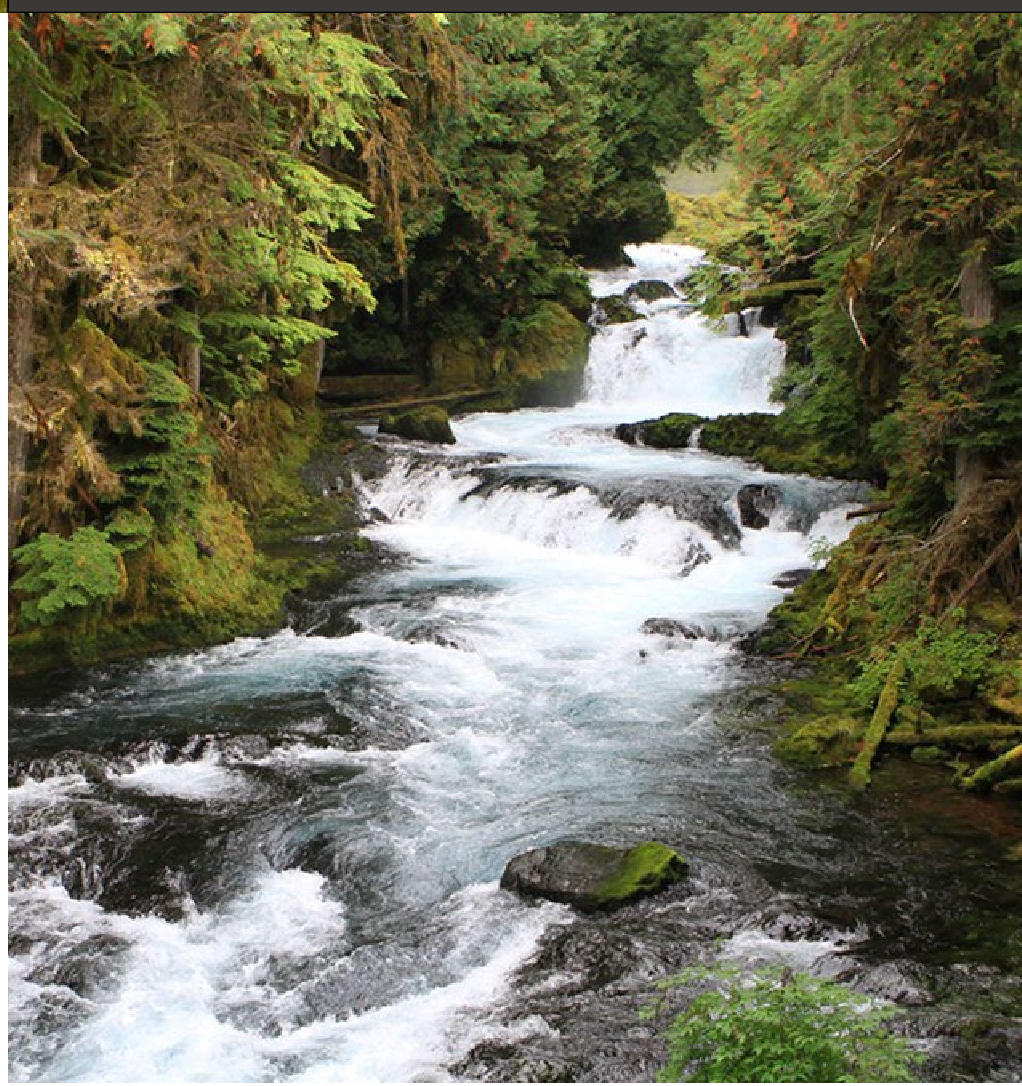
Draft Total Maximum Daily Loads for the Willamette Subbasins

Technical Support Document Appendix B: Lower Willamette Shade Model Memo

January 2024



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CITY OF PORTLAND
ENVIRONMENTAL SERVICES
1120 SW Fifth Avenue, Suite 613, Portland, Oregon 97204 ▪ Mingus Mapps, Commissioner ▪ Michael Jordan, Director

TECHNICAL MEMORANDUM

April 14, 2022

TO: TMDL Implementation Program File

FROM: Julia Bond

CC: Kaitlin Lovell, Loren Shelley, Barb Adkins

RE: Riparian Shade Assessment

1 Introduction

A healthy riparian canopy provides multiple benefits to a stream, including the shading of the stream channel. In the Portland area, the shade provided by riparian vegetation is of particular importance to streams in the summer when water temperatures frequently exceed the conditions needed by salmon and trout to survive. Riparian shade reduces the amount of incoming solar radiation from reaching the stream, which in turn helps prevent the water from warming.

To address excess stream temperatures, Oregon's Department of Environmental Quality (DEQ) developed a total maximum daily load (TMDL) for temperature for the Lower Willamette basin. The temperature TMDL includes load allocations for all perennial streams, including the Columbia Slough, Johnson Creek, and Tryon Creek (DEQ, 2006). The Tualatin River subbasin temperature TMDL applies to the perennial or fish-bearing streams located in the Fanno Creek and Rock Creek basins. The TMDLs use percent effective shade as a surrogate for measuring temperature nonpoint source pollutant loading. Effective shade is the proportion of solar radiation that is attenuated or scattered before reaching the stream. DEQ defines system potential shade as the maximum effective shade possible for a stream reach. System potential shade is achieved when the riparian plant community has reached its mature, undisturbed condition in which vegetation heights are at or near their expected potential, resulting in the maximum effective shade for the stream.

Anthropogenic activities in the Portland area have degraded riparian conditions, resulting in a loss of riparian vegetation and an increase in solar loading. Based on modeling for the 2006 TMDL, the loss of stream shade has resulted in a 25% increase in solar loading to the Columbia Slough mainstem. The increase in solar loading due to the loss of riparian shade, or excess thermal load, to the Johnson Creek mainstem was found to be 51% above system potential shade conditions. The TMDL identifies restoration and protection of riparian vegetation as the primary methods for increasing stream shading and bases the nonpoint source load allocations on achieving system potential shade conditions.

The City and its watershed partners have engaged in riparian restoration activities for several decades. These activities include tree plantings and efforts to revegetate streambanks, as well as maintaining natural areas to promote mature riparian conditions. Monitoring of these projects has demonstrated an increase in streamside vegetation and improved riparian canopy across the Portland area, but these monitoring efforts are not able to assess riparian conditions in a single citywide effort.

The City committed to conducting an effective shade assessment in the City's 2019 TMDL Implementation Plan (Goal ID TIP-01; City of Portland, 2019). This report documents the findings of the effectives shade assessment. Assessing the current level of effective shade along the streams in the Portland area provides insight into the City's progress toward meeting the TMDL nonpoint source load allocation of system potential shade. The results of this assessment are compared to the TMDL goal of system potential shade and can be used to inform the prioritization of areas that would benefit from future riparian restoration.

2 Methods

The effective shade values presented in this memo were calculated using the shade module of Heat Source version 26 (Michie et al., 2021), a computer model used and maintained by DEQ to simulate stream thermodynamics and hydrology (Boyd & Kasper, 2003). The model can be used to calculate the effective shade at any point (or points) along a stream channel for a specified time of the year. The key model parameters used in this assessment are presented in Table 1.

Table 1. Heat Source model parameter values used to calculate effective shade along streams in the Portland area.

Model Parameter	Parameter Value
Model start date	July 1
Model end date	August 31
Model time step	15 minutes
Longitudinal stream sample distance	25 meters
Number of transects per stream node	8
Number of samples per transect	25
Distance between transect samples	3 meters
Cloud cover	0%
Topographic shade angles	East, South, West
Topographic angle sampling distance	Maximum of 10 km

To calculate effective shade, the model relies on GIS inputs that characterize the surrounding topography and land use (including vegetation) that affect the amount of solar radiation that can reach the surface of the modeled stream. For this effort, these GIS inputs were gathered using TTools version 9.0 (Michie, 2021). The GIS inputs used to characterize surrounding land use and topography are listed in Table 2.

Table 2. GIS datasets used to characterize land use surrounding the modeled streams. See the References section for links to complete GIS metadata.

GIS Dataset	Purpose	Source
Stream center lines	Linear feature used to locate the modeling nodes	City of Portland (2010)*
Impervious areas	To construct land cover code for current and future conditions	City of Portland (2017)*
Canopy classification	To construct land cover code for current and future conditions, including specifying canopy density values and future feature heights	Oregon Metro (2016)
Waterbodies	To identify right and left stream bank lines and to construct land cover codes for current and future conditions	City of Portland (2005)*
Wetlands	To construct land cover codes for current and future conditions, including where future canopy growth may occur	City of Portland (2005)*
Management areas	To support modeling scenarios of future conditions with changes limited to areas with environmental protections	City of Portland (1996)*
2007 LiDAR	To characterize the surrounding topography and the heights of the surrounding land use in 2007	City of Portland (2013)
2014 LiDAR	To characterize the surrounding topography and the heights of the surrounding land use in 2014	City of Portland (2015)
2019 LiDAR	To characterize the surrounding topography and the heights of the surrounding land use in 2019	City of Portland (2021)

* Regularly updated GIS layers

The GIS layers in Table 2 were all (where needed) converted to raster datasets. These raster layers were then combined to create unique land cover codes that represent both the features on the landscape (e.g., canopy type, impervious areas, open water, wetlands, etc.) as well as the height above the ground surface of any features (e.g., trees or buildings) at that location. The land cover codes also include whether the area falls within a management area with environmental restrictions that limit riparian disturbances. Separate land cover layers were created for each of the three evaluated time periods (2007, 2014, and 2019). The raster layers representing land cover codes had a pixel resolution of 3 feet.

Stream channel widths were characterized based on field measurements from stream surveys conducted by the Oregon Department of Fish and Wildlife (ODFW). ODFW staff conducted stream habitat surveys during the summers of 2019 and 2020 throughout the Portland area (ODFW 2019, 2020). For this shade modeling effort, the stream channel widths measured by ODFW were used to generate a variable buffer around the stream center line to represent the right and left banks of the channel.

As noted above, TTools was used to sample the area surrounding each modeling node (Figure 1). The TTools sampling provided information on the adjacent topography, land cover, and feature heights above the ground surface within 75 meters of the center of the stream with a sample spacing of 3 meters.

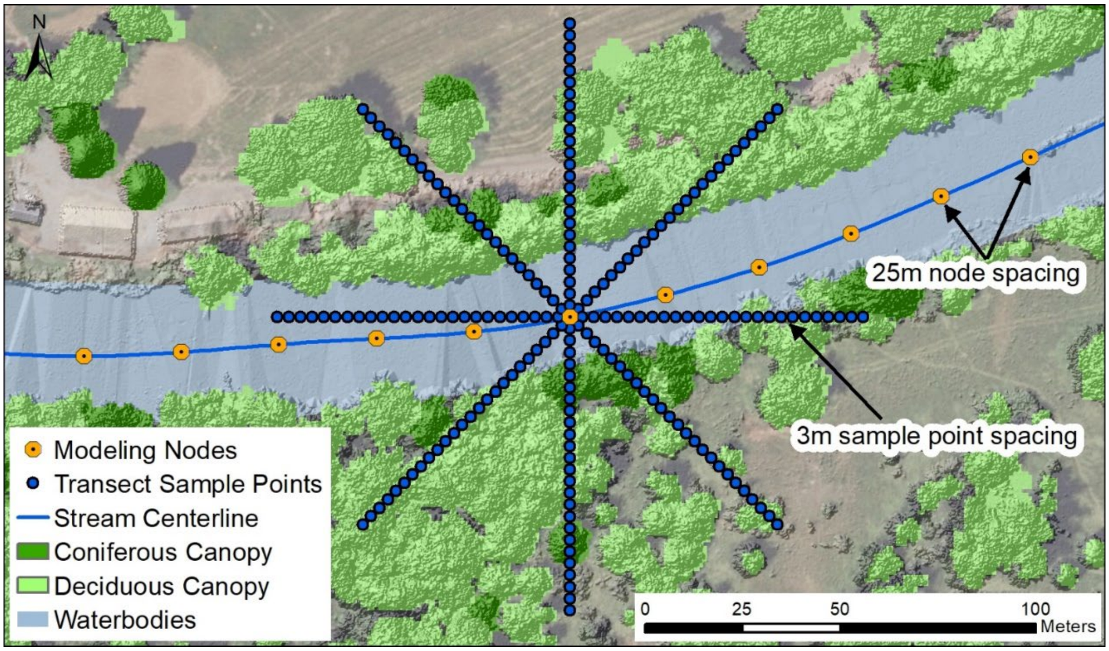


Figure 1. Example of the GIS sampling approach used to calculate effective shade. Effective shade values are calculated for each of the orange modeling nodes (25 meter spacing between nodes). The blue transect sample points (3 meter spacing between points) are used to characterize the surrounding land use and serve as inputs to the model.

2.1 Modeling Scenarios

Six modeling scenarios were evaluated as part of the assessment. The scenarios aim to represent the conditions on the landscape during different years, as well as estimate future conditions based on changes in vegetation.

Three of the modeling scenarios were designed to represent riparian canopy conditions based on available LiDAR collected in 2007, 2014, and 2019. These three scenarios represent observed canopy conditions. Three other modeling scenarios were developed to represent possible future riparian canopy conditions. The scenarios are described more fully in Table 3.

Table 3. Shade modeling scenarios.

Model Scenario	Description
Topography Only	Topographic conditions with no vegetation. Represents existing topographic conditions in 2019.
2007 Canopy	Riparian vegetation conditions characterized by 2007 LiDAR tree heights. Represents existing conditions in 2007.
2014 Canopy	Riparian vegetation conditions characterized by 2014 LiDAR tree heights. Represents existing conditions in 2014.
2019 Canopy	Riparian vegetation conditions characterized by 2019 LiDAR tree heights. Represents existing conditions, in 2019.
Maximum System Potential	A hypothetical future condition representing the maximum projected riparian shade. All existing vegetation from 2019 is assumed to have reached mature

Model Scenario	Description
	heights (system potential) and all areas with no vegetation is assumed to have a mature tree canopy.
System Potential within Management Areas	A hypothetical future condition representing the maximum projected riparian shade within only areas protected by existing policies or regulations. All current vegetation within management areas is assumed to have reached mature heights (system potential) and all areas with no vegetation is assumed to have a mature tree canopy in these management areas. No change to the 2019 conditions outside of the management areas.
System Potential within Management Areas + Canopy Loss in Unprotected Areas	A hypothetical future condition representing the maximum projected riparian shade within only areas protected by existing policies or regulations and complete loss of tree canopy outside of these protected areas. All current vegetation within management areas is assumed to have reached mature heights (system potential) and all areas with no vegetation is assumed to have a mature tree canopy in these management areas. Outside of the management areas, tree heights are set to zero.
System Potential within Portland's p-zone + 2019 canopy in c-zone	A hypothetical future condition representing the maximum projected riparian shade within only areas in Portland covered by Portland's Environmental Protection overlay zones (p-zone) and management areas outside of Portland. All current vegetation within p-zones is assumed to have reached mature heights (system potential) and all areas with no vegetation is assumed to have a mature tree canopy in these management areas. Management areas covered by Portland's Environmental Conservation overlay zones (c-zone) are characterized by 2019 canopy conditions. No change to the 2019 conditions outside of the management areas.
System Potential within Portland's p-zone + no canopy in c-zone	A hypothetical future condition representing the maximum projected riparian shade within only areas in Portland covered by Portland's Environmental Protection overlay zones (p-zone) and management areas outside of Portland. All current vegetation within p-zones is assumed to have reached mature heights (system potential) and all areas with no vegetation is assumed to have a mature tree canopy in these management areas. In the management areas covered by Portland's Environmental Conservation overlay zones (c-zone), tree heights are set to zero. No change to the 2019 conditions outside of the management areas.

As noted above, system potential shade is achieved when the riparian plant community has reached its mature, undisturbed condition. The modeling scenarios that represent system potential include the following important assumptions:

- System potential tree heights
    - Deciduous canopy is assumed to have a mature height of 100 feet
    - Coniferous canopy is assumed to have a mature height of 150 feet
    - Unidentified tree canopy (or no current tree canopy) is assumed to be deciduous and will have a mature height of 100 feet
- Open water remains unchanged in terms of feature heights (vegetation overhanging the stream channel is assumed to grow as above)
- Vegetation heights within emergent wetlands are represented with 2019 LiDAR heights, no future growth is assumed

- Buildings are unchanged in terms of feature heights (vegetation overhanging a building is assumed to grow as above)
- Streets are unchanged in terms of feature heights (vegetation overhanging a street is assumed to grow as above)
- Tree planting possible on parking lots and the scenarios assume future mature tree heights as above
- Areas with no identified land use (no canopy, impervious area, waterbody, or wetland) are assumed to have a future condition of mature deciduous trees

2.2 *Model Extent*

The focus of this modeling effort was limited to the perennial streams within Portland and the immediate area. To streamline the modeling, the area was divided into two model runs, representing: (1) streams east of the Willamette River, and (2) streams west of the Willamette River. A map of the modeled stream reaches and a list of modeling nodes is included in the Appendix.

2.3 *Model Calibration*

A key parameter in the shade calculation is the canopy density value. Streamside vegetation does not attenuate 100% of the light that passes through it, only a portion of it. The canopy density parameter in the model represents the proportion of incoming solar radiation that is blocked by a section of riparian vegetation. The canopy density values used in the initial model runs were based on the vegetation characteristics described in the Lower Willamette temperature TMDL (DEQ, 2006) and included a 75% density value for deciduous vegetation and an 80% density value for coniferous vegetation.

The canopy density value plays an important role in the effective shade calculation, as such it was important to evaluate how well the density value reflected conditions on the ground. The data available for calibration was limited to canopy cover measurements collected from the center of the stream channel using a densiometer (ideally, canopy cover measurement from within the riparian area itself would be used for calibration, however, these data were not available). Densiometer values were recorded as part of the City's watershed monitoring program (Portland Area Watershed Monitoring and Assessment Program) and the bureau's Restoration Monitoring Program. Densiometer readings were collected and converted canopy cover using the methods of Lemmon (1957). A complete list of canopy cover values used in the model calibration are included in the Appendix.

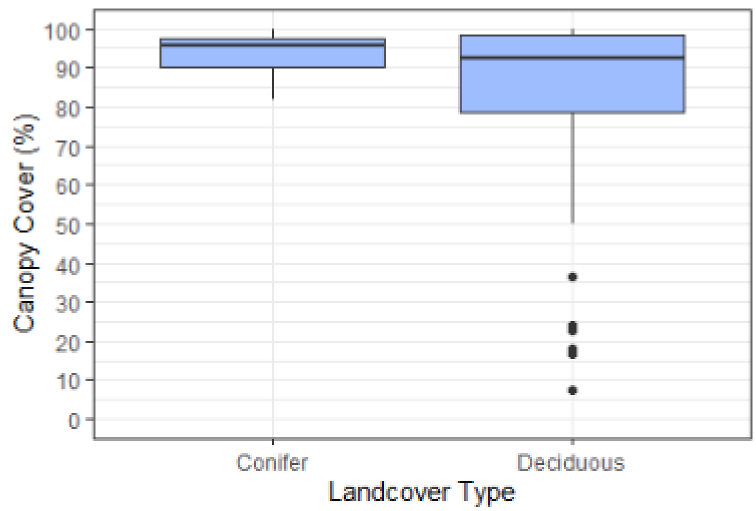


Figure 2. Distribution of canopy cover values measured in the field at the center of the stream for the two major canopy types.

The measured canopy cover values were typically substantially higher than the initial density values, particularly in riparian areas dominated by conifers (Figure 2). For the purposes of this assessment, the 25th percentile canopy cover values were used as the canopy density value in the model to better reflect measured field conditions. As such, both density values were increased, with the density value for deciduous canopy increased to 78% and the density for coniferous canopy increased to 90%.

3 Results

Effective shade was modeled for all streams from July 1 to August 31 at a 15-minute timestep (Table 1). These results have been summarized as the July–August mean at each modeling node. This summer time period represents the period where stream temperatures in Portland tend to be highest. The following sections summarize the effective shade results for the different streams in the Portland area for all six modeling scenarios.

3.1 Johnson Creek

Effective shade varied along the modeled streams in the Johnson Creek watershed. The conditions along the smaller tributaries located west of the Kelley Creek confluence (e.g. Deardorff, Mitchell, and Wahoo creeks) produced high amounts of effective shade, with most reaches achieving approximately 90% of system potential shade in 2019 (Table 4). The highly urbanized Crystal Springs Creek differed from these other tributaries, with conditions in 2019 achieving approximately 70% of system potential.

Table 4. Mean effective shade results for the six model scenarios for the mainstem of Johnson Creek and its tributaries. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	Total Length (km)	Mean Width (m)	Mean Effective Shade (%)					
			2007	2014	2019	Max System Potential	System Potential in Management Areas	System Potential in Management Areas + Loss
Mainstem								
Johnson Creek 0-10 km	10.0	7.6	53.0	63.3	61.9	80.9	77.8	77.0
Johnson Creek 10-20 km	10.0	7.4	59.7	64.7	66.7	82.4	80.3	79.5
Johnson Creek 20-30 km	10.0	9.2	59.6	65.5	65.6	85.0	84.9	84.9
Johnson Creek 30-43 km	12.6	4.5	59.8	64.8	66.9	85.0	84.0	83.7
Tributaries								
Badger Creek	3.9	1.9	75.4	77.2	76.6	89.0	87.2	86.1
Butler Creek	2.7	1.3	74.9	79.3	78.2	85.9	84.7	84.3
Clatsop Creek	2.3	0.9	84.8	87.8	86.6	90.7	89.9	88.4
Crystal Springs	3.9	9.1	39.2	47.3	51.1	71.4	68.1	67.6
Deardorff Creek	1.7	1.5	83.0	85.9	85.3	89.7	88.5	87.7
Errol Creek	0.6	1.3	61.6	68.7	50.4	82.8	75.7	59.8
Frog Creek	1.5	0.7	74.7	79.8	78.7	88.3	82.4	79.4
Indian Creek	1.5	0.7	69.2	79.7	81.0	88.2	85.2	83.2
Jenne Creek	2.0	0.6	69.9	73.2	72.7	88.7	86.3	82.9
Kelley Creek	7.2	2.2	70.2	77.8	76.5	89.6	88.4	87.0
Mitchell Creek	3.1	1.2	76.2	78.2	75.0	90.2	88.9	87.7
Sunshine Creek	6.7	1.9	55.6	58.4	59.1	87.1	84.5	84.0
Veterans Creek	2.1	1.3	70.3	75.6	75.4	87.6	86.0	84.2
Wahoo Creek	1.1	1.3	89.3	91.0	90.6	92.8	92.7	92.6

Conditions along the mainstem of Johnson Creek were variable in 2019 (Figure 3), with few reaches achieving close to system potential shade. Along the mainstem, 2019 conditions were within approximately 78% of system potential.

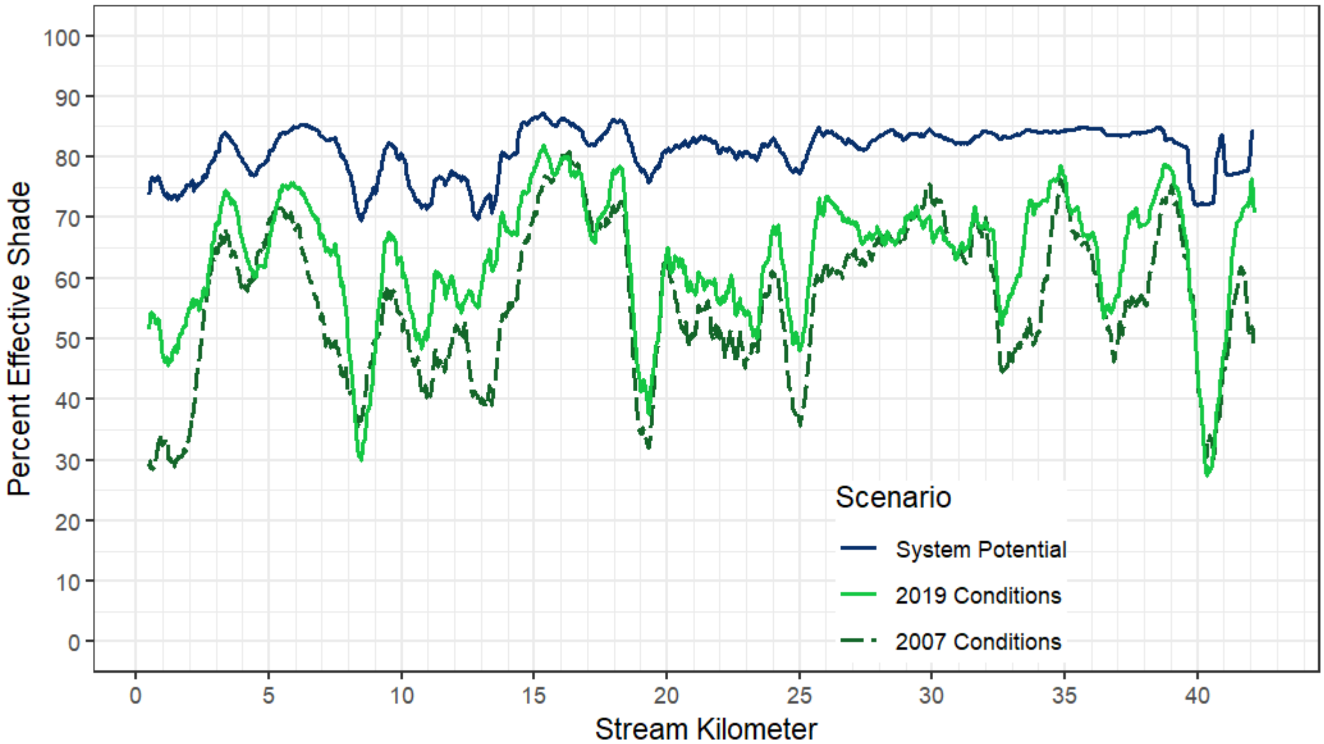


Figure 3. Johnson Creek effective shade scenarios for 2007, 2019, and system potential. Results are presented as 1000 meter rolling averages centered on the reporting node.

3.2 *Columbia Slough*

The wide reaches of the Lower Columbia Slough generally had the lowest values of effective shade in the watershed, 13.3% in 2019, while many of the narrower reaches had substantially more effective shade (Table 5). The results from the system potential scenarios highlight what is possible along these different reaches, emphasizing how the wide channels of Buffalo and the Lower Slough are more difficult to shade. Even with their low effective shade values, both reaches are currently achieving approximating 60% of the shade that is possible along that reach.

Table 5. Mean effective shade results for the six model scenarios for the mainstem of the Columbia Slough and its tributaries and side channels. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	Total Length (km)	Mean Width (m)	Mean Effective Shade (%)					
			2007	2014	2019	Max System Potential	System Potential in Management Areas	System Potential in Management Areas + Loss
Lower Slough	13.9	51.2	6.4	13.2	13.3	21.0	20.7	20.4
North Slough	1.4	23.4	22.7	35.9	36.4	57.1	57.1	57.1
Blind Slough	0.5	37.8	16.4	26.1	27.3	37.4	37.4	37.4
Wapato Wetland	1.7	34.5	5.0	25.1	25.0	38.6	35.8	33.9
Middle Slough	11.3	15.7	19.2	46.3	44.4	67.3	67.1	67.1

Stream	Total Length (km)	Mean Width (m)	Mean Effective Shade (%)					
			2007	2014	2019	Max System Potential	System Potential in Management Areas	System Potential in Management Areas + Loss
Buffalo Slough	1.5	47.8	19.3	11.7	13.4	24.1	23.9	23.9
Whitaker Slough	5.5	5.5	14.3	37.2	39.5	54.3	53.3	53.1
Upper Slough	4.6	17.7	10.2	20.4	17.6	45.0	44.7	44.6
Warren Slough	1.1	8.9	23.8	76.6	75.6	83.9	83.7	83.6
Wilkes Creek	1.6	0.9	17.8	61.4	53.8	84.0	76.3	72.7

Conditions along the Upper Slough in 2019 were furthest from system potential conditions (Figure 4). Despite having a mean channel width similar to that of the Middle Slough, the effective shade in 2019 represented less than 40% of what is possible for that reach. Generally, the amount of shade along the waterways in the Columbia Slough watershed has increased since 2007. With the exception of the Upper Slough, all of the waterways achieved over half of system potential shade in 2019.

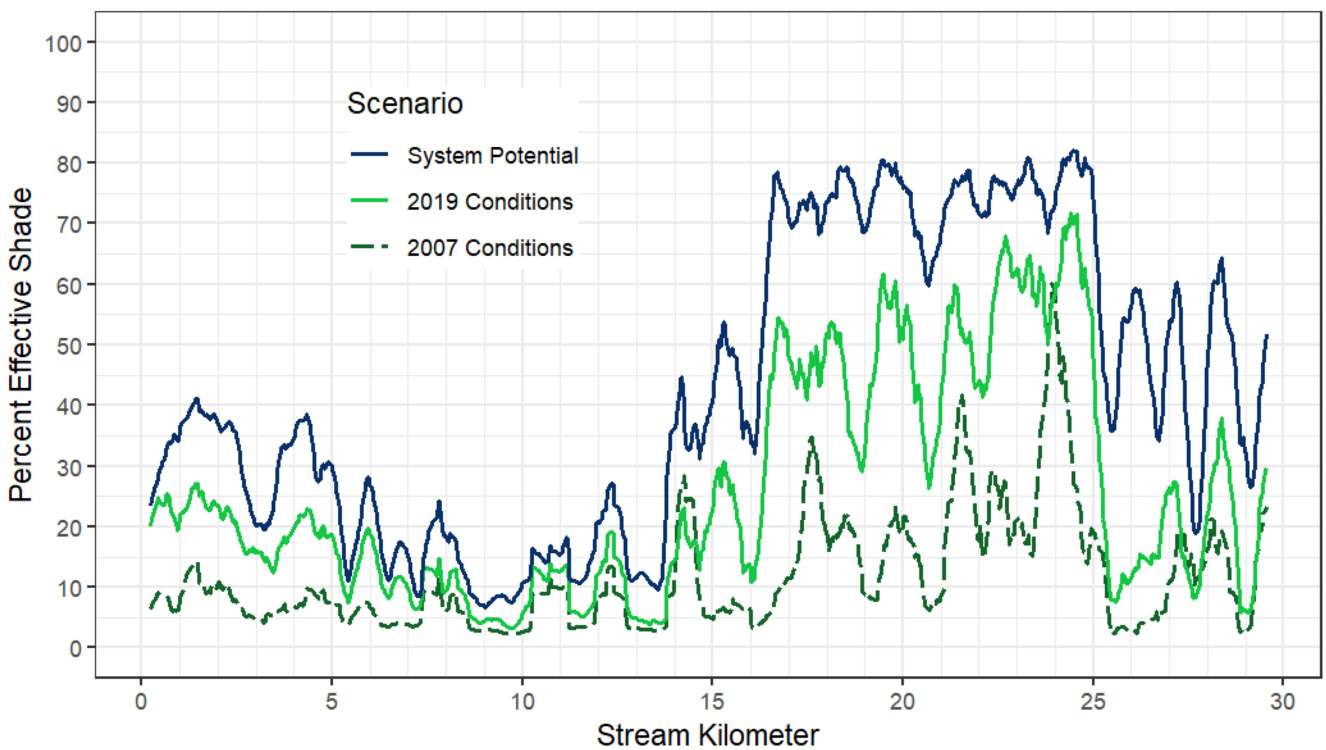


Figure 4. Columbia Slough effective shade scenarios for 2007, 2019, and modeled system potential. Results are presented as 500 meter rolling averages centered on the reporting node.

3.3 *Tryon Creek*

The streams within the Tryon Creek watershed are well shaded. In 2019, the modeled effective shade along all of the reaches was at least 90% of system potential, with some reaches in the Tryon Creek Natural Area achieving more than 97% of system potential in 2019.

Table 6. Mean effective shade results for the five model scenarios for the mainstem of Tryon Creek and its tributaries. Effective shade results from 2007 are not included due to concerns related to the accuracy of the available LiDAR used to characterize canopy conditions in 2007. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	Total Length (km)	Mean Width (m)	Mean Effective Shade (%)				
			2014	2019	Max System Potential	System Potential in Management Areas	System Potential in Management Areas + Loss
Arnold Creek	3.3	1.5	90.8	90.5	92.3	92.1	92.1
Falling Creek	2.4	1.2	78.8	80.4	86.8	82.2	77.8
Nettle Creek	2.6	1.9	82.0	81.1	90.2	86.3	83.1
Park Creek	1.2	1.4	89.9	88.8	90.8	90.7	90.7
TCNA Tributaries	4.9	0.9	89.8	88.4	91.4	91.3	91.1
Tryon Creek Tributaries	1.3	1.1	83.2	84.9	88.9	84.3	76.5
Tryon Creek	7.5	3.9	82.2	80.1	89.0	86.8	84.1

* TCNA: Tryon Creek Natural Area

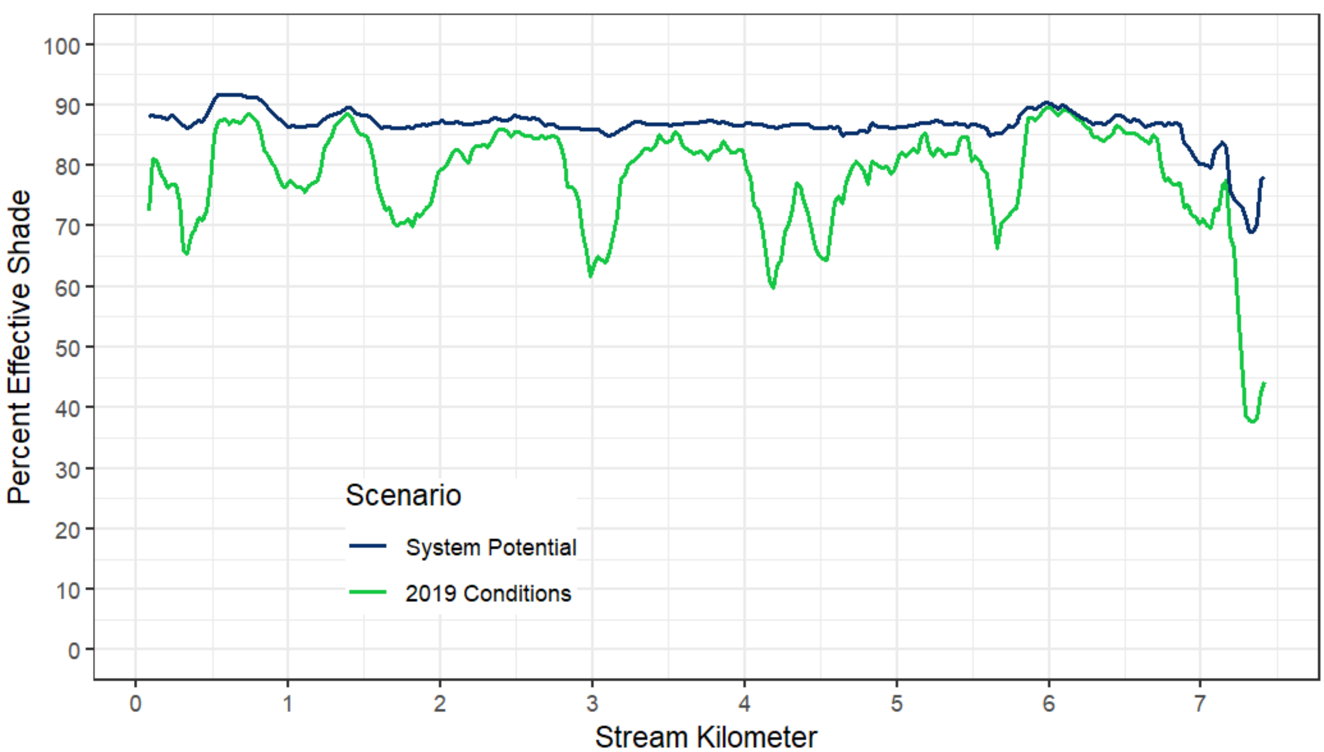


Figure 5. Mainstem Tryon Creek effective shade scenarios for 2019 and system potential. Results are presented as 200 meter rolling averages centered on the reporting node. The 2007 scenario is not included here due to concerns related to the accuracy of the available LiDAR used to characterize canopy conditions in 2007.

3.4 *Fanno Creek*

Fanno Creek and its tributaries in Portland are well shaded. Conditions in 2019 achieved over 85% of system potential along all of the modeled reaches, with conditions along some of the small tributaries, such as Columbia and Lowell creeks, achieving over 97% of system potential.

Table 7. Mean effective shade results for the six model scenarios for the mainstem of Fanno Creek in Portland and its tributaries. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	Total Length (km)	Mean Width (m)	Mean Effective Shade (%)					
			2007	2014	2019	Max System Potential	System Potential in Management Areas	System Potential in Management Areas + Loss
Fanno Creek	5.8	2.7	49.5	77.2	77.7	86.8	81.5	77.5
Ash Creek	6.6	1.6	54.9	72.5	72.8	84.2	79.3	77.0
Ash Creek South Fork	3.3	1.2	71.4	80.3	80.1	88.7	84.2	77.5
Columbia Creek	1.9	1.2	55.7	85.5	84.3	90.6	86.6	82.2
Ivey Creek	1.9	0.6	52.2	83.1	82.6	89.2	85.5	81.2
Lowell Creek	2.2	0.6	51.7	87.2	87.4	91.1	88.6	86.6
Pendleton Creek	1.8	0.7	46.4	78.0	77.3	86.8	82.7	79.9
Restoration Creek	0.6	0.7	51.3	76.0	74.5	88.3	73.6	67.4
Sylvan Creek	4.5	1.2	37.8	76.5	75.9	88.5	84.4	74.9
Vermont Creek	3.4	3.1	43.1	76.5	77.1	87.0	83.0	80.3
Woods Creek	4.7	4.3	50.4	80.9	80.5	88.8	85.9	77.3

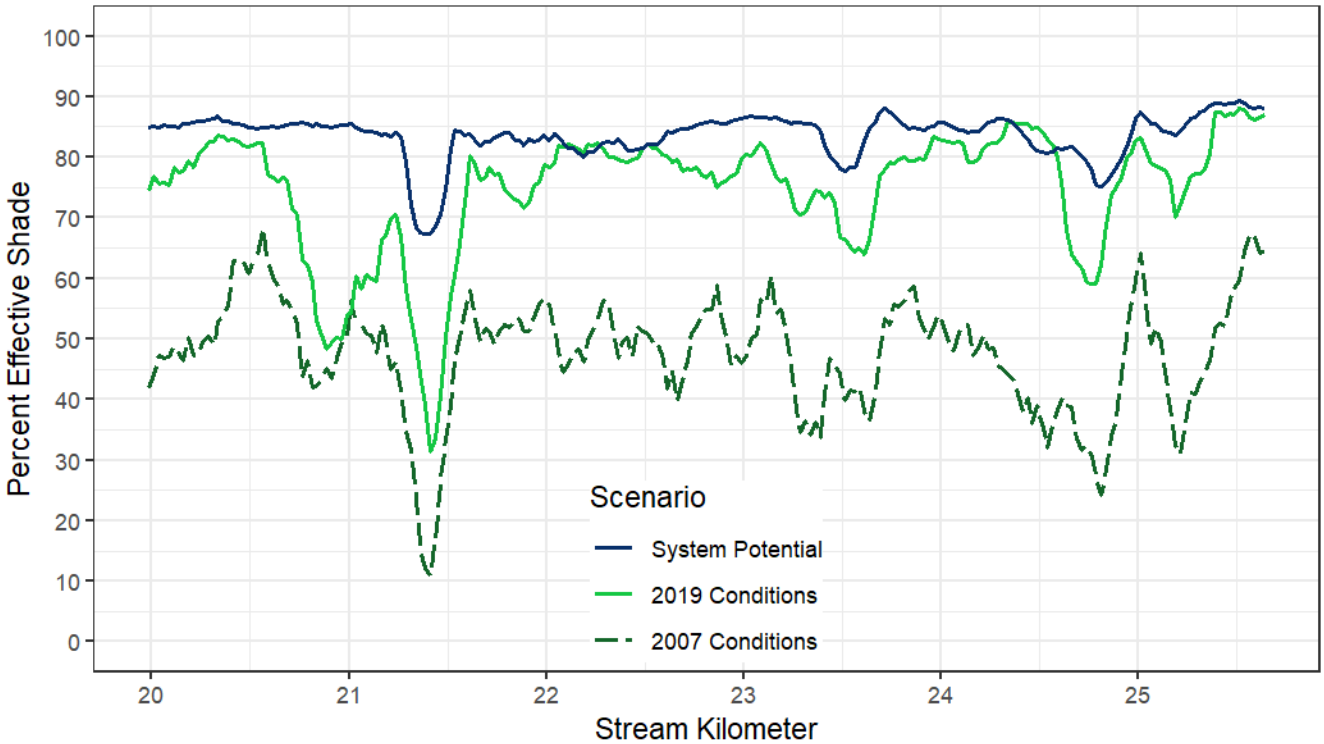


Figure 6. Fanno Creek effective shade scenarios for 2007, 2019, and system potential. Results are presented as 200 meter rolling averages centered on the reporting node. Results are presented for the mainstem of Fanno Creek from the confluence of Vermont Creek to SW 25th Ave.

3.5 *Westside Willamette Streams*

Many of the small streams draining to the Willamette River on the westside (the area referred to as the Tualatin Mountains in the Lower Willamette temperature TMDL) are located in the well-forested Forest Park. Conditions in 2019 for most of the streams produced effective shade values that are very close to system potential.

Table 8. Mean effective shade results for the five model scenarios for the streams and their tributaries on the westside that flow directly to the Willamette River. Effective shade results from 2007 are not included due to concerns related to the accuracy of the available LiDAR used to characterize canopy conditions in 2007. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	Total Length (km)	Mean Width (m)	Mean Effective Shade (%)				
			2014	2019	Max System Potential	System Potential in Management Areas	System Potential in Management Areas + Loss
Balch Creek	4.9	1.8	90.7	89.9	92.9	92.9	92.8
Doane Creek	3.9	1.1	77.1	76.9	90.6	79.4	74.1
Doane Creek Tribs	3.9	0.7	92.9	92.4	93.6	93.6	93.6
Linnton Creek NF	0.9	1.0	93.2	92.3	95.1	95.1	95.1
Linnton Creek SF	1.9	1.4	94.9	94.6	95.8	95.8	95.8

Stream	Total Length (km)	Mean Width (m)	Mean Effective Shade (%)				
			2014	2019	Max System Potential	System Potential in Management Areas	System Potential in Management Areas + Loss
Miller Creek	3.1	1.1	90.2	89.5	93.5	92.7	90.3
Miller Creek Trib	1.6	1.1	93.5	93.7	95.1	95.0	93.2
Munger Creek	1.4	0.7	94.4	93.4	95.2	95.2	94.7
Munger Creek Trib	0.6	1.1	94.2	93.6	94.7	94.7	94.7
Newton Creek	2.1	1.36	93.1	92.5	95.0	94.9	94.7
River View Streams	2.8	0.8	86.9	86.8	89.8	88.5	82.0
Rocking Chair Creek	2.1	1.2	92.9	92.2	93.8	93.5	83.1
Rocking Chair Creek NF	0.7	0.9	95.4	94.8	96.0	96.0	96.0
Saltzman Creek	2.7	1.0	73.6	74.4	90.4	76.3	70.6
Stephens Creek	3.3	1.5	72.6	73.2	85.7	78.6	71.8
Stephens Creek Trib	1.0	0.7	85.8	85.7	90.5	87.3	83.4

4 Portland's Environmental Overlay Zones

The management areas in Portland are composed of environmental overlay zones that limit activities in riparian areas. Two environmental overlay zones apply to the modeled streams in Portland: Environmental Protection (p-zone) and Environmental Conservation (c-zone) zones (Portland City Code 33.430). The two environmental overlay zones help protect natural resources in the city. The p-zone overlay is applied to areas where the natural resources are critical and development activities are not permitted except under special circumstances. The c-zone overlay is applied to areas with important natural resources, but where some environmentally sensitive development may be permitted.

Two modeling scenarios were evaluated to understand the relative contribution to system potential shade of Portland's two environmental overlay zones. As described in Table 3, both scenarios assume mature vegetation (system potential) within the p-zone. The first of the environmental overlay scenarios includes the 2019 canopy conditions in the c-zone, while the second scenario assumes no canopy is present in the c-zone. The results of these two scenarios are presented in the following sections.

It is important to note that results presented in the following sections represent modeled conditions based on the mapping of the environmental overlays zones at the time of this report. Portland's Bureau of Planning and Sustainability is currently working on an effort to update and refine the environmental overlay zones.[1] The purpose of the Environmental Overlay Zone Map Correction Project is to align the mapped location of the overlay zones with the most current information identifying the locations of

[1] For more information see: https://www.portland.gov/bps/ezones.

existing natural resources. The project will not alter the protections placed on the City's natural resources through the environmental overlay zones, but the location and extent of current environmental overlay zones may change as a result of this effort.

4.1 Johnson Creek

Current and future riparian vegetation in the two environmental overlays zones plays an important role in achieving system potential shade along Johnson Creek and its tributaries. In many places existing vegetation is approaching mature conditions and providing abundant shade. The results of the modeling indicate that much of this shade is provided by the riparian canopy currently with p-zone overlays; however, vegetation within areas covered by c-zone also contributes to system potential. Along certain tributaries, such as Crystal Springs and Indian creeks, vegetation within the c-zone provides a greater proportion of both the current and potential riparian shade. Along Crystal Springs Creek, the loss of riparian canopy from areas covered by c-zones would reduce the potential stream shading by close to 25%, while along Indian Creek a similar canopy loss would reduce the shading potential by over 40% (Table 9).

Table 9. Mean effective shade results for the environmental overlay zone model scenarios for the mainstem of Johnson Creek and its tributaries. Effective shade values represent July–August means. See Table 3 for scenario definitions. Streams that are entirely outside of the Portland city limits are not included in the table.

Stream	**Mean Effective Shade (%)**				**Shade Reduction (%)**	
	2019	**System Potential in Management Areas**	**System Potential in P-Zones + 2019 Canopy in C-Zones**	**System Potential in P-Zones + No Canopy in C-Zones**	**2019 Canopy in C-Zones**	**No Canopy in C-Zones**
Mainstem						
Johnson Creek 0-10 km	61.9	77.8	76.4	75.2	-1.9	-3.5
Johnson Creek 10-20 km	66.7	80.3	75.0	68.7	-7.4	-14.7
Tributaries						
Clatsop Creek	86.6	89.9	89.7	82.2	-0.2	-9.1
Crystal Springs	51.1	68.1	61.6	51.7	-10.1	-23.5
Deardorff Creek	85.3	88.5	87.7	86.5	-0.9	-2.3
Errol Creek	50.4	75.6	67.6	59.0	-10.0	-20.4
Frog Creek	78.7	82.4	82.2	75.3	-0.3	-8.3
Indian Creek	81.0	85.3	81.2	50.4	-5.2	-41.8
Jenne Creek	72.7	86.7	86.6	86.6	-0.4	-0.4
Kelley Creek	76.5	88.9	88.7	87.5	-0.2	-1.8
Mitchell Creek	75.0	88.9	88.9	88.9	-0.0	-0.0
Veterans Creek	75.4	86.0	84.6	78.8	-1.8	-8.7
Wahoo Creek	90.6	92.7	92.3	91.6	-0.5	-1.3

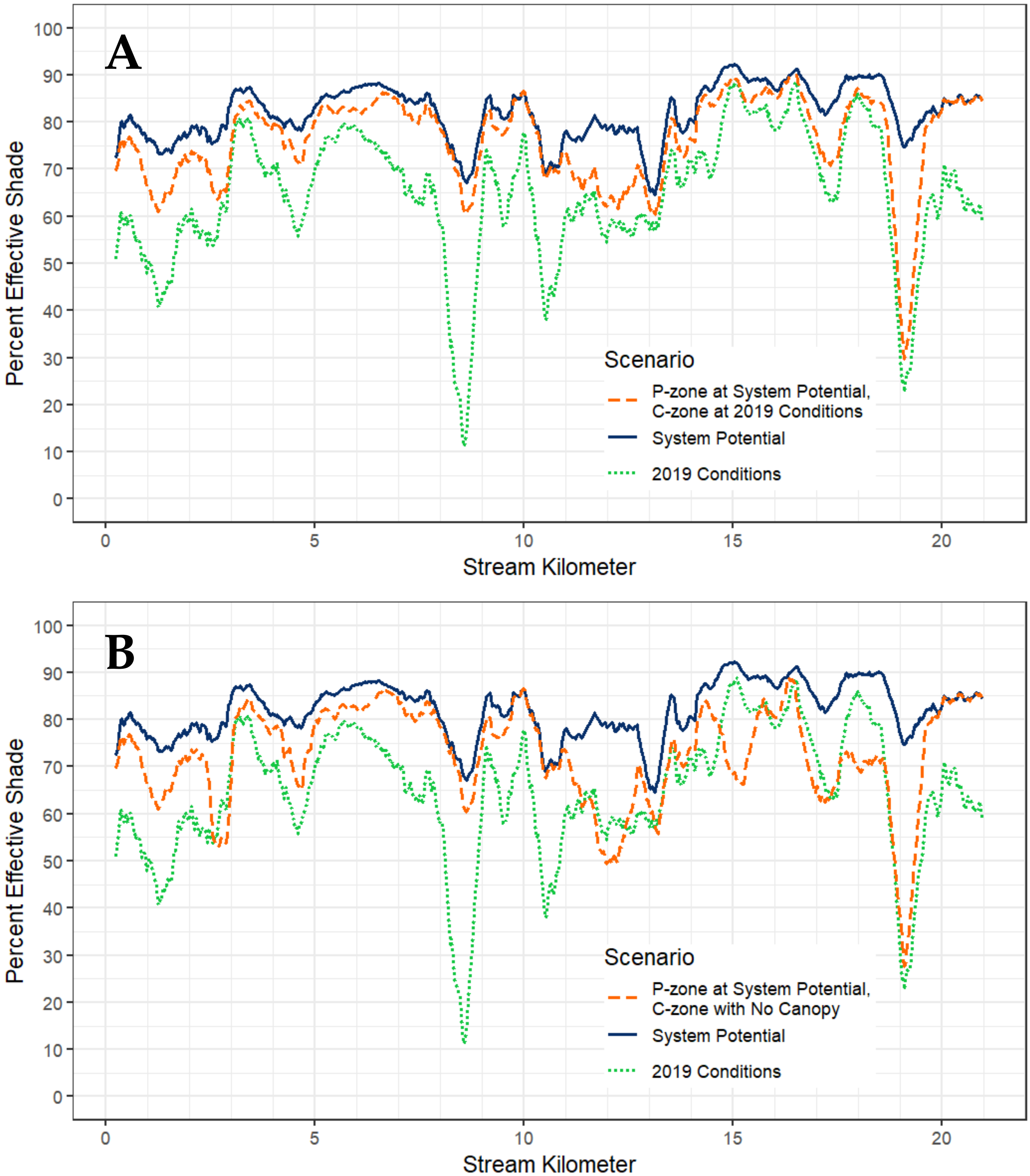


Figure 7. Johnson Creek mainstem effective shade scenarios for 2019, system potential, and the environmental overlay scenarios with p-zone at system potential and (A) c-zone with 2019 canopy conditions and (B) c-zone with no canopy. Results are presented as 1000 meter rolling averages centered on the reporting node. See Table 3 for scenario definitions.

4.2 *Columbia Slough*

The riparian vegetation within the two environmental overlays zones plays an important role in achieving system potential shade. Along the Columbia Slough the majority of the riparian shade is being produced by the vegetation within the c-zone (Table 10). Particularly along the Lower Slough, close to all of the existing riparian shade is being produced by vegetation within the c-zone. Along some reaches of the Lower Slough, the complete loss of riparian canopy from areas covered by c-zones would result in more than an 80% reduction in riparian shade compared to system potential. The modeling results emphasize the importance of vegetation within Portland's c-zone in achieving riparian shade in the Columbia Slough.

Table 10. Mean effective shade results for the environmental overlay zone model scenarios for the mainstem of the Columbia Slough and its tributaries and side channels. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	**Mean Effective Shade (%)**				**Shade Reduction (%)**	
	2019	**System Potential in Management Areas**	**System Potential in P-Zones + 2019 Canopy in C-Zones**	**System Potential in P-Zones + No Canopy in C-Zones**	**2019 Canopy in C-Zones**	**No Canopy in C-Zones**
Lower Slough	13.3	20.8	13.9	5.1	-35.3	-70.6
North Slough	36.4	57.1	56.4	55.4	-2.1	-4.6
Blind Slough	27.3	37.4	27.7	4.0	-23.7	-82.7
Wapato Wetland	25.0	35.7	33.9	25.7	-6.4	-26.1
Middle Slough	44.4	67.1	56.7	44.0	-19.2	-39.1
Buffalo Slough	13.4	23.9	15.5	8.1	-28.7	-54.9
Whitaker Slough	39.5	53.4	43.4	30.7	-25.2	-50.2
Upper Slough	17.6	44.7	44.7	44.7	0.0	0.0
Warren Slough	75.6	83.7	83.7	83.7	0.0	0.0
Wilkes Creek	53.8	76.3	54.4	14.2	-30.3	-81.3

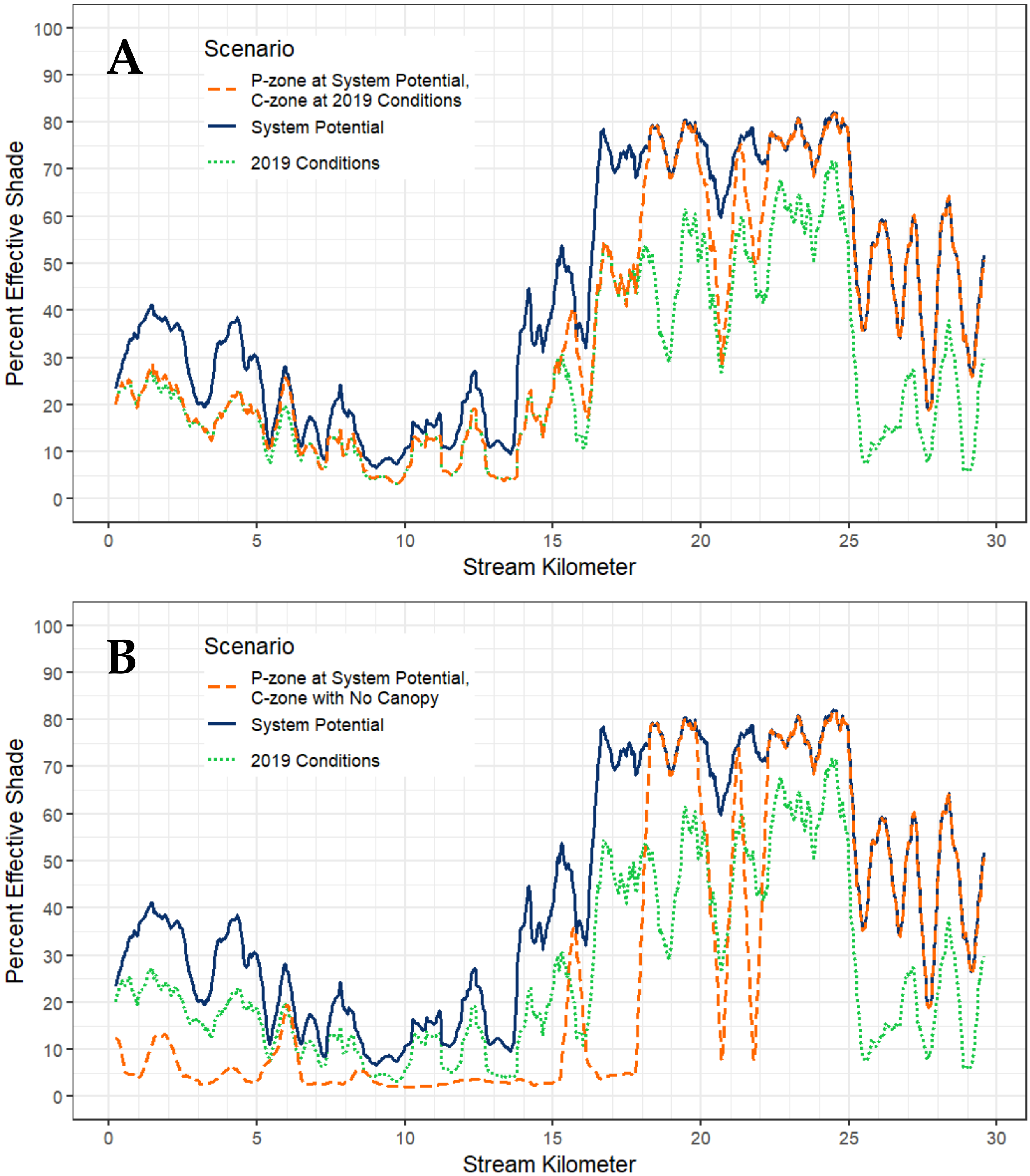


Figure 8. Mainstem Columbia Slough effective shade scenarios for 2019, system potential, and the environmental overlay scenarios with p-zone at system potential and (A) c-zone with 2019 canopy conditions and (B) c-zone with no canopy. Results are presented as 500 meter rolling averages centered on the reporting node. See Table 3 for scenario definitions.

4.3 *Tryon Creek*

The riparian vegetation within the two environmental overlays zones plays an important role in achieving system potential shade in the Tryon Creek watershed; however, the modeling results highlight that much of the shade is provided by vegetation covered by p-zones. Throughout the watershed, much of the riparian areas are covered by p-zones, with the exception of Falling Creek and the private land along many of the tributaries. A greater portion of these riparian areas are covered by c-zone overlays.

Table 11. Mean effective shade results for the environmental overlay zone model scenarios for the mainstem of Tryon Creek and its tributaries. Effective shade values represent July–August means. See Table 3 for scenario definitions. Streams that are entirely outside of the Portland city limits are not included in the table.

Stream	Mean Effective Shade (%)				Shade Reduction (%)	
	2019	System Potential in Management Areas	System Potential in P-Zones + 2019 Canopy in C-Zones	System Potential in P-Zones + No Canopy in C-Zones	2019 Canopy in C-Zones	No Canopy in C-Zones
Arnold Creek	90.5	92.2	90.8	86.7	-1.5	-6.1
Falling Creek	80.4	82.2	78.3	48.5	-5.0	-41.5
Park Creek	88.8	90.7	90.7	88.9	-0.1	-2.0
TCNA Tributaries	88.4	91.3	91.2	90.1	-0.1	-1.3
Tryon Creek Tributaries	84.9	84.3	83.5	65.1	-1.0	-23.0
Tryon Creek	80.1	86.8	86.5	84.1	-0.3	-3.2

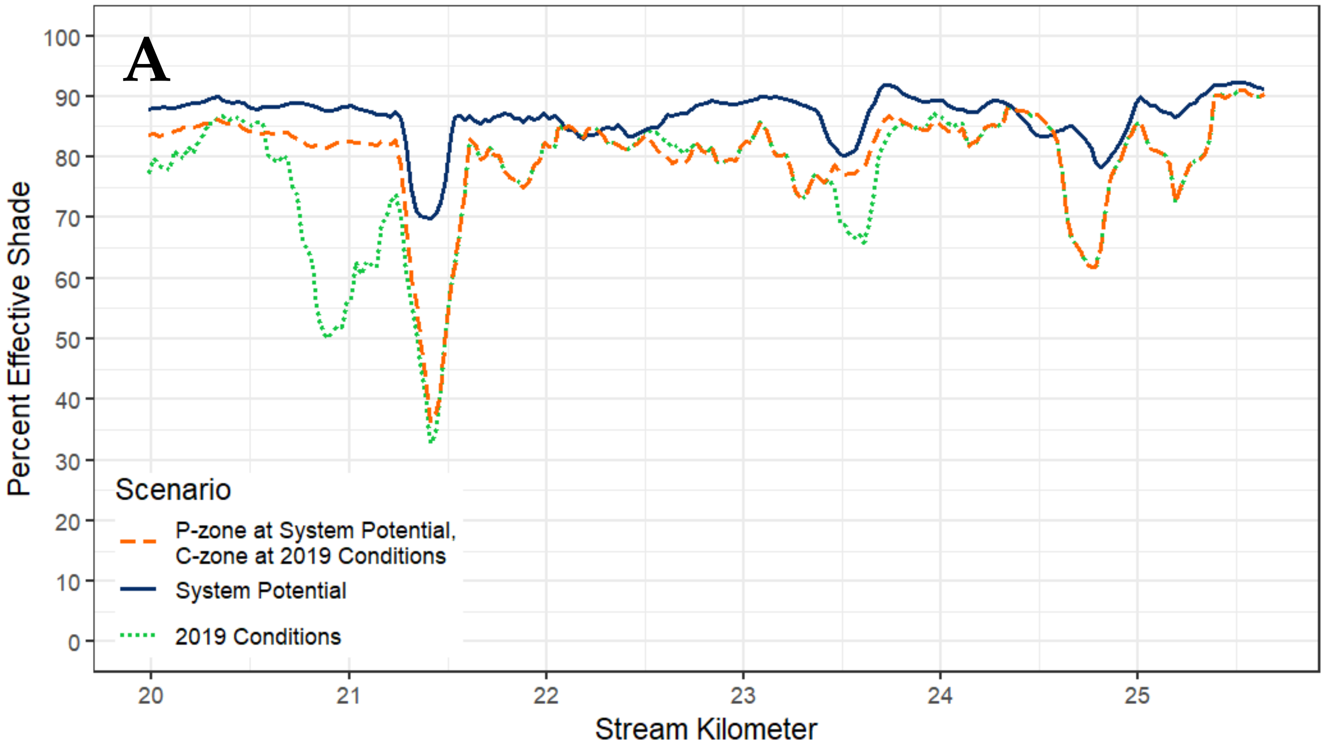
* TCNA: Tryon Creek Natural Area

4.4 *Fanno Creek*

The environmental overlays around the mainstem of Fanno Creek are currently primarily composed of c-zones. These riparian areas currently provide a substantial proportion of the effective shade to the mainstem. The loss of existing riparian canopy would reduce the mainstem shade by over 40% (Table 12). Other smaller streams in the watershed, such as Pendleton and Restoration creeks, are also largely covered by c-zones, showing a similar result to the Fanno mainstem.

Table 12. Mean effective shade results for the environmental overlay zone model scenarios for the mainstem of Fanno Creek and its tributaries. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	Mean Effective Shade (%)				Shade Reduction (%)	
	2019	System Potential in Management Areas	System Potential in P-Zones + 2019 Canopy in C-Zones	System Potential in P-Zones + No Canopy in C-Zones	2019 Canopy in C-Zones	No Canopy in C-Zones
Fanno Creek	77.7	81.7	80.5	45.1	-1.3	-44.2
Ash Creek	72.8	79.3	78.9	72.5	-0.6	-8.3
Ash Creek SF	80.1	84.3	84.0	80.3	-0.3	-4.9
Columbia Creek	84.3	86.5	84.8	68.0	-2.1	-22.4
Ivey Creek	82.6	85.5	84.5	61.6	-1.4	-27.5
Lowell Creek	87.4	88.6	87.7	76.7	-1.2	-14.3
Pendleton Creek	77.3	82.8	80.4	49.3	-2.9	-41.8
Restoration Creek	74.5	73.7	73.6	33.7	-0.3	-47.3
Sylvan Creek	75.9	84.5	84.4	84.0	-0.1	-0.6
Vermont Creek	77.1	83.1	82.1	76.4	-1.2	-7.5
Woods Creek	80.5	86.0	85.4	81.4	-0.6	-5.2



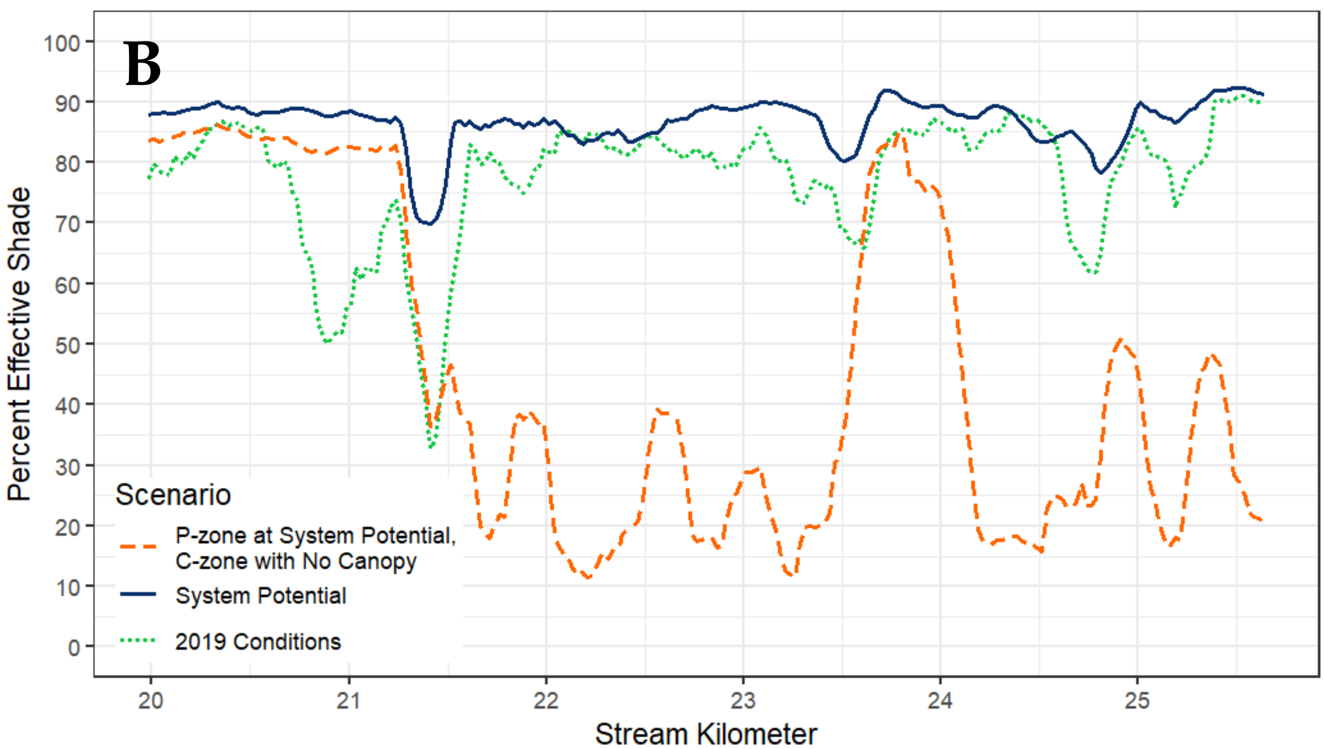


Figure 9. Mainstem Fanno Creek effective shade scenarios for 2019, system potential, and the environmental overlay scenarios with p-zone at system potential and (A) c-zone with 2019 canopy conditions and (B) c-zone with no canopy. Results are presented as 200 meter rolling averages centered on the reporting node. Results are presented for the mainstem of Fanno Creek from the confluence of Vermont Creek to SW 25th Ave. See Table 3 for scenario definitions.

4.5 *Westside Willamette Streams*

The majority of the small westside streams are located in Forest Park. As such, the environmental overlays covering these riparian areas are almost exclusively p-zones. Outside of Forest Park, the c-zones cover a greater proportion of the riparian areas of streams like Stephens Creek. In the case of Stephens Creek, the riparian vegetation within the existing c-zones contributes to approximately 15% of the system potential shade along the stream.

Table 13. Mean effective shade results for the environmental overlay zone model scenarios for the streams and their tributaries on the westside that flow directly to the Willamette River. Effective shade values represent July–August means. See Table 3 for scenario definitions.

Stream	Mean Effective Shade (%)				Shade Reduction (%)	
	2019	System Potential in Management Areas	System Potential in P-Zones + 2019 Canopy in C-Zones	System Potential in P-Zones + No Canopy in C-Zones	2019 Canopy in C-Zones	No Canopy in C-Zones
Balch Creek	89.9	92.9	92.9	92.9	0.0	0.0
Doane Creek	92.4	93.6	93.5	92.9	0.0	-0.7
Doane Creek Tribs	76.9	79.4	77.8	70.7	-2.3	-10.6
Linnton Creek NF	92.3	95.1	95.1	95.1	0.0	0.0
Linnton Creek SF	94.6	95.8	95.8	95.8	0.0	0.0
Miller Creek	89.5	92.7	92.4	92.4	-0.3	-0.4
Miller Creek Trib	93.7	95.1	95.1	95.1	0.0	0.0
Munger Creek	93.4	95.2	95.2	95.2	0.0	0.0
Munger Creek Trib	93.6	94.7	94.6	94.1	-0.1	-0.6
Newton Creek	82.8	84.9	84.9	83.9	-0.1	-1.2
River View Streams	86.8	88.5	88.1	82.7	-0.5	-6.4
Rocking Chair Creek	92.2	93.8	93.8	93.8	0.0	0.0
Rocking Chair Creek NF	94.8	96.0	96.0	96.0	0.0	0.0
Saltzman Creek	74.4	76.3	76.2	75.6	-0.1	-0.7
Stephens Creek	73.2	78.6	75.1	65.6	-4.2	-15.4
Stephens Creek Trib	85.7	87.3	85.9	81.0	-2.3	-7.8

5 Summary

The streams west of the Willamette River were found to have higher amount of modeled effective shade than those east of the Willamette. The size of the waterbodies plays a role in this difference—the Columbia Slough and Johnson Creek are wider waterways which limits the extent to which riparian vegetation can shade the stream channel. System potential on these wider channels is lower—across both watersheds the mean effective shade under the maximum system potential scenario is approximately 70% compared to 90% for streams on the westside.

While the wider stream channels do limit the possible shade, it is not the only explanation of the difference in effective shade between the two areas. Generally, there is more riparian canopy present along the streams west of the Willamette River. This is evident when comparing how far the results from the 2019 effective shade scenario are from system potential. West of the Willamette, the 2019 riparian canopy is achieving over 90% of system potential. In comparison, for streams east of the Willamette, the 2019 conditions are achieving only 73% of system potential.

Across all of the modeled streams, the results from the scenarios looking at canopy conditions in 2007, 2014, and 2019 indicate that the streams in the Portland area are gaining riparian shade—no substantial reach-wide losses in effective shade were identified. Small reductions in effective shade were noted in certain locations. For example, within the Luther Road project area (located along Johnson Creek near SE 73rd Ave and Luther Road), riparian vegetation was removed as part of the restoration work conducted in 2014 and 2019. The project represents a short-term loss in riparian canopy while the newly planted vegetation takes time to mature.

The Kelley Creek confluence project (located at the confluence of Kelley and Johnson creeks) provides a good example of how quickly riparian shade can be restored along a smaller stream. The restoration project was completed in 2005 and included re-meandering the stream channel to a historic location. All vegetation along the new channel was newly installed after construction was completed. Conditions in 2007 reflect the minimal riparian canopy present at the site with the newly planted vegetation producing only 16% effective shade in 2007. By 2014, the vegetation had grown enough such that the site's mean effective shade had increased to 83%, and to 85% effective shade in 2019, which is within a few percent of system potential at the site.

The changes in the Columbia Slough watershed highlight the importance and effectiveness of the City's revegetation work along the Slough. The bureau's Revegetation Program began in 1995 in the Columbia Slough Watershed planting streamside trees throughout the watershed. Aerial imagery from the late-1990s shows minimal riparian vegetation present along many of the channels in the Slough. The beneficial impact of the bureau and its partners continued planting and stewardship of riparian vegetation can be seen in the steady improvements in effective shade throughout the watershed.

The observed improvements in riparian shade emphasize the importance of retaining riparian vegetation and allowing it to grow to maturity. Environmental zoning and restrictions on riparian disturbances appear to have limited the loss of riparian canopy since 2007 across the study area. The benefit to the stream in term of effective shade can be seen when comparing the results from the different system potential scenarios. Under the scenarios representing system potential within management areas (where canopy conditions within management areas are assumed to reach maturity, but assumed to remain the same as 2019 conditions outside of these areas), the modeled potential effective shade was found to be slightly lower, but still within a few percent of the maximum system potential scenario (mature canopy conditions everywhere). That is, if the riparian canopy within these management areas is maintained and allowed to mature, the future riparian canopy will provide close to the greatest possible effective shade to the stream. The modeling also results emphasize that in Portland, the riparian vegetation protected by both environmental overlay zones contributes substantially to shading the streams.

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Appendix A: Canopy Cover Measurements

Project	Sample Point	Sample Date	Canopy Cover (%)	Coordinates
Brunkow	Cc1_2020	10/1/2020	83.5	45.481581, -122.493047
Brunkow	Cc2_2020	10/1/2020	36.5	45.481970, -122.492489
Brunkow	CC3_2020	10/1/2020	82.0	45.482316, -122.491921
Luther Rd. Repair	CC2	8/27/2020	0.0	45.458372, -122.587833
Luther Rd. Repair	CC4	9/3/2020	0.0	45.458803, -122.585433
Oxbow Phase II	Bypass cc3	8/4/2020	88.0	45.462471, -122.618211
Oxbow Phase II	cc_sub	7/30/2020	27.0	45.463254, -122.617920
Oxbow Phase II	Cc4_2020	7/30/2020	56.0	45.464086, -122.618086
PAWMAP	P0012	8/16/2018	92.5	45.468831, -122.679336
PAWMAP	P0016	6/24/2019	98.5	45.466684, -122.481781
PAWMAP	P0058	8/21/2018	97.0	45.461908, -122.725529
PAWMAP	P0060	9/27/2018	98.5	45.464306, -122.559901
PAWMAP	P0078	7/3/2018	92.5	45.541688, -122.750016
PAWMAP	P0124	9/19/2018	65.0	45.475543, -122.515614
PAWMAP	P0129	7/31/2018	12.0	45.557441, -122.508147
PAWMAP	P0137	9/4/2018	95.5	45.550354, -122.756821
PAWMAP	P0144	7/24/2018	98.5	45.429271, -122.676874
PAWMAP	P0153	8/20/2019	97.0	45.568189, -122.768583
PAWMAP	P0185	8/13/2019	95.5	45.591922, -122.792416
PAWMAP	P0208	7/10/2018	82.0	45.444613, -122.683359
PAWMAP	P0250	7/23/2018	98.5	45.532319, -122.716678
PAWMAP	P0272	9/5/2018	24.0	45.486646, -122.481899
PAWMAP	P0297	7/29/2019	100.0	45.587175, -122.797750
PAWMAP	P0298	8/28/2018	98.5	45.535867, -122.783413
PAWMAP	P0313	7/1/2020	95.5	45.604061, -122.811966
PAWMAP	P0314	9/10/2018	98.5	45.483097, -122.712615
PAWMAP	P0337	9/30/2020	0.0	45.586373, -122.670805
PAWMAP	P0352	9/11/2018	50.0	45.455848, -122.603152
PAWMAP	P0380	7/23/2019	100.0	45.470614, -122.529716
PAWMAP	P0444	8/1/2019	16.5	45.488193, -122.463728
PAWMAP	P0464	9/16/2019	89.5	45.461733, -122.689420
PAWMAP	P0498	8/29/2019	98.5	45.448503, -122.730792
PAWMAP	P0513	10/2/2019	65.5	45.563579, -122.537784
PAWMAP	P0524	7/17/2018	80.5	45.468823, -122.670229
PAWMAP	P0526	7/9/2019	100.0	45.537531, -122.739525
PAWMAP	P0544	8/7/2019	30.5	45.458222, -122.642001
PAWMAP	P0554	8/27/2019	95.5	45.536832, -122.777025

Project	Sample Point	Sample Date	Canopy Cover (%)	Coordinates
PAWMAP	P0592	10/1/2019	100.0	45.436542, -122.675387
PAWMAP	P0633	8/14/2019	82.0	45.607094, -122.796643
PAWMAP	P0705	9/19/2019	29.0	45.578852, -122.617189
PAWMAP	P0720	7/18/2019	95.5	45.453423, -122.668508
PAWMAP	P0746	9/24/2019	95.5	45.489287, -122.719557
PAWMAP	P0754	9/4/2019	97.0	45.456470, -122.708394
PAWMAP	P0762	7/17/2019	86.5	45.527765, -122.725957
PAWMAP	P0800	7/21/2020	95.5	45.453442, -122.662653
PAWMAP	P0828	10/7/2019	89.5	45.471003, -122.525190
PAWMAP	P0892	7/30/2019	18.0	45.474182, -122.559758
PAWMAP	P0940	7/15/2020	100.0	45.463090, -122.528831
PAWMAP	P1010	7/31/2020	100.0	45.444324, -122.713304
PAWMAP	P1020	8/6/2019	97.0	45.477216, -122.499041
PAWMAP	P1102	7/28/2020	91.0	45.538187, -122.762109
PAWMAP	P1130	7/9/2020	92.5	45.538561, -122.782940
PAWMAP	P1148	8/23/2021	94.0	45.467592, -122.530931
PAWMAP	P1184	8/18/2020	76.0	45.462983, -122.636416
PAWMAP	P1194	9/30/2021	97.0	45.497063, -122.738882
PAWMAP	P1473	10/1/2020	24.0	45.577503, -122.620142
PAWMAP	P1593	8/13/2020	98.5	45.612211, -122.812364
PAWMAP	P1612	8/19/2021	22.5	45.463385, -122.617889
PAWMAP	P1616	9/15/2021	95.5	45.439227, -122.671563
PAWMAP	P1744	9/2/2021	100.0	45.459530, -122.671366
PAWMAP	P1769	7/27/2021	100.0	45.616890, -122.808750
PAWMAP	P1770	9/29/2020	94.0	45.492050, -122.718789
PAWMAP	P1778	10/12/2021	98.5	45.455481, -122.721983
PAWMAP	P1834	7/8/2021	100.0	45.540177, -122.777702
PAWMAP	P1872	7/7/2020	91.0	45.429589, -122.674861
PAWMAP	P1916	8/4/2020	88.0	45.465717, -122.562163
PAWMAP	P1936	8/26/2021	83.5	45.448595, -122.686744
PAWMAP	P2185	7/20/2021	98.5	45.556943, -122.751266
PAWMAP	P2208	8/5/2021	82.0	45.458937, -122.612571
PAWMAP	P2290	10/7/2021	92.5	45.448437, -122.742861
PAWMAP	P2320	7/22/2021	76.0	45.482536, -122.491601
PAWMAP	P2362	8/26/2020	100.0	45.473566, -122.726399
PAWMAP	P2384	9/3/2020	100.0	45.434906, -122.680302
PAWMAP	P2512	9/22/2020	92.5	45.455235, -122.693936
PAWMAP	P2524	8/10/2021	98.5	45.459051, -122.499942
SW 45th Culvert Replacement	Cc1_2020	10/12/2020	98.5	45.486768, -122.722873
SW 45th Culvert Replacement	Cc4_2020	10/12/2020	70.0	45.487013, -122.723386

Project	Sample Point	Sample Date	Canopy Cover (%)	Coordinates
SW Boones Ferry Rd. Culvert Replacement	Cc4	10/21/2020	76.0	45.447322, -122.687389
SW Boones Ferry Rd. Culvert Replacement	TC CC 1	10/21/2020	79.0	45.446758, -122.686517
West Lents	Wl_cc2_2020	8/6/2020	24.0	45.464041, -122.578341
West Lents	WL_cc3_2020	8/6/2020	62.0	45.464639, -122.577851
West Lents	WL_cc4_2020	8/6/2020	7.5	45.465123, -122.577232
West Lents	WL_cc5_2020	8/6/2020	98.5	45.465386, -122.576296
West Lents	Wl_cc6_2020	8/6/2020	77.5	45.465561, -122.575307
West Lents	Wl_cc7_2020	8/6/2020	88.0	45.465788, -122.574399

Appendix B: Model Nodes

Model Group	Watershed	Stream Reach ID	Modeled Length (km)	Model Nodes
East	Johnson Creek	Badger Creek_1	3.9	0–156
		Butler Creek_1	2.65	157–263
		Clatsop Creek_1	2.275	264–355
		CrystalSpringsCreek_1	0.45	3101–3119
		CrystalSpringsCreek_2	1.55	3120–3182
		CrystalSpringsCreek_3	1.175	3183–3230
		CrystalSpringsCreek_4	0.6	356–380
		DeardorffCreek_1	1.225	381–430
		DeardorffCreek_2	0.45	5369–5387
		Errol Creek_1	0.575	431–454
		Frog Creek_1	1.475	455–514
		Indian Creek_1	1.525	515–576
		Jenne Creek_1	1.95	577–655
		JohnsonCreek_01	1.125	2192–2237
		JohnsonCreek_02	0.85	2238–2272
		JohnsonCreek_03	0.4	2273–2289
		JohnsonCreek_04	0.625	2290–2315
		JohnsonCreek_05	0.875	2316–2351
		JohnsonCreek_06	0.575	2352–2375
		JohnsonCreek_07	0.35	2376–2390
		JohnsonCreek_07a	0.125	4515–4520
		JohnsonCreek_08	1.1	2391–2435
		JohnsonCreek_09	0.95	2436–2474
		JohnsonCreek_10	0.55	2475–2497
		JohnsonCreek_11	1.15	2498–2544
		JohnsonCreek_12	0.5	2545–2565
		JohnsonCreek_13	0.775	2566–2597
		JohnsonCreek_14	0.55	2598–2620
		JohnsonCreek_15	0.675	2621–2648
		JohnsonCreek_16	1.675	2649–2716
		JohnsonCreek_17	1.6	2717–2781
		JohnsonCreek_18	1.075	2782–2825
		JohnsonCreek_19	1.2	2826–2874
		JohnsonCreek_20	1.275	2875–2926
		JohnsonCreek_21	1.075	2927–2970
		JohnsonCreek_22	0.825	4481–4514
		JohnsonCreek_23	0.325	5355–5368
		Johnson Creek_24	21.8	656–1528

Model Group	Watershed	Stream Reach ID	Modeled Length (km)	Model Nodes
		KelleyCreek_1	0.375	2971–2986
		KelleyCreek_2	1.1	2987–3031
		KelleyCreek_3	5.675	1529–1756
		MitchellCreek_1	1.025	3032–3073
		MitchellCreek_2	0.65	3074–3100
		MitchellCreek_3	0.625	4455–4480
		MitchellCreek_4	0.675	1757–1784
		Sunshine Creek_1	6.7	1785–2053
		VeteransCreek_1	2.125	2054–2139
		WahooCreek_1	0.075	5452–5455
		WahooCreek_2	0.35	5437–5451
		WahooCreek_3	0.575	5413–5436
		WahooCreekTrib1_1	0.6	5388–5412
		WahooCreekTrib2_1	1.275	2140–2191
	Columbia Slough	BlindSlough_1	0.5	3231–3251
		Buffalo Slough_1	1.525	3252–3313
		LowerSlough_1a	2.75	4521–4631
		LowerSlough_1b	2.45	4682–4780
		LowerSlough_1e	2.675	4781–4888
		LowerSlough_1f	2.125	4889–4974
		LowerSlough_1g	3.775	3364–3515
		LowerSloughSideChannel_1e	1.075	3516–3559
		MiddleSlough_3a	2.45	4356–4454
		MiddleSlough_3b	1.65	5288–5354
		MiddleSlough_4a	2.025	5179–5260
		MiddleSlough_4b	4.4	3560–3736
		MiddleSlough_4c	0.65	5261–5287
		NorthSlough_1	0.975	3759–3798
		NorthSlough_2	0.425	4632–4649
		UpperSlough_6a	2.3	5060–5152
		UpperSlough_6b	2.25	3956–4046
		WapatoWetland_1	0.775	4650–4681
		WapatoWetland_2	0.925	4047–4084
		Warren Slough_1	1.1	4085–4129
		WhitakerSlough_1	1.975	4975–5054
		WhitakerSlough_2	3.525	4130–4271
		Wilkes Creek Trib_1	0.475	4336–4355
		Wilkes Creek_1	1.575	4272–4335
West	Tryon Creek	ArnoldCreek_1	0.7	4364–4392
		ArnoldCreek_2	1.725	3451–3520
		ArnoldCreek_3	0.85	4393–4427

Model Group	Watershed	Stream Reach ID	Modeled Length (km)	Model Nodes
		FallingCreek_1	0.725	4290–4319
		FallingCreek_2	0.65	4320–4346
		FallingCreek_4	0.575	3521–3544
		Nettle Creek_1	2.625	3545–3650
		ParkCreek_1	1.15	3651–3697
		TryonCreek_1	0.45	3989–4007
		TryonCreek_2	1.375	4008–4063
		TryonCreek_3	1.275	4064–4115
		TryonCreek_4	1.55	4116–4178
		TryonCreek_5	1.375	4179–4234
		TryonCreek_6	0.775	4235–4266
		TryonCreek_7	0.55	4267–4289
		TryonCreekTrib1_1	0.35	3729–3743
		TryonCreekTrib2_1	0.275	4804–4815
		TryonCreekTrib2_2	0.6	3744–3768
		TryonCreekTrib4_1	0.65	3814–3840
		TryonCreekTrib5_1	0.7	3841–3869
		TryonCreekTrib5_2	0.3	4784–4796
		TryonCreekTrib5TribA_1	0.175	3870–3877
		TryonCreekTrib5TribA_2	0.075	4800–4803
		TryonCreekTrib6_1	0.4	3878–3894
		TryonCreekTrib6_2	0.05	4797–4799
		TryonCreekTrib7_1	1.05	3895–3937
		TryonCreekTrib8_1	0.575	3938–3961
		TryonCreekTrib8TribA_1	0.35	3962–3976
		TryonCreekTrib8TribB_1	0.275	3977–3988
	Fanno Creek	AshCreek-SouthFork_1	2.025	99–180
		AshCreek-SouthFork_2	0.475	1941–1960
		AshCreek-SouthFork_3	0.75	1741–1771
		AshCreek_0	2.45	0–98
		AshCreek_1	1.75	4485–4555
		AshCreek_2	1.225	1891–1940
		AshCreek_3	1.05	1772–1814
		Columbia Creek Trib A_1	1	325–365
		Columbia Creek Trib_1	1.625	259–324
		Columbia Creek_1	1.925	181–258
		FannoCreek_1	1.4	4428–4484
		FannoCreek_2	1.025	2180–2221
		FannoCreek_3	1.175	2132–2179
		FannoCreek_4	0.55	2109–2131
		FannoCreek_5	0.975	2069–2108

Model Group	Watershed	Stream Reach ID	Modeled Length (km)	Model Nodes
		FannoCreek_6	0.575	2045–2068
		Ivey Creek Trib_1	0.6	1277–1301
		Ivey Creek_1	1.925	1199–1276
		Lowell Creek_1	2.225	1302–1391
		Pendleton Creek_1	1.775	1392–1463
		Restoration Creek_1	0.625	1464–1489
		Sylvan Creek Trib_1	0.425	1671–1688
		Sylvan Creek_1	4.5	1490–1670
		VermontCreek_1	0.7	2016–2044
		VermontCreek_2	1.275	1689–1740
		VermontCreek_3	1.35	1961–2015
		WoodsCreek_0	1.125	1845–1890
		WoodsCreek_1	0.975	4629–4668
		WoodsCreek_2	1.8	4556–4628
		WoodsCreek_3	0.725	1815–1844
	Westside Willamette Streams	BalchCanyon_1	2.1	3187–3271
		BalchCanyon_2	1.225	3272–3321
		BalchCanyon_3	1.55	2222–2284
		DoaneCreek_0	1.2	5069–5117
		DoaneCreek_1	1	4856–4896
		DoaneCreek_2	0.525	4897–4918
		DoaneCreek_3	1.075	2366–2409
		DoaneCreekTrib1_1	0.55	2343–2365
		DoaneCreekTrib1_2	0.3	4919–4931
		DoaneCreekTrib2_1	0.5	4932–4952
		DoaneCreekTrib2_2	1.075	2299–2342
		DoaneCreekTrib3_1	1.35	2410–2464
		LinntonCreek_0	0.3	5026–5038
		LinntonCreekNF_1	0.9	2531–2567
		LinntonCreekSF_1	0.15	4849–4855
		LinntonCreekSF_2	1.75	2568–2638
		MillerCreek_0	0.325	5055–5068
		MillerCreek_1	1.45	2639–2697
		MillerCreek_2	1.275	3322–3373
		MillerCreekTrib_1	1.575	2698–2761
		MungerCreek_1	0.975	2762–2801
		MungerCreek_2	0.35	4967–4981
		MungerCreekTrib_1	0.6	2802–2826
		NewtonCreek_0	0.375	5039–5054
		NewtonCreek_1	0.8	4816–4848
		NewtonCreek_2	1.25	2827–2877

Model Group	Watershed	Stream Reach ID	Modeled Length (km)	Model Nodes
		RiverViewStream2_1	0.35	4769–4783
		RiverViewStream2_2	0.625	2878–2903
		RiverViewStream6_1	1	2904–2944
		RiverViewStream7_1	0.25	4749–4759
		RiverViewStream7_2	0.25	2945–2955
		RiverViewStream7_3	0.2	4760–4768
		RockingChairCreek_1	0.325	4982–4995
		RockingChairCreek_2	0.75	2998–3028
		RockingChairCreek_3	0.525	3044–3065
		RockingChairCreek_4	0.4	4996–5012
		RockingChairCreekNF_1	0.3	5013–5025
		RockingChairCreekNF_2	0.35	3029–3043
		SaltzmanCreek_0	0.825	5118–5151
		SaltzmanCreek_1	0.325	4953–4966
		SaltzmanCreek_2	1.5	3066–3126
		Stephens Creek I5 Trib_1	0.075	3183–3186
		StephensCreek_1	0.175	3408–3415
		StephensCreek_2	0.2	3399–3407
		StephensCreek_3	0.6	3374–3398
		StephensCreek_4	1.375	3127–3182
		StephensCreek_5	0.475	3416–3435
		StephensCreek_6	0.35	3436–3450
		StephensCreekTrib1_1	1.025	2956–2997

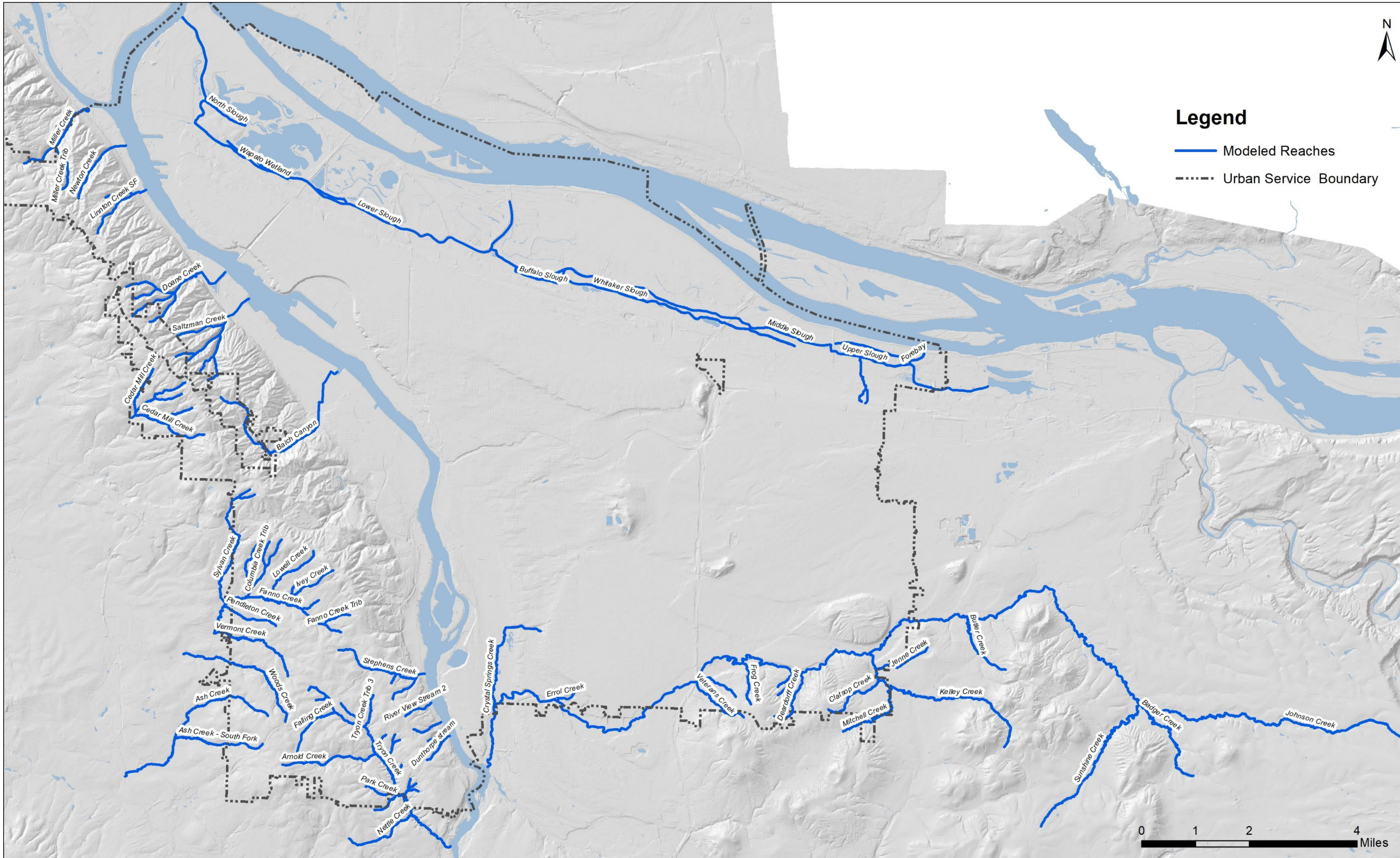

Figure 10. Stream reaches in the Portland area modeled for effective shade.