BUREAU OF ENVIRONMENTAL SERVICES • CITY OF PORTLAND

Portland Area Watershed Monitoring and Assessment Program

Executive Summary—Findings from Years 1-4

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ENVIRONMENTAL SERVICES
CITY OF PORTLAND
working for clean rivers

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Tideman Johnson restoration site in the Johnson Creek watershed

EXECUTIVE SUMMARY

Portland Area Watershed Monitoring and Assessment Program
Findings from Years 1-4

PAWMAP gathers and analyzes data from these Portland-area watersheds:

- Columbia Slough
- Fanno Creek
- Johnson Creek
- Tryon Creek
- Tualatin Streams
- Willamette Streams (west-side tributaries to the Willamette River)

Many different types of streams and rivers flow in and through Portland. The city is located at the joining of two of the West's largest rivers – the snowmelt-driven Columbia and the rain-fed Willamette.

Local streams include the low gradient, tidally-influenced Columbia Slough; moderate gradient Johnson Creek; and small, higher gradient streams draining the West Hills. Portland's watersheds are as diverse an assemblage of flowing waters as can be found within 150 square miles[1].

The Portland Area Watershed Monitoring and Assessment Program (PAWMAP) measures water quality, habitat, and biological conditions in Portland's streams to assess their health and identify key threats. PAWMAP supports the implementation of the Portland Watershed Management Plan by supplying key data to guide actions and evaluate the success of those actions. For more about the monitoring program design and background, see **www.portlandoregon.gov/bes/PAWMAP**.

This report summarizes data collected over the first four years of the program, from 2010 - 2014. This analysis provides an important baseline for the program, as it represents the first assessment of the complete set of stations that the program samples. PAWMAP uses a four-year rotational panel of stations to characterize conditions across a diverse set of watersheds. The first four years of data thus provide the first analysis of the full set of sampling stations and the full spatial resolution for which the program was designed.

What We Measure

PHYSICAL HABITAT

- Stream substrate
- Large wood
- Bank condition
- Riparian vegetation and shading
- Human disturbance
- Gradient, habitat type, depth, etc.

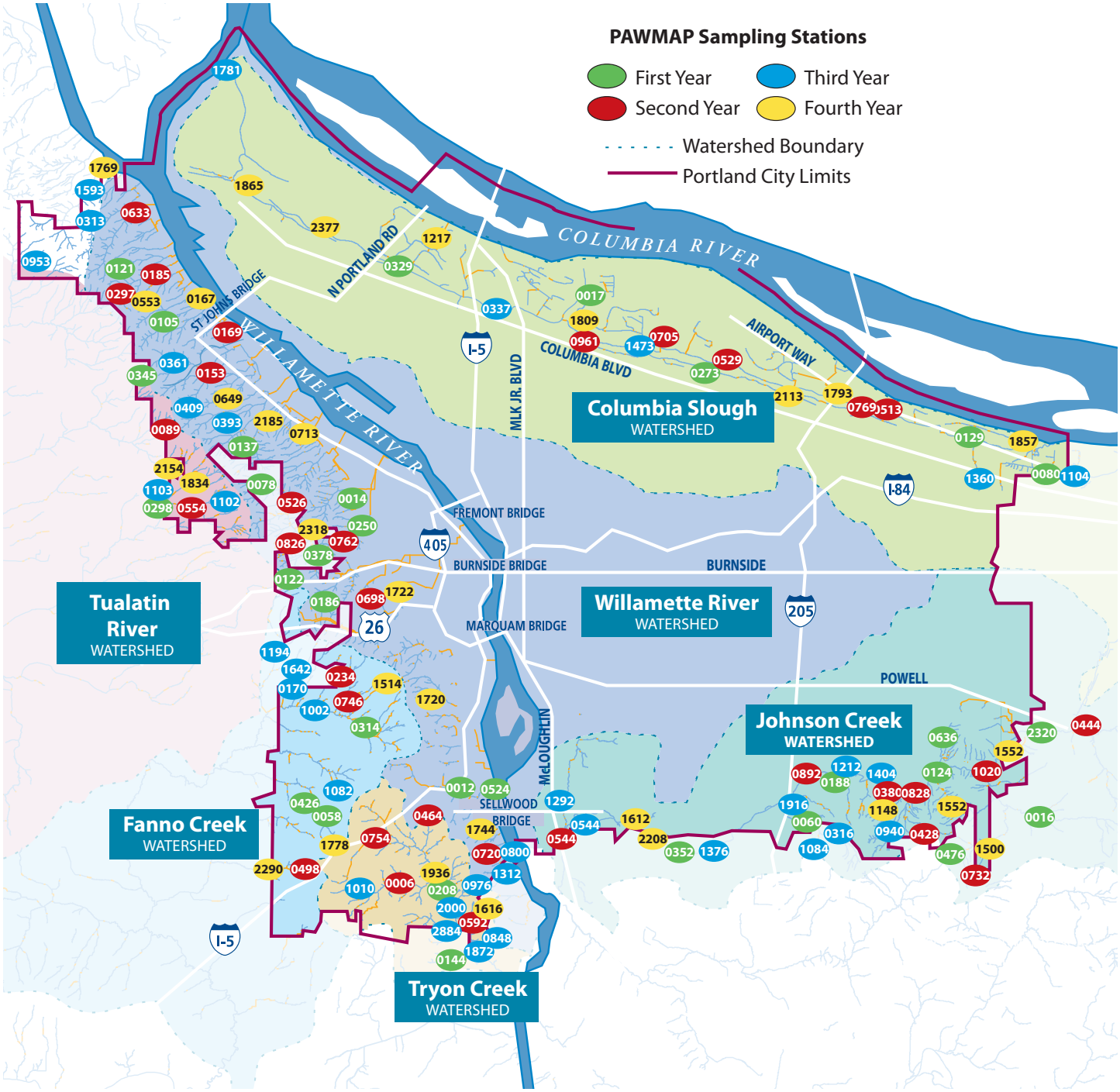
WATER QUALITY

- Temperature
- Total suspended solids
- Dissolved oxygen
- *E. coli*
- Nutrients (e.g., phosphorus)
- Metals (e.g., copper)
- Other conventional water quality indicators (hardness, pH, etc.)

BIOLOGICAL COMMUNITIES

- Fish
- Birds
- Macroinvertebrates (e.g., aquatic insects)

Sampling Sites



Key Citywide Findings

Restoration projects like the Lower Columbia Slough Refugia Project add in-stream wood using boats, cranes and barges. The logs improve habitat without impacting existing natural resources or the slough levee.

- The volume of large wood in Portland streams is very low. This is true even in some reaches with well-vegetated riparian areas. The results suggest that a long legacy of removing wood in streams to protect urban infrastructure and the relatively young age of Portland forests are two factors that may explain the lack of wood even in well-vegetated stream reaches. Adding wood into instream restoration projects will be an important priority until riparian forests mature to the point that they provide wood naturally, and efforts to leave wood instream unless it presents an unacceptable risk to infrastructure should continue.
- In contrast, the data on stream substrates indicates that problems with inadequate gravel or excessive fine sediments from scour and excess deposition are not as prevalent. The report identifies sites with substrate issues and recommends site visits to assess geomorphological condition with possible wood addition to retain gravel and improve stream structure, and sediment evaluation with possible erosion control efforts (depending on the results of the sediment budget) in the areas where excessive fines have been documented.
- High stream temperatures and levels of *E. coli* are the two water quality issues most consistently seen across Portland streams. High temperatures are particularly problematic in the eastside streams. The Columbia Slough is naturally susceptible to high temperatures because it was originally a vast system of wetlands and waterways where water moved slowly across wide expanses. The conversion of this floodplain wetland to a channelized, pumped drainage system with limited riparian vegetation has clearly altered fundamental components of the hydrology and habitat and further exacerbated problems with stream temperatures. Ecologically, one of the highest priorities for temperature improvements is Johnson Creek. Johnson Creek has more intact fish communities than other Portland watersheds, but large sections of the stream – particularly the mainstem – spend the majority of the summer well above the state temperature standard.

- The pathogen indicator *E. coli* was much higher during storms than during seasonal sampling in Portland streams. Within the seasonal sampling, summer *E. coli* levels were higher than the other three seasons, and the report describes possible reasons that may explain this pattern. There were significant differences in *E. coli* among watersheds. The Willamette Streams had the lowest median *E. coli* values for seasonal sampling and *E. coli* was significantly lower in the Willamette Streams and Columbia Slough than in most of the other watersheds.

A juvenile steelhead measured at site #2320 in the Johnson Creek watershed.

- The first four years of PAWMAP data indicate that evidence of eutrophication – excessive nutrients that lead to overproduction of algae – in Portland streams is primarily limited to the Columbia Slough. Eutrophication in the Slough was evident through nutrient concentrations, chlorophyll *a* levels, and dissolved oxygen. Nutrient control and eutrophication are important issues to address in the Tualatin Streams and Fanno Creek as well, however, because these systems drain to the Tualatin River where nutrients and eutrophication are a problem lower in the river system and are regulated through Total Maximum Daily Loads.
- In general, the metals copper, lead, mercury and zinc were highly correlated with each other so that there are similarities in the metals results. In addition, total metals were significantly correlated with total suspended solids. Metals infrequently exceeded the state hardness-adjusted water quality criteria. Total copper was the metal which exceeded criteria most frequently: 23 of the 547 copper samples were above the criterion. All but one of these occurred during storms. The only other metal to exceed water quality criteria over the first four years of sampling was a single sample in Veterans Creek (Johnson Creek) which exceeded the acute criterion for zinc.
- The Willamette Streams and Tryon Creek had the highest macroinvertebrate (aquatic insect) community scores. The health of macroinvertebrate communities is assessed through the "Observed/Expected" ratio – a measure of how closely stream macroinvertebrates resemble unimpacted reference communities. The Willamette Streams had the six highest O/E scores across the four years. It was the only watershed with an O/E score above DEQ's "least impacted" benchmark of 0.91 – a Miller Creek station had an O/E of 0.95, indicating that conditions in that stream are comparable to the least impacted reference streams across western Oregon. One other site in Balch Creek – 0250 – had a score (0.86) above the "minimally impacted" benchmark of 0.85. All other sites across the city were below this benchmark and considered "most impacted."

Key Findings—Years 1-4

Cutthroat trout are among the five most commonly found species in Portland streams.

- A total of 30 different fish species were captured in wadeable streams in the first four years, 16 native and 14 non-native species. While the number of native and non-native species were roughly similar, the number of individual native fish greatly outnumbered the number of non-native individuals. The five most commonly detected species were reticulate sculpin (*Cottus perplexus*), cutthroat trout (*Oncorhynchus clarki*), redside shiners (*Richardsonius balteatus*), speckled dace (*Rhinichthys osculus*), and rainbow trout/steelhead (*Oncorhynchus mykiss*), which are all native and include two salmonids. The ten most common species in fish communities in Portland streams are all native. Pumpkinseed, small- and largemouth bass and brown bullheads were the most frequently encountered non-native species.
- The Index of Biotic Integrity (IBI) is a score that assesses the health of fish communities. There was large variability in IBIs even within a single watershed. Most of the sites scored poorly against the benchmarks for the IBI. No sites scored acceptable (>75). Twelve sites had scores considered marginally impaired (>50): seven in Johnson Creek, two in Tryon Creek, and one each in Fanno Creek, Willamette Streams and the Columbia Slough. All other scores were below 50 and considered severely impaired. Fanno Creek had the station with the highest overall IBI (61.7 at Sylvan (0170)) and Johnson Creek had the next six highest IBIs and the highest overall average IBI.

- Culverts clearly impaired fish communities. Over the first four years, over 45% of the sites above impassable culverts had zero fish present and therefore an IBI score of zero. In contrast, none of the sites above partially or fully accessible reaches ever had zero fish. This result is particularly striking because of the fact that much of Portland's highest quality habitat (e.g., nearly all of Forest Park) is above impassable culverts.

Culverts, like this one on Tryon Creek at SW Boones Ferry Road near SW Arnold Street, impair fish by blocking passage to some of Portland's highest quality fish habitats.

- A total of 77 different bird species were found in riparian surveys. Of these, 75 species (97%) were native. Non-native bird species were most common in the riparian areas of Columbia Slough and Johnson Creek. Over 70% of the sites in the Columbia Slough and 45% of the sites in Johnson Creek had non-native species present. In contrast, no non-native birds were observed in the Willamette Streams, and they were infrequently observed in Fanno, Tualatin and Tryon.
- At Risk and Special Status species were observed in each watershed. The greatest number of individuals of At Risk species per survey was observed in the Columbia Slough, and Tryon Creek had the second highest number. The highest average Bird Integrity Index score by watershed was in the Willamette Streams, while the lowest was in Fanno Creek. Analysis of variance indicates that the differences among watersheds were highly significant, and that the differences were due to higher scores in the Willamette Streams than in Fanno Creek, the Columbia Slough, and Johnson Creek. The Bird Integrity Index showed a highly significant relationship to the percentage of riparian canopy within a 300-foot buffer, with percent canopy explaining about 45% of the variability in the BII.
- Macroinvertebrates were used as a biological indicator to evaluate the impact of the components of stream habitat and water quality variables measured by PAWMAP. Riparian conditions were clearly important, as the variables accounting for disturbance and canopy were identified as the first and fourth most important variables in the models. Zinc was identified as the second most important variable, and *E. coli* was the third most important variable. It is unlikely that *E. coli* directly impacts macroinvertebrate communities, as it is primarily an indicator of pathogens that are a threat to human health. It is more likely an indicator that other sewage-related inputs may be affecting macroinvertebrate communities. Bank hardening was identified as the fifth most important variable.

Site #0129 is an example of a typical slough site. The slough is a naturally low-gradient, slow-flowing system, which is very different from the other streams in Portland.

WATERSHED: COLUMBIA SLOUGH

The Columbia Slough begins at Fairview Lake and meanders west for 19 miles to Kelley Point Park where it empties into the Willamette River. Historically, the Columbia Slough waterway was a low-gradient collection of wetlands, lakes and streams that formed the Columbia and Willamette River floodplains. The slough is Portland's most altered watershed and waterway. Over the years, the area was heavily altered to accommodate industry, transportation and agriculture. Beginning in 1918, levees were built to provide flood protection. Wetlands and side channels were drained and filled to allow for development. The waterway was channelized, and dozens of streams were filled or diverted to underground pipes.

The Columbia Slough at Whitaker Slough (site 0273) is an example of a "boatable" survey site, where deep water does not allow field staff to traverse the stream safely and sampling must be done from a boat.

Fanno Creek sampling location #0314 is adjacent to the Beaverton-Hillsdale Highway. Culverts are common along urban streams and have major impacts on stream health. They can limit the ability of fish and wildlife to move between different habitats seasonally, impact water quality, and alter natural stream flows and the movement of gravel and wood through the system.

WATERSHED: FANNO CREEK

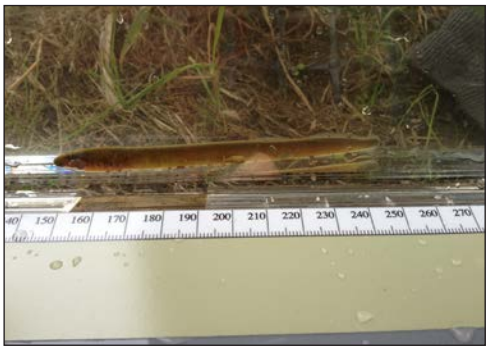
Riparian vegetation at sampling location #0234.

Fanno Creek is one of a series of streams that drain the west slope of the Tualatin Mountains to the Tualatin River, then flow to the Willamette River above Willamette Falls. As part of the Tualatin River Basin, Fanno Creek drains about 20,500 acres. Of that land area, 4,528 acres are within the City of Portland. Land use in the Fanno Creek Watershed is dominated by residential, industrial and commercial activities.

Water quality is sampled quarterly on the Fanno mainstem to capture seasonal changes, and once during storm flows at each site. Stormwater can be a major threat to the health of urban watersheds. Sampling during storm flows helps show how stormwater affects stream health.

The East Powell Butte Restoration Project in 2005 restored 22 acres in the Johnson Creek watershed to increase habitat for fish and other wildlife; to stabilize and shade stream banks to improve water quality; and to add about 74-acre feet of flood storage in the floodplain. Above is how the site looks today.

WATERSHED: JOHNSON CREEK



A Pacific lamprey counted at sampling site #2320.

Johnson Creek originates in the hills east of Portland and flows westward approximately 25 miles to its confluence with the Willamette River. The stream receives water from several major tributaries, including Crystal Springs Creek, Kelley Creek, Mitchell Creek, Butler Creek, Hogan Creek, Sunshine Creek and Badger Creek. Land use in the 34,310-acre watershed ranges from heavily developed urban and industrial areas to rural farm and nursery lands.

Johnson Creek flows through the Luther Road Natural Area. The land bordering the restored area is primarily industrial use.

Taking macroinvertebrate (aquatic insect) samples at location #0144 on Tryon Creek.

WATERSHED: TRYON CREEK

Sampling location # 0144 is at Nettle Creek, a small tributary that flows from Lake Oswego into the lower mainstem of Tryon in the Tryon Creek State Natural Area.

Tryon Creek is a seven-mile long free-flowing stream that drains a roughly 4,200-acre watershed. The stream flows in a southeasterly direction from Mt. Sylvania in the Southwest Hills of Portland to the Willamette River near Lake Oswego. It is primarily a moderate gradient stream with steep slopes, which results in a high frequency of landslides and erosion. The upper watershed has suffered impacts commonly associated with urban development, including increased stream flow velocities and volumes following storm events, with subsequent stream bank erosion.

An adult cutthroat trout (captured in Tryon Creek). Cutthroat trout are the second most commonly captured fish species in Tryon Creek, behind reticulate sculpin.

Measuring stream channel habitat features at site location #0298

WATERSHED: TUALATIN STREAMS

Over the crest of the West Hills (also known as the Tualatin Mountains) is a long range of streams that drain to the Tualatin River, then flow to the Willamette River above Willamette Falls. Some of these streams, such as Bronson and Cedar Mill creeks, start within the City of Portland's boundaries. This is also referred to as the Skyline West watershed area. Land use around these streams ranges widely from well-forested natural areas to residential and transportation uses. Fanno Creek also drains to the Tualatin River, but is characterized and monitored separately since such a large portion of its watershed is within Portland.

The Cedar Mill Creek site shows wood and boulders piling up at a culvert. Culverts often limit the passage of large wood and fish and wildlife and degrade stream flow and water quality, which adversely affects stream health.

Field crew gathers information at sampling site #0524. Information on in-stream habitat and riparian conditions helps identify the major factors threatening stream health.

WATERSHED: WILLAMETTE STREAMS

The Willamette Streams are a diverse set of streams that range from the highly impacted and urbanized Stephens Creek to the well-vegetated and protected streams within Forest Park. These small watersheds all drain the West Hills before discharging to the Willamette River mainstem. They are therefore grouped together into a "watershed" called the Willamette Streams, a sub-area of Portland's Willamette River Watershed. Because of their diverse land uses and characteristics, these streams typically had wide ranges in watershed metrics.

Measuring stream channel characteristics at site #0617, an intermittent stream heavily affected by invasive plant species.

Conclusions

Since the first four years of data represent the full set of sampling stations and the full spatial resolution for which the program was designed, this analysis serves as an ***important baseline*** *for the program.*

The goal of the Portland Area Watershed Assessment and Monitoring Program (PAWMAP) is to provide a base of scientific information that guides actions to improve watershed health in Portland. The data and results presented in this report are an assessment of the first four years of PAWMAP monitoring data. Since the first four years of data represent the full set of sampling stations and the full spatial resolution for which the program was designed, this analysis serves as an important baseline for the program. Ongoing data collection through PAWMAP will continue to enhance our understanding of the condition of Portland's watersheds. Over time, as PAWMAP stations are revisited, the data that will be collected can be used to assess overall trends in watershed health, allowing the city to adaptively manage restoration projects and programs and implement actions that target the most important watershed stressors.

PAWMAP collects a large amount of data with complex patterns. In order to interpret the data and evaluate the health of Portland's watersheds, each PAWMAP parameter can be evaluated individually against a standard or benchmark, but no single metric can fully represent the conditions of a stream or watershed. Rather, it is the combination of multiple metrics that characterize watershed conditions. Even with all of the metrics and their benchmarks, however, it can be challenging to articulate the many components that comprise the overall health of Portland's watersheds.

Fish, bugs and birds help provide a more complete picture

Tracking biological communities—the fish, bugs and birds that live in or by streams—is one of the most effective ways of assessing the health of a stream. They are always present and responding to the conditions of a stream. Plus they can help us understand how a combination of stressors in their environment can harm their health and survival.

One way to best approaches for assessing the health of Portland's watersheds is through data on biological communities. The Portland Watershed Management Plan (PWMP) places special emphasis on biological communities – the fish, bugs and birds that live in or by a stream – as indicators of watershed health. Biological indicators are in essence the pulse of a river, and one of the most effective ways of assessing conditions as they provide a more realistic and comprehensive assessment of the key stressors that impair watershed health. The condition of a biological community reflects impacts from all stressors, rather than merely those we for which we have standards, benchmarks or criteria. They can account for the fact that multiple stressors in combination may have different impacts than when assessed individually, and can point to synergistic or antagonistic effects among multiple stressors. Many biological communities are "continuous" monitors – they are always present in the stream and responsive to its conditions. Others can reflect past impacts that may be missed by occasional monitoring visits or that occur during storms when streams are infrequently sampled.

Perhaps most importantly, biological indicators are most closely tied to watershed objectives. The goals and objectives for hydrology, water quality, and habitat – like the water quality standards and habitat benchmarks on which they are based – are set at levels necessary to protect the fish, bugs and birds that rely on the streams for their survival. We can begin to answer the questions: "are we prioritizing the right problems?" and "are we doing enough?" by the conditions, trends and improvements in biological communities.

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The condition of biological communities in Portland's streams provide causes for concern as well as hope. Causes for concern include the fact that the biological metrics tracked under the Portland Watershed Management Plan score very poorly in comparison to reference areas and regional benchmarks. Using fish as an example, the Fish Index of Biotic Integrity (IBI) developed for the Pacific Northwest (Hughes and others 1998), indicate that none of the sites in Portland streams scored above the acceptable benchmark (> 75). Twelve sites had scores considered marginally impaired (>50): seven in Johnson Creek, two in Tryon Creek, and one each in Fanno Creek, Willamette Streams and the Columbia Slough. All other scores were below 50, the level at which fish communities are considered severely impaired.

Metrics of macroinvertebrate community health were consistent with the fish results. The "Observed/Expected" (O/E) ratio developed by Oregon Department of Environmental Quality provides a measure of how closely stream macroinvertebrates resemble unimpacted reference communities across Western Oregon. Only one site across the city had an O/E score above DEQ's "least impacted" benchmark of 0.91: a Miller Creek station had an O/E of 0.95, indicating that conditions in that stream are comparable to the least impacted reference streams in western Oregon. One other site in Balch Creek – P0250 – had a score (0.86) above the "minimally impacted" benchmark of 0.85. All other sites across the city were below this benchmark and considered "most impacted."

What is hurting biological communities?

What are the causes of degraded biological communities in Portland streams? This can often be difficult to determine in urban watersheds where "everything is broken," and key stressors such as impervious surfaces, flashy flows, lack of riparian vegetation, high stream temperatures, hardened banks, and pollutants are all highly correlated. These factors tend to vary together so it can be hard to separate the impacts and determine which is the highest priority to address, or whether they all are inextricably linked and need to be addressed together.

There are several ways to try and determine which stressors are the greatest threats to watershed health. One is to compare the habitat and water quality metrics collected by PAWMAP to water quality standards, habitat benchmarks and other criteria to see which metrics exceed their respective criteria. Those that substantially exceed their criteria are more likely to be key threats than those that do not exceed their criteria, or only do so by a little. Using this approach, the first four years of PAWMAP data indicate that the abundance of large wood is one of the habitat metrics that is furthest away from meeting its benchmark. Ninety of the 127 stations had levels of wood that were less than half the "Not Properly Functioning" benchmark. For water quality, temperature and *E. coli* were the metrics that most frequently exceed water quality criteria.

Another approach for identifying the greatest threats to watershed health is to use the biological indicators to help evaluate the relative severity of key threats. The analyses indicate the critical importance of the stream-riparian corridor. Three of the top five most important predictors of macroinvertebrate community health were riparian and bank variables: riparian disturbance, riparian canopy and bank condition were the first, fourth and fifth most important variables. The results also indicate a strong water quality signal; zinc was the second most important variable. *E. coli* (third) and ammonia (sixth) were also important variables. Possible sources of these water quality stressors are discussed within the report.

In urban environments, stormwater infrastructure can quickly carry polluted runoff to streams.

Urban watersheds

It is important to emphasize that these analyses currently provide an incomplete answer. For this report the model only included those metrics measured as part of the PAWMAP program, which captures conditions within the stream-riparian corridor. In urban watersheds, however, stressors that originate far outside the stream-riparian corridor such as impervious surfaces, roads, and industrial and municipal discharges can be major causes of stream degradation. In urban areas stormwater infrastructure rapidly delivers runoff to the stream and bypasses the natural treatment processes that occur through overland flow and infiltration into the ground. These urban upland metrics are currently being assembled and will be analyzed and reported in the next PAWMAP report. The land use analysis will provide further insight into the likely sources of water quality pollutants which were rated as important predictors in the random forest analysis.

The results from the first four years of PAWMAP monitoring are not unexpected for an urban watershed. There is an extensive body of research and monitoring data from across the globe documenting the pervasive and severe impacts of urbanization on watershed health, to the point that the impacts associated with urbanization have

been given a term – the "urban stream syndrome" (Walsh et al. 2005). Despite the impact of urbanization, the PAWMAP data also highlight that there is potential for restoring the biological communities in Portland's streams. The vast majority of fish (>99%) in Portland's streams are native. In fact, the ten most commonly encountered fish species are all native, and four of the top eleven are sensitive salmonids. The macroinvertebrates tell a similar story. There are streams within the city that meet or are near reference conditions for macroinvertebrates – reflecting that those watersheds have highly functional hydrology, water quality and habitat. While these represent a small minority of sites across the city where watersheds are well-vegetated and stormwater inputs are limited, they underline the fact that important regional urban issues like air quality, atmospheric deposition, invasive species, and disturbance of natural areas from intensive use by humans and their pets do not preclude the attainment of reference conditions in well-vegetated watersheds, even within an urban area. The characteristics of Portland's bird populations are also encouraging. The vast majority of riparian bird species (97%) were native, and At-Risk and Special Status bird species were observed in each watershed, pointing to the important functions still provided by our remaining intact urban riparian areas.

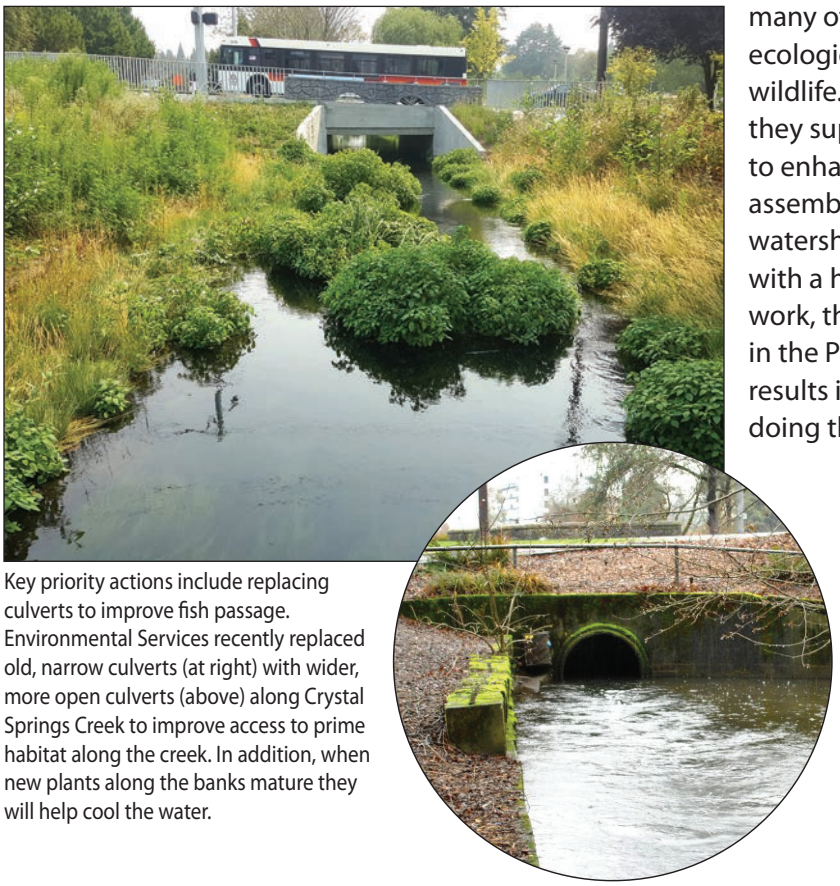
The vast majority of fish (>99%) in Portland's streams are native.

There are also some surprising positive habitat and water quality results that are consistent with the biological metrics and that similarly might not be expected for urban watersheds. For example, metals infrequently exceed their criteria, signs of eutrophication are limited to the Columbia Slough and Fanno Creek, and while the eastside watersheds (Columbia Slough and Johnson Creek) exceed their temperature criteria by a considerable amount across the summer, temperature exceedances in many well-vegetated Willamette Streams and portions of Tryon Creek only exceed the standard for short periods if at all in a typical summer.

Going Forward

What do these results tell us about watershed conditions and the potential for restoration in Portland?

The biological results document that 150 years of extensive degradation through urban development and runoff has taken its toll on the biological communities in Portland's streams. Consequently, the task of restoring these communities will be difficult and will take considerable time. At the same time, however, the biological data collected through PAWMAP demonstrate that many of Portland's streams still provide sufficient critical ecological functions necessary to sustain native fish and wildlife. These areas, and the biological communities that they support, illustrate that there is substantial potential to enhance the health of Portland's streams – the desired assemblages of native species are present in Portland's watersheds, but, they lack the abundance associated with a healthy system. Through targeted restoration work, the City can work towards meeting the goals set in the Portland Watershed Management Program. The results indicate that some of the key priority actions for doing this include



Key priority actions include replacing culverts to improve fish passage. Environmental Services recently replaced old, narrow culverts (at right) with wider, more open culverts (above) along Crystal Springs Creek to improve access to prime habitat along the creek. In addition, when new plants along the banks mature they will help cool the water.

- Continuing to restore riparian areas to address temperature, particularly in Johnson Creek where some of the city's healthiest fish communities reside.
- Adding wood until existing riparian forests mature to the point that they provide wood naturally
- Improving passage at culverts that block access to some of the highest quality habitats in the city.

The results also suggest that urban water quality impacts stream communities as well, since zinc and *E. coli* were important predictors of stream community health. However, it is not yet known whether these are pollutants that affect stream communities directly, or whether they are indicators of other unmeasured pollutants and urban impacts with which they are correlated (e.g., polycyclic aromatic hydrocarbons (PAHs) or sewage-related impacts). The next PAWMAP report will evaluate a suite of land use indicators and data on urban stormwater infrastructure to provide more focused recommendations on priority stormwater actions to improve stream water quality.

GLOSSARY

Bird Integrity Index: An index based off an index developed by Bryce et al. (2002) that uses bird communities as an index of riparian condition for streams in the Willamette Valley. (Bryce, S. A., R. M. Hughes, and P. R. Kaufman. 2002. Development of a bird integrity index: using bird assemblages as indicators of riparian condition. Environmental Management 30:294–310.)

Eutrophication: The process by which a body of water becomes enriched in dissolved nutrients (such as phosphates) that stimulate the growth of aquatic plant life usually resulting in the depletion of dissolved oxygen.[5]

Fine sediments: Sediments <0.06 mm in size, although sometimes this can include sand which is < 2 mm in size.[6]

Gradient: The degree of inclination, or the rate of ascent or descent in a river or stream. [3]

Gravels: Loose rounded fragments of rock[5], typically 2 – 64 mm in size (about the size of a ladybug to a tennis ball).

Levee: A natural or man-made earthen obstruction along the edge of a stream, lake, or river, usually built to restrain the flow of water out of a river bank and protect land from flooding. [3]

Macroinvertebrates: Macroinvertebrates are organisms that are large enough to be seen with the naked eye but do not have a back bone. Many types of macroinvertebrates live in or near the water. They are abundant in lakes, streams, ponds, marshes, and puddles.[6] The types of macroinvertebrates present in a stream are often used to assess its health.

Metals: A dense, opaque element that is usually a lustrous solid and is a good conductor of heat or electricity.[4] In high concentrations metals can be toxic to aquatic life.

Properly Functioning Condition: The sustained presence of natural habitat-forming processes that are necessary for the long-term survival of the species through the full range of environmental variation. [4]

Not Properly Functioning: The lack of the sustained presence of natural habitat-forming processes that are necessary for the long-term survival of the species through the full range of environmental variation. [4]

Portland Water Quality Index: An index comprised of eight measures that is designed to compile water quality data of importance in Portland's streams into a single value that can be tracked over time. The eight measures are temperature, dissolved oxygen, ammonia, phosphorus, total suspended solids, dissolved copper, total mercury and *E. coli*.

Riparian canopy: The canopy of the trees on the banks of a waterbody.[2]

Riparian conditions: The conditions on the banks of a waterbody.[4]

Riffles: Shallow rapids in an open stream, where the water surface is broken into waves by obstructions such as shoals or sandbars wholly or partly submerged beneath the water surface.[3]

Salmonids: Any of a family (Salmonidae) of elongate bony fishes (as a salmon or trout) that have the last three vertebrae upturned.[5] Salmonids that are present in local Portland streams and rivers include coho and Chinook salmon, and cutthroat and steelhead trout. Chum salmon are present in the Columbia River and sockeye salmon are occasionally observed in the Willamette and Columbia rivers.

Substrate: The material underlying something, such as the soil beneath plants and animals, or the gravels and sediments composing a stream bottom.[2]

Suspended sediments: Particles of organic and inorganic matter that are suspended in or are carried by water.[6]

Total suspended solids: A measure of suspended sediments in water, obtained by filtering water and weighing the amount of sediment retained on a filter.[6]

Watershed: A topographically discrete unit or stream basin that includes the headwaters, main channel, slopes leading to the channel, tributaries and mouth area.[2]

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1 Because of the time required to secure access to sample stream reaches through private property, temperature probes were often not installed until mid- to late-summer. This will be an issue in sampling the four rotating panels for the first time but, since access permissions have been acquired, will not be an issue for the second and subsequent rounds of sampling each panel.

2 Framework for Integrated Management of Watershed Health www.portlandoregon.gov/bes/33528

3 The Ecology Dictionary www.ecologydictionary.org

4 Oxford Dictionary of Environment and Conservation. www.oxfordreference.com/view/10.1093/acref/9780198609957.001.0001/acref-9780198609957

5 Merriam Webster www.merriam-webster.com/dictionary

6 Chris Prescott, Portland Bureau of Environmental Services, Personal Communication.

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Springwater Wetlands along Johnson Creek