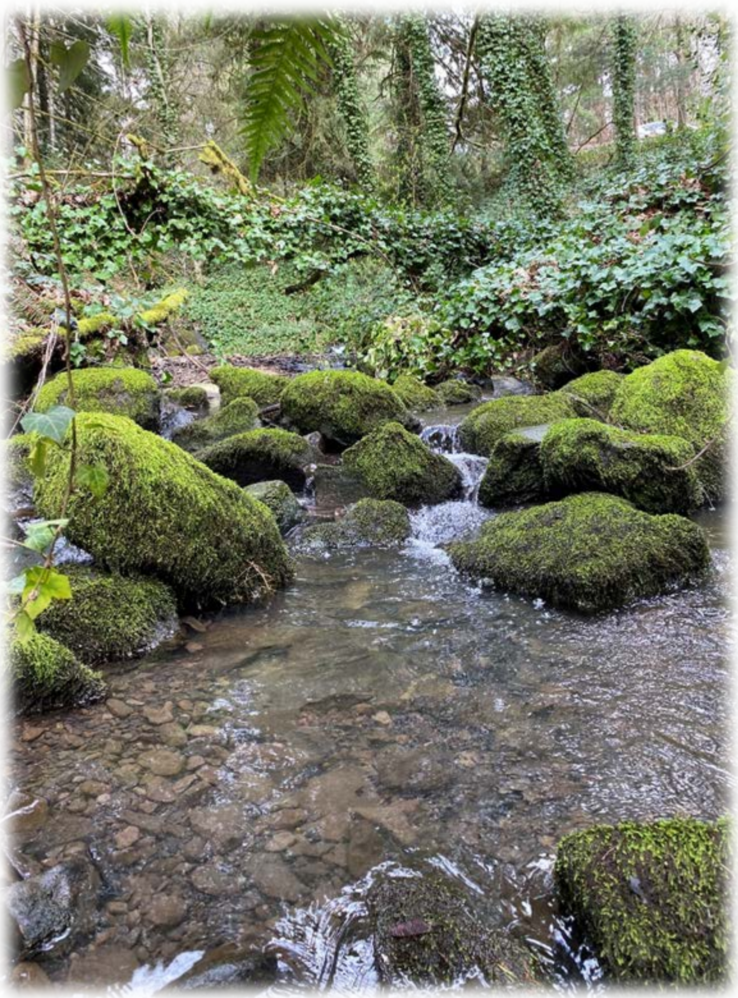
2021

Effective Shade Report



Credit: Ball Creek, Lake Oswego, OR (S. Johnson)

December, 2021

700 NE MULTNOMAH, SUITE 1000 | PORTLAND, OR 97232 | P 503.233.2400, 360.694.5020

EFFECTIVE STREAM SHADE IN LAKE OSWEGO

Background

Several factors contribute to elevated in-stream temperature; changes in watershed processes, channel morphology, climate, geographic location, riparian vegetation, dams, reservoirs, and point sources such as industrial wastewater (DEQ 2006). Elevated stream temperatures negatively impact salmonid species and have detrimental consequences to riparian habitat and watershed health. DEQ determined that increased solar radiation from disturbed or removed riparian vegetation is the largest contributor to elevated temperatures in small streams without a point source discharge.

To address the increased temperatures, the Oregon Department of Environmental Quality (DEQ) issued a temperature TMDL (total maximum daily load) which requires jurisdictions along the Willamette River to stabilize stream temperatures to 17.8°C for cool water habitat (rearing and migration) and to 13°C for essential salmonoid habitat (spawning). The City of Lake Oswego (City) uses a DEQ program called HeatSource to model effective shade and determine compliance with effective shade targets.

Effective Stream Shade and Shade Targets

The term “effective shade” is used because not all stream-adjacent vegetation is equally successful at cooling streams. Channel morphology and near-stream vegetation characteristics greatly influence effective stream shade and cooling. Stream width, orientation, and incision are all qualities of channel morphology that alter effective shade. Near-stream vegetation characteristics like canopy height, buffer width, density, and placement also play a critical role in shading streams. Figure 1 highlights how these conditions of channel morphology and near-stream vegetation can positively or adversely impact effective stream shade.

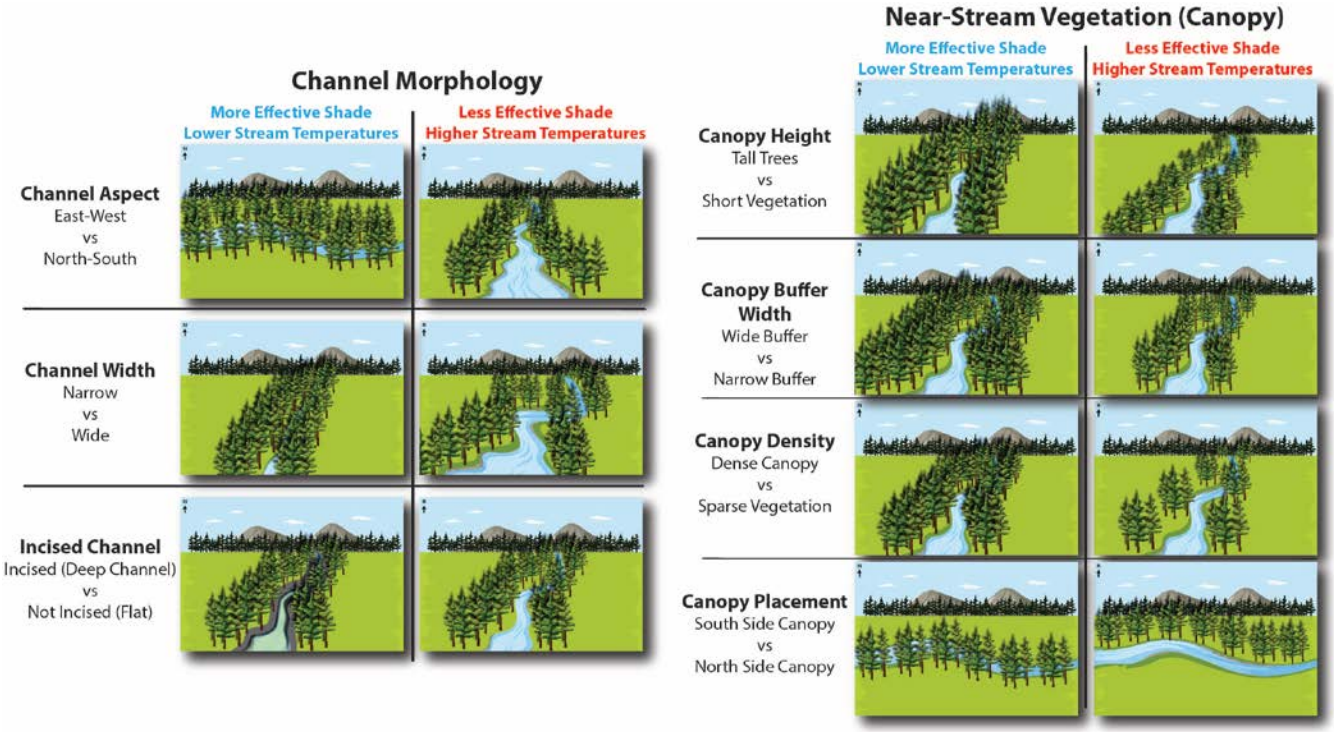


Figure 1. Channel morphology and near-stream vegetation influences on effective stream shade.

Effective shade targets are determined using shade curves on a region-specific basis. The shade curves, along with stream orientation and width, provide a target for percent effective shade and corresponding solar radiation loading (DEQ 2006). The effective shade target is interpreted by DEQ to represent the effect of historically prevalent riparian vegetation, referred to as "system potential", coupled with natural topography in blocking solar radiation loads. Shade is more effective at maintaining cold water temperatures on narrow streams than wide streams because canopy cover in the riparian zone of a narrow stream will cover a larger percentage of the stream's surface. Because of this correlation, DEQ has determined that the most effective method for managing stream temperature in the mainstems of the Willamette River and Tualatin River is by increasing shade on their tributaries. Since most tributaries to the Willamette River within the city boundaries are 20 feet wide or less, canopy cover in riparian areas is expected to be the most effective strategy for stabilizing or reducing stream temperatures.

DEQ (2001, 2006) estimated effective shade targets required to meet temperature load allocations using shade curves for 15 different ecoregions. The ecoregions within the City's jurisdiction include Prairie Terraces and the Willamette Foothills (see Figure 2). Land cover thought to be present in 1851 has been reconstructed through historical records by Christy et al. (2011) and maintained in GIS. Using these data, the distribution of forest coverage was calculated for riparian areas in the lower Willamette Basin (DEQ 2006), the Tualatin Basin (DEQ 2001, 2012), and the City of Lake Oswego as follows:

- Lower Willamette Watershed
  - 77.5% Forested (closed forests and woodland)
- Tualatin Watershed
  - 86.6% Forested
- Lake Oswego Watershed
  - 94.2% Forested

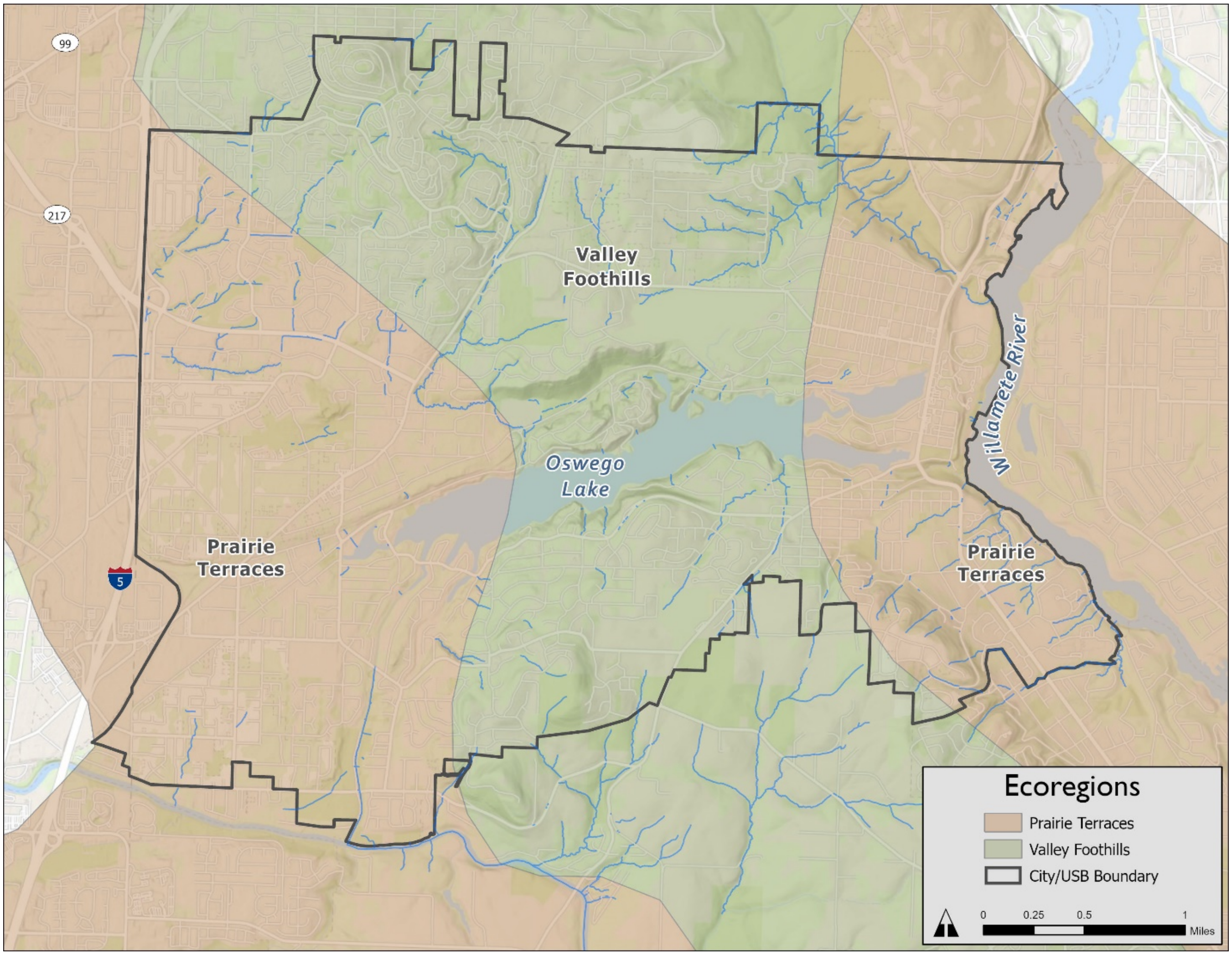


Figure 2. The Prairie Terraces and the Willamette Foothills ecoregions.

By knowing the width of the channel and its compass orientation, the curves in Figure 3 provide the "percent effective shade that each geomorphic unit tree composition provides to the stream based on the stream's channel width and stream aspect from north" (DEQ 2006).

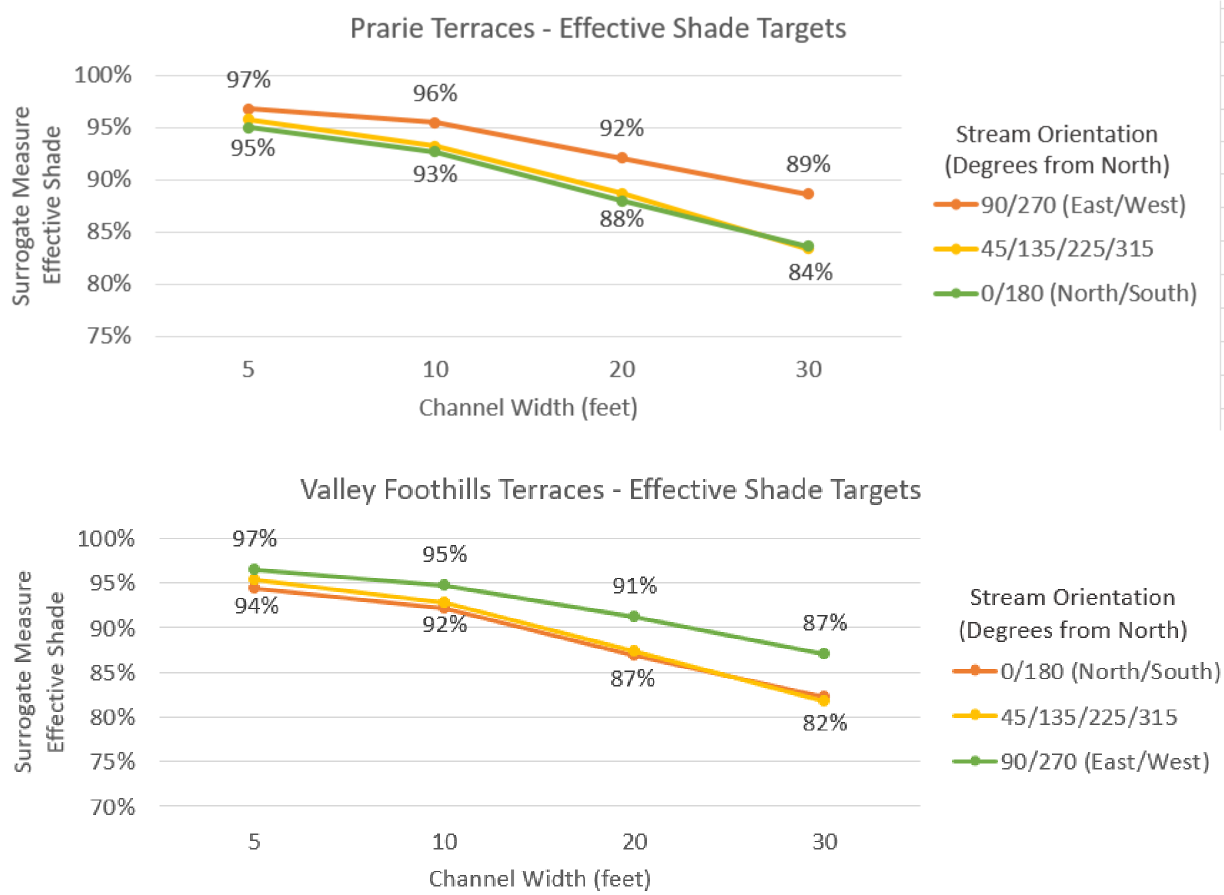


Figure 3. Ecoregions and associated effective shade curves applicable to the City of Lake Oswego.
(Source: Reformatted from DEQ 2006)

The effective shade targets determined by DEQ are intended to represent shade conditions that are the climax vegetation of a particular site, and it assumes that the best vegetation for a specific site will maximize the stream's water quality. A system's maximum potential represents a close equivalent to the vegetative conditions (though not necessarily plant species and distribution) experienced by early settlers before substantial land clearing.

Current Shade Conditions in Riparian Areas

Lake Oswego implements Metro's Title 3 and 13 requirements through its Sensitive Lands Overlay (LOC 50.05.010); primarily the Resource Protection (RP) and Resource Conservation (RC) districts. The resource protection districts allow for very limited disturbance of riparian habitat; the resource conservation districts create an additional buffer for habitat preservation on public and private open space tracts by limiting disturbance to 15% with the assumption that the protected area will be the portion closest to the stream. The City also implements Title 13 with a Habitat Benefit Areas (HBA) designation which is a voluntary, incentive-based program for private properties with upland habitat.

For modeling purposes, the riparian buffers in these other adjacent jurisdictions were assumed to be protected through Title 3 and provide localized shade to City streams:

- West Linn protections on Arbor Creek (along southeast jurisdictional boundary)

- Protections by City of Portland and adjacent unincorporated Multnomah County in the vicinity of Tryon Creek State Natural Area or PCC Sylvania (Multnomah County gave land use planning authority to Portland in this area)
- Protections by Clackamas County on riparian lands under Metro Title 3 (areas within the USB only)

The shade curve data was used to estimate the effective shade target for the Lake Oswego. Because Lake Oswego has limited data on channel widths, even with recent high resolution LiDAR data, streams were divided into width classes ranging from 5 to 30 feet. The City calculated the effective shade target for approximately 33 miles of streams and open channels, coupled with data on measures of estimated stream width and orientation. The calculations were made at about 8,400 nodes spaced 25-feet apart for all streams mapped within the city limits and urban services boundary (USB). Figure 4 shows the stream and open channel centerlines as well as the 2019 Lidar-derived canopy height model used in the effective shade analysis. A detailed description of the GIS Models and DEQ Tools used for the effective shade and canopy analysis are provided in the Effective Shade Technical Memo in Appendix A.

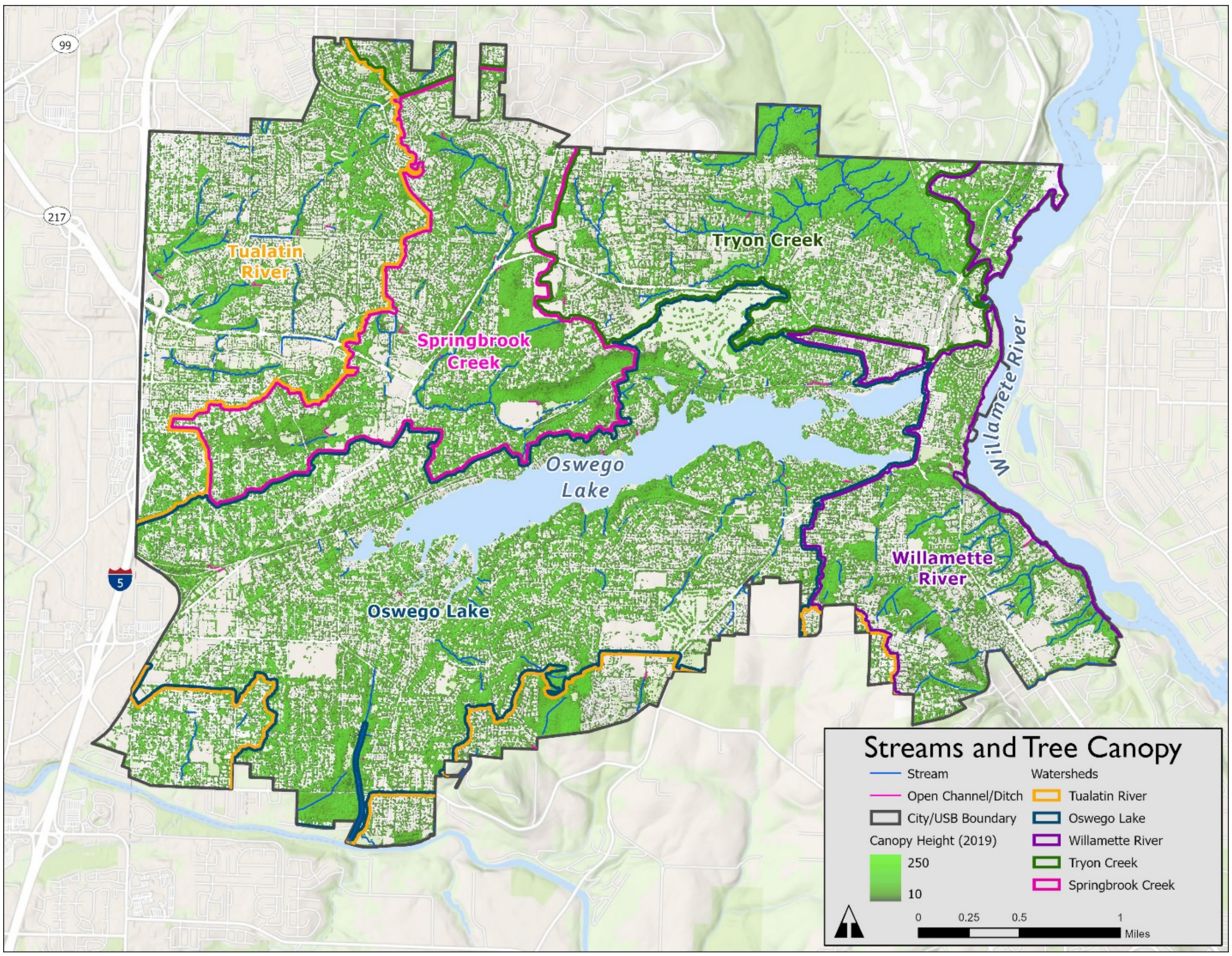


Figure 4. Streams and watershed boundaries displayed over the 2019 Canopy Height Model showing tree height between 10 and 250 feet.

The City modeled the effective shade for its canopy cover using the 2014 and 2019 LiDAR data and DEQ's HeatSource program. The analysis was done on two different canopy scenarios. The first scenario used the city-wide canopy, while the second scenario used only canopy within the City's Sensitive Lands to measure effective shade (Illustrated in Figure 5).

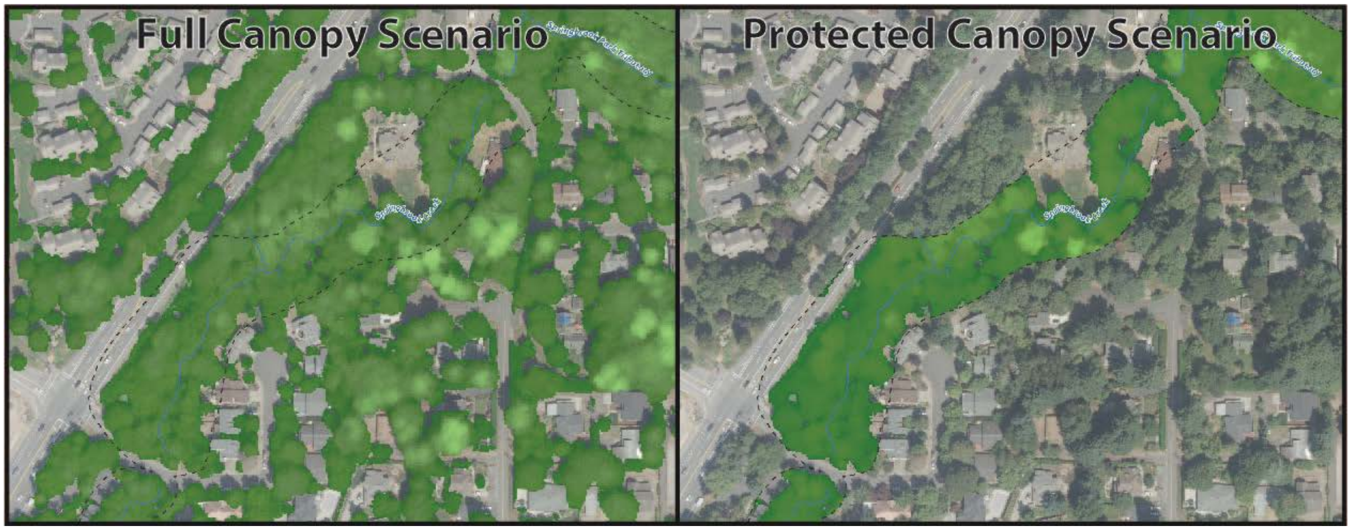


Figure 5. Full Canopy and Protected Canopy scenario example.

The analysis showed a city-wide average effective shade of 88.2% for 2014 and 88.6% for 2019. The effective shade results were charted and mapped at the watershed level (See Figure 6 chart and Figure 7 map). Effective shade targets were exceeded in the Tryon Creek watershed and nearly met in the Springbrook Creek watershed. The largest gap between current effective shade and the TMDL effective shade target (nearly 10%) was found in the Tualatin watershed; however it has shown an increase of 2% from 2014 to 2019.

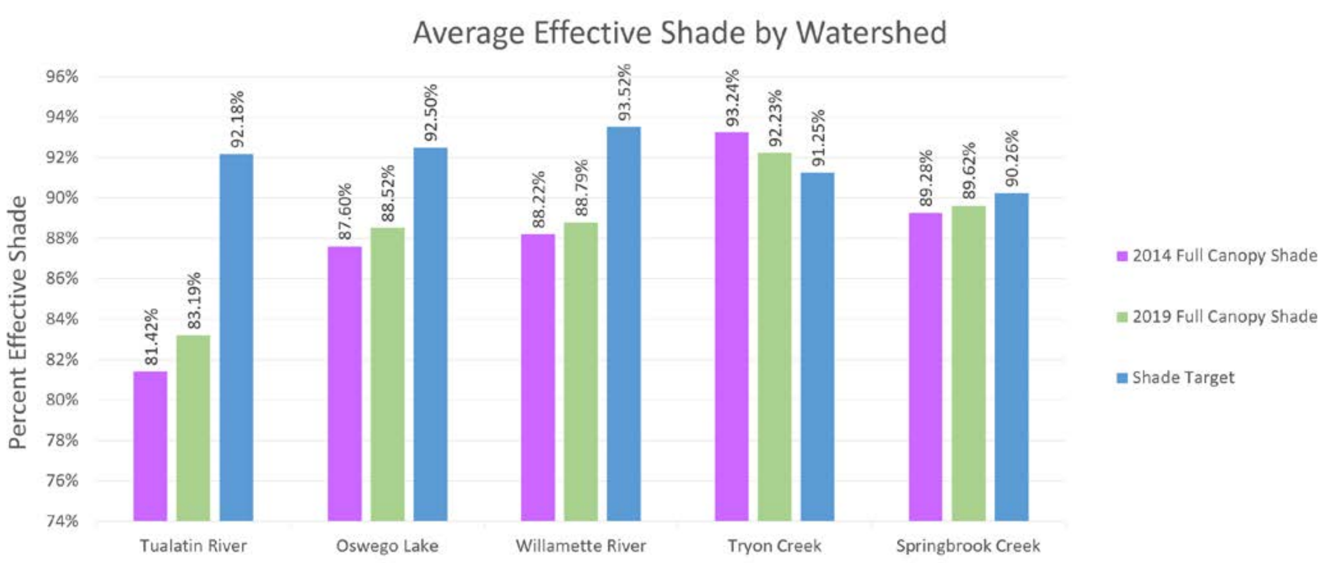


Figure 6. Full Canopy Scenario average effective stream shade by watershed for 2014 and 2019 compared to the shade targets established by DEQ.

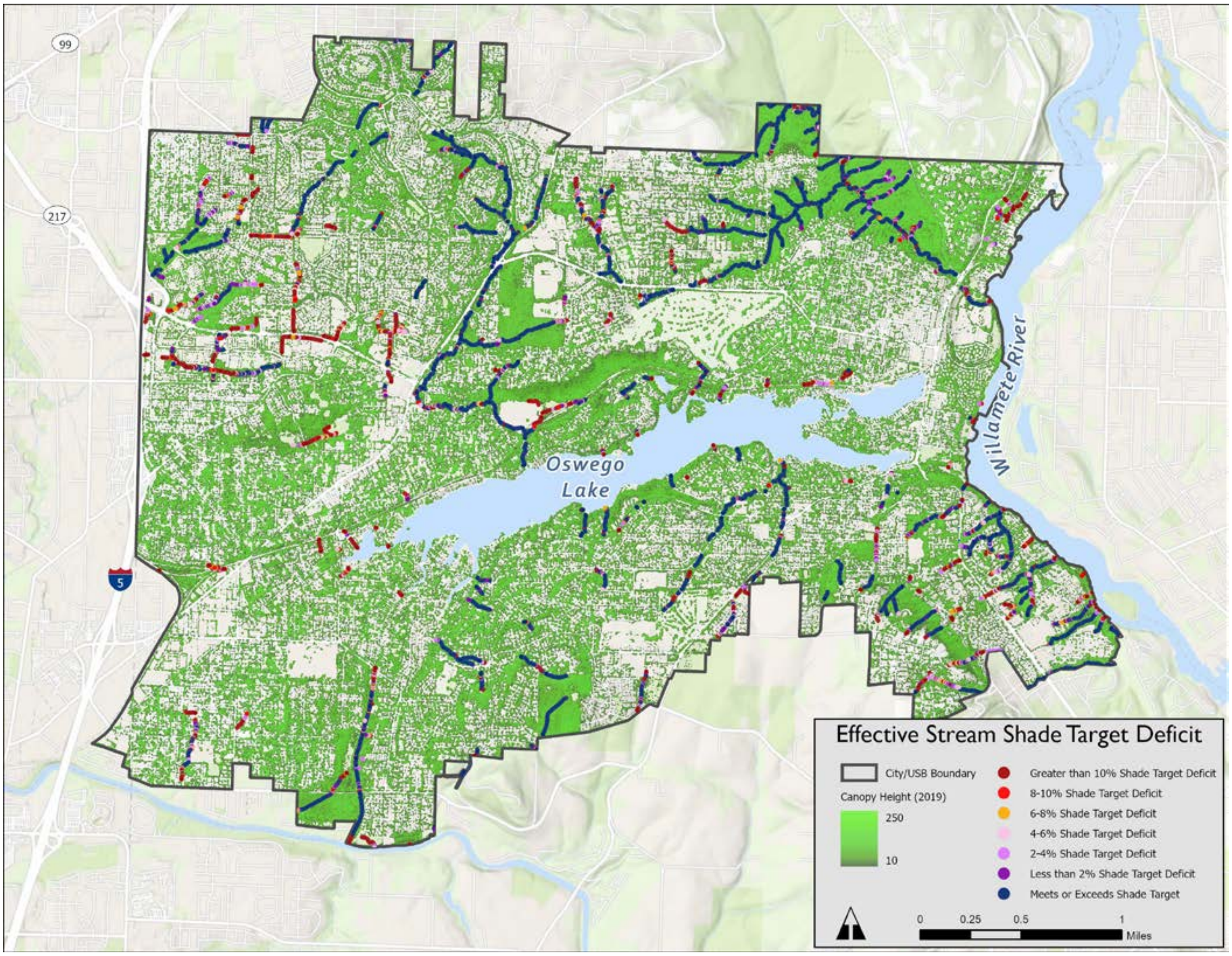


Figure 7. Effective Stream Shade Target Deficit for all streams and open channels city-wide based on the 2019 Full Canopy Scenario HeatSource results.

Sensitive Lands (Protected Canopy) Results

Effective shade was modeled for each watershed within the RP and RC districts of the Sensitive Lands Overlay. The analysis showed a slight increase of about 0.35% city-wide (83.11% to 83.46%) from 2014 to 2019 and a slight increase in each watershed except for Tryon Creek. Tryon Creek and Springbrook Creek already show that they have the greatest potential to meet shade targets based on shade provided by the protected tree canopy.

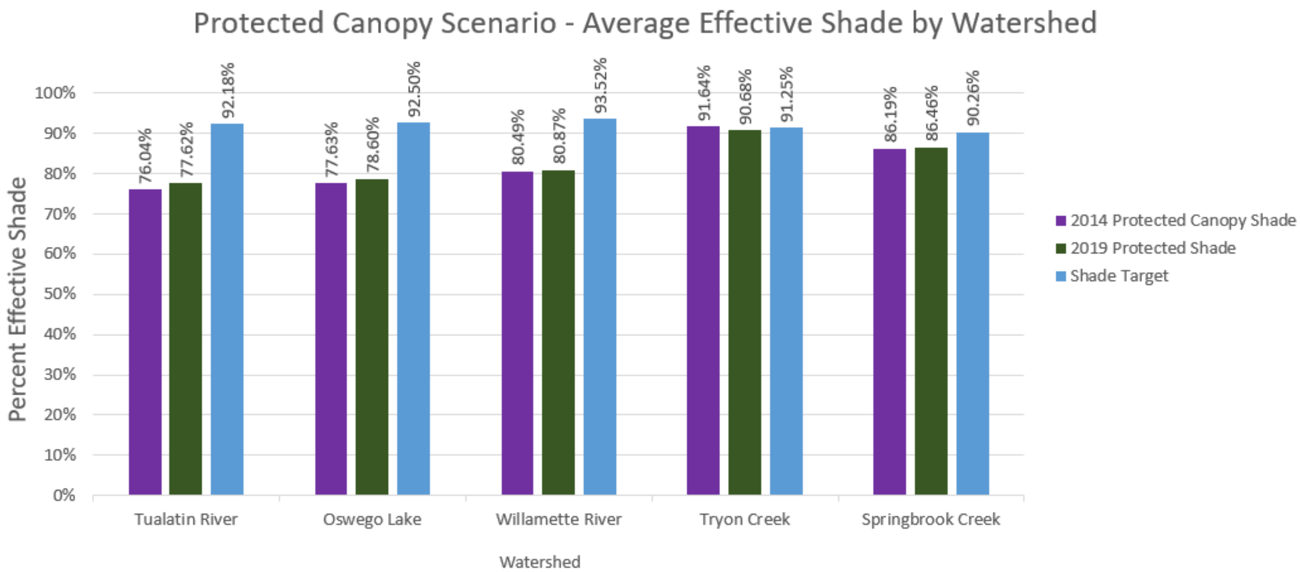


Figure 8. Protected Canopy Scenario average effective stream shade by watershed for 2014 and 2019 compared to the shade targets established by DEQ.

Comparison of Full Canopy vs Protected Canopy

City-wide, there is a difference of nearly 5% between the average Full Canopy Scenario effective ehade (88.6%) and the Protected Canopy Scenario effective shade (83.4%). The largest contributor to gaps between the shade targets and effective shade provided by sensitive lands buffers occurs on waterways that are classified by the city as open channels rather than streams. Open channels are historical streams that have been channelized through development and are not protected by the City's Sensitive Lands Program. Figure 9 demonstrates the difference between the Full Canopy Scenario and the Protected Canopy Scenario, highlighting the change in effective stream shade for an unprotected open channel segment. Open channels are not protected by riparian buffers, so the only shade that is counted in the protected canopy scenario for these channels is provided by the slopes of the stream bank. City-wide, 85% of the stream lengths met shade targets and only 49% of open channel lengths met shade targets.

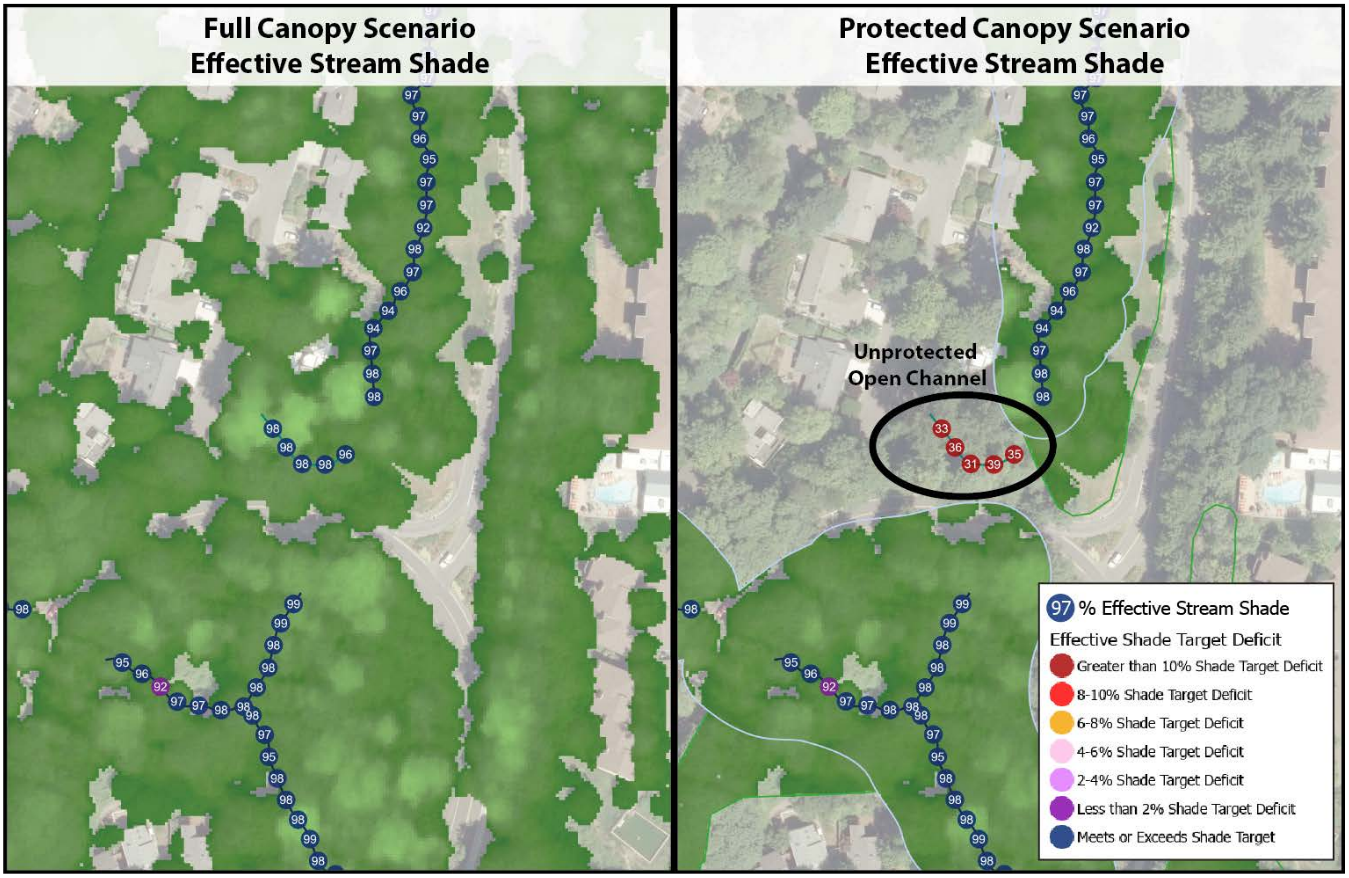


Figure 9. Full Canopy Scenario effective shade (left) and Protected Canopy Scenario effective shade surrounding an unprotected open channel.

City-Wide Canopy Change

In Figure 10, the bright green areas represent new canopy in the model. Most of the growth from 2014 to 2019 is attributed to horizontal growth of tree canopy. There are also existing trees that reached the minimum height of 10 feet to be included in the model. Orange areas in Figure 10 represent canopy loss or tree removal. Canopy loss occurs from hazard tree removal, weather related loss, permitted or unpermitted removal on residential lots, and new development. Mitigation is required for removals through a Type II application and in some other circumstances. The location shown in Figure 10 is representative of typical growth interspersed with small pockets of tree removal seen across the city. The model includes all types of trees including native, nonnative, and invasive species.

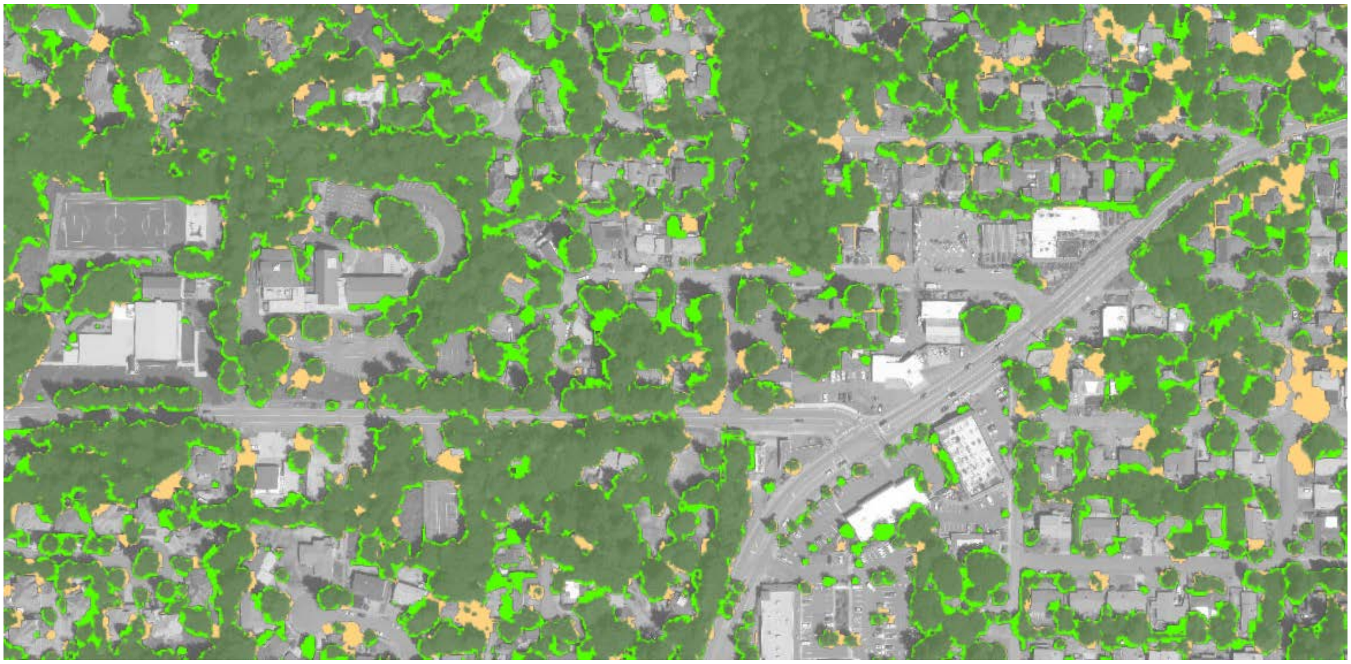


Figure 10. Canopy change from 2014 to 2019 city-wide as shown by the canopy growth (bright green) and canopy loss/removal (orange).

Development Effects

The data was analyzed to determine the effects of development on changes to tree canopy and effective shade from 2014 to 2019 (see Figure 11). Areas displayed as orange, indicating complete tree removal or canopy loss adjacent to stream corridors, are identified and the shade results are compared in the area for 2014 and 2019. The example area in Figure 11 shows an effective shade decrease of up to 23% within the protected riparian buffer due to tree removal. The dark blue outlines represent the sensitive lands program protected riparian buffers. Red points with negative values represent the effective shade percent loss from 2014 to 2019 and blue points with positive values represent the effective shade percent increase from 2014 to 2019.

It is important to note that mitigation is required for tree removal during development. Areas of mitigation following development have not been tracked closely and many restoration efforts involve planting trees that may not reach the minimum 10-foot height to be captured by the shade model until future analyses.

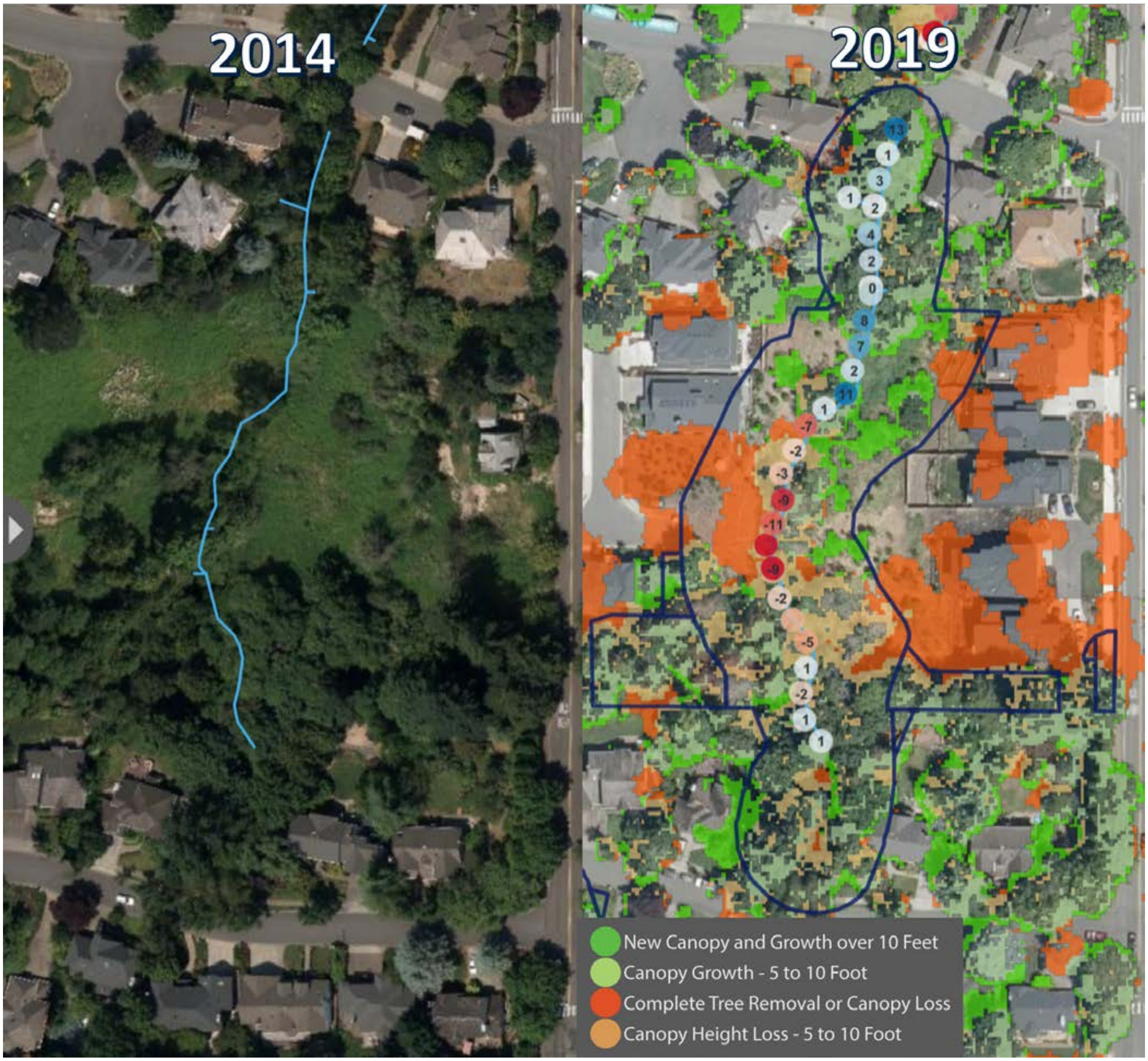


Figure 11. Effect of development on canopy cover and effective shade.

Tree Removal Effects

There are instances where removal of hazard trees with large canopies results in an outsized effect on canopy coverage. These hazard trees are generally either invasive species or safety concerns. Figure 12 shows the removal of a hazard tree that resulted in a shade decrease of 45% at that location along the stream.

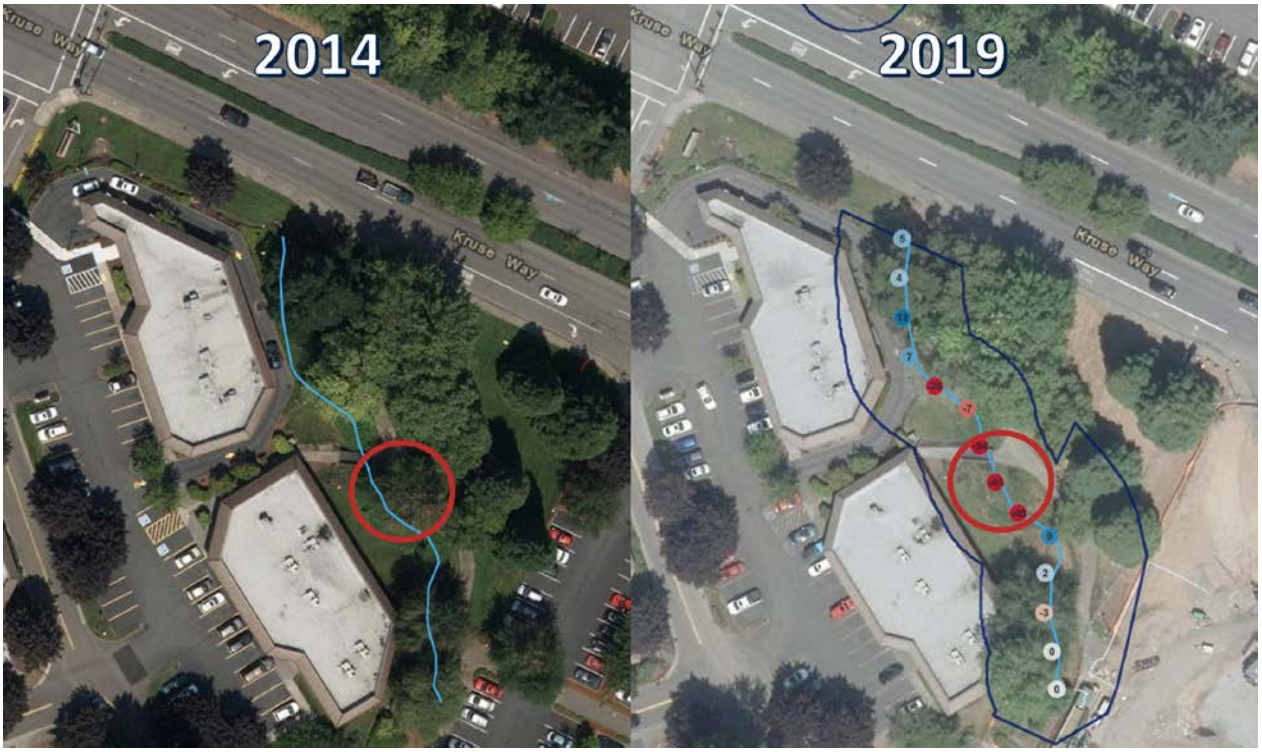


Figure 12. Removal of hazard tree resulting in decreased effective stream shade.

Restoration Effects and Opportunities

The City works with several organizations within the various watersheds to locate restoration opportunities. It is important to note that restoration efforts may not show immediate positive impacts with regards to effective stream shade depending on the scope of the work. Many restoration efforts involve planting trees that may not be captured by the shade model until they reach the 10-foot minimum. Additionally, many restoration efforts involve the removal of invasive species. The pictures in Figure 13 show before and after a riparian restoration project on Nettle Creek. Hazard trees and invasives were removed, and native vegetation is returning. This is an example of a restoration effort that would likely show a decrease in effective stream shade, but has positive benefits to watershed and stream health.

Figure 13. Tryon Creek Watershed Council Restoration Project before and after (Source: Tryon Creek Watershed Council)

Conclusions

The analysis of the Lidar data with DEQ's HeatSource model shows that the City is continuing to increase effective shade throughout the city even with the rapid development and population growth that has occurred in the same time period. The City can increase the effective shade in the protected scenario by adding a sensitive lands designation to the open channels that are currently unprotected.

The City intends to use the new data to identify areas that have not met shade targets to maximize restoration funds and to assist the execution of public projects. The analysis provides insight into the effects of protective buffers, tree removal, and development on effective shade and can be used to balance water-quality regulatory requirements, development, and the City's vision of the future.

References

City of Lake Oswego. 2019-2023 TMDL Implementation Plan. Lake Oswego, Oregon.

Boyd, M., and Kasper, B. 2003. Analytical methods for dynamic open channel heat and mass transfer: Methodology for heat source model Version 7.0.

Christy, J.A., E.R. Alverson, M.P. Dougherty, S.C. Kolar, C.W. Alton, S.M. Hawes, L. Ashkenas & P. Minear. 2011. GLO historical vegetation of the Willamette Valley, Oregon, 1851-1910. ArcMap shapefile, Version 2011_04. Oregon Biodiversity Information Center, Portland State University.

DEQ (Oregon Department of Environmental Quality). 2001. Tualatin River TMDL, Chapter 4.

DEQ (Oregon Department of Environmental Quality). 2006. Willamette Basin TMDL, Chapter 5.

DEQ (Oregon Department of Environmental Quality). 2013. TMDL Implementation Plan Guidance: Fifth Year Review Report Template for City and County Designated Management Agencies. April. 24 p.

700 NE MULTNOMAH, SUITE 1000 | PORTLAND, OR 97232 | P 503.233.2400, 360.694.5020

APPENDIX A

EFFECTIVE SHADE MODEL AND PROCESS

Purpose and Process:

The process of developing a GIS Canopy Height Model (CHM) and modeling effective shade for the City of Lake Oswego's streams was completed using Lidar and aerial imagery collected 2019. The results are compared to a similar process completed with Lidar data collected in 2014.

The general process of this analysis is:

- Extract the CHM in GIS
- Run the Department of Environmental Quality's (DEQ's) TTools in GIS to gather information on stream characteristics, topography, and canopy.

Determine effective shade using DEQ's HeatSource program

To quantify the effective shade in stream corridors, the DEQ provides various tools that gather data from the GIS stream lines and polygons, a digital terrain model, and a CHM.

1. Extracting the Canopy Height Model (CHM)

The CHM is a city-wide GIS coverage displaying the above-ground canopy height. The canopy height model is derived with ArcGIS Pro software tools using Lidar and multispectral imagery.

1.A. Aerial Imagery Processing

Infrared cameras are used to collect multispectral imagery that includes a near-infrared band that GIS software can make use of to create a Normalized Difference Vegetation Index (NDVI). The NDVI is calculated using values from the red and near-infrared bands from the imagery and is a great indicator of vegetation that can be used to isolate tree canopy coverage.

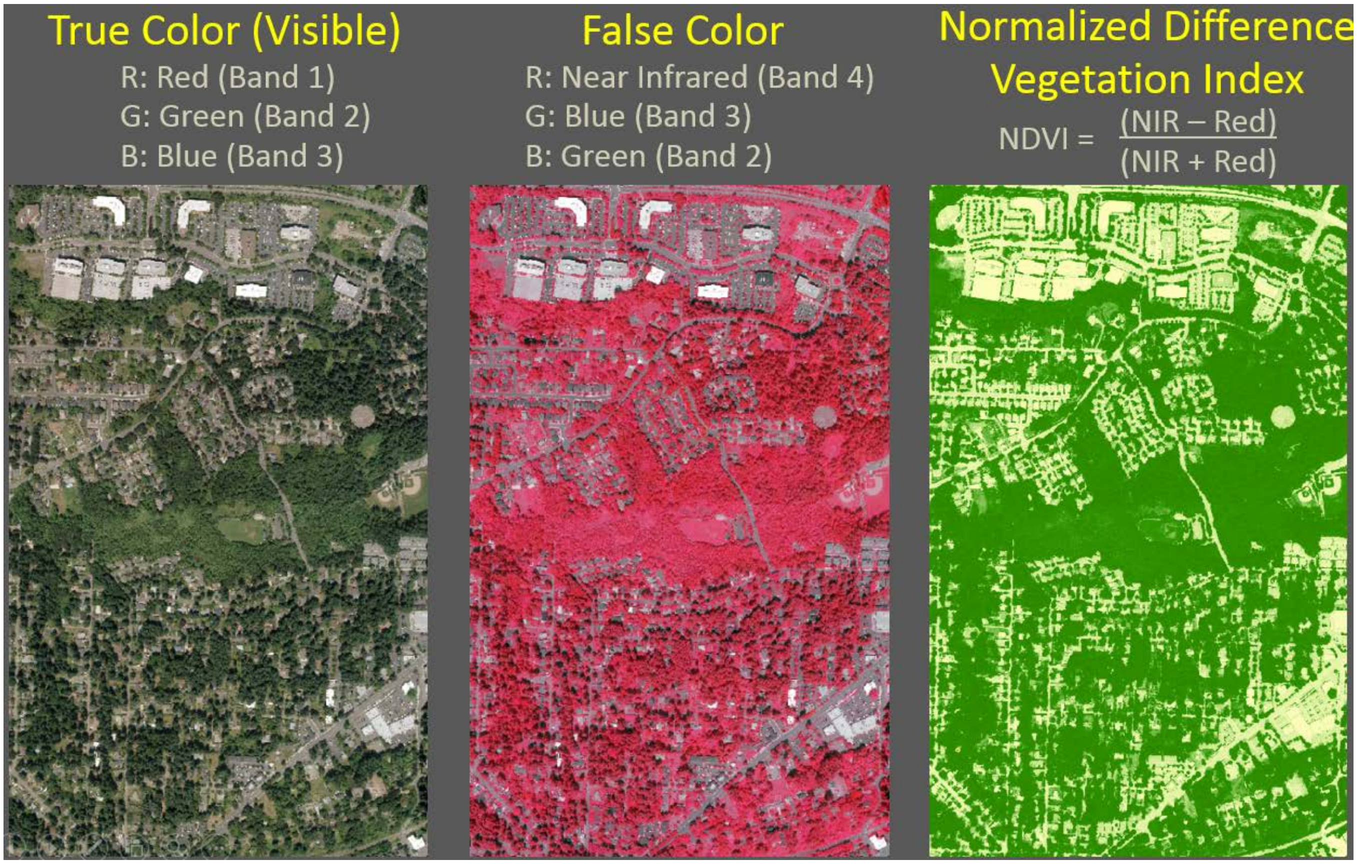


Figure A.1. Creation of the NDVI Layer using multispectral imagery.

1.B. Lidar Processing

The Lidar point cloud for the City of Lake Oswego is made up of over 2 billion points that represent individual pulses from aerial Lidar collection. Each point is populated with important information such as elevation, classification, return number, color, and intensity. Some of these lidar values are highlighted in the image below.

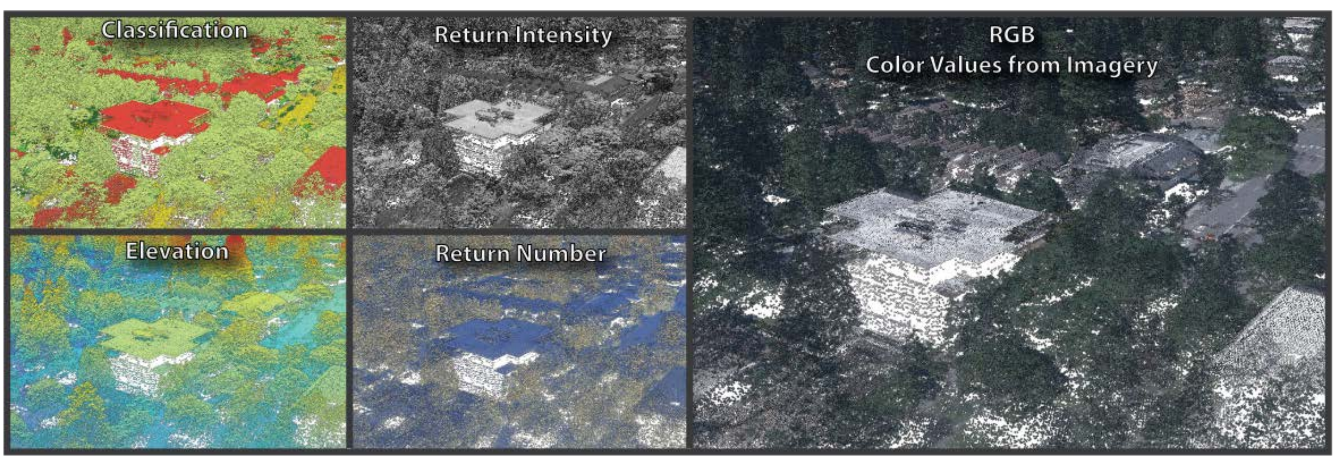


Figure A.2. Lidar point cloud with the various attributes used for visualizations and feature extractions.

1.C. Isolating the Canopy Height Model

Parametrix created an automated process in the ArcGIS Pro environment to combine elements from the multi-spectral imagery and Lidar to create the canopy height model. From the point cloud information, a Normalized Digital Surface Model (nDSM) is first created. The nDSM represents the height above ground of all objects. By using information such as height and slope from the nDSM with information from the imagery like the NDVI we can isolate the canopy (from other above-ground features like buildings) and use the height values from the Lidar (see figure 1.3).

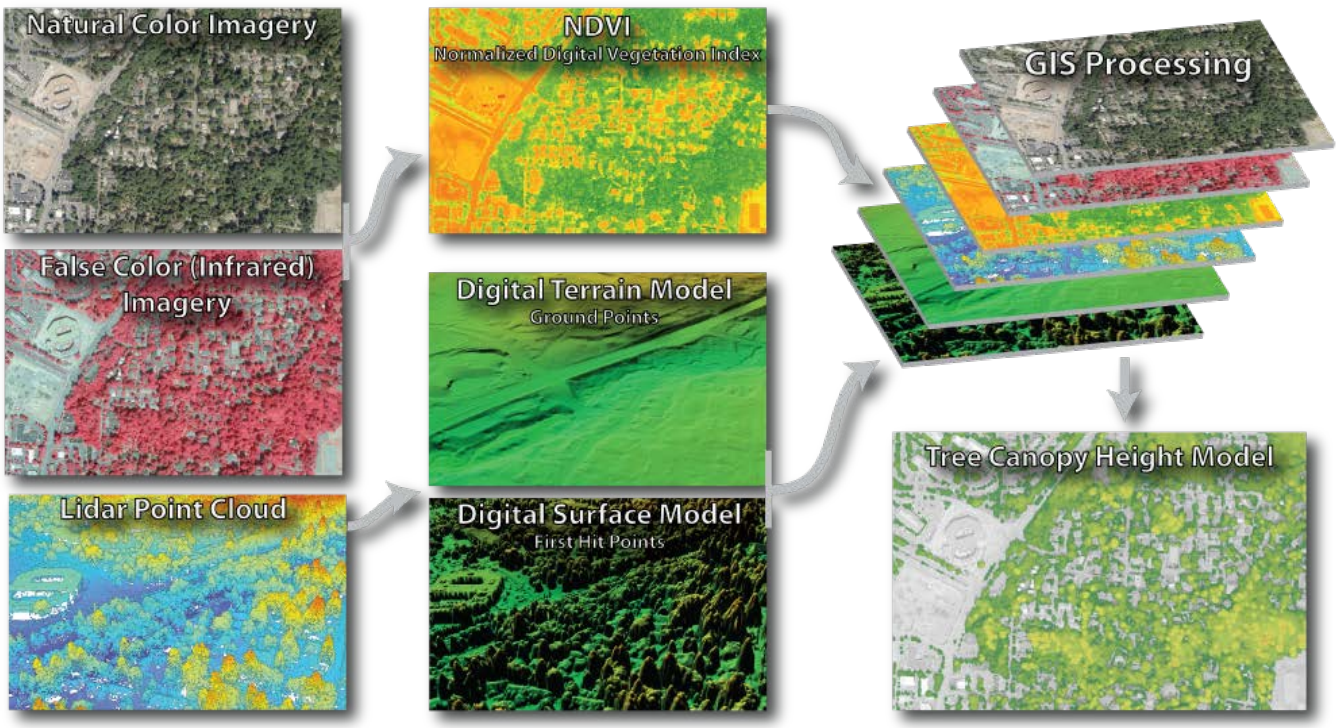


Figure A.3. Canopy Height Model derived in ArcGIS Pro using information from the Lidar and multi-spectral imagery

2. Running TTools in GIS to gather information on the streams, topography, and canopy

DEQ's TTools is a process that works as an ArcGIS extension to extract data from geospatial layers and create the necessary inputs for the HeatSource model. The GIS data layers used for TTools includes:

- Stream Centerlines
- Top of Bank Polygons
- Digital Terrain Model (Raster)
- Canopy Height Model (Raster)

Stream nodes are created at specified distance intervals and the remaining data is added to each note. The information is used by DEQ's HeatSource model for the effective shade calculation.

Step 1. Creating Stream Nodes

The first script takes the stream centerlines as inputs and creates evenly spaced nodes along each line. Nodes were established every 25 feet to provide a continuous representation of effective shade along each stream. Fields are added to each node in GIS; assigning a unique Node ID, a unique ID for each stream segment, distance to the node from the start of the stream segment, and the geographic coordinates.

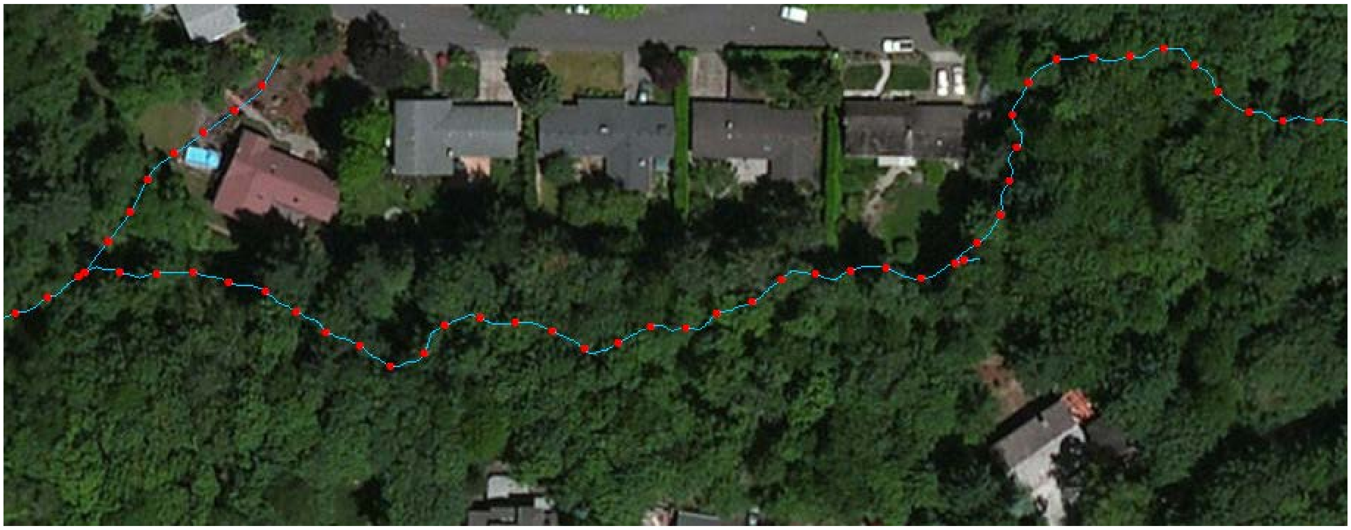


Figure A.4. Nodes (red points) created from TTools script 1 every 25 feet along the stream.

Step 2. Measure Channel Width

The second step adds a field that measures the direction (degrees from north) of the stream at each node's location (see Figure A.5). The script also takes a polygon or lines representing the stream channel edge and measures the distance from the stream centerline to each side of the channel and the channel width at each node. The city uses assigned channel widths at increments of 5 feet as an approximate measure of channel width for their narrow tributaries.

Figure A.5. TTools Script 2 measures the distance to the mapped top of bank (purple polygon) and returns the left/right distance as an attribute to the nodes.

Step 3. Sample Elevation Gradient

This script uses the nodes and the digital terrain model to find the lowest elevation near each point in order to calculate the downstream gradient. The elevation and the gradient values are added as a field to each node.

Step 4. Measure Topographic Angles

The fourth step determines shade due to topography instead of canopy. It uses a maximum search distance and calculates topographic angles in sample directions at each node. Points are created in a new feature class that represent the highest topographic angles from each node to the west, south, and east.

Step 5. Sample Landcover

The last script creates a new point layer using the digital terrain model and CHM that extracts the ground elevation and the canopy height around each node. . The points are created at 8 defined angles (N, NE, E, SE, S, SW, W, NW) from each node at equidistant intervals. Fifteen sample points are generated at each angle at 3-meter intervals creating 45 meters of canopy at each node in the effective shade analysis. It has been found that minimal effective shade is provided within a stream channel from canopy 45 meters beyond stream centerlines. The height of vegetation and the terrain at each sample point and the canopy height are associated as data attributes with the node.

The 5th script is applied to two canopy scenarios: the full canopy and the canopy clipped to the protected riparian buffers from the City's RP and RC districts of the City's Sensitive Lands Program. The two scenarios for our focus area are displayed with the different canopy height models in Figures A.6 and A.7 with the sample points. The sample points are shown for one node with 8 samples in each direction. Both the elevation and canopy height that are recorded for each sample point are added as a field to the node (a total of 16 fields: 8 for elevation and 8 for canopy height).

In figures A.6 and A.7 below, the darker green canopy represents taller trees in the CHM. In Figure A.6, the Blue outlines represent the protected riparian buffers from the sensitive lands program that are made up of the Riparian Protection (RP) and the 85% of Riparian Conservation (RC) nearest to the stream that are reserved for protection. The yellow dots represent the samples taken for the elevation and canopy height for that single node. Samples like this are taken for each node. Any canopy outside the protected area will have a height of zero associated with that point.

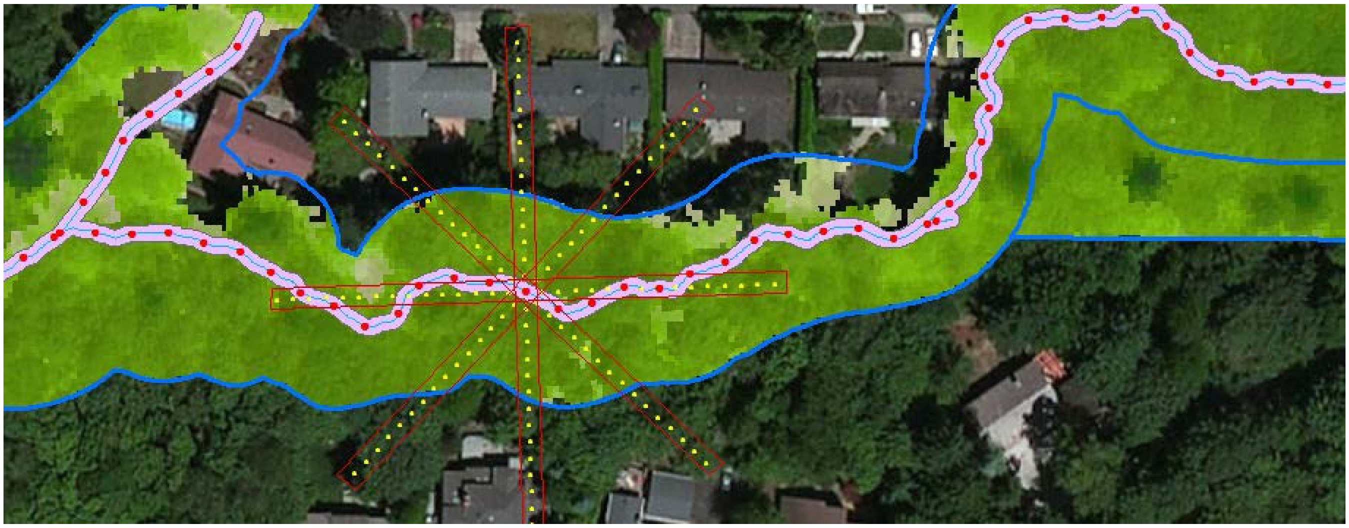


Figure A.6. Protected Canopy Scenario CHM

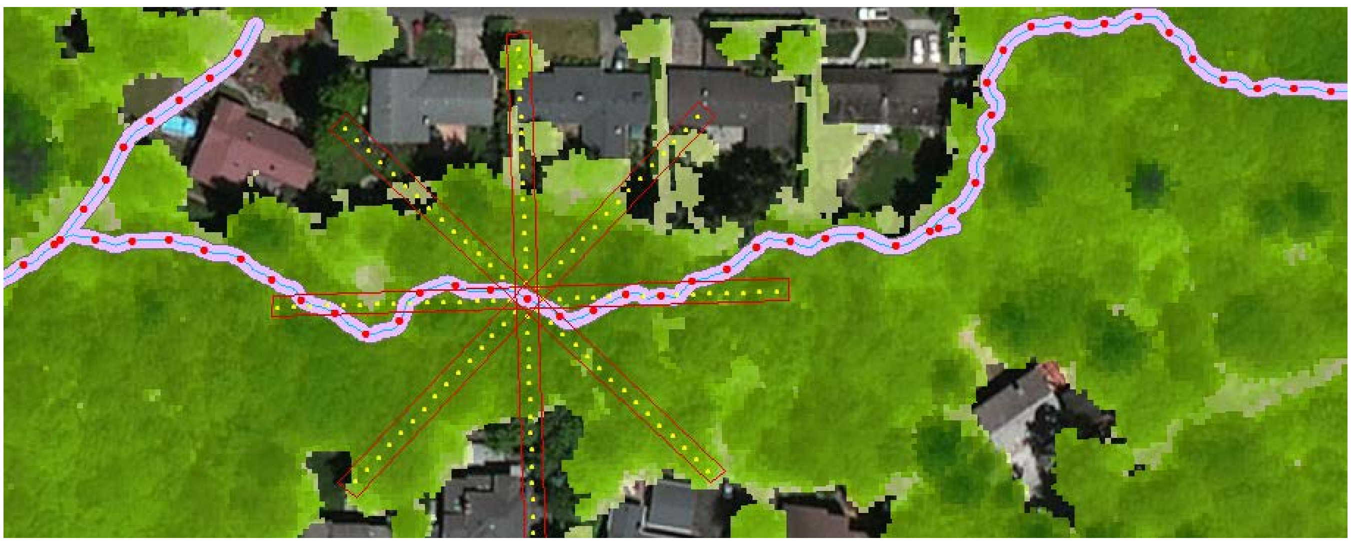


Figure A.7. Full Canopy Scenario CHM

3. Determining effective shade

DEQ's HeatSource program calculates the effective shade from the data gathered at each stream node using TTools. One critical input, that is not provided by the GIS data acquired from TTools or the Lidar data, is the canopy density. Canopy density, in this instance, refers to the amount of incoming solar radiation that is blocked by the canopy in cases where it is modeled as closed. In modeling the incoming solar radiation, the canopy density is effectively a metric of the canopy height model opacity.

DEQ establishes canopy density averages based on the subbasin and ecoregion in their subbasin TMDLs. Because the City intersects both the Lower Willamette River Subbasin and the Tualatin River Subbasin as well as two ecoregions, (Willamette Valley Foothills and Prairie Terraces), DEQ established that the City should use a 90% canopy density value within the Valley Foothills Ecoregion and 75% canopy density value for the nodes that lie in the Prairie Terraces Ecoregion.

Sheet 1: HeatSource Inputs

The first sheet in the HeatSource tool is used to set up the conditions for running the model. Many of these inputs receive the defaults as defined in Willamette Partnership's *Protocol for Quantifying Thermal Benefits of Riparian Shade.* Other inputs allow you to specify project specific conditions. These include:

- Modeling start and end date (August 1st)
- Distance steps and transverse sample rates that were used for the TTools data
- Whether inputs are based on use of Lidar or vegetation classes and the vegetation calculation method ("point" if using Lidar and "zone" if using vegetation classes)
- A landcover canopy density determined by DEQ which is based on ecoregion

Incorporating TTools and Morphology Data into HeatSource

The TTools data sheet can be completed by importing directly from the nodes. This allows HeatSource to access the data that was acquired at each node for the desired scenario including topographic elevation and vegetation heights at all angles from the transverse sample points.

The morphology data is populated using more information from the nodes feature class including the elevation, gradient, and bottom width at each node. Other inputs can be left at their default values, as they deal with sediment heat exchange and hyporheic flow that do not affect the Shade-a-lator component results.

Running HeatSource

Once the data inputs have been populated, HeatSource is run. The effective shade output at each node for the various scenarios (full canopy and protected canopy for 2014 and 2019) can be joined back with the Nodes GIS layer based on the unique Node ID. The effective shade for all scenarios is stored in a single table along with each node information that was collected in TTools. GIS tools are then used for displaying effective shade percent at each node in maps and graphics.

Effective Shade Targets for Stream Nodes

GIS is used to compare the effective shade results from HeatSource against the effective shade targets. The effective shade target varies based on ecoregion, channel width, and stream direction. Using the channel width and orientation associated with each node, the effective shade target is added as a new field to the nodes feature class. The deficit or progress towards achieving the target effective shade is color coded at each node (See Figure A.8)

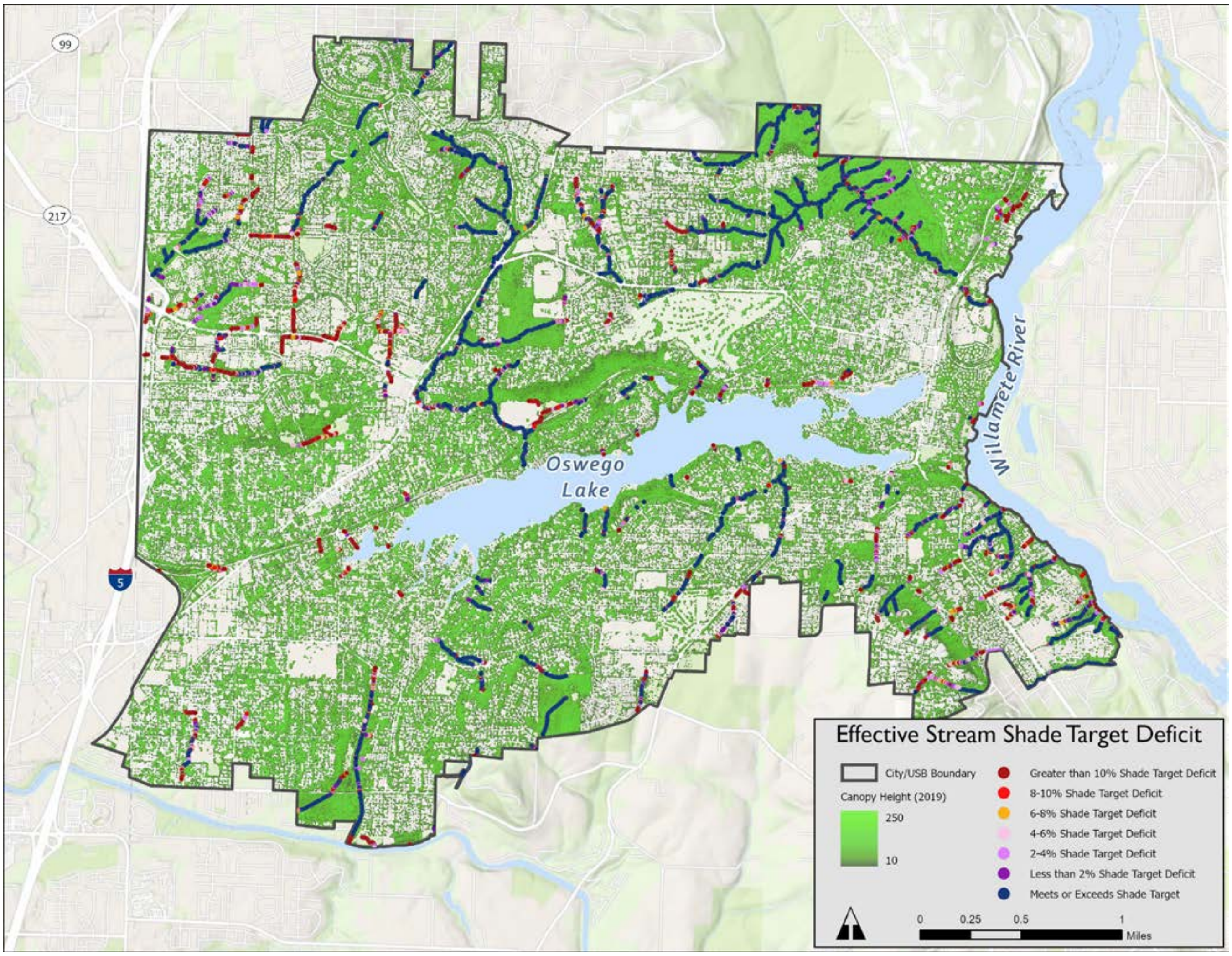


Figure A.8. City-Wide Effective Stream Shade Target Deficits

LAKE OSWEGO
healthy
watersheds
Stewardship for a Sustainable Future

THE
RIVER
STARTS
HERE