Efficacy – SWMP Effectiveness Study

Prepared for:

Washington State Department of Ecology
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1.0 INTRODUCTION

Permeable pavement is a newly emerging stormwater best management practice (BMP) in Washington State. Some research studies have concluded it has been effective for flow control. However, little information exists regarding the treatment capacity permeable pavement could provide regarding water quality.

Increasingly, the focus of stormwater management has shifted from efficient disposal to treatment and infiltration. Stormwater and combined sewer overflows (CSO) have been identified as a major source of pollution to the nation's waterways. In a traditional regulatory and municipal setting, the sewer and stormwater systems are treated as separate entities with separate time frames for pollution reduction strategies. Currently, Ecology does not allow stormwater treatment credit for the permeable pavement itself, rather relying on the organic matter and cation exchange capacity of the soil below for treatment. Some evidence suggests that permeable pavements do provide treatment, but not enough data exists to substantiate full stormwater treatment credit.

The Sharp Avenue permeable pavement study supports the City of Spokane's overall investigation into the effectiveness of incorporating additional green infrastructure practices to manage stormwater. Other studies are planned or being conducted to gain better understanding of these practices and how they can be best suited for managing stormwater within our regional needs.

The City of Spokane is interested in gaining a better understanding of treatment capacity through the permeable pavement profile. The City proposes to evaluate the effectiveness of the permeable pavement system with respect to durability, infiltration rates, and water quality. In addition, the City proposes to design, construct, monitor, and maintain a permeable pavement system on an arterial street (Sharp Avenue) located in north Spokane. Sharp Avenue is located in a municipal separate storm sewer system (MS4) basin that discharges to the Spokane River. Furthermore, the City proposes to use two different types of permeable pavement: porous asphalt and pervious concrete.

2.0 BACKGROUND

The City of Spokane manages stormwater with infrastructures consisting of a MS4, combined sewer overflow (CSO), and underground injection controls (UIC). The combined sewer system collects and conveys both wastewater and stormwater to the Riverside Park Water Reclamation Facility (RPWRF). Stormwater flows to the CSO system predominantly on the south side of the City, where geology does not readily allow infiltration. During large storm events, the extra flow from stormwater can exceed the capacity in the collection system and RPWRF. Therefore, the excess combined stormwater and wastewater overtops flow regulators and discharges into the Spokane River. These combined sewer overflows are referred to as CSO.

Conversely, the City of Spokane's MS4 is a dedicated system to collect and convey only stormwater. It collects stormwater runoff from within City limits predominantly on the north side of the City and conveys it to the Spokane River and Latah Creek. It serves residential land use areas and receives limited runoff from commercial and industrial land use areas. It is a conventional stormwater system designed to efficiently remove excess water from the public right-of-way to prevent localized flooding.

Construction of the CSO collection system began as early as the 1890s and expanded as the City developed. The unpredictable and large peak flows of stormwater to the CSO system is a recognized issue, both for system capacity as well as water quality. In the 1980s and 1990s, the MS4 was constructed to alleviate stormwater flows to the CSO system. In addition, the City began constructing more infiltration facilities to further reduce stormwater flows to CSO basins, and that policy was enhanced with the adoption of the Integrated Clean Water Plan.

2.1 Spokane River Basin

The City is located in the Upper Columbia basin within the Spokane River watershed. The Spokane River begins at the outlet of Lake Coeur d'Alene, Idaho, and flows 112 miles westward to its confluence with the Columbia River. The Spokane River flows through multiple cities and urban areas in both Idaho and Washington, including Long Lake and the Spokane Indian Reservation, prior to discharging to the Columbia River. The Spokane River basin encompasses more than 6,000 square miles and the City encompasses only approximately 18 miles of the river. In addition, much of the Spokane region, upstream from Long Lake, is located above the Spokane Valley Rathdrum Prairie (SVRP) Aquifer. This sole-source aquifer provides drinking water to nearly half a million people. An interconnection between the Spokane River and SVRP aquifer exists as some reaches of the river feeds into the aquifer and the aquifer feeds into the river. This interconnection can be a potential contaminant migration through the ecosystem.

2.2 Permeable Pavement

Depending on the type of surface pavement, permeable pavement can be referred to as: porous asphalt, pervious concrete, or interlocking concrete pavers. Permeable pavement has several permeable layers and has the ability to store stormwater runoff until it infiltrates through the subgrade soil or is collected by an underdrain. Because permeable pavements have the ability to reduce runoff volume, they are typically used in low impact development (LID) designs as a stormwater best management practices (BMP). For permeable pavement to function effectively, there are many components that must perform and work well. These components include the physical and structural stability of surface pavement, the ability to handle traffic speed and loads, the ability to store stormwater within the aggregate beneath the pavement surface, the ability of the subgrade soil to infiltrate water, and the absence of clogging to ensure water infiltration and continuous functionality.

Design and construction of permeable pavement, regardless of the type of surface pavement, requires structural and hydrologic analysis with both requirements being satisfied in order for the pavement to function properly. Generally, the structural design of the pavement is performed to determine the thickness of the pavement and aggregate that is necessary to support the design traffic loads while protecting the subgrade from permanent deformation. The hydrological design determines the aggregate depth required to store a design volume of runoff that can be infiltrated into the existing subgrade at a rate sufficient achieve stormwater management objectives. An optimal permeable pavement design is one that is just strong enough to handle design traffic load and speed while maintaining the necessary porosity to provide sufficient stormwater management.

2.3 Regulatory Requirements

The Environmental Protection Agency (EPA) phase II regulations went into effect in early 2003 and apply to all regulated small MS4. In 2007, the Department of Ecology Washington State (Ecology) issued the first Eastern Washington Phase II Municipal Stormwater Permit (permit) to the City of Spokane. In 2012, the City received the current permit with an effective date of 2014. The permit requires the Stormwater Management Program to allow non-structural preventive actions and source reduction approaches such as LID techniques, measures to minimize the creation of impervious surfaces, and measures to minimize the disturbance of native soils and vegetation.

The Spokane River is an impaired waterbody with a Total Maximum Daily Load (TMDL) for metals (cadmium, lead and zinc), dissolved oxygen (phosphorus, ammonia, and CBOD), and sections of the river are also on Washington's Section 303(d) list for PCBs, chromium, arsenic, pH, temperature, and sediment bioassay.

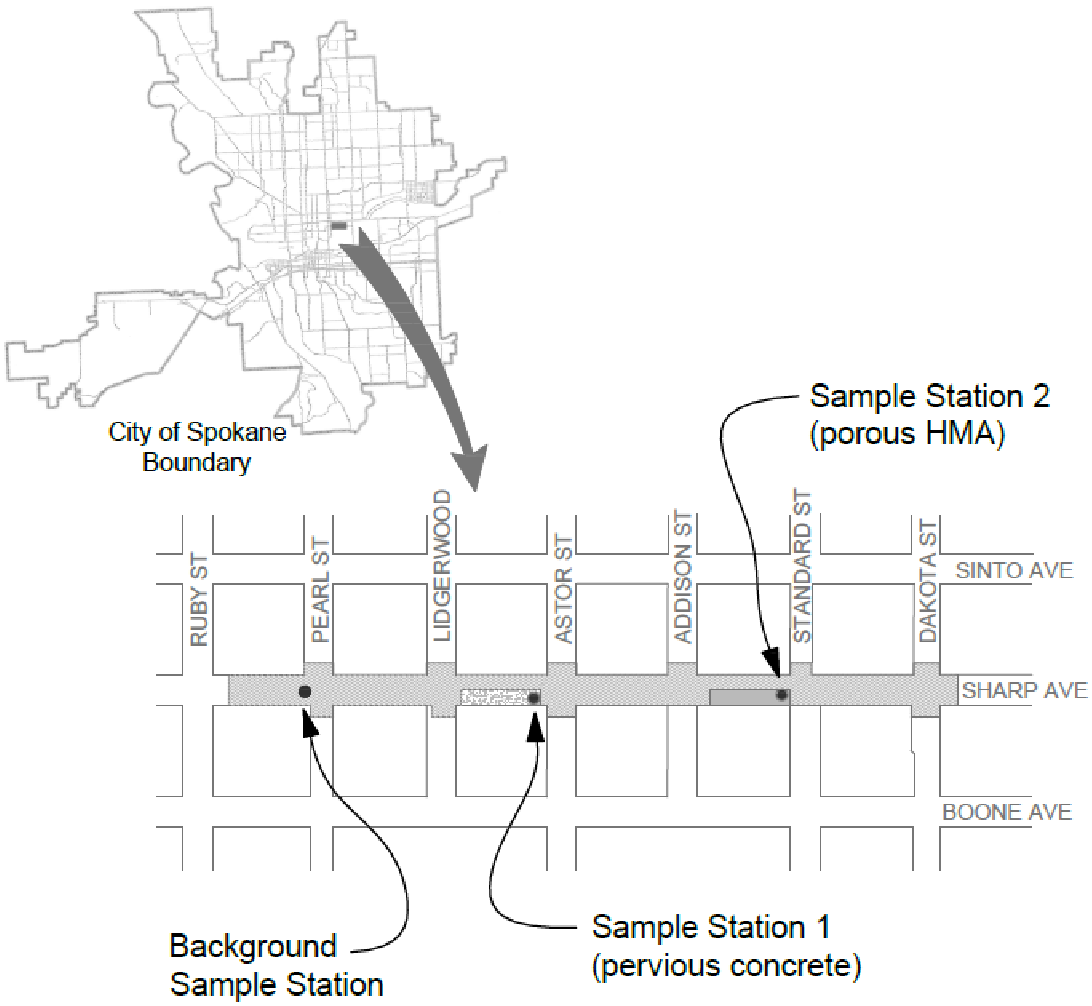
Furthermore, the City obtains its drinking water from the Spokane Valley Rathdrum Prairie (SVRP) Aquifer. This unconfined aquifer was designated by EPA as a sole source aquifer in the mid-1970s.

As a permit requirement the City adopted the *Eastern Washington Low Impact Development Guidance Manual June 2013* and ordinance that allowed for the exploration of LID approaches throughout the City. LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. It employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. Permeable pavement is an LID approach that the City is interested in developing a better understanding of its capabilities and effectiveness of treating stormwater runoff.

2.4 Project Location Area

Sharp Avenue is located in the northeast quadrant of the City in a primarily residential area. Runoff from within this stormwater basin typically flows to the Spokane River. The City proposes to improve Sharp Avenue from Pearl street eastward to Hamilton Street. The study is located in the Logan Neighborhood adjacent to Gonzaga University. Sharp is a minor arterial that connects major arterials: Division/Ruby to the west and Hamilton Street to the east. The Average Daily Traffic count for this portion of Sharp Avenue is 7,500 vehicles per 24 hour period.

Figure 1. Map Study Location Area



3.0 LOGISTICAL PROBLEMS

Weather conditions may not meet minimum "representative" storm criteria creating sampling issues. The timing of storm event sampling poses a problem as storm events within the Okanogan, Spokane, and Palouse region are sporadic. Hydrology in eastern Washington is highly influenced by landscape, topography, and precipitation. Across the region, much of the winter precipitation falls as snow which does not melt until warmer temperatures of spring that cause high-runoff to occur from April to June. By July, most of the mountain snow has melted and streamflow is low.

This region is comprised of inter-mountain areas and includes areas near Okanogan, Spokane, and the Palouse. It is bounded to the northwest by the contour line of 16 inches average annual precipitation at the base of the east slopes of the Cascade Mountains. It is bounded to the south and west by the contour line of 12 inches average annual precipitation at the eastern edge of the Central Basin. It is bounded to the northeast by the Kettle River Range and Selkirk Mountains at approximately the contour line of 22 inches average annual precipitation. It is bounded to the southeast by the Blue Mountains also at the contour line of 22 inches average annual precipitation. Furthermore, the intermittent storm events produce challenges of sample collection because a portion of the City could receive rain; and, other portions do not.

The unpredictable nature of storm events poses one of the greatest logistical challenges for this study. Only storms of particular rainfall volumes, antecedent dry periods, etc. will result in qualifying storm events and successful sample collection. However, the location, timing, duration, magnitude, and intensity of storm events cannot be forecast with certainty. Since long-term forecasts have greater uncertainty, mobilization of the sampling team and equipment setup for a potential storm sampling event cannot occur more than two days ahead of a forecasted storm. It is not uncommon that during long duration and intense monitoring studies, equipment malfunction and human error will result in unsuccessful sample collection of qualifying storm event.

3.1 Practical Constraints

Designing, constructing, monitoring, and maintaining permeable pavement systems are a new application for the City. The Eastern Washington region has not been accustomed to such systems and local suppliers have minimal experience with implementation and application. Unknown and unforeseen variables, outside of the City's control, could potentially affect this study; such as, but not limited to, construction delays, coordination with events at Gonzaga University, and weather conditions. Regardless, the City is interested in implementing and understanding this new application, and proposes to work towards minimizing such variables while accelerating our learning curve.

Monitoring water quality and flow utilizing underdrains beneath the permeable pavement and sub-bases are new concepts for the City. Sampling and monitoring runoff infiltrated into a collection system can be very challenging and the sampling design makes many assumptions about the ability to collect samples and monitor flow. Until equipment is designed, constructed, installed, and tested, the success of the sampling design is unknown.

Furthermore, qualifying events may need to be adjusted throughout the course of the study resulting from learned information. Sampling equipment has a limited volume capacity of nine liters. Coupled with inherently unpredictable weather conditions, this could result in limiting analyses for all constituents during sampling events. Some constituents could be measured during separate storms.

4.0 PROJECT DESCTIPTION

The intent of permeable pavement is to allow for precipitation and stormwater runoff to infiltrate into the subsurface. Therefore, the location of this study is its own catchment area or drainage basin. This drainage basin includes a portion of a minor arterial with Average Daily Traffic (ADT) count of 7,500 that is surrounded by residential and campus land use. The approach of this study is to collect stormwater infiltrated into the permeable pavements and associated sub-base via underdrains and piping conveyance systems to separate monitoring locations.

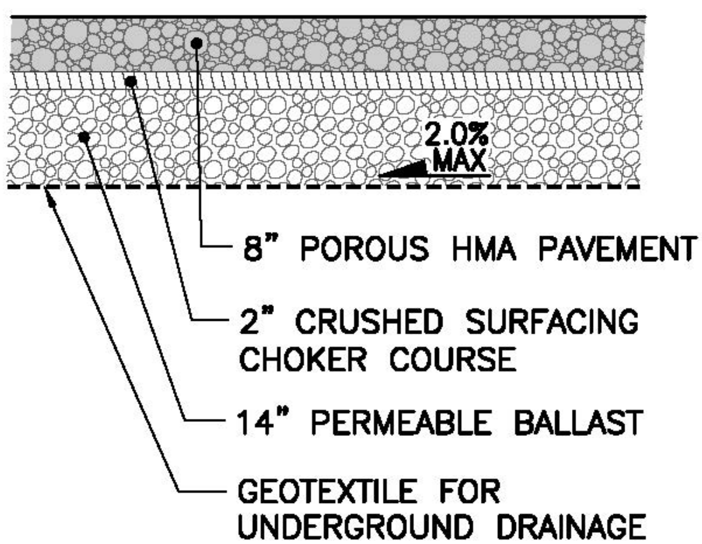
Two different types of permeable pavements have been constructed on Sharp Avenue: porous hot mix asphalt (HMA) and pervious concrete. Pervious concrete with associated sub-base materials was constructed on Sharp Avenue between the side streets of Lidgerwood Street and Astor Street, where a liner and underdrain were installed on the south side of Sharp Avenue to collect infiltrated stormwater for sampling. Porous HMA with associate sub-base materials was constructed on Sharp Avenue between the side streets of Addison Street and Dakota Street, where a liner and underdrain were installed on the south side of Sharp Avenue between Addison Street and Standard Street to collect infiltrated stormwater for sampling. In order to collect a background stormwater sample to determine the efficacy of pollutant removal by the permeable pavements, catch basins and conveyance piping were installed to the west of the permeable pavement areas in order to collect un-infiltrated stormwater runoff.

4.1 Sampling Design Overview

The goal of this study is to assess the effectiveness of permeable pavements with respect to durability, infiltration rates, and water quality of infiltrated stormwater effluents. The City will sample stormwater from three locations: 1) a background monitoring point on Sharp Avenue (Background Sample Station), 2) an infiltrated stormwater effluent monitoring point for the pervious concrete (Sample Station 1), and 3) an infiltrated stormwater effluent monitoring point for the porous HMA (Sample Station 2). Background constituent concentrations will be determined by monitoring stormwater runoff from impermeable pavement collected in catch basins and conveyed via piping to the Background Station for monitoring. Infiltrated stormwater effluent sample concentrations for the pervious concrete and porous HMA will be determined by monitoring the stormwater after infiltration through the permeable pavements and sub-base, and subsequently collected by the underdrains and conveyed via piping to be sampled at Sample Stations 1 and 2, respectively. Furthermore, the City will monitor durability and infiltration rates of the permeable pavements over time.

The porous HMA profile will be comprised of porous HMA, crushed surfacing choker course, permeable ballast, and an impermeable geotextile as illustrated by the following figure.

Figure 2. Porous HMA Profile



The pervious concrete profile will be comprised of pervious concrete, permeable ballast, and an impermeable geotextile as illustrated by the following figure.

Figure 3. Pervious Concrete Profile.

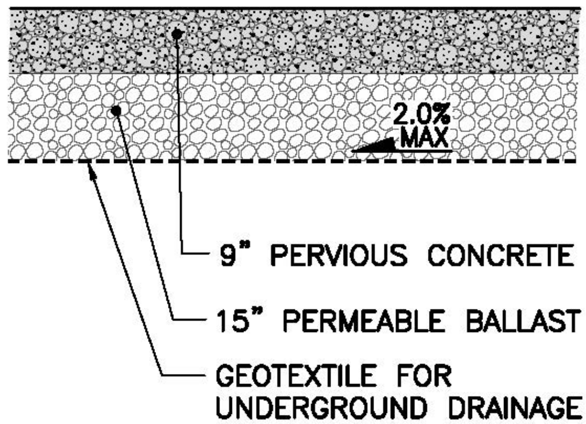


Figure 4. Sample Collection Profile of Both Pavements.

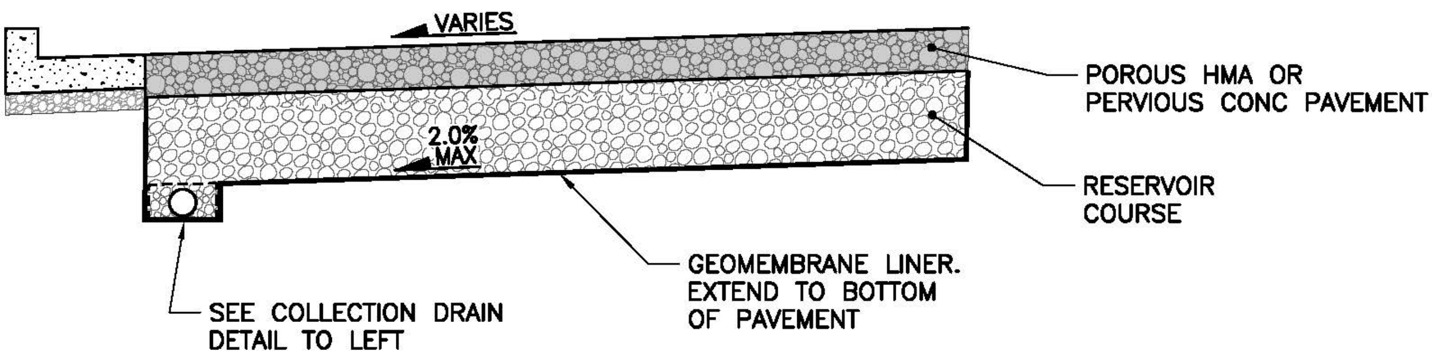
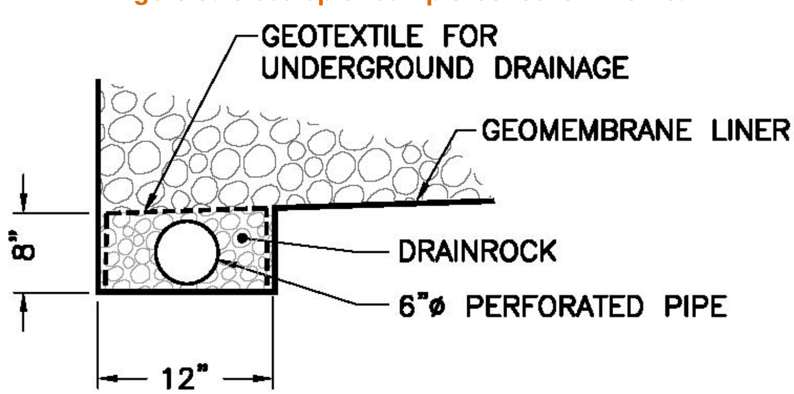


Figure 5. Close up of Sample Collection Profile.



In order to determine pollutant removal efficiencies for selected stormwater constituents, background samples of un-infiltrated stormwater runoff will be collected at the Background Sample Station, and compared to samples collected after infiltration through the pervious concrete and porous HMA pavement systems at Sample Station 1, and Sample Station 2, respectively. The objective is to review and determine pollutant removal efficiency, durability of the permeable pavements, and infiltration rate dynamics over time.

As detailed on Figure 1, the Background Sample Station is located just west of the intersection of Sharp Avenue and Pearl Street, Sample Station 1 is located just west of the intersection of Sharp Avenue and Astor Street, and Sample Station 2 is located just west of the intersection of Sharp Avenue and Standard Street.

4.2 Sampling Parameters of Interest

Pollution sources that may affect stormwater quality include land use activities, operation and maintenance activities, illicit discharges and spills, atmospheric deposition, and vehicular traffic conditions. Many of these sources are not under the direct control of a municipality that own or operate storm sewers.

Roadway and pavement runoff could contain organic and inorganic contaminants that can impair receiving water quality and disrupt aquatic and benthic ecosystems. Potential contaminants in roadway runoff include suspended solids, heavy metals, hydrocarbons, indicator bacterial and pathogens, and deicing salts. Runoff from roadways can contribute as much as 50% of the total suspended solids, 16% of the total hydrocarbons, and 35 to 75% of the total metal pollutants inputs to impaired receiving waters. The principal sources of contaminants in roadway runoff from roadways are atmospheric deposition (precipitation and dust fall), automobiles, and the road surfaces themselves. Samples will be analyzed for a suite of constituents including:

- pH
- Total suspended solids (TSS)
- Total and Dissolved Metals (arsenic, cadmium, calcium, chromium, copper, magnesium, lead, zinc)
- Hardness
- Total petroleum hydrocarbon
- Total phosphorus

These parameters assess the general quality of stormwater and may explain any outliers that are occasionally detected.

5.0 ORGANIZATION AND SCHEDULE

5.1 Roles and Responsibilities

This study developed a team that consist of representatives from key groups with varying roles in the design, construction, sampling, flow monitoring, data analysis, data evaluation, maintenance protocols, and reporting of the study. Team members include both internal and external members. Key group members consist of internal team members that will execute different protocols through the duration of this study depending upon which phase the study is currently in. For example, team members within the Construction Manager Engineer's group will carry out protocols needed during the construction phase of the study. Team members within the Flow Monitoring Manager's group will carry out protocols needed during flow monitoring and sample collection events.

The organizational structure is designed to provide project control and proper quality assurance/quality control (QA/QC) for field investigations. The roles of key groups and their responsibility in this study are presented in the following table.

Table 1. Roles and Responsibilities

Name:	Title:	Responsibility:
James George III City of Spokane Wastewater Management 509.625.7914	Project Manager	Develop, implement, and maintain the QAPP. Verify the QAPP is followed and the project is producing data of known acceptable quality. Supervision of all monitoring and data collection activities. Validate and verify data collected, monitor and determine qualifying sampling events, deploy sampling team, data analysis and prepare reports. Overall management of the City's NPDES Phase II compliance activities.
Johnathan Adams City of Spokane Engineering Design 509.625.6276	Study Engineer	Design and develop engineering plans and specifications of the study.
Joel Graff City of Spokane Engineering Construction Manager 509.625.7757	Construction Management Engineer	Manages and inspects the construction phase of the study. Ensures project was constructed per engineering design plans and specifications. Obtains the NPDES Construction Permit for the construction phase of the study.
Jeff Donovan City of Spokane RPWRF 509.625.4638	QA Manager	Oversee monitoring activities, including sampling data management, and documented summaries are complete for reporting purposes. Review laboratory data against the study specific QA/QC requirements.
Jon Eckhart City of Spokane RPWRF 509.625.4641	Laboratory Manager	Supervise laboratory personnel involved in generating analytical data for the RPWRF Laboratory and sampling team members. Ensure all QA/QC procedures are completed as required and documentation is accurate and complete. Enforce and implement corrective action as necessary.
Angela Tagnani City of Spokane RPWRF 509.625.4620	Laboratory Pre-Treatment Program Manager	Supervise laboratory personnel involved in generating analytical data for the RPWRF Pre-Treatment Program and sampling team members. Enforce and implement corrective

Name:	Title:	Responsibility:
		action as necessary.
Kyle Arrington City of Spokane RPWRF 509.625.4647	Laboratory QA Manager	Supervise and verify all aspects of QA/QC in the RPWRF laboratory. Validate and verify data before released from the laboratory.
Bruce Brurud City of Spokane RPWRF 509.625.4631	Flow monitoring Manager	Supervises flow monitoring activities. Ensure flow monitors, meters, and precipitation gauge equipment operation and maintenance. Enforce and implement corrective action as necessary.
Bill Peacock City of Spokane Wastewater Management 509.625.7902	Infiltration Rate Manager	Manage and oversee infiltration rate monitoring activities. Ensure procedures are completed as required and documentation is accurate and complete. Enforce and implement corrective action as necessary.
Gary Kaesemeyer City of Spokane Street Department 509.232.8810	Durability Manager	Manage and oversee durability monitoring activities. Ensure procedures are completed as required and documentation is accurate and complete. Manage and oversee operation and maintenance of street.
Raylene Gennett City of Spokane Wastewater Management 509.625.7900	Collection System Manager	Manage and oversee collection system operation and maintenance activities.

5.2 Special Training and Certifications

Sampling team members have a wide range of experience sampling wastewater and stormwater throughout the City's collection system. The RPWRF laboratory is a Washington State accredited laboratory for analysis of each of the constituents per the methods in the table provided in Section 5.6 Sampling Constituents. Also, contracted laboratories are Washington State accredited laboratories for the constituents per the methods listed in the table provided in Section 5.6 Sampling Constituents.

Sampling and flow monitoring team members installing or maintaining equipment will be exposed to weather conditions, traffic hazards, confined spaces, biological hazards (e.g. stagnant water), vector (e.g. spiders, rats), fall hazards, hazardous materials, fast moving stormwater, and slippery conditions. Sampling team staff will be required either to obtain or already process, necessary certifications such as Confined Space Entry and Flagger Certification.

5.3 Study Schedule

Sample collection and flow monitoring will occur on a long term basis starting after the finalization of this QAPP and Department of Ecology's (Water Quality Program) approval. There should be a minimum of at least five years' worth of sample and data collection. In addition, the Project Manager will determine if sampling beyond five years would be necessary. Also, after review of statistical analysis data, the Project Manager will determine if adjustment(s) in sampling frequency would be necessary. Furthermore, the Project Manager will also determine if a schedule for adaptive management is needed. The following table summarizes the study's tentative schedule. The schedule could be subject to change.

Table 2. Study Schedule

	When:	**Description:**
Prepare Study Design Proposal:	1st and 2nd Quarter 2017	Initial preparation of study design proposal
Final Design proposal Submittal:	June 30, 2017	**Due** to Ecology
Prepare QAPP:	6 months after Ecology's written approval of study design proposal	Initial preparation of QAPP
Ecology QAPP review:	2nd Quarter 2018	Ecology review and provide written comments to the City of Spokane
Final QAPP Submittal:	After Ecology's review and written comments were provided	Respond to comments and submit final QAPP to Ecology
Engineer design phase:	2017 through 1st Quarter 2018	Complete study design and bid the project
Construction phase: (Grant #WQC-2016-Spokan-00016)	2nd Quarter through 4th Quarter 2018	Construct the study project
Implement Monitoring:	6 months after Ecology's approval of QAPP and after construction is complete	Conduct stormwater monitoring through the end of the permit cycle
Evaluate Results:	After sampling events	Review analytical results
Annual Reporting:	March 30th of the year of completion	Upon completion, the final report and dataset will be included with that year's annual report
Final Report:	6 months after the study is completed	Summarize monitoring efforts and recommend future actions
Enter Data into International BMP database:	6 months after the study is completed	Enter applicable data collected into the International BMP database

5.4 Project Schedule Limitations

Stormwater sampling is inherently unpredictable because it is weather dependent. The frequency and timing of stormwater sample collection is very difficult to predict. Therefore, the schedule will need to be adaptive. Weather should be monitored continuously and sampling staff should be ready to deploy with little notice. Due to funding limitations, sampling and laboratory analysis will be conducted during normal working days (Monday through Friday excluding holidays).

5.5 Sampling Collection Frequency Schedule

A reasonable attempt will be made to collect stormwater samples from all qualifying events during the calendar year, with a maximum of 12 samples collected for the calendar year. The following table summarizes the sample collection frequency schedule.

Table 3. Tentative Sample Collection Frequency Schedule

When:	Frequency:
1st Quarter (January – March):	All qualifying events
2nd Quarter (April – June):	All qualifying events
3rd Quarter (July – September):	All qualifying events
4th Quarter (October – December):	All qualifying events
Total Samples (per year):	**≤12**

Sampling events should meet the qualifying criteria(s) and occur during the normal work week (Monday through Friday excluding holidays) due to availability of sampling personnel. Sampling frequency and schedule is weather dependent.

5.6 Sampling Constituents

The constituents identified in Table 4 will be monitored for this study.

Table 4. Summary of Sampling Constituents

Constituent:	Matrix:	Analytical Method:	Preservative:	Sample Container:	Laboratory:	Reporting Limit:	Holding Time:	Comments
pH	Water	pH: SM 4500-H+B	N/A	500 mL HDPE	RPWRF	4 – 10 s.u.	2 hrs	
Total Suspended Solids (TSS)	Water	SM 2540-D	≤6°C	1L HDPE	RPWRF	2.5 mg/L	48 hrs	
Total Metals (As, Ca, Cd, Cr, Cu, Mg, Pb, Zn)	Water	EPA 1638	HNO_3 to pH <2	250 mL HDPE	Eurofins Frontier Global Sciences	As (0.3 µg/L), Ca (0.1 mg/L), Cd (0.02 µg/L), Cr, Cu (0.1 µg/L), Mg (0.1 mg/L), Pb (0.04 µg/L), Zn (0.5 µg/L)	6 months	
Dissolved Metals (As, Ca, Cd, Cr, Cu, Mg, Pb, Zn)	Water	EPA 1638	HNO_3 to pH <2 after filtration	250 mL HDPE	Eurofins Frontier Global Sciences	As (0.3 µg/L), Ca (0.1 mg/L), Cd (0.02 µg/L), Cr, Cu (0.1 µg/L), Mg (0.1 mg/L), Pb (0.04 µg/L), Zn (0.5 µg/L)	6 months	Samples will be filtered in the lab using a 0.45 µm filter
Hardness	Water	SM 2340 B	HNO_3 to pH <2	500 mL HDPE	Eurofins Frontier Global Sciences	0.3 mg/L	6 months	
Total Phosphorus	Water	Low: EPA 365.3 High: SM 4500-PE	H_2SO_4 to pH <2, ≤6°C	1L HDPE	RPWRF	Low: 0.003 mg/L High: 0.059 mg/L	28 days	

Constituent:	Matrix:	Analytical Method:	Preservative:	Sample Container:	Laboratory:	Reporting Limit:	Holding Time:	Comments
Total petroleum hydrocarbons (NWTPH-Dx)	Water	Ecology 1997 (Pub. No. ECY 97-602)	HCl to pH <2, ≤6°C	8 fl. oz. Amber	Test America	0.25 mg/L	7 days	NWTPH-Dx will be collected using the Isco GLS composite sampler and noted in the lab report narrative

Note: EPA: Environmental Protection Agency; RPWRF: Riverside Park Water Reclamation Facility; SM: Standard Method; °C: degrees Celsius; mg/L: milligrams per liter; µg/L: micrograms per liter; NWTPH-Dx: Northwest Total Petroleum Hydrocarbon; As: Arsenic; Ca: Calcium, Cd: Cadmium; Cr: Chromium; Cu: Copper; Mg: Magnesium, Pb: Lead; Zn: Zinc

Equipment blank sampling will be included with sample collection activities. Equipment blank samples are to be collected once per calendar year early in the sampling season, and considered valid for the duration of this project. Equipment blank samples will also be analyzed for the constituents identified in the above table. The Project Manager will determine if adjustments to the sampling frequency, and quantity, of equipment blank sample collection are needed. New tubing will be used for each sample event.

If possible, replicate samples will also be included with sample collection. Replicate samples are to be collected once per calendar year for the background and effluent samples, which will result in an approximate 10% frequency of yearly samples. Replicate samples will also be analyzed for the constituents identified in the above table. The Project Manager will determine if adjustments to the sampling frequency, and quantity, of replicate sample collection are needed.

5.7 Budget and Funding

The City received state grant funding from the Department of Ecology for the engineering design and construction of the BMPs through the Stormwater Financial Assistance Program (Grant number WQC-2016-Spokan-00016). Funding sources for other attributes of this study will be budgeted and funded by the utility rates specifically from different utility departmental budgets depending on the attribute. Costs of other attributes include the development of this QAPP, purchase of automatic sampling and flow monitoring equipment, laboratory analysis of samples, personnel completing various protocols, data collection, data analysis, data evaluation, and reporting.

6.0 SAMPLING PROCESS DESIGN (EXPERIMENTAL DESIGN)

6.1 Design Area

Section 2.4 discusses the location of the study area, and Figure 1 illustrates the roadway being sampled for this study. The design area for sample collection of infiltrated stormwater is the south side of Sharp Avenue between the side roads of Lidgerwood Street and Astor Street for the pervious concrete, and Addison Street and Standard Street for the porous HMA. The background area for this study is just west of the intersection of Sharp Avenue and Pearl Street, which is to the west of the permeable pavement construction areas.

6.2 Field Measurements

Temperature and pH will be measured in the lab. These measurements will be obtained at the time the samples are collected at the end of each storm event and arrive at the lab. These measurements will be taken by portable meters. Meters will be calibrated prior to each sample event.

6.3 Storm Event Measurements

Rainfall/runoff curves will be developed for each sampling location in this study by monitoring the flow to each sample location for several initial storm events. The Isco GLS automatic samplers will be set up to collect flow weighted samples for each sample location using the information collected from several initial storm events, where the goal will be to collect 75% of the rainfall hydrograph over time as composite samples.

Rainfall measurements will be collected using an Isco rainfall logging system. These rain gauges use a tipping bucket method with precision sapphire bearings for accurate measurement. Gauges are connected with telemetry to allow nearly instantaneous data retrieval through the Flowlink Pro software.

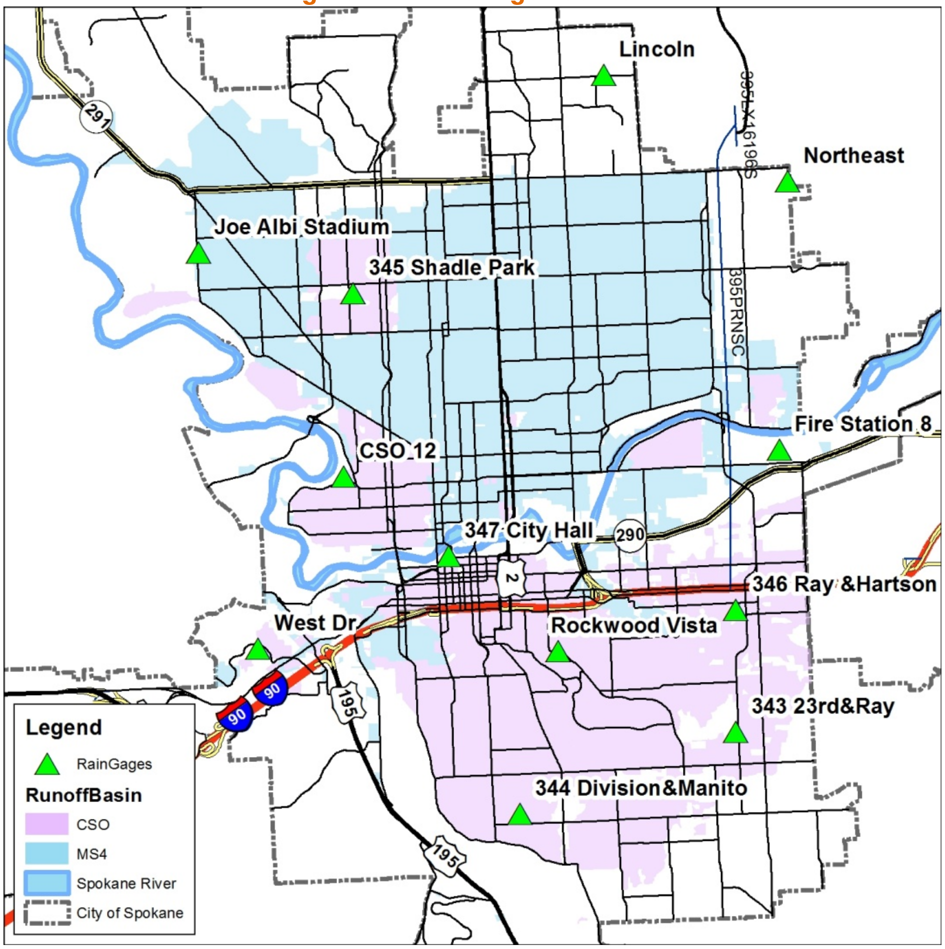
The locations of rain gages are illustrated in the following figure. Total rainfall for each sampling event is calculated by triangulating the three nearest gages to the Sharp Avenue Basin: City Hall, CSO12, and Fire Station #8. In the event that one of these gages fails, the next closest operational gage will be used.

The Inverse power of Distance Weighted Interpolation (IDW) method is used to calculate total rainfall in the Havana Street basin for each storm:

$$Po = \Sigma(P * W)/\Sigma W$$
$$W = 1/d^2$$

Where: P = precipitation
W = weighted distance
d = distance

Figure 6. Rain Gauge Locations



Note: The three closest rain gages to the study area basin centroid are the 347 City Hall gage (1.16 miles), CSO 12 gage (1.96 miles), Fire Station #8 gage (2.42 miles).

6.4 Composite Stormwater Samples

Automated sample equipment will collect samples into a pre-cleaned glass carboy for the duration of the precipitation event of each sample event, or until the approximately 9.4 liter volume of the sample carboy is reached, whichever comes first.

Samples will be transported to the RPWRF laboratory in the glass carboy, where proper aliquots per analyte will subsequently be poured off into appropriate containers per analytical analysis requirements. The RPWRF laboratory will prepare samples for shipment under chain-of-custody to contracted laboratories for analysis for constituents that cannot be analyzed at the RPWRF lab.

Sample sets will consist of laboratory-prepared bottles appropriate for each analysis. Sample bottles will be filled with the collected stormwater runoff samples and analyzed at the respective laboratory.

6.5 Storm Events

Sampling will be attempted for storms that are predicted to meet the following qualifying criteria*. The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service, Spokane forecast office website will be monitored for storm predictions (http://graphical.weather.gov/sectors/otx.php).

Qualifying wet season storm event goal (October 1 through April 30):

- Rainfall volume: 0.20" minimum, no fixed maximum
- Rainfall duration: No fixed minimum or maximum
- Antecedent dry period: Les than or equal to 0.05" rain in the previous 24 hours
- Inter-event dry period: 6 hours

Qualifying dry season storm event goal (May 1 through September 30):

- Rainfall volume: 0.20" minimum, no fixed maximum
- Rainfall duration: No fixed minimum or maximum
- Antecedent dry period: Less than or equal to 0.02" rain in the previous 48 hours
- Inter-event dry period: 6 hours

Storm Event Collection Goals:

- Collect at least 75% of the event hydrograph up to the first 24 hours
- At least 10 aliquots from each sample station
- Total volume between minimum sample volume and maximum carboy capacity (~9 liters)

**The Western WA Phase II permit qualifying storm events are a minimum of 0.2 inches for both wet and dry seasons (Ecology, 2012). The Western WA Phase II permit qualifying storm event criteria are being adopted for this study.*

6.6 Observing Rainfall Predictions

- Monitor the NOAA National Weather Service Forecast Office for Spokane, WA website when storm events are predicted. https://forecast.weather.gov/MapClick.php?lat=47.65889&lon=-117.425&unit=0&lg=english&FcstType=graphical
- Determine if predicted storm will meet qualifying event criteria.

6.7 Storm Event Staff Deployment

Field crews should be fully prepared to deploy when a qualifying storm event has been forecasted. Once deployed and onsite powder-free gloves should be worn and clean techniques practiced. Upon site arrival, field staff should perform field checks to ensure proper operation of the sampling equipment.

7.0 DATA QUALITY OBJECTIVES

All data should meet precision, recovery, and accuracy requirements specified in the laboratory method used. Each laboratory used for this study should maintain internal quality assurance/quality control procedures as documented in its laboratory quality assurance manual. Data represent the field site and are of a known precision, bias, and accuracy; and, have sufficient analytical sensitivity to achieve study objectives for decision making.

The laboratory will use a combination of blanks; laboratory control spikes, surrogates, and duplicates to evaluate analytical results. Instruments used to measure parameters temperature and pH will be calibrated before each sample event to ensure data quality objectives are met.

7.1 Decision Quality Objectives (DQOs)

Decision Quality Objectives (DQOs) are to select between two clear alternative conditions, or to determine compliance with a standard. The DQO for this study is to identify if stormwater loading from the permeable pavement profile meets state water quality criteria.

7.2 Measurement Quality Objectives (MQOs)

Measurement Quality Objectives (MQOs) specify how good the data must be in order to meet the objectives of this study. They are often obtained from the participating laboratories, and/or the analytical methods used. Data analyzed should meet the precision, recovery, and accuracy requirements specified in the laboratory method used. The laboratory maintains internal quality assurance/quality control procedures as documented in its laboratory quality assurance manual. Laboratories will use a combination of blanks, laboratory control spikes (LCS), surrogates, matrix spikes, matrix spike duplicates, and laboratory duplicates as appropriate for the method to evaluate the analytical results. The following tables detail the measurement quality objectives for this study.

Table 5. Laboratory Measurement Quality Objectives

Analyte:	Laboratory Blank:	CCV Recovery:	LCS Recovery (%):	Surrogate Recovery (%):	Laboratory Duplicate RPD:	Matrix Spike Recovery (%):	Matrix Spike Dup RPD:	Field Replicate
TSS	<2.5 mg/L	N/A	80-120	N/A	<30%	N/A	N/A	±30%
TPH NWTPH-Dx	<0.24 mg/L	N/A	50-150	50-150	N/A	N/A	N/A	±30%
Total Phosphorous	N/A	N/A	80-120	N/A	N/A	N/A	N/A	±30%
Arsenic, total	<0.3 µg/L	85-115	85-115	N/A	20%	85-115	<20%	±30%
Cadmium, total	<0.020 µg/L	84-113	84-113	N/A	20%	84-113	<20%	±30%
Calcium, total	<40 µg/L	80-120	80-120	N/A	20%	70-130	<20%	±30%
Chromium, total	<0.1 µg/L	85-115	85-115	N/A	20%	85-115	<20%	±30%
Copper, total	<0.1 µg/L	80-120	51-145	N/A	20%	51-145	<20%	±30%
Lead, total	<0.040 µg/L	91-109	72-143	N/A	20%	72-143	<20%	±30%
Magnesium, total	<3.0 µg/L	85-115	85-115	N/A	20%	80-120	<20%	±30%
Zinc, total	<0.5 µg/L	79-121	46-146	N/A	20%	46-146	<20%	±30%
Arsenic, dissolved	<0.3 µg/L	85-115	85-115	N/A	20%	85-115	<20%	±30%

Analyte:	Laboratory Blank:	CCV Recovery:	LCS Recovery (%):	Surrogate Recovery (%):	Laboratory Duplicate RPD:	Matrix Spike Recovery (%):	Matrix Spike Dup RPD:	Field Replicate
Cadmium, dissolved	<0.020 µg/L	84-113	84-113	N/A	20%	84-113	<20%	±30%
Calcium, dissolved	<40 µg/L	80-120	80-120	N/A	20%	70-130	<20%	±30%
Chromium, dissolved	<0.1 µg/L	85-115	85-115	N/A	20%	85-115	<20%	±30%
Copper, dissolved	<0.1 µg/L	80-120	51-145	N/A	20%	51-145	<20%	±30%
Lead, dissolved	<0.040 µg/L	91-109	72-143	N/A	20%	72-143	<20%	±30%
Magnesium, dissolved	<3.0 µg/L	85-115	85-115	N/A	20%	80-120	<20%	±30%
Zinc, dissolved	<0.5 µg/L	79-121	46-146	N/A	20%	46-146	<20%	±30%

Notes: mg/L: milligrams per liter equivalent to ppm; µg/L: micrograms per liter

Table 6. Equipment Blank QC Sample Quality Objectives

Analyte:	Equipment Blank
TSS	< 2.5 mg/L
Total Phosphorous	Low: <0.003 mg/L High: <0.059 mg/L
TPH NWTHP-Dx	< 0.25 mg/L
Arsenic, total	< 0.3 µg/L
Cadmium, total	< 0.02 µg/L
Calcium, total	<40 µg/L
Chromium, total	< 0.1 µg/L
Copper, total	< 0.1 µg/L
Lead, total	< 0.04 µg/L
Magnesium, total	<3.0 µg/L
Zinc, total	< 0.5 µg/L
Arsenic, dissolved	< 0.3 µg/L
Cadmium, dissolved	< 0.02 µg/L
Calcium, dissolved	<40 µg/L
Chromium, dissolved	< 0.1 µg/L
Copper, dissolved	< 0.1 µg/L
Lead, dissolved	< 0.04 µg/L
Magnesium, dissolved	<3.0 µg/L
Zinc, dissolved	< 0.5 µg/L
Hardness	< 0.201 mg/L

Note: Equipment blank analytical results above the sample quality objective values identified in Table 6 will be repeated until the results are below the identified values.

Table 7. Field Measurement Specification

Analyte:	*Instrument:*	*Measurement Range:*	*Accuracy:*	*Resolution:*
pH	Accumet	-1.99 to 19.99	± 0.01	0.01
Temperature	Accumet	0 to 100 °C	± 0.3 °C	0.1 °C

7.3 Targets for Precision, Bias, and Sensitivity

7.3.1 Precision

Precision is a measure of the variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Precision for laboratory duplicate samples will be expressed as relative percent difference (RPD). Precision for field replicate samples will be expressed as the relative standard deviation (RSD) for the group of duplicate pairs.

$$\mathrm{RPD} = \frac{|C_1 - C_2|}{\bar{x}} \text{ x } 100\%$$

Where:

RPD = relative percent difference
C_1 = concentration of original sample
C_2 = concentration of duplicate
$\bar{x}$ = mean of samples

7.3.2 Bias

Bias is the difference between the population mean and the true value. Bias affecting laboratory measurement procedures can be inferred from the results of QC procedures. Bias in field measurements and samples will be minimized by strictly following measurement, sampling, and handling protocols. Field sampling precision bias will be addressed by submitting replicate samples.

Field Bias

Bias from meters used in the field will be consistently evaluated using calibration methods. Sampling bias will be minimized by adhering to procedures outline in this QAPP.

Laboratory Bias

Laboratories use method blanks and matrix spikes to identify potential laboratory or sample matrix biases affecting results. Laboratory method blanks should not exceed the reporting limit. The targeted range for percent recovery of matrix spikes and matrix spike duplicates are presented in Table 3.

7.3.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as detection limit. In a regulatory sense, the method detection limit (MDL) is usually used to describe sensitivity. Targets for field and lab measurement sensitivity required for the project are listed in Tables 3 through 5.

7.4 Targets for Comparability, Representativeness, and Completeness

7.4.1 Representativeness

Representativeness ensures that the study includes samples that are representative of existing conditions. Samples should be collected during all seasons, representing a proportional amount of spring, summer, fall, and winter rainfall conditions.

7.4.2 Completeness

Completeness is a measure of the amount of valid data needed to be obtained from a measurement system. The goal for this study is to correctly collect and analyze all of the samples for each of the sites. However, problems occasionally arise during sample collection that cannot be controlled. Therefore, a completeness of 95% is acceptable.

8.0 SAMPLING (FIELD) PROCEDURES

This section describes field procedures that will be utilized to ensure that samples are collected in a consistent manner, are representative of the matrix being sampled, and that the data will be comparable to data collected by other existing and future monitoring programs.

The quality of data collected in an environmental study is critically dependent upon the quality and thoroughness of field sampling activities. General field operations, practices, and specific samples will be planned, implemented, and follow specific standard operating procedures (SOPs) that support automatic sampling. Stormwater sampling procedures are based on data collection methods adapted from Ecology's Standard Operating Procedures for Automatic Sampling for Stormwater Monitoring Version 1.1 (Ecology, 2018).

8.1 Equipment Decontamination Procedures

8.1.1 Sample Bottles

The RPWRF and contracted laboratories will provide sample collection containers for collecting stormwater samples. Containers, jars, and lids will be pre-cleaned and certification information will be kept with the RPWRF laboratory information.

8.1.2 Automated Sampling Equipment

Prior to deployment, all sampling equipment, will be cleaned by running the following solutions through the equipment:

- Hot soapy water (liquid-Nox or equivalent)
- Hot water
- 5% nitric acid
- Reagent grade water

After decontamination, the sampling equipment will be wrapped in plastic bags until placed in the field. Equipment rinsate blanks will be performed by running enough reagent grade water through sampling equipment into a pre-cleaned container until sufficient volume is collected to run the analytes of interest.

Rinse blank performance will determine if the correct decontamination procedures is sufficient for the project.

8.2 Sampling Handling and Custody

Sample handling and custody procedures ensure that uniquely identifiable samples are transported to the analytical laboratory with appropriate preservation within prescribed holding times and with proper documentation. Written documentation of sample custody from the time of sample collection through the generation of data by analysis of that sample is recognized as a vital aspect of an environmental study. All personnel involved with handling the samples will be wearing appropriate gear (e.g. powder free rubber gloves) through sample handling activities. The chain-of-custody of the physical sample and its corresponding documentation will be maintained through the handing of the sample by following the procedures outlined below.

8.2.1 Sample Identification

All samples will be clearly labeled with indelible ink. Each sample will be uniquely identified by a nomenclature system maintained and implemented by the RPWRF laboratory. The standard format is YY-NNNNN, where YY is the two digit year and NNNNN is the count of samples processed through the lab for that year, beginning at 00001. In addition, all sample containers will be labeled with date, time, sample number, sampling team initials, and sample analytes.

8.2.2 Sample Transportation

The sampling team will retrieve collected samples will be place on ice or cooling gel packs, and transported as soon as possible to the selected analytical laboratory. For all samples shipped to laboratories, samples will be placed in coolers and placed on cooling gel packs. Copies of shipping papers will be taken prior to shipment and will be a component of documentation for this study.

8.2.3 Sample Preservation

Other than ice or cooling gel packs, sample preservation will not be required in the field. Chemical preservatives are provided in sampling containers and/or added to the samples for certain analyses to prolong the stability of the parameters during transport and storage. For composite sampling, no preservatives are added to the composite container because no single chemical preservative is suitable for all of the parameters to be analyzed. The laboratory must first divide the composite sample into the appropriate bottle for each analysis, and then add chemical preservatives (if not already provided in the sample container) as appropriate for each analysis.

8.2.4 Sample Processing

In general, all samples will be minimally processed in the field to prevent potential contamination from trace pollutants in the atmosphere. Samples will be transported to the analytical laboratory as soon as possible after sample collection.

8.2.5 Holding Times

Holding times are short for some parameters and long for others. Table 3 summarizes holding times for analyses. To minimize the risk of exceeding holding times, the QA Manager will coordinate with the analytical laboratory, and the sampling team, prior to each sampling event to ensure that the laboratory is prepared to begin processing samples, or begin prepping samples for submission to contracted laboratories, as soon as samples are received. In addition, samples will be delivered to the laboratory immediately after retrieval from field equipment.

8.2.6 Chain-of-Custody Forms

A chain-of-custody form will accompany each sample batch that is delivered to the laboratory. The purpose of chain-of-custody (COC) forms is to keep a record of the sample submittal information and to document the transfer of sample custody. The COC forms used in this study will include sample location identifier, analyses to be performed, and any special considerations, such as analyses priority order and sample filtration needs. At the time of sample collection, the sampling team will record the sample date and time, sample location, matrix, and analyses requested. The COC form must be signed by both the person relinquishing the samples and the person receiving the samples every time the samples change hands, thus documenting the chain-of-custody. During non-work hours, samples will be stored in a refrigerator at the RPWRF laboratory until custody officially changes hands.

For replicate and equipment blank samples, these samples will not be specifically identified on the COC (e.g. replicate sample or equipment blank sample) form that will be submitted to the laboratory analyzing the samples. But rather distinguished and documented in field sampling notes.

8.3 Sample Equipment Installation

All sampling equipment will be decontaminated prior to installation. Assemble the sampler. Set the intake adjusting screen to allow appropriate intake flow. Ensure the center port valve is in the closed position. Install the sampler by handing it below the cover or setting it on a pre-installed supportive structure located at the proper elevation to allow sample collection.

8.4 Sample Equipment Retrieval

At the end of the storm event, sampling team will retrieve sampling equipment. Upon arrival, inspect all components of the sampling system to ensure samples were properly collected. If any warranted conditions were found, note conditions in field notes. Visually inspect the components of the sample structure for damage and/or clogging.

Retrieve the sampler equipment from the sampling structure. Gently shake the sampler. Use the center port valve located on the bottom of the sampler to transfer the sample to the laboratory prepared jars. Conduct field measurements using the equipment manufacturers' instructions. Calibrate the equipment prior to collecting field measurements. Immediately transport samples into sample storage area and/or laboratory.

8.5 Infiltration Testing

Staff within Wastewater Management's engineering group will complete infiltration testing annually during the spring season. Baseline infiltration testing should be performed to quantify surface infiltration rates of each permeable pavement immediately following the construction phase. Different locations of infiltration testing will be determined at the time of baseline infiltration testing. GPS coordinates of each location will be recorded such that the same location can be repeated over the course of the study. Locations should not be in areas that are lined with an impermeable liner for water quality sampling. The following table summarizes quantity of locations.

Table 8. Infiltration Testing Location and Quantity

Pavement Type:	Location:	Quantity:
Pervious Concrete	Parking lane	3
	Travel lane	4
Porous HMA	Parking lane	3
	Travel lane	4
	Intersection	2
Total Locations:		**16**

Infiltration testing will follow procedures as described in ASTM C1701/1701M –09 Standard Test Method for Infiltration Rate of In Place Pervious Concrete. The ASTM standard is presented in Appendix A.

The field data from each test will be recorded on standardized forms and used to determine the infiltration rate at each test location. The Project Manager will coordinate with the Key individuals in Wastewater Management and determine if adjustments to infiltration

8.6 Durability Measurements

Staff within the Street Department will complete durability measurements, referred to as pavement condition index. Durability measurements should be completed twice a year. Street Department adopted the Washington State Department of Transportation (WSDOT) Field Rating Manual and is presented in Appendix B. The Street Department will follow the field rating manual when completing pavement condition index procedures.

In addition, the Street Department uses a rating cheat sheet while completing field procedures. The field data will be collected and entered into the Pavement Management System (StreetSaver) computer software program, maintained by the Street Department. The program calculates a pavement score with a rating system of 0-100. This is a general rating system that does not account for all variables associated with street conditions. The purpose of the rating system is to determine the condition(s) of a street that are evaluated by Street Department. The definition of each score is as follows:

Table 9. Pavement Condition Index Rating

Rating:	Condition:
<25	Failed
26-50	Not good
>50	Fair
>70	Good

Note: <: less than; > greater than

Street Department will use the pavement condition index for both the pervious and impervious street materials during inspections. The impervious (HMA) material will be the baseline and compared to the permeable materials. The rating cheat sheet is presented in Appendix C. The Project Manager will coordinate with the Key individuals in the Street Department and determine if adjustments are needed.

9.0 MEASUREMENT PROCEDURES

The section describes the analytical methods to be used for each constituent, the reporting limits for each constituent, the frequency of analysis, number of samples to be analyzed, needed sample volume, container type, holding time, and preservation. All laboratories analyzing constituents will be accredited by the Washington Department of Ecology Laboratory Accreditation Program for the constituents to be analyzed. The Project Manager will obtain and maintain current copies of laboratory certifications throughout the duration of this study.

9.1 Analytical Methods, Reporting Limits, and Containers

Section 5.6 Sampling Constituents details sample container type, holding time, preservative and reference for each constituent to be analyzed.

9.2 Sample Volume Requirements

A significant sampling design concern is the ability to obtain adequate sample volume to complete the selected analyses. This section discusses the selected parameters, the volumes required to analyze those parameters, and the priority order in which analyses will be completed. Section 5.6 Sampling Constituents summarizes the estimated volumes needed for stormwater analytical chemistry samples.

If volume of stormwater sample collected from a qualifying storm is insufficient to allow analysis for all parameters detailed in Section 5.6 Sampling Constituents, samples shall be analyzed for as many parameters as possible starting from top down in Table 4.

10.0 QUALITY CONTROL (QC) PROCEDURES

Samples will be analyzed using the designated EPA method or Standard Methods. Chain-of-custody procedures will be followed for samples submitted to the laboratory. The quality control procedures outlined in the RPWRF laboratory SOPs will be followed.

10.1 Field and Lab QC Required

Laboratory QC samples are described in Section 7.0 Data Quality Objectives. Field QC samples include equipment blanks and field replicate samples. Sampling equipment will not be cleaned in the field.

10.2 Corrective Action Processes

Each laboratory will provide a summary of all QA/QC results. The QA/QC summary will be reviewed by the laboratories own designated personnel and the QA Manager to assess the adequacy of the quality control checks and to identify any potential problems.

Any blank, duplicate or spike results that are out of acceptance ranges will be denoted with data qualifier flags. If method criteria are not met, the laboratory should take appropriate corrective action including re-extraction if necessary.

11.0 DATA MANAGEMENT PROCEDURES

11.1 Documents and Records

There will be different types of documentation that will be managed that includes

- Field Operation Records
- Laboratory records
- Data handling records
- QAPP

11.2 Field Operation Records

11.2.1 Water Quality Sample Collection

Sample log sheets will be completed by the sample collection team members during sampling activities. The sheets will serve as a daily record of events and observation during sampling activities. All information pertinent to sampling activities will be recorded on the sample log sheet. Sample log sheets will be maintained by sampling staff at all times documenting activities and conditions. In addition, photographs of field and samples collection activities will be completed for the project file. Copies of all sample log sheets and photographs will be made following each sampling event and maintained in the project file(s).

Entries on the sample log sheet will include:

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from this QAPP
- Site conditions
- Date, time, location, ID, and description of each sample
- Field instrument calibration procedures
- Field measurement results
- Identity of QC samples collected
- Unusual circumstances that might affect interpretation of results

Field data will be recorded by field personnel during sampling activities and reviewed for accuracy and completeness. Data and field information will be checked by the QC Manager. Field data documentation and procedures includes the following criteria:

- Keep all field notes and/or field notebook notes on file.
- Keep all photos associated with the project on file.
- Be sure to save and back up any electronic notes/files/downloads collected in the field.
- It is recommended to enter the notes into an electronic data system, save and backup the files.
- Keep files available for at least 5 years.

- When using field data forms, create an original and field test the sheet for adaptation to the field procedure. This will help to avoid comprehensive updates. Use a finalized form and update every year.

11.2.2 Infiltration Rate Measurements

Infiltration rate measurements and all pertinent information will be recorded on field log sheets. The sheets will serve as a daily record of events and observation during measurement activities. Field log sheets will be maintained by staff in Wastewater Management's engineering group at all times. In addition, photographs of field and measurement collection activities will be completed for the project file. Copies of all log sheets and photographs will be made following each measurement event and maintained in the project file(s). On an annual basis, field log sheets and photographs will be provided to the Project Manager.

Entries on the field log sheet will include:

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from this QAPP
- Site conditions
- Weather conditions
- Date and time
- Infiltration rate measurements
- Unusual circumstances that might affect interpretation of results

Photographs should have a description

11.2.3 Durability Measurements

Durability measurements and all pertinent information will be recorded on field log sheets. The sheets will serve as a daily record of events and observation during measurement activities. Field log sheets will be maintained by staff in Street Department at all times. In addition, photographs of field and measurement collection activities will be completed for the project file. Copies of all log sheets and photographs will be made following each measurement event and maintained in the project file(s). On an annual basis, field log sheets and photographs will be provided to the Project Manager.

11.3 Laboratory Records

Contracted laboratories shall submit electronic copies of analytical data and quality control data to the QA Manager, preferably in PDF or excel formats. The RPWRF laboratory will keep written and electronic records of sample analysis performed on site. Furthermore, the laboratory will provide sample analysis to the Project Manager. Laboratory data will include measurement of each parameter as well as QA/QC documentation and explanation of any data qualifier flags assigned to sample results. The RPWRF laboratory will keep electronic copies of analytical data and quality control data in their files. In addition, sampling data and reports will be retained. Laboratory data will be entered into the laboratory database.

11.4 Laboratory Data Verification

The Laboratory QA Manager will be responsible for verification of laboratory-generated data, through the laboratory Standard Analytical Procedures for each method require some components of the verification to also be conducted at the bench level. Laboratory verification will include both contracted laboratories verification and the RPWRF Laboratory verification. Laboratory verification will include assessing that the procedures used to generate the data are consistent with the method requirements and that the QA/QC requirements for the method are met. Examples of method requirements include verifying the calibration and data reduction procedures. Once the data have been verified and approved by the laboratory, the QA manager shall document that verifications have been reviewed. The QA manager shall notify the Project Manager. Laboratory verification documentation should be included in reports.

12.0 AUDITS AND REPORTS

12.1 Audits

Each laboratory is accredited by the State of Washington for analysis of the respective analytes for this project. As part of the accreditation process, the State of Washington will perform on-site audits of the laboratories staff, facilities, and analytical capabilities. The laboratory's quality system, test methods, records, and reports will also be evaluated as part of the accreditation process. Each laboratory must participate in performance and system audits of their routine procedures. Results of these audits must be made available on request.

12.2 Deficiencies, Nonconformance, and Corrective Action

Deficiencies are defined as unauthorized deviation from procedures documented in this QAPP. Nonconformances are deficiencies that affect quality and render the data unacceptable or indeterminate. Field deficiencies and nonconformances will be documented and summarized in reports. Additional deficiencies and nonconformance may be found through the life of this study. Some examples of deficiencies and nonconformances include:

- Deficiencies
  - Chain-of-custody deviation such as incorrect sample time, resulting in holding time exceedances.
  - Not conducting field measurements such as temperature and pH.
  - Non-reporting of sampling equipment issues resulting in loss of sample collection.
- Nonconformance
  - Preservation of nitrogen samples with incorrect (nitric acid) preservative.

If laboratory deficiencies and nonconformances, and field sample collection deficiencies, occur throughout the course of this study, the Project Manager, Laboratory Manager, and Pre-treatment Program Manager, will collaborate to develop corrective actions to be implemented. The Laboratory Supervisor and Pre-treatment Program Supervisor are responsible for tracking field sample collection and RPWRF laboratory deficiencies and nonconformances.

If deficiencies and nonconformances regarding other components of this study (i.e. flow monitoring, durability, and infiltration rates) occur throughout the course of this study, the Project Manager will collaborate with the appropriate Key groups to develop corrective actions to be implemented.

The Project Manager is responsible for summarizing all deficiencies, field deficiencies, nonconformances, and corrective actions.

12.2 Reporting

The Project Manager will be responsible for writing reports related to this study. The Project Manager will rely on key individuals to assemble the necessary information to compile reports. Reports will be developed and available summarizing results with respect to pollutant removal efficiency. Reports will be distributed to internal staff and management for review. Quarterly reports will be developed after each sampling event. Annual reports will be developed summarizing yearly sampling activities and statistical analysis. A final report will be developed summarizing the project including sampling events, monitoring results, conclusions, and recommendations. Reports shall include the following:

12.2.1 Field Summary

The QA Manager will be responsible for summarizing field activities. The summary will include a case narrative for each sampling event include:

- Description of each sampling event including date, time, antecedent and rainfall data
- Comparison to rainfall event goals
- Description of each sampling event including dates of installation and retrieval and total rainfall during the sampling event
- Field observations
- Deviation of field procedures
- Other information deemed necessary

12.2.2 Quality Assurance/Quality Control Summary

The QA Manager will be responsible for summarizing QA/QC. The summary will include a case narrative for each sampling event including:

- A narrative analysis of appropriate field quality control procedures, data quality indicator results, and of any associated issues and corrections made.
- A narrative analysis of appropriate laboratory quality control procedures with measurement quality objectives discusses, any associated issues and corrections made.
- Chain-of-custody procedures used, and explanation of any deviations from this QAPP procedures.
- Summary of the data quality assurance results from each sampling event (i.e. were data quality objectives met and, if not, why not).
- An overall assessment of the usability and representativeness of the data.
- A summary description of any planned changes or deviations from this QAPP to address problems encountered during QA/QC

12.2.3 Annual Report

Annual reports will be developed containing monitoring data collected during the previous year. Reports will also include statistical analysis data and other information the Project Manager deems necessary to include.

12.2.4 International Stormwater BMP Database data upload procedures

Analytical data will be entered into the International BMP Database Procedures for submitting data can be found on International Stormwater BMP Database website (http://www.bmpdatabase.org/data-entry.html).

13.0 DATA VERIFICATION AND VALIDATION

Data verification is defined as a detailed examination of results to determine if the project's MQOs have been met. The intent is to ensure data of known and documented quality and quantity meet the use for which they are intended. The quality of the data is indicated by data qualifier codes, notations used by laboratories and data reviewers to briefly describe, or qualify, data and the systems producing data.

During data review, verification, and validation, results are either accepted or reported with data qualifiers or flags. Data that meet all QC acceptance limits are potentially usable and are not qualified. Data that fail one or more QC criteria are qualified as estimated (with the J-flag). The distinction between estimated and rejected data resides in the degree of the QC failure and is highly dependent upon the reviewer's understanding of the objectives of the study.

13.1 Data Review, Verification, and Validation

For the purposes of this document, data verification is a systematic process for evaluating performance and compliance for a set of data to ascertain its completeness, correctness, and consistency using the methods and criteria defined in this QAPP. Validation means those processes taken independently of the data-generation processes to evaluate the technical usability of the verified data with respect to the planned objectives or intention of this project. Additionally, validation can provide a level of overall confidence in the reporting of the data based on the methods used.

All data obtained from field and laboratory measurements will be reviewed and verified for conformance to study requirements, and then validated against the measurement quality objectives, which are described in Section 7.0 Data Quality Objectives. Only those data that are supported by appropriate quality control data and meet the measurement performance specification defined for this project will be considered acceptable and used in this project.

13.2 Verification and Validation Methods

All data will be verified to ensure they are representative of the samples analyzed and locations where measurements were made, and that the data and associated quality control data conform to project specifications. The data verification procedures will generally include:

- Storm event verification (i.e. did the sampling event meet the established storm criteria).
- Sampling equipment verification (i.e. did the sampling equipment capture enough volume).
- Field QC (i.e. were samples collected at appropriate frequency and did they meet the established control limits).
- Laboratory QA/QC (i.e. did the lab meet method quality objectives).

14.0 DATA QUALITY (USABILITY) ASSESSMENT

The Project Manager will assess the quality of the data based on case narratives and data packages. Laboratory QC tests and field QC parameters will be examined to determine if the field staff and laboratory met the project's MQOs. Reporting limits will be examined to ensure that the contract-defined reporting limit was met. Data will either be accepted, accepted with additional qualification, or rejected and re-analysis considered depending on the severity of the infraction. During the data usability assessment, data that are believed to be completely unusable with a high degree of confidence (e.g. because of the gross failure of QC criteria) are qualified as rejected and would not normally be used to support decisions for an environmental study.

Usability is defined as a qualitative decision process whereby the decision-makers evaluate the achievement of measurement quality objectives and determine whether the data may be used for the intended purpose.

Data reduction is the process of converting raw data into results. Study-specific data reduction methods are designed to ensure that data are accurately and systematically reduced into a usable form.

Data Quality Assessment (DQA) is the scientific and statistical evaluation of data to determine if data obtained from environmental data operations are of the right type, quality, and quantity to support their intended use.

14.1 Data Usability Assessment

There are three categories of data quality that are used and are as followed:

- Accepted – Data conform to all requirements, all quality control criteria are met, methods were followed, and documentation is complete.
- Qualified – Data conform to most, but not all, requirements, critical QC criteria are met, methods were followed or had only minor deviations, and critical documentation complete.
- Rejected – Data do no conform to some or all requirements, critical QC criteria are not met, methods were not followed or had significant deviations, or critical documentation is missing or incomplete. The results are unusable.

Data usability assessment is a more complex and comprehensive activity than data review or validation and is usually performed by the end user (rather than by the data reviewer) because the data user typically possesses a greater understanding of the project's DQOs (e.g. because of a more extensive knowledge of the study's history). Therefore, the end user must ultimately determine the acceptability of the data. However, this does not imply that the end user may apply qualified data in an indiscriminate fashion.

Ideally, estimated data (i.e. J-qualified) though presumed to be usable by the data reviewer, should be accepted by the end user only after the reasons for the data qualifications and their impact on the achievement of study DQOs have been examined.

The usability assessment includes assessment of potential outliers and confirmation that the data is comparable and representative.

14.2 Data Quality Assessment Metrics

The data quality assessment process determines whether the sampling and analytical program has fulfilled the project objectives, including the DQOs, and whether the data can be used to support project management decisions with the desired level of confidence. Data quality assessment is a professional judgement based on several lines of evidence:

- **Laboratory Data Validation Results.** This metric evaluates laboratory data quality, i.e. the extent to which MQOs for accuracy, precision, sensitivity, and bias have been met during laboratory analysis, as determined by the data validation process.
- **Field and Laboratory Completeness**. This metric evaluates data quantity, i.e. the extent to which the QAPP-specified number of valid field and laboratory measurements has been obtained and whether field and laboratory completeness goals have been achieved.
- **Sample Representativeness**. The degree to which the monitoring program provides a representative sample of the physical-chemical characteristics of stormwater in space and time will be evaluated. An assessment as to whether the data are suitably representative of the spatial characteristics of the drainage area (i.e. land use, gradient, ground cover, etc.).

14.3 Data Analysis Methods

Statistical analysis and trending will be completed using the laboratory analytical results. Summary statistics will be calculated each year for the current monitoring year as well as for the entire duration of the study. For each constituent analyzed, infiltration rates, and durability the following summary statistics should be calculated:

- Number of samples analyzed and infiltration rates.
- Number and percentages of samples with detected concentrations.
- Arithmetic mean concentration
- Standard deviation of the arithmetic mean
- Median concentration
- Percent coefficient of variation
- Minimum and maximum concentrations
- 95^{th} percentile upper and lower confidence limits of the arithmetic mean and the median

Statistical analysis will also be performed on the flow rates and rainfall depths for the Sharp Avenue basin. An annual average flow volume will need to be refined for use in loading calculations. This will be done by comparing total rainfall observed per year in comparison to annual average precipitation. The total flow volume will be adjusted accordingly to determine annual average flow.

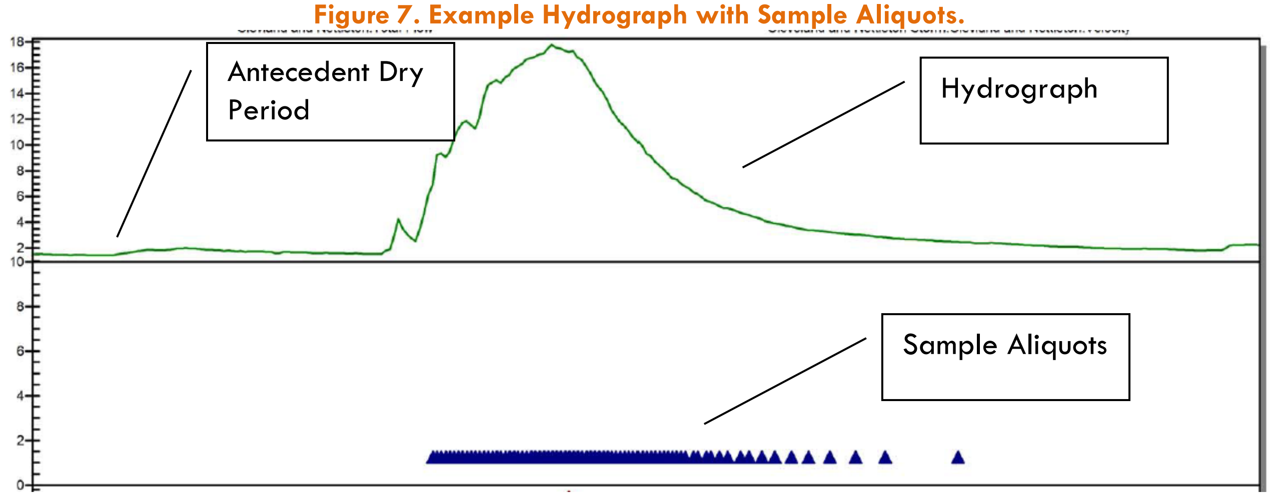
14.4 Treatment of Non-Detected Values

The analytical laboratory will be required to report estimated values for any detections between the Method Detection Limit (MDL) and the reporting limit (RL), and appropriate data qualifiers (e.g. J-flags). For general summary statistics, undetected values will be substituted at one-half the MDL for statistical calculations.

14.5 Study Design Evaluation

Effectiveness of the sampling design will be evaluated from hydrograph plots that also include sample aliquots obtained during sample events. These hydrographs can be exported from the Flowlink Pro software. If samples were obtained that meet the sample event goals outlined in Section 6, then it can be inferred that the sampling design is successful. Sample events that come close to meeting sample event goals will be evaluated on a case-by-case basis to determine acceptability. An example of a hydrograph plot from a successful sample event is shown below.

Figure 7. Example Hydrograph with Sample Aliquots.



15.0 REVISION HISTORY

This QAPP is a living document and revisions will be completed on an as needed basis. In the event that significant changes to this QAPP are required prior to the completion of the study, revisions will be documented and submitted to key individuals identified in section 5.0.

Revision:	Affected Page:	Revision Date:	Completed by:	Revision Details:
0	All	March 2019	AP/JG	Developed, provided to Ecology for comment, addressed Ecology's comments, finalized.

16.0 REFERENCES

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Appendix A

ASTM Standard C1701/C1701M – 09

Designation: C1701/C1701M – 09

Standard Test Method for Infiltration Rate of In Place Pervious Concrete[1]

1. Scope

1.1 This test method covers the determination of the field water infiltration rate of in place pervious concrete.

1.2 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system may not be exact equivalents; therefore, each system shall be used independently of the other. Combining values from the two systems may result in non-conformance with the standard.

1.3 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.4 The text of this standard references notes that provide explanatory material. These notes shall not be considered as requirements of the standard.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

C125 Terminology Relating to Concrete and Concrete Aggregates

C920 Specification for Elastomeric Joint Sealants

2.2 *Other Standards*

Federal Specification A-A-3110 (TT-P-1536A) Plumbing Fixture Setting Compound[3]

3. Terminology

3.1 *Definitions:*

3.1.1 The terms used in this test method are defined in Terminology C125.

4. Summary of Test Method

4.1 An infiltration ring is temporarily sealed to the surface of a pervious pavement. After prewetting the test location, a given mass of water is introduced into the ring and the time for the water to infiltrate the pavement is recorded. The infiltration rate is calculated in accordance with 9.1.

5. Significance and Use

5.1 Tests performed at the same location across a span of years may be used to detect a reduction of infiltration rate of the pervious concrete, thereby identifying the need for remediation.

5.2 The infiltration rate obtained by this method is valid only for the localized area of the pavement where the test is conducted. To determine the infiltration rate of the entire pervious pavement multiple locations must be tested and the results averaged.

5.3 The field infiltration rate is typically established by the design engineer of record and is a function of the design precipitation event.

5.4 This test method does not measure the influence on in-place infiltration rate due to sealing of voids near the bottom of the pervious concrete slab. Visual inspection of concrete cores is the best approach for determining sealing of voids near the bottom of the pervious concrete slab.

6. Apparatus

6.1 *Infiltration Ring*—A cylindrical ring, open at both ends (See Fig. 1). The ring shall be watertight, sufficiently rigid to retain its form when filled with water, and shall have a diameter of 300 ± 10 mm [12.0 ± 0.5 in.] with a minimum height of 50 mm [2.0 in.]. The bottom edge of the ring shall be even. The inner surface of the ring shall be marked or scored with two lines at a distance of 10 and 15 mm [0.40 and 0.60 in.] from the bottom of the ring. Measure and record the inner diameter of the ring to the nearest 1 mm [0.05 in.].

NOTE 1—Ring materials that have been found to be suitable include steel, aluminum, rigid plastic, and PVC.

6.2 *Balance*—A balance or scale accurate to 10 g [0.02 lb].

6.3 *Container*—A cylindrical container typically made of plastic having a volume of at least 20 L [5 gal], and from which water may be easily poured at a controlled rate into the infiltration ring.

6.4 *Stop Watch*—Accurate to 0.1 s.

6.5 *Plumbers Putty (Non-Hardening)*—Meeting Specification C920 or Federal Specification A-A-3110.

6.6 *Water*—Potable water.

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[1] This test method is under the jurisdiction of ASTM Committee C09 on Concrete and Concrete Aggregates and is the direct responsibility of Subcommittee C09.49 on Pervious Concrete.

Current edition approved Aug. 1, 2009. Published September 2009. DOI: 10.1520/C1701_C1701M-09.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] http://www.everyspec.com

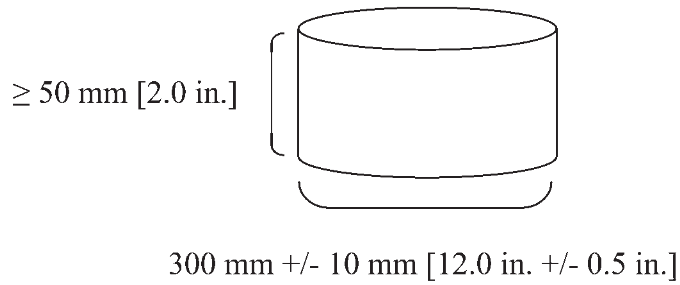

FIG. 1 Dimensions of Infiltration Ring

7. Test Locations

7.1 Perform tests at multiple locations at a site as requested by the purchaser of testing services. Unless otherwise specified, use the following to determine the number of tests to perform:

7.1.1 Three test locations for areas up to 2,500 m^2 [25,000 ft^2].

7.1.2 Add one test location for each additional 1,000 m^2 [10,000 ft^2] or fraction thereof.

7.2 Provide at least 1 m [3 ft] clear distance between test locations, unless at least 24 h have elapsed between tests.

7.3 Do not test if there is standing water on top of the pervious concrete. Do not test within 24 h of the last precipitation.

8. Procedure

8.1 *Infiltration Ring Installation*—Clean the pavement surface by only brooming off trash, debris, and other non-seated material. Apply plumbers putty around the bottom edge of the ring and place the ring onto the pervious concrete surface being tested. Press the putty into the surface and around the bottom edge of the ring to create a watertight seal. Place additional putty as needed

NOTE 2—In a hot environment where the surface temperature is over 38 °C [100 °F] plumbers putty may not adhere to the concrete surface easily. Therefore it is advisable to perform this test during cooler temperature.

8.2 *Prewetting*—Pour water into the ring at a rate sufficient to maintain a head between the two marked lines. Use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Begin timing as soon as the water impacts the pervious concrete surface. Stop timing when free water is no longer present on the pervious surface. Record the amount of elapsed time to the nearest 0.1 s.

8.3 *Test*—The test shall be started within 2 min after the completion of the prewetting. If the elapsed time in the prewetting stage is less than 30 s, then use a total of 18.00 ± 0.05 kg [40.00 ± 0.1 lb] of water. If the elapsed time in the prewetting stage is greater than or equal to 30 s, then use a total of 3.60 ± 0.05 kg [8.0 ± 0.1 lb] of water. Record the weight of water to the nearest 10 g [0.02 lb] (M). Pour the water into the ring at a rate sufficient to maintain a head between the two marked lines and until the measured amount of water has been used. Begin timing as soon as the water impacts the pervious concrete surface. Stop timing when free water is no longer present on the pervious surface. Record the testing duration (t) to the nearest 0.1 s.

NOTE 3—If a sloped pavement is being measured, maintain head between the two marked lines at the lowest point of the slope.

8.4 If a test is repeated at the same location, the repeat test does not require pre-wetting if conducted within 5 min after completion of the first test. If more than one test is conducted at a location on a given day, the infiltration rate at that location on that day shall be calculated as the average of the two tests. Do not repeat this test more than twice at the same location on a given day.

9. Calculation

9.1 Calculate the infiltration rate (I) using consistent units as follows:

$$I = \frac{KM}{(D^2 * t)}$$

where:

I = Infiltration rate, mm/h [in./h],
M = Mass of infiltrated water, kg [lb],
D = Inside diameter of infiltration ring, mm [in.],
t = time required for measured amount of water to infiltrate the concrete, s, and
K = 4 583 666 000 in SI units or 126 870 in [inch-pound] units.

NOTE 4—The factor K has units of $(mm^3s)/(kgh)$ $[(in.^3s)/(lbh)]$ and is needed to convert the recorded data (W, D, and t) to the infiltration rate I in mm/h [in./h].

10. Report

10.1 Report the following information:

10.1.1 Identification number,

10.1.2 Location,

10.1.3 Date of test,

10.1.4 Age and thickness of concrete (label Unknown if not known),

10.1.5 Time elapsed during prewetting, s,

10.1.6 Amount of rain during last event, if known, mm [in.],

10.1.7 Weight of infiltrated water, kg [lb],

10.1.8 Inside diameter of infiltration ring, mm [in.],

10.1.9 Time elapsed during infiltration test, s,

10.1.10 Infiltration rate, mm/h [in./h], and

10.1.11 Number of tests performed at each location, if applicable.

11. Precision and Bias

11.1 Repeatability testing was performed by a single laboratory by making 2 replicate measurements at three locations on a newly placed pervious concrete pavement. The replicate measurements were repeated daily from day 1 to day 10. The single-operator coefficient of variation of the infiltration rate at one test location was found to be 4.7 %.

11.2 The multi-operator variability data has not been developed. The reproducibility of this test method is being determined and will be available on or before October 1, 2014.

11.3 This test method has no bias because the infiltration rate of in-place pervious concrete is defined only in terms of this test method.

12. Keywords

12.1 concrete; infiltration; pervious; water

Appendix B

WSDOT Field Rating Manual

Pavement Surface Condition Field Rating Manual for Asphalt Pavements

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Inspection Procedure and Guidelines

Rating Considerations

Flexible Pavement

Acknowledgments

Northwest Pavement Management Association

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Pavement Surface Condition Field Rating Manual for Asphalt Pavements

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CONTENTS

Inspection Procedure and Guidelines

These inspection procedures offer a method of determining pavement condition through observing and recording the presence of specific types and severities of defects or distresses in the pavement surface.

The elements of pavement condition rating are as follows:

1. The type of defect.
2. The severity of the defect.
3. The extent to which the road surface is affected by the defect.

There are several types of defects and several possible severities and extents for each defect. These are described and illustrated for flexible pavements in the following pages of this manual.

Rating Considerations

Listed below are important factors to consider when you collect pavement condition data.

- Each agency must decide whether to record the extent of the **predominant severity** of each defect type or to record the extent of **each severity** of each defect type. The agency must also decide whether to estimate/measure and record these extents using finite values or standardized ranges of values.

  If the ***predominate severity*** *procedure is used for each type of defect observed*, you should record only one severity, the **predominant severity**. Always record the higher rated severity if approximately equal proportions of more than one severity exist. The purpose is to establish a severity that represents the typical condition of the roadway segment. The extent you record is always the overall extent associated with all levels of severity for a given distress type. *This extent may be a range of values or it may be a finite value*. Your individual agency may wish to note (in the comments section of the form) the occurrence of any level of severity that is significantly higher than what you have recorded in the rating.

If you are recording the extent associated with ***each severity*** *of each distress type*, then instead of recording the total extent and the **predominant severity**, you will record the extent of **each severity** of each type of defect. It is recommended that a finite value (the actual percentage or count) of the extent is recorded for each of the severity categories as use of ranges will probably result in too large an extent for the total of the severities.

- Roads can be rated on foot or by vehicle. In urban areas, rating is frequently done on foot. The best driving speeds for observing the defects range from 2 to 5 miles per hour. A single lane is generally used, but if time and funds allow, an agency can measure more than one lane.

  Note: *Different values will likely be obtained in walking vs. driving and the agency needs to be aware of possible problems in comparing results obtained by using more than one technique.*

- The relative sun angle and direction of viewing the roadway surface will greatly affect your visual observation. Be sure to view the pavement from more than one direction occasionally during the survey to assure the true nature of the pavement surface is being observed.

- The time of year and weather (moisture and temperature) conditions over a given time period can also affect the severity and visibility of certain distresses. If at all possible, rate the roadway network at a similar time of the year and only while the pavement is dry.
- When rating a roadway, you must observe the entire area of the traveled roadway segment or sample and determine the defect severities and extents over this full pavement surface area.
- When rating composite pavements (such as asphalt over rigid pavement), classify cracks that may correspond with the concrete joints as distresses and rate these, and other cracks, as the type of crack they represent (transverse or longitudinal).
- When rating the width of cracks, use the average width, not the extremes. Cracks often vary in width and the intent is to rate the overall severity of the crack.

- Condition ratings apply only to the traveled surface of a road. Do not include the conditions of shoulders or other adjacent areas. Shoulder condition, drainage information, or other items may be accounted for and collected separately from or with the pavement rating data.
- Areas within the curb returns are considered a part of the intersection for rating purposes. Intersections are generally rated with a higher functional class street or in a given direction. Intersections may also be separately rated and recorded. Each agency needs to develop its own policy.
- If opposite sides of the roadway or individual lanes are rated separately, use separate forms and enter the data into the database as separate multilane segments.
- When any type of defect is not observed, write an “N” in the first space on the field form for that defect. The “N” indicates clearly that a defect was not present and reduces the potential for confusion when the data are entered into the database.
- Your PMS manager may wish you to observe and collect additional information during the survey. This might include such things as historical and physical information, documenting new segments, or noting items needing repair.
- It is important that you receive clear direction from the PMS manager on all details related to data collection prior to beginning the survey project.

Flexible Pavement Distresses

1. Rutting and Wear

Rutting is a surface depression within the wheel path. Rutting results from a permanent deformation in any of the pavement layers or subgrades, usually caused by consolidation or lateral movement of the materials due to traffic loads. When the upper pavement layers are severely rutted, the pavement along the edges of the rutted area may be raised. Usually, the rutting occurs gradually across the wheel path, reaching a maximum depth in the center of the wheel path. Ruts are most obvious after rainfall when they are full of water.

Wear is surface depression in the wheel path resulting from tire abrasion.

Measurement for Rutting

Severity: The average rut depth in the wheel path for the segment or sample.

Recommended ranges for estimated severity.

Low — 1/4-inch to 1/2-inch

Medium — 1/2-inch to 3/4-inch

High — over 3/4-inch

Extent: The extent of rutting is assumed to be the full length of the segment in the wheel path.

Measure: Take measurements in as many locations as is practical and average them.

Rutting

2. *Alligator Cracking*

Alligator fatigue cracking is associated with loads and is usually limited to areas of repeated traffic loading. The cracks surface initially as a series of parallel longitudinal cracks within the wheel path that progresses with time and loads to a more branched pattern that begins to interconnect. The stage at which several discontinuous longitudinal cracks begin to interconnect, is defined as alligator cracking. Eventually the cracks interconnect sufficiently to form many pieces, resembling the pattern of an alligator.

On narrow, two-lane roads, alligator cracking may form along the center line rather than in the customary wheel paths.

Almost always, the pattern of the cracking (the longer dimension of the connected cracks) is parallel to the roadway or direction of vehicle travel. However, alligator cracking occasionally occurs in a pattern transverse to the roadway direction because of poor trench compaction, settlement, or frost action.

Pot holes and other occurrences of destroyed or missing pavement are accumulated as high severity alligator cracking and may also be noted in the comments area of the field form.

Severity:

Low — Branched, longitudinal, discontinuous thin cracks are beginning to interconnect and form the typical alligator pattern with no spalling.

Medium — Cracking is completely interconnected and has fully developed an alligator pattern. Some spalling may appear at the edges of cracks. The cracks may be greater than $^1/_4$-inch wide, but the pavement pieces are still in place.

High — The pattern of cracking is well developed. Spalling is very apparent at the crack. Individual pieces may be loosened and may rock under traffic. Pieces may be missing. Pumping of fines up through the cracks may be evident.

Low

Medium

High

Option A — Measurement for Alligator Cracking

Extent: The extent of alligator cracking is related to the length of wheel paths. There are two wheel paths in every lane. Therefore, a 100-foot lane has 200 feet of wheel paths. Accurate measurement and recording as a percentage of wheel path length is preferable.

Recommended ranges for estimated extent.

1 percent to 9 percent of both wheel paths
10 percent to 24 percent of both wheel paths
25 percent to 49 percent of both wheel paths
50 percent to 100 percent of both wheel paths

Measure: Accumulate the lengths along the surveyed lane of each severity of the alligator cracking as it occurs in both wheel paths. Divide the accumulated lengths by twice the length of the segment (two wheel paths per lane). Multiply by 100 to get percent, and round to a whole number.

Option B — Measurement for Alligator Cracking

Extent: The extent of alligator cracking is related to the entire survey area.

Measure: Alligator Cracking is measured in square feet. The major difficulty in measuring this type of distress is that two or three levels of severity often exist within one distressed area. If these portions can be easily distinguished from each other, they should be measured and recorded separately. However, if the different levels of severity cannot be divided easily, the entire area should be rated at the highest severity level present.

3. *Longitudinal Cracking*

Longitudinal cracks run roughly parallel to the roadway center line. Longitudinal cracks associated with the beginning of alligator cracking are generally discontinuous, broken, and occur in the wheel path. However, any longitudinal crack that is clearly within the wheel path should be rated.

Note: Do not include cracks which reside only within 6 inches of a lane edge. These cracks are assumed to be caused by, or related to, a paving construction joint and should be rated as nonwheel path longitudinal cracking. If your survey includes an item for joint or crack seal condition, you should include the seal condition of these lane edge construction joints in that survey item.

Severity:

Low — The cracks have very little or no spalling along the edges and are less than $^1/_4$-inch in width. If the cracks are sealed and the width of the crack prior to sealing is invisible, they should be classified as Low Severity.

Medium — The cracks have little or no spalling but they are greater than $^1/_4$-inch in width. There may be a few randomly spaced low severity connecting cracks near the main crack or at the corners of intersecting cracks.

High — Cracks are spalled and there may be several randomly spaced cracks near the main crack or at the corners of intersecting cracks. Pieces are visibly missing along the crack. At some point, this longitudinal cracking becomes alligator cracking.

Low

Medium

High

Option A — Measurement for Longitudinal Cracking

Extent: The extent of longitudinal cracking is recorded as a percent of the length of the surveyed segment.

Recommended ranges for estimated extent.

1 percent to 99 percent of length of segment
100 percent to 199 percent of length of segment
200 percent or more of length of segment

Measure: Accumulate the lengths along the surveyed lane of each severity of the longitudinal cracking as it occurs. Divide the accumulated lengths by the length of the segment. Multiply by 100 to get percent, and round to a whole number.

Option B — Measurement for Longitudinal Cracking

Extent: The extent of longitudinal cracking is related to the entire survey area.

Measure: Longitudinal cracks are measured in linear feet. The length and severity of each crack should be recorded after identification.

4. *Nonwheel Path Longitudinal Cracking*

Nonwheel path longitudinal cracks run roughly parallel to the roadway center line. They may be caused by a poorly constructed paving joint, a reflective crack caused by joints and cracks beneath the surface course, including joints and cracks near the edge of the pavement. These types of cracks are not load-associated.

Low severity nonwheel path longitudinal cracking looks very similar to low severity alligator cracking; however, low severity alligator cracking always occurs in the wheel path and should be rated as alligator cracking.

Severity:

Low — The cracks have very little or no spalling along the edges and are less than 1/4-inch in width. If the cracks are sealed and the width of the crack prior to sealing is invisible, they should be classified as Low Severity.

Medium — The cracks have little or no spalling but they are greater than 1/4-inch in width. There may be a few randomly spaced low severity connecting cracks near the main crack or at the corners of intersecting cracks.

High — Cracks are spalled and there may be several randomly spaced cracks near the main crack or at the corners of intersecting cracks. Pieces are visibly missing along the crack.

Low

Medium

High

Option A — Measurement for Nonwheel Path Longitudinal Cracking

Extent: The extent of nonwheel path longitudinal cracking is recorded as a percent of the length of the surveyed segment.

Recommended ranges for estimated extent.

1 percent to 99 percent of length of segment
100 percent to 199 percent of length of segment
200 percent or more of length of segment

Measure: Accumulate the lengths along the surveyed lane of each severity of the nonwheel path longitudinal cracking as it occurs. Divide the accumulated lengths by the length of the segment. Multiply by 100 to get percent, and round to a whole number.

Option B — Measurement for Nonwheel Path Longitudinal Cracking

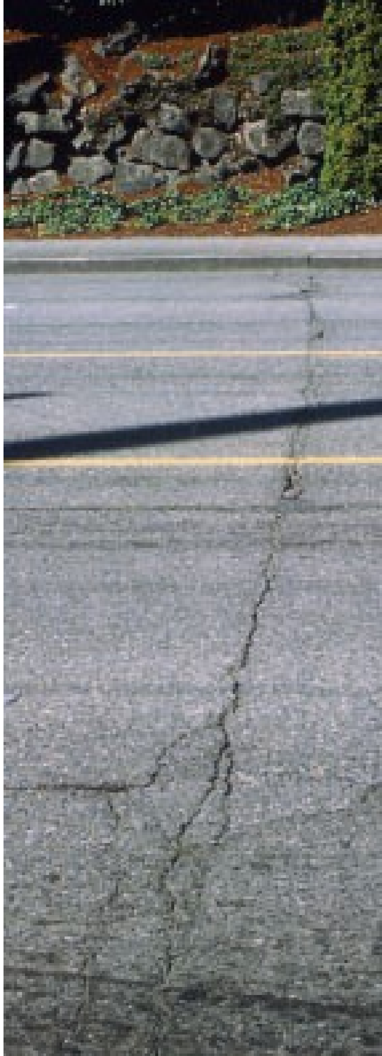
Extent: The extent of nonwheel path longitudinal cracking is related to the entire survey area.

Measure: Nonwheel path longitudinal cracks are measured in linear feet. The length and severity of each crack should be recorded after identification.

5. *Transverse Cracking*

Transverse cracks run roughly perpendicular to the roadway center line. They may be caused by surface shrinkage due to low temperatures, hardening of the asphalt, or cracks in underlying pavement layers such as PCCP slabs. They may extend partially or fully across the roadway.

Consider only those transverse cracks that are a minimum of two feet in length.



Severity:

Low — The cracks have very little or no spalling along the edges and are less than 1/4-inch in width. If the cracks are sealed and the width of the crack prior to sealing is invisible, they should be classified as Low Severity.

Medium — The cracks have little or no spalling but they are greater than 1/4-inch in width. There may be a few randomly spaced low severity connecting cracks near the main crack or at the corners of intersecting cracks.

High — Cracks are spalled and there may be several randomly spaced cracks near the main crack or at the corners of intersecting cracks. Pieces are visibly missing along the crack.

Low

Medium

High

Option A — Measurement for Transverse Cracking

Extent: The extent of transverse cracking is quantified as a frequency of occurrence expressed as a count per 100 feet of lane length.

Recommended ranges for estimated extent.

1 to 4 cracks per 100 feet
5 to 9 cracks per 100 feet
10 or more cracks per 100 feet

Measure: Accumulate the count along the surveyed lane of each severity of transverse crack as it occurs. Divide the accumulated counts by the length of the segment. Multiply by 100 to get the frequency, and round to a whole number.

Option B — Measurement of Transverse Cracking

Extent: The extent of transverse cracking is related to the entire survey area.

Measure: Transverse cracks are measured in linear feet. The length and severity of each crack should be recorded after identification.

6. *Raveling and Aging*

Raveling and aging are pavement surface deterioration that occurs when aggregate particles are dislodged (raveling) or oxidation causes loss of the asphalt binder (aging). An ACP loses its smooth surface and begins to appear very open and rough.

The severity is rated by the degree of aggregate and binder loss. Rate the overall severity within the segment as the most predominate observed level.

This distress is measured or observed differently depending on whether the road surface is BST or ACP. Care should be exercised when rating chip sealed pavements, as they tend to look raveled because of the inherent nature of the chip seal surface. However, raveling in chip sealed pavements (loss of aggregate) actually results in a condition of excess asphalt, and should be rated as flushing (see next distress, Flushing/Bleeding).

Severity:

Low — The aggregate and/or binder has started to wear away but has not progressed significantly. The pavement only appears slightly aged and slightly rough.

Medium — The aggregate and/or binder has worn away and the surface texture is moderately rough and pitted. Loose particles may be present, and fine aggregate is partially missing from the surface.

High — The aggregate and/or binder have worn away significantly, and the surface texture is deeply pitted and very rough. Fine aggregate is essentially missing from the surface, and pitting extends to a depth approaching one half the coarse aggregate size.

High

Low

Medium

High

Extent: The extent of raveling is estimated and expressed relative to the surface area of the surveyed lane.

Recommended ranges for estimated extent.

Localized — Patchy areas, usually in the wheel paths.

Wheel Path — Majority of wheel tracks are affected, but little or none elsewhere in the lane.

Entire Lane — Most of the lane is affected.

Measure: Estimate the severity and extent.

7. *Flushing/Bleeding*

Flushing and bleeding is indicated by an excess of bituminous material on the pavement surface which presents a shiny, glass-like reflective surface that may become sticky in hot temperatures.

At the lower severity levels, the extents “localized” and “wheel path” may be difficult to differentiate; however, as the severity increases, “wheel path” becomes more well defined. Wheel path refers to tire tracking area and may be used to represent the condition of only one wheel track being heavily involved.

This distress is measured or observed differently depending on whether the road surface is BST or ACP. In BST pavements, loss of aggregate (raveling), commonly referred to as “chip loss”, leaves the binder exposed. This condition looks like flushing, and should be rated as flushing.

Severity:

Low — Minor amounts of the aggregate have been covered by excess asphalt but the condition has not progressed significantly.

Medium — Significant quantities of the surface aggregate have been covered with excessive asphalt. However, much of the coarse surface aggregate is exposed, even in those areas showing flushing.

High — Most of the aggregate is covered by excessive asphalt in the affected area. The area appears wet and is sticky in hot weather.

Low

Medium

High

Extent: The extent of flushing is estimated and expressed relative to the surface area of the surveyed lane.

Recommended ranges for estimated extent.

Localized — Patchy areas, usually in the wheel paths.

Wheel Path — Majority of wheel tracks are affected, but little or none elsewhere in the lane.

Entire Lane — Most of the lane is affected.

Measure: Estimate the severity and extent.

8. *Patching*

A patch is an area of pavement which has been replaced with new material to repair the existing pavement or access the utility.

A patch is considered a defect no matter how well it is performing (a patched area or adjacent area usually does not perform as well as an original pavement section). Generally, some roughness is associated with this distress. In general, a patch is less than a typical rehabilitation in size and scope. They are less than full roadway width and/or are less than project length. Some agencies may have patches as long as the work defined by another agency as a rehabilitation.

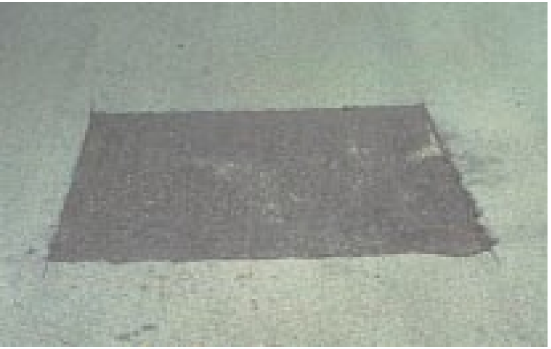
Temporary patches, as well as localized permanent repairs (dig-out repair), are included in this distress category. Utility cut patches are also included as part of the patching values.

Low — Patch has at most low severity distress of any type.

Medium — Patch has medium severity distress of any type.

High — Patch has high severity distress of any type.

low



Medium

Low

Medium

High

Option A — Measurement for Patching

Extent: The extent of patching is related to the length of wheel paths. Each half of the lane is considered one wheel path.

Recommended ranges for estimated extent.

1 percent to 9 percent of both wheel paths
10 percent to 24 percent of both wheel paths
25 percent or more of both wheel paths.

Option B — Measurement for Patching

Extent: The extent of patching is related to the entire survey area.

Measure: Patching is measured in square feet of entire inspection area. No other distresses (e.g., rutting or cracking) are recorded within a patch. Other distresses in the patch area are used to determine the severity level of the patch.

9. *Original WSDOT Patching*

In general, a patch is less than a typical rehabilitation in size and scope. They are less than full roadway width and/or are of less than project length. Some agencies may have patches as long as the work defined by another agency as a rehabilitation. WSDOT defines a lane with "new surfacing" as a patch if it is less than about half a mile in length. Definition of minimum rehabilitation vs. maximum patch length is a matter of agency policy.

Temporary patches, as well as localized permanent repairs (dig-out repair), are included in this distress category. The patches or repairs which are obviously the result of utility work are the exception, and are not included as part of the patching values.

While appropriately done repairs are an asset rather than a liability to the life of a segment of pavement, the fact that they were required (other than for utility work) generally indicates some failure in the pavement structure.

If any patch (including a utility patch) shows surface defects, such as alligator cracking, accumulate those defects also, and include them in the overall segment rating.

Patching

Severity: Severity of patching is defined in three categories which are most easily recognized by the method of construction.

Low — The lowest severity is BST patching or chip seal patching. It is constructed by spraying hot asphalt onto the roadway (usually using a truck with a spray bar) and then spreading and rolling crushed stone onto the surface. It is identified by its nearly straight edges, rough texture, and surface contours which mimic the surface below. This is assumed to cover low severity cracking or raveling.

Medium — Blade patching is the medium severity patching. It has edges shaped to the contours of the surrounding pavement and is of variable thickness with feathered edges. This type is assumed to cover (or replace) medium to severe alligator cracking, pot holes, rutting, or other significant pavement defects. Cold patches are of this type.

High — Dig-Out or Full Depth patching is the most severe of the types rated. A patch (or repair) of this type is constructed by neatly cutting out a full depth portion of the pavement, removing all disturbed materials, and refilling the void with an appropriate pavement section. This appropriately reconstructed section should be as strong as the original pavement section, perhaps even stronger. This type of patch is assumed to replace severe alligator cracking.

Chip Seal Repair Low

Blade Repair Medium

Dig Out High

Extent: The extent of patching is related to the length of wheel paths. Accurate measurement expressed as a percentage of wheel path length is preferable. Each half of the lane is considered one wheel path. This form of measurement is identical to that of alligator cracking because the general assumption is that patching replaces alligator cracking.

Recommended ranges for estimated extent.

1 percent to 9 percent of both wheel paths
10 percent to 24 percent of both wheel paths
25 percent or more of both wheel paths

Note: Patching was included in the WSPMS because without a deduction for patching, a roadway which is virtually made of patches would appear to be a "perfect" segment or project. This would result in the segment or project never being included in a prioritized list of pavements needing rehabilitation.

If an agency has separate maintenance districts, or crews assigned to specific areas, the more efficient crew/district can be penalized by the pavement management system for doing a better job. If its roadways rate higher as a result of better maintenance operations, those roadways might not receive repair and rehabilitation funds as a result.

The way in which the PMS uses these distress severities can vary, and the desired effect can be accommodated by using different deduct values to reflect the needs of the agency. If patching and/or repairs are not deemed a serious issue within your agency, then reduce or remove the optional local deducts associated with the patching severities.

Measure: Accumulate the lengths along the surveyed lane of each severity (type) of patching as it occurs in both wheel paths. Divide the accumulated lengths by twice the length of the segment (two wheel paths per lane). Multiply by 100 to get percent, and round to a whole number.

10. *Corrugation and Waves*

This distress category covers a general form of surface distress which is not limited to the wheel path, although they may occur in the wheel path. The distress may occur in isolated areas, such as at intersections, or it may occur over a large part of the roadway surface.

Corrugations and waves are regularly occurring transverse undulations in the pavement surface. Corrugations occur as closely spaced ripples, while waves are undulations whose distance from peak to valley is more than 3 feet.

Severity: The severity of corrugation is defined as the maximum vertical deviation from a 10-foot straightedge placed on the pavement parallel to the center line of the roadway.

Low — $^{1}/_{8}$-inch to 2 inches per 10 feet.

Medium — 2 inches to 4 inches per 10 feet.

High — Over 4 inches per 10 feet.

Option A — Measurement of Corrugation and Waves

Extent: The extent of corrugations is expressed in percent of the lane area affected.

1 percent to 9 percent of the area of the segment
10 percent to 24 percent of the area of the segment
25 percent or more of the area of the segment

Measure: Determine severity by measuring the maximum difference in elevation that occurs within a 10-foot straightedge length centered over the area of displacement. Rate the overall distress by using the highest observed level.

Option B — Measurement of Corrugation and Waves

Extent: The extent of corrugations is expressed in square feet of the entire survey area.

Measure: Determine severity by measuring the maximum difference in elevation that occurs within a 10-foot straightedge length centered over the area of displacement. Rate the overall distress by using the highest observed level.

11. *Sags and Humps*

This distress category also covers forms of surface distress that are not limited to the wheel path, although they generally include the wheel paths. The distress usually occurs in isolated areas of the roadway surface.

Sags and humps are localized depressions or elevated areas of the pavement that result from settlement, pavement shoving, displacement due to subgrade swelling, or displacement due to tree roots.

Severity: The severity of sags or humps, like corrugation, is defined as the maximum vertical deviation from a 10-foot straightedge placed on the pavement parallel to the center line of the roadway.

Low — $^{1}/_{8}$-inch to 2 inches per 10 feet.

Medium — 2 inches to 4 inches per 10 feet.

High — Over 4 inches per 10 feet.

Option A — Measurement for Sags and Humps

Extent: The extent of sags and humps is expressed in percent of the lane area affected.

1 percent to 9 percent of the area of the segment
10 percent to 24 percent of the area of the segment
25 percent or more of the area of the segment

Measure: Determine severity by measuring the maximum difference in elevation that occurs within a 10-foot straightedge length centered over the area of displacement. Rate the overall distress by using the highest observed level.

Option B — Measurement for Sags and Humps

Extent: The extent of sags and humps is expressed in square feet of the entire survey area.

Measure: Determine severity by measuring the maximum difference in elevation that occurs within a 10-foot straightedge length centered over the area of displacement. Rate the overall distress by using the highest observed level.

12. *Block Cracking*

Block cracks divide the pavement surface into nearly rectangular pieces with cracks that intersect at about 90 degrees. This type of distress differs from alligator cracking in that alligator cracks form smaller, irregular shaped pieces with sharp angles. Also, alligator cracks are caused by repeated traffic loadings and are, therefore, generally located in traffic areas (i.e., the wheel paths).

Block cracking is caused principally by shrinkage of the asphalt concrete and daily temperature cycling. It is not load-associated, although load can increase the severity of individual cracks. The occurrence of block cracking usually indicates that the asphalt has hardened significantly through aging. Block cracking normally occurs over a large portion of the pavement area including nontraffic areas. However, various fatigue related defects may occur in the same segment.

Severity: The severity of block cracking is defined by the average size of the blocks and the average width of the cracks that separate them.

Block Size

Low — 9 × 9 feet or greater.

Medium — 5 × 5 feet to 8 × 8 feet blocks.

High — 4 × 4 feet blocks or less.

Crack Size

Low — Less than 1/4 inch.

Medium — Over 1/4 inch.

High — Spalled.

Option A — Measurement of Block Cracking

Extent: The extent of block cracking is assumed to be the full surveyed segment. If the block cracking does not extend throughout the segment, then rate the segment using longitudinal and transverse cracking.

Measure: Estimate the typical size of the blocks and select the appropriate standard block size and crack size.

Option B — Measurement of Block Cracking

Extent: The extent of block cracking is assumed to be square feet or percent of length. If the block cracking does not extend throughout the segment, then rate the segment using longitudinal and transverse cracking.

Measure: Measure the typical size of the blocks and select the appropriate standard block size and crack size.

13. Pavement Edge Condition

Edge raveling occurs when the pavement edge breaks away from roadways without curbs or paved shoulders. However, edge conditions can still occur with paved shoulders. Edge patching is the repair of this condition. The “lane less than 10 feet” distress indicates that the edge raveling has progressed to the point where the pavement width from the center line to the outer edge of roadway has been reduced to less than 10 feet.

Severity: The severity of Pavement Edge Condition is defined as follows.

Low — Edge Raveling

Medium — Edge Patching

High — Edge lane less than 10 feet.

Measure: Accumulate the lengths along the surveyed lane of each type edge defect as it occurs. Divide the accumulated lengths by the length of the segment. Multiply by 100 to get percent, and round to a whole number.

Extent: The extent of pavement edge conditions is recorded as a percentage of the length of the surveyed segment. Recommended ranges for estimated extent.

1 percent to 9 percent of the length of the segment
10 percent to 24 percent of the length of the segment
25 percent or more of the length of the segment

Edge Raveling

Edge Patching

14. Crack Seal Condition

Rate the condition of any existing crack (or joint) sealant. There may be separate information fields available for recording the amount (total length) of seal and the year it was installed or recording the absence of any sealant on the entire section.

Severity:

None — There are no sealed cracks.

Low — Sealant in good to excellent condition.

Medium — Hairline failure in the sealant allows a minimal amount of water to pass.

High — The sealant is severely cracked and may allow significant quantities of water to pass. The sealant is wide open (or nonexistent) and will allow water to pass freely.

Low

Medium

High

Extent: The extent of crack sealing is quantified as the percent of the total length of the cracks (or joints) in the segment which exhibit the seal condition.

1 percent to 9 percent of the total length of cracks or joints
10 percent to 24 percent of the total length of cracks or joints
25 percent or more of the total length of cracks or joints

Measure: Count (or estimate) and accumulate the length of cracks and joints that exhibit each severity of seal condition. Count (or estimate) the total length of cracks and joints in the segment. Divide each of the accumulated lengths of condition by the total length of cracks and joints, multiply by 100, and round to a whole number.

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The revision of this manual is the result of cooperation among the members of the Northwest Pavement Management Association, their respective agencies, the County Road Administration Board, the Washington State Department of Transportation (WSDOT), and private industry. The following individuals contributed considerable time and effort in reviewing drafts.

Cities

Renton	John Stein
	Bill Wressell
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	Dan Soderlind
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Linda Pierce
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Island	Larry Frostad
Kitsap	Callene Abernathy Lucy Mills
Marion (Oregon)	Michael L. Rybka Joel M. Conder
Skagit	Vicki Griffiths
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Spokane	Lamont Glabb
Thurston	Pat Carroll

County Road Administration Board

Dave Whitcher

Private Industry

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Pavedex, Inc.	Don Meyers
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Cities

Airway Heights
Bellevue
Bellingham
Bonney Lake
Bremerton
Edmonds
Ellensburg
Forks
Gig Harbor
Lacey
Lynden
Moses Lake
Normandy Park
Olympia
Port Angeles
Seattle
Shelton
Spokane
Sunnyside

Counties

Ada (Idaho)
Adams
Asotin
Benton
Clallam
Columbia
Franklin
Klamath (Oregon)
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Final editing for compliance with the Washington State Pavement Management System standards was done by R. Keith Kay, Pavement Management Engineer for WSDOT.

Appendix C

Rating Cheat Sheet

Asphalt Concrete
Pavement Distress Identification
Field Reference Sheet

Alligator Cracking

Low:	Fine, interconnecting cracks. Generally less than 3/8".
Medium:	Fully developed alligator pattern, may contain light spalling.
High:	Well defined alligator pattern with spalling. Pieces may be missing or loose, may contain potholes.
Data Entry:	Record area of each severity in square feet.

Longitudinal Cracking

Low:	Fine longitudinal cracks which are less than 3/8" wide or any properly filled crack.
Medium:	Longitudinal cracks between 3/8" & 3". May contain light spalling.
High:	Longitudinal crack 3" or wider or smaller cracks with high spalling. Pieces may be missing or loose.
Data Entry:	Record length of each severity in lineal feet.

Transverse Cracking

Low:	Fine transverse cracks which are less than 3/8" wide or any properly filled crack.
Medium:	Transverse cracks between 3/8" & 3", may contain light spalling.
High:	Transverse crack 3" or wider or smaller cracks with high spalling. Pieces may be missing or loose.
Data Entry:	Record number of each severity of full width cracks.

Patching

Low:	Patch is in good condition. May contain low distresses but ride quality is good.
Medium:	Moderately deteriorated. Contains medium distresses and ride quality is affected.
High:	Patch in poor condition. Contains high distresses, poor ride quality, and is in need of replacement.
Data Entry:	Record area of each severity in sq. ft. Do not rate distresses in patches, just determine severity of patch.

Block Cracking

Low:	Fine, interconnecting longitudinal cracks. Generally less than 3/8".
Medium:	Fully developed alligator pattern, may contain light spalling.
High:	Well defined alligator pattern with spalling. Pieces may be loose, may contain potholes.
Data Entry:	Record area of each severity in sq. ft.

Rutting/Depressions

Low:	Rutting or depression of ½" to less than 1"
Medium:	Rutting or depression of 1" to less than 2"
High:	Rutting or depression of 2" or greater
Data Entry:	Record area of each severity in square feet.

Raveling

Low:	*No Low Severity for Raveling
Medium:	Moderate wear with rough & pitted surface. Loss of aggregate.
High:	Very rough & pitted surface. Missing pieces.
Data Entry:	Record area of each severity in square feet.

Weathering

Low:	Aggregate or binder starting to wear, starting to show loss of binder.
Medium:	Moderate wear with rough surface. Loss of fine aggregate.
High:	Rough surface. Pitting is prominent with loss of course aggregate.
Data Entry:	Record area of each severity in square feet.

Distortions

Low:	Distortion that produces noticeable vehicle vibration but no reduction in speed is required
Medium:	Significant vehicle vibration and some reduction in speed is necessary for comfort.
High:	Excessive vehicle vibrations that require a reduction in speed for safety and comfort.
Data Entry:	Record area of each severity in sq. ft.