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Clackamas River Basin

Pollutant Load Modeling Tool

Prepared for

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1. INTRODUCTION

In 2010, the Clackamas River Water Providers (CRWP) adopted the Drinking Water Protection Plan (Plan, CRWP, 2010) for the Clackamas River watershed providing a comprehensive roadmap for source water protection. In the last two years the CRWP developed a Geodatabase with added analyses to conduct an assessment of the relative pollutant loading from individual land uses (septic systems, agriculture, forestry, vulnerable soils, urban development, and point sources of pollution).

CRWP hired Geosyntec to better understand the relative and cumulative impacts to the drinking water source quality including all of the land uses. To conduct this assessment a pollutant load modeling tool (PLMT, or the "tool") was developed which can be readily used by the Water Resources Manager to assess baseline conditions and consider scenarios for management and risk reduction.

The PLMT was developed to make it easy to update the analyses in the future or extend it to conduct additional analyses as the Plan is implemented. The tool builds upon the Geodatabase and was designed to assist CRWP with (1) prioritizing future water quality sampling to assess progress or performance; (2) selecting best management practices (BMPs) for mitigating various land use-based threats to source water quality; and (3) prioritizing funding to obtain the greatest benefit out of CRWP's available resources.

This report is a companion report to the PLMT User's Manual which focuses strictly on how to use the PLMT.

2. MODELING FRAMEWORK

The overall framework of the PLMT is presented in Figure 1. The framework is broken up into four main categories: 1) Applications (computer programs); 2) Data source - shapefiles (input data for GIS); 3) Data source – input (data used as input in other applications); and 4) Output. The framework workflow is from top to bottom, beginning with the application 'GIS[1]'. An analysis of the given shapefiles in a GIS application produces the necessary inputs for the second application, 'SWMM'. Using meteorological input data, SWMM is run to generate output runoff coefficients used in the third application, 'Excel', or the PLMT. This application uses characteristic

[1] Geographic Information System

pollutant data to calculate annual pollutant loads, which can then be visualized using a GIS application. BMPs can be implemented in the PLMT to evaluate their ability to reduce annual pollutant loads. Each application is further discussed in the following sections.

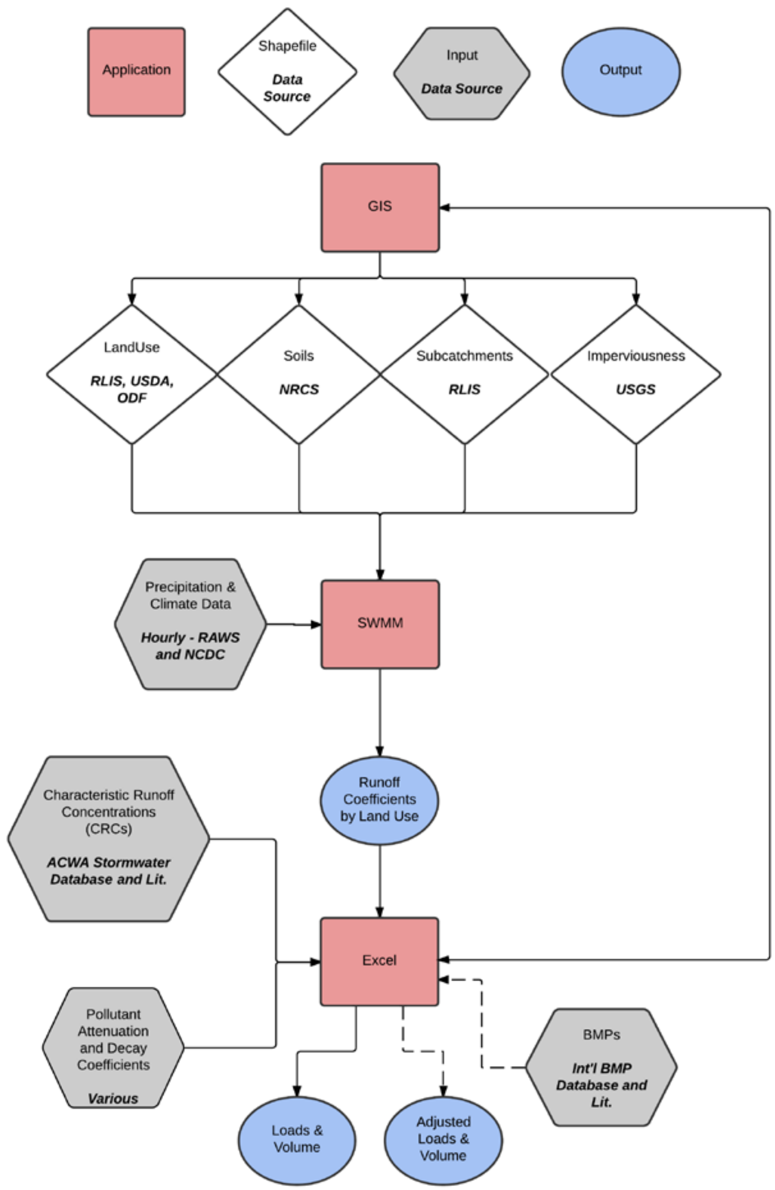

Figure 1: The PLMT Modeling Framework.

The model breaks up the Clackamas River watershed into 34 subwatersheds according to the United States Geological Survey's (USGS) 12-digit hydrologic unit code (HUC) as shown in Figure 2 (with the boundaries of the MT Hood National Forest shown in green). Each subwatershed is then divided up into distinct land uses from which pollutant runoff is estimated and adjusted with the application of BMPs and/or attenuation due to in-stream travel through the reservoirs.

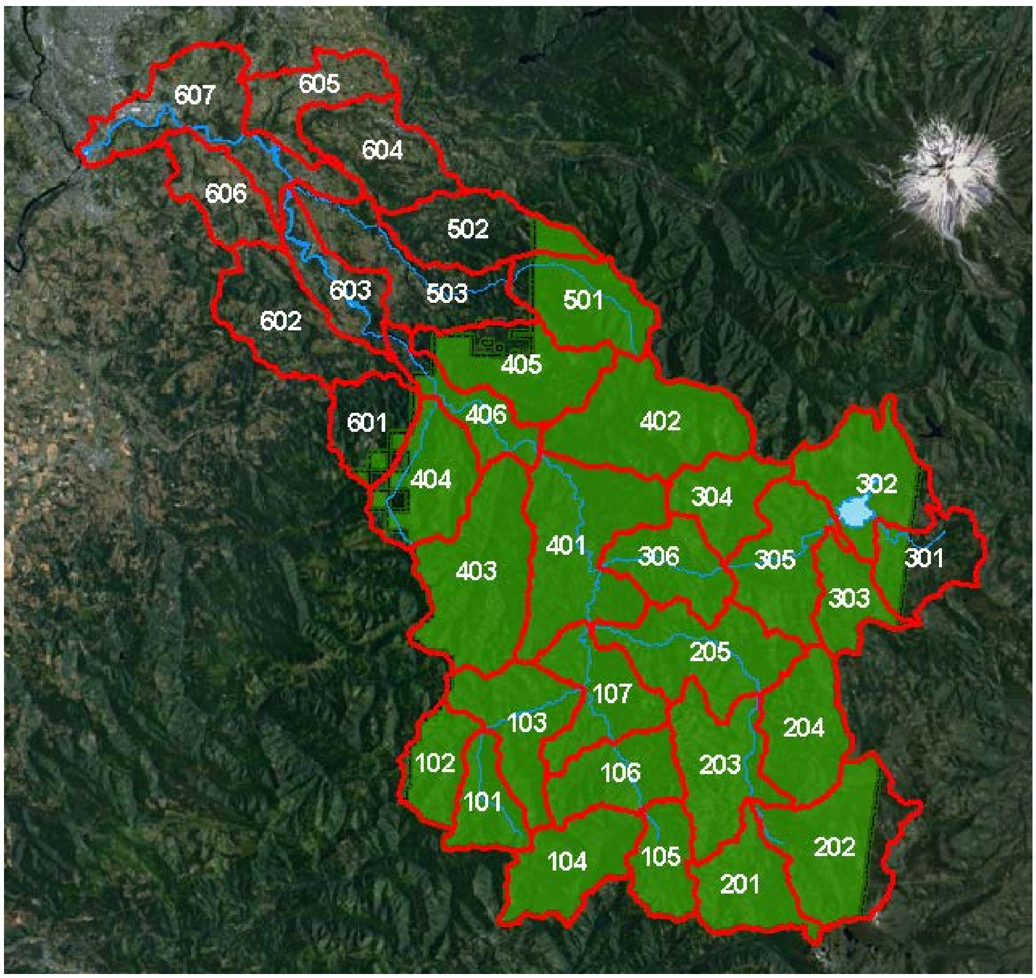

Figure 2: Clackamas River watershed with delineation of subwatersheds. The green shading represents the boundaries of the Mt. Hood National Forest. The last 3 digits of the 12-digit subwatershed HUCs are shown.

Prior to implementation of the framework, pollutants of concern and permissible BMPs were identified. There are 13 representative pollutants included in the PLMT. In the creation of the pollutant list, pharmaceuticals were not included due to the lack of scientific data on loadings and BMP removal rates. This resulted in the inclusion of seven types of pollutants within the PLMT: (1) Soils (Total suspended solids), (2) Organic matter, (3) Nutrients, (4) Heavy metals, (5) Pathogens (E. coli), (6) Pesticides, and (7) Hydrocarbons (Oil & Grease). The PLMT supported nutrients are total phosphorus (TP), nitrates, and ammonia. TP and nitrates were included because they are representative of constituents that are transported with sediments or in the dissolved phase in water, respectively, and ammonia is a common base for fertilizers used in agriculture. Three heavy metals were included: lead, copper, and zinc. These heavy metals are more common than others and pose a considerable threat to aquatic resources.

16 pesticides were identified in the geodatabase but three of the 16 are supported in the tool and are representative of the larger set. Two of the pesticides are herbicides (2,4-D and glyphosate) and one is an insecticide (carbaryl). The pesticides were chosen based on their adsorption, solubility, and level of application within the watershed. The level of application was a qualitative determination based on crop cover acreages and average annual recommended pesticide application rates presented by Herrera Environmental Consultants (Herrera) to the CRWP in the development of the geodatabase (Herrera, 2012). In addition, a USGS study of pesticide occurrence in the Lower Clackamas River Basin (Carpenter, 2008) was considered as well. Glyphosate is water soluble but also strongly adsorptive, attaching itself to suspended soils and organic matter. 2,4-D is also water soluble and although it has a low soil persistence, it is one of the most commonly detected pesticides due to the high level of application; and glyphosate was another considered to have a high application rate (Carpenter, 2008). Carbaryl, the only insecticide listed by Herrera for the largest crop coverage, pastures and hay, adsorbs to organic matter and can be transported in soil runoff. The representative pollutants included in the PLMT are listed below in Table 1.

Table 1: Representative Pollutants included in the PLMT.

#	Pollutant	Reason for Inclusion
1	Total suspended solids (TSS)	must filter out from drinking water and pollutant transport after adsorption onto soil particles
2	Total phosphorus (TP)	representative of contaminants that are transported with sediments
3	Nitrate (NO3)	representative of contaminants that are transported in the dissolved form with water
4	Ammonia (NH3)	common base for fertilizers used within the watershed

#	Pollutant	Reason for Inclusion
5	Lead (Pb)	more common than other heavy metals and pose a significant threat to aquatic resources
6	Copper (Cu)	more common than other heavy metals and pose a significant threat to aquatic resources
7	Zinc (Zn)	more common than other heavy metals and pose a significant threat to aquatic resources
8	Biological Oxygen Demand (BOD)	indicates degree of organic pollution
9	E. Coli	common pathogen
10	Oil & Grease	proximity of roadways to watercourses
11	Glyphosate (herbicide)	based on their adsorption, solubility, and level of application within the watershed; water soluble but also strongly adsorptive, attaching itself to suspended soils and organic matter
12	2,4-D (herbicide)	based on their adsorption, solubility, and level of application within the watershed; water soluble and although it has a low soil persistence, it is one of the most commonly detected pesticides due to the high level of application Full name: 2,4-Dichlorophenoxyacetic acid (2,4-Dichloro)
13	Carbaryl (insecticide)	based on the level of application within the watershed; adsorbs to organic matter and can be transported in soil runoff

The PLMT also supports 13 different types of BMPs and includes a mixture of structural (physical structures, e.g. water quality basins) and programmatic (changing current practices to reduce pollutant loading, e.g. organic farming) BMPs, which are listed in Table 2. The table provides a description of each BMP, the pollutants treated, and the source of those pollutants.

Table 2: PLMT Supported BMPs

BMP	Description	Pollutant(s)	Source/Risk
1) Nutrient Management Plans - Agriculture	Managing the amount, source, placement, form, and timing of application of nutrients/soil amendments and irrigation water such that crop nutrient needs are met while minimizing loss to surface and groundwater.	TP, Nitrates, Ammonia	Agriculture – Field/Lot Runoff
2) Nutrient Management Plans – Urban Landscaping	Managing the amount, source, placement, form, and timing of application of nutrients/soil amendments and irrigation water.	TP, Nitrates, Ammonia	Urban - Runoff
3) Integrated Pest Management	Sustainable approach that combines biological, cultural, physical, and chemical tools to minimize the economic, health, and environmental risks associated with pest management.	Glyphosate; 2,4-D; Carbaryl	Agriculture – Field/Lot Runoff Urban - Runoff
4) Incentive Program	Incentives (fee/cost reduction) for connecting septic system to sewer and/or performing annual inspections and maintenance.	BOD TP, Nitrates, Ammonia E. Coli, Fecal Coliform	Septic – Failed System
5) Conservation Buffers	Strips of permanently vegetated land placed to trap and degrade pollutants from field runoff.	TSS BOD TP, Nitrates, Ammonia Lead, Copper, Zinc Glyphosate; 2,4-D; Carbaryl	Agriculture – Field/Lot Runoff
6) Streamside Management Areas	Restriction of activities (forestry) and/or livestock (agriculture) near watercourses.	TSS BOD TP, Nitrates, Ammonia E. Coli, Fecal Coliform Glyphosate; 2,4-D; Carbaryl	Agriculture – Field/Lot Runoff Forestry – Harvesting Forestry – Landslides Forestry - Roadways
7) Water Quality Basins (detention, retention, wetland)	Storage of stormwater runoff in an excavated basin. Three main types of basins include: 1) Detention (temporarily stores excess stormwater which is slowly drained into a receiving channel), 2) Retention (indefinite storage of excess stormwater where water losses are due to evaporation and infiltration into adjacent soils), 3) Wetland (shallow retention pond with wetland vegetation which acts as a sedimentation basin and biological filter).	TSS BOD TP, Nitrates, Ammonia Lead, Copper, Zinc E. Coli, Fecal Coliform Glyphosate; 2,4-D; Carbaryl	Agriculture – Field/Lot Runoff Urban – Runoff Agriculture – Fish Hatchery Effluent
8) Bioretention/Biofilters (swales, media strips, rain gardens)	Swales are engineered channels with gently sloped sides and filled with vegetation and/or rip-rap. The channels are shallow and wide to aid in the trapping of pollutants. Media strips are evenly sloped vegetated areas (grass or woody) on permeable soils – influent is filtered as it travels through the vegetation. A rain garden is a planted, depressed ponding area which captures and filters stormwater as it infiltrates into the underlying soil.	TSS BOD TP, Nitrates, Ammonia Lead, Copper, Zinc E. Coli, Fecal Coliform Glyphosate; 2,4-D; Carbaryl Oil/Grease, PAH's	Urban - Runoff
9) Media Filter	Bed of aggregate with gypsum, perlite, or dolomite which filters influent. In general, fine-sized particles are placed as the top layer of the filter, with each subsequent layer composed of coarser particles. Unlike a biofilter, vegetated soils are not a component.	TSS TP, Ammonia Lead, Copper, Zinc E. Coli, Fecal Coliform Glyphosate; 2,4-D; Carbaryl Oil/Grease, PAH's	Agriculture – Field/Lot Runoff Urban – Runoff Agriculture – Fish Hatchery Effluent Highway Runoff
10) Impervious Area Reduction (IAR)	Techniques which minimize the amount of impervious areas from buildings, roadways, parking areas and sidewalks. Examples include porous pavement (pavement without fine-grained aggregate which increases void space and infiltration rates of water), green roofs (roof that is partially or completed covered with vegetation), and dry wells (subsurface storage facility which temporarily stores and infiltrates runoff to the groundwater).	TSS TP, Nitrates, Ammonia Lead, Copper, Zinc	Urban - Runoff

BMP	Description	Pollutant(s)	Source/Risk
11) Organic Farming	Form of agriculture in which no synthetic fertilizers or pesticides are used.	BOD TP, Nitrates, Ammonia Glyphosate; 2,4-D; Carbaryl	Agriculture – Field/Lot Runoff
12) Drinking Water Protection Zones	Restriction of activities or facilities that could jeopardize purity of drinking water source, particularly around a source water intake.	TSS BOD TP, Nitrates, Ammonia Lead, Copper, Zinc E. Coli, Fecal Coliform Glyphosate; 2,4-D; Carbaryl Oil/Grease, PAH's	Agriculture – Field/Lot Runoff Agriculture – Fish Hatchery Effluent Forestry – Harvesting Forestry - Roadways
13) Emergency Response Plan	Documented plan that describes actions taken in response to a major event.	Oil/Grease, PAH's	Urban – Runoff Highway Runoff

As outlined in Figure 1 above there are various analysis steps in the PLMT framework where data analyses and modeling are conducted. The sections below outline the analyses conducted as part of the PLMT framework.

3. GIS ANALYSIS

The GIS datasets used in the PLMT analysis are presented in Table 3. The National Land Cover Dataset consists of a 10 meter digital elevation model (DEM) raster, a slope raster, and a percent imperviousness raster.

Table 3: GIS datasets used in the development of the PLMT

Description	Source
Clackamas River Watershed Boundary	Oregon Metro Regional Land Information System (RLIS)
Streets	Oregon Metro RLIS
Zoning Designations	Oregon Metro RLIS
National Land Cover Dataset	United States Geological Survey (USGS) Multi-Resolution Land Characteristics Consortium
Soils	National Resources Conservation Service (NRCS) Web Soil Survey
Infrastructure (Roads)	United States Forest Service (USFS) Mt. Hood National Forest Data Library

The DEM and slope rasters were clipped to each subwatershed boundary to calculate the average percent slope and flow length for each subwatershed. The flow length calculates the distance from the farthest point upstream to the subwatershed outlet at the downstream end and is used to determine the width of the subwatershed. The width of the watershed is an input parameter for the Environmental Protection Agency's (EPA) Storm Water Management Model (SWMM). The width is calculated by dividing the subwatershed area by the flow length.

The land use zoning and road GIS data sets were then broken up into seven main land uses. Table 4 describes which original GIS zoning classifications were merged to create each land use data set for the PLMT.

Table 4: Land uses in the PLMT and the zoning classifications which make up each land use

Land Use	Original Zoning Classification
Agriculture (AGR)	Rural - All sub classifications other than timber
Commercial (COM)	Commercial
	Industrial
	Mixed Use Employment
Forestry (FOR)	Rural - Timber
Open Space (OPS)	Parks and open space
Public Facilities (PUB)	Public Facilities
Residential (RES)	Mixed-use residential
	Single family residential
	Multi-family residential
Transportation (TRA)	Roads/Streets

The Transportation Land use, TRA, was further delineated into five sub land uses:

- TRA1 – Highways (includes ramps)
- TRA2 – Primary arterial roads
- TRA3 – Other paved roads outside of Mt. Hood National Forest
- TRA4 – Paved roads within Mt. Hood National Forest
- TRA5 – Aggregate/native roads within Mt. Hood National Forest

The entire road GIS shapefiles were provided as “polylines” which have no surface area associated with them in the ArcGIS software, and the PLMT needs the acreage of each land use to determine pollutant loads. Therefore, buffers were placed around all of these polylines, creating a dataset of polygons which occupied measureable acreage. The sizes of the buffers for roads outside of national forestland were based on the paved width standards given in Clackamas County Roadway Standards (Clackamas County, 2013), while roads within national forestland were given buffers of 12 ft. or 24 ft. depending on the number of lanes (one or two).

The PLMT treats all transportation sub land uses the same, assigning the same pollutant concentrations for each land use category. But, as more pollutant concentration data from local roads is collected and/or the decision is made to adjust pollutant concentrations according to traffic loads, adjustments can easily be made for each sub land use.

Vulnerable soils were not specifically identified as a land use because they were considered contributing factors in increasing the risks associated with other land uses. In addition, soil characteristics are considered when estimating runoff in the watershed using SWMM. All land uses were merged into one main polygon shapefile which is shown in Figure 3 and serves as input to the PLMT.

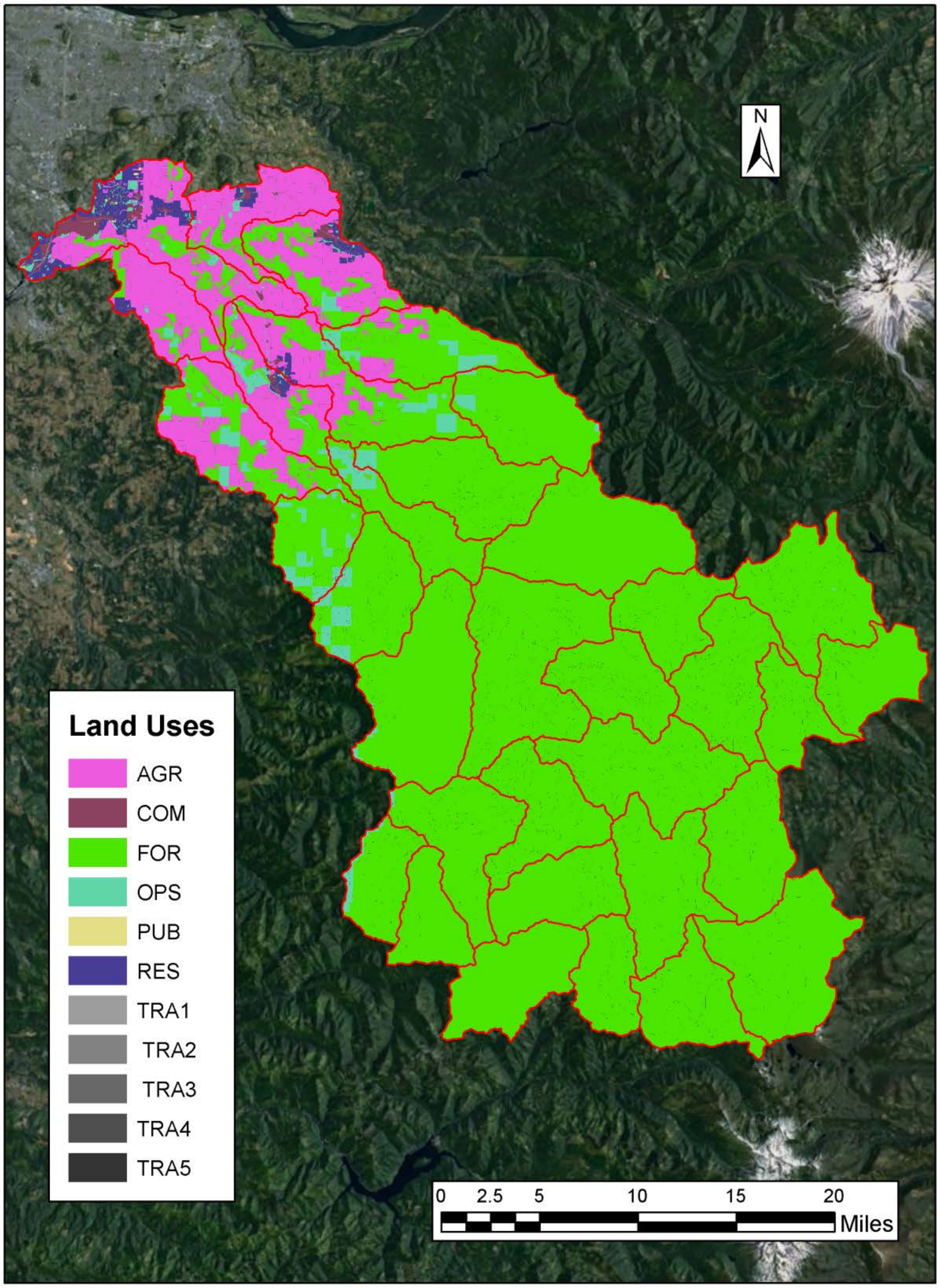

Figure 3: Land use designations in the PLMT, including the various sub categories for transportation.

In order to estimate runoff in the PLMT it was necessary to determine the percent imperviousness of each land use in each subwatershed. The percent imperviousness raster GIS file from the National Land Cover Database (NLCD) dataset was converted into a polygon shapefile dataset and clipped to the subwatershed boundaries. A "union" was then performed between the land use polygon shapefile created in the previous task and the percent imperviousness polygon to merge the characteristics into one GIS dataset. An area-weighted average percent imperviousness for each land use was then calculated for use in SWMM.

Once the average percent imperviousness was calculated, the Natural Resources Conservation Service (NRCS) soils dataset was processed. The dataset is a polygon shapefile which breaks up the watershed into map units, or polygon surface areas that share an associated set of soil characteristics, including the hydrologic soil group which defines the runoff characteristics of the soil. There are four hydrologic soil groups: A, B, C, and D. One of the defined runoff characteristics is the saturated hydraulic conductivity, which describes the movement of water through saturated media (soil). The saturated hydraulic conductivity is a necessary parameter for SWMM.

A union was performed between the resultant land use shapefile from the previous task and the soils dataset in order to determine the map units located within each land use area. The average weighted hydraulic soil group was calculated for each land use based on acreage, and the saturated hydraulic conductivity was then determined using the information in Table 5. This table is based on information from Table 7.2 in NRCS's Hydrology National Engineering Handbook (NRCS, 2007).

Table 5: Hydrologic soil group properties

Hydrologic Soil Group	Runoff Potential	Saturated Hydraulic Conductivity (in/hr.)
A	Low	1.43
B	Moderately Low	0.995
C	Moderately High	0.315
D	High	0.03

A table of the parameter inputs for SWMM can be found in Table 17 in the appendix. The table breaks each subwatershed up by land use and lists the acreage, percent imperviousness, and saturated hydraulic conductivity.

4. U.S. EPA SWMM MODEL

EPA's SWMM is used to model the hydrology of the Clackamas Basin based on imperviousness, soil characteristics, and topography. Specifically, SWMM is used to calculate a runoff coefficient for each land use per subwatershed. A runoff coefficient is a dimensionless coefficient that relates the amount of runoff volume to the amount of precipitation. For example, a runoff coefficient of 0.5 would mean that 50% of the rainfall volume would not infiltrate into the soil but run off the land as overland flow. Four weather stations were used to characterize precipitation amounts as shown in Figure 4.

SWMM does have the ability to model snowmelt, groundwater baseflow, and evaporation in addition to rainfall. However, due to the lack of significant levels of snowfall and groundwater baseflow data over the majority of the watershed, these hydrologic components were not included. Evaporation was set to zero in order to calculate a conservative runoff coefficient. The resultant runoff coefficients are included in Table 17 in the appendix.

5. METEOROLGICAL DATA

Precipitation data was the only meteorological component required by SWMM as noted above. In order to capture geographic variations in precipitation, the data from four weather stations were used. Three of the stations were Remote Automatic Weather Stations (RAWS) operated by the U.S. Forest Service and Bureau of Land Management and one was an Automated Surface Observing Systems (ASOS) station, which is a joint program of the National Weather Service, the Federal Aviation Administration, and the Department of Defense. The data was downloaded from Weather Underground (http://www.wundergound.com) and consisted of at least five years of precipitation totals, as shown in Table 6. The data at each site was analyzed before using it as input to the SWMM model. The ASOS dataset consisted of five-minute precipitation totals and any gaps in the data were filled using linear interpolation. None of the gaps were larger than a few hours. The RAWS datasets provided cumulative rolling daily precipitation totals with data provided every five to twenty-five minutes. To use these datasets in SWMM, the cumulative rolling daily totals were transformed into hourly precipitation totals.

Table 6: Precipitation datasets used in SWMM modeling.

Station Type	Station Name	Data Type	Date Range
ASOS	Aurora	5-minute Precipitation Totals	1/1/2005 - 7/31/2013
RAWS	Eagle Creek	Hourly Precipitation Totals	12/5/2007 - 10/1/2013
RAWS	Wanderer's Peak	Hourly Precipitation Totals	12/5/2007 - 10/1/2013
RAWS	Red Box	Hourly Precipitation Totals	12/5/2007 - 10/1/2013

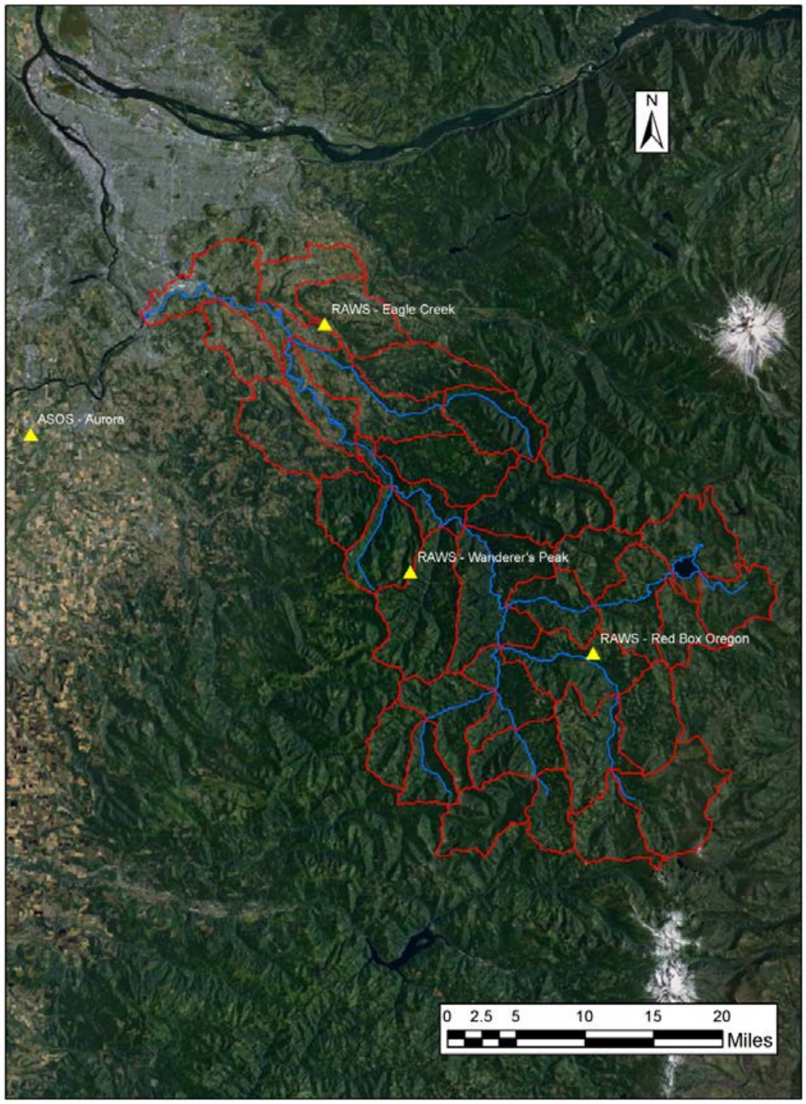

Figure 4: Meteorological stations used to characterize rainfall intensity in SWMM. The station name is given along with the type (RAWS or ASOS).

6. POLLUTANT LOAD MODEL

The PLMT is a customized pollutant load model in Microsoft Excel utilizing the existing CRWP Geodatabase, characteristic land use pollutant runoff concentrations derived from literature sources, and average annual runoff coefficients based on SWMM continuous simulations. The PLMT allows the CRWP Water Resources Manager to simulate watershed development and stormwater quality improvement project scenarios, generate output graphics, and compare scenario results.

The model uses the 30 year normal average annual rainfall amounts from the PRISM Climate Group dataset (PRISM, 2012). The most current PRISM dataset was used and covers the period of 1981-2010. Two distinct rainfall areas were delineated within the model, the upper and lower basins. The upper basin consists of the subwatersheds located within the Mt. Hood National Forest, represented by the green shading in Figure 2. The lower basin, where the majority of development occurs, consists of nine subwatersheds. The current 30 year normals for the upper and lower basins are 73 in. and 45 in., respectively.

The PLMT uses the Rational Method to estimate the annual runoff volume per land use per subwatershed. The equation for the Rational Method is given below:

$$Q = CIA \qquad \text{Equation 1}$$

where: Q = runoff volume
C = runoff coefficient
I = rainfall intensity
A = drainage area

Once the annual runoff volume of each land use is calculated, the PLMT makes use of pollutant event mean concentrations (EMCs) to determine existing pollutant loadings. An EMC is a typical concentration for a pollutant from which one could expect in a storm runoff event. The EMC is often based on compositing flow weighted samples over a runoff event. Pollutant EMCs were estimated from various sources including the ACWA stormwater database (Kennedy/Jenks, 2009) and are shown in Table 7.

Table 7: Pollutant EMCs in the PLMT

	Land Use										
Pollutant	AGR	COM	FOR	OPS	PUB	RES	TRA1	TRA2	TRA3	TRA4	TRA5
TSS, mg/L	66.00	81.70	66.00	52.90	79.24	135.3	150.9	150.9	150.9	150.9	150.9
TP, mg/L	0.082	0.451	0.016	0.175	0.274	0.408	0.347	0.347	0.347	0.347	0.347
NO3, mg/L	2.445	0.681	0.023	0.400	0.503	0.677	1.530	1.530	1.530	1.530	1.530
NH3, mg/L	0.114	1.561	0.002	0.738	0.981	1.471	1.715	1.715	1.715	1.715	1.715
PB, mg/L	0.0134	0.040	0.0134	0.003	0.024	0.021	0.055	0.055	0.055	0.055	0.055
CU, mg/L	0.0085	0.026	0.0085	0.004	0.013	0.015	0.032	0.032	0.032	0.032	0.032
ZN, mg/L	0.05	0.165	0.05	0.025	0.075	0.101	0.211	0.211	0.211	0.211	0.211
BOD, mg/L	6.47	13.55	4.67	4.67	8.28	9.76	14.86	14.86	14.86	14.86	14.86
E. Coli, MPN/100 mL	1340	3247	1000	1000	1679	2926	6002	6002	6002	6002	6002
Glyphosate, mg/L	0.000412	0.000070			0.000070	0.000100					
2,4-D, mg/L	0.000412	0.000070			0.000070	0.000070					
Carbaryl, mg/L	0.000100	0.000070			0.000070	0.000070					
Oil & Grease, mg/L	2.886	5.738	2.886	0.833	4.938	3.678	9.664	9.664	9.664	9.664	9.664

ACWA stormwater database (Kennedy/Jenks, 2009)

ACWA stormwater database - average of 'Open Space' and 'Mixed' land uses

USGS Report (Carpenter, 2003)

White Paper (Herrera, 2007)

ACWA stormwater database - set equal to the 'OpenSpace' land use

USGS Report (Kelly et al., 2012)

Set equal to TRA2 levels

The PLMT also adjusts the pollutant loads due to attenuation from in-stream travel through five reservoirs operated by Portland General Electric. Pollutant load attenuation is based on the settling of particles as water moves downstream through the reservoirs. The reservoirs include: Timothy Lake, Lake Harriet, North Fork Reservoir, Faraday Diversion Pool and Lake, and River Mill Reservoir which are along the Oak Grove Fork and main stem of the Clackamas River.

The estimated median particle size used in the settling calculations is based on urban stormwater and may be slightly biased for agricultural stormwater. In addition, the partition coefficients used in determining the fraction of the pollutant load which is adsorbed onto particles is taken from literature (Leisenring et al., 2013) or estimated. The partition coefficients are listed in Table 9.

The settling algorithm is based on surface overflow rates, or critical velocities, for each reservoir. The critical velocity was determined using the following equation:

$$v_c = \frac{Q}{A} \qquad \text{Equation 2}$$

where: v_c = critical velocity
Q = average reservoir discharge
A = reservoir surface area

The full pool surface area was used for each of the reservoirs and was determined using surface area-elevation curves from a CE-QUAL-W2 model of the Clackamas River (Annear et al., 2002). The average daily discharges are based on powerhouse flows or minimum fish flows except for Timothy Lake which was estimated using the mean daily discharge from USGS Gauge 14208700, which is located 0.3 mi downstream. The surface area and average daily discharge for each reservoir are listed in Table 8.

Table 8: Reservoir characteristics used in the PLMT

Reservoir	Full Pool Surface Area (ac)	Daily Average Discharge (cfs)
Timothy Lake	1,384	123
Harriet Lake	19	353
North Fork	319	1,766
Faraday Diversion Pool	54	200
Faraday Lake	47	1,413
River Mill	103	1,413

The critical velocity, v_c, was then used in Equation 3 (Leisenring et al., 2013) to calculate the percent of particles which are removed due to settling.

$$R = 1 - \left(1 + \frac{v_s}{Nv_c}\right)^{-N} \qquad \text{Equation 3}$$

where: R = percent of particles removed
v_s = settling velocity
v_c = critical velocity
N = number of continuous stirred tank reactors (CSTRs) represented by the system as given in Table 7.2 (EPA, 2006)

The PLMT is conservative in that it only allows particle attenuation to occur once on the loading from each subwatershed. For example, the loading from subwatershed 301 will attenuate through Timothy Lake but not the remaining four reservoirs (Figure 5) because once a particle has fallen out it cannot fall out again.

Table 9: Pollutant partition coefficients used in the PLMT.

Pollutant[1]	% Dissolved	% Solid
TSS	0	1
TP	0.3	0.7
NO3	0.3	0.7
NH3	0.3	0.7
PB	0.35	0.65
CU	0.35	0.65
ZN	0.7	0.3
BOD	0.7	0.3
E. Coli	0.7	0.3
Glyphosate	0.2	0.8
2,4-D	0.7	0.3
Carbaryl	0.2	0.8
Oil & Grease	0.15	0.85

1. The highlighted values are taken from the WERF BMP Algorithm Report (Leisenring et al., 2013). The non-highlighted values are best estimates.

With the exception of TSS, Equation 3 does not calculate pollutant load reductions directly, but only the reduction due to adsorption (adhesion) of the pollutant to solids. Therefore, to determine the overall pollutant load reduction, the reduction in the amount of solids calculated by the equation was multiplied by the pollutant's solid percentage in Table 9. The overall pollutant load reductions are shown in Table 10.

Table 10: Pollutant load reductions (as percentages) per reservoir due to particle settling (attenuation)

Site	TSS	TP	NO3	NH3	PB	CU	ZN	BOD	E. Coli	Glyphosate	2,4-D	Carbaryl	Oil & Grease
Timothy Lake	0.998	0.699	0.699	0.699	0.649	0.649	0.299	0.299	0.299	0.799	0.299	0.799	0.848
Harriet Lake	0.406	0.284	0.284	0.284	0.264	0.264	0.122	0.122	0.122	0.324	0.122	0.324	0.345
North Fork	0.741	0.519	0.519	0.519	0.482	0.482	0.222	0.222	0.222	0.593	0.222	0.593	0.630
Faraday Diversion Pool	0.822	0.575	0.575	0.575	0.534	0.534	0.247	0.247	0.247	0.658	0.247	0.658	0.699
Faraday Lake	0.311	0.218	0.218	0.218	0.202	0.202	0.093	0.093	0.093	0.249	0.093	0.249	0.265
River Mill	0.487	0.341	0.341	0.341	0.317	0.317	0.146	0.146	0.146	0.390	0.146	0.390	0.414

Figure 5: Reservoirs where attenuation is applied in the PLMT with catchment 301 highlighted.

BMP performance within the PLMT is based on either the effluent quality (i.e. concentration) for a pollutant or, if there was insufficient data to estimate the effluent quality, an overall percent reduction for the pollutant. In order to ensure the overall percent reductions did not reduce loadings to unrealistic levels, minimum pollutant concentrations were identified to serve as lower limits in the model and are shown in Table 11.

Table 11: Minimum pollutant concentrations use in the PLMT.

Pollutant	Minimum Concentration
TSS, mg/L	8.1
TP, mg/L	0.09
NO3, mg/L	0.23
NH3, mg/L	0.03
PB, mg/L	0.001
CU, mg/L	0.0046
ZN, mg/L	0.017
BOD, mg/L	2.47
E. Coli, MPN/100 mL	300
Glyphosate, mg/L	0.00005
2,4-D, mg/L	0.00005
Carbaryl, mg/L	0.00005
Oil & Grease, mg/L	2.33

Table 12 provides an overview of the approach for modeling the BMP performance per pollutant. The BMP hydraulics provided in Table 12 are broken up into two categories: 1) Percent capture and 2) Percent reduction. Percent capture refers to the ability of the BMP to accept all incoming runoff. A percent capture of 100% indicates the BMP is able to treat the entire runoff volume. Percent reduction refers to the decrease in the runoff volume due to infiltration through the BMP. For example, if the annual runoff from a land use was 100,000 cubic feet before entering a BMP with a percent reduction of 10%, the annual runoff after exiting the BMP would be reduced by 10% to 90,000 cubic feet. The extra 10,000 cubic feet would have infiltrated into the soils surrounding the BMP, decreasing the pollutant loading for the land use. In some cases the BMP has no effect on the effluent concentration.

Table 12: The BMP hydraulics provided in the PLMT.

BMP Type Description	BMP Type	TSS	TP	NO3	NH3	CU	PB	ZN	BOD	Glyphosate	2,4-D	Carbaryl	Oil & Grease	E. Coli	Hydraulics % Capture	Hydraulics % Reduction
Nutrient Mgmt Plan (Ag)	1		0.20	0.20	0.20										100%	0%
Nutrient Mgmt Plan (Urban)	2		0.20	0.20	0.20										100%	0%
Integrated Pest Mgmt	3									0.20	0.20	0.20			100%	0%
Incentive Program	4		0.10	0.10	0.10				0.10					0.10	100%	0%
Conservation Buffer	5	16.35	0.18	0.44	0.11	0.0069	0.0020	0.0236	4.61	0.20	0.20	0.20	5.55	0.25	90%	0%
Streamside Mgmt Area	6	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	90%	0%
Water Quality Basin (detention, retention, wetland)	7	15.59	0.14	0.31	0.08	0.0047	0.0024	0.0243	6.32	0.50	0.50	0.50	2.34	0.60	90%	10%
Bioretention/Biofilter (swales, media strips, rain gardens)	8	13.85	0.15	0.34	0.11	0.0066	0.0022	0.0202	4.69	0.20	0.20	0.20	4.66	0.33	90%	25%
Media Filter	9	8.69	0.09	0.59	0.08	0.0060	0.0017	0.0179	4.85	0.25	0.25	0.25	6.30	0.60	90%	0%
Impervious Area Reduction	10	8.11	0.29	0.23	0.03	0.0102	0.0011	0.0201	2.48	0.20	0.20	0.20	2.86	0.25	90%	15%
Organic Farming	11		0.15	0.15	0.15				0.15	0.50	0.50	0.50			100%	0%
Drinking Water Protection Zones	12	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	100%	0%
Emergency Response Plan	13												0.25		100%	0%

% reduction

Effluent Concentration (mg/L)

BMP has no effect on the effluent concentration

The PLMT is run by using the following overall "procedure" for calculating loads when implementing BMPs.

The first step in the procedure is the PLMT checks if there is runoff from a subwatershed basin. If there is runoff then the procedure continues and if there is no runoff then the loading for the basin is set to zero for all representative pollutants.

The tool then checks if the influent water quality concentration (from the subwatershed) to the BMP is less than the minimum concentrations listed in Table 11. If it is, then the loading (post BMP) is set to the incoming runoff concentration. If it's not lower than the minimum the procedure continues and the PLMT then evaluates if the BMP performance is being assessed by effluent quality (concentration) or as a percent reduction (Table 12). This will vary depending on which representative pollutant that is being considered.

If the percent reduction approach applies for the representative pollutant in question, the tool checks if the percent reduction multiplied by the influent water quality concentration is less than the minimum concentration in Table 11. If it is less than the minimum concentration, the BMP effluent loading is estimated based on the runoff volume multiplied by the minimum water quality concentration in Table 11. If the percent reduction multiplied by the influent water quality concentration is not less than the minimum concentration (Table 11) then the loading equals the runoff volume multiplied by the percent reduction and the influent water quality.

If the BMP effluent quality concentration approach applies for a representative pollutant, the tool checks if the BMP effluent quality concentration is greater than the influent water quality concentration. If it is then the loading equals the runoff volume multiplied by the influent water quality concentration. If not then then loading equals the runoff volume multiplied by the effluent water quality concentration.

7. RESULTS AND DISCUSSION

First a baseline of an "existing conditions" scenario was developed and run to assess the current loadings in the watershed for the 13 representative pollutants.

7.1 Existing Conditions

The existing conditions scenario was developed to create a baseline condition with no structural or programmatic BMPs in the watershed. The purpose of the scenario is to understand the cumulative impacts from the various land use pollutant sources and therefore risks to the downstream drinking water supplies.

As described above, current land uses and watershed characteristics were used to develop estimates of current pollutant loading in the subwatersheds. The model directly builds off the previously completed Geodatabase and independent risks and loadings from septic systems, agriculture, forestry, vulnerable soils, urban development, and point sources of pollution. The existing conditions scenario considers these various categories of risks by focusing on the seven types of pollutants within the PLMT: (1) Soils, (2) Organic matter, (3) Nutrients, (4) Heavy metals, (5) Pathogens, (6) Pesticides, and (7) Hydrocarbons. Figures 6 through 10 show the model results for these seven types of pollutants.

It should be noted that the annual pollutant loading calculated by the PLMT and presented in the GIS maps is the loading from the individual subwatersheds and not the cumulative loading from the all points upstream.

Figure 6 compares annual loads (lbs) for three heavy metals: copper (Cu), lead (Pb), and zinc (Zn). While the color scales are different between the metals loading in each panel, all three panels show that metals loading is heaviest in the downstream reaches where there is higher density urban development and more transportation corridors. It should be noted that the loading scale for copper is the smallest and zinc is the largest. Sources of zinc include roofs and other galvanized materials, tires and industrial uses, among others. The heavy metal loading is the heaviest in the subwatersheds that contribute to the Lower Clackamas River below River Mill Dam (red line shown in the middle panel).

Figure 7 compares annual loads (lbs) for nutrients: ammonia (NH3), nitrate-nitrite (NO3), and total phosphorus (TP). The figure show similar results for metals in that the highest concentrations are in the subwatersheds that contribute flow and loadings below River Mill Dam. Loads are the highest for nitrates due to the septic systems loading and fertilizers. Loadings of ammonia and total phosphorus are due to fertilizer use for both agriculture urban landscaping.

Figure 8 shows the loading results for three pesticides: Glyphosate, 2,4-D, and Carbaryl. The figure indicates there is an increase in loading for all three pesticides in the lower watershed which is dominated by urban development and agriculture. Further up in the watershed there is a large reduction in pesticides loading because of the land use shift to forestry in the Mt Hood National Forest. Similar to the results for metals and nutrients the higher concentrations occur in subwatersheds contributing loading to the Lower Clackamas River below River Mill Dam.

Figure 9 shows annual loading results for oil and grease (hydrocarbons) and total suspended solids (TSS, soils). The figure also shows the location of highways and State Routes in the right panel. Both panels show the highest loading from the subwatersheds which are lower in the basin, and increased loading even in forested areas is due to transportation corridors (Access). The left panel shows the loading of oil and grease tends to be higher near urban development (residential and commercial) and transportation corridors.

As noted previously in the report, TSS is attenuated as the sediment particles settle out of the multiple reservoirs. However, the loadings from the subwatersheds contributing to the Lower Clackamas River do not have the opportunity to settle out, as they are located downstream of all of the reservoirs. TSS loading is often derived from roads, urbanization (residential and commercial), and agriculture.

Figure 10 shows maps of the annual loading from pathogens (E. Coli) in the left panel and organic matter (biochemical oxygen demand, BOD) in the right panel. E. Coli sources include pets, wildlife, and domesticated animal wastes and can be influenced by urban development, parks with pet access, failing septic systems and agriculture. The BOD loading follows a similar pattern to E. Coli and both are a little more distributed in the basin than TSS or nutrients. BOD loads are higher in the lower basin (urbanization) as expected, but also higher in the subwatersheds with transportation corridors and agriculture.

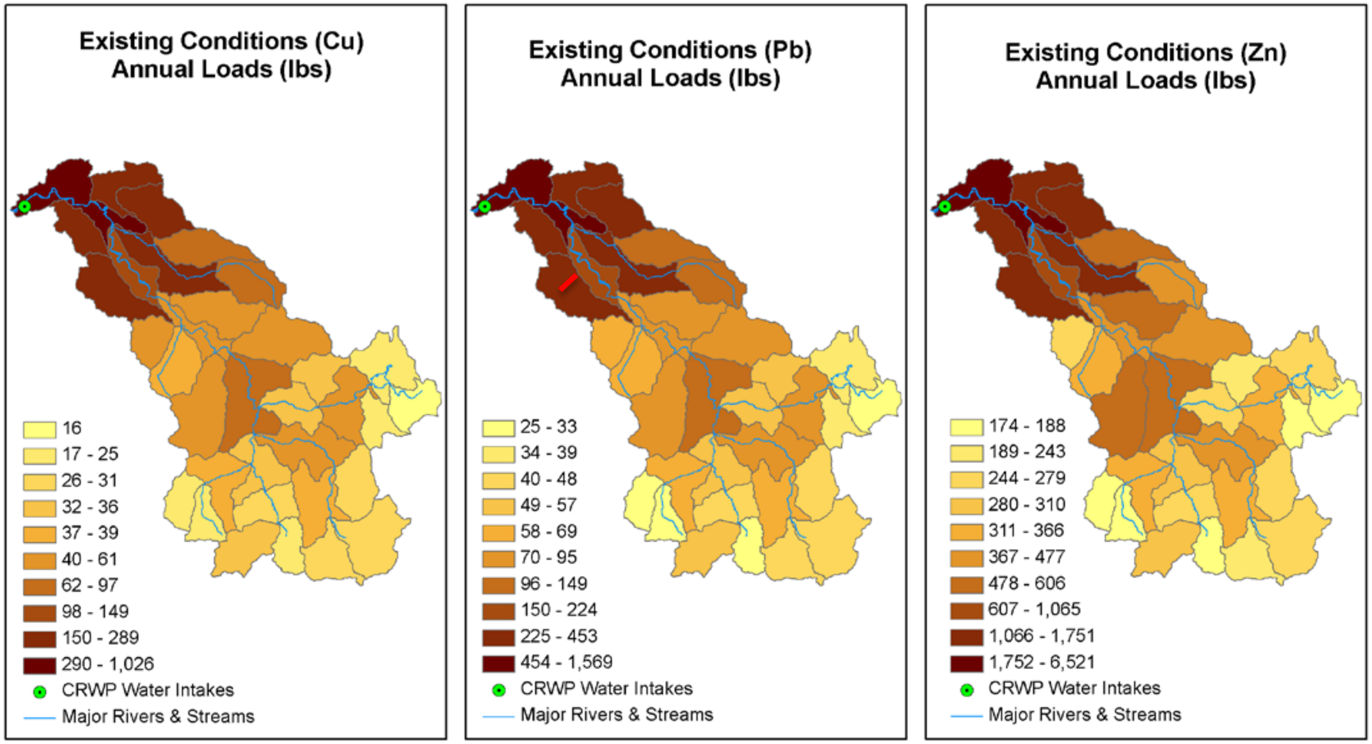

Figure 6: Existing conditions maps – heavy metals. The red line in the middle map represents River Mill Dam.

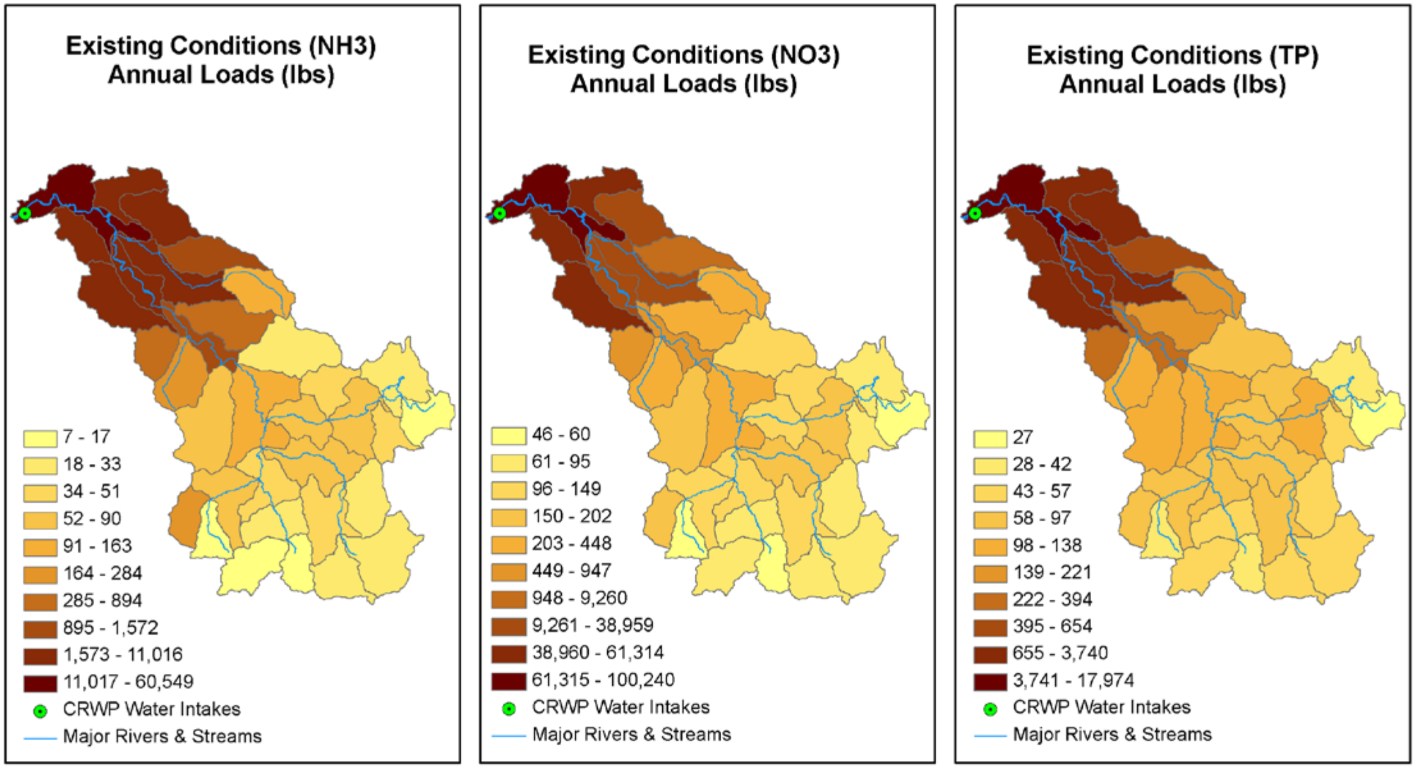

Figure 7: Existing conditions maps – Nutrients.

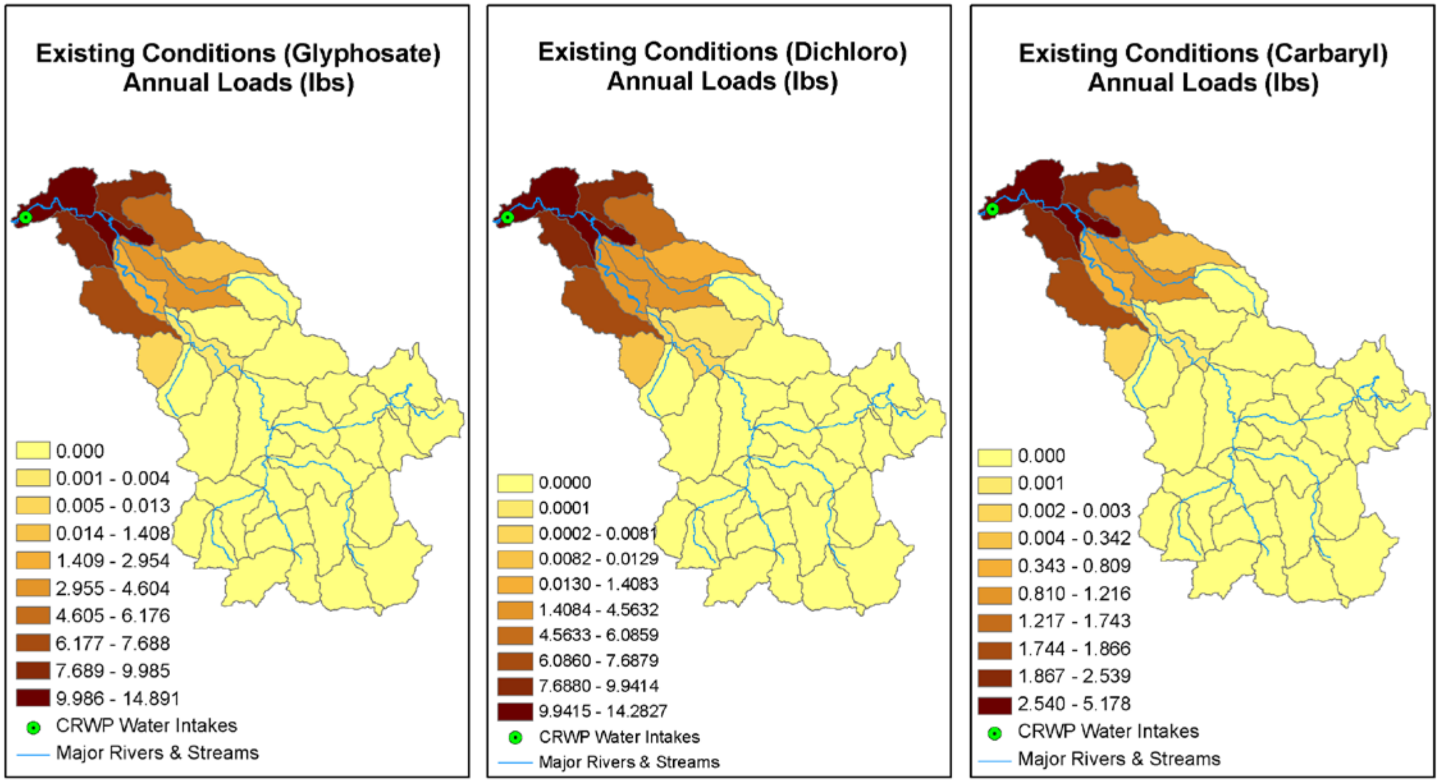

Figure 8: Existing conditions maps – Pesticides.

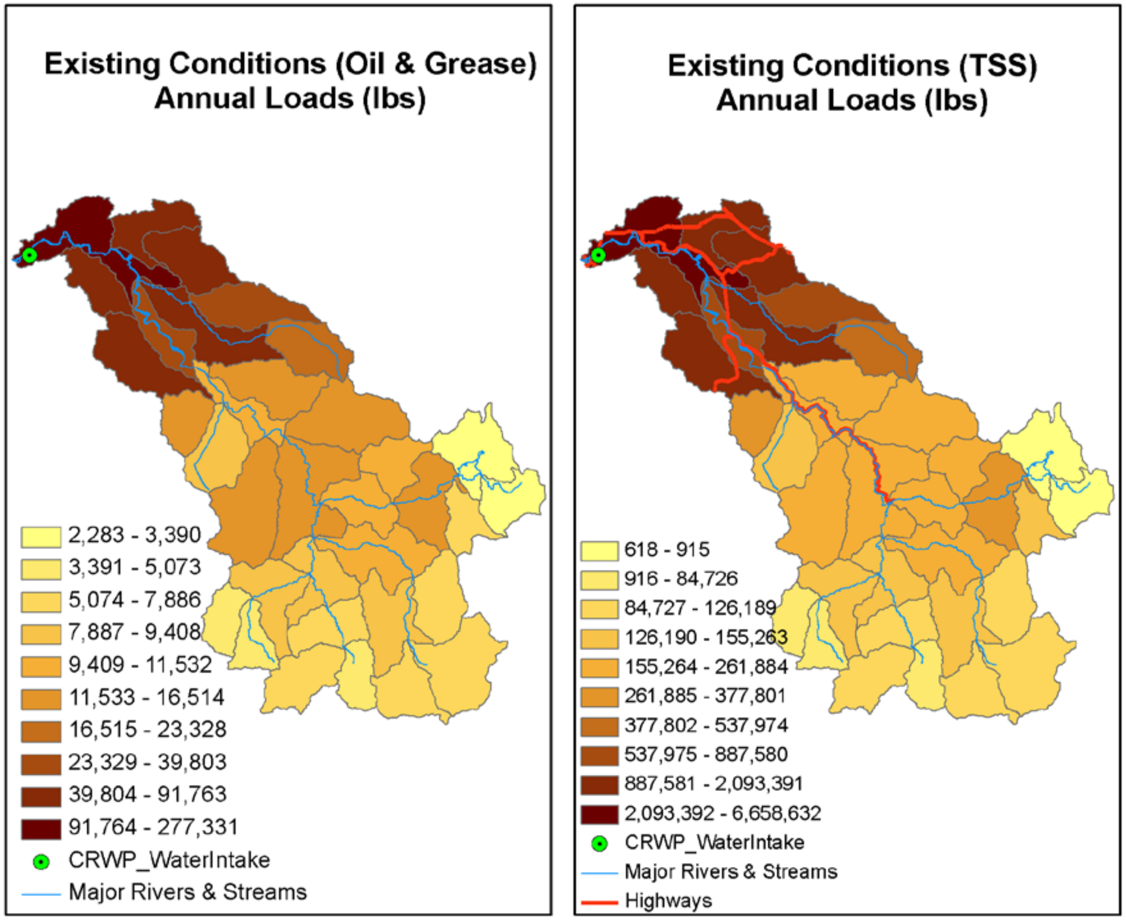

Figure 9: Existing conditions maps – Hydrocarbons and Soils (oil & grease, and TSS).

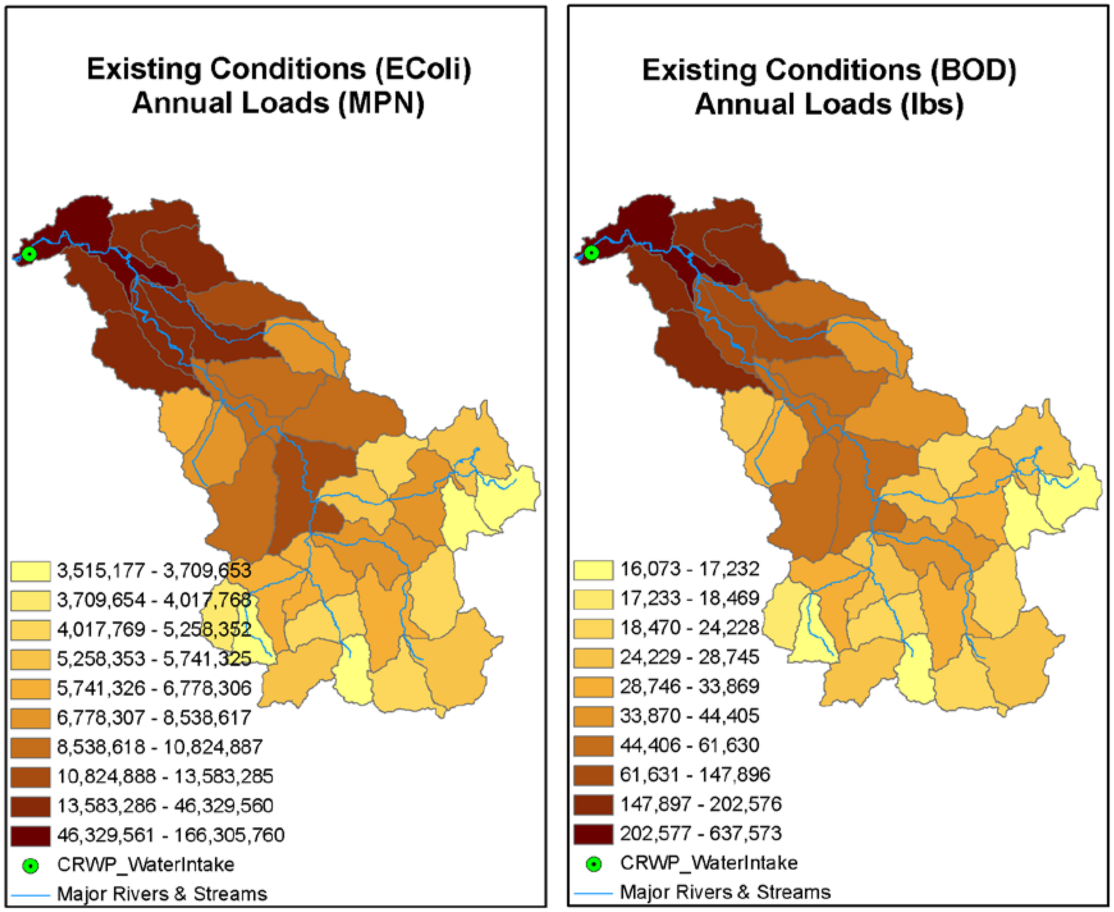

Figure 10: Existing conditions maps - Pathogens and Organic Matter (E. Coli and BOD).

7.2 Summary Findings

Overall the existing conditions simulation results indicate the majority of the pollutant loading is occurring in the subwatersheds contributing flows to the Lower Clackamas River below River Mill Dam, even though some of these subwatersheds have the majority of their basin areas above River Mill Dam. The effects of the reservoirs have considerable impact on reducing the soils/sediment loading from the upstream watershed.

Land uses such as urban development, agriculture and forestry each result in pollutant loading but their impacts vary depending on the pollutant in question. For example, pesticides are dominated by urban development and agriculture where as TSS and BOD are more distributed due to land uses that exist throughout more of the watershed.

7.3 Management Scenarios

Four broad categories of management scenarios were performed using the PLMT to investigate the efficacy of some BMPs (Table 2) and their respective costs. In addition to investigating the effects of complete implementation of the septic system incentive program, three management scenarios were performed to determine possible load reductions for three pollutant groups: heavy metals, nutrients, and pesticides.

Presented below are a series of tables describing the PLMT annual load reductions from implementing BMPs. While these scenario comparisons are informative to evaluate the relative performance of the various BMPs and their implementation costs, it should be noted that the results represent “full” implementation, which may take years to implement and achieve these results. This has implications not just for load reductions but also for the estimated cost.

7.3.1 Cost Estimates for BMP Implementation

The cost estimating analysis recognizes that the Water Resources Manager and the CRWP do not have the authority to implement the majority of these BMPs; the implementation of which means collaborating with various stakeholders and local, regional and federal agencies. As a result, BMP implementation for the CRWP involves outreach, building relationships, meetings, workshops and developing education or outreach materials. Hourly estimates and hourly salary costs were provided by the Water Resources Manager to develop the cost estimates.

An estimated cost is included for each management scenario and consists of the estimated non-construction costs for BMP implementation. To determine the cost, five categories were considered: 1) Meetings, 2) Workshops, 3) Phone conversations, 4) Email correspondence, and 5) Brochures. The first four categories costs were determined by estimating the number of hours the Water Resources Manager might spend on those tasks and using an hourly salary rate cost. The brochure cost was set at $2,500 for the design and printing of 3,000 brochures. Both the hourly rate and brochure cost can be revised in the PLMT.

7.3.2 Scenario Results

7.3.2.1 Septic System Incentive Program

The first scenario tested in the PLMT was to examine the representative pollutant load reductions for all residential land uses with septic systems if a septic system incentive program was implemented. The scenario assumes 100% implementation across the applicable residential land uses in the watershed.

Table 13 lists the percentage reduction in annual loading for three nutrients (TP, NO3, and NH3), BOD, and E. Coli. A reduced loadings map for NH3, compared to the existing conditions map, is provided in Figure 11 in the Appendix. Table 13 shows that 100% implementation of the septic system incentive program across the watershed would result in 0.5% to 3.3% reduction in nutrients and a roughly 1.5% reduction in BOD and E. Coli. The estimated cost is roughly $28,000.

Table 13: Septic incentive program scenario results

Land Use	BMP	Percent Implementation	Percent Reduction					Estimated Cost
			TP	NO3	NH3	BOD	E. Coli	
RES	Incentive Program - Septic	100	2.7%	0.5%	3.3%	1.4%	1.7%	$27,648

7.3.2.2 Metals

The heavy metals management scenario focuses primarily on zinc reduction. Of the three heavy metals included in the PLMT, zinc loadings were over four times greater than those for lead and close to seven times greater than copper loadings. The major sources of heavy metals in the PLMT are urbanization and Access (through transportation corridors). The land uses with the highest heavy metal EMCs are commercial, residential, and transportation and the subwatersheds with the largest acreages of these land uses are located in the lower basin (503, and 602 to 607). There are several BMPs which can be applied to the urban development sources including water quality basins, bioretention, and impervious area reduction (IAR). Of these, IAR provides the best effluent quality for zinc based on current data (Geosyntec et al., 2012). There are two programmatic BMPs and one structural BMP which could be applied to Access sources. One of the programmatic BMPs (Emergency Response Plan) only impacts oil & grease loadings and is not warranted for the reduction of heavy metals. The other programmatic BMP (Drinking Water Protection Zone) necessitates a considerable amount of cooperation and education. Therefore, the management scenarios will base reductions with the incorporation of media filters along roadways to address Access loadings.

A total of seven scenarios were tested in the PLMT to examine combinations of BMPs implemented for different land uses. In all scenarios the BMPs were assumed to be implemented 100% across the key subwatersheds identified above. Table 14 lists the percentage reduction (compared to existing conditions) in the annual loadings for lead, copper and zinc under the seven metals management scenarios. There are several ways to evaluate the efficacy of the different scenarios. One approach is to compare the highest load reductions relative to the estimated cost (scenario 1). But it should be noted that the estimated cost does not reflect the full cost of implementation which means that some scenarios may cost the CRWP less, but partner agencies may need to spend a lot more resources to achieve implementation.

Existing loading and reduced loading maps for zinc are provided in Figure 12 in the Appendix. The reduced loadings shown are based on implementation of scenarios 1 and 2.

Table 14: Metals management scenario results

Scenario	Land Use	BMP	Percent Implement-ation	Percent Reduction			Estimated Cost
				Lead	Copper	Zinc	
1	COM RES	Bioretention Bioretention	100 100	19.7%	16.1%	20.0%	$31,248
2	COM	IAR	100	10.5%	7.1%	9.8%	$33,600
3	RES	IAR	100	9.4%	4.6%	9.6%	$33,600
4	COM RES	IAR Bioretention	100 100	19.7%	14.5%	19.8%	$49,224
5	COM RES	IAR IAR	100 100	20.0%	11.7%	19.4%	$67,200
6	COM RES TRA1	IAR Bioretention Media Filter	100 100 100	21.1%	15.5%	21.0%	$85,056
7	TRA1 TRA2 TRA3	Media Filter Media Filter Media Filter	100 100 100	8.7%	6.5%	7.9%	$107,496

7.3.2.3 Nutrients

The nutrient management scenarios focused on three representative pollutants (TP, NO3, and NH3) from three key sources: urbanization, agriculture, and access through transportation corridors. The land uses associated with these sources are as follows: Urbanization through residential, commercial and public space land uses; Agriculture; and Access through transportation land use categories 1 to 4, which represent all of the paved roads.

Each of these land uses has an EMC which drives the nutrient loading. A major source of NO3 is agriculture, which has an EMC of 2.45 mg/L. This is then followed by access, with an EMC of 1.53 mg/L. Access is also the major source of ammonia (EMC = 1.72 mg/L) followed by urbanization (EMCs = 0.74 – 1.56 mg/L). The major land use source for TP is urbanization and associated land uses.

A total of 10 nutrient management scenarios were developed in the PLMT to test several different BMPs and mix and match them for different land uses. The BMPs explored in the PLMT for nutrient load reductions were implemented in the lower basin subwatersheds and includes: Conservation Buffer, IAR, Media Filter, Nutrient Management Plans, and Organic Farming.

Table 15 lists the percentage reduction (compared to existing conditions) in annual loadings for total phosphorus, nitrates and ammonia under the 10 management scenarios. The table also lists the cost to the CRWP for implementing each management scenario. One of the more cost effective scenarios (based dollars/percent reduction in nutrients) is scenario 6 where three BMPs are implemented in combination resulting in significant reductions in TP, NO3, and NH3 loadings (7%, 20%, and 20%, respectively). But scenarios 1 through 3 also provided cost effective reductions in nutrients such as NO3 and NH3 but no reduction in TP. This is due to the influent concentration of TP being lower than the BMP effluent concentrations under the agriculture land use.

Existing loading and reduced loading maps (for scenarios 1 and 6) for NO3 are provided in Figure 13 in the Appendix.

Table 15: Nutrients management scenarios results

Scenario	Land Use	BMP	Percent Implementation	Percent Reduction			Estimated Cost
				TP	NO3	NH3	
1	AGR	Conservation Buffer	85	0.0%	55.5%	1.2%	$41,824
2	AGR	Organic Farming	100	0.0%	13.3%	3.5%	$45,792
3	AGR	Nutrient Mgmt Plan	100	0.0%	17.7%	4.6%	$47,776
4	RES	Nutrient Mgmt Plan	100	4.0%	0.7%	5.0%	$18,600
5	RES	Nutrient Mgmt Plan IAR	50 50	7.2%	1.8%	15.6%	$52,200
6	RES AGR	Nutrient Mgmt Plan IAR Nutrient Mgmt Plan	50 50 100	7.2%	19.5%	20.2%	$99,976
7	RES AGR	Nutrient Mgmt Plan IAR Nutrient Mgmt Plan	50 50 100	7.7%	19.7%	21.5%	$135,808

Scenario	Land Use	BMP	Percent Implementation	Percent Reduction			Estimated Cost
				TP	NO3	NH3	
8	TRA 1	Media Filter	85				
	RES	Nutrient Mgmt Plan	50	7.2%	43.3%	18.6%	$141,800
	AGR	IAR	50				
		Nutrient Mgmt Plan	50				
		Conservation Buffer	50				
9	RES	Nutrient Mgmt Plan	50	11.9%	20.6%	29.2%	$152,176
	AGR	IAR	50				
		Nutrient Mgmt Plan	100				
	COM	Nutrient Mgmt Plan	50				
		IAR	50				
10	RES	Nutrient Mgmt Plan	50	11.9%	44.4%	27.6%	$194,000
	AGR	IAR	50				
		Nutrient Mgmt Plan	50				
		Conservation Buffer	50				
	COM	Nutrient Mgmt Plan	50				
		IAR	50				

7.3.2.4 Pesticides

Urbanization and agriculture land uses are the two major sources of pesticides loading in the watershed. Agriculture EMC's are approximately twice the value of urban EMC's for all three pesticides considered. As a result the focus of the pesticides management scenarios was placed on the agricultural land use.

A total of four pesticide management scenarios were developed in the PLMT to test several different BMPs and mix and match them for different land uses. The BMPs explored in the PLMT for nutrient load reductions includes: Bioretention facilities; Conservation Buffers; Integrated Pest Mgmt Plans; Organic Farming; and Water Quality Basins. These BMPs were implemented in the lower basin subwatersheds where the majority of urbanization and agriculture is located.

Table 16 lists the percentage reduction (compared to existing conditions) in annual loadings for Glyphosate, 2,4-D and Carbaryl for the four management scenarios, as well as the estimated implementation cost for CRWP.

The table shows the most cost effective (dollars per % reduction) scenario is scenario 1 which includes Integrated Pest Management Plans and Organic Farming BMPs. Additional pesticide load reductions can be achieved but the increase in cost is much greater than any increase in load reductions when compared to those presented by scenario 1.

Existing loading and reduced loading maps for 2,4-D are provided in Figure 14 in the Appendix. The reduced loading maps are based on scenarios 1 and 4.

Table 16: Pesticides management scenario results

Scenario	Land Use	BMP	Percent Implem-entation	Percent Reduction			Estimated Cost
				Glyphosate	2,4-D	Carbaryl	
1	AGR	Integrated Pest Mgmt Organic Farming	50 50	33.3%	33.6%	30.5%	$91,584
2	AGR RES	Integrated Pest Mgmt Organic Farming Bioretention	50 50 85	34.5%	34.5%	33.4%	$107,208
3	AGR RES	Integrated Pest Mgmt Organic Farming Water Quality Basin	50 50 85	34.8%	34.3%	32.9%	$112,416
4	AGR	Integrated Pest Mgmt Organic Farming Conservation Buffer	40 40 20	30.0%	30.3%	27.6%	$133,408

8. SUMMARY

8.1 Existing Conditions

Overall the existing conditions simulation results indicate:

- The majority of the pollutant loading is occurring in the subwatersheds contributing flow to the Lower Clackamas River below River Mill Dam,
- The reservoirs have considerable impact on reducing the soils/sediment loading from the upstream watershed.
- Land uses such as urban development, agriculture and forestry each result in pollutant loading but their impacts vary depending on the pollutant in question.

8.2 BMP Management Scenarios

Four groups of management scenarios were explored to investigate the effectiveness of multiple BMPs on reducing nutrient, organic matter, metals, pesticides and pathogen loading to the Clackamas River.

If a septic system incentive program was implemented in 100% of subwatersheds on residential land uses with septic systems then there would be a small reduction in nutrient, BOD and E. Coli loading to the river.

The heavy metals management scenarios, focused on zinc reduction, illustrated the importance of addressing both commercial and residential land uses. A 100% implementation of either the impervious area reduction or bioretention BMPs in these land uses within the lower basin (subwatersheds 503 and 602 to 607) would reduce loadings by approximately 10% per land use. When Access was included in scenario 6 (TRA1) with a 100% implementation of media filters, the reduction in zinc loadings only increased by approximately 1%, whereas the estimated cost increased by 115% (compared with scenario 1) or 37% (compared with scenario 3).

The nutrients management scenarios primarily dealt with loadings from two land uses, agriculture and residential. The inclusion of Access with the transportation land uses did not provide a large benefit to cost ratio, as shown by comparing the results for scenarios 6 and 7. If nitrates are a primary concern, implementation of conservation buffers in agricultural land provides the greatest reduction potential. If total phosphorus or ammonia is the primary concern, implementation of BMPs in residential land uses should be considered.

Pesticides management should focus primarily in agricultural land uses. Substantial load reductions for all three pesticides of concern is achieved with the implementation of integrated pest management and organic farming BMPs. Inclusion of additional BMPs only increase load reductions by approximately 1% while the cost estimates increase by approximately $15,000 or 17% at least.

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APPENDIX

Table 17: SWMM input parameters and resultant runoff coefficients

Land use	HUC	Acres	Percent Impervious	Ksat (in/hr.)	Runoff Coefficient
FOR	101	10,195	2.75	0.607	0.028
TRA4	101	2.6	3.32	0.995	0.033
TRA5	101	13.1	3.04	0.328	0.030
TRA3	102	3.0	0.00	0.995	0.000
FOR	102	9,629	2.78	0.579	0.028
OPS	102	860	3.81	0.933	0.038
TRA4	102	4.4	2.76	0.662	0.028
TRA5	102	59	2.60	0.599	0.026
FOR	103	18,019	2.77	0.723	0.028
OPS	103	146	4.04	0.994	0.040
TRA4	103	24.1	3.06	0.871	0.031
TRA5	103	78	2.28	0.752	0.023
FOR	104	17,163	2.61	0.684	0.026
TRA5	104	0.4	1.61	0.995	0.016
FOR	105	10,355	2.64	0.629	0.026
TRA4	105	0.8	2.23	0.315	0.022
TRA5	105	32.8	2.73	0.652	0.027
FOR	106	14,484	2.68	0.728	0.027
TRA4	106	6.7	2.92	0.747	0.029
TRA5	106	40	2.49	0.645	0.025
FOR	107	16,212	2.87	0.773	0.029
TRA4	107	26.6	3.24	0.942	0.032
TRA5	107	84	2.21	0.732	0.022
FOR	201	14,800	2.50	0.604	0.025
TRA4	201	20.6	2.45	0.452	0.025
TRA5	201	51	2.76	0.605	0.028
FOR	202	25,864	1.64	0.899	0.016
TRA4	202	14.8	2.38	0.690	0.024
TRA5	202	65	1.57	0.869	0.016
FOR	203	19,621	2.60	0.753	0.026
TRA4	203	28.4	3.12	0.898	0.031
TRA5	203	76	2.52	0.765	0.025
FOR	204	17,289	2.32	0.698	0.023
TRA4	204	28.7	2.47	0.635	0.025

Land use	HUC	Acres	Percent Impervious	Ksat (in/hr.)	Runoff Coefficient
TRA5	204	51	2.19	0.702	0.022
FOR	205	22,804	2.84	0.640	0.028
TRA4	205	40.1	3.24	0.941	0.032
TRA5	205	112	2.62	0.545	0.026
FOR	301	13,532	2.28	0.994	0.023
TRA4	301	18.6	1.59	0.995	0.016
TRA5	301	40.2	2.51	0.995	0.025
FOR	302	20,813	2.22	0.914	0.022
OPS	302	14.0	4.04	0.995	0.040
TRA4	302	33.0	1.62	0.963	0.016
TRA5	302	104	2.50	0.983	0.025
FOR	303	10,064	2.28	0.993	0.023
TRA4	303	9.5	1.59	0.995	0.016
TRA5	303	64	2.51	0.995	0.025
FOR	304	12,578	2.54	0.695	0.025
TRA4	304	14.1	2.27	0.642	0.023
TRA5	304	67	2.69	0.730	0.027
FOR	305	18,745	2.55	0.762	0.026
TRA4	305	13.4	1.92	0.769	0.019
TRA5	305	131	2.65	0.727	0.027
FOR	306	14,033	2.83	0.761	0.028
TRA1	306	2.5	7.97	0.995	0.080
TRA4	306	41	3.25	0.951	0.033
TRA5	306	90	2.01	0.843	0.020
FOR	401	31,312	2.87	0.790	0.029
TRA1	401	33.3	9.50	0.995	0.095
TRA4	401	26.4	3.32	0.995	0.033
TRA5	401	168	2.25	0.721	0.023
FOR	402	27,250	2.74	0.672	0.027
TRA1	402	0.1	18.79	0.995	0.188
TRA5	402	44	2.73	0.574	0.027
FOR	403	29,400	2.84	0.600	0.028
OPS	403	337	2.88	0.684	0.029
TRA4	403	11.1	2.85	0.790	0.029
TRA5	403	42	2.57	0.706	0.026

Land use	HUC	Acres	Percent Impervious	Ksat (in/hr.)	Runoff Coefficient
FOR	404	15452.8	3.28	0.654	0.033
OPS	404	2071.4	1.94	0.644	0.019
TRA4	404	43.4	2.42	0.499	0.024
TRA5	404	81.0	2.75	0.496	0.028
TRA3	405	6.6	13.00	0.995	0.130
AGR	405	0.8	3.44	0.995	0.034
FOR	405	19896.3	3.56	0.820	0.036
OPS	405	626.8	13.84	0.995	0.138
TRA1	405	0.4	18.79	0.995	0.188
TRA4	405	16.4	3.08	0.859	0.031
TRA5	405	86.2	2.17	0.760	0.022
TRA3	406	7.8	16.59	0.995	0.166
AGR	406	13.0	11.83	0.995	0.118
FOR	406	10107.1	5.27	0.982	0.053
OPS	406	1494.6	13.84	0.995	0.138
TRA1	406	59.7	18.79	0.995	0.188
TRA4	406	10.1	3.13	0.995	0.031
TRA5	406	24.6	2.07	0.944	0.021
TRA3	501	0.7	16.59	0.995	0.166
AGR	501	0.4	0.00	0.995	0.000
FOR	501	16643.4	2.92	0.584	0.029
OPS	501	661.1	1.49	0.906	0.015
TRA4	501	17.9	2.50	0.481	0.025
TRA5	501	15.4	2.36	0.642	0.024
TRA3	502	128.6	14.16	0.995	0.142
AGR	502	2914.7	11.50	0.995	0.115
FOR	502	12919.0	5.15	0.964	0.051
OPS	502	1866.6	5.95	0.995	0.060
TRA4	502	11.8	3.10	0.858	0.031
TRA5	502	1.5	2.28	0.676	0.023
TRA3	503	259.0	20.66	0.861	0.207
AGR	503	7567.6	13.91	0.815	0.139
COM	503	114.7	58.80	0.368	0.589
FOR	503	12311.4	6.55	0.965	0.066
OPS	503	1684.8	10.24	0.975	0.102
RES	503	403.3	33.20	0.956	0.332

Land use	HUC	Acres	Percent Impervious	Ksat (in/hr.)	Runoff Coefficient
TRA1	503	12.6	44.13	0.315	0.444
TRA5	503	0.6	1.61	0.995	0.016
TRA3	601	27.4	14.93	0.995	0.149
AGR	601	26.0	11.83	0.995	0.118
FOR	601	9631.1	4.83	0.958	0.048
OPS	601	2525.0	4.17	0.807	0.042
TRA4	601	6.0	3.10	0.995	0.031
TRA5	601	23.0	2.34	0.660	0.023
TRA2	602	17.1	16.57	0.494	0.166
TRA3	602	194.1	21.77	0.663	0.218
AGR	602	10577.0	17.32	0.653	0.173
FOR	602	9080.3	8.34	0.753	0.083
OPS	602	1907.6	20.78	0.601	0.208
TRA1	602	16.2	18.79	0.995	0.188
TRA5	602	0.9	3.26	0.995	0.033
TRA2	603	8.6	14.61	0.990	0.146
TRA3	603	235.6	21.96	0.887	0.220
AGR	603	6757.4	13.93	0.915	0.139
COM	603	209.1	57.39	0.483	0.574
FOR	603	3599.9	8.54	0.983	0.085
OPS	603	1389.1	22.95	0.940	0.229
RES	603	395.1	35.74	0.798	0.357
TRA1	603	38.9	22.55	0.894	0.226
TRA3	604	320.6	17.50	0.896	0.175
AGR	604	10340.2	13.24	0.906	0.132
COM	604	396.3	49.56	0.517	0.496
FOR	604	5217.8	7.69	0.853	0.077
OPS	604	606.3	14.26	0.971	0.143
RES	604	915.6	32.28	0.933	0.323
TRA1	604	50.8	25.08	0.783	0.251
TRA2	605	19.5	22.87	0.315	0.231
TRA3	605	225.6	24.73	0.439	0.247
AGR	605	11239.9	20.72	0.460	0.207
COM	605	185.6	47.80	0.315	0.479
FOR	605	1202.2	9.89	0.381	0.099
OPS	605	301.1	25.49	0.315	0.256

Land use	HUC	Acres	Percent Impervious	Ksat (in/hr.)	Runoff Coefficient
RES	605	485.9	29.50	0.333	0.296
TRA1	605	66.5	39.54	0.319	0.397
TRA2	606	46.5	25.44	0.420	0.255
TRA3	606	159.6	29.39	0.332	0.295
AGR	606	9953.6	21.49	0.338	0.215
COM	606	11.7	47.79	0.315	0.480
FOR	606	1574.0	11.09	0.319	0.112
OPS	606	328.7	26.68	0.324	0.268
RES	606	415.5	29.42	0.315	0.296
TRA2	607	31.8	32.66	0.503	0.327
TRA3	607	768.0	34.59	0.463	0.346
AGR	607	14380.0	19.89	0.559	0.199
COM	607	2046.3	55.89	0.345	0.559
FOR	607	3521.9	11.65	0.656	0.116
OPS	607	1258.3	28.05	0.527	0.281
PUB	607	80.7	42.68	0.322	0.428
RES	607	5108.8	38.94	0.413	0.389
TRA1	607	154.5	50.35	0.469	0.504

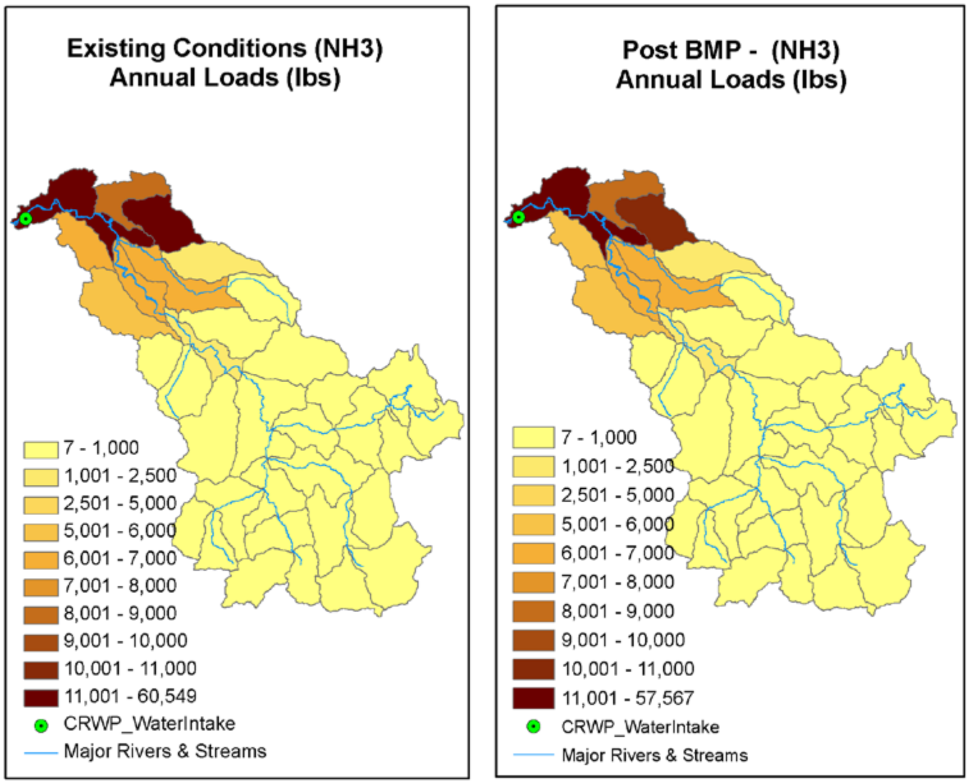

Figure 11: Septic management scenario - Ammonia (NH3) results

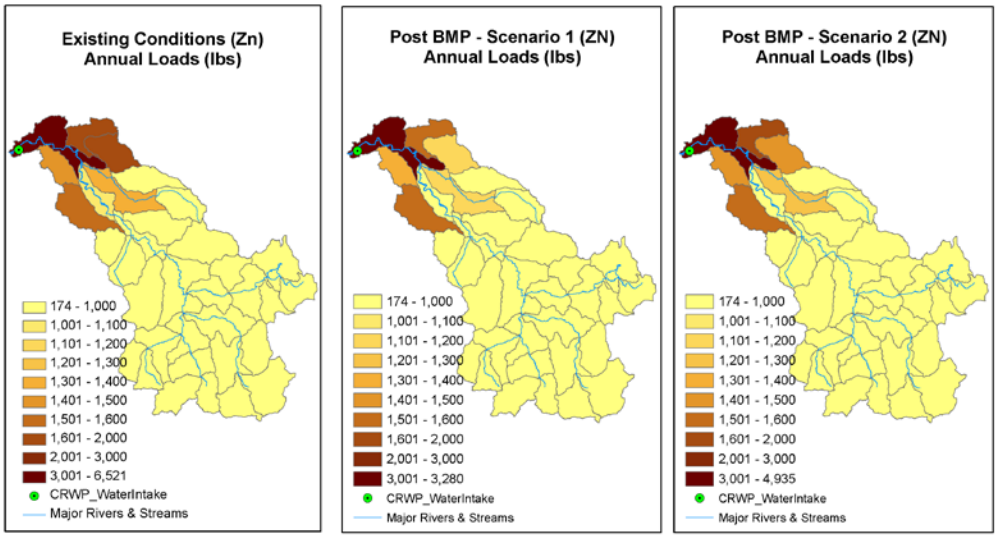

Figure 12: Metals management scenario - Zinc (ZN) results

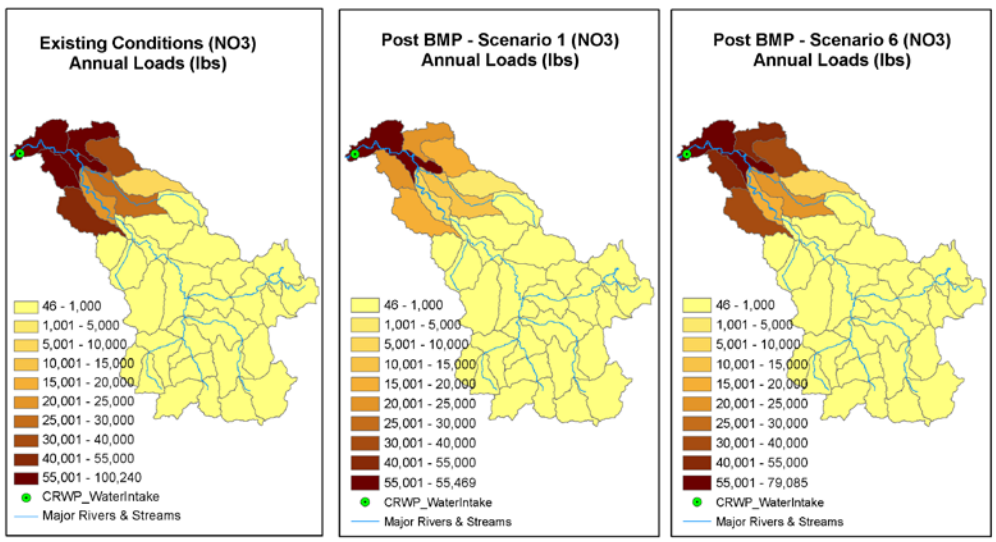

Figure 13: Nutrients management scenarios - Nitrate (NO3) results

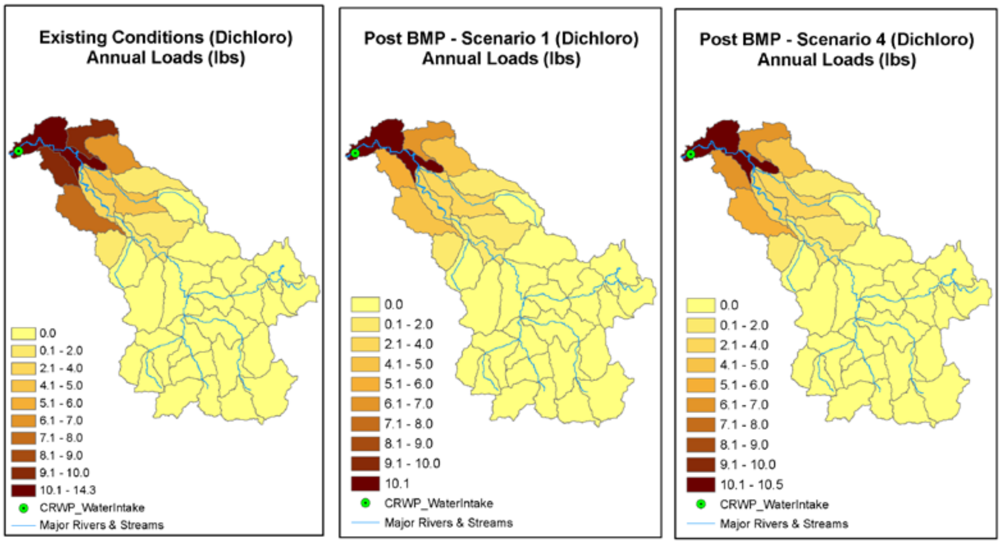

Figure 14: Pesticides management scenario - 2,4-D (Dichloro) results