City of Portland, Oregon

National Pollutant Discharge Elimination System (NPDES)
Municipal Separate Storm Sewer System (MS4) Discharge Permit

Permit Number: 101314

HYDROMODIFICATION ASSESSMENT

November 1, 2014

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EXECUTIVE SUMMARY

This Hydromodification Assessment evaluates hydromodification impacts related to discharges from the City of Portland's municipal separate storm sewer system (City MS4). These impacts include erosion, sedimentation, and alteration to stormwater flow, volume, and duration that may cause or contribute to water quality degradation.

***Hydromodification*:** The alteration of hydrologic characteristics caused by urbanization.
***Hydromodification impact*:** A stream impact caused specifically by hydromodification.

The assessment includes streams in the Fanno/Tryon Watershed, Willamette subwatersheds, and Johnson Creek Watershed. It does not include the Willamette River mainstem, the Columbia Slough, or the Columbia River. The Willamette and Columbia Rivers and the Lower Columbia Slough are excluded because City MS4 stormwater discharges account for a very small fraction of a percent of the total flow in these water bodies. The Middle and Upper Columbia Slough are not included because that system is managed for both water level and flow.

The assessment identified the following number of hydromodification impact sites related to the City MS4.

Fanno/Tryon Watershed:	12
Willamette Subwatersheds:	11
Johnson Creek Watershed:	11
Total	34

Most of the identified impacts are near-field (related mostly to the concentration of flow energy around an outfall pipe). Few far-field impacts (beyond the direct influence of outfall hydraulics) were identified. This is because the majority of the City was developed in the late-19th to early- to mid- 20th centuries, and stream channels have adjusted to the hydromodification effects that followed that development.

Several stream reaches were identified as being potentially susceptible to hydromodification impacts if dramatic future changes in hydrologic characteristics were to occur as a result of large-scale development. This is considered unlikely to happen, however, because most of the area has already been developed, and most development occurring today is infill development or redevelopment on a relatively small (lot-by-lot) scale. In addition, the *Stormwater Management Manual* requirements mitigate the alterations to hydrology normally associated with new development and redevelopment.

The City has a number of measures in place to reduce the potential for MS4 hydromodification impacts. In addition, the City is currently developing its long-term *Stormwater System Plan* (SWSP), which will include elements related to reducing or minimizing hydromodification impacts.

INTRODUCTION

Purpose

The purpose of this Hydromodification Assessment is to evaluate hydromodification impacts related to discharges from the City of Portland's municipal separate storm sewer system (City MS4). These impacts include erosion, sedimentation, and alteration to stormwater flow, volume, and duration that may cause or contribute to water quality degradation.

Permit Requirements

The Hydromodification Assessment fulfills the following requirements of the City's National Pollutant Discharge Elimination System (NPDES) MS4 Discharge Permit #101314 (January 31, 2011):

Schedule A.5

Hydromodification Assessment: The co-permittee must conduct an initial hydromodification assessment and submit a report by November 1, 2014 that examines the hydromodification impacts related to the co-permittee's MS4 discharges, including erosion, sedimentation, and alteration to stormwater flow, volume and duration that may cause or contribute to water quality degradation. The report shall describe existing efforts and proposed actions the co-permittee has identified to address the following objectives:

a. Collect and maintain information that will inform future stormwater management decisions related to hydromodification based on local conditions and needs;

b. Identify or develop strategies to address hydromodification information or data gaps related to waterbodies within the co-permittee's jurisdiction;

c. Identify strategies and priorities for preventing or reducing hydromodification impacts related to the co-permittee's MS4 discharges; and,

d. Identify or develop effective tools to reduce hydromodification.

Definitions

***Erosion*:** Detachment, entrainment and removal of stream bank or streambed material as individual grains or as aggregates by fluvial and sub-aerial processes. Fluvial erosion is evidenced by exposed soils or rock, scalloped or collapsed banks, undercut banks, tension cracks in banks adjacent to the stream channel, blocks of bank material at the toe of the bank and scoured channels at MS4 outfalls (Lewis et al., 1997).

> ***Active Erosion*:** Erosion is considered to be active if vegetation has not grown over exposed soils or if exposed materials are erodible.

Far-field impact: Impact resulting from changes in the ambient flow-field of a stream downstream of an outfall. Far-field impacts occur in the stream channel beyond the direct influence of outfall hydraulics and represent hydromodification as it is generally understood.

***Hydromodification*:** The alteration of hydrologic characteristics caused by urbanization.

***Hydromodification impact*:** A stream impact caused specifically by hydromodification.

***Near-field impact*:** Impact related mostly to the concentration of flow energy around a structure (e.g., an outfall pipe or culvert pipe). Near-field impacts are the direct result of hydraulics around structures and are confined to the proximity of the structure, where energy dissipates. Such impacts indicate the need for adequate energy dissipation at an outfall.

Possible impact: A stream impact that has been observed or reported that may or may not be related to hydromodification.

***Sedimentation*:** A deposit of sediment within the stream channel.

> ***Active Sedimentation*:** Sedimentation is considered to be active if vegetation is absent, sparse, or covered by sediment.

Stormwater Release Potential (SRP): Flashiness, or a measure of how fast water is shed from a landscape in terms of volume, intensity, and timing. Because the stormwater release potential is more than just a function of imperviousness, the SRP is based on the variables of ground slope, soil type, and conveyance density, in addition to mapped impervious area, in order to account for the spatial variability of landscape sensitivity to physical changes within watersheds.

***Stream impact*:** Observed active erosion or active sedimentation within or near the stream channel or at an MS4 discharge point. A stream impact can be caused by anthropogenic (manmade) factors, including hydromodification, and non-anthropogenic (natural) factors, such as landslides and floods.

Scope of Assessment

The City's hydromodification assessment focuses on impacts from City MS4 discharges within the City of Portland's urban services boundary (USB). The assessment identifies hydromodification impacts; identifies the impact sources (whether MS4 or not); identifies areas potentially susceptible to future hydromodification impacts; and discusses strategies, priorities, and tools that may help prevent or reduce hydromodification impacts.

The hydromodification assessment includes only those stream channels within the City that receive flows from City MS4 outfalls. The assessment includes streams in the Fanno/Tryon Watershed, Willamette subwatersheds, and Johnson Creek Watershed.

The assessment does not include the Willamette River mainstem, the Columbia Slough, or the Columbia River. The Willamette and Columbia Rivers and the Lower Columbia Slough are excluded because City MS4 stormwater discharges account for a very small fraction of a percent of the total flow in these water bodies. The Middle and Upper Columbia Slough are not included because that system is managed for both water level and flow.

Other Phase I NPDES Permittees (Multnomah County and the Oregon Department of Transportation) operate and maintain MS4 systems that discharge to streams covered by this hydromodification assessment. The impacts of discharges from those systems were considered as part of this assessment; however, it is not the City's responsibility to address any possible impacts attributable to those discharges.

The City used the following assumptions in conducting the hydromodification assessment:

1. Base condition = current conditions (stream channel conditions).
2. If a stream channel is currently stable, no further assessment of that channel was conducted.
3. The geographic hydromodification assessment study area includes secondary streams that receive drainage from City MS4 outfalls.

WATERSHED ASSESSMENTS

Methodology

The methodology used for this Hydromodification Assessment involved the following steps:

- Assessing the general susceptibility of stream channels to hydromodification
- Assessing hydromodification impacts
- Identifying potential hydromodification source areas
- Identifying data gaps where the source of the possible impact could not be determined

The methodology relied on a combination of available GIS data, historical field observations, the BES drainage complaint hotline database, and professional judgment.

The methodology steps are described in more detail below.

Assessing the General Susceptibility of Stream Channels to Hydromodification Impacts

BES Asset Systems Management (ASM) staff used available GIS data to identify geographic regions that share common landscape factors (terrain and geology, bank soils, and bed materials) that could make stream channels susceptible to hydromodification impacts. These regions were assigned a Region ID that includes a watershed identifier and a region identifier – for example, "F-C" represents the Fanno watershed (F) and the region within that watershed (C).

The stream channels within each region were assigned a hydromodification susceptibility rating from low to high, based on the region's landscape factors. Finer bed materials, erodible soils, and steeper slopes contribute to high susceptibility to hydromodification.

The high susceptibility stream reaches were identified with the corresponding Region ID on review maps. These maps were provided to BES Watershed staff for review. This process identified the stream channels susceptible to hydromodification impacts, as shown in Tables 1, 4, and 7 and on the figures in this report.

Assessing Hydromodification Impacts

BES Watershed staff reviewed the stream hydromodification impact susceptibility maps to confirm conditions. They also provided an inventory of sites throughout the watershed with observed erosion or sedimentation that are possible hydromodification impacts (using historical field observations and citizen reports to the BES drainage complaint hotline). These sites were labeled with a unique identifier, the Impact ID. An example Impact ID is "IF45," which represents that the site is a possible impact (I) located in the Fanno watershed (F) and is number (45) for that watershed. Together, the Watershed staff and ASM staff then evaluated all possible impacts to determine if they were related to hydromodification that could be attributable to City MS4 discharges. This process resulted in identifying the MS4 hydromodification impacts that are listed in Tables 2, 5, and 8 and shown on the figures in this report.

Identifying Potential Hydromodification Source Areas

ASM staff developed a Stormwater Release Potential (SRP) model to identify potential hydromodification source areas within the City, in order to associate upland MS4 areas with the identified MS4 hydromodification impacts.

This GIS-based spatial analysis model scores 100-foot cells arranged in a seamless grid covering the entire City. The scores are a measure of the relative rates at which rainfall sheds from the land surface. The factors incorporated in the scores include ground slope, soil permeability, surface imperviousness, and drainage conveyance density.

Imperviousness influences runoff characteristics by reducing infiltration over a given ground surface area and reducing roughness for overland flow, resulting in an increased volume and velocity of runoff. Conveyances (e.g. rills, natural channels, rivers, ditches or pipes) increase the rate that rainfall sheds off land surfaces by concentrating and conveying runoff through the landscape.

In addition, proximity to natural stream channel was incorporated into the SRP score in order to distinguish between stream channel and uplands. It is assumed that hydromodification impacts are observed only within stream channels, while hydromodification sources are associated with uplands. To account for this assumption, the SRP score was further refined by using a spatial process called flow accumulation, which is an algorithm that accumulates flow from grid cells representing the landscape into stream channels, based upon the terrain.

For each 100-foot grid cell within the City, refined SRP scores were assigned for predevelopment conditions and for current development conditions. Predevelopment conditions were simulated by including natural conveyances and drainage ways and excluding built impervious surfaces and human-made conveyances. Differences in each cell's SRP scores for these two conditions were used as a measure of alteration of the land surface's hydrologic characteristics. This resulting difference represents the Potential Hydromodification Source Area (PHSA) score for each grid cell in the study area.

The PHSA score grid differentiates natural and human-made stormwater release potential. Within the study area, PHSA scores ranged from 0.0 to 2.0. The score of 0.0 represents current conditions unchanged from natural hydrologic characteristics. The score of 2.0 represents current conditions with the most human-made change from natural hydrologic characteristics within the modeled area, representing those upland areas with the greatest change in stormwater release potential. The PHSA scores were divided into three quantiles to differentiate between unlikely source areas (0.0 to <0.02), marginal source areas (0.02 to < 0.06), and likely source areas (0.06 to 2.0). The likely source areas represent those upland areas with the greatest stormwater release potential. These likely source areas were identified so improvements could be targeted to them if they are associated with hydromodification impacts. Results are shown in Tables 3, 6, and 9 and shown on the figures in this report.

Identifying Data Gaps

Sufficient information was not always available to determine if some possible impact sites are related to hydromodification. These impact sites are considered data gaps, since additional fieldwork is required.

Fanno/Tryon Watershed Assessment

Setting

Fanno and Tryon Creek watersheds were assessed together because of their geographic proximity to each other and their geologic and geomorphic similarities. These drainages have an underlying basalt geology characterized by steep slopes (greater than 3 percent), convex hillsides, and broad rolling ridge tops divided by steep canyons. Low-permeability silt soils and clay fragipan layers create high runoff rates under natural conditions.

The total area of the Fanno Creek watershed is approximately 20,000 acres. Of this, 4,700 acres are located within the City of Portland: 3,200 acres drain to open stream channels via the City MS4, and 1,500 acres drain directly to stream channels or non-City systems. Approximately 23 miles of open stream channel are within the City's portion of the watershed; 22 of the 23 miles are downstream of City MS4 outfalls.

The total area of the Tryon Creek watershed is approximately 4,300 acres. Of this, 3,000 acres are located within the City of Portland: 1,700 acres drain to open stream channels via the City MS4, and 1,300 acres drain directly to stream channels or non-City systems. The area within City of Portland jurisdiction includes 425 acres owned by State of Oregon Parks and Recreation, all of which drains directly to stream channels. Approximately 23 miles of open stream channel are within the City's portion of the watershed; 18 of the 23 miles are downstream of City MS4 outfalls.

Fanno and Tryon Creek watershed areas within the City of Portland are largely developed, which is also true for the other watersheds in the City. Development in the Fanno and Tryon Creek watersheds began around 1900, with the advent of rail service via the Southern Pacific Railroad and the West Portland Motor Line trolley. Development continued in the 1920s and 1930s, following construction of main transportation routes, including Terwilliger Boulevard, Capitol Highway, the Beaverton Hillsdale Highway, Barbur Boulevard, and the Oregon Electric railroad. Development increased in the 1950s and 1960s, especially after Interstate 5 was completed in 1966 (City of Portland, 2011).

Based on spatial analysis, approximately 85 percent of development in the Fanno Creek watershed and 90 percent of development in Tryon Creek occurred before 2000. Approximately 92 percent of development in the Fanno Creek watershed and 94 percent of development in Tryon Creek occurred more than ten years ago (2004 or earlier). Most development occurring today is redevelopment. Any redevelopment occurring since 1999 must meet the requirements of the City of Portland *Stormwater Management Manual*. These standards strictly limit changes to hydrology and even improve hydrologic conditions as redevelopment occurs.

Fanno and Tryon Results

Susceptibility of Stream Channels to Hydromodification Impacts

Table 1 identifies three geographic regions with stream reaches likely to be susceptible to hydromodification impacts, based on the methodology described above. These three regions were determined susceptible because of steep channel slopes and/or large deposits of fine, erodible sediments and/or bank materials. Stream reaches within each region listed in Table 1 are highlighted and labeled with the Region ID on Figure FT_1. Stream channels in regions not included in this table are not thought to be susceptible to hydromodification impacts.

Table 1: Fanno/Tryon Stream Reaches Susceptible to Hydromodification Impacts

Region ID (Identifier used in Figure FT_1)	Surficial Geology	Soil Erodibility	Terrain Type	Grain Sizes
F-C	Alluvial deposits	Slight	Stream channel on broad (150-200 ft. wide) deep alluvium floodplain. Low channel slope 0.3%-4%.	Fine grains
F-D	Primarily Hillsboro formation	Slight	Rolling hills with stream channels in deep (25 ft.) ravines confined by valley walls. Intermediate channel slope 6%.	Fine grains
T-C	Alluvial deposits	Moderate to severe	Main channel of Tryon Creek is a low slope (0.5 - 1%) meandering channel formed on deep alluvium and disconnected from flood plain. Channel in 100+ ft. deep valley with valley floor width that varies from 50 to 200 ft.	35-47% fine grains by area; balanced with coarse and medium grains.

MS4 Hydromodification Impacts

Using the methodology described above, 55 possible hydromodification impact sites were mapped and given an Impact ID (from IF02 to IF45 and from IT46 to IT73). Evaluation results are as follows:

- 12 of the possible impact sites are likely related to MS4 hydromodification. All 12 sites are near-field impacts, with the probable cause being inadequate energy dissipation at a City MS4 outfall. These sites are described in Table 2 and shown on Figure FT_1.

- 26 of the possible impact sites are not related to MS4 hydromodification. These impacts are caused by erosion within conveyances not considered waters of the state (e.g., ditches), flooding within a floodplain, erosion near private outfalls, or a result of other natural causes or human activities unrelated to City MS4 drainage (e.g., road fill, culverts in streams).

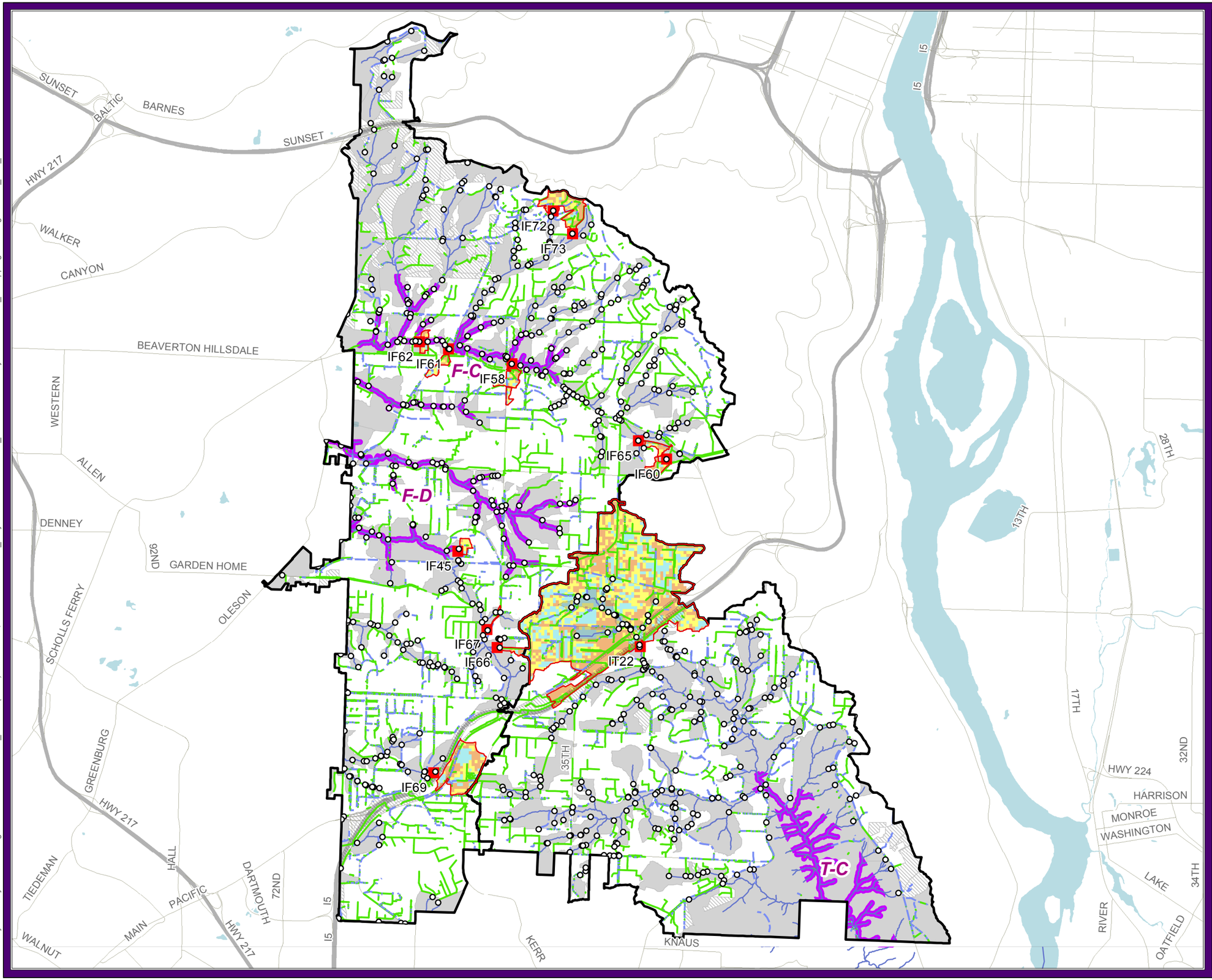
- 17 of the possible impact sites have insufficient information to determine if they are related to MS4 hydromodification. The "Strategies to Address Data Gaps" section of this report discusses next steps for these sites.

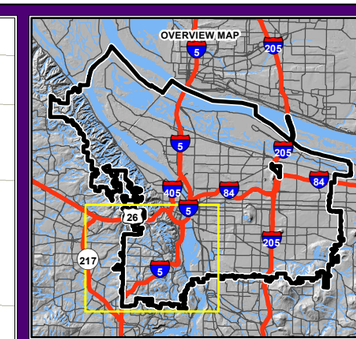
Table 2: Fanno/Tryon MS4 Hydromodification Impacts

Impact ID	Description	Probable Cause of Impact
IF45	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IF58	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IF60	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IF61	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IF62	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IF65	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IF66	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IF67	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IF69	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IF72	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IF73	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IT22	Erosion near outfall	Inadequate energy dissipation at MS4 outfall

Potential Hydromodification Source Areas

As described in the Methodology section, the SRP model was used to identify potential hydromodification source areas within MS4 drainage areas associated with impacts in the Fanno and Tryon watersheds. Table 3 includes the average PHSA scores for areas that drain to the identified MS4 hydromodification impact sites listed in Table 2. (The average PHSA score is the average of scores for individual cells.)





Legend

- Water Surface
- Watershed Boundaries
- Non-MS4 Area within City
- Other MS4 Jurisdiction*
- Pipe
- Surface
- Natural Channel
- MS4 Outfalls
- Stream Reach Susceptible to Impacts
- MS4 Hydromodification Impacts
- Areas Draining to Impacts

Potential Hydromodification Source Areas Draining to Impacts

- Unlikely Source Areas (0.0-0.02)
- Marginal Source Areas (0.02-0.06)
- Likely Source Areas (0.06-2.0

Note: MS4 hydromodification impact ID labels (format "IT##") and the hydromodification susceptibility ID labels (format "T-A") correspond to references in text.

*All other unshaded and non-hatched areas within watershed boundary are Portland MS4 areas.

N
W E
S

1 inch = 3,200 ft

0 1,600 3,200 ft

Figure FT_1
Hydromodification Assessment

Fanno and Tryon Creeks

Environmental Services
City of Portland
working for clean rivers

Produced by Asset Systems Management: 9ESPP0000055_NPDES (YMM) October 28, 2014 \\cassio\ASM_Projects\9ESPP0000055_NPDES\2011\02Hydromod\Phase_2\Mapping\MXD\Figure2.1.4_FT1_FINAL.mxd

Table 3. Fanno/Tryon PHSA Scores for Drainage Areas That Drain to Identified MS4 Hydromodification Impact Sites

Impact ID	Drainage Area (ac)	Metric	City MS4	ODOT MS4	Mult. Co. MS4	Non-MS4	Mean Score for Drainage Area
IF45	4.13	% of Drainage Area	90%	-	-	10%	
		Average PHSA Score	0.05	-	-	0.12	0.06
IF58	11.16	% of Drainage Area	100%	-	-	-	
		Average PHSA Score	0.088	-	-	-	0.09
IF60	6.6	% of Drainage Area	100%	-	-	-	
		Average PHSA Score	0.17	-	-	-	0.17
IF61	5.49	% of Drainage Area	100%	-	-	-	
		Average PHSA Score	0.08	-	-	-	0.08
IF62	3.6	% of Drainage Area	94%	-	-	6%	
		Average PHSA Score	0.07	-	-	0.1	0.07
IF65	4.72	% of Drainage Area	84%	-	-	16%	
		Average PHSA Score	0.11	-	-	0.15	0.12
IF66	3.37	% of Drainage Area	80%	-	-	20%	
		Average PHSA Score	0.1	-	-	0.05	0.09
IF67	0.82	% of Drainage Area	67%	-	-	33%	
		Average PHSA Score	0.09	-	-	0.05	0.08
IF69	42.7	% of Drainage Area	91%	9%	-	-	
		Average PHSA Score	0.08	0.19	-	-	0.09
IF72	7.84	% of Drainage Area	100%	-	-	-	
		Average PHSA Score	0.07	-	-	-	0.07
IF73	18.39	% of Drainage Area	98%	-	-	2%	
		Average PHSA Score	0.12	-	-	0.19	0.12
IT22	486	% of Drainage Area	84%	8%	-	8%	
		Average PHSA Score	0.08	0.18	-	0.04	0.08

PHSA scores for 100-foot grid cells within the Fanno and Tryon watersheds range from 0 to 1.67, with 0 representing no hydrologic change that would contribute to hydromodification impacts and 1.67 representing the maximum change that has occurred within the watershed.

Figure FT_1 shows Likely Source Areas (those with PHSA scores from 0.06 to 1.67). Marginal Source Areas and Unlikely Source Areas are shown for comparison and to indicate relative drainage areas for each designation.

The average PHSA score for both watersheds is 0.06. The average PHSA scores for the areas draining to impact sites are typically only marginally greater than the average PHSA scores for the watersheds as a whole. These relatively low PHSA scores are consistent with the finding that no far-field impacts were identified. Impacts in the Fanno and Tryon watersheds are near-field.

Typically, Likely Source Areas would be considered locations where hydromodification source controls would be most effective in mitigating hydromodification impacts. However, since all the identified impacts are near-field, the most effective way to address them is through energy dissipation at the outfalls.

West Willamette Streams Subwatersheds Assessment

Setting

Tributaries to the west side of the Willamette River have geologic characteristics similar to the Fanno and Tryon Creek watersheds. These drainages have an underlying basalt geology characterized by steep slopes (greater than 3 percent), convex hillsides, and broad rolling ridge-tops divided by steep canyons. Low permeability silt soils and clay fragipan layers create high runoff rates under natural conditions.

The west Willamette streams include small tributaries that drain approximately 16,100 acres. Of this, 15,100 acres are located within the City of Portland: 1,300 acres drain to open stream channels via the City MS4, and 13,800 acres drain directly to stream channels through non-City systems, via pipes to the river, or are collected and sent to the Columbia Boulevard wastewater treatment plant by Portland's combined sanitary and storm system. Approximately 110 miles of open stream channel are within the City's portion of the watershed; 21 of the 110 miles are downstream of City MS4 outfalls. Figure WR_1 provides an overview of the West Willamette Streams.

Much of the area draining to the Willamette tributaries is included in Forest Park and will remain undeveloped. West Willamette streams watershed areas within the City are largely developed, which is also true for the other watersheds in the City. Development began in the late 19th century. Based on spatial analyses, approximately 92 percent of the development in the subwatersheds occurred prior to 2000. Most development occurring today is redevelopment. Any redevelopment occurring since 1999 must meet the requirements of the City of Portland Stormwater *Management Manual*. These standards strictly limit changes to hydrology and even improve hydrologic conditions as redevelopment occurs.

West Willamette Streams Subwatersheds Results

Susceptibility of Stream Channels to Hydromodification Impacts

Table 4 identifies three geographic regions with stream reaches likely to be susceptible to hydromodification impacts, based on the methodology described above. These three regions (two in the Stephens Creek subwatershed and one in the Balch Creek subwatershed) were determined to be susceptible to impacts because of steep channel slopes and fine, erodible sediments and/or bank materials. Reaches within each region listed in Table 4 are highlighted and labeled with the Region ID on Figures WR_2, and WR_3. Stream channels in regions not included in this table are not thought to be susceptible to hydromodification impacts.

Table 4: Stream Reaches Susceptible to Hydromodification Impacts

Region ID (on Figures WR_2 & WR_3)	Surficial Geology	Soil Erodibility	Terrain Type	Grain Sizes
W-D (Balch Creek)	Landslides, alluvial deposits along channel, basalt on side slopes	Severe	Deep valleys with steep (50%) side-slopes. Steep, lateral, first order stream channels (>10%). Mainstem has higher sediment storage, and therefore high potential for channel change.	Mainly gravels-cobbles. Fines <20%.
W-G (Stephens Creek)	Alluvium and landslide deposits over basalt	Severe	Transport reach of stream channel with alluvial floodplain in narrow valley. Channel somewhat confined by side-slopes.	Primarily coarse gravels > 32.0 mm. With high, erodible banks
W-I (Stephens Creek)	Colluvium hillsides, landslide deposits and stream channel	Severe	Steep lateral channel with abundant supply of sediment from side-slopes.	Fines to small gravels. Based on limited visual observation

MS4 Hydromodification Impacts

Using the methodology described above, 37 possible hydromodification impact sites were mapped and given an Impact ID (from IW1 through IW37). Evaluation results are as follows:

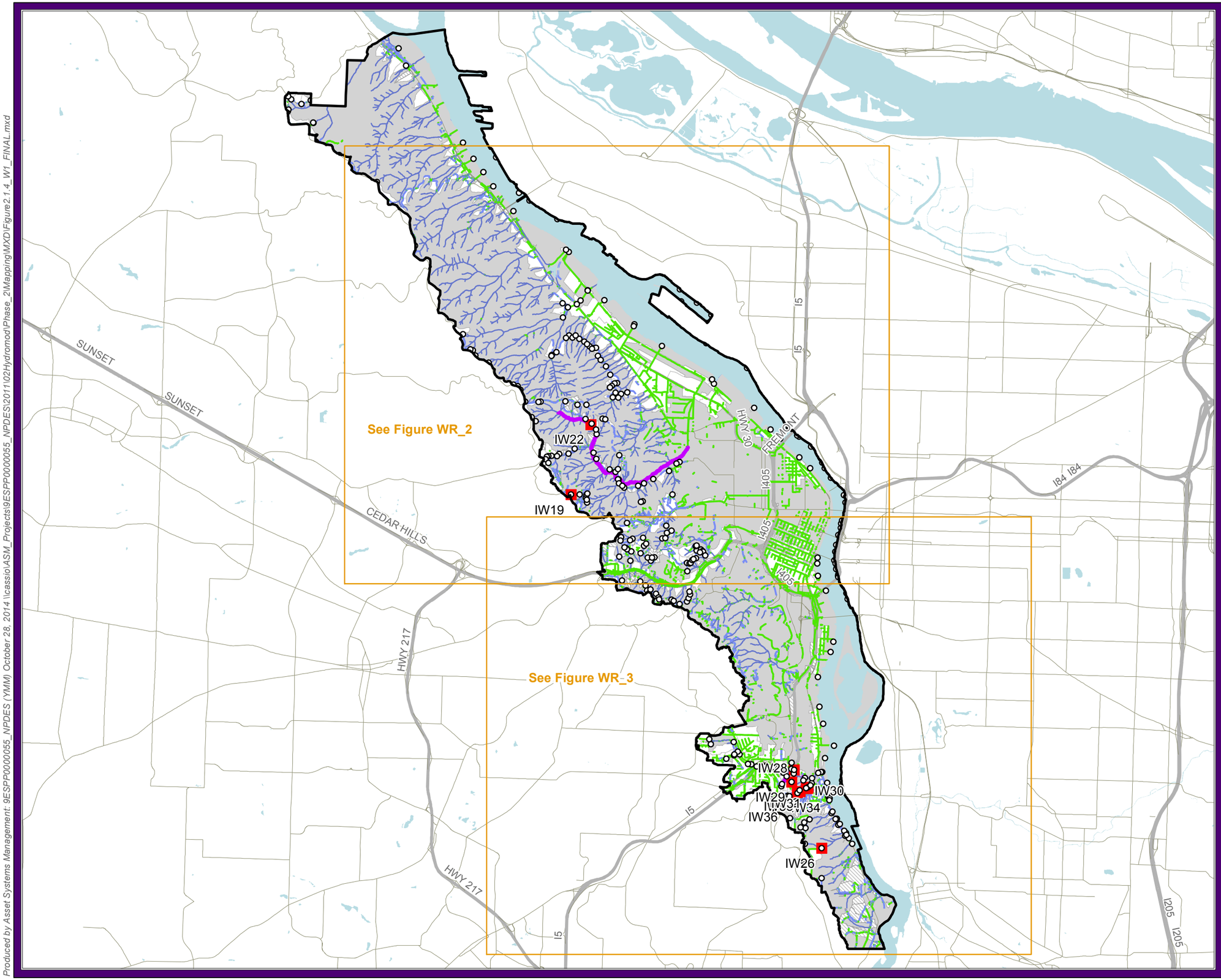
- 11 of the possible impact sites are likely related to MS4 hydromodification: eight sites in the Stephens Creek subwatershed and three sites in other subwatersheds. All sites, with the exception of IW31, are near-field impacts, probably caused by inadequate energy dissipation at a City MS4 outfall. The impact at IW31 is related to increased sediment supply from upstream erosion at near-field impact sites IW32, IW33, IW34, IW35, and IW36. These 11 impact sites are described in Table 5 and shown in Figures WR_2 and WR_3.

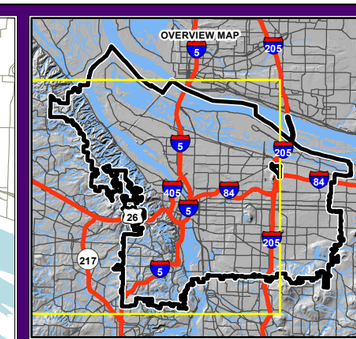
- 18 of the possible impact sites are not related to MS4 hydromodification: two in the Stephens Creek subwatershed and 16 in the rest of the watershed. In the Stephens Creek subwatershed, these sites are caused by erosion around a non-functioning inlet on the upstream end of a stream culvert and a failing boulder weir. In the remainder of the watershed, impacts are from a variety of conditions, primarily poorly aligned and undersized culverts associated with non-City MS4 drainage.

- Eight of the possible impact sites did not have sufficient information to determine if they are related to MS4 hydromodification: with one site in the Stephens Creek subwatershed and seven sites in the remainder of the Willamette subwatersheds. The “Strategies to Address Data Gaps” section of this report discusses next steps for these sites.

Table 5: West Willamette Streams MS4 Hydromodification Impacts

Impact ID	Description	Probable Cause of Impact
IW19	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IW22	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IW26	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IW28	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IW29	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IW30	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IW31	Active sedimentation at upstream end of culvert on stream	Increased sediment supply from upstream erosion at impacts IW32, IW33, IW34, IW35, and IW36. Culvert alignment and size are compounding factors (not related to MS4 hydromodification) promoting sedimentation.
IW32	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IW33	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IW34	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IW36	Erosion near outfall	Inadequate energy dissipation at MS4 outfall





Legend

- Water Surface
- Watershed Boundaries
- Non-MS4 Area within City
- Other MS4 Jurisdiction*
- Pipe
- Surface
- Natural Channel
- MS4 Outfalls
- Stream Reach Susceptible to Impacts
- MS4 Hydromodification Impacts
- Map Extents for Figures WR_2 & WR_3

Note: MS4 hydromodification impact ID labels (format "IW##") and the hydromodification susceptibility ID labels (format "W-A") correspond to references in text.

*All other unshaded and non-hatched areas within watershed boundary are Portland MS4 areas.

N
W E
S

1 inch = 7,000 ft

0 3500 7000 ft

Figure WR_1
Hydromodification Assessment

Willamette Tributaries Overview

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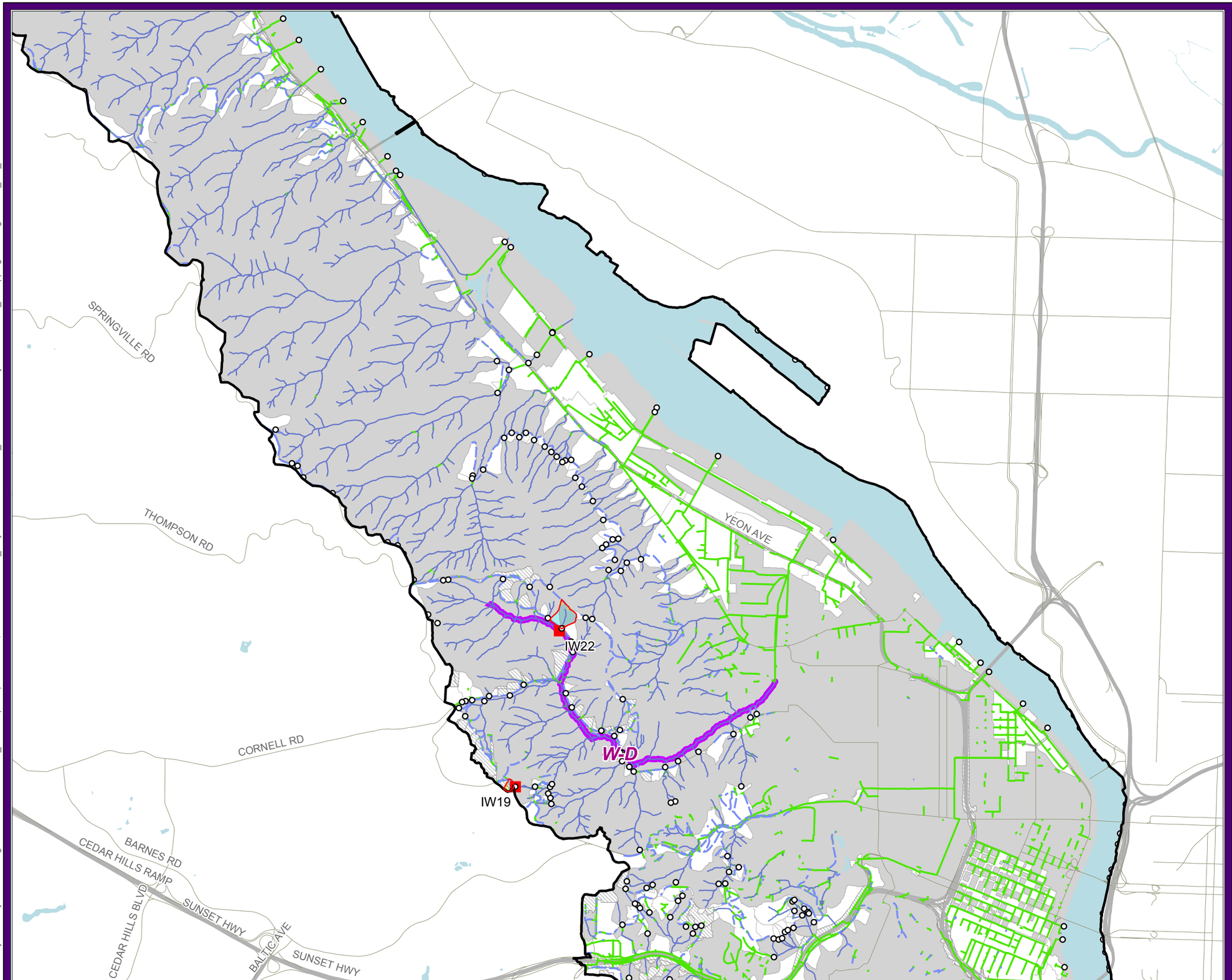

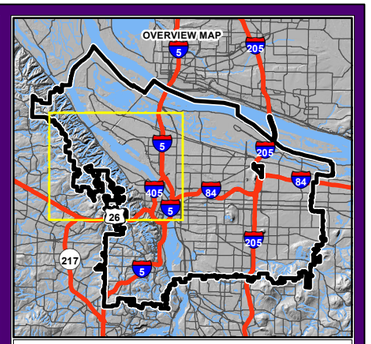

Legend

- Water Surface
- Watershed Boundaries
- Non-MS4 Area within City
- Other MS4 Jurisdiction*
- Pipe
- Surface
- Natural Channel
- MS4 Outfalls
- Stream Reach Susceptible to Impacts
- MS4 Hydromodification Impacts
- Areas Draining to Impacts

Potential Hydromodification Source Areas Draining to Impacts

- Unlikely Source Areas (0.0-0.02)
- Marginal Source Areas (0.02-0.06)
- Likely Source Areas (0.06-2.0)

Note: MS4 hydromodification impact ID labels (format "IW##") and the hydromodification susceptibility ID labels (format "W-A") correspond to references in text.

*All other unshaded and non-hatched areas within watershed boundary are Portland MS4 areas.

N
W E
S

1 inch = 3,200 ft

0 1600 3200 ft

Figure WR_2
Hydromodification Assessment

North Willamette Tributaries

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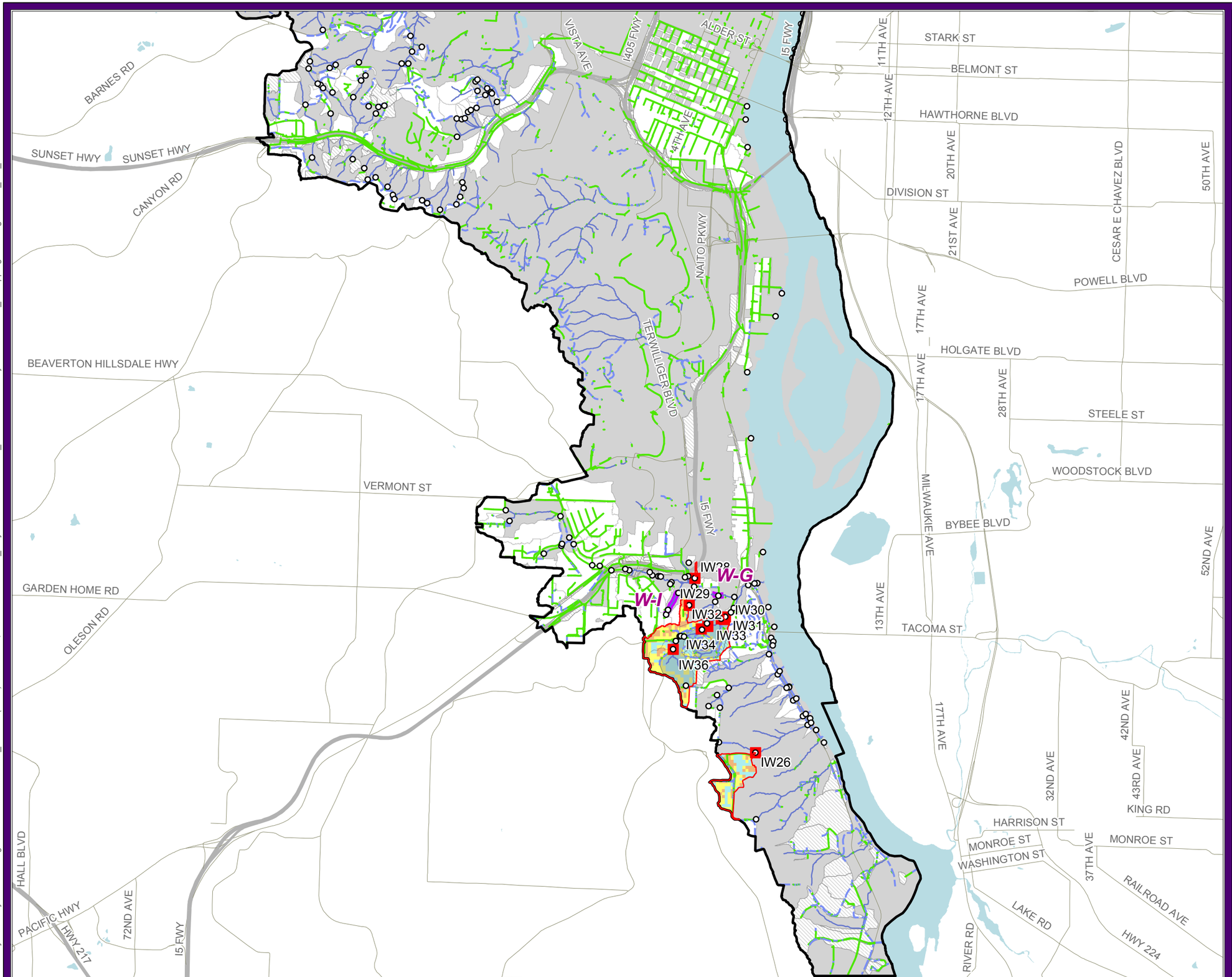

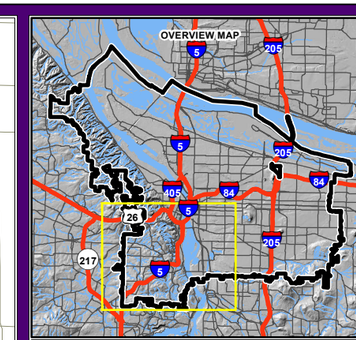

Legend

- Water Surface
- Watershed Boundaries
- Non-MS4 Area within City
- Other MS4 Jurisdiction*
- Pipe
- Surface
- Natural Channel
- MS4 Outfalls
- Stream Reach Susceptible to Impacts
- MS4 Hydromodification Impacts
- Areas Draining to Impacts

Potential Hydromodification Source Areas

Draining to Impacts

- Unlikely Source Areas (0.0 - 0.01)
- Marginal Source Areas (0.01 - 0.08)
- Likely Source Areas (0.08 - 2.0)

Note: MS4 hydromodification impact ID labels (format "IW##") and hydromodification susceptibility ID labels (format "W-A") correspond to references in text.

*All other unshaded and non-hatched areas within watershed boundary are Portland MS4 areas.

N W E S

1 inch = 3,200 ft

0 1600 3200 ft

Figure WR_3
Hydromodification Assessment

South Willamette Tributaries

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Produced by Asset Systems Management: 9ESPP0000055_NPDES\2011\02Hydromod\Phase_2\Mapping\MXD\Figure2.1.4_W3_FINAL.mxd

Potential Hydromodification Source Areas

As described in the Methodology section, the SRP model was used to identify potential hydromodification source areas within MS4 drainage areas associated with impacts in the Willamette subwatersheds. Table 6 includes the average PHSA scores for areas that drain to the identified MS4 hydromodification impact sites listed in Table 5. (The average PHSA score is the average of scores for individual cells.)

Table 6. PHSA Scores for Drainage Areas That Drain to Identified MS4 Hydromodification Impact Sites

Impact ID	Drainage Area (ac)	Metric	City MS4	ODOT MS4	Mult. Co. MS4	Non-MS4	Mean Score for Drainage Area
IW19	2.1	% of Drainage Area	27%	-	73%	-	
		Average PHSA Score	0.20	-	0.04	-	0.09
IW22	11	% of Drainage Area	17%	-	-	83%	
		Average PHSA Score	0.00	-	-	0.01	0.01
IW26	35	% of Drainage Area	99%	-	-	1%	
		Average PHSA Score	0.07	-	-	0.01	0.07
IW28	0.62	% of Drainage Area	67%	-	-	33%	
		Average PHSA Score	0.20	-	-	0.09	0.17
IW29	5.7	% of Drainage Area	100%	-	-	0%	
		Average PHSA Score	0.07	-	-	-	0.07
IW30	0.27	% of Drainage Area	50%	-	-	50%	
		Average PHSA Score	0.10	-	-	0.00	0.05
IW31	110	% of Drainage Area	36%	-	-	64%	
		Average PHSA Score	0.08	-	-	0.02	0.04
IW32	1.5	% of Drainage Area	86%	-	-	14%	
		Average PHSA Score	0.04	-	-	0.14	0.05
IW33	4.4	% of Drainage Area	100%	-	-	-	
		Average PHSA Score	0.04	-	-	-	0.04
IW34	0.77	% of Drainage Area	80%	-	-	20%	
		Average PHSA Score	0.06	-	-	0.02	0.05
IW36	9.0	% of Drainage Area	98%	-	-	2%	
		Average PHSA Score	0.06	-	-	0.03	0.06

PHSA scores for 100-foot grid cells within the West Willamette Tributaries Subwatersheds range from 0 to 2.0, with 0 representing no hydrologic change that would contribute to hydromodification and 2.0 representing the maximum change that has occurred within the watershed.

Figures WR_2 and WR_3 show Likely Source Areas (those with PHSA scores from 0.06 to 2.0). Marginal Source Areas and Unlikely Source Areas are shown for comparison and to indicate relative drainage areas for each designation.

The average PHSA score for the watershed is 0.04. The average PHSA scores for the areas draining to impact sites are typically only marginally greater than the average PHSA scores for the watershed as a whole. These relatively low PHSA scores are consistent with the finding that only one far-field impact was identified. Impacts in the West Willamette Tributaries Subwatersheds are primarily near-field.

Typically, Likely Source Areas would be considered locations where hydromodification source controls would be most effective in mitigating hydromodification impacts. However, since all but one of the identified impacts are near-field, most impacts can be effectively addressed through energy dissipation at the outfalls.

Johnson Creek Watershed Assessment

Setting

Johnson Creek is a tributary to the east side of the Willamette River. The Johnson Creek mainstem channel is gently sloped (less than 1 percent) and flows over geology of catastrophic flood deposits. Tributaries to the east and south of the mainstem are steep (greater than 5 percent) and originate on basalt buttes, and they flow over flood deposits in their lower reaches. The Works Progress Administration armored the mainstem of Johnson Creek in many places in the 1930s. Rainfall on deep alluvium deposits to the north of the mainstem infiltrates to groundwater.

The total area of the Johnson Creek watershed is approximately 34,000 acres. Of this, 12,800 acres are located within the City of Portland: 1,400 acres drain to open stream channels via the City MS4, and 11,400 acres drain directly to stream channels, infiltrate via Underground Injection Control Systems (UICs), or are collected and conveyed to the Columbia Boulevard wastewater treatment plant by the combined sanitary and storm sewer system. Approximately 42 miles of open stream channel are within the City's portion of the watershed; 23 of the 42 miles are downstream of City MS4 outfalls.

Johnson Creek watershed areas within the City are largely developed, which is also true for the other watersheds in the City. Development in Johnson Creek began in the early 20th century with completion of the Springwater Division Line rail service in 1903. Many communities developed along the rail line, including Sellwood, Eastmoreland, Lents, and Pleasant Valley. Residential development in the watershed continued through the 20th century (City of Portland, 2014).

Based on spatial analysis, approximately 85 percent of development in the watershed occurred before 2000, and approximately 92 percent occurred more than ten years ago. Much of the development occurring today is redevelopment. Any redevelopment occurring since 1999 must meet the requirements of the City of Portland *Stormwater Management Manual*. These standards strictly limit changes to hydrology and even improve hydrologic conditions for redevelopment.

Johnson Creek Results

Susceptibility of Stream Channels to Hydromodification Impacts

Table 7 identifies two geographic regions with stream reaches likely to be susceptible to hydromodification impacts, based on the methodology described above. These two regions were determined susceptible to impacts because of steep channel slopes and/or fine, erodible sediments and/or bank materials. Stream reaches within each region listed in Table 7 are highlighted and labeled with the region ID on Figure JC_1. Stream channels in regions not included in this table are not thought to be susceptible to hydromodification impacts.

Table 7: Stream Reaches Susceptible to Hydromodification Impacts

Region ID (on Figure JC_1)	Surficial Geology	Soil Erodibility	Terrain Type	Grain Sizes
J-D	Alluvium of catastrophic floods	Slight to severe	Channels steepen on edge of escarpment bordering Missoula flood deposits	Slightly higher coverage of fine grains, but also significant amount of gravels and coarse grains
J-F (Clatsop Creek)	Basalt, Springwater formation, alluvium of catastrophic floods	Slight to moderate	Rolling hills with moderately steep stream channel	Dominated by silt

MS4 Hydromodification Impacts

Using the methodology described above, 24 possible hydromodification impact sites were mapped and given Impact IDs (from IJ01 to IJ29). Evaluation results are as follows:

- 11 of the possible impact sites are likely to be related to MS4 hydromodification. Of these, seven sites are near-field impacts, most probably caused by inadequate energy dissipation at a City MS4 outfall. The remaining four sites are far-field impacts, probably caused by altered hydrology from upland source areas, compounded by modified channel flow routes and inadequate energy dissipation downstream of a culvert. These 11 impact sites are described in Table 8 and shown on Figure JC_1.

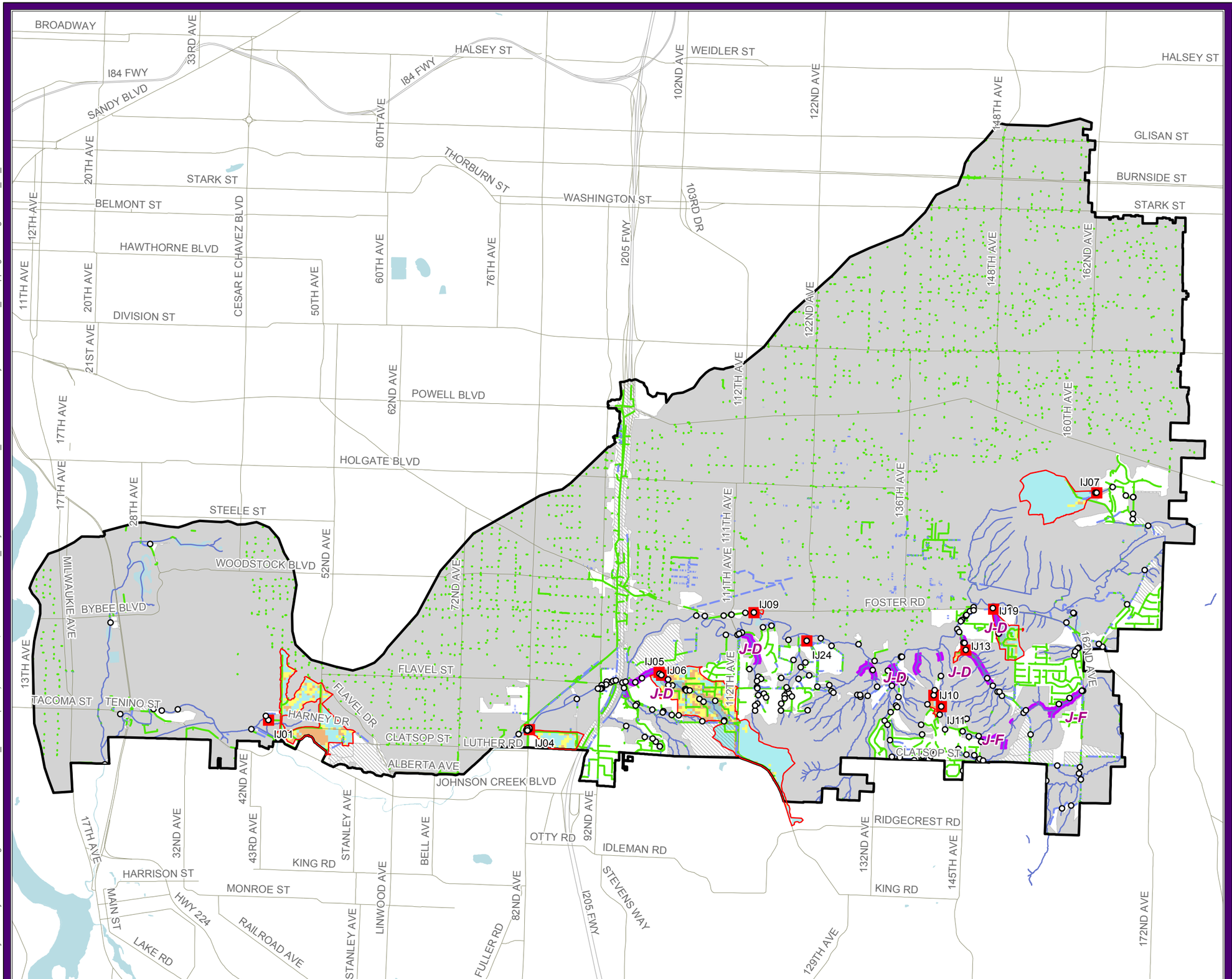
- Eight of the possible impact sites are not related to MS4 hydromodification. These impacts are caused by a variety of conditions not related to City MS4 systems or

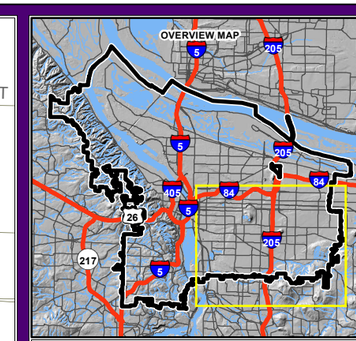
drainage areas. For example, Barbara Welch Road was built encroaching on the natural stream channel. The channel is now narrower than its natural formation and tends to erode the bank in adjustment to the direct modification to its channel. Another example is erosion around an outfall not owned by the City.

- Five of the possible impact sites have insufficient information to determine if they are related to MS4 hydromodification. The "Strategies to Address Data Gaps" section of this report discusses next steps for these sites.

Table 8: Johnson Creek MS4 Hydromodification Impacts

Impact ID	Description	Probable Cause of Impact
IJ01	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IJ04	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IJ05	Erosion in channel downstream of outfalls (far-field)	Likely Source Areas of altered hydrology; also inadequate energy dissipation at in-stream culvert (not related to MS4 hydromodification)
IJ06	Erosion in channel downstream of outfalls (far field)	Likely Source Areas of altered hydrology and erodible channel
IJ07	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IJ09	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IJ10	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IJ11	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IJ13	Erosion near outfall	Inadequate energy dissipation at MS4 outfall
IJ19	Erosion in channel downstream of outfall (far field)	Likely Source Areas of altered hydrology and erodible channel
IJ24	Erosion between outfall and stream channel (far-field)	Likely Source Areas of altered hydrology and modified stormwater flow routes





Legend

- Water Surface
- Watershed Boundaries
- Non-MS4 Area within City
- Other MS4 Jurisdiction*
- Pipe
- Surface
- Natural Channel
- MS4 Outfalls
- Stream Reach Susceptible to Impacts
- MS4 Hydromodification Impacts
- Areas draining to impacts

Potential Hydromodification Source Areas

Draining to Impacts

- Unlikely Source Areas (0.00-0.02)
- Marginal Source Areas (0.02-0.06)
- Likely Source Areas (0.06-2.0)

Note: MS4 hydromodification impact ID labels (format "IJ##") and the hydromodification susceptibility ID labels (format "J-A") correspond to references in text.

*All other unshaded and non-hatched areas within watershed boundary are Portland MS4 areas.

N
W E
S

1 inch = 3,600 ft

0 1800 3600 ft

Figure JC_1
Hydromodification Assessment

Johnson Creek

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Potential Hydromodification Source Areas

As described in the Methodology section, the SRP model was used to identify potential hydromodification source areas within MS4 drainage areas associated with impacts in the Johnson Creek Watershed. Table 9 includes the average PHSA scores for areas that drain to the identified MS4 hydromodification impact sites listed in Table 8. (The average PHSA score is the average of scores for individual cells.)

PHSA scores for 100-foot grid cells within the Johnson Creek watershed range from 0 to 1.8, with 0 representing no hydrologic change that would contribute to hydromodification impacts and 1.8 representing the maximum change that has occurred within the watershed.

Figure JC_1 shows Likely Source Areas (those with PHSA scores from 0.06 to 1.8). Marginal Source Areas and Unlikely Source Areas are shown for comparison and to indicate relative drainage areas for each designation.

The average PHSA score for the watershed is 0.02. The average PHSA scores for the areas draining to impact sites are typically only marginally greater than the average PHSA scores for the watershed as a whole. The relatively low PHSA scores of areas draining to impact sites is consistent with the finding that most hydromodification impacts in the Johnson Creek watershed are near-field.

Typically, Likely Source Areas would be considered locations where hydromodification source controls would be most effective in mitigating identified hydromodification impacts. However, since most of the identified impacts are near-field, the most effective way to address them is through energy dissipation at the outfalls.

Table 9: PHSA Scores for Drainage Areas That Drain to Identified MS4 Hydromodification Impact Sites

Impact ID	Drainage Area (ac)	Metric	City MS4	Clack. Co. MS4	Mult. Co. MS4	Non-MS4	Outside USB	Mean Score for Drainage Area
IJ01	91	% of Drainage Area	72%	2%	24%	0%	2%	
		Average PHSA Score	0.08	0.02	0.04	-	0.08	0.07
IJ04	24	% of Drainage Area	93%	0%	0%	7%	0%	
		Average PHSA Score	0.03	-	-	0.09	-	0.03
IJ05	180	% of Drainage Area	76%	0%	11%	11%	1%	
		Average PHSA Score	0.04	-	0.03	0.02	0.24	0.04
IJ06	170	% of Drainage Area	74%	0%	12%	12%	1%	
		Average PHSA Score	0.04	-	0.03	0.02	0.20	0.04
IJ07	80	% of Drainage Area	99%	0%	0%	1%	0%	
		Average PHSA Score	0.00	-	-	0.01	-	0.00
IJ09	1.1	% of Drainage Area	100%	0%	0%	0%	0%	
		Average PHSA Score	0.09	-	-	-	-	0.09
IJ10	2.7	% of Drainage Area	100%	0%	0%	0%	0%	
		Average PHSA Score	0.09	-	-	-	-	0.09
IJ11	1.5	% of Drainage Area	100%	0%	0%	0%	0%	
		Average PHSA Score	0.10	-	-	-	-	0.10
IJ13	2.1	% of Drainage Area	80%	0%	0%	20%	0%	
		Average PHSA Score	0.11	-	-	0.10	-	0.11
IJ19	28	% of Drainage Area	66%	0%	0%	34%	0%	
		Average PHSA Score	0.05	-	-	0.01	-	0.03
IJ24	13	% of Drainage Area	97%	0%	0%	3%	0%	
		Average PHSA Score	0.09	-	-	0.06	-	0.09

Summary

This Hydromodification Assessment evaluated stream channel susceptibility to hydromodification, identified and characterized hydromodification impacts, and evaluated upland source areas potentially related to hydromodification impacts.

Several stream reaches were determined to be susceptible to hydromodification, but had no impacts identified for those reaches. In these cases, the stream channel could be susceptible to hydromodification impacts if dramatic future changes in hydrologic characteristics occurred as a result of large-scale development. These reaches are not considered at risk, however, because the hydromodification study area is built out, and most development that is occurring is infill development or redevelopment on a relatively

small (lot-by-lot) scale. The *Stormwater Management Manual* requirements mitigate the alterations to hydrology normally associated with new development and redevelopment.

This assessment found few impacts related to hydromodification within the City's watersheds (as summarized in Table 10). Most identified impacts were near-field and confined to the proximity of outfalls. This finding may be slightly unexpected, given the level of urbanization in Portland, but it can be explained by stream channel response to development, landscape sensitivity, and managed hydrology. Since the majority of the City was developed in the late-19th to early- to mid- 20th centuries, the stream channels have adjusted to old hydromodification effects. If impacts related to the initial development of the City did occur, they took place long before this assessment and were part of the adjustment process following that development. Active far-field hydromodification impacts documented in this assessment are in Johnson Creek and are downstream of development that has occurred between 1970 and now.

The streams throughout the West Hills of Portland (Fanno, Tryon, Stephens, west Willamette tributaries) have hydrologic regimes that are not very sensitive to land use changes. The landforms and surface conditions are naturally conducive to rapid runoff generation. The streams are situated on a terrain characterized as having steep, canyon-like lower and middle reaches that taper off to convex side slopes and rolling ridge tops in the upper reaches. The West Hills are primarily loess (silty soils) deposited on mostly uplifted basalt formations that are less sensitive to changes in hydrology. Throughout the west side, the soils also contain a thick, hard clay fragipan that is at a depth of about 2 to 6 feet below the ground surface. With the exception of the Fanno Creek tributaries that drain to the Tualatin River, the westside streams are mostly small, lateral tributaries that drain directly to the Willamette River through steep, V-shaped valleys. Long before development, the streams in most places had cut their way down through the highly erodible loess to either the fragipan layer or bedrock to where they reached a certain level of streambed stability. The west side streams' lower sensitivity to land use changes has the following two elements: 1) Because the streams are often incised down to bedrock or fragipan, they are inherently more stable and confined, so are less likely to change forms with a marginal change in hydrology; and 2) the very low-permeability soils and steep slopes throughout the landscapes and the naturally rapid runoff have allowed the streams to adjust to the historically flashy conditions of the watersheds.

For Johnson Creek on the east side, managed hydrology has played a major role in limiting impacts related to hydromodification. The western half of the basin is the most developed portion of the watershed, and most of it falls within the City of Portland. Increased flows to the creek resulting from development have been limited because the majority of the watershed area within the City is served by combined sewers and sumps.

Table 10: Summary of Impact Sites by Watershed

Watershed	Number of Hydromodification Impacts			
	Possible Impacts	City MS4 Impacts	Impacts Not Related to City MS4	Data Gaps
Fanno/Tryon	55	12	26	17
Willamette	37	11	18	8
Johnson Creek	24	11	8	5
Total	116	34	52	30

STRATEGIES TO ADDRESS DATA GAPS

As discussed in the previous sections, sufficient information was not available to determine if impacts were caused by hydromodification for several possible impact sites in each subwatershed. The watershed teams identified a total of 30 sites (17 in Fanno/Tryon, 8 in Willamette, and 5 in Johnson Creek) that are considered data gaps.

These sites were identified based on citizen calls to the drainage complaint hotline or from watershed staff field observations. The impact descriptions suggest erosion or sedimentation, but the locations, site conditions, and severity are not clear enough to determine if the possible impacts are caused by hydromodification. Additional field investigation may be required to determine if impacts were caused by hydromodification.

In addition to investigating these sites, BES's *Stormwater System Plan* (SWSP), discussed in detail in the following section, will provide a means of identifying other possible hydromodification impacts. The SWSP includes coordination with BES watershed teams to more fully assess current instream conditions.

STRATEGIES, PRIORITIES, AND TOOLS TO REDUCE HYDROMODIFICATION IMPACTS

Ongoing Programs

The City has been implementing stormwater management measures for water quality and flow control under the NPDES permit program since 1995. The City's *Retrofit Plan* (November 1, 2014) identifies the various existing City policies, programs, and plans that support measures to reduce water quality impacts from existing development that drains to the MS4. Because many of these measures also address stormwater flow control for both new development and redevelopment, they also reduce the potential for MS4 hydromodification impacts. These measures, discussed in detail in the *Retrofit Plan* include:

- *Stormwater Management Manual* (SWMM) (in effect since 1999)
- Green Street Policy (in effect since 2007)
- Technical Assistance, Incentives, and Grants
  - Clean River Rewards Program (in effect since 2006)
  - Ecoroof Program (in effect since 1996)
  - Innovative Wet Weather Demonstration Projects
- Public Stormwater Quality Facilities

Long-Term Strategy

Stormwater System Plan

As discussed in the *Retrofit Plan*, BES periodically conducts systems planning for the infrastructure systems it manages, including the combined sewer system, the sanitary sewer system, and the separated storm sewer system. BES completed the combined and sanitary sewer elements of its most recent *System Plan* in 2012 and is currently working on the *Stormwater System Plan* (SWSP). Early-action recommendations from the SWSP will be proposed for capital funding beginning in FY15-16.

The City's long-term retrofit strategy is being integrated into the SWSP planning process. The SWSP also includes elements related to reducing or minimizing hydromodification impacts. The SWSP will address near-field impacts and will be the primary means to address far-field impacts that require a geographically large-scale or drainage subbasin-wide stormwater management approach.

The City's adopted planning approach for systems planning relies on asset management principles. Asset management is a tool to identify the most cost-effective way to protect assets; provide community services; and safeguard public health, environmental quality, and economic security. Asset management is commonly defined as meeting agreed-upon customer service levels, while minimizing life cycle costs at an acceptable level of risk. It

focuses on delivering value to the customer – both in terms of the services provided and the rates charged – in an efficient and transparent manner. The goal is to make better decisions about infrastructure acquisition, planning, design, construction, operation and maintenance, and renewal or replacement.[1]

Table 11 shows the service categories that will be analyzed as part of the SWSP. Long-term planning to address or minimize hydromodification impacts will be integrated into the shaded service categories: reducing localized/nuisance flooding and disruption to the hydrologic cycle.

Table 11: Stormwater System Plan Service Categories

Strategic Commitments	**Service Categories**
Stormwater is managed to meet regulations in a watershed context to achieve:	*Services delivered to the customer - What we manage to reduce risk & improve conditions:*
protection of public health and property and **improvement of** public safety	• sanitary sewage releases
	• erosion and landslide hazards
	• localized/nuisance flooding
	• groundwater contamination
protection of biological communities and **improvement** of ecological function	• loss of habitat
	• contamination of surface water and sediment
	• disruption to hydrologic cycle
support of community needs	• deficiencies that impede community improvements

[1] Additional information about asset management can be found in the International Infrastructure Management Manual (http://www.nams.org.nz/pages/273/international-infrastructure-management-manual-2011-edition.htm)

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