Palouse River Subbasin

TMDL Five-Year Review

Final

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TMDL Five-Year Review

April 2016

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Executive Summary

This document presents a 5-year review of the *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load* (1998), *Palouse River Tributaries Subbasin Assessment and TMDL* (DEQ 2005a), *Cow Creek Subbasin Assessment and Nutrient Total Maximum Daily Load* (2005b), and *South Fork Palouse River Watershed Assessment and TMDLs* (2007). This review addresses the water bodies in the Palouse River subbasin that are in Category 4(a) of Idaho's most recent Integrated Report. In compliance with Idaho Code §39-3611(7), the review describes current water quality status, pollutant sources addressed by established total maximum daily loads (TMDLs), and recent pollution control efforts in the Palouse River subbasin to address the TMDLs. The TMDLs subject to 5-year review are shown in Table A.

Table A. Existing TMDL's general status.

Assessment Unit Name	Assessment Unit Number	Pollutant	TMDL Approval Year	Implementation Plan	Implementation Activities
Cow Creek—source to Idaho/Washington border[a]	ID17060108CL001_02	Nutrients (TP), temperature	2006, 2014	Yes	Yes
Cow Creek—source to Idaho/ Washington border[a]	ID17060108CL001_03	Nutrients (TP), temperature	2006, 2014	Yes	Yes
South Fork Palouse River—Gnat Creek to Idaho/ Washington border[b]	ID17060108CL002_03	Sediment (TSS), temperature, bacteria (*E coli*), nutrients (TP)	2007	Yes	Yes
South Fork Palouse River—source to Gnat Creek; tributaries[b]	ID17060108CL003_02	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP)	2007	Yes	Yes
South Fork Palouse River—source to Gnat Creek[b]	ID17060108CL003_03	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP)	2007	Yes	Yes
Paradise Creek—urban boundary to Idaho/ Washington border[c]	ID17060108CL005_02	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP), ammonia	1998	Yes	Yes
Paradise Creek—forest habitat boundary to urban boundary[c]	ID17060108CL005_02a	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP), ammonia	1998	Yes	Yes
Idlers Rest Creek—source to forest habitat boundary[c]	ID17060108CL005_02b	Sediment (TSS), temperature, nutrients (TP), ammonia	1998	Yes	Yes

Assessment Unit Name	Assessment Unit Number	Pollutant	TMDL Approval Year	Implementation Plan	Implementation Activities
Flannigan Creek—source to T41N, R05W, Sec. 23[d]	ID17060108CL011a_02	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP)	2005	Yes	Yes
Flannigan Creek—source to T41N, R05W, Sec. 23[d]	ID17060108CL011a_03	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP)	2005	Yes	Yes
Flannigan Creek—T41N, R05W, Sec. 23 to mouth[d]	ID17060108CL011b_02	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP)	2005	Yes	Yes
Flannigan Creek—T41N, R05W, Sec. 23 to mouth[d]	ID17060108CL011b_03	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP)	2005	Yes	Yes
Rock Creek—confluence of WF and EF Rock Creek to mouth[d]	ID17060108CL012_03	Sediment (TSS), bacteria (*E. coli*)	2005	Yes	None known
West Fork Rock Creek—source to T41N, R04W, Sec. 30[d]	ID17060108CL013a_02	Sediment (TSS), bacteria (*E. coli*)	2005	Yes	None known
West Fork Rock Creek—T41N, R04W, Sec. 30 to mouth[d]	ID17060108CL013b_03	Sediment (TSS), bacteria (*E. coli*)	2005	Yes	None known
East Fork Rock Creek—source to T41N, R04W, Sec. 29[d]	ID17060108CL014a_02	Sediment (TSS), bacteria (*E. coli*)	2005	Yes	None known
East Fork Rock Creek—T41N, R04W, Sec. 29 to mouth[d]	ID17060108CL014b_02	Sediment (TSS), bacteria (*E. coli*)	2005	Yes	None known
Hatter Creek—source to T40N, R04W, Sec. 3[d]	ID17060108CL015a_02	Sediment (TSS), temperature, bacteria (*E. coli*)	2005	Yes	None known
Hatter Creek—T40N, R04W, Sec. 3 to mouth[d]	ID17060108CL015b_02	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP)	2005	Yes	None known
Hatter Creek—T40N, R04W, Sec. 3 to mouth[d]	ID17060108CL015b_03	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP)	2005	Yes	None known
Big Creek—source to T42N, R03W, Sec. 08[d]	ID17060108CL027a_02	Temperature	2005	Yes	None known
Big Creek—T42N, R03W, Sec. 08 to mouth[d]	ID17060108CL027b_02	Temperature	2005	Yes	None known

Assessment Unit Name	Assessment Unit Number	Pollutant	TMDL Approval Year	Implementation Plan	Implementation Activities
Gold Creek—T42N, R04W, Sec. 28 to mouth[d]	ID17060108CL029_02	Sediment (TSS), temperature, bacteria (*E. coli*)	2005	Yes	None known
Gold Creek—T42N, R04W, Sec. 28 to mouth[d]	ID17060108CL029_03	Sediment (TSS), temperature, bacteria (*E. coli*)	2005	Yes	None known
Gold Creek—source to T42N, R04W, Sec. 28[d]	ID17060108CL030_02	Sediment (TSS), temperature, bacteria (*E. coli*)	2005	Yes	None known
Crane Creek—source to T42N, R04W, Sec. 28[d]	ID17060108CL031a_02	Sediment (TSS), temperature, bacteria (*E. coli*)	2005	Yes	None known
Crane Creek—T42N, R04W, Sec. 28 to mouth[d]	ID17060108CL031b_02	Sediment (TSS), temperature, bacteria (*E. coli*)	2005	Yes	None known
Deep Creek—source to T42, R05, Sec. 02[d]	ID17060108CL032a_02	Sediment (TSS), temperature, bacteria (*E. coli*)	2005	Yes	Yes
Deep Creek—source to T42, R05, Sec. 02[d]	ID17060108CL032a_03	Sediment (TSS), temperature, bacteria (*E. coli*)	2005	Yes	Yes
Deep Creek—T42, R05, Sec. 02 to mouth[d]	ID17060108CL032b_02	Sediment (TSS), temperature, bacteria (*E. coli*)	2005	Yes	Yes
Deep Creek—T42, R05, Sec. 02 to mouth[d]	ID17060108CL032b_03	Sediment (TSS), temperature, bacteria (*E. coli*)	2005	Yes	Yes

[a] *Cow Creek Subbasin Assessment and Nutrient Total Maximum Daily Load* (DEQ 2005b)
[b] *South Fork Palouse River Watershed Assessment and TMDLs* (DEQ 2007)
[c] *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load* (DEQ 1997)
[d] *Palouse River Tributaries Subbasin Assessment and TMDL* (DEQ 2005a)
Notes: total suspended solids (TSS); *Escherichia coli* (*E. coli*); total phosphorus (TP)

Subbasin at a Glance

The Palouse River subbasin (hydrologic unit code 17060108) covers 407 square miles in northwestern Idaho and borders the state of Washington. The subbasin is sparsely populated with one major town, Moscow, and several other small towns and communities, including Potlatch, Princeton, and Harvard.

The economy of the Palouse is dominated by agriculture and two universities: the University of Idaho and Washington State University. Forestry, livestock, grazing, construction, and recreation are other economic factors. All of these factors affect water quality to some degree. The Palouse prairie is one of the most productive agricultural areas in the world, and agriculture will continue to be the dominant economic force in the subbasin.

This document reviews four TMDLs that were written for watersheds within the subbasin as shown in Table B.

Table B. Subbasin at a glance.

TMDL	TMDL Status	Pollutant	Assessment Unit Recommendation
Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load (DEQ 1997) *Paradise Creek E. coli Bacteria TMDL Addendum* (Draft DEQ 2015)	Paradise Creek TMDL (DEQ 1997): approved by EPA in 1998 Paradise Creek E. coli addendum (DEQ 2015): draft	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP), ammonia	Remove ammonia as impairment from Paradise Creek assessment units (AUs): ID17060108CL005_02 ID17060108CL005_02a ID17060108CL005_02b
Palouse River Tributaries Subbasin Assessment and TMDL (DEQ 2005a)	Palouse River tributaries TMDL (DEQ 2005a): approved by EPA in 2005	Sediment (TSS), temperature, bacteria (*E coli*), nutrients (TP)	Move from Category 4a to 2 in Integrated Report for bacteria and secondary contact recreation for Deep Creek AUs: ID17060108CL032a_02 ID17060108CL032a_03 ID17060108CL032b_02 ID17060108CL032b_03 Remove sediment as impairment from Gold Creek AU: ID17060108CL030_02
Cow Creek Subbasin Assessment and Nutrient Total Maximum Daily Load (DEQ 2005b) *Cow Creek Temperature Total Maximum Daily Loads Addendum* (DEQ 2013)	Cow Creek nutrient TMDL (DEQ 2005b): approved by EPA in 2006	Temperature, nutrients (TP)	None
South Fork Palouse River Watershed Assessment and TMDLs (DEQ 2007)	South Fork Palouse River TMDLs (DOE 2007): approved by EPA in 2007	Sediment (TSS), temperature, bacteria (*E. coli*), nutrients (TP)	None

Notes: total suspended solids (TSS); *Escherichia coli* (*E. coli*); total phosphorus (TP)

1 Introduction

The federal Clean Water Act (CWA) requires that states and tribes restore and maintain the chemical, physical, and biological integrity of the nation's waters (33 USC §1251). States and tribes, pursuant to Section 303 of the CWA, are to adopt water quality standards necessary to protect fish, shellfish, and wildlife while providing for recreation in and on the nation's waters whenever possible. Section 303(d) of the CWA establishes requirements for states and tribes to identify and prioritize water bodies that are water quality limited (i.e., water bodies that do not meet water quality standards). States and tribes must periodically publish a priority list (a "§303(d) list") of impaired waters. For waters identified on this list, states and tribes must develop a total maximum daily load (TMDL) for the pollutants, set at a level to achieve water quality standards.

Idaho Code §39-3611(7) requires a 5-year cyclic review process for Idaho TMDLs:

> The director shall review and reevaluate each TMDL, supporting subbasin assessment, implementation plan(s) and all available data periodically at intervals of no greater than five (5) years. Such reviews shall include the assessments required by section 39-3607, Idaho Code, and an evaluation of the water quality criteria, instream targets, pollutant allocations, assumptions and analyses upon which the TMDL and subbasin assessment were based. If the members of the watershed advisory group, with the concurrence of the basin advisory group, advise the director that the water quality standards, the subbasin assessment, or the implementation plan(s) are not attainable or are inappropriate based upon supporting data, the director shall initiate the process or processes to determine whether to make recommended modifications. The director shall report to the legislature annually the results of such reviews.

To meet the intent and purpose of Idaho Code §39-3611(7), this report documents the review of the *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load* (1998), *Palouse River Tributaries Subbasin Assessment and TMDL* (DEQ 2005a), *Cow Creek Subbasin Assessment and Nutrient Total Maximum Daily Load* (2005b), and *South Fork Palouse River Watershed Assessment and TMDLs* (2007) and addresses the water bodies in the Palouse River subbasin that are in Category 4(a) of Idaho's most recent Integrated Report. This report reviews the approved TMDL and implementation plan, considers the most current and applicable information in conformance with Idaho Code §39-3607, evaluates the appropriateness of the TMDL to current watershed conditions, evaluates the implementation plan, and provides for watershed advisory group (WAG) consultation. The evaluation of the recommendations is provided. Final decisions for TMDL modifications are decided by the Idaho Department of Environmental Quality (DEQ) director. Approval of TMDL modifications is decided by the US Environmental Protection Agency (EPA) with consultation by DEQ.

Assessment Units

Assessment units (AUs) are groups of similar streams that have similar land use practices, ownership, or land management. Stream order is the main basis for determining AUs—even if ownership and land use change significantly, the AU usually remains the same for the same stream order.

Using AUs to describe water bodies offers many benefits primarily that all waters of the state are defined consistently. AUs are a subset of water body identification numbers, which allows them to relate directly to the water quality standards.

2 TMDL Review and Status

2.1 Subbasin Characteristics

The Palouse River subbasin (hydrologic unit code 17060108) covers 407 square miles in northwestern Idaho and borders the state of Washington. The subbasin is a sparsely populated area with one major town, Moscow, and several other small towns and communities, including Potlatch, Princeton, and Harvard.

Most of the wetlands and floodplains in the Palouse prairie have been eliminated by modern land use, urbanization, and transportation infrastructure. These activities have affected instream flows, channel sinuosity, and habitat diversity. In addition, the topography, soils, and climate make the Palouse River subbasin very susceptible to erosion. Land uses that contribute excess sediment, nutrients, and bacteria to the river can degrade water quality.

The economy of the Palouse is dominated by agriculture and two universities: the University of Idaho and Washington State University. Forestry, livestock, grazing, construction, and recreation are other economic factors. All of these factors affect water quality to some degree. The Palouse prairie is one of the most productive agricultural areas in the world and agriculture will continue to be the dominant economic force in the subbasin.

2.1.1 1997 Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load

Paradise Creek is divided into three AUs: an upper forested headwaters section (ID17060108CL005_02b), an agricultural use middle section (ID17060108CL005_02a), and an urban section (ID17060108CL005_02). The headwaters of Paradise Creek are located on Moscow Mountain, with the creek flowing southwest for approximately 19 miles through agricultural land and then through the urban area of Moscow, Idaho, ultimately joining the South Fork Palouse River in Pullman, Washington (Figure 1). The Paradise Creek watershed is 23,038 acres (36 square miles), with 13,888 acres located within Idaho and the other 9,150 acres in Washington.

Paradise Creek receives pollutants from several sources, including non-irrigated croplands, grazing lands, construction, urban runoff, and roads. In addition, Moscow's wastewater treatment plant (WWTP) (ID-002149-1) and the University of Idaho's Aquaculture Laboratory (ID-002715-4) discharge to the creek through National Pollutant Discharge Elimination System (NPDES) permits. The Aquaculture Laboratory has not discharged effluent since May 2, 2007, but outflow rates fluctuate depending on the current research direction (Scott Williams, Facility Manager, University of Idaho Aquaculture Laboratory, personal communication). The University of Idaho’s Aquaculture Laboratory has effluent and monitoring requirements set in its NPDES permit, and no reduction of its wasteload allocation is required as long as they meet the effluent limits. The *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load* is found at *deq.idaho.gov/media/463472-_water_data_reports_surface_water_tmdls_paradise_creek_paradise_creek_entire.pdf*. EPA approved the Paradise Creek TMDL in 1998.

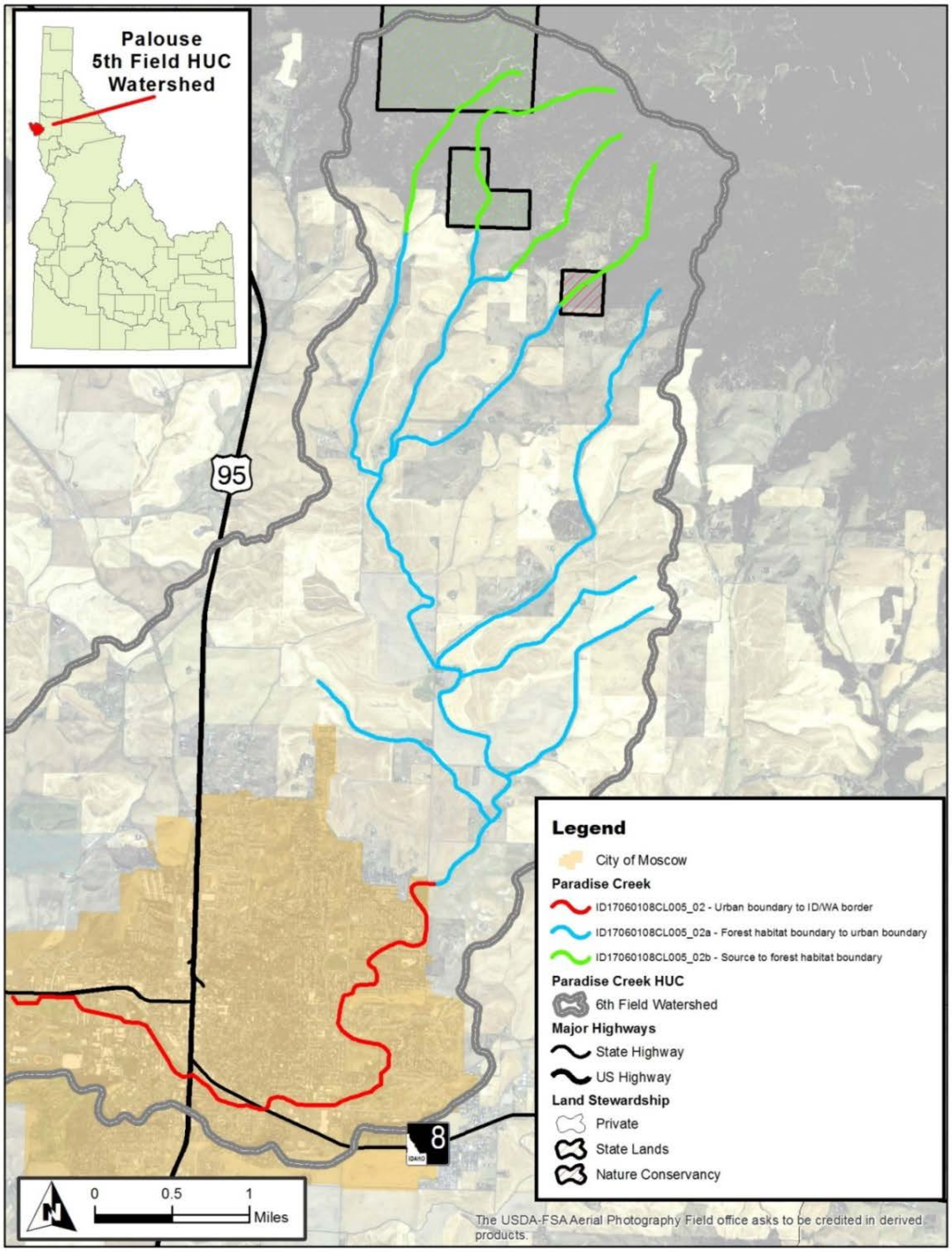

Figure 1. Paradise Creek watershed.

2.1.2 2005 Palouse River Tributaries Subbasin Assessment and TMDL

The *Palouse River Tributaries Subbasin Assessment and TMDL* addressed six water bodies in the Palouse River subbasin: Big, Deep, Flannigan, Hatter, Gold, and Rock Creeks (Figure 2) (DEQ 2005a). The pollutants in the Palouse River subbasin are from nonpoint sources, including erosion, solar radiation, livestock, fertilizers, and septic systems.

The headwaters of the Palouse River originate in the Hoodoo Mountains of the St. Joe National Forest. The Palouse River and most of its tributaries originate in forested, mountainous terrain and flow downstream into the lower gradient rolling hill terrain of the Palouse River subbasin, which is dominated by agricultural uses. The *Palouse River Tributaries Subbasin Assessment and TMDL* is found at *deq.idaho.gov/media/463321-_water_data_reports_surface_water_tmdls_palouse_river_tribs_palouse_river_tribs_entire.pdf*. EPA approved the Palouse River tributaries TMDL in 2005.

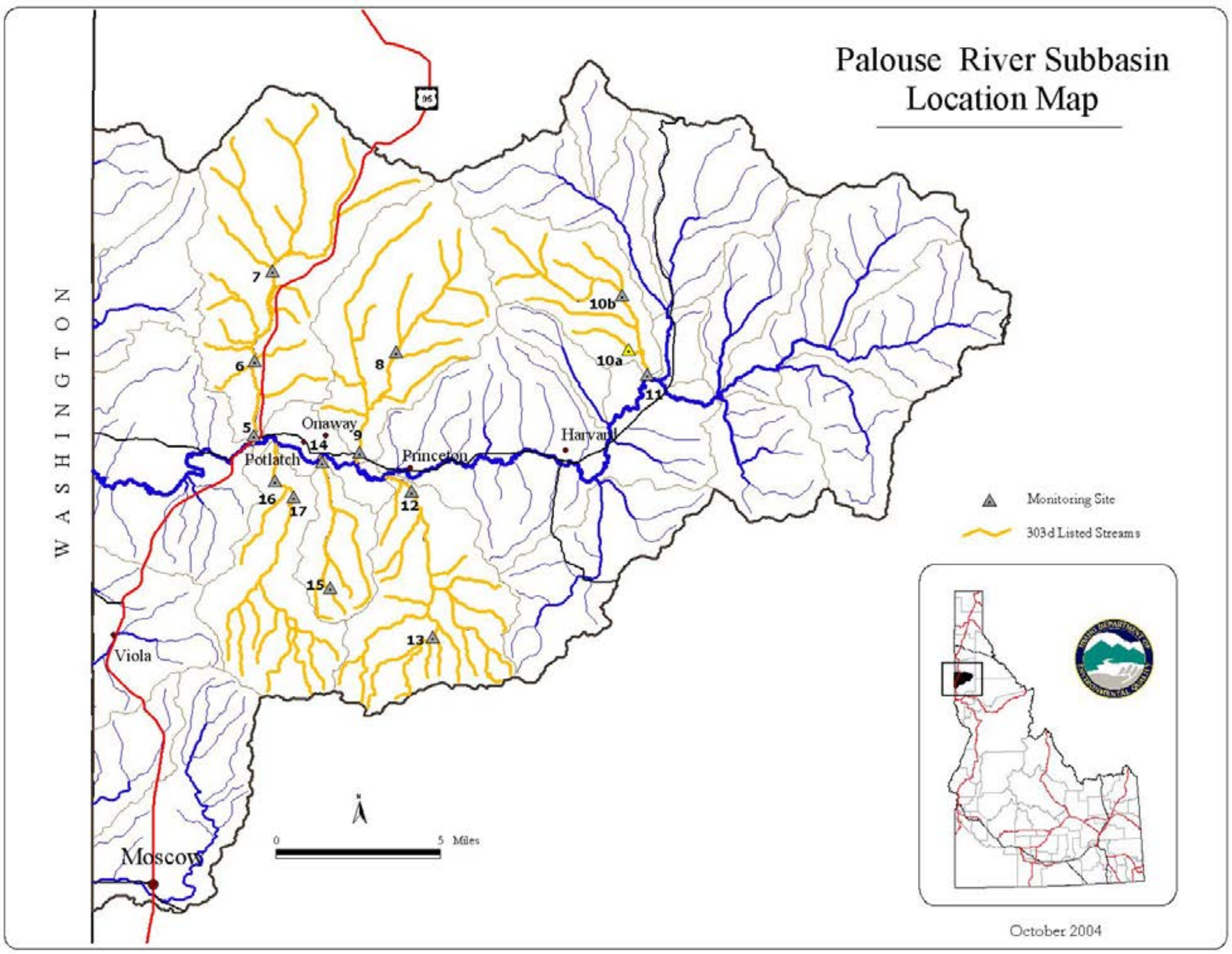

Figure 2. Location of Palouse River subbasin with Palouse River tributary TMDL §303(d) water bodies.

2.1.3 2005 Cow Creek Subbasin Assessment and Nutrient Total Maximum Daily Load

Cow Creek is considered both a 2nd- and 3rd-order tributary of the Palouse River in the southern part of Latah County and northern part of Nez Perce County, Idaho (Figure 3). The creek flows primarily southwest for about 18.5 miles before it enters Union Flat Creek. The watershed is approximately 32.8 square miles (21,000 acres). A sewage lagoon facility is located along Cow Creek just downstream of the city of Genesee.

The Genesee wastewater treatment lagoon is the only point source permitted to discharge in the Cow Creek watershed. The primary nonpoint sources of pollutants in the Cow Creek watershed are nonirrigated croplands and grazing lands. The entire length of Cow Creek and its tributaries typically receive pollutants from agricultural fields during rainfall and snowmelt. At these times, nutrients associated with sediment also enter the creek from fields and unstable banks. During the summer low-flow periods, portions of Cow Creek experience temperature increases and low dissolved oxygen concentrations. The *Cow Creek Subbasin Assessment and Nutrient Total Maximum Daily Load* is found at *deq.idaho.gov/media/454085-_water_data_reports_surface_water_tmdls_cow_creek_cow_creek_entire.pdf*. EPA approved the Cow Creek nutrient TMDL in 2006.

A temperature TMDL addendum was developed using the potential natural vegetation method and finalized for the Cow Creek watershed. The addendum addressed the temperature impairment in the Cow Creek watershed and provided load and wasteload allocations. The *Cow Creek Temperature Total Maximum Daily Loads Addendum* is found at *deq.idaho.gov/media/1088/cow-creek-temperature-tmdl-addendum-1213.pdf*. EPA approved the Cow Creek temperature addendum in 2014.

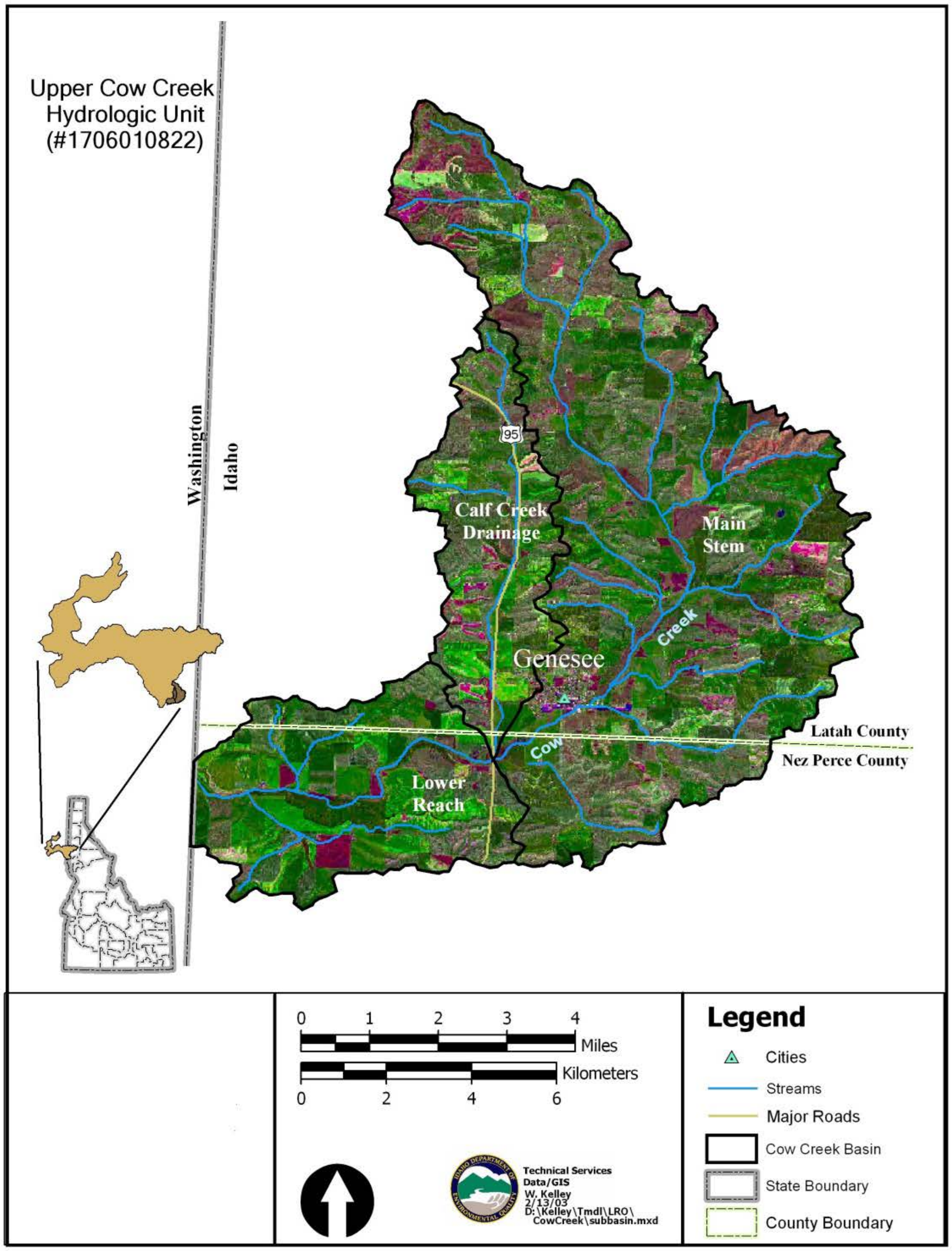

Figure 3. Cow Creek watershed.

2.1.4 2007 South Fork Palouse River Watershed Assessment and TMDLs

The South Fork Palouse River drains from the southern slope of Moscow Mountain, skirts the south side of the city of Moscow, and enters Washington upstream of the city of Pullman (Figure 4). The watershed is approximately 30 square miles (19,200 acres).

TMDLs were established for *Escherichia coli* (*E. coli)* bacteria and temperature throughout the watershed, and for sediment and nutrients in specific portions of the watershed. In addition to nonpoint source load allocations, February and March wasteload allocations were developed for the Syringa Mobile Home Park and Country Homes Mobile Park, both of which discharged small amounts of wastewater to the river from wastewater lagoons. These wasteload allocations are included with the load allocation in the existing load. The *South Fork Palouse River Watershed Assessment and TMDLs* is found at *deq.idaho.gov/media/463293-_water_data_reports_surface_water_tmdls_palouse_river_sf_palouse_river_sf_entire.pdf*. EPA approved the South Fork Palouse River TMDLs in 2007.

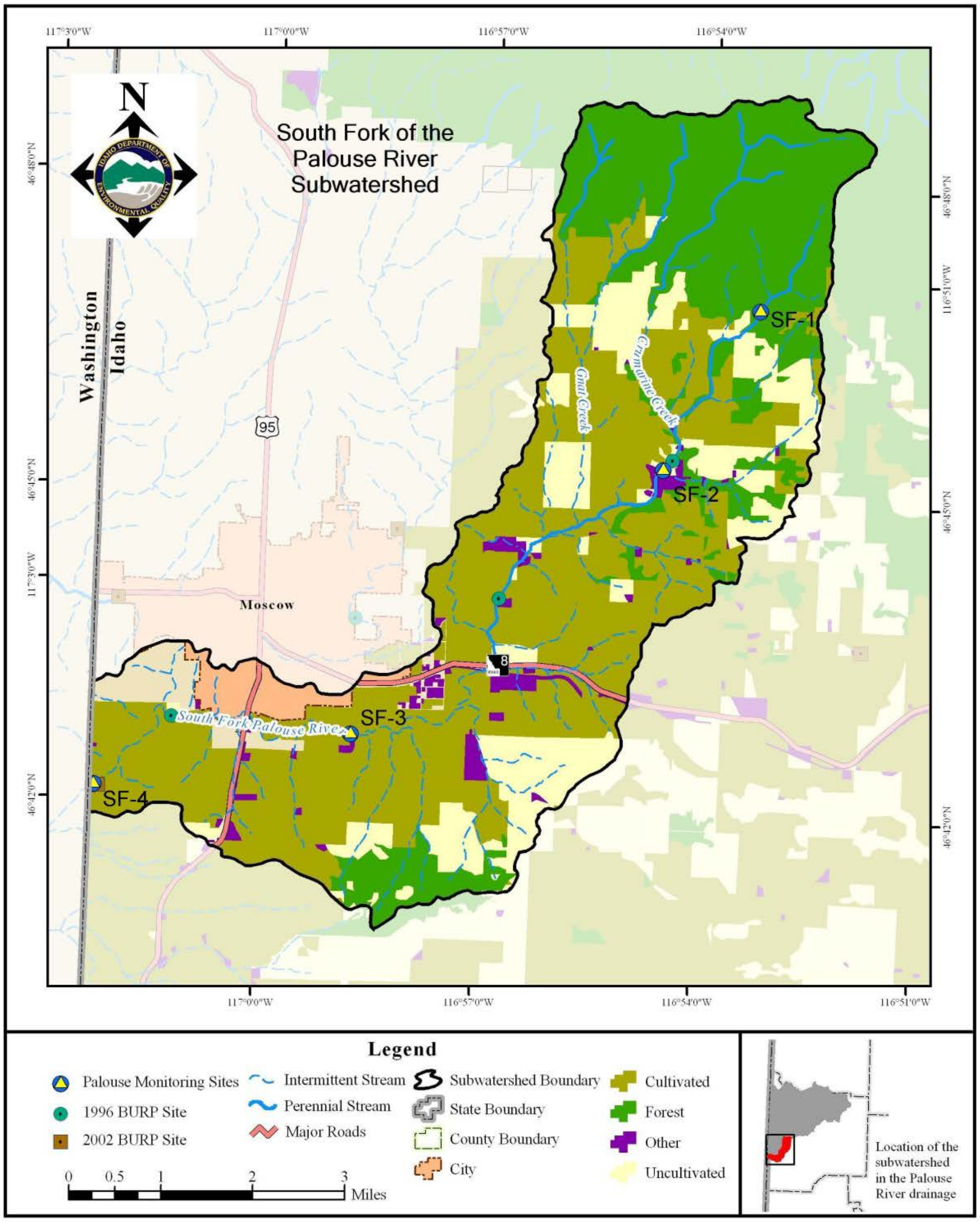

Figure 4. South Fork Palouse River watershed.

2.2 TMDL Review and Status by Pollutant

2.2.1 Sediment

2.2.1.1 Instream Water Quality Targets

The sediment criteria found in the water quality standards (IDAPA 58.01.02.200.08) is narrative, meaning there is not a numeric value to assess whether a water body is in compliance with standards. Instead, the standard states sediment shall be limited to a quantity that does not impair beneficial uses.

Numeric criteria exist for turbidity—the measure of light dispersion caused by particles suspended in a water column. Light penetration, turbidity, and suspended solids are correlated, though the characteristics of the particles in suspension can change the degree of light dispersion or penetration (DEQ 2003). This criterion relates specifically to mixing zones that are typically associated with point sources. Total suspended solids (TSS) have been found to correlate with turbidity in specific watersheds; however, the relationship between the two water column measures are sensitive to location and time period, so the application of a predictive model may be limited to the year and specific sites for which the model was developed (DEQ 2003).

The effects of sediment on the most sensitive designated beneficial uses in the South Fork Palouse River, salmonid spawning and aquatic life, are dependent on concentration and duration of exposure (DEQ 2003). Guidance developed by DEQ for applying the narrative sediment criteria to protect aquatic life beneficial uses states that a sediment target should incorporate both concentration and duration of exposure, not only to properly protect aquatic life but also to allow for episodic spikes in TSS that can occur naturally with spring runoff or heavy precipitation events.

2.2.1.1.1 Target Development

South Fork Palouse River

Sediment targets for the South Fork Palouse River TMDL were developed using the *Guide to Selection of Sediment Targets for Use in Idaho TMDLs* (DEQ 2003). Based on the information contained in the guidance, a 25 milligram per liter (mg/L) TSS target averaged over a 30-day period, not to exceed 50 mg/L daily has been used to develop the sediment TMDL for the upper AUs. This target is designed to maintain a high level of protection for salmonid spawning populations (DEQ 2003).

A 50 mg/L TSS target averaged over a 30-day period, not to exceed 80 mg/L daily has been used to develop the sediment TMDL for the lower AU. This target is designed to maintain a moderate level of protection for salmonid rearing populations (DEQ 2003) in the South Fork Palouse River watershed.

Paradise Creek

Sediment targets for the Paradise Creek TMDL were arrived at by relating Idaho's turbidity standard to TSS. A 2:1 TSS/turbidity relation was applied between the nephelometric turbidity unit (NTU) and TSS, which led to a TSS target of 100 mg/L maximum above natural background, not to exceed 50 mg/L above natural background over a 10-day period.

Palouse River Tributaries

Sediment targets for the Palouse River subbasin were based on a TSS load measured and calculated in tons per year in the stream, and represented as a load reduction percentage. The TSS load amounts for each §303(d)-listed stream were derived from the turbidity standard of turbidity levels not to exceed 25 NTU above background turbidity levels for a period greater than 10 consecutive days or no more than 50 NTU above background turbidity levels instantaneously and from the equations in Appendix C of the Palouse River tributaries TMDL (DEQ 2005a).

The design of a stochastic flow model requires a more thorough discharge profile for each stream than was collected during November 2001 and November 2002. Ten years of data from the US Geological Survey's Palouse River gage site near the town of Potlatch was gathered and compiled. Modifications were then made to the flows based on watershed size differences between each stream and the Palouse River, elevation, precipitation, geology, land cover, basin slope, and channel characteristics, following the Lipscomb (1998) methodology for each §303(d)-listed stream.

Based on the collected data in the monitoring year, November 2001–November 2002, numeric relationships between discharge and NTU, discharge and TSS, and NTU and TSS were developed by plotting the values on a graph. These relationships can be expressed as mathematical equations, called regression equations, which were used to calculate values for TSS, NTU, background TSS, background NTU, and TSS levels over background.

These equations were then used to determine existing TSS and NTU values on a daily basis for a 10-year period. A background ratio was calculated by dividing the background erosion value from the total sediment erosion value within the Revised Universal Soil Loss Equation (RUSLE) model:

1. The background TSS value is calculated by multiplying the background ratio and the existing TSS value.
2. The load capacity is calculated by taking the TSS value equal to 25 NTU, multiplying by daily flow and a conversion factor (to express the load capacity in tons per day), and adding the background TSS in tons per day.
3. Once the load capacity is determined, the excess load or load reduction is calculated by subtracting the load capacity from the exiting TSS load.
4. The excess load is then expressed in tons per year and a percentage is calculated.

These steps were performed for each §303(d)-listed stream in the Palouse River subbasin.

2.2.1.1.2 Listed Streams

For the Paradise Creek TMDL (DEQ 1997*)*, a comprehensive analysis of available sediment data was completed. This document reviews the sediment TMDL for Paradise Creek (Appendix A, Paradise Creek TMDL Five-Year Review: Sediment).

The streams listed for sediment impairment in the Paradise Creek TMDL (DEQ 1997), Palouse River tributaries TMDL (DEQ 2005a), and South Fork Palouse River TMDLs (DEQ 2007)

(Table 1) are designated for cold water aquatic life, and five AUs are designated for salmonid spawning (section 3.1, Table 22).

Table 1. Assessment units with sediment TMDLs.

Assessment Unit Name	Assessment Unit Number	TSS Numeric Target	Critical Period
South Fork Palouse River—Gnat Creek to Idaho/Washington border[a]	ID17060108CL002_03	50 mg/L/30 day avg; no greater than 80 mg/L daily	February–April
South Fork Palouse River—source to Gnat Creek; tributaries[a]	ID17060108CL003_02	25 mg/L/30 day avg; no greater than 50 mg/L daily	February–April
South Fork Palouse River—source to Gnat Creek[a]	ID17060108CL003_03	25 mg/L/30 day avg; no greater than 50 mg/L daily	February–April
Paradise Creek—urban boundary to Idaho/Washington border[b]	ID17060108CL005_02	100 mg/L instantaneous; 50 mg/L for 10 consecutive days	Year-round
Paradise Creek—forest habitat boundary to urban boundary[b]	ID17060108CL005_02a	100 mg/L instantaneous; 50 mg/L for 10 consecutive days	Year-round
Idlers Rest Creek—source to forest habitat boundary[b]	ID17060108CL005_02b	100 mg/L instantaneous; 50 mg/L for 10 consecutive days	Year-round
Flannigan Creek—source to T41N, R05W, Sec. 23[c]	ID17060108CL011a_02	25.91 mg/L for 10 consecutive days	January–May
Flannigan Creek—source to T41N, R05W, Sec. 23[c]	ID17060108CL011a_03	25.91 mg/L for 10 consecutive days	January–May
Flannigan Creek—T41N, R05W, Sec. 23 to mouth[c]	ID17060108CL011b_02	25.91 mg/L for 10 consecutive days	January–May
Flannigan Creek—T41N, R05W, Sec. 23 to mouth[c]	ID17060108CL011b_03	25.91 mg/L for 10 consecutive days	January–May
Rock Creek—confluence of WF and EF Rock Creek to mouth[c]	ID17060108CL012_03	9.36 mg/L for 10 consecutive days	January–May
West Fork Rock Creek—source to T41N, R04W, Sec. 30[c]	ID17060108CL013a_02	9.36 mg/L for 10 consecutive days	January–May
West Fork Rock Creek—T41N, R04W, Sec. 30 to mouth[c]	ID17060108CL013b_03	9.36 mg/L for 10 consecutive days	January–May
East Fork Rock Creek—source to T41N, R04W, Sec. 29[c]	ID17060108CL014a_02	9.36 mg/L for 10 consecutive days	January–May
East Fork Rock Creek—T41N, R04W, Sec. 29 to mouth[c]	ID17060108CL014b_02	9.36 mg/L for 10 consecutive days	January–May
Hatter Creek—source to T40N, R04W, Sec. 3[c]	ID17060108CL015a_02	25.81 mg/L for 10 consecutive days	January–May
Hatter Creek—T40N, R04W, Sec. 3 to mouth[c]	ID17060108CL015b_02	25.81 mg/L for 10 consecutive days	January–May
Hatter Creek—T40N, R04W, Sec. 3 to mouth[c]	ID17060108CL015b_03	25.81 mg/L for 10 consecutive days	January–May
Gold Creek—T42N, R04W, Sec. 28 to mouth[c]	ID17060108CL029_02	23.36 mg/L for 10 consecutive days	January–May
Gold Creek—T42N, R04W, Sec. 28 to mouth[c]	ID17060108CL029_03	23.36 mg/L for 10 consecutive days	January–May
Gold Creek—source to T42N,	ID17060108CL030_02	23.36 mg/L for	January–May

Assessment Unit Name	Assessment Unit Number	TSS Numeric Target	Critical Period
R04W, Sec. 28[c]		10 consecutive days	
Crane Creek—source to T42N, R04W, Sec. 28[c]	ID17060108CL031a_02	23.36 mg/L for 10 consecutive days	January–May
Crane Creek—T42N, R04W, Sec. 28 to mouth[c]	ID17060108CL031b_02	23.36 mg/L for 10 consecutive days	January–May
Deep Creek—source to T42, R05, Sec. 02[c]	ID17060108CL032a_02	23.36 mg/L for 10 consecutive days	January–May
Deep Creek—source to T42, R05, Sec. 02[c]	ID17060108CL032a_03	23.36 mg/L for 10 consecutive days	January–May
Deep Creek—T42, R05, Sec. 02 to mouth	ID17060108CL032b_02	23.36 mg/L for 10 consecutive days	January–May
Deep Creek—T42, R05, Sec. 02 to mouth[c]	ID17060108CL032b_03	23.36 mg/L for 10 consecutive days	January–May

[a] *South Fork Palouse River Watershed Assessment and TMDLs* (DEQ 2007)
[b] *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load* (DEQ 1997)
[c] *Palouse River Tributaries Subbasin Assessment and TMDL* (DEQ 2005a)
Note: milligrams per liter (mg/L)

2.2.1.2 Monitoring Points

The established monitoring sites used in the TMDLs are also the compliance points. Since sediment can travel throughout the entire stream, beneficial uses must be met throughout each §303(d) stream; therefore, each monitoring site is a compliance point for the sediment TMDLs. Figure 5 provides the monitoring points.

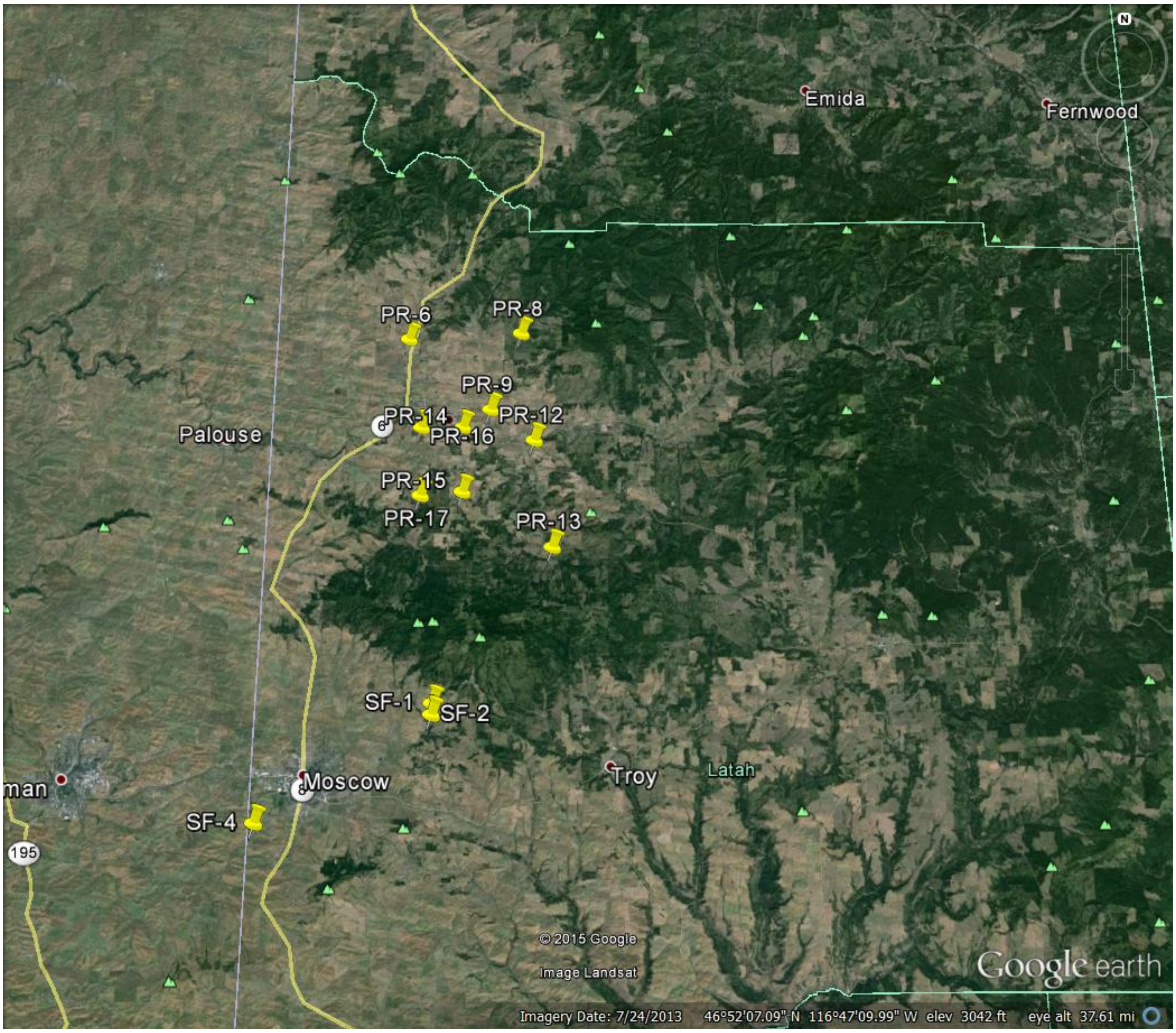

Figure 5. Palouse River subbasin TMDL sediment monitoring points.

2.2.1.3 Load Capacity

The load capacity used to establish the instream target and allocations for these streams were based on different methods for each TMDL. For this review, the listed streams in the Palouse River tributaries TMDL (DEQ 2005a) and South Fork Palouse River TMDLs (DEQ 2007) existing pollutant loads were calculated per sample event. The equations below describe how the existing loads were generated:

Existing load (pounds per day) = sample concentration (mg/L)*flow (cfs)*5.39

Load capacity (pounds per day) = target (mg/L)*flow (cfs)*5.39

Where:

5.36 is the conversion factor from milligrams per liter per cubic feet per second (mg/L/cfs) to pounds per day (lb/day).

2.2.1.4 Load Allocation

Table 2–Table 13 list the existing sediment (TSS) concentrations calculated from measurements at the monitoring points established in the Palouse River subbasin TMDLs. The tables also show the load capacity and load reduction where needed.

2.2.1.5 Margin of Safety

For the AUs in the Palouse River Tributaries TMDL (DEQ 2005a), the TMDL provided a significant margin of safety (MOS) by using a more conservative limit in the calculation; therefore, no further MOS was built into the TMDL. The South Fork Palouse River TMDL (DEQ 2007) used an explicit MOS of 10% in the calculations and that has been applied to the calculations in this review. The Paradise Creek TMDL (DEQ 1997) had a nonpoint source MOS of 10% of the current load or 29% of the load capacity.

Table 2–Table 10 show the results from sites listed in the Palouse River tributaries TMDL (DEQ 2005a).

Table 2. Daily TSS load for Deep Creek (ID17060108CL032b_03) (monitoring point PR6).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)
5/8/2014	11.94	7.1	456.93	1,503.37
5/14/2014	7.709	5.51	228.95	970.64
5/20/2014	4.806	5.71	147.91	605.13
5/28/2014	2.766	6.4	95.42	348.27
6/4/2014	1.883	5.21	52.88	237.09
6/10/2014	0.778	4.86	20.38	97.96
2/19/2015	20.41	3.83	421.34	2,569.83
3/2/2015	8.055	4.49	194.94	1,014.21
3/16/2015	53.8	14.8	4,291.73	6,773.98

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); pounds per day (lb/day)

Table 3. Daily TSS load for Upper Gold Creek (ID17060108CL030_02) (monitoring point PR8).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)
5/8/2014	3.738	3.11	62.66	470.65
5/14/2014	3.117	4.7	78.96	392.46
5/20/2014	2.593	16	223.62	326.49
5/28/2014	1.458	2.84	22.32	183.58
6/4/2014	0.82	2.99	13.22	103.25
6/10/2014	0.614	3.31	10.95	77.31
2/19/2015	5.366	2.02	58.42	675.64
3/2/2015	2.836	1.14	17.43	357.08
3/16/2015	11.64	7.93	497.53	1,465.60

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); pounds per day (lb/day)

Table 4. Daily TSS load for Lower Gold Creek (ID17060108CL029_03) (monitoring point PR9).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)	Load Reduction (%)
5/8/2014	10.42	8.17	458.86	1,311.99	0
5/14/2014	6.172	5.95	197.94	777.12	0
5/20/2014	4.233	7.79	177.74	532.98	0
5/28/2014	2.874	4.97	76.99	361.87	0
6/4/2014	1.795	4.67	45.18	226.01	0
6/10/2014	0.847	4.57	20.86	106.65	0
2/19/2015	9.058	7.92	386.68	1,140.50	0
3/2/2015	7.29	12.9	506.88	917.89	0
3/16/2015	31.57	59.7	10,158.69	3,974.99	61

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); pounds per day (lb/day)

Table 5. Daily TSS load for Lower Hatter Creek (ID17060108CL015b_03) (monitoring point PR12).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)	Load Reduction (%)
5/8/2014	18.22	8.36	821.0	2,534.7	0
5/14/2014	10.61	8.57	490.1	1,476.0	0
5/20/2014	8.107	7.78	340.0	1,127.8	0
5/28/2014	5.541	4.06	121.3	770.8	0
6/4/2014	3.471	3.78	70.7	482.9	0
6/10/2014	2.036	2.28	25.0	283.2	0
2/19/2015	22.61	22.9	2,790.8	3,145.4	0
3/2/2015	17	14.8	1,356.1	2,365.0	0
3/16/2015	26.72	52.4	7,546.7	3,717.2	51

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); pounds per day (lb/day)

Table 6. Daily TSS load for Upper Hatter Creek (ID17060108CL015a_02) (monitoring point PR13).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)
5/8/2014	7.846	3.86	163.24	1,091.50
5/14/2014	5.755	3.38	104.85	800.61
5/20/2014	4.44	2.95	70.60	617.67
5/28/2014	2.386	2.52	32.41	331.93
6/4/2014	1.556	2.15	18.03	216.46
6/10/2014	1.341	4.11	29.71	186.55
2/19/2015	7.17	4.48	173.14	997.46
3/2/2015	5.62	2.09	63.31	781.83
3/16/2015	7.286	6.82	267.83	1,013.60

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); pounds per day (lb/day)

Table 7. Daily TSS load for Lower Rock Creek (ID17060108CL012_03) (monitoring point PR14).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)	Load Reduction (%)
5/8/2014	0.662	7.09	25.30	33.40	0
5/14/2014	0.391	5.09	10.73	19.73	0
5/20/2014	0.185	4.32	4.31	9.33	0
5/28/2014	0.105	4.27	2.42	5.30	0
6/4/2014	0.059	3.58	1.14	2.98	0
6/10/2014	0.033	11.1	1.97	1.66	16
2/19/2015	2.449	4.13	54.52	123.55	0
3/2/2015	1.15	6.29	38.99	58.02	0
3/16/2015	6.209	29	970.53	313.25	68

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); pounds per day (lb/day)

Table 8. Daily TSS load for Upper Rock Creek (ID17060108CL013a_02) (monitoring point PR15).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)	Load Reduction (%)
5/8/2014	0.154	3.91	3.25	7.77	0
5/14/2014	0.068	3.92	1.44	3.43	0
5/20/2014	0.043	2.31	0.54	2.17	0
5/28/2014	0.062	3.1	1.04	3.13	0
6/4/2014	0.032	3.14	0.54	1.61	0
6/10/2014	0.007	3.8	0.14	0.35	0
2/19/2015	0.627	17.6	59.48	31.63	47
3/2/2015	0.379	1.59	3.25	19.12	0
3/16/2015	1.054	11.4	64.76	53.17	18

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); pounds per day (lb/day)

Table 9. Daily TSS load for Lower Flannigan Creek (ID17060108CL011b_03) (monitoring point PR16).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)	Load Reduction (%)
5/8/2014	5.646	26.4	803.40	788.49	2
5/14/2014	3.836	25	516.90	535.72	0
5/20/2014	3.223	6.26	108.75	450.11	0
5/28/2014	2.669	20	287.72	372.74	0
6/4/2014	0.622	11.7	39.23	86.87	0
6/10/2014	1.023	19.3	106.42	142.87	0
2/19/2015	5.778	5.94	184.99	806.93	0
3/2/2015	4.452	6.3	151.18	621.74	0
3/16/2015	13.13	20.8	1,472.03	1,833.67	0

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); pounds per day (lb/day)

Table 10. Daily TSS load for Upper Flannigan Creek (ID17060108CL011a_02) (monitoring point PR17).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)
5/8/2014	7.264	4.77	186.76	1,014.45
5/14/2014	5.329	4.82	138.45	744.22
5/20/2014	4.12	4.08	90.60	575.38
5/28/2014	2.812	4.42	66.99	392.71
6/4/2014	1.623	5.29	46.28	226.66
6/10/2014	1.193	5.48	35.24	166.61
2/19/2015	15.61	15.9	1,337.79	2,180.01
3/2/2015	11.67	17.9	1,125.93	1,629.77
3/16/2015	6.823	7.51	276.19	952.87

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); pounds per day (lb/day)

Table 11–Table 13 show the results from sites listed in the South Fork Palouse River TMDL (DEQ 2007)

Table 11. Daily TSS load for South Fork Palouse River (ID17060108CL003_02) (monitoring point SF1).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)	MOS (lb/day)	Load Allocation
5/7/2014	0.986	17.4	92.47	265.73	26.5727	239.15
5/15/2014	0.596	3.09	9.93	160.62	16.0622	144.56
5/21/2014	0.305	2.84	4.67	82.20	8.21975	73.98
5/29/2014	0.239	3.01	3.88	64.41	6.44105	57.97
6/5/2014	0.187	2.91	2.93	50.40	5.03965	45.36
6/11/2014	0.087	4.11	1.93	23.45	2.34465	21.10
2/20/2015	2.021	9.36	101.96	544.66	54.46595	490.19
3/3/2015	1.463	4.14	32.65	394.28	39.42785	354.85
3/17/2015	1.398	5.91	44.53	376.76	37.6761	339.08

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); margin of safety (MOS); pounds per day (lb/day)

Table 12. Daily TSS load for South Fork Palouse River (ID17060108CL003_03) (monitoring point SF2).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)	MOS (lb/day)	Load Allocation
5/7/2014	3.658	5.66	111.6	985.8	98.6	887.2
5/15/2014	2.801	6.39	96.5	754.9	75.5	679.4
5/21/2014	2.394	6.37	82.2	645.2	64.5	580.7
5/29/2014	1.41	7.64	58.1	380.0	38.0	342.0
6/5/2014	1.434	7.88	60.9	386.5	38.6	347.8
6/11/2014	0.877	7.7	36.4	236.4	23.6	212.7
2/20/2015	3.284	11.8	208.9	885.0	88.5	796.5
3/3/2015	3.023	4.3	70.1	814.7	81.5	733.2
3/17/2015	3.957	7.52	160.4	1,066.4	106.6	959.8

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); margin of safety (MOS); pounds per day (lb/day)

Table 13. Daily TSS load for South Fork Palouse River (ID17060108CL002_03) (monitoring point SF4).

Sample Date	Flow (cfs)	TSS (mg/L)	Existing Load (lb/day)	Load Capacity (lb/day)	MOS (lb/day)	Load Allocation
5/7/2014	7.4	15.2	606.3	3,190.9	319.1	2,871.8
5/15/2014	3.509	8.16	154.3	1,513.1	151.3	1,361.8
5/21/2014	3.854	6.15	127.8	1,661.8	166.2	1,495.7
5/29/2014	3.405	6.3	115.6	1,468.2	146.8	1,321.4
6/5/2014	1.404	7.54	57.1	605.4	60.5	544.9
6/11/2014	0.445	5.47	13.1	191.9	19.2	172.7
2/20/2015	20.19	26.7	2,905.6	8,705.9	870.6	7,835.3
3/3/2015	4.882	13.8	363.1	2,105.1	210.5	1,894.6
3/17/2015	11.2	24.1	1,454.9	4,829.4	482.9	4,346.5

Notes: total suspended solids (TSS); cubic feet per second (cfs); milligrams per liter (mg/L); margin of safety (MOS); pounds per day (lb/day)

2.2.1.6 Wasteload Allocation

No wasteload allocations were assigned for TSS in the Palouse River tributaries TMDL (DEQ 2005a) or South Fork Palouse River TMDLs (DEQ 2007). Current NPDES sediment point sources permitted by EPA include Moscow's WWTP (ID-002149-1). The Paradise Creek TMDL (DEQ 1997) included a wasteload allocation for Moscow's WWTP of 91 tons/year or 15 mg/L average monthly limit. NPDES permit limits are provided in Table 14.

Table 14. NPDES effluent limit for the City of Moscow wastewater treatment plant.

Parameter	Average Monthly Limit	Average Weekly Limit
Total suspended solids	15 mg/L	30 mg/L
	450.4 lb/day	900.7 lb/day

Notes: milligrams per liter (mg/L); pounds per day (lb/day)

Moscow's WWTP has TSS effluent and monitoring requirements set in its NPDES permit. The WWTP discharge monitoring reports show that the plant is meeting its TSS effluent requirements with an efficiency of 99% removal for TSS in 2014, and no reduction in its wasteload allocation is required as long as TSS effluent limits are met.

2.2.2 Bacteria

2.2.2.1 Instream Water Quality Targets

Instream water quality targets for the listed streams in the Palouse River subbasin TMDLs for *E. coli* bacteria were set from the Idaho water quality standards. Waters designated for primary or secondary contact recreation are not to contain *E. coli* bacteria in concentrations exceeding a geometric mean of 126 colony forming units/100 milliliters (cfu/100 mL) based on a minimum of five samples taken every 3–7 days over a 30-day period (IDAPA 58.01.02.251.01.a).

The streams listed for bacterial impairment in the *Palouse River Tributaries Subbasin Assessment and TMDL* (DEQ 2005a) and the *South Fork Palouse River Watershed Assessment and TMDLs* (DEQ 2007) (Table 15) are designated for secondary contact recreation. The load capacity used to establish the instream target and allocations for these streams is based on the Idaho geometric mean criterion of 126 cfu/100 mL for *E. coli* bacteria.

Table 15. Assessment units with *E. coli* bacteria TMDLs.

Assessment Unit Name	Assessment Unit Number	*E. coli* Bacteria Numeric Criteria (cfu/100 mL)	Critical Period
South Fork Palouse River—Gnat Creek to Idaho/Washington border[a]	ID17060108CL002_03	126	Year-round
South Fork Palouse River—source to Gnat Creek; tributaries[a]	ID17060108CL003_02	126	Year-round
South Fork Palouse River—source to Gnat Creek[a]	ID17060108CL003_03	126	Year-round
Flannigan Creek—source to T41N, R05W, Sec. 23[b]	ID17060108CL011a_02	126	Year-round
Flannigan Creek— source to T41N, R05W, Sec. 23[b]	ID17060108CL011a_03	126	Year-round
Flannigan Creek—T41N, R05W, Sec. 23 to mouth[b]	ID17060108CL011b_02	126	Year-round
Flannigan Creek—T41N, R05W, Sec. 23 to mouth[b]	ID17060108CL011b_03	126	Year-round
Rock Creek— confluence of WF and EF Rock Creek to mouth[b]	ID17060108CL012_03	126	Year-round
West Fork Rock Creek—source to T41N, R04W, Sec. 30[b]	ID17060108CL013a_02	126	Year-round
West Fork Rock Creek—T41N, R04W, Sec. 30 to mouth[b]	ID17060108CL013b_03	126	Year-round
East Fork Rock Creek—source to T41N, R04W, Sec. 29[b]	ID17060108CL014a_02	126	Year-round
East Fork Rock Creek—T41N, R04W, Sec. 29 to mouth[b]	ID17060108CL014b_02	126	Year-round

Assessment Unit Name	Assessment Unit Number	***E. coli*** **Bacteria Numeric Criteria (cfu/100 mL)**	Critical Period
Hatter Creek— source to T40N, R04W, Sec. 3[b]	ID17060108CL015a_02	126	Year-round
Hatter Creek—T40N, R04W, Sec. 3 to mouth[b]	ID17060108CL015b_02	126	Year-round
Hatter Creek—T40N, R04W, Sec. 3 to mouth[b]	ID17060108CL015b_03	126	Year-round
Gold Creek—T42N, R04W, Sec. 28 to mouth[b]	ID17060108CL029_02	126	Year-round
Gold Creek—T42N, R04W, Sec. 28 to mouth[b]	ID17060108CL029_03	126	Year-round
Gold Creek—source to T42N, R04W, Sec. 28[b]	ID17060108CL030_02	126	Year-round
Crane Creek—source to T42N, R04W, Sec. 28[b]	ID17060108CL031a_02	126	Year-round
Crane Creek—T42N, R04W, Sec. 28 to mouth[b]	ID17060108CL031b_02	126	Year-round
Deep Creek—source to T42, R05, Sec. 02[b]	ID17060108CL032a_02	126	Year-round
Deep Creek—source to T42, R05, Sec. 02[b]	ID17060108CL032a_03	126	Year-round
Deep Creek—T42, R05, Sec. 02 to mouth[b]	ID17060108CL032b_02	126	Year-round
Deep Creek—T42, R05, Sec. 02 to mouth[b]	ID17060108CL032b_03	126	Year-round

[a] *South Fork Palouse River Watershed Assessment and TMDLs* (DEQ 2007)
[b] *Palouse River Tributaries Subbasin Assessment and TMDL* (DEQ 2005a)
Note: colony forming units/100 milligrams (cfu/100 mL)

The *Paradise Creek E. coli Bacteria TMDL Addendum* (DEQ 2015) provides additional details on the bacteria TMDLs in the Paradise Creek watershed.

2.2.2.2 Monitoring Points

The established monitoring sites used in the TMDLs are also the compliance points. Since bacteria can travel throughout the entire stream, beneficial uses must be met throughout each §303(d) stream; therefore, each monitoring site is a compliance point for the bacteria TMDLs. Figure 6 provides the monitoring points.

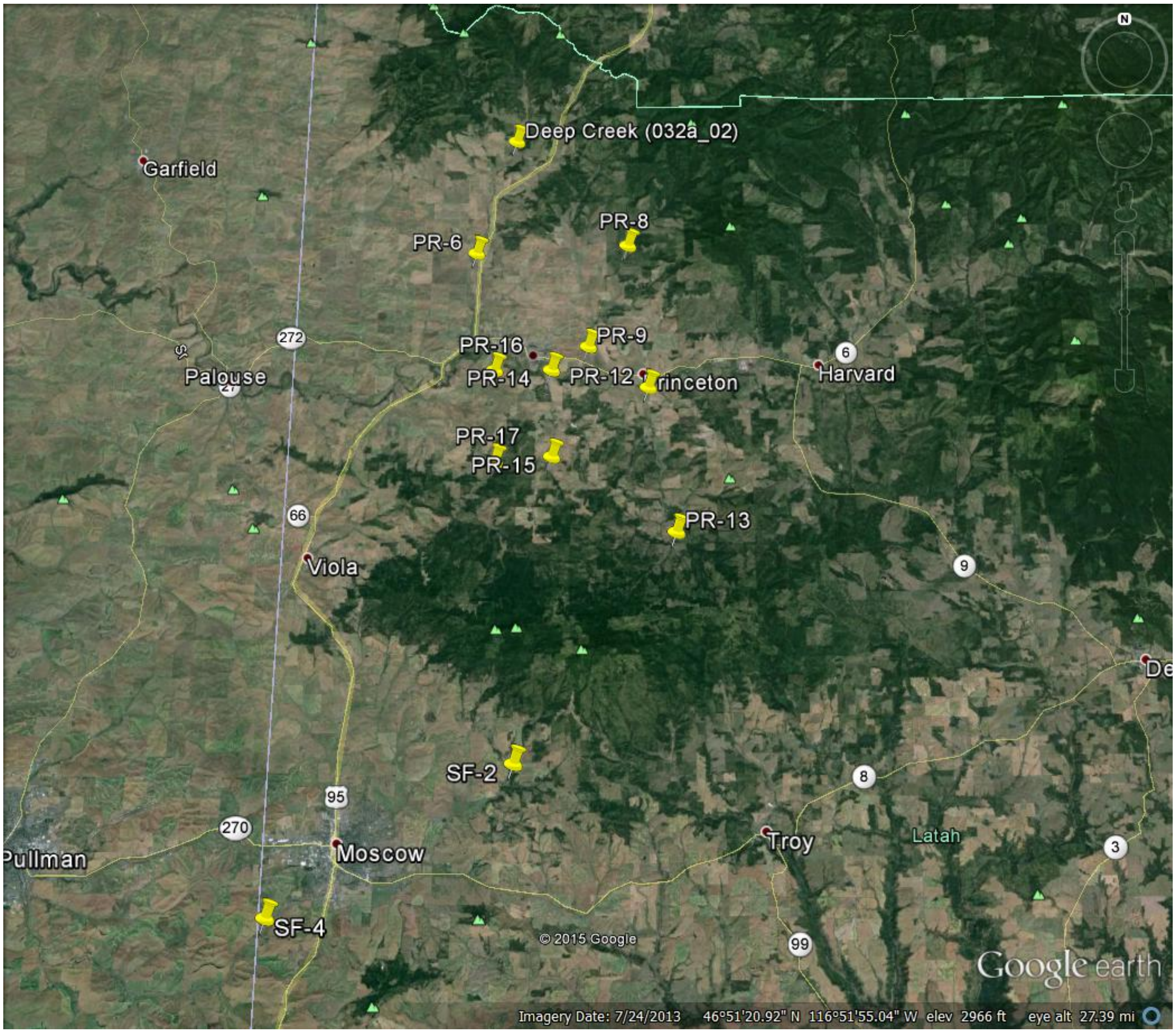

Figure 6. Palouse River subbasin TMDL bacteria monitoring points.

2.2.2.3 Load Capacity

The *E. coli* bacteria load capacity for the listed streams in the Palouse River subbasin TMDLs is a geometric mean of 126 cfu/100 mL. The load capacity is expressed as a concentration (cfu/100 mL) because the calculation of mass load is difficult due to the variability of temperature, moisture conditions, and flow, which can all influence the die-off rate of *E. coli* bacteria in the environment (EPA 2001).

2.2.2.4 Load Allocation

Bacteria are living organisms, and varying water quality and atmospheric conditions, which fluctuate continuously, dictate the actual mass of bacteria in the water. This fluctuation can complicate the load allocation process. For the purpose of this TMDL review, the daily load allocation for nonpoint and point sources alike is 126 cfu/100 mL, the geometric mean concentration currently allowed by Idaho's water quality standards.

Table 16 lists the existing *E. coli* monthly geometric mean bacteria concentrations calculated from measurements at the monitoring points established in the Palouse River subbasin TMDLs. The table also shows the load reduction needed to comply with the 126 cfu/100 mL criterion. A full data set is provided in Appendix B.

Table 16. *E coli* bacteria.

Stream Name and Monitoring Point	Assessment Unit Number	Existing Load (cfu/100 mL)	Load Capacity (cfu/100 mL)	Load Allocation (cfu/100 mL)	Load Reduction (%)
South Fork Palouse River—SF4	ID17060108CL002_03	102	126	126	0
South Fork Palouse River—SF2	ID17060108CL003_03	72	126	126	0
Flannigan Creek—PR17	ID17060108CL011a_02	1,940	126	126	93.5
Flannigan Creek—PR16	ID17060108CL011b_03	2,239	126	126	94.4
Rock Creek—PR14	ID17060108CL012_03	239	126	126	47
Rock Creek—PR15	ID17060108CL013a_02	141	126	126	11
Hatter Creek—PR13	ID17060108CL015a_02	190	126	126	34
Hatter Creek—PR12	ID17060108CL015b_03	764	126	126	84
Gold Creek—PR9	ID17060108CL029_03	234	126	126	46
Gold Creek—PR8	ID17060108CL030_02	223	126	126	43
Deep Creek—PR6	ID17060108CL032a_02	31	126	126	0
Deep Creek	ID17060108CL032b_03	48	126	126	0

Note: colony forming units per 100 milliliters (cfu/100 mL)

The *E. coli* bacteria TMDLs for the Palouse River subbasin TMDLs allocate a daily concentration to all nonpoint sources of *E. coli* bacteria upstream from the sample site. As such, sources extending upstream from these locations must be managed to reduce the instream *E. coli* bacteria concentrations in accordance with the load reductions in Table 16. To ensure the criterion is not exceeded, this allocation will apply daily throughout the year.

2.2.2.5 Wasteload Allocation

Wasteload allocations were provided for Syringa Mobile Home Park and Country Homes Mobile Park located in the South Fork Palouse River watershed. Wasteload allocations were based on an allowable daily concentration of 126 cfu/100 mL. In the *South Fork Palouse River Watershed Assessment and TMDLs* (DEQ 2007), a wasteload allocation was developed to accommodate a once a year discharge from the Country Homes Mobile Park lagoons. However, Country Homes Mobile Park applied for and received a land application permit in December 2012 and is no longer discharging to the South Fork Palouse River. The Syringa Mobile Home Park is operated as a no discharge-contained system. The system discharges only when ground water infiltration and surface runoff into the lagoon create a threat that the lagoon will breach. Discharge occurs as overflow through a gate in the lagoon wall, so only the top layer of the second lagoon is discharged. Since weather conditions dictate when overflow conditions occur, discharge only occurs during high instream flow periods since the instream flow is affected by the same weather conditions as the lagoons. For further discussion, see the South Fork Palouse River TMDLs (DEQ 2007).

2.2.2.6 Margin of Safety

In the case of *E. coli*, the pollutant load capacity has been calculated for the most critical time periods identified and is applied year-round. Existing loads are based on recent data and the geometric mean. The MOS for point and nonpoint sources is provided using recent data and the geometric mean. The load capacity of the effluent is the wasteload allocation for the point sources. The application of the conservative geometric mean criteria methods for TMDL calculations provides an implicit MOS.

2.2.3 Nutrients

2.2.3.1 Instream Water Quality Targets

In Idaho, a narrative water quality standard is used to protect cold water aquatic life beneficial uses from excessive nutrients. Idaho's narrative standard for nutrients states "surface waters of the state shall be free from excess nutrients that can cause visible slime growths or other nuisance aquatic growths impairing designated beneficial uses" (IDAPA 58.01.02.200.06). Aquatic life beneficial uses can be impaired when excessive algae decompose, depleting dissolved oxygen in the water column.

Monitoring data in the TMDLs indicate that phosphorous is the limiting nutrient for aquatic plant growth in the subbasin (Table 17). Total phosphorus (TP) was used as a surrogate target for nutrients in the Palouse River subbasin TMDLs. A TP target of 0.1 mg/L was used for the *Palouse River Tributaries Subbasin Assessment and TMDL* (DEQ 2005a), *Cow Creek Subbasin Assessment and Nutrient Total Maximum Daily Load* (DEQ 2005b), and *South Fork Palouse River Watershed Assessment and TMDLs* (DEQ 2007) based on EPA guidance and watershed characteristics. A TP target of 0.136 mg/L was used for the *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load* (DEQ 1997) based on natural background TP levels in the watershed.

2.2.3.1.1 Target Development

Cow Creek

A TP target of 0.1 mg/L was selected based on the watershed's characteristics and the EPA Gold Book (EPA 1986) as opposed to EPA's Ecoregional Criteria (see phosphorus compounds discussion in section 2.4, on page 26 in the TMDL).

South Fork Palouse River

A TP target of 0.1 mg/L was used for this TMDL based on the national EPA guidance, watershed characteristics, and other regional nutrient TMDLs addressing TP in the Palouse River subbasin.

Paradise Creek

A TP target of 0.136 mg/L was established based on data collected at the Idler's Rest Nature Conservancy in the upper reaches of Paradise Creek and determined to be the natural background phosphorous levels.

Palouse River Tributaries

The in-stream water quality target for nutrients was developed to restore full support of designated beneficial uses. The in-stream load reduction amount is based on measured TP amounts above the load capacity of 0.1 mg/L TP during the growing season May through October.

2.2.3.1.2 Listed Streams

The streams listed for nutrient impairment in the Paradise Creek TMDL (DEQ 1997), Palouse River tributaries TMDL (DEQ 2005a), Cow Creek nutrient TMDL (DEQ 2005b), and South Fork Palouse River TMDLs (DEQ 2007) are designated for cold water aquatic life and secondary contact recreation uses (section 3.1, Table 22).

Table 17. Assessment units with nutrient TMDLs.

Assessment Unit Name	Assessment Unit Number	Total Phosphorus Numeric Target (mg/L)	Critical Period
Cow Creek—source to Idaho/Washington border[a]	ID17060108CL001_02	0.1	June–September
Cow Creek—source to Idaho/Washington border[a]	ID17060108CL001_03	0.1	June–September
South Fork Palouse River—Gnat Creek to Idaho/Washington border[d]	ID17060108CL002_03	0.1	May–October
South Fork Palouse River—source to Gnat Creek; tributaries[d]	ID17060108CL003_02	0.1	May–October
South Fork Palouse River—source to Gnat Creek[d]	ID17060108CL003_03	0.1	May–October
Paradise Creek—urban boundary to Idaho/Washington border[b]	ID17060108CL005_02	0.136	May–October
Paradise Creek—forest habitat boundary to urban boundary[b]	ID17060108CL005_02a	0.136	May–October
Idlers Rest Creek—source to forest habitat boundary[b]	ID17060108CL005_02b	0.136	May–October
Flannigan Creek—source to T41N, R05W, Sec. 23[c]	ID17060108CL011a_02	0.1	May–October
Flannigan Creek—source to T41N, R05W, Sec. 23[c]	ID17060108CL011a_03	0.1	May–October
Flannigan Creek—T41N, R05W, Sec. 23 to mouth[c]	ID17060108CL011b_02	0.1	May–October
Flannigan Creek—T41N, R05W, Sec. 23 to mouth[c]	ID17060108CL011b_03	0.1	May–October
Hatter Creek—T40N, R04W, Sec. 3 to mouth[c]	ID17060108CL015b_02	0.1	May–October

Assessment Unit Name	Assessment Unit Number	Total Phosphorus Numeric Target (mg/L)	Critical Period
Hatter Creek—T40N, R04W, Sec. 3 to mouth[c]	ID17060108CL015b_03	0.1	May–October

[a] *Cow Creek Subbasin Assessment and Nutrient Total Maximum Daily Load* (DEQ 2005b)
[b] *Paradise Creek TMDL Water Body Assessment and Total Maximum Daily Load* (DEQ 1997)
[c] *Palouse River Tributaries Subbasin Assessment and TMDL* (DEQ 2005a)
[d] *South Fork Palouse River Watershed Assessment and TMDLs* (DEQ 2007)
Note: milligrams per liter (mg/L)

2.2.3.2 Monitoring Points

The established monitoring sites used in the TMDLs are also the compliance points and beneficial uses must be met throughout each §303(d) stream; therefore, each monitoring site is a compliance point for the nutrient TMDLs. Figure 7 provides the monitoring points.

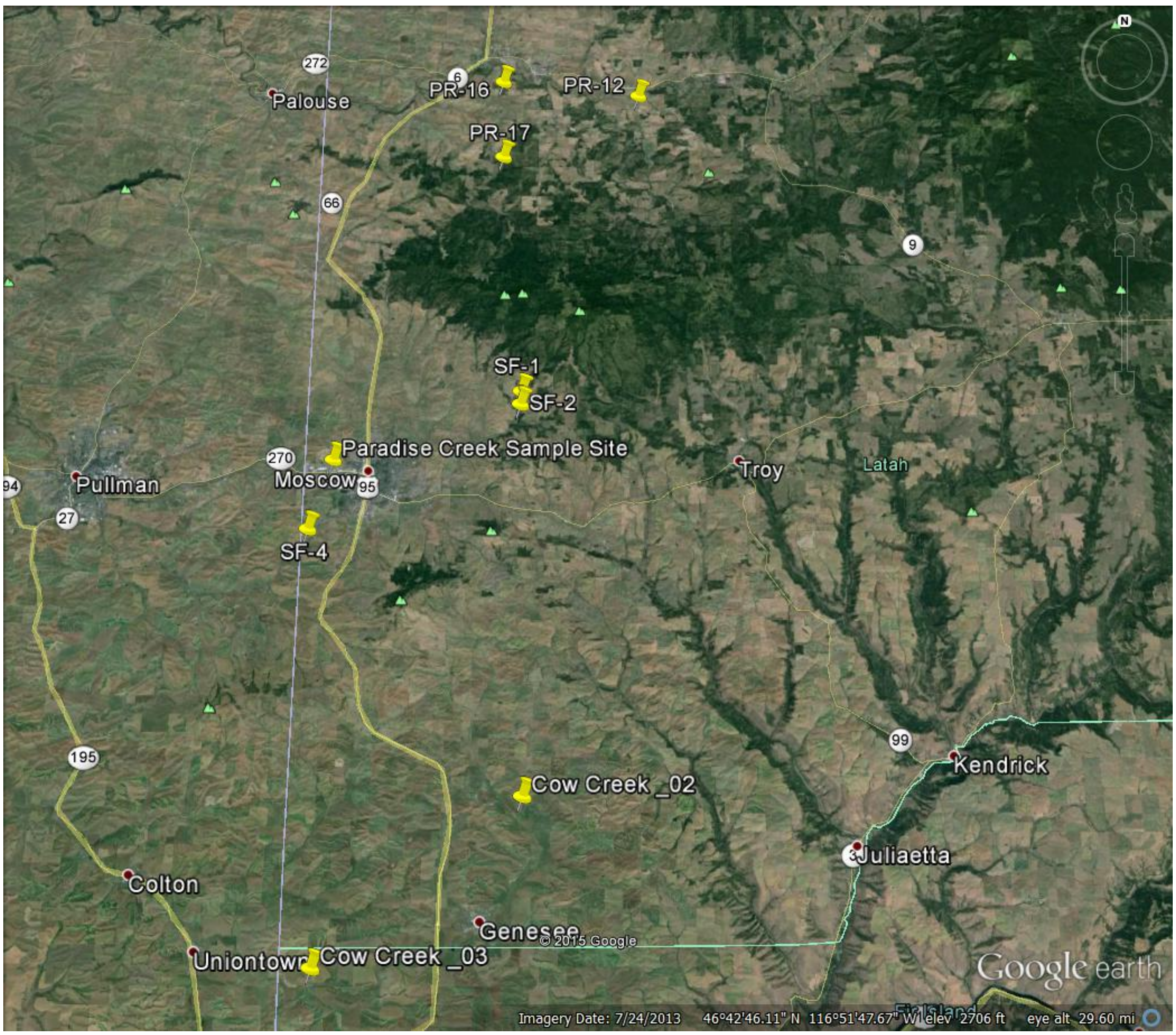

Figure 7. Palouse River subbasin TMDL nutrient monitoring points.

2.2.3.3 Load Capacity

The TP load capacity has been developed for each monitoring point using flow and TP data collected during the critical time period listed in the TMDLs (Table 17). Daily load was estimated by multiplying the measured concentration of TP and the streamflow estimates. Background loads are included as part of the load capacity. A MOS of 10% was subtracted from the load capacity to produce an available load capacity to account for errors (Table 18). Some of the initial TMDLs in the Palouse River subbasin used methods that are not comparable to the current methods used. As a result, the TMDLs may not be comparable and different outcomes may occur.

Table 18. Average total phosphorous nonpoint source load allocations.

Stream Name and Monitoring Point	Assessment Unit Number	Average Daily Flow	Total Load Capacity (kg/day)	10% Margin of Safety (kg/day)	Available Load Capacity (kg/day)	Existing Load (kg/day)	Load Reduction (%)
Cow Creek	ID17060108CL001_02	0.64	0.16	0.02	0.14	0.09	0
Cow Creek	ID17060108CL001_03	4.52	1.11	0.11	1	1.05	5
South Fork Palouse River—SF4	ID17060108CL002_03	3.34	0.82	0.08	0.74	0.87	15
South Fork Palouse River—SF1	ID17060108CL003_02	0.4	0.1	0.01	0.09	0.14	36
South Fork Palouse River—SF2	ID17060108CL003_03	2.1	0.51	0.05	0.46	0.48	4
Paradise Creek	ID17060108CL005_02	1.2	0.29	0.03	0.26	0.43	40
Flannigan Creek—PR17	ID17060108CL011a_02	3.72	0.91	0.09	0.82	0.76	0
Flannigan Creek—PR16	ID17060108CL011b_03	2.84	0.69	0.07	0.63	0.76	17
Hatter Creek—PR12	ID17060108CL015b_03	8	1.96	0.2	1.76	1.18	0

Notes: kilograms per day (kg/day)

2.2.3.4 Load Allocation

Pollutant loads for TP are presented in Table 18. Since specific source load data are not available, listed loads are comprehensive estimates between each monitoring station. These gross allocations account for all sources, such as stormwater runoff, agricultural practices, septic systems, and livestock operations. Load capacities include background conditions. A 10% MOS was specifically subtracted from the load capacity to produce an available load for allocation. For additional TP data and flow measurements, see Appendix C.

Several point sources in the Palouse River subbasin were documented and assigned wasteload allocations in the Palouse River subbasin TMDLs.

2.2.3.5 Wasteload Allocation

City of Moscow Wastewater Treatment Plant

Moscow's WWTP was given a wasteload allocation in the Paradise Creek TMDL (DEQ 1997) as seen in Table 19. Moscow's WWTP has continued to improve their TP removal process, and in the *NPDES Annual Report of Progress for 2014 Reporting Period* (City of Moscow WWTP 2014), they showed no phosphorus excursions for the 2014 season and had an overall efficiency of 99% phosphorus removal.

Table 19. Wasteload allocations for the City of Moscow wastewater treatment plant.

Source	Pollutant	Allocation	Critical Time Period
City of Moscow WWTP	Total phosphorus	2.0 kilograms per day (4.5 pounds per day)[a]	May 15–October 15

[a] The limit listed in the National Pollutant Discharge Elimination System permit is 4.1 pounds per day due to the actual facility design flow rather than the estimated design flow used in the TMDL calculations.

City of Genesee Wastewater Treatment Facility

The City of Genesee was issued a NPDES permit by EPA, effective April 2005. The NPDES permit did not include limits for TP but did include provisions for the facility to monitor TP. Therefore, Genesee's wastewater treatment facility (WWTF) was given an interim wasteload allocation in the Cow Creek nutrient TMDL (DEQ 2005b) (Table 20). Genesee has been complying with the monitoring requirements and anticipates improvements to further reduce the phosphorus input from the WWTF to Cow Creek.

Table 20. Waste load allocations for the City of Genesee wastewater treatment facility.

Source	Pollutant	Allocation
City of Genesee WWTF	Total phosphorus	0.60 kilograms per day

Country Homes Mobile Park

In the South Fork Palouse River TMDLs (DEQ 2007), a wasteload allocation was developed to accommodate a once a year discharge from the Country Homes Mobile Park lagoons. However, Country Homes Mobile Park applied for and received a land application permit in December 2012 and is no longer discharging to the South Fork Palouse River.

Syringa Mobile Home Park

The Syringa Mobile Home Park was designed to be operated as a no discharge contained system. Any discharge in the system occurs as overflow. According to a DEQ memo from the Regional Water Program dated November 28, 2006, Gerald Sholander informed the South Fork Palouse River Watershed Advisory Group of the potential for seasonal overflow wastewater discharges dictated by weather conditions. The 2007 South Fork Palouse River TMDL included a WLA for Syringa Mobile Home Park for that load during the non-critical season identified by the TMDL monitoring program and adopted in the TMDL. The WLA was provided to support Syringa Mobile Home Park's previously submitted NPDES permit application.

In 2013, DEQ issued a Notice of Violation to Syringa Mobile Home Park for failure to maintain the wastewater system in good repair and failure to conduct seepage testing for the wastewater lagoons. Those violations were not resolved and DEQ filed a civil complaint against Magar Magar, Syringa Mobile Home Park's owner, on January 31, 2014. A judgment was issued in DEQ's favor on June 11, 2014, but because of Magar's pending bankruptcy, the judgment has not been fully resolved.

The WLA for Syringa Mobile Home Park identified in the 2007 TMDL remains valid. However, the WLA is reserved for permitted discharges only. Should the mobile home park resolve its current wastewater difficulties and receive an NPDES permit for an appropriate discharge, the WLA is available for that use. If the mobile home park does not develop a permitted discharge, the WLA will remain in reserve for future growth to be used by other permitted entities within the South Fork Palouse watershed.

For more information on these systems and their discharge, see the South Fork Palouse River TMDLs (DEQ 2007).

2.2.3.6 Margin of Safety

An explicit MOS of 10% of the target load was deducted from the nonpoint source load allocation. Since the period of greatest aquatic plant growth and lowest flows was used to calculate the load capacity, the load capacity reflects a conservative estimate.

2.2.4 Ammonia

The *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load* listed Paradise Creek as impaired by ammonia (DEQ 1997). Idaho water quality standards include ammonia criteria intended to protect cold water biota. Idaho criteria for ammonia are based on calculations that take into account temperature and pH (IDAPA 58.01.02.250.02.d). No exceedances of the proposed ammonia targets were found upstream of Moscow's WWTP during the TMDL data collection; therefore, no load reductions from nonpoint sources were required.

After the Paradise Creek TMDL (DEQ 1997) was published, DEQ modified how water bodies are categorized. Prior to 2002, impaired waters were defined as stream segments with geographical descriptive boundaries. In 2002, DEQ modified how streams were categorized in the Integrated Report, which included identifying stream segments by AUs instead of nonuniform stream segments. These AUs and the methods used to describe them are found in the *Water Body Assessment Guidance* (Grafe et al. 2002). Due to this change, the upper AUs of Paradise Creek (ID17060108CL005_02a and ID17060108CL005_02b) were incorrectly listed for ammonia impairment. During the development of the Paradise Creek TMDL (DEQ 1997), Moscow's WWTP was found to be the most significant source of ammonia to Paradise Creek. The WWTP was given a wasteload allocation of 47.5 lb/day during the winter and 28.5 lb/day during the summer. These numbers were based on the Washington state ammonia criteria that were applicable while the TMDL was being written. The Washington state criteria have since been updated and are reflected in Moscow's WWTP NPDES permit limits shown in Table 21.

Table 21. NPDES effluent limit for the City of Moscow wastewater treatment plant.

Source	Pollutant	Average Monthly Limit	Maximum Daily Limit
City of Moscow WWTP	Total ammonia April–October	1 mg/L	2 mg/L
		30 lb/day	60 lb/day
	Total ammonia November–March	1.7 mg/L	3.5 mg/L
		51 lb/day	105.1 lb/day

Notes: milligrams per liter (mg/L); pounds per day (lb/day)

The Moscow WWTP has been in compliance with the total ammonia discharge limits set in the NPDES permit since 2002. For 2014, the effluent ammonia concentrations averaged 0.038 mg/L and the WWTP had 99% ammonia removal efficiency.

3 Beneficial Use Status

Idaho water quality standards require that surface waters of the state be protected for beneficial uses, wherever attainable (IDAPA 58.01.02.050.02). These beneficial uses are interpreted as existing uses, designated uses, and presumed uses. The *Water Body Assessment Guidance* (Grafe et al. 2002) gives a detailed description of beneficial use identification for use assessment purposes.

Existing uses under the CWA are “those uses actually attained in the water body on or after November 28, 1975, whether or not they are included in the water quality standards.” Designated uses are specifically listed for Idaho water bodies in tables in the Idaho water quality standards (IDAPA 58.01.02.003.27 and .02.109–.02.160 in addition to citations for existing and presumed uses).

Undesignated uses are to be designated. In the interim, and absent information on existing uses, DEQ presumes that most waters in the state will support cold water aquatic life and either primary or secondary contact recreation (IDAPA 58.01.02.101.01). To protect these so-called “presumed uses,” DEQ will apply the numeric cold water aquatic life criteria and primary or secondary contact recreation criteria to undesignated waters.

3.1 Beneficial Uses

All AUs in the TMDLs included in this review are designated for cold water aquatic life (CW) and secondary contact recreation (SCR) beneficial uses. Five AUs are also designated for salmonid spawning beneficial uses (Table 22).

Table 22. Beneficial uses of TMDL water bodies.

Assessment Unit Name	Assessment Unit Number	Beneficial Uses	Type of Use	Use Support[a]
Cow Creek—source to Idaho/Washington border[b]	ID17060108CL001_02	CW, SCR	Designated	NFS (CW) FS (SCR)
Cow Creek—source to Idaho/Washington border[b]	ID17060108CL001_03	CW, SCR	Designated	NFS (CW) FS (SCR)
South Fork Palouse River—Gnat Creek to Idaho/Washington border[e]	ID17060108CL002_03	CW, SS, SCR	Designated	NFS
South Fork Palouse River—source to Gnat Creek; tributaries[e]	ID17060108CL003_02	CW, SS, SCR	Designated	NFS
South Fork Palouse River—source to Gnat Creek[e]	ID17060108CL003_03	CW, SS, SCR	Designated	NFS
Paradise Creek—urban boundary to Idaho/Washington border[c]	ID 17060108CL005_02	CW, SCR	Designated	NFS
Paradise Creek—forest habitat boundary to urban boundary[c]	ID 17060108CL005_02a	CW, SCR	Designated	NFS
Idlers Rest Creek—source to forest habitat boundary[c]	ID 17060108CL005_02b	CW, SCR	Designated	NFS
Flannigan Creek—source to T41N, R05W, Sec. 23[d]	ID17060108CL011a_02	CW, SCR	Designated	NFS
Flannigan Creek—source to T41N, R05W, Sec. 23[d]	ID17060108CL011a_03	CW, SCR	Designated	NFS
Flannigan Creek—T41N, R05W, Sec. 23 to mouth[d]	ID17060108CL011b_02	CW, SCR	Designated	NFS
Flannigan Creek—T41N, R05W, Sec. 23 to mouth[d]	ID17060108CL011b_03	CW, SCR	Designated	NFS
Rock Creek—confluence of WF and EF Rock Creek to mouth[d]	ID17060108CL012_03	CW, SCR	Designated	NFS
West Fork Rock Creek—source to T41N, R04W, Sec. 30[d]	ID17060108CL013a_02	CW, SCR	Designated	NFS
West Fork Rock Creek—T41N, R04W, Sec. 30 to mouth[d]	ID17060108CL013b_03	CW, SCR	Designated	NFS
East Fork Rock Creek—source to T41N, R04W, Sec. 29[d]	ID17060108CL014a_02	CW, SCR	Designated	NFS
East Fork Rock Creek—T41N, R04W, Sec. 29 to mouth[d]	ID17060108CL014b_02	CW, SCR	Designated	NFS
Hatter Creek—source to T40N, R04W, Sec. 3[d]	ID17060108CL015a_02	CW, SCR	Designated	NFS
Hatter Creek—T40N, R04W, Sec. 3 to mouth[d]	ID17060108CL015b_02	CW, SCR	Designated	NFS
Hatter Creek—T40N, R04W, Sec. 3 to mouth[d]	ID17060108CL015b_03	CW, SCR	Designated	NFS
Big Creek—source to T42N, R03W, Sec. 08[d]	ID17060108CL027a_02	CW, SS, SCR	Designated	NFS (CW, SS) FS (SCR)
Big Creek—T42N, R03W, Sec. 08 to mouth[d]	ID17060108CL027b_02	CW, SCR	Designated	NFS (CW) FS (SCR)
Gold Creek—T42N, R04W, Sec. 28 to mouth[d]	ID17060108CL029_02	CW, SCR	Designated	NFS

Assessment Unit Name	Assessment Unit Number	Beneficial Uses	Type of Use	Use Support[a]
Gold Creek—T42N, R04W, Sec. 28 to mouth[d]	ID17060108CL029_03	CW, SCR	Designated	NFS
Gold Creek—source to T42N, R04W, Sec. 28 [d]	ID17060108CL030_02	CW, SS, SCR	Designated	NFS
Crane Creek—source to T42N, R04W, Sec. 28[d]	ID17060108CL031a_02	CW, SCR	Designated	NFS
Crane Creek—T42N, R04W, Sec. 28 to mouth[d]	ID17060108CL031b_02	CW, SCR	Designated	NFS
Deep Creek—source to T42, R05, Sec. 02[d]	ID17060108CL032a_02	CW, SCR	Designated	NFS
Deep Creek—source to T42, R05, Sec. 02[d]	ID17060108CL032a_03	CW, SCR	Designated	NFS
Deep Creek—T42, R05, Sec. 02 to mouth[d]	ID17060108CL032b_02	CW, SCR	Designated	NFS
Deep Creek—T42, R05, Sec. 02 to mouth[d]	ID17060108CL032b_03	CW, SCR	Designated	NFS

[a] FS = fully supporting, NFS = not fully supporting
[b] *Cow Creek Subbasin Assessment and Nutrient Total Maximum Daily Load* (DEQ 2005b)
[c] *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load* (DEQ 1997)
[d] *Palouse River Tributaries Subbasin Assessment and TMDL* (DEQ 2005a)
[e] *South Fork Palouse River Watershed Assessment and TMDLs* (DEQ 2007)
Notes: cold water aquatic life (CW); secondary contact recreation (SCR); salmonid spawning (SS)

Beneficial uses are protected by a set of criteria, which include *narrative* criteria for pollutants such as sediment and nutrients and *numeric* criteria for pollutants such as bacteria, dissolved oxygen, pH, ammonia, temperature, and turbidity (IDAPA 58.01.02.250). Table 23 includes numeric criteria used in TMDLs; Figure 8 provides the stream assessment process for determining support status of the beneficial uses of cold water aquatic life, salmonid spawning, and contact recreation.

Table 23. Selected numeric criteria supportive of designated beneficial uses in Idaho water quality standards.

Parameter	Primary Contact Recreation	Secondary Contact Recreation	Cold Water Aquatic Life	Salmonid Spawning[a]
Water Quality Standards: IDAPA 58.01.02.250–251				
Bacteria				
Geometric mean	<126 *E. coli*/100 mL[b]	<126 *E. coli*/100 mL	—	—
Single sample	≤406 *E. coli*/100 mL	≤576 *E. coli*/100 mL	—	—
pH	—	—	Between 6.5 and 9.0	Between 6.5 and 9.5
Dissolved oxygen (DO)	—	—	DO exceeds 6.0 milligrams/liter (mg/L)	**Water Column DO**: DO exceeds 6.0 mg/L in water column or 90% saturation, whichever is greater **Intergravel DO**: DO exceeds 5.0 mg/L for a 1-day minimum and exceeds 6.0 mg/L for a 7-day average
Temperature[c]	—	—	22 °C or less daily maximum; 19 °C or less daily average **Seasonal Cold Water**: Between summer solstice and autumn equinox: 26 °C or less daily maximum; 23 °C or less daily average	13 °C or less daily maximum; 9 °C or less daily average **Bull Trout**: Not to exceed 13 °C maximum weekly maximum temperature over warmest 7-day period, June–August; not to exceed 9 °C daily average in September and October
Turbidity	—	—	Turbidity shall not exceed background by more than 50 nephelometric turbidity units (NTU) instantaneously or more than 25 NTU for more than 10 consecutive days.	—
Ammonia	—	—	Ammonia not to exceed calculated concentration based on pH and temperature.	—
EPA Bull Trout Temperature Criteria: Water Quality Standards for Idaho, 40 CFR Part 131				
Temperature	—	—	—	7-day moving average of 10 °C or less maximum daily temperature for June–September

[a] During spawning and incubation periods for inhabiting species
[b] *Escherichia coli* per 100 milliliters
[c] Temperature exemption: Exceeding the temperature criteria will not be considered a water quality standard violation when the air temperature exceeds the ninetieth percentile of the 7-day average daily maximum air temperature calculated in yearly series over the historic record measured at the nearest weather reporting station.

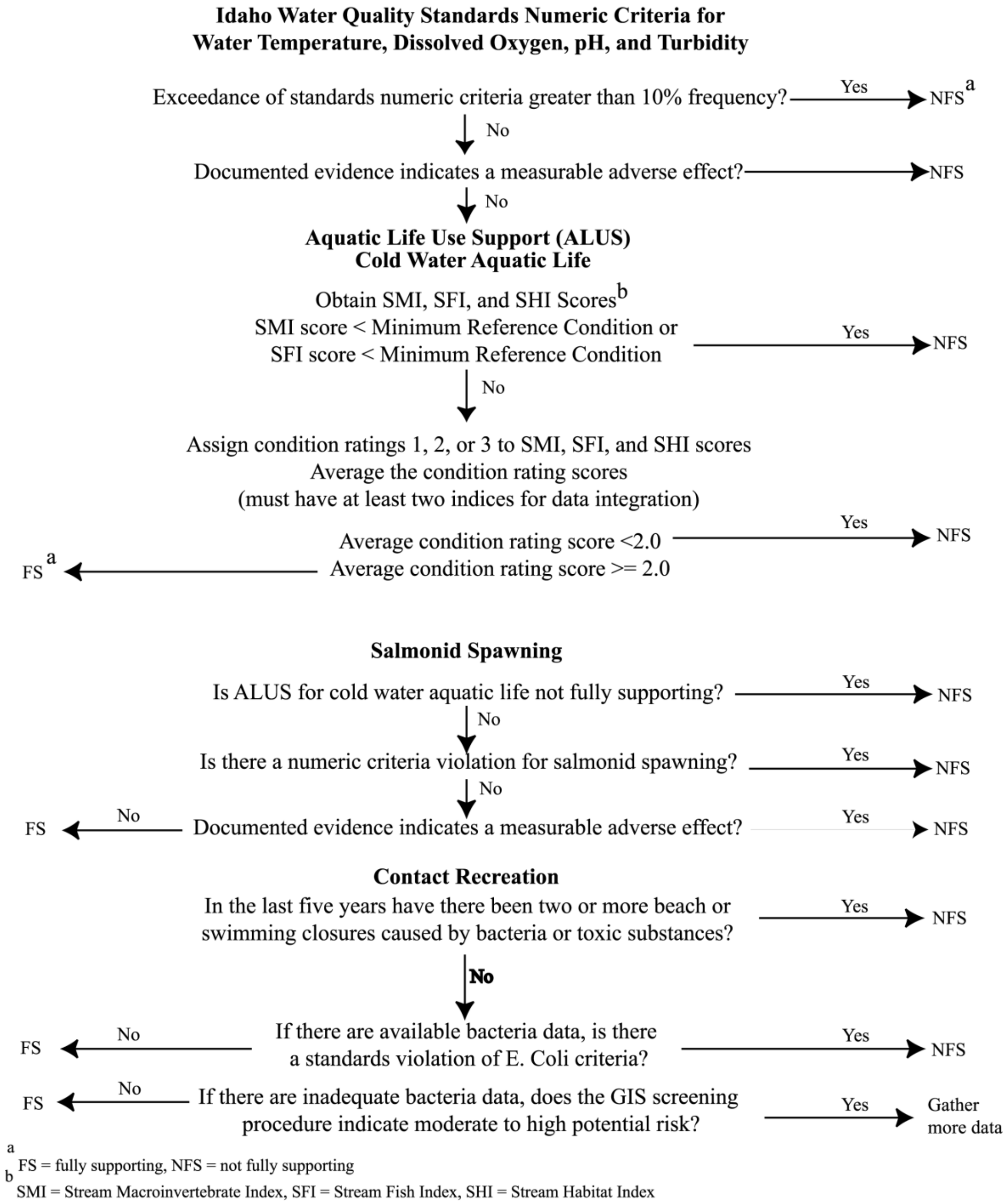

Figure 8. Determination steps and criteria for determining support status of beneficial uses in wadeable streams (Grafe et al. 2002)

3.2 Summary and Analysis of Current Water Quality Data

The data listed in section 2.2 were collected for this review. In addition, Beneficial Use Reconnaissance Program (BURP) data, which relate to the cold water aquatic beneficial use support, were collected and compiled into Table 24. At the request of the Palouse River Subbasin WAG, additional sampling for bacteria for the South Fork Palouse River took place during September and October 2015. The geometric mean showed that the South Fork Palouse River was achieving recreation beneficial uses during fall as well. The additional data are provided in Appendix B.

Table 24. Beneficial Use Reconnaissance Program data for the Palouse River subbasin.

Assessment Unit Name	Assessment Unit Number	SMI[a]	SFI[b]	SHI[c]	Average	Current Integrated Report Category
Cow Creek—source to Idaho/Washington border	ID17060108CL001_02	Dry	Dry	Dry	Dry	4a, 4c, 5
Cow Creek—source to Idaho/Washington border	ID17060108CL001_03	0	1	1	0	4a, 4c, 5
South Fork Palouse River—Gnat Creek to Idaho/Washington border	ID17060108CL002_03	0	0	1	0	4a, 4c
South Fork Palouse River—source to Gnat Creek; tributaries	ID17060108CL003_02	Dry/Denied	Dry/Denied	Dry/Denied	Dry/Denied	4a, 4c
South Fork Palouse River—source to Gnat Creek	ID17060108CL003_03	1	0	1	0	4a, 4c
Paradise Creek—urban boundary to Idaho/Washington border	ID17060108CL005_02	NA	0	1	0	4a, 4c
Paradise Creek—forest habitat boundary to urban boundary	ID17060108CL005_02a	NA	NA	NA	NA	4a, 4c
Idlers Rest Creek—source to forest habitat boundary	ID17060108CL005_02b	Dry	Dry	Dry	Dry	4a, 4c
Flannigan Creek—source to T41N, R05W, Sec. 23	ID17060108CL011a_02	Dry	Dry	Dry	Dry	4a, 4c
Flannigan Creek— source to T41N, R05W, Sec. 23	ID17060108CL011a_03	1	0	2	0	4a, 4c
Flannigan Creek—T41N, R05W, Sec. 23 to mouth	ID17060108CL011b_02	Dry	Dry	Dry	Dry	4a, 4c
Flannigan Creek—T41N, R05W, Sec. 23 to mouth	ID17060108CL011b_03	0	0	1	0	4a, 4c
Rock Creek—confluence of WF and EF Rock Creek to mouth	ID17060108CL012_03	Dry	Dry	Dry	Dry	4a, 4c
West Fork Rock Creek—source to T41N, R04W, Sec. 30	ID17060108CL013a_02	Dry	Dry	Dry	Dry	4a, 4c
West Fork Rock Creek—T41N, R04W, Sec. 30 to mouth	ID17060108CL013b_03	Dry	Dry	Dry	Dry	4a, 4c
East Fork Rock Creek—source to T41N, R04W, Sec. 29	ID17060108CL014a_02	Dry	Dry	Dry	Dry	4a, 4c
East Fork Rock Creek—T41N, R04W, Sec. 29 to mouth	ID17060108CL014b_02	Dry	Dry	Dry	Dry	4a, 4c
Hatter Creek—source to T40N, R04W, Sec. 3	ID17060108CL015a_02	1	3	1	1.67	4a, 4c
Hatter Creek—T40N, R04W, Sec. 3 to mouth	ID17060108CL015b_02	No flow	No flow	No flow	No flow	4a, 4c
Hatter Creek—T40N, R04W, Sec. 3 to mouth	ID17060108CL015b_03	NA	NA	NA	NA	4a, 4c
Big Creek—source to T42N, R03W, Sec. 08	ID17060108CL027a_02	NA	NA	NA	NA	4a, 4c
Big Creek—T42N, R03W, Sec. 08 to mouth	ID17060108CL027b_02	2	1	1	1.33	4a, 4c
Gold Creek—T42N, R04W, Sec. 28 to mouth	ID17060108CL029_02	Dry	Dry	Dry	Dry	4a, 4c
Gold Creek—T42N, R04W, Sec. 28 to mouth	ID17060108CL029_03	Denied	Denied	Denied	Denied	4a, 4c

Assessment Unit Name	Assessment Unit Number	SMI[a]	SFI[b]	SHI[c]	Average	Current Integrated Report Category
Gold Creek—source to T42N, R04W, Sec. 28	ID17060108CL030_02	3	3	3	3	4a, 4c
Crane Creek—source to T42N, R04W, Sec. 28	ID17060108CL031a_02	Beaver	Beaver	Beaver	Beaver	4a
Crane Creek—T42N, R04W, Sec. 28 to mouth	ID17060108CL031b_02	Dry	Dry	Dry	Dry	4a
Deep Creek—source to T42, R05, Sec. 02	ID17060108CL032a_02	Dry	Dry	Dry	Dry	4a, 4c
Deep Creek—source to T42, R05, Sec. 02	ID17060108CL032a_03	Denied	Denied	Denied	Denied	4a, 4c
Deep Creek—T42, R05, Sec. 02 to mouth	ID17060108CL032b_02	Dry	Dry	Dry	Dry	4a, 4c
Deep Creek—T42, R05, Sec. 02 to mouth	ID17060108CL032b_03	0	1	1	0	4a, 4c

[a] Stream Macroinvertebrate Index
[b] Stream Fish Index
[c] Stream Habitat Index
Note: NA – Not Assessed

4 Review of Implementation Plan and Activities

The *Paradise Creek Total Maximum Daily Load Implementation Plan* (Paradise Creek WAG 1999) *deq.idaho.gov/media/463500-_water_data_reports_surface_water_tmdls_paradise_creek_paradise_creek_imp_plan.pdf*; *Palouse River Tributaries Total Maximum Daily Load Implementation Plan for Agriculture* (Palouse River tributaries WAG 2009), *South Fork of the Palouse River Total Maximum Daily Load Implementation Plan for Agriculture* (South Fork Palouse River WAG 2009), and *Cow Creek Watershed Total Maximum Daily Load Implementation Plan for Agriculture* (Cow Creek WAG 2009) *deq.idaho.gov/media/449970-cow_creek_watershed_agriculture_implementation_plan_revised_0513.pdf* outlined critical areas for project activities with input from watershed stakeholders and the WAG. The Palouse River tributaries implementation plan and South Fork of the Palouse River implementation plan are not available in the Idaho DEQ website but can be requested through the Idaho Soil and Water Conservation Commission. Many watershed improvement projects with diverse funding sources have been completed or are ongoing in the Palouse River subbasin. Local watershed management agencies have worked together and with private landowners to implement best management practices (BMPs) to help restore the subbasin and prevent degradation.

Since the Paradise Creek TMDL was approved by EPA in 1998, many projects to directly improve water quality and instream habitat have been implemented in the Paradise Creek watershed. A summary of several of the restoration and improvement activities, provided by the University of Idaho, City of Moscow, and Palouse-Clearwater Environmental Institute (PCEI) are included in the following sections.

4.1 Paradise Creek

4.1.1 University of Idaho

Paradise Creek flows across the northern edge of the University of Idaho's main campus in Moscow. It enters the campus on the east side just north of Sweet Avenue and flows across the entire campus to the Washington–Idaho border.

Predating the University of Idaho creation in 1889 as a land grant college, landowners straightened and channelized the creek and constructed road and railroad crossings without adequate study or engineering to provide enough hydraulic capacity to properly convey flood events. In 1963 and 1965, the university covered approximately 1,300 linear feet of the creek. The result was that the creek was historically prone to flooding, with multiple inadequate under-crossings.

For the past 15 years, the university has been working to address flooding. An initial project was carried out in 1999–2000 in conjunction with the revitalization of the Sweet Avenue neighborhood on the east side of campus. A portion of that project restored a reach of Paradise Creek from Highway 95 to College Avenue and included creating large flood benches aimed at providing detention capacity to accommodate flood waters.

In 2010, the university completed a major restoration of Paradise Creek in collaboration with the US Army Corps of Engineers in the reach from Line Street to Perimeter Drive. This project completely reconstructed the channel from Line Street to Stadium Drive and diverted the main channel flow from under Paradise Creek Street. The project created a new undercrossing of Line Street in the form of a new, precast concrete deck bridge at Line Street that was engineered with enough hydraulic capacity to accommodate flow during a 500-year flood event. The 2010 restoration efforts were carried out in parallel with a project administered by the Division of Public Works that constructed two new Paradise Creek undercrossings at Stadium Drive. The new bridges at Stadium Drive are cast-in-place concrete deck bridges engineered and designed to accommodate flow during a 500-year flood event.

A new channel (2,100 feet) was constructed and runs along the east side of Line Street to Third Street, and then north and west adjacent to Idaho State Route 8 before merging with the original Paradise Creek channel. The segment includes gentle channel meanders and riparian vegetation, improving the habitat and aesthetics of the creek and enhancing its ability to provide water quality treatment.

Future projects will include replacing the three parallel, corrugated culverts under Perimeter Drive with a structure that has enough hydraulic capacity to accommodate flow during a 500-year flood event.

4.1.2 City of Moscow Wastewater Treatment Plant

4.1.2.1 Facility Description

The WWTP treats all wastewater collected from domestic, commercial, and institutional users within Moscow, including the University of Idaho. The majority of treated wastewater is discharged into Paradise Creek, a tributary of the South Fork Palouse River, under an NPDES permit. In addition to discharge to Paradise Creek, an estimated 75 million gallons of reclaimed treated effluent was diverted to the University of Idaho and used for irrigation during the summer months.

4.1.2.2 History

The first Moscow WWTP was constructed in 1918 and consisted of two large septic tanks with contact beds for secondary treatment.

A new WWTP was constructed in 1938 that included updating the contact beds to trickling filters and installing primary and secondary clarifiers and sludge digesters. The trickling filter plant was upgraded several times over the years, including addition of new primary and secondary clarifiers, grit removal, and chlorination in 1957; effluent irrigation, prechlorination, and sludge disposal facilities in 1961; updates to chlorination and aeration in 1973; and installation of a sludge storage lagoon in 1976.

The WWTP improvements Phase I upgrades were completed in 1996 and included the construction of sludge dewatering facilities as well as new chlorination and dechlorination buildings including a scrubber system in the event of a chlorine or sulfur dioxide leak.

The plant headworks were upgraded in 1998 with the construction of a new headworks building and the installation of two Auger Monsters capable of grinding and screening the influent stream to remove rags, plastics, and large debris as well as a Pista grit system to remove inorganic, abrasive solids.

In 1997, DEQ performed an assessment of Paradise Creek water quality that determined cold water aquatic life and secondary contact recreation to be the beneficial uses for the creek. Paradise Creek was listed as impaired for water quality, and a TMDL was prepared to quantify the various sources of pollutants and allocate the maximum load that can be discharged by each source in support of the beneficial uses. A more stringent NPDES permit was issued to the WWTP in 1999 that established discharge limits for ammonia, biochemical oxygen demand (BOD), chlorine, dissolved oxygen (DO), fecal coliform, pH, total phosphorus, TSS, and flow/temperature.

To comply with the new permit limits, in 2002 the City of Moscow completed construction of an advanced secondary biological nutrient removal treatment plant. The new plant included an influent pump station, biological treatment system, two secondary clarifiers, reaeration tank, chlorine contact chamber, utility water system, and sludge holding tanks. The new plant was quickly compliant with discharge limits for ammonia, BOD, chlorine, coliform, pH, and TSS.

To meet the phosphorus discharge limits set forth in the NPDES permit, the City of Moscow began constructing and installing tertiary filtration in fall 2008. Installation of five Parkson DynaSand filters was complete in October 2010. The system includes a continuous backwash, upflow, deep-bed granular media filter to remove phosphorus after coagulation with aluminum sulfate.

During warmer weather, the amount of discharge from the treatment plant to Paradise Creek is regulated under the NPDES permit. Allowable effluent discharge to the creek is calculated based on creek flow and temperature and the effluent temperature. Historically, the WWTP has had difficulty in meeting the lower temperature discharge limits in the summer months. In 2010, preliminary planning for Phase V began to address this issue, with 17 potential alternatives being considered such as reducing the temperature of the effluent through evaporative cooling towers, expanding wetland capability to reduce effluent temperature through evaporative transpiration, and expanding reuse options to reduce effluent discharge volume and increase effluent storage capacity so discharge to the creek could be delayed until cooler periods.

4.1.2.3 Current Treatment Configuration and Processes

Preliminary treatment of raw wastewater occurs in the plant headworks and consists of screening to remove rags, plastics, and large debris and degritting to remove abrasives. Rags, plastics, and large debris are removed with a mechanical screen. The screenings are washed before removal and hauled off site for landfill disposal. Heavy inorganic materials such as sand and gravel are removed in the grit basin, thus protecting moving mechanical equipment from abrasive wear and minimizing the accumulation of these materials in basins. The settled grit is periodically pumped from the grit basin, further separated from organic matter, drained, and hauled off site for landfill disposal.

The influent pump station consists of three constant speed enclosed screw (Archimedes) pumps. These pumps run at a constant speed but can handle variable flow rates into the pump station. Each pump is rated at 7.0 million gallons per day and only one pump is required for routine operation. Influent is lifted by the screw pumps and delivered to the advanced secondary treatment system.

The advanced secondary treatment process consists of the conditioning tanks and the aeration basin. The biological nutrient removal system for the Moscow WWTP is designed to remove nitrogen and phosphorus from the wastewater in addition to traditional secondary treatment removal of BOD and TSS.

- Anaerobic Conditioning Basins (AA basins): Influent wastewater and return activated sludge are combined in the anaerobic basins. Operated under anaerobic conditions, the AA basins act as biological selectors for organisms with the ability to retain excess phosphorus for energy storage. The anaerobic tank mixture is discharged to the anoxic basins.
- Anoxic Basins (AO basins): Discharge from the AA basins enters the AO basins, where it is mixed with recirculated mixed liquor from the AA basins. The mixture undergoes anoxic conditions where nitrates and DO in the recirculated mixed liquor are consumed by the activated sludge biological organisms, but no new oxygen is added by aeration.
- Aeration Basin (AB basin): The AO basins discharge to the AB basin, where the mixed liquor is maintained in an aerobic state for BOD and ammonia removal and flocculation of suspended solids.

Two 100-foot-diameter final clarifiers provide a quiescent zone where biological solids from the aeration basin are settled out. The settled solids are either recycled back to the AA basin as return-activated sludge or wasted from the system and sent to the sludge holding tanks as waste-activated sludge.

Effluent filtration occurs through Parkson DynaSand filters that are operational during the WWTP phosphorus compliance season (May 15–October 15). The system includes a continuous backwash, upflow, deep-bed, granular media filter to remove phosphorus after coagulation with aluminum sulfate. Filtration may also be valuable in meeting requirements for expanding effluent reuse in the future.

The reaeration basin contains one constant speed floating surface aerator. Flow from the final clarifiers can be sent to the reaeration basin depending on whether aerator operation is necessary to meet effluent DO discharge requirements.

To meet disinfection requirements, chlorine solution is injected into the flow stream at the head end of the chlorine contact chamber to allow adequate detention time for disinfection.

Effluent dechlorination is achieved by rapid reaction with sulfur dioxide gas injected into utility water and discharged into the effluent flow at the effluent weir.

The waste-activated sludge is stored under aerobic conditions in the sludge storage tanks. Two belt filter presses are used in sludge dewatering. The dewatered sludge is then hauled to Latah Sanitation for composting.

4.1.3 Palouse-Clearwater Environmental Institute

The PCEI is a nonprofit organization with programs that encourage sustainable living, provide experiential learning, and offer opportunities for serving in the community, while actively protecting and restoring natural resources. As part of PCEI's restoration work in the Paradise Creek watershed, over 42,691 linear feet of streambank has been restored, including 2,455,737 square feet of floodplain and 2,666,983 square feet of vegetated buffer. In addition, 54,211 herbaceous and woody plants have been planted; 139,702 square feet of wetlands have been created; and 2,541 feet of fencing has been installed through the efforts of PCEI and associated partners and volunteers.

The following restoration projects were funded in part by DEQ, EPA, the Idaho Bureau of Disaster Services, University of Idaho, and the City of Moscow with in kind match from organizations and individuals including the City of Moscow, University of Idaho, Washington State University, AmeriCorps National Civilian Community Corps, TerraGraphics Environmental Engineers, Bon Terra, Nez Perce Soil and Water Conservation District, Natural Resources Conservation Service, and community volunteers.

4.1.3.1 Carol Ryrie Brink Nature Park (1995–1996)

Paradise Creek had been straightened and channelized, creating unstable banks lacking riparian vegetation. The land adjacent to the stream was an active wheat field and plant diversity along the stream channel was low. The creek was heated by direct solar radiation. The water quality was impaired by direct, unbuffered flows of stormwater runoff.

During the project, the floodplain and streambanks were restored. A 5-acre floodplain was excavated and 1,200 feet of stream channel remeandered, moving 12,000 cubic yards of earth. Three 175-foot revetments for stabilization and demonstration purposes were built, including a log-crib revetment, BioLog revetment, and root-wad and rock revetment. Over 3,000 square feet of streambank and 5 acres of floodplain were seeded and mulched; over 6,000 square feet of geotextiles were installed, and over 750 native plants were planted.

4.1.3.2 Sweet Avenue Project (1998)

This section of Paradise Creek was channelized by previous landowners. In the past, this site was occupied by a concrete batch plant and a pesticide and diesel storage facility. Hazardous waste cleanup was conducted by the state. Eroding banks rose steeply on both sides.

During the project, channel meanders, a tighter low-flow channel, and a floodplain were constructed. The meanders provided more surface area for infiltration and more contact with riparian plants, which improved water quality and created better wildlife habitat. The reconstructed low-flow channel, sized for 2-year flows, increased baseflow during the hot summer months, which also benefitted aquatic life. The riparian floodplain was built to contain a 500-year flood event and provide water storage during heavy storm events. The floodplain was planted with native riparian vegetation, which acts as a buffer. Water quality was improved as suspended sediment and associated pollutants settled out on the floodplain during flood events. Hydraulic modeling showed that the constructed two-stage flood channel would not cause a rise in 100-year flood elevations. In fact, the modeling showed a drop in localized flood elevations of up to 1.5 feet.

Streambanks were resloped and sculpted for stabilization purposes, then covered with geotextile fabric to prevent erosion. Some of the streambanks were terraced and geotextile fabric applied in a stairstep fashion to form soil wraps. Red osier dogwoods were planted between the soil wraps to provide future bank stabilization with their root systems, and 20-foot coconut fiber BioLogs were interlocked to line the stream course to prevent bank erosion. The entire area was hydroseeded with grass and planted with native woody vegetation. These plants, in addition to their future aesthetic and erosion control value, will provide cooling shade to the stream, decrease water temperature, and increase the amount of DO available to fish and other aquatic organisms. In addition, this vegetation acts as a food and cover source for a diversity of wildlife, including songbirds, amphibians, and mammals.

The Sweet Avenue project also included construction of biofilters including grassy swales and *pocket* wetlands. These swales, or biofilters, are structural BMPs designed to treat stormwater runoff from the adjacent parking lot. The pocket wetlands were built in the bank of the existing stream channel and currently treat stormwater runoff as well as water flowing into Paradise Creek during higher flow events.

4.1.3.3 Chipman Trail (1999–2000)

This reach of Paradise Creek was characterized by weedy banks, devoid of woody vegetation. The channel was dredged in the past and is wide, with steep, vertical banks. In this project, native willow poles were planted along the stream to stabilize the banks. In addition, over 2,000 native trees and shrubs were planted in approximately 40-foot-wide buffer strips on either side of the creek. This vegetation will grow to shade the stream, helping to moderate stream temperatures. Woody riparian buffers offer many benefits, including runoff filtration, wildlife habitat, and floodwater retention. The City of Moscow Parks Department also cooperated with PCEI to plant native trees along the Chipman Trail, which parallels the project site, to expand the buffer width on the north side of the stream to approximately 75 feet.

4.1.3.4 Mountain View Park (1999–2000)

The 900-foot segment of the creek that flows through Mountain View Park was impacted by heavy pedestrian use. Activities such as soccer, baseball, and dog walking are typical park uses; consequently, the stream channel has few significant meanders due to this intensely managed landscape. Lack of significant vegetation allowed direct flow of stormwater runoff containing pollution to the creek. Reed canary grass is the dominant cover type, providing little shade to the creek channel. Canopy cover was minimal along this segment of the creek.

Volunteer groups helped plant 1,100 trees and shrubs along the tops of the streambanks. In spring 2000, 600 plants were planted and in the fall of the same year an additional 500 plants were planted at this site. These plantings will create a riparian forest buffer along the creek, which improves water quality, wildlife habitat, and aesthetics.

4.1.3.5 Meadow Street Projects (2000)

The stream channel was being impacted by the surrounding urban development and past land use practices. The riparian area was degraded due to water flow barriers such as concrete walls, chunks of concrete in the creek, and the steep gravel embankment along Meadow Street before the bridge across Joseph Street. Reed canary grass was the dominant cover type. These conditions significantly affected the stability of the inner streambank. Undercutting and bank failure was a common result.

The 65-foot project on the Lorfing property, located on the east side of the creek along Meadow Street, was manually constructed. The streambank was resloped and stabilized. A bundle of red osier dogwood cuttings was placed along the toe of the bank; vertical bundles of red osier dogwood were installed in shallow trenches running from the creek up the bank; and preplanted coconut fiber BioLogs were tiered along the toe of the bank for stabilization during the higher winter and spring flows. The entire area was seeded with a native riparian grass seed mix and then covered with erosion control fabric.

The second phase of this project included a 300-foot stream segment where an excavator removed a leaning concrete wall and the fill material associated with it. A two-tier floodplain was created along the length of the project. Over 50 live red osier dogwood poles were planted. The exposed streambanks were seeded with a native riparian grass seed mix, which was covered by erosion control fabric.

4.1.3.6 Nichols Project (2000)

The western side of Paradise Creek on this property was severely eroded and was slumping down into the creek. The streambanks were frequently undercut during heavy storm events. The area of concern along the western streambank was approximately 60 feet long. Restoration activity occurred from the creek edge to approximately 9 feet up the west streambank. BioLogs were installed to secure the toe of the slope. The site was also planted with native vegetation and willow poles to assist in securing the banks.

4.1.3.7 Berman Creekside Park (2001)

A tree revetment was installed at the west end of the park, on the south bank of Paradise Creek. Plantings were installed along the north streambank, where Paradise Creek passes through the park. At the location of the tree revetment, the stream segment had near-vertical, slumping, eroding streambanks that were frequently undercut by high water events, contributing to the sediment load in the creek. Areas of steep, exposed banks were eroding due to a lack of vegetative cover.

The purpose of the tree revetment was to stabilize and revegetate a 150-foot section of eroding streambank to reduce the amount of sediment entering the stream and provide habitat for fish and wildlife. A cedar/fir revetment was constructed, which involved securing 18 fallen trees along the base of the outside bank with cables and posts. Once that was completed, the upper bank was sloped back and covered with erosion control fabric, and native woody vegetation was planted. Plantings were also installed on the north side of Paradise Creek to stabilize the bank and add plant diversity to the riparian zone.

4.1.3.8 State Line Project (2001)

Streambanks along this segment of Paradise Creek were eroding due to a lack of woody vegetation and the steepness of the banks. The streambanks were frequently undercut during heavy storm events. The main purpose of this project was to stabilize and revegetate a 1,020-foot section of stream to provide habitat for fish and wildlife, provide shade to reduce stream temperatures, provide a vegetated buffer from agricultural runoff, and reduce the amount of sediments entering the stream. Earth moving was completed by University of Idaho Farm Operations. PCEI staff, volunteers, and the AmeriCorps National Civilian Community Corps team completed the other bank stabilization activities.

The steep streambanks were resloped to either a 2:1 slope (in areas where space was limited due to the proximity of a road) or to a 3:1 slope (where space was not limited). These more gradual slopes reduce erosion, reconnect the stream to its floodplain, and create an area in which to plant native vegetation. The resloped banks were seeded with a riparian grass mixture and covered with geotextile fabric. Native woody vegetation was planted in the fall. Where feasible, concrete that was dumped in or along the stream channel was also removed. The removal of concrete will allow for vegetation to be planted along the stream to provide habitat for fish and wildlife. In selected areas, coconut fiber BioLogs, preplanted with wetland plants, were installed along the toe of the streambank to stabilize the bank.

4.1.3.9 Bridge Street Park and West Bridge Street Bank Stabilization (2001–2002)

These stream segments were typified by slumping, eroding streambanks that were frequently undercut during heavy storm events, contributing sediment to Paradise Creek. In addition, annual dredging artificially widened and incised the stream channel. Few trees or woody vegetation grew along the stream segment.

The purpose of the Bridge Street Park project was to reconfigure approximately 450 linear feet of a straight, ditch-like creek to a low-flow channel with a terraced floodplain. Approximately 390 cubic yards of soil were excavated from this site. The newly constructed low-flow channel has a 3- to 4-foot bottom width, compared to the old width of 8 feet, and conveys the 1.5- to 2-year flow. Approximately 195 of the 390 cubic yards of soil were used as backfill to create the two-tiered floodplain with soil wraps to increase the flood storage capacity of this reach. The remaining 200 cubic yards of soil were removed off site. The local 10-year flood elevation was decreased by a maximum of 0.2 feet, and the 100-year flood elevation was decreased by 0.1 feet upstream of the project. Geotextile fabric soil wraps were used and seeded with native grasses. Each soil wrap is about 6 feet wide and 1 foot high. To create the terraces, the excavator constructed soil wraps out of erosion control blankets and some of the excavated material and secured them in place. The floodplain was constructed to a width of 20 feet on the west side of the stream in Bridge Street Park. In fall 2001, woody shrubs and trees were planted along the bank to introduce shade to the stream.

An additional 100-foot stream segment was stabilized just downstream of the Bridge Street Park project. The steep streambanks were resloped to reduce the sediment entering the stream. Erosion control blankets and coconut fiber-filled BioLogs preplanted with wetland plants were installed along the streambanks to stabilize the toe of the slope and to help improve water quality by reducing nutrients through the water-filtering qualities of wetland plants.

4.2 Palouse River Tributaries—Palouse-Clearwater Environmental Institute

4.2.1 Deep Creek Stabilization Project

For the Deep Creek Stabilization Project, PCEI stabilized 2,782 linear feet of streambank to decrease nonpoint source pollutant loads in Deep Creek. This project was cooperative in nature involving private landowners, Natural Resources Conservation Service, university professors and students, local students, community organizations, and volunteers. PCEI focused restoration activities along the segment of Deep Creek that bisects the property of Buck Espy, a long-time resident of Potlatch, Idaho. The goal of the project was to provide direct water quality improvements. Due to the intensive impacts from agriculture, ranching, and residential development in the watershed, sediment and temperature reduction were the primary targeted pollutants for the project based on the Deep Creek watershed priorities. The stabilization and revegetation of 2,782 feet of streambank will reduce instream erosion. Bank stabilization techniques included excavation and resloping of the streambank and installation of coir log and erosion control fabric. The 43,789-square-feet variable riparian buffer was planted with over 1,400 native woody species. The riparian buffer will act as a filter reducing overland sediment flows, while filtering nutrients and bacteria generated from upland land use practices. Restoration also included constructing a riparian fence and hardened rock crossing to allow livestock and tractor access to both sides of the creek. Off-stream watering was also installed to help reduce impacts of the livestock on Deep Creek.

4.2.2 Deep Creek Riparian Restoration Project

In cooperation with the Latah Soil and Water Conservation District, PCEI completed the Deep Creek Riparian Restoration Project. PCEI's restoration project was one part of a larger, inclusive watershed-wide project aimed at addressing watershed priorities and goals. Potlatch Corporation, Idaho Department of Lands, University of Idaho and North Latah County Highway District were also partners on the Palouse River Water Quality Improvement Project funded by 319 Nonpoint Source Management grant. Each organization focused on different BMPs. PCEI's focus was on riparian restoration. Restoration work took place on private property in the lower Deep Creek watershed. Restoration work was designed to reduce sediment, bacteria, nutrients, and temperature. In addition, this project improved riparian habitat. The stabilization and revegetation of 1,070 feet of creek will reduce in-stream erosion. Bank stabilization techniques included resloping and erosion control fabric installation. The estimated 22,500-square-feet variable riparian buffer was planted with native woody, herbaceous and grass species. The riparian buffer acts as a filter reducing overland sediment flows, while filtering nutrients and bacteria generated from upland land use practices. In addition to acting as a filter for pollutants, the established riparian buffer will also provide shade, reducing extreme summer temperatures. Two wetlands were also created to help filter overland flows that flow through the landowner's horse pasture. These wetlands will help reduce nutrient and bacteria from entering Deep Creek.

4.2.3 Flannigan Creek Riparian Restoration Project

PCEI completed restoration work on Flannigan Creek, which took place on private properties in the upper Flannigan Creek watershed. Restoration on Flannigan Creek targeted reductions in sediment, bacteria, nutrients, and temperature. In addition, this project improved riparian habitat through native plantings. Six adjacent landowners participated in riparian restoration work on their property. Water quality improvement projects focused on stabilizing streambanks where active erosion was visible and increasing wetland area in priority locations to collect and filter runoff. Riparian plantings focused on bare areas and current construction areas. The stabilization and revegetation of 1,336 feet of streambank involved resloping the streambank and installing erosion control fabric to reduce instream erosion. The 330,280-square-foot variable riparian buffer was planted with native species and acts as a filter reducing overland sediment flows, while filtering nutrients and bacteria generated from upland land use. Wetland swales were enhanced and created in areas suitable for runoff filtration to help expand stormwater holding capacity in the watershed.

4.3 South Fork Palouse River—Palouse-Clearwater Environmental Institute

4.3.1 Fountain Project

The riparian restoration at the Fountain Property project included resloping, stabilization, and revegetation of 1,670 feet of unstable creek bank and berm removal. An estimated 68,572-square-foot variable riparian buffer was planted with native plants. The goal of the restoration at this site was to reconnect the stream with the floodplain, reslope and stabilize eroding streambanks, and plant native shrubs and trees to create a variable-width riparian buffer. The restoration of the streambank and implementing a riparian buffer will reduce the sediment load as well as contribute to load reductions for phosphorous and nitrogen transported in sediment to the South Fork Palouse River.

4.3.2 Palouse River Drive Park Site

The riparian restoration at the City of Moscow site on the South Fork Palouse River aimed to decrease nonpoint source pollution and restore riparian and floodplain areas along the riverbank. BMPs included developing a functional floodplain, resloping and stabilizing eroding streambanks with various bioengineering techniques, constructing five riparian wetlands to treat surface runoff waters before it enters the South Fork Palouse River, and planting native woody and herbaceous vegetation to create a variable-width riparian forest buffer.

4.3.3 Robinson Park Project

Restoration took place on the South Fork Palouse River at the Robinson Park site with the focus of reducing sediment and nutrient loads, stabilizing temperature, improving habitat for wildlife and cold water biota, and mitigating local flood damage. To decrease nonpoint source pollutant loads, the PCEI restored 3,000 linear feet of streambank. This was a cooperative restoration project involving Latah County Parks and Recreation Department, private landowners, local students, community organizations, and volunteers. PCEI focused restoration efforts in the upper South Fork Palouse River watershed on two stream segments within Robinson County Park. Down-cutting of the stream and extensive areas of active erosion characterize this reach. Restoration of this reach will have a significant impact on water quality.

These projects restored 517,957 square feet of streambank and riparian area, created nine wetlands, and installed livestock fencing and hardened crossings at one site.

4.4 Cow Creek

In June 2009, DEQ issued a municipal wastewater reuse permit to the City of Genesee, allowing land application of its wastewater effluent from May through October. Between 2008 and 2012, EPA discharge monitoring reports show the City of Genesee did not discharge during July through September.

In 2004, the Latah Soil and Water Conservation District and Nez Perce Soil and Water Conservation District received a §319 grant for water quality improvement in Cow Creek. The goal was to improve water quality conditions within the Cow Creek watershed by implementing cost-share programs designed to support individual growers' transitions from current agricultural management practices to those designed to improve water quality through erosion and sediment reduction, improved nutrient management, extended crop rotations, and incorporation of new crops designed to reduce production inputs.

In 2007, the Idaho Transportation Department completed a State Highway 95 improvement project and compensated for filling 5 acres of wetlands by creating 10 acres of floodplain wetlands adjacent to Cow Creek at a cost of $2,000,000. The mitigations project planted floodplain vegetation along Cow Creek that will help restore the natural riparian canopy and help buffer runoff, mitigating nutrient inputs to Cow Creek.

4.5 Future Strategy

Continued monitoring will determine the effectiveness of current and future BMP implementation. Continuing to reduce nonpoint pollutant sources will be a priority in the Palouse River subbasin with continued monitoring to assess beneficial use support in the subbasin. The implementation plan for the Palouse River subbasin will be updated with input from the Palouse subbasin WAG to prioritize restoration work that needs to be completed or augmented within the subbasin.

Based on input from the Palouse River subbasin WAG, additional sampling for bacteria will take place in September 2015 in the South Fork Palouse River AUs and that information will be added to this review when it becomes available.

5 Summary of Five-Year Review

A review of the Palouse River subbasin TMDLs showed that existing pollutant loads in listed streams are generally improving. Ammonia in two upper Paradise Creek AUs (ID17060108CL005_02a and ID17060108CL005_02b) was listed in error, and the City of Moscow WWTP has been in compliance with their permit limits for ammonia since 2002. Bacteria sampling at 12 monitoring points established in the TMDLs showed that four sites need a load reduction of 0% and eight sites need load reductions ranging from 11% to 94.4% (Table 16). Nutrient sampling at nine monitoring points established in the TMDLs showed three sites need 0% load reductions while the other six sites need phosphorus reductions ranging from 4% to 40% (Table 18). Sediment sampling at 12 monitoring points established in the TMDLs showed seven sites need 0% load reductions while the other five sites need TSS reductions ranging from 2% to 68% (Table 2 to Table 13). In the Paradise Creek watershed, the review shows that while progress has been made, TMDL load allocations are not consistently met in Paradise Creek (Appendix A). Table 25 provides recommended changes to AU listing status in the next Integrated Report.

Table 25. Summary of recommended changes for AUs based on 5 year review.

Assessment Unit Name	Assessment Unit Number	Pollutant	Recommended Changes to Next Integrated Report	Justification
South Fork Palouse River—Gnat Creek to Idaho/Washington border	ID17060108CL002_03	Bacteria (*E. coli*)	Move from Category 4a to 2 for contact recreation use	Data show 126 cfu/100 mL geometric mean criteria is being met.
South Fork Palouse River—source to Gnat Creek; tributaries	ID17060108CL003_02	Bacteria (*E. coli*)	Move from Category 4a to 2 for contact recreation use	Data show 126 cfu/100 mL geometric mean criteria is being met.
South Fork Palouse River—source to Gnat Creek	ID17060108CL003_03	Bacteria (*E. coli*)	Move from Category 4a to 2 for contact recreation use	Data show 126 cfu/100 mL geometric mean criteria is being met.
Paradise Creek—urban boundary to Idaho/Washington border	ID17060108CL005_02	Ammonia	Keep in Category 4a; remove ammonia as an impairment	City of Moscow WWTP is meeting their permit effluent limits for ammonia.
Paradise Creek—forest habitat boundary to urban boundary	ID17060108CL005_02a	Ammonia	Keep in Category 4a; remove ammonia as an impairment	Listed in error
Idlers Rest Creek—source to forest habitat boundary	ID17060108CL005_02b	Ammonia	Keep in Category 4a; remove ammonia as an impairment	Listed in error
Gold Creek—source to T42N, R04W, Sec. 28	ID17060108CL030_02	Sediment (TSS)	Keep in Category 4a, remove sediment as an impairment	BURP data score of 3, indicating aquatic life beneficial uses are fully supporting; sediment data show no exceedance of the sediment surrogate.
Deep Creek—source to T42, R05, Sec. 02	ID17060108CL032a_02	Bacteria (*E. coli*)	Move from Category 4a to 2 for contact recreation use	Data show 126 cfu/100 mL geometric mean criteria is being met.
Deep Creek—source to T42, R05, Sec. 02	ID17060108CL032a_03	Bacteria (*E. coli*)	Move from Category 4a to 2 for contact recreation uses	Data show 126 cfu/100 mL geometric mean criteria is being met.

Assessment Unit Name	Assessment Unit Number	Pollutant	Recommended Changes to Next Integrated Report	Justification
Deep Creek—T42, R05, Sec. 02 to mouth	ID17060108CL032b_02	Bacteria (*E. coli*)	Move from Category 4a to 2 for contact recreation use	Data show 126 cfu/100 L geometric mean criteria is being met.
Deep Creek—T42, R05, Sec. 02 to mouth	ID17060108CL032b_03	Bacteria (*E. coli*)	Move from Category 4a to 2 for contact recreation use	Data show 126 cfu/100 mL geometric mean criteria is being met.

5.1 Water Quality Trend

Overall, water quality has not significantly changed in the Palouse River subbasin since the TMDLs were approved (Table B). In most cases, AUs in the Palouse River subbasin TMDLs are not supporting beneficial uses (Table 24). Table 25 shows the four Deep Creek AUs and three South Fork Palouse River AUs that are supporting recreational beneficial uses and the one Gold Creek AU that is supporting aquatic life beneficial uses.

5.2 Review of Pollutant Targets

The Palouse River subbasin TMDLs included targets for sediment (TSS) and nutrients (TP). No changes to the pollutant targets are recommended at this time.

5.3 Review of Beneficial Uses

All AUs in the TMDLs included in this review are designated for cold water aquatic life and secondary contact recreation beneficial uses. Five AUs are also designated for salmonid spawning beneficial uses (Table 22). No changes to the beneficial use designations are recommended.

5.4 Watershed Advisory Group Consultation

This review was developed with participation from the Palouse River subbasin WAG. Meeting dates were as follows:

- September 23, 2014—Palouse River subbasin TMDL review status and structuring of the WAG
- December 4, 2014—Finalize WAG structure, review of the Paradise Creek bacteria addendum
- January 14, 2015—Review of CWA and Idaho's water quality standards, overview of IPDES program
- February 24, 2015—Palouse subbasin TMDL review; *E. coli* and nutrient data review
- April 23, 2015—Review of Palouse River subbasin TMDL temperature addendum data
- June 8, 2015—Palouse River subbasin TMDL review; sediment data review

- September 30, 2015—Paradise Creek TMDL bacteria addendum review and concurrence to submit for finalization; Palouse River subbasin TMDL review discussion and concurrence to submit as final

5.5 Recommendations for Further Action

The implementation plan will be updated to reflect the observations and results in this 5-year review. As part of this, the designated management agencies will continue to work with landowners on riparian restoration.

References Cited

City of Moscow WWTP (City of Moscow Wastewater Treatment Plant). 2014. *NPDES Annual Report of Progress for 2014 Reporting Period*. Moscow, ID: City of Moscow.

Cow Creek WAG (Cow Creek Watershed Advisory Group). 2008. *Cow Creek Watershed Total Maximum Daily Load Implementation Plan for Agriculture.* Genesee, ID: Idaho Soil and Water Conservation Commission.

DEQ (Idaho Department of Environmental Quality). 1997. *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load*. Lewiston, ID: DEQ.

DEQ (Idaho Department of Environmental Quality). 2003. *Guide to Selection of Sediment Targets for Use in Idaho TMDLs.* Boise, ID: DEQ.

DEQ (Idaho Department of Environmental Quality). 2005a. *Palouse River Tributaries Subbasin Assessment and TMDL*. Lewiston, ID: DEQ.

DEQ (Idaho Department of Environmental Quality). 2005b. *Cow Creek Subbasin Assessment and Nutrient Total Maximum Daily Load*. Lewiston, ID: DEQ.

DEQ (Idaho Department of Environmental Quality). 2007. *South Fork Palouse River Watershed Assessment and TMDLs*. Lewiston, ID: DEQ.

DEQ (Idaho Department of Environmental Quality). 2013. *Cow Creek Temperature Total Maximum Daily Loads Addendum.* Lewiston, ID: DEQ.

DEQ (Idaho Department of Environmental Quality). 2014. *Idaho's 2012 Integrated Report*. Boise, ID: DEQ. Available at *http://www.deq.idaho.gov/water-quality/surface-water/monitoring-assessment/integrated-report.aspx*.

DEQ (Idaho Department of Environmental Quality). 2015. Draft *Paradise Creek E. coli Bacteria TMDL Addendum*. Boise, ID: DEQ.

EPA (US Environmental Protection Agency). 1986. *Quality Criteria for Water* (The Gold Book). Washington, DC: Office of Water. EPA 440/5-86-001.

EPA (US Environmental Protection Agency). 2001. *Protocol for Developing Pathogen TMDLs*. Washington, DC: EPA, Office of Water. EPA 841-R-00-02.

Grafe, C.S., C.A. Mebane, M.J. McIntyre, D.A. Essig, D.H. Brandt, and D.T. Mosier. 2002. *Water Body Assessment Guidance*. 2nd ed. Boise, ID: Idaho Department of Environmental Quality.

Idaho Code. 2012. "Revisions and Attainability of Beneficial Uses." Idaho Code §39-3607.

Idaho Code. 2012. "Development and Implementation of Total Maximum Daily Load or Equivalent Processes." Idaho Code §39-3611.

IDAPA. 2012. "Idaho Water Quality Standards." Idaho Administrative Code. IDAPA 58.01.02.

Lipscomb, W.S. 1998. *Hydrologic Classification and Estimation of Basin and Hydrologic Characteristics of Subbasins in Central Idaho*. US Geological Survey Professional Paper 1604.

Palouse River Tributaries WAG (Palouse River Tributaries Watershed Advisory Group). 2009. *Palouse River Tributaries Total Maximum Daily Load Implementation Plan for Agriculture.* Potlatch, ID: Idaho Soil and Water Conservation Commission.

Paradise Creek WAG (Paradise Creek Watershed Advisory Group). 1999. *Paradise Creek Total Maximum Daily Load Implementation Plan.* Moscow, ID: Latah Soil and Water Conservation District.

South Fork Palouse River WAG (South Fork Palouse River Watershed Advisory Group). 2009. *South Fork of the Palouse River Total Maximum Daily Load Implementation Plan for Agriculture.* Moscow, ID: Idaho Soil and Water Conservation Commission.

US Congress. 1972. Clean Water Act (Federal Water Pollution Control Act). 33 USC §1251–1387.

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Appendix A. Paradise Creek TMDL Five-Year Review—Sediment

1. Summary

Since the total maximum daily load (TMDL) data were collected in the mid-1990s and US Environmental Protection Agency approval of the TMDL in 1998, much work has been done in the Paradise Creek watershed both in expanding data sets to better understand the hydrology and water quality of the creek and to improve those factors by implementing best management practices (BMPs). Agricultural BMPs such as conservation and no-till practices, gully plugs, riparian buffers, contour farming, and others have been implemented throughout the watershed. Urban stream restoration practices have also been used, such as riparian plantings, wetlands construction, and remeandering. Due to historically high sediment loads in the Palouse region as a whole, sediment has been the primary monitoring focus in the Paradise Creek watershed. Since the Paradise Creek TMDL development in 1997, the annual sediment load target has been met 25% of the time (2001, 2005, 2010, and 2013), generally corresponding with dry watershed conditions. The data show that while progress has been made, TMDL load allocations are not consistently met in Paradise Creek. Sediment concentrations tend to be highest in January, February, and March. The data and analysis show targets may be more appropriately set if seasonality and flow, among other factors, are considered.

2. Watershed Background

The Paradise Creek watershed (4,890 hectares; hydrologic unit code 17060108) is located in the Palouse River hydrologic basin within the Northwest Wheat and Range Region in north-central Idaho and eastern Washington. The *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load* (DEQ 1997), approved by EPA in 1998, is for the Idaho segment of the creek from its headwaters to the state line. The watershed is comprised primarily of rural areas (62%) with urban and forest making up 20% and 18%, respectively (Figure A-1). Elevation ranges from 770 meters (m) to 1,330 m and precipitation from 650 millimeters (mm) to 1,000 mm with 70% falling in the winter months as rain and snow (Brooks et al. 2010). The headwaters of Paradise Creek are on Moscow Mountain, which is forested with limited logging and steep gradients. The creek then runs through approximately 9 kilometers of agricultural lands comprised mainly of winter wheat–spring grain–pea rotations. Some fields have been converted to conservation tillage, but conventional tillage still remains. The predominant soil in the agricultural area is Palouse silt loam, which is deep and well-draining. Soils with intermittent shallow argillic horizons are also present (e.g., Southwick, Garfield and Thatuna). Downstream of the agricultural lands, Paradise Creek passes through Moscow, Idaho, an urban area of approximately 24,000 people. The Moscow wastewater treatment plant (WWTP) has an outflow into the creek at the end of the urban area, just above the state line with Washington.

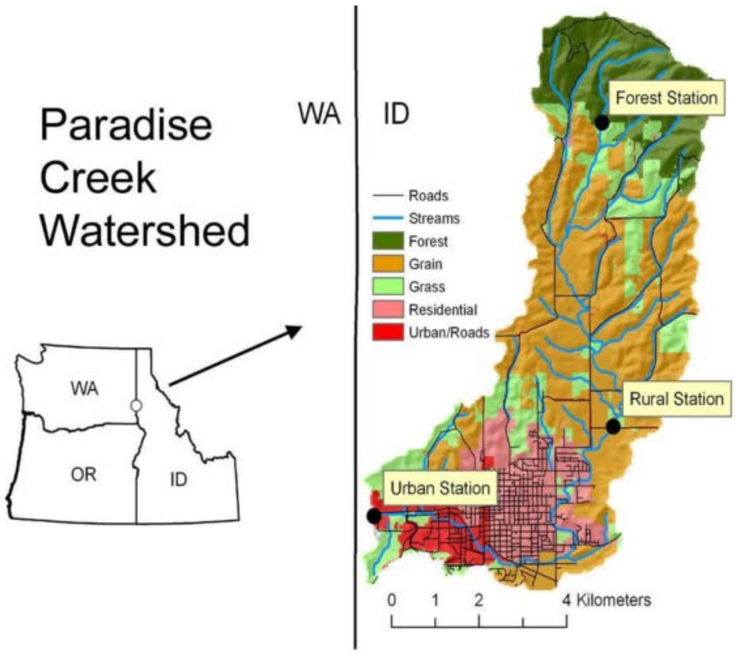

Figure A-1. Location of the Paradise Creek watershed in the Palouse region of the Pacific Northwest, and land use and sampling stations.

The Paradise Creek TMDL was written to address pollutants including nutrients, sediment, bacteria and temperature (DEQ 1997). Reducing sediment loads has been a primary focus of conservation and restoration work in the watershed since the TMDL was written because of the historically high sediment loads in the region (Kok et al. 2009) and potential to reduce phosphorus loads by reducing sediment loads. In the TMDL, the load allocation for sediment from nonpoint sources including the margin of safety was set at 260 tons per year (tons/year), requiring a 75% reduction from 1997 levels (DEQ 1997). The wasteload allocation from point sources was 96 tons/year, for a watershed total of 356 tons/year. The target has not yet been consistently achieved, but significant improvements have been made (Brooks et al. 2010) (Figure A-2).

In many streams and rivers, the majority of sediment load is delivered during a small proportion of the year, specifically during a few large storm events (Larson et al. 1997; Boardman 2006). Therefore, in this report we will also analyze sediment loads by season and event by characterizing the dominant soil, weather, and hydrologic conditions during the largest events so those attributes can be targeted with BMPs to reduce sediment loads.

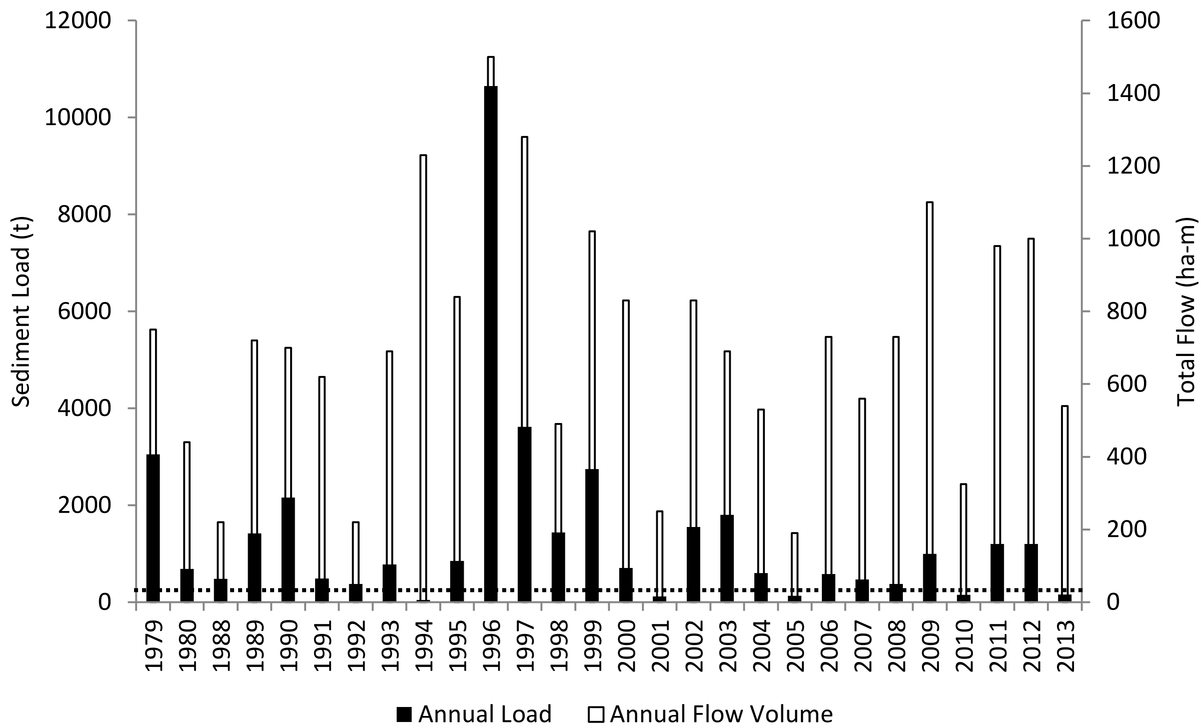

Figure A-2. Paradise Creek watershed annual sediment loads and flow, 1979–1980 and 1988–2013 at watershed outlet (adapted from Brooks et al. 2010). Dashed line indicates TMDL annual sediment load target for watershed outlet (356 tons/year).

3. Summary of Available Data and Methods

3.1 Monitoring Data and Methods

From 2000–2013, the Brooks and Boll laboratory at the University of Idaho collected continuous 15-minute water quality and hydrological data as well as event-based samples from two monitoring stations on Paradise Creek, one located at the approximate transition between rural/agricultural and urban land uses and the other below the urban area above the outlet of Moscow’s WWTP near the Idaho-Washington state line (Figure A-1). Detailed sampling methods can be found in Brooks et al. (2010).

We developed rating curves based on manual discharge measurements (velocity-area method) during the collection period to obtain continuous discharge data from stage height. From 2011–2013, we used discharge data from a US Geological Survey gaging station just upstream of the urban station in order to remove noise in the data from WWTP backflow. We collected weekly and event samples based on height and flow-volume thresholds that were used to measure total suspended sediment (TSS) concentration using the vacuum filtration standard method 2540D (Eaton et al. 1995). To obtain continuous TSS data, we found a regression relationship between turbidity and measured TSS. We calculated sediment load (kilograms per15 minutes) by multiplying 15-minute sediment concentration and 15-minute discharge, and then summing for each event and each water year. We subtracted the load calculated at the rural station (Darby Road) from the load at the urban station (Moscow’s WWTP) to isolate the influence of each land use on the event and annual sediment loads. We refer to those loads as *rural* and *urban* throughout the analysis, while we refer to the total load measured at the urban station as *watershed outlet*. The urban load is an approximation of the actual load because some sediment between the rural and urban stations may have been deposited or resuspended in the stream channel during a given event or year. A small tributary (Hog Creek) with rural land use before entering the urban area also was attributed to the urban load.

We collected precipitation (depth, timing, and intensity) and snowfall data using a tipping bucket rain gauge with snow adaptor at the rural station. During periods when that station malfunctioned, we supplemented data from a nearby monitoring station at the Cook Agronomy Farm (46°46'42.067"N; 117°5'21.533"W) near Pullman, Washington, using a correction factor calculated from total annual precipitation for each location. We obtained daily data for snowmelt, frozen soils, and snow cover from the University of Idaho’s Plant Science Farm in Moscow, Idaho (46°43'33.013"N; 116°57'18.388"W).

3.2 Event Analysis

3.2.1 Event Selection

Runoff and erosion events were selected during water years 2001–2013 by creating annual hydrographs for each station and visually identifying all peaks. We did not use a specific numerical cutoff in the initial selection of events and thus included all events that appreciably impacted the hydrograph or sediment load. Events started when discharge began to increase consistently above baseflow with little noise in the data. Events ended when discharge returned to baseflow (either antecedent levels or a consistent elevated level due to seasonal baseflow increases), identified using the constant slope method (Hewlett and Hibbert 1967). Generally, events that occurred early or late in the water year returned to antecedent baseflow. For events during late winter and spring, baseflow rarely returned to antecedent levels, so we selected the end of the event when the decrease in discharge was minimal to none, or when the next event began (if events were close to each other). Occasionally, small peaks occurred during the falling limb of a larger event and were included within the larger event. Multiple peaks in a short period of time occurred often during spring snowmelt and were considered to be one event because discharge never approached baseflow levels. After visually approximating runoff events in the hydrograph, we found corresponding dates in the continuous streamflow data and recorded specific start and end times. Using a lower limit of 1 ton for sediment load, we identified 137 events at the rural station and 191 at the watershed outlet.

We identified precipitation events as the start of precipitation to the end of a runoff event using the continuous climate data. We selected the start of a precipitation event at either the start of the runoff event, or the beginning of precipitation in the time period leading up to the runoff event if there was consistent precipitation (i.e., > 0.25 mm recorded hourly). We did not include sporadic small amounts of precipitation (< 0.5 mm greater than 2 hours apart) recorded before the start of the runoff event.

Variables analyzed for each event are described throughout the remainder of this section and listed in Table A-1. Total precipitation depth (P) is the sum of precipitation from the start of the precipitation event to the end of the runoff event; we also identified peak precipitation intensity (i) and time to peak precipitation (t_p).We recorded snowfall (S) during runoff events using data collected at the University of Idaho’s Plant Science Farm that separated out snowfall (as depth of snow) in the observed precipitation. We summed daily amounts beginning 1 day before the start of the runoff event (if runoff began in morning hours) and the same day as the runoff start (if runoff began after 12:00 hours). We assumed a snow-water equivalent (SWE) of 15% for new snow. We did not include snowfall occurring on the final day of the runoff event since it would not have had time to melt and contribute to streamflow. We recorded the presence of snow cover during the rising limb, falling limb, or entirety of the event. We calculated snowmelt (*M*) as the difference between the depth of snow cover at the beginning of the event, including 1 day prior, and the depth at the end of the event. If the event ended in early morning hours (i.e., before solar radiation is present to melt the snow), we did not include the final day in this calculation since snow cover observations were recorded at 17:00 hours. We assumed a SWE of 30% for older snow.

We calculated net $P + M$, or the available inflow (*A*) for each event to account for both precipitation immediately contributing to the system and snowmelt (Equation A-1):

$$A = P - S + M$$ **Equation A-1.**

Where:

A is available inflow (mm)
P is total measured precipitation (mm) using a tipping bucket rain gauge with snow adaptor
S is snowfall SWE (mm)
M is snowmelt SWE (mm).

In a small number of events when measured snowfall was much greater than measured precipitation (perhaps due to instrument malfunction or precipitation differences between sites), a negative value resulted from $P - S$. For these events, we set net precipitation to zero, since snowfall was the dominant component, implying that snow density was lower (e.g., 10%) or that the newly fallen snow did not contribute to streamflow during that event.

Examining the relationship between *A* and streamflow depth (*D*) can indicate the proportion of direct flow during a runoff event (Merz et al. 2006; Lana-Renault and Regüés 2009). We found *D* by calculating the total runoff volume during an event and dividing it by the area of the catchment. We calculated the stormflow coefficient (*SC*) for each event by finding the ratio of streamflow depth to available inflow (Equation A-2):

$$SC = \frac{D}{A}$$ **Equation A-2.**

Table A-1. Variables found for each erosion event, including variable abbreviations used throughout the text, measurement units, and descriptions.

Variable	Abbreviation	Unit	Description
Total precipitation depth	P	mm	Depth of precipitation during and immediately leading up to event measured with rain gauge and snow adaptor
Snowfall snow water equivalent (SWE)	S	mm	Depth of snowfall during and immediately leading up to event, multiplied by 0.15 for SWE
Snowmelt SWE	M	mm	Depth of snow that melted during event, multiplied by 0.3 for SWE
Available inflow	A	mm	Depth of water available to system considering precipitation and snowmelt, calculated as $R_m = P - S + M$
Time to maximum rainfall intensity	t_p	mm	Time elapsed from start of rainfall event to maximum rainfall intensity
Maximum rainfall intensity	i	mm h^{-1}	Maximum rainfall intensity over 1 hour that occurred during event
Peak discharge	Q_{max}	$m^3 s^{-1}$	Peak stream discharge during event
Average discharge	Q_{ave}	$m^3 s^{-1}$	Average stream discharge during event
Event intensity	Q_{max}/Q_{ave}	—	Relative intensity of event runoff
Streamflow depth	D	mm	Depth of streamflow calculated as total volume of water during event divided by catchment area
Event water volume	V	ha-m	Streamflow water volume during event calculated as average discharge multiplied event duration
Antecedent baseflow	B	$m^3 s^{-1}$	Stream discharge immediately before event start; used as surrogate for soil moisture
7-day antecedent precipitation.	P_7	mm	Total precipitation summed for 7 days before event start; used as surrogate for soil moisture
Water year cumulative precipitation.	CP	mm	Total precipitation depth measured from October 1 of water year to event start; used as surrogate for soil moisture
Time to runoff peak	t_r	min	Time elapsed from start of runoff event to peak stream discharge (length of rising limb)
Event runoff duration	t_d	min	Duration of runoff event from start to end
Relative rising limb length	t_r/t_d	—	Ratio of time to peak discharge to event duration; larger number indicates proportionally longer rising limb
Stormflow coefficient	SC	—	Stormflow coefficient indicates proportion of direct flow during event, calculated as $SC = D/A$
Snow cover	C	Categorical	Presence of snow cover
Snowmelt event	SM	Categorical	Presence of snowmelt
Frozen soils	F	Categorical	Presence of frozen soils
Thawing soils	T	Categorical	Presence of thawing soils
Limiting factor	lf	Categorical	Transport or supply limited event
Land use	U	Categorical	Event measured at rural or urban station

Notes: millimeter (mm); hour (h); second (s); hectare (ha); minute (min)

The resulting value indicates the proportion of available inflow (precipitation and snowmelt) that enters the stream through direct flow rather than baseflow. A greater value indicates greater amounts of direct flow. In this research, we also used antecedent baseflow (*B*), 7-day antecedent precipitation (P_7), and water year cumulative precipitation (*CP*) as surrogates for antecedent moisture conditions in the watershed.

Using frost tube data at the University of Idaho's Plant Science Farm, we identified the presence of frozen (*F*) or thawing (*T*) soils during events. When the frost tube was not installed (typically from beginning of March to October or November), or not functioning, we used the 10-centimeter soil temperature data to determine the presence of frozen soil. We observed in the data that when maximum and minimum soil temperatures for a given day were both at 1.1 °Celsius or less, soils were typically frozen. Therefore, we applied that assumption when the frost tube data were absent.

3.2.2 Sediment Delivery Behavior

The *first flush* concept for sediment delivery, initially introduced by Helsel et al. (1979), can be used to identify when disproportionately high sediment delivery occurs during an event. This concept has most often been applied to urban systems (Cristina and Sansalone 2003; Piro and Carbone 2013) due to the characteristic *flushing* of impervious surfaces, but it was also applied to agricultural and forested systems (Helsel et al. 1979). To determine when the sediment flush occurs, the normalized sediment mass, $M(t)$, and the normalized flow volume, $V(t)$, were calculated as (Equations A-3 and A-4):

$$\mathrm{M(t)} = \frac{\sum_{i=0}^{k} \bar{Q}(t_i)\bar{C}(t_i)\Delta t}{\sum_{i=0}^{n} \bar{Q}(t_i)\bar{C}(t_i)\Delta t}$$

Equation A-3.

$$\mathrm{V(t)} = \frac{\sum_{i=0}^{k} \bar{Q}(t_i)\ \Delta t}{\sum_{i=0}^{n} \bar{Q}(t_i)\ \Delta t}$$

Equation A-4.

Where:

$\overline{Q}(t)$ is the average flow rate
$\overline{C}(t)$ is the average sediment concentration during the time interval $k < n$ where $n =$ time at end of event (Helsel et al. 1979; Cristina and Sansalone 2003).

When these curves are plotted together, the sediment flush is at the point when $M(t) > V(t)$ (Figure A-3, A-C).

Hydrologic systems can be classified as *transport limited* or *supply limited*. An erosion event is characterized as transport limited if there is sufficient sediment available, but the flow rate is the limiting factor (Piro and Carbone 2013). An event is supply limited when there is not sufficient sediment available for transport, such as immediately following another event that flushed the system. To quantify when an event is transport or supply limited, the ratio of the area under the $M(t)$ and $V(t)$ curves is used (Cristina and Sansalone 2003). When the area ratio of $M(t){:}V(t) > 1$, the event is transport limited. When $M(t){:}V(t) < 1$, the event is supply limited (Figure A-3, A-C). We applied this concept to our event data set to determine if the Paradise Creek system is generally supply or transport limited.

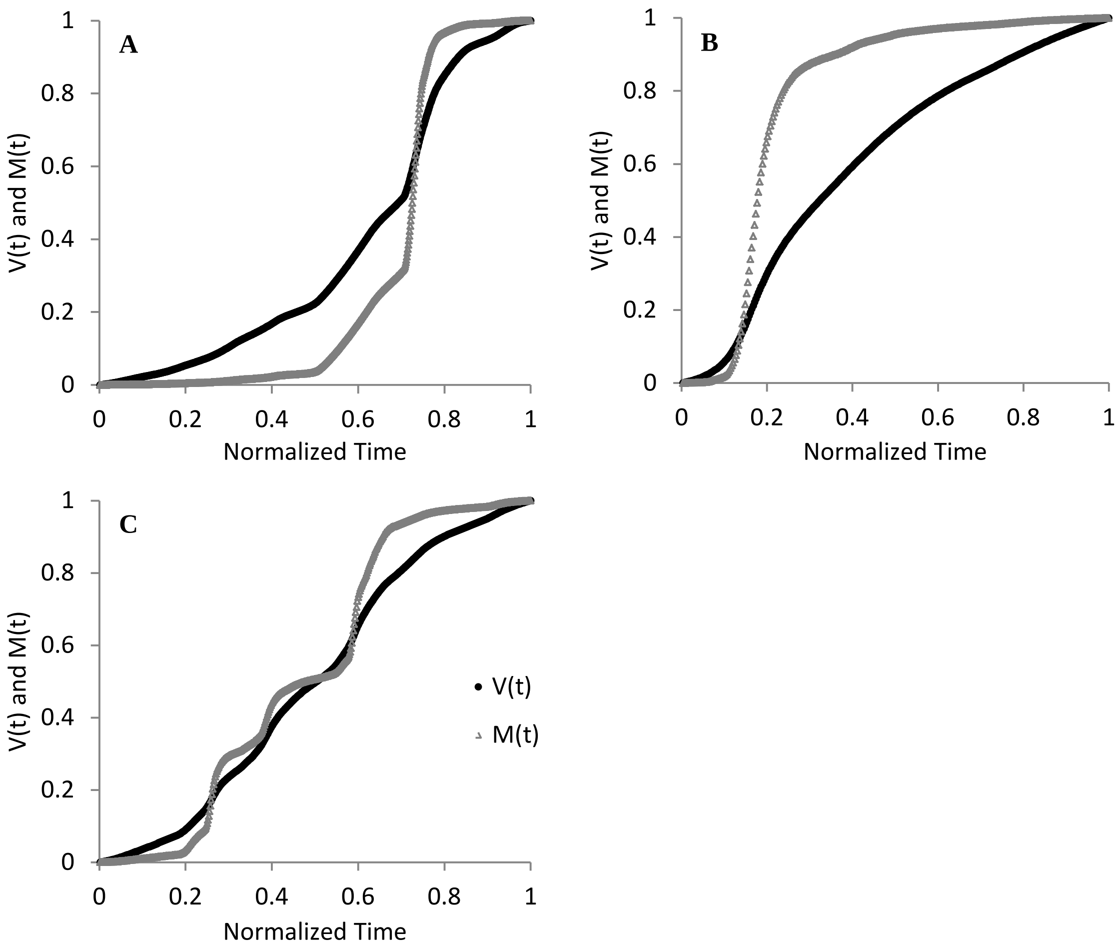

Figure A-3 (A-C). Normalized sediment mass, M(t), and normalized flow volume, V(t), as a function of normalized time. When M(t) crosses V(t), a sediment flush occurs. A. Supply limited event because area ratio of M(t):V(t) < 1; B. Transport limited event because area ratio of M(t):V(t) > 1; C. No limiting factor because area ratio of M(t):V(t) = 1.

3.2.3 Statistical Analysis

We statistically analyzed the impact of multiple variables on event sediment load in the Paradise Creek watershed using multiple linear regression and ANOVA in the R statistical package (R Development Core Team 2008) for 328 events. The variables analyzed account for climate, watershed, and antecedent conditions (Table A-1).

We log transformed the response variable (event sediment load) and removed variables from the model based on collinearity with another variable. Using stepwise regression with Akaike Information Criterion, we narrowed down the variables to those with statistical significance ($p < 0.05$) in explaining the response of event sediment load.

3.2.4 Land Use Contributions, Seasonality, and Flush Timing

Paradise Creek watershed is dominated by winter hydrology that results in significant storm events during late winter and early spring (December–April) when the catchment is saturated and precipitation generates greater levels of runoff. To determine the seasonal distribution of events, we found average monthly sediment load and concentration and streamflow volume, and compared across sites. Additionally, we plotted the annual hydrograph with cumulative sediment load to show interaction of events.

We examined the difference in the timing of the sediment flush at each station to determine if the load measured at the urban station could be attributed to a flush of sediments from the rural area. For events that were observed at both stations, flush timing is the difference in timing of the sediment flush at each site compared to the estimated travel time of the sediment wave, which can suggest the origin of the sediment load. Average stream velocity is approximately equal to the travel time of the sediment wave (Williams 1989). We used manual discharge measurements from 2001–2013 at the rural site to find stream velocity, which we calculated as discharge divided by stream cross-sectional area. We found average stream velocity for Paradise Creek's high runoff season (January–March, 0.51 meters per second) and used it to estimate the travel time of the sediment wave. Stream distance between the two monitoring sites is 8,850 m; therefore, the travel time of the sediment wave is, on average, 4.8 hours.

We found the timing of the sediment flush using *first flush* curves for each event. Those curves, because they are normalized by time, show at what percent through the event the sediment flush occurred, which we then used to find the actual time of the sediment flush during the event. We also compared the timing of peak sediment concentration between sites to confirm the timing of the sediment flush. We used both methods to increase confidence in determining when the sediment flush occurred at each site. When the sediment flush occurred first at the rural site and travel time of the sediment wave was less than or equal to the flush difference (i.e., the sediment wave from the rural area arrived at the urban station before a flush occurred there), the sediment measured at the watershed outlet likely came from the rural area. If travel time was greater than the flush difference, then the sediment measured at the watershed outlet cannot be attributed to the rural area. When the sediment flush occurred first at the watershed outlet, we considered the sediment load measured there to be from the urban area or the stream channel within the urban area. We then used the flush versus travel time analysis to reapproximate annual and monthly sediment loads from each land use and estimate how many urban events can potentially be attributed to the rural area.

4. Results

4.1 Sediment Delivery Behavior

Most events in Paradise Creek are transport limited (Figure A-4). Rural events are more transport limited than events at the watershed outlet, indicating a continual availability of sediment in the rural area as well as greater discharge at the watershed outlet. While we expected to observe that supply limited events occur mainly in the fall before the watershed is saturated or in the spring when crops have emerged, that did not occur. Furthermore, we did not notice any influence of the previous event on the subsequent one with respect to sediment delivery behavior. Specifically, we hypothesized that supply limited events would follow large events because the immediate availability of sediment would have been greatly reduced. However, that pattern was not apparent. This suggests that deposition may occur at the end of each event, thus replenishing streambed sediments. In transport-limited events, the sediment flush occurred early in the event, generally in the first 20%. In supply limited events, the sediment flush occurred closer to the middle of the event. In all events, the majority of the sediment load was transported during the flush period.

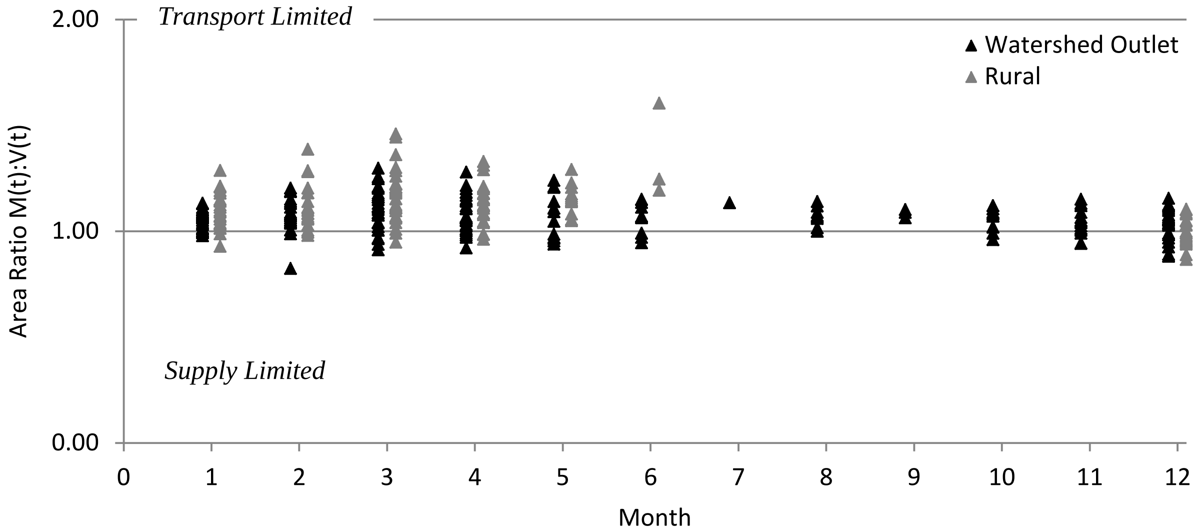

Figure A-4. Area ratio of normalized sediment mass and flow volume curves, M(t):V(t), in the Paradise Creek watershed for watershed outlet and rural events by month. The *equal area line* is at 1.00; above that line, events are considered transport limited and below it, events are considered supply limited.

4.2 Characterization of Extreme Events

Each erosion event is unique. While a statistical analysis of the variables that explain sediment load for all events provides useful insight to processes and conditions that lead to high loads, the characteristics of individual extreme events point to specific climate and land use conditions that have the greatest impact on the sediment budget. In the Paradise Creek watershed, one event contributes, on average, 33% of the annual sediment load but only accounts for 2% of the time in a year (Figure A-5, A-B). All events account for 86% of the average annual sediment load and 16% of the time in a year, leaving the remainder for the baseflow period. The five largest events in the watershed during the study period occurred on February 17–27, 2002; March 10–16, 2002; January 28–February 5, 2003; March 8–14, 2003; and March 20–April 4, 2012. These events each exceeded 285 tons at both monitoring stations and were within the top six at each station. (January 28, 2004, was the fifth largest for rural and January 12, 2011, the fifth largest for watershed outlet, but each one was not in the top six for the other station and so was not included.)

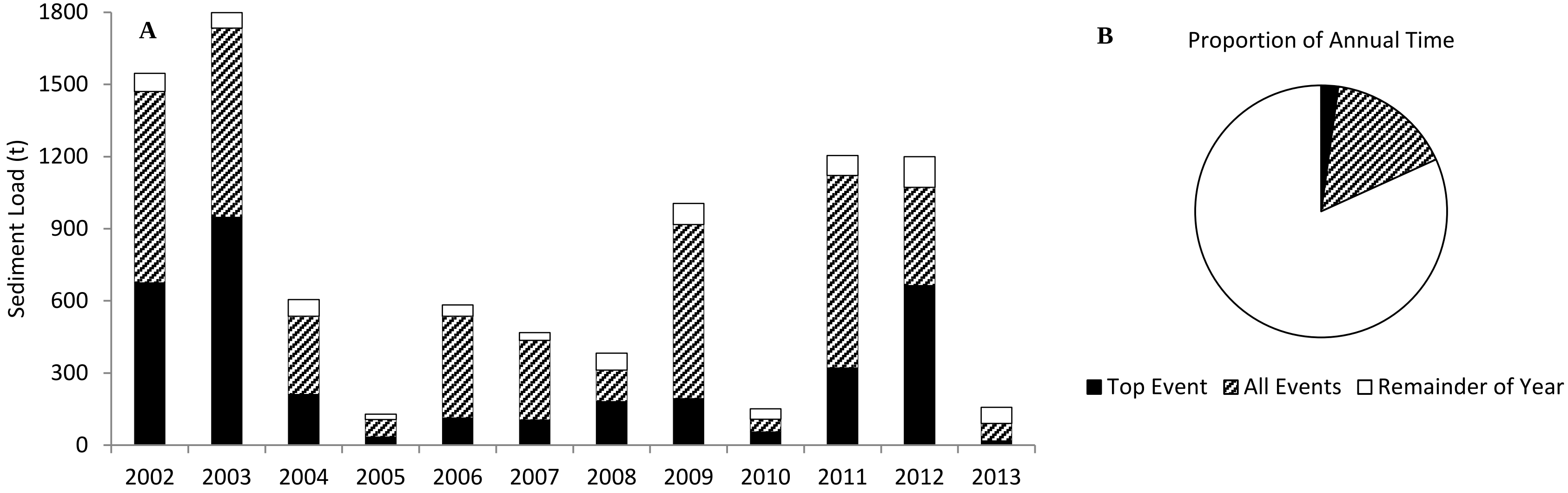

Figure A-5 (A-B). A. Contribution of erosion events to annual sediment load in the Paradise Creek watershed as measured at watershed outlet for the top erosion event, all events, and the entire water year, respectively. B. Average proportion of time during the year represented by those events.

The event in March 2012 was the largest recorded event in the rural area, where it was much larger than at the watershed outlet (954 tons compared to 666 tons). According to the National Climatic Data Center Storm Events Database, heavy rainfall occurred on March 25–26 following a period of moderate to heavy snowfall (NCDC 2014). This long duration rain-on-snow event resulted in the fourth highest crest level on record for Paradise Creek because large quantities of water from rain and snowmelt (201.9 mm; Table A-2) were added to an already saturated watershed. This event exhibited two extremely high discharge peaks and sustained high flows between the peaks (Figure A-6, E). The majority of the sediment load was transported during the hydrograph peaks. The March 2003 event was also a rain-on-snow event with saturated soil conditions that resulted in a greater sediment load in the rural area than at the watershed outlet (Figure A-6, D).

The January 2003 event produced the greatest sediment load observed at the watershed outlet during the study period and was a result of heavy rain and snowmelt (NCDC 2014). Similar to the March 2012 event, two extremely high discharge peaks occurred in January 2003 (Figure A-6, C). Peak discharge at the watershed outlet was approximately equal to that of the March 2012 event (Table A-2); rural peak discharge was lower than in March 2012 but still well above mean and median values for all events. For the five extreme events, peak discharge, event duration, and available inflow are greater than the mean and median event values (Table A-2). Discharge throughout the event is always greater at the watershed outlet than the rural area, but for the two largest events (January 2003 and March 2012), the difference was minimal. For some extreme events, antecedent baseflow and maximum rainfall intensity are greater than the mean and median event values but not consistently across all extreme events. In 2002 and 2003, two extreme events were observed. In 2002, the second event was much smaller than the first. The same is true in 2003 for the watershed outlet; however, at the rural station, the two events are of similar size (531 tons and 544 tons).

Cumulative water year precipitation for the five extreme events ranges from 228 to 397 mm (Table A-2). Compared to all events during the study period, a similar window of cumulative precipitation (228–467 mm) is apparent for most large events (> 100 tons) (Figure A-7). This is the period of time when the watershed is saturated enough to produce runoff and spring crops have not yet emerged.

Table A-2. Selected variables for extreme events in Paradise Creek watershed during study period.[a]

Variables	Feb 2002		Mar 2002		Jan 2003		Mar 2003		Mar 2012		Mean		Median	
	R	**WO**	**R**	**WO**	**R**	**WO**	**R**	**WO**	**R**	**WO**	**R**	**WO**	**R**	**WO**
Sediment load (t)	515	676	289	341	531	949	544	286	954	666	43.7	44.2	7.0	9.2
Peak discharge (m^3 s^{-1})	5.04	9.60	3.08	7.45	7.77	11.23	4.87	8.02	9.37	11.27	1.53	2.70	1.01	2.00
Event duration (d)	9.3	8.9	5.9	6.0	6.7	6.7	5.4	6.0	14.7	14.5	4.3	3.6	3.3	3.0
Available inflow (mm)	40.1	42.3	27.4	27.4	75.8	75.8	78.0	78.0	201.9	201.9	32.5	31.6	21.3	21.8
Anticipated baseflow (m^3 s^{-1})	0.16	0.21	0.11	0.30	0.04	0.19	0.15	0.29	0.53	0.40	0.19	0.20	0.13	0.10
Maximum precipitation intensity (mm h^{-1})	3.6	3.6	3.3	3.3	7.1	7.1	13.2	13.2	7.4	7.4	4.5	4.9	3.8	4.1
Cumulative precipitation (mm)	249.1	251.2	294.4	294.4	228.4	228.4	363.7	363.7	397.1	397.1	396.1	356.3	384.7	363.7
Snow cover	Yes	Yes	No	No	Rising	Rising	Rising	Rising	Rising	Rising	—	—	—	—

a. Mean and median values are for all erosion events > 1 t ; observations are included for each monitoring station, rural (R) and watershed outlet (WO). Snow cover is during entire event (Yes), during rising limb (Rising), or not at all (No).

Notes: ton (t); day (d); millimeter (mm); cubic meter (m^3); second (s); hour (h)

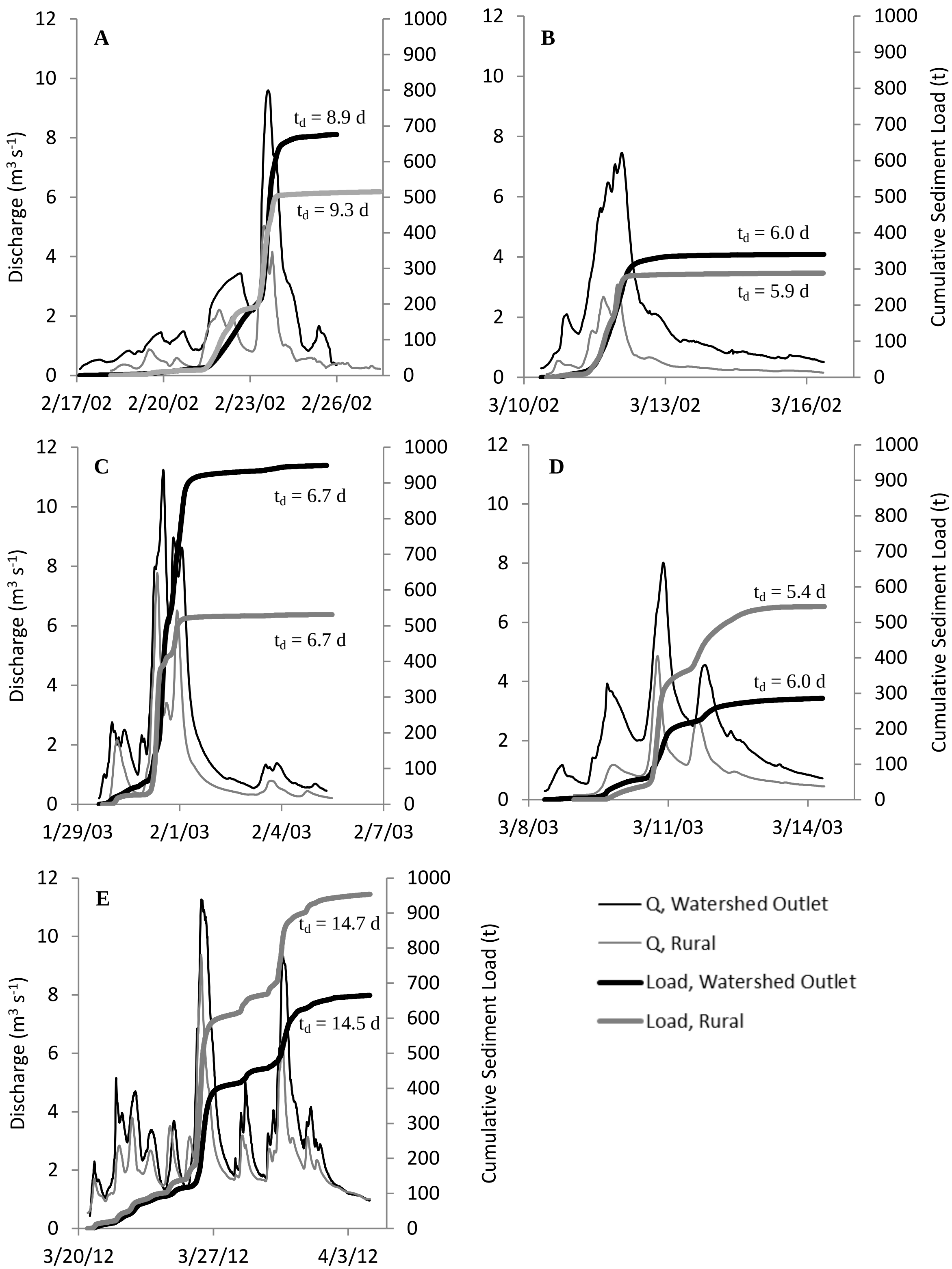

Figure A-6 (A-E). Stream hydrograph and cumulative sediment load for watershed outlet and rural station, respectively, for extreme events in the Paradise Creek watershed during study period; t_d = event duration in days.

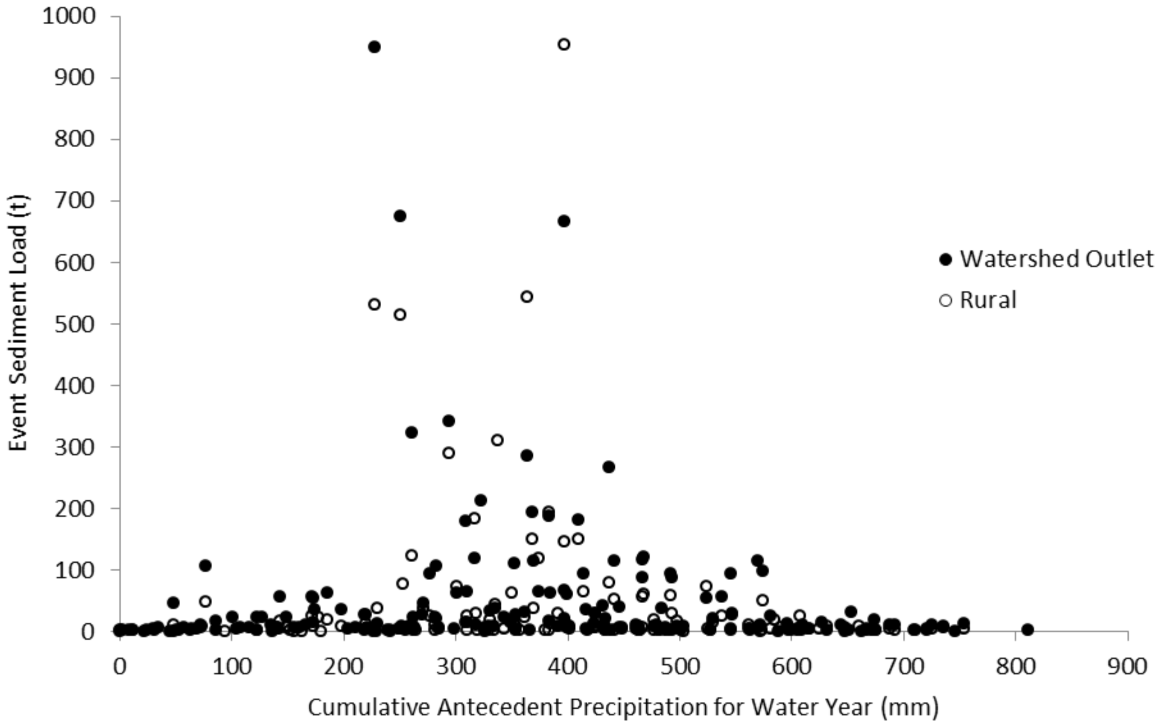

Figure A-7. Event sediment load as a function of cumulative antecedent precipitation beginning on October 1 of given year in the Paradise Creek watershed. Most events of > 100 tons occur in a window of 228 to 467 mm of cumulative antecedent precipitation.

4.3 Statistical Analysis

The results from the statistical analysis generally confirm the observations made for the extreme events in the watershed. Using multiple linear regression, peak discharge after log transformation explains a large proportion of the variation in event sediment load. Models were created for all events (watershed outlet and rural combined) (R^2 = 0.725), rural (R^2 = 0.775), and watershed outlet (R^2 = 0.767). Peak discharge explains 63.7%, 87.6%, and 60.0% of event sediment load for all, rural, and watershed outlet events, respectively (Tables A-3–A-5). The strength of the relationship between peak discharge and event sediment load is shown in Figure A-8. A linear relationship was examined in the multiple linear regression models, but on an individual basis, the relationship between these two variables is best explained with a polynomial function.

After peak discharge, event duration and antecedent baseflow are important factors. Duration explains approximately one-quarter of the variation for all events and watershed outlet events whereas for rural events, it only explains 3.5% of variation. Similarly, antecedent baseflow explains 7.1% and 8.8% of variation for all and watershed outlet events, respectively, but only 3.3% for rural events. The final variables of importance for all events and rural events include maximum precipitation intensity and the presence of thawing soils, and the presence of thawing soils and frozen soils for urban events.

Other streamflow-related variables (e.g., event water volume and streamflow depth) also have strong positive correlations with event sediment load in single variable linear regression but not as strong as peak discharge (Figure A-9). (See Appendix A for correlation matrices.) When considered in the multiple linear regression models, because of colinearity with peak discharge, the effects of water volume and streamflow depth manifest as negative correlations with load. For that reason, they were not used in the multiple linear regression models but should still be considered important factors. The effect of all other variables listed in Table A-1 on event sediment load was examined using the stepwise function in R but did not produce statistically significant relationships.

Table A-3. Multiple linear regression performed in R for all events.[a]

Variable	DF	SS	F	P	Estimate	SE	Variation Explained (%)
Q_{max}	1	31.96	254.50	< 2.20E-16	1.95E-01	1.22E-02	63.7
t_d	1	13.01	103.58	< 2.20E-16	5.67E-05	5.57E-06	25.9
B	1	3.57	28.41	1.87E-07	5.12E-01	9.61E-02	7.1
T	1	1.14	9.04	0.00285	2.59E-01	8.60E-02	2.3
I	1	0.54	4.29	0.0390	1.32E-02	6.38E-03	1.1

a. n = 328; residual SE = 0.354 on 318 DF; adjusted R2 = 0.725; F-statistic = 171.6 on 5 and 318 DF; p-value < 2.2E-16. Results are significant at p < 0.05.
Notes: Degrees of Freedom (DF); Sum of Squares (SS); f-statistic (F); p-value (P); Standard Error (SE)

Table A-4. Multiple linear regression performed in R for rural events.[a]

Variable	DF	SS	F	P	Estimate	SE	Variation Explained (%)
Q_{max}	1	20.67	200.90	< 2.20E-16	3.19E-01	2.25E-02	87.6
t_d	1	0.82	7.95	0.00557	2.20E-05	7.81E-06	3.5
B	1	0.77	7.52	0.00697	4.28E-01	1.56E-01	3.3
i	1	0.71	6.88	0.00978	2.37E-02	9.05E-03	3.0
T	1	0.63	6.15	0.0144	2.94E-01	1.18E-01	2.7

a. n = 137; residual SE = 0.321 on 129 DF; adjusted R^2 = 0.775; F-statistic = 93.25 on 5 and 129 DF; p-value < 2.2E-16. Results are significant at p < 0.05.
Notes: Degrees of Freedom (DF); Sum of Squares (SS); f-statistic (F); p-value (P); Standard Error (SE)

Table A-5. Multiple linear regression performed in R for watershed outlet events.[a]

Variable	DF	SS	F	P	Estimate	SE	Variation Explained (%)
Q_{max}	1	17.26	159.96	< 2.20E-16	1.77E-01	1.40E-02	60.0
t_d	1	7.73	71.62	7.82E-15	6.58E-05	7.77E-06	26.9
B	1	2.52	23.35	2.82E-06	5.40E-01	1.12E-01	8.8
F	1	0.74	6.82	0.00977	2.01E-01	7.68E-02	2.6
T	1	0.51	4.73	0.0310	2.34E-01	1.08E-01	1.8

a. n = 191; residual SE = 0.329 on 185 DF; adj. R^2 = 0.767; F-statistic = 125.9 on 5 and 185 DF; p-value < 2.2E-16. Results are significant at p < 0.05.
Notes: Degrees of Freedom (DF); Sum of Squares (SS); f-statistic (F); p-value (P); Standard Error (SE)

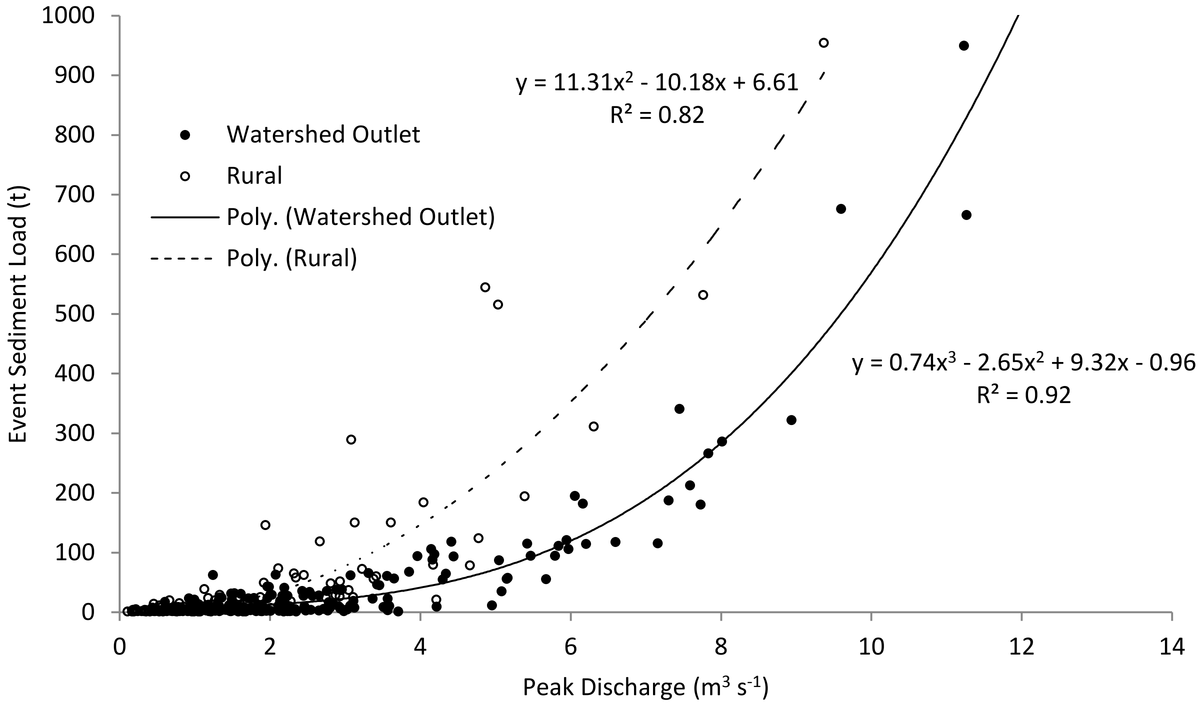

Figure A-8. Event sediment load as a function of peak discharge for both watershed outlet and rural events in the Paradise Creek watershed. Polynomial relationship and R^2 values are shown for each site.

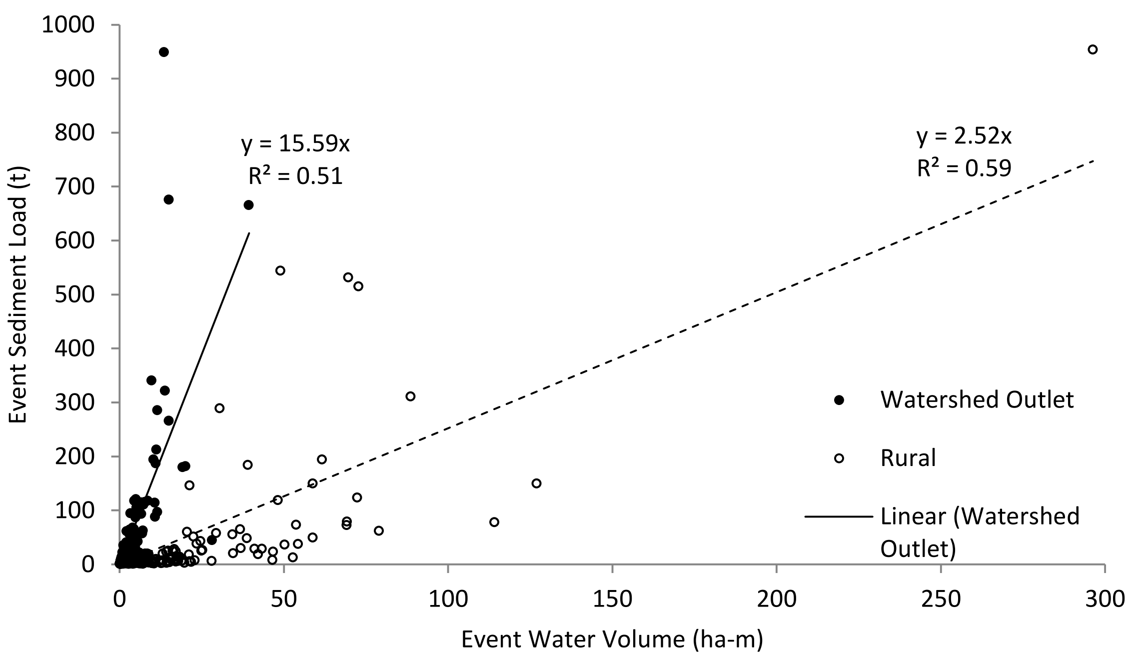

Figure A-9. Event sediment load as a function of event water volume for both watershed outlet and rural events in the Paradise Creek watershed. Linear trendlines and R^2 values are shown for each site.

4.4 Land Use, Seasonality, and Flush Timing

We observed an alternating influence from urban and rural land uses throughout the study period. The load measured at the watershed outlet was greater than the load measured in the rural area for all years except 2012 and 2013 (Figure A-10). For a rough estimation of the urban contribution to sediment load, we subtracted the load measured at the rural station from the load measured at the watershed outlet. This assumes that all sediment measured at the rural station traveled all the way through the urban area during the given water year. The urban load was greater than the rural load in 2005–2007 and 2010–2011. The rural load was greater than the urban load in the remaining years. In 2012 and 2013, the rural load was greater than the watershed outlet load, which indicates that deposition occurred in the stream channel in the urban area.

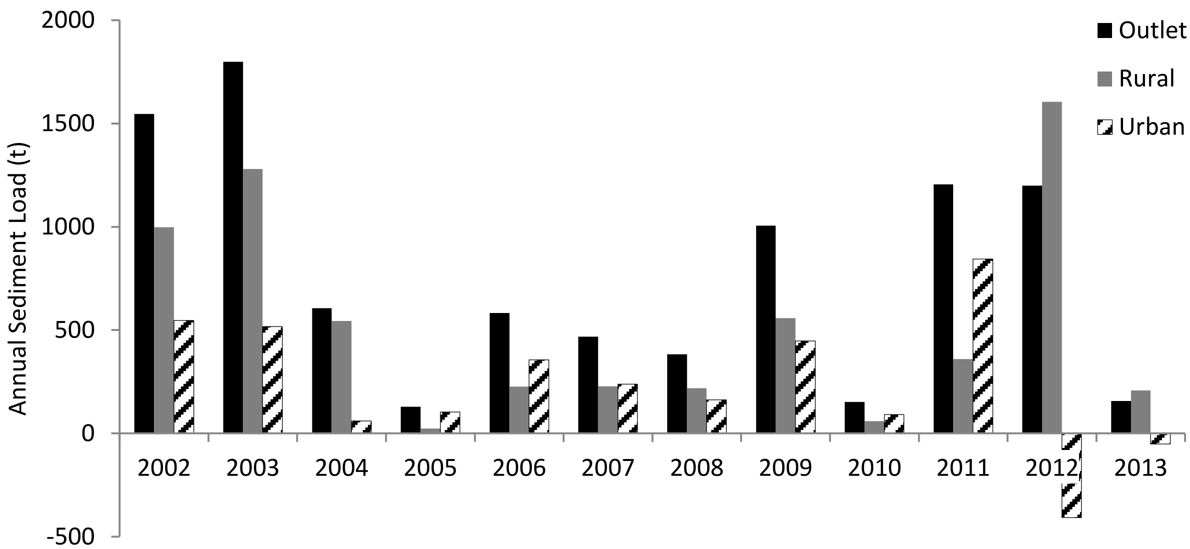

Figure A-10. Annual sediment loads measured in the Paradise Creek watershed. Black bar is total load measured at the watershed outlet. Gray bar is total load measured at rural station. Diagonally hashed bar is load attributed to urban land use by subtracting rural load from watershed outlet load. Negative value indicates deposition.

Winter hydrology is apparent in the Paradise Creek watershed as the majority of the sediment load is delivered in December through April, with peaks in January and March (Figure A-11). A clear difference exists between the peak sediment load contributions from each land use. The urban area supplies the majority of its load during January, whereas the rural area peaks in March. Insignificant sediment loads are recorded during the summer at both sites. At the beginning of the water year, the urban load begins to accumulate before the rural load does; the urban load remains greater than the rural load until January. From January to April, the rural load is greater. When observed as average sediment concentration by month, the rural site peaks in March, and the watershed outlet has sustained high concentrations from January–May (Figure A-12). Varying from the monthly sediment load distribution, however, the rural sediment concentration is only greater than the watershed outlet sediment concentration in March.

The largest annual load at the watershed outlet and the largest single event at that site (January 29, 2003–February 5, 2003) were recorded in 2003. Seasonal patterns of sediment loads at the two sites in 2003 are very similar but with much greater loads measured at the outlet (Figure A-13, A). The cumulative sediment load exhibits a two-step pattern; nearly 6 weeks separate those two significant events. The second large rural event (early March) was approximately the same magnitude as the first (late January) despite a substantially lower peak discharge. Conversely, in the remainder of March, several moderately sized flows separated by a few days did not result in as large of an increase in sediment load. For 2012, the largest rural annual load and single event (March 20, 2012–April 4, 2012), the cumulative load exhibits a more continuous increase from January through March and a clear dominance from the rural area in March (Figure A-13, B). In agreement with Figures A-11 and A-12, the rural contribution is dominant in March in both 2003 and 2012 (Figure A-13, A-B).

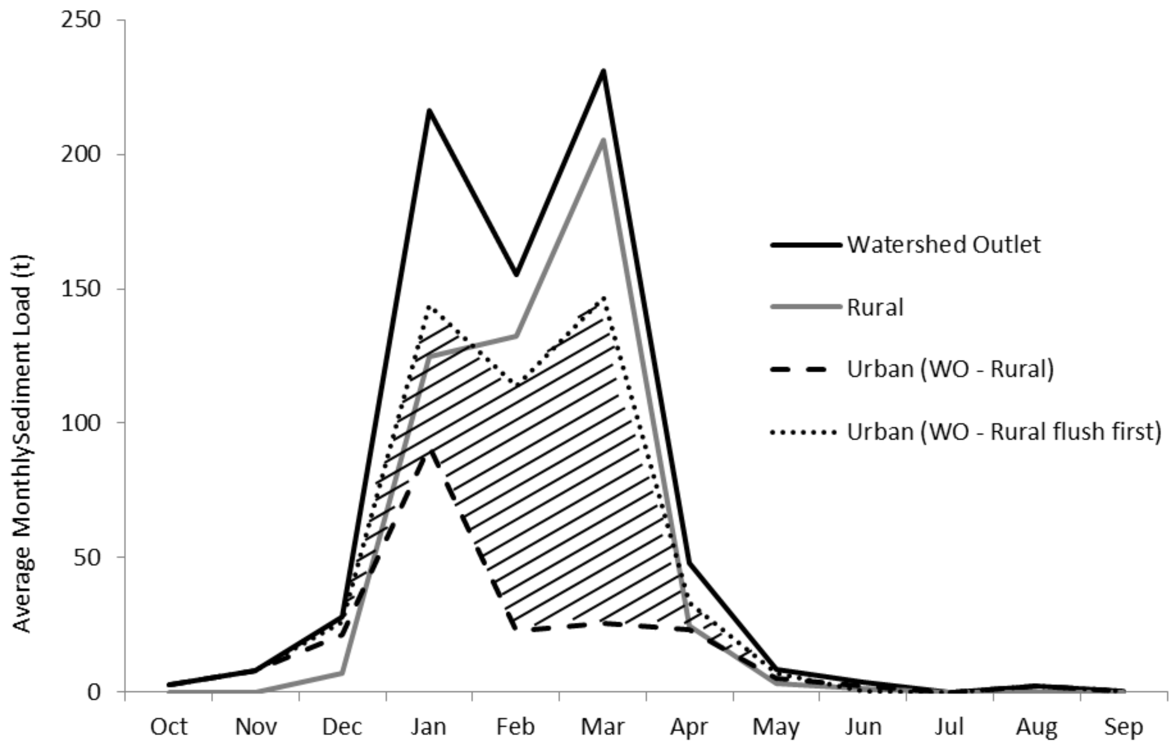

Figure A-11. Average monthly sediment loads in the Paradise Creek watershed from 2002–2013. Black line indicates the average monthly load measured at watershed outlet. Gray line indicates the average monthly load measured at the rural station. Dashed line indicates the average monthly urban load when subtracting rural load from the load measured at watershed outlet. Dotted line indicates average monthly urban load when subtracting rural load only when indicated by flush timing. The area between the dashed and dotted lines represents the estimated range for the urban load.

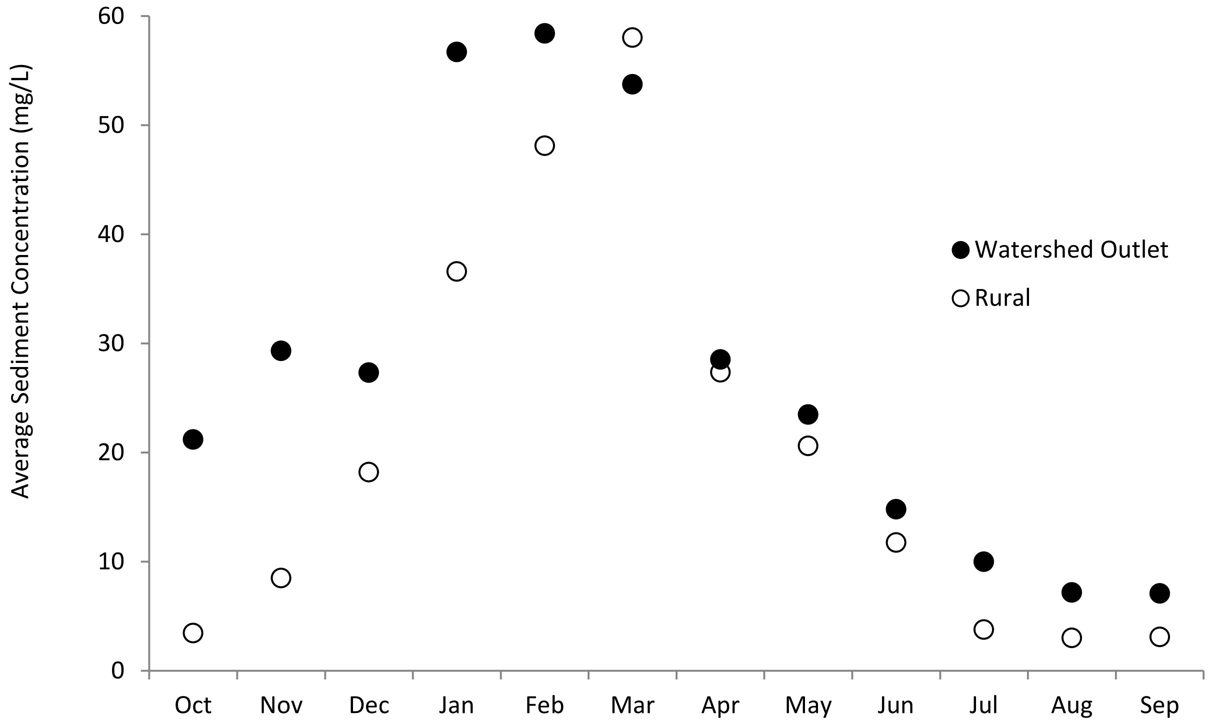

Figure A-12. Average 15-minute sediment concentration by month in the Paradise Creek watershed from 2002–2013 at the watershed outlet and rural sites. Sediment concentration is higher at the watershed outlet in all months except March when it peaks in the rural area.

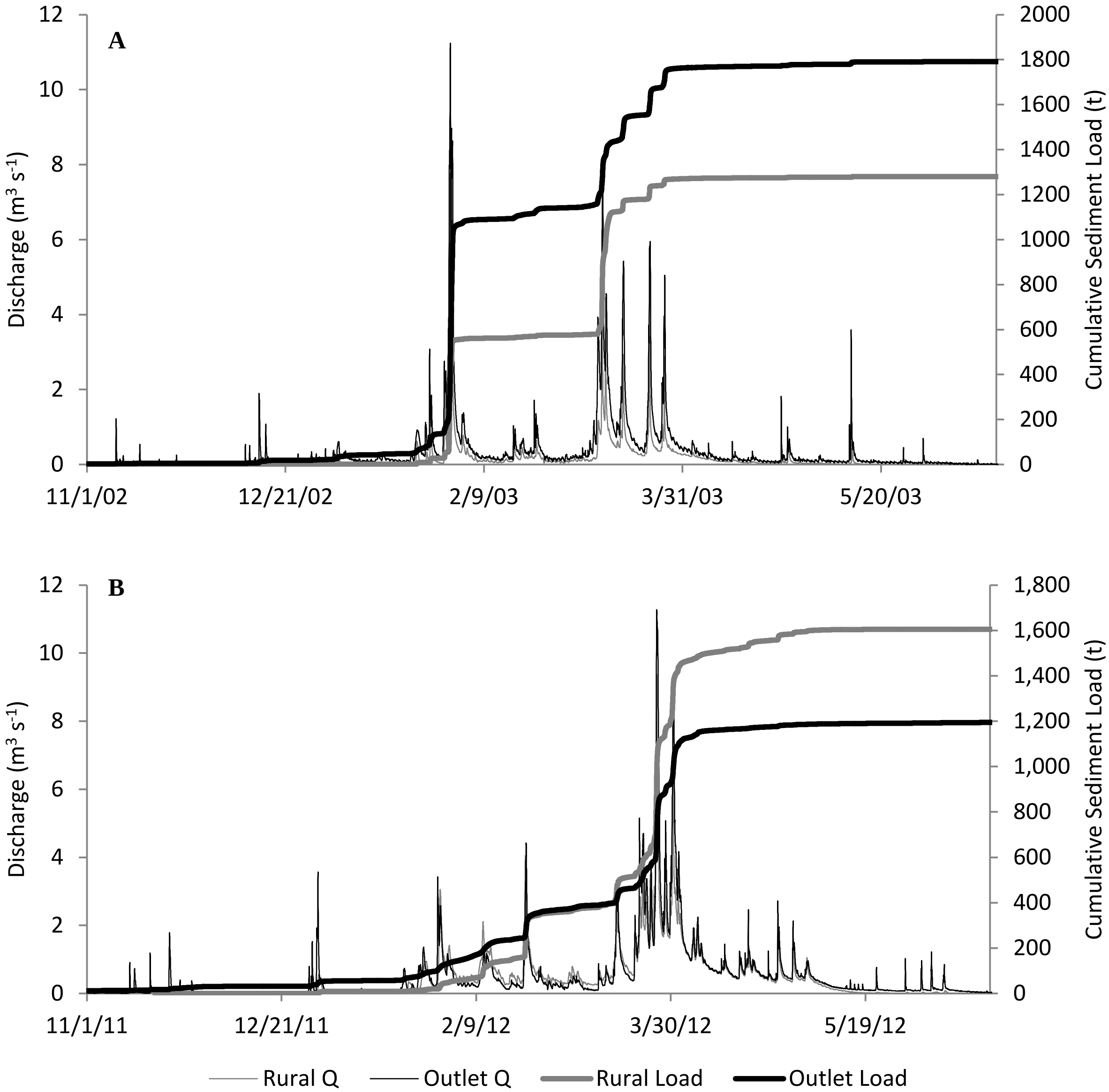

Figure A-13 (A-B). Cumulative sediment load and hydrograph for the Paradise Creek watershed, rural and watershed outlet for A. 2003, the largest annual sediment load at the watershed outlet; and B. 2012, the largest annual rural sediment load.

For 53 of 209 events that occurred at both sites, the sediment wave from the rural site could have reached the watershed outlet before its sediment flush and concentration peaks occurred. When this analysis is applied to annual loads by subtracting only these events from the total load measured at the watershed outlet, the large amount of sediment deposition in the urban stream channel for 2012–2013 is not present, and the urban contribution is greater than in the original method (Figure A-14). Additionally, consideration of flush timing in the analysis of average monthly sediment loads results in greater urban than rural loads in January, and a more significant influence of urban loads in March compared with the original method (Figure A-11).

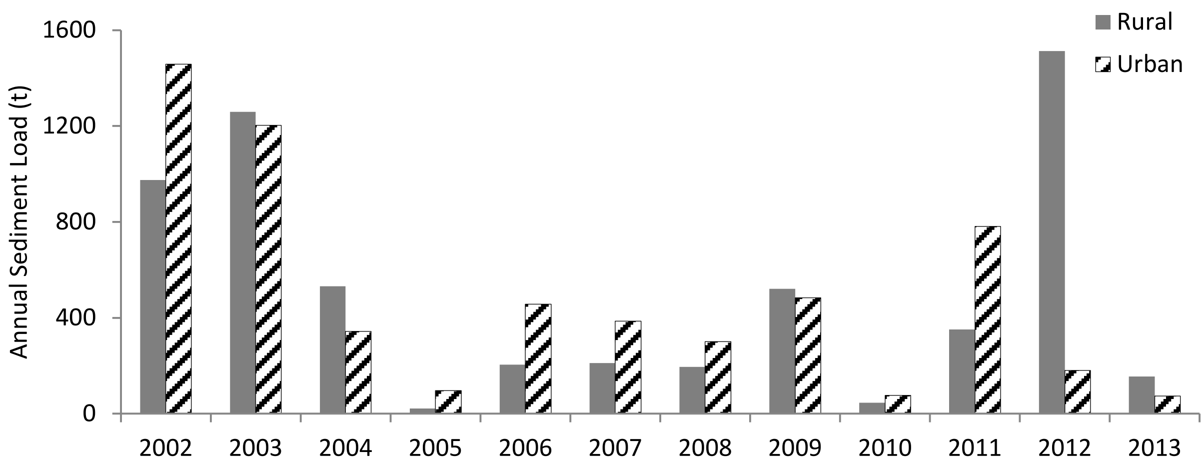

Figure A-14. Annual sediment loads in the Paradise Creek watershed by land use considering flush timing. Urban load was calculated as watershed outlet minus rural when rural flushes first and travel time of sediment wave is greater than the flush difference.

5. Discussion

Like many agricultural areas, Paradise Creek is generally a transport-limited system in the rural portion with a continual supply of sediment from fields and the stream channel (Brooks et al. 2010; Wagenbrenner et al. 2010). When transport capacity and stream power increase due to high peak discharge and sustained elevated flows, the available sediment is readily eroded from the upland areas and streambanks or resuspended in the stream channel. Flow volume positively correlates with sediment load but not as strongly as peak flow, indicating that the extra force exerted by high peak flows is important in detaching or resuspending sediment, and generating and carrying greater loads. High peak discharge also leads to increased sediment concentrations because of the likelihood of expanding contributing areas, as seen with the variable source area concept (Walling and Webb 1982). In such events, the contributing area expands to locations that are not reached in smaller magnitude events and thus have stores of easily erodible sediment. The interaction and related recovery period of events also dictates the resulting sediment loads. An event with high peak discharge may not generate an equivalently large sediment load if it is preceded by another large event with a short recovery period between the two (Walling and Webb 1982). We see this in March 2003 with a series of four high peak discharge events with recovery periods of less than 7 days (Figure A-13, A). The first event in the series produced a much greater load than the subsequent events. Furthermore, that first March event generated the same sediment load as a January 2003 event that had a much higher peak discharge. This is likely a result of the 38-day recovery period that occurred after the January event when stream runoff was relatively low.

In the Paradise Creek watershed, when high antecedent soil moisture conditions are paired with high peak flows, event sediment loads are greater (Tables A-3–A-5). Through both quantitative and qualitative data, we observed saturated soils in mid to late winter as expected with the winter hydrology of the region. Events in the fall do not generate as much runoff or erosion because most precipitation infiltrates into the relatively dry soil, rather than contributing to streamflow response (Lana-Renault et al. 2007). Using antecedent baseflow as a proxy for soil moisture, we found that it was statistically significant in predicting sediment load. In a watershed dominated by saturation excess processes, a logical connection can be made between elevated baseflow levels and saturated soils ready to generate surface runoff. In areas with saturation excess, antecedent conditions have been related to an expansion of contributing areas (Zehe and Blöschl 2004; García-Ruiz et al. 2005). Furthermore, when soils are saturated, or *primed*, it is expected that more erosion will occur because subsurface soil cohesion is reduced as water content increases (Kemper and Rosenau 1984; Pelletier 2012). With reduced soil cohesion, or increased soil erodibility, detachment potential increases with increased shear velocity causing rill and gully erosion (Govers 1985).

The three largest events in the watershed had relatively high maximum precipitation intensities: 7.4, 7.1, and 13.2 mm h^{-1}, compared to mean and median values during the study period of less than 5 mm h^{-1} (Table A-1). Maximum precipitation intensity was statistically significant at explaining a small amount of the variation in the rural event sediment loads (Table A-3). Nadal-Romero et al. (2008) found a significant correlation between maximum precipitation intensity and peak discharge. Through experiments in an area of low intensity rainfall and permeable soils, Dunne and Black (1970) showed that only when soils were fully saturated, increased precipitation intensity generated more runoff through an increased proportion of overland flow.

We observed that the majority of annual sediment loads in Paradise Creek are measured in January–March (Figure A-11), coinciding with the period of high peak runoff observed by Brooks et al. (2010). While agricultural BMPs have produced significant results in recent decades, when winter wheat farmers follow conventional practices, soil is left bare during the vulnerable winter period, increasing erosion potential (Kok et al. 2009). Interestingly, Brooks et al. (2010) showed that in the rural area of the Paradise Creek watershed, average annual runoff volume peaks in February, whereas we found that average annual sediment load peaks in March. This disparity between the timing of runoff and sediment loads is likely due to high antecedent moisture conditions and rain-on-snow events in March, which decreases surface storage. We expect that soil saturation peaks in March after a winter of snowfall, thereby increasing erosion. Additionally, rain-on-snow events that are characteristic of March increase direct runoff (Kattelmann 1997; Marks et al. 1998; Merz et al. 2006); therefore, peak flows lead to large sediment loads, as seen with the two largest events in the Paradise Creek watershed during the study period. The urban contribution was greatest in January, despite peak runoff occurring in March, which may be more characteristic of a supply limited system. Elevated January loads could be a result of channel flushing of deposited sediment from the previous year. By January, flows are high enough to resuspend channel sediments and flush the system, reducing the sediment available in the stream channel during the remainder of the winter, which would be measured as contributing to the urban load. Elevated loads in January could also be partially attributed to the material laid out on city roads to improve traction for driving on snow and ice. The City of Moscow currently uses approximately 125 tons of clean chip rock annually, the majority applied in December and January, with an estimated 75% recovery rate (T. Palmer, personal communication, March 27, 2014). Application amounts and recovery rates were unknown earlier in the study period.

The stream channel appears to play a large role in the Paradise Creek sediment budget (Brooks et al. 2010). Many of the events in Paradise Creek exhibited an early flush as characterized by *first flush* curves and hysteretic loops. Such behavior is typically due to a flush of channel sediments (Eder et al. 2013). The availability of those sediments is dependent upon the deposition characteristics of the previous event while the resuspension of them is dependent upon the stream power of the current event. For example, an event with a relatively low peak flow may be more likely to deposit sediments rather than flush them through the system. Whereas an event with a relatively high peak flow may flush more sediment out of the system because of increased stream power. However, since stream power is a function of both discharge and stream gradient, the low stream gradient in the rural (0.5%) and urban (0.01%) sections likely leads to deposition after many of the events. Subsequently, resuspension of streambed sediments occurs after those events. Erosion of the stream channel itself may also be a factor, particularly in the urban area. As downstream urban sediment sources increase with development and upstream rural sources decrease with improved BMPs, channel erosion in the urban area may increase (Wolman 1967), which is potentially attributable to increased magnitude and number of peak flows associated with urban runoff.

In the Paradise Creek TMDL (DEQ 1997), only 5% of the sediment load was attributed to the urban area. Brooks et al. (2010) showed that an average of 43% of annual loads in Paradise Creek comes from the urban area. We found that the urban and rural land uses alternate in their influence on the sediment budget in Paradise Creek, which is likely due to annual differences in activities and watershed conditions. For example, a short-term construction site could significantly increase the urban load for a given year and even exceed agricultural yields (Wolman 1967); alternatively, an increased proportion of fallow fields (Zuzel et al. 1993) or increased conventional tillage (Gaynor and Findlay 1995) could result in a larger rural load. Recent years were the most interesting with high annual loads in 2011 and 2012 after several years of loads that met or were close to the TMDL target (Figure A-2). The urban influence was much greater in 2011, followed by a much greater rural influence in 2012 (Figure A-10). In 2011, Paradise Creek restoration projects were implemented in the urban area, including rerouting the stream channel on the University of Idaho campus. The activity likely led to the high urban load. The high rural load in 2012 was likely due to high antecedent moisture conditions resulting from the previous year's fallow fields. In 2011, half of Latah County was not planted due to an extremely wet spring. The absence of crops reduced the influence of transpiration on the water balance and thus soils remained wetter through the summer and fall (Sivapalan et al. 2005) leading to wet antecedent soil conditions going into the winter of 2011–2012. We suspect that the wetter than normal conditions in the watershed led to high erosion in the rural area in 2012. Additionally, in 2012, the sediment load recorded at the rural station was much greater than the sediment load recorded at the watershed outlet, indicating deposition in the stream channel. We would expect that in 2013, the stream channel deposits from 2012 would have resulted in an increased urban load. However, 2013 was a very low water year (Figure A-2), so stream power and transport capacity may have been too low to detach and carry the deposited sediment to the outlet.

6. Conclusions

In recent decades, annual sediment loads in Paradise Creek have been declining due to the implementation of agricultural BMPs and urban stream restoration (Kok et al. 2009; Brooks et al. 2010). Correspondingly, we observed that most extreme erosion events in the Paradise Creek watershed occurred early in the study period (2002 and 2003). Despite the declining trend in event sediment loads, the single largest event (largest rural event, third largest urban event) occurred late in the study period (March 2012). The extreme event was a result of a perfect storm of influential factors impacting the watershed: peak discharge, event duration, antecedent baseflow, available inflow (rain + melt), and precipitation intensity were all well above mean and median values. It was also a rain-on-snow event and occurred in 2012 when the watershed itself was highly erodible due to wet antecedent moisture conditions.

Our findings suggest that to further reduce sediment loads and consistently comply with the TMDL, BMPs designed to target the factors characteristic of the largest events may be effective at further reducing annual sediment loads. Specifically, BMPs that increase infiltration in upland areas, such as conservation or no tillage, residue cover, and cover crops, could dampen the response of peak discharge while also reducing the impact of high intensity precipitation. When possible, not leaving fields fallow or planting cover crops to increase transpiration may reduce antecedent moisture conditions. While many BMPs are presently used in the Paradise Creek watershed that have likely contributed to the reduced sediment loads, because of the lack of above and below monitoring to isolate their influence, we cannot draw any conclusions about the impact of specific BMPs.

The influence of the rural and urban land uses alternated throughout the study period, depending partly on antecedent conditions and activities in the watershed. The urban contribution to Paradise Creek annual sediment loads peaked in January, while the rural contribution peaked in March, coinciding with soil saturation in the watershed. We suspect a cycle of deposition and resuspension of streambed sediments occurs in Paradise Creek, but more research is needed to determine the magnitude of the stream channel contribution to annual loads.

Currently, TMDL targets for sediment are focused on annual loads. Because of the seasonality of erosion, refocusing load targets on monthly or seasonal periods could better elucidate the sediment delivery behavior of the stream system and provide insight to when loads can be reduced. In Paradise Creek, the highest average sediment loads and concentrations over the study period were recorded in January, February, and March. As such, those months should be specifically targeted for reducing sediment loads. Instantaneous and 10-day concentration targets were not analyzed in this report because the actual targets were unclear in the original TMDL. They were set based on the natural background concentration for the creek, which was not defined in the TMDL and would inherently vary based on watershed conditions. Future research and management efforts should investigate the timing of planting and crop rotations to target the periods most vulnerable to erosion and the effectiveness of BMPs at reducing the impact of extreme events.

7. References

Boardman, J. 2006. “Soil Erosion Science: Reflections on the Limitations of Current Approaches.” *Catena* 68(2-3):73–86.

Brooks, E.S., J. Boll, A.J. Snyder, K.M. Ostrowski, S.L. Kane, J.D. Wulfhorst, L.W. Van Tassell, and R. Mahler. 2010. “Long-Term Sediment Loading Trends in the Paradise Creek Watershed.” *Journal of Soil and Water Conservation* 65(6):331–341.

Cristina, C.M. and J.J. Sansalone. 2003. “First Flush, Power Law and Particle Separation Diagrams for Urban Storm-Water Suspended Particulates.” *Journal of Environmental Engineering* 129(4):298–307.

DEQ (Idaho Department of Environmental Quality). 1997. *Paradise Creek TMDL: Water Body Assessment and Total Maximum Daily Load*. Lewiston, ID: DEQ.

Dunne, T., and R.D. Black. 1970. "An Experimental Investigation of Runoff Production in Permeable Soils." *Water Resources Research* 6(2):478–490.

Eaton, A.D., L.S. Clesceri, and A.E. Greenberg, eds. 1995. *Standard Methods for the Examination of Water and Wastewater*. 19th ed.

Eder, A., M. Exner-Kittridge, P. Strauss, and G. Blöschl. 2013. "Re-Suspension of Bed Sediment in a Small Stream – Results from Two Flushing Experiments." *Hydrology and Earth System Sciences Discussions* 10:12077–12104.

García-Ruiz, J.M., J. Arnáez, S. Beguería, M. Seeger, C. Martí-Bono, D. Regüés, N. Lana-Renault, and S. White. 2005. "Runoff Generation in an Intensively Disturbed, Abandoned Farmland Catchment, Central Spanish Pyrenees." *Catena* 59(1):79–92.

Gaynor, J.D., and W.I. Findlay. 1995. "Soil and Phosphorus Loss from Conservation and Conventional Tillage in Corn Production." *Journal of Environmental Quality* 24(4):734–741.

Govers, G. 1985. "Selectivity and Transport Capacity of Thin Flows in Relation to Rill Erosion." *Catena* 12:35–49.

Helsel, D.R., J.I. Kim, T.J. Grizzard, C.W. Randall, and R.C. Hoehn. 1979. "Land Use Influences on Metals in Storm Drainage." *Journal of Water Pollution Control Federation* 51(4):709–717.

Hewlett, J.D. and A.R. Hibbert. 1967. "Factors Affecting the Response of Small Watersheds to Precipitation in Humid Regions." In W.E. Sopper and H.W. Lull, eds. *Forest Hydrology*. Pergamon, Oxford.

Kattelmann, R. 1997. "Flooding from Rain-on-Snow Events in the Sierra Nevada." Proceedings of the *International Conference on Destructive Water: Water-Caused Natural Disasters, their Abatement and Control*. Anaheim, CA.

Kemper, W.D. and R.C. Rosenau. 1984. "Soil Cohesion as Affected by Time and Water Content." *Soil Science Society of America Journal* 48(5):1001–1006.

Kok, H., R.I. Papendick, and K.E. Saxton. 2009. "STEEP: Impact of Long-Term Conservation Farming Research and Education in Pacific Northwest Wheatlands." *Journal of Soil and Water Conservation* 64(4):253–264.

Lana-Renault, N., J. Latron, and D. Regüés. 2007. "Streamflow Response and Water-Table Dynamics in a Sub-Mediterranean Research Catchment (Central Pyrenees)." *Journal of Hydrology* 347(3-4):497–507.

Lana-Renault, N., and D. Regüés. 2009. "Seasonal Patterns of Suspended Sediment Transport in an Abandoned Farmland Catchment." *Earth Surface Processes and Landforms* 34(9):1291–1301.

Larson, W., M. Lindstrom, and T. Schumacher. 1997. "The Role of Severe Storms in Soil Erosion: A Problem Needing Consideration." *Journal of Soil and Water Conservation* 52(2):90–95.

Marks, D., J. Kimball, D. Tingey, and T. Link. 1998. "The Sensitivity of Snowmelt Processes to Climate Conditions and Forest Cover during Rain-On-Snow: A Case Study of the 1996 Pacific Northwest Flood." *Hydrological Processes* 12:1569–1587.

Merz, R., G. Blöschl, and J. Parajka, 2006. "Spatio-Temporal Variability of Event Runoff Coefficients." *Journal of Hydrology* 331(3-4):591–604.

Nadal-Romero, E., J. Latron, N. Lana-Renault, P. Serrano-Muela, C. Martí-Bono, and D. Regüés. 2008. "Temporal Variability in Hydrological Response within a Small Catchment with Badland Areas, Central Pyrenees." *Hydrological Sciences Journal* 53(3):629–639.

NCDC (National Climatic Data Center). 2014. *Storm Events Database.* National Oceanic and Atmospheric Administration. Accessed March 19. *https://www.ncdc.noaa.gov/stormevents/*

Pelletier, J.D. 2012. "Fluvial and Slope-Wash Erosion of Soil-Mantled Landscapes: Detachment- or Transport-Limited?" *Earth Surface Processes and Landforms* 37(1):37–51.

Piro, P., and M. Carbone. 2013. "A Modelling Approach to Assessing Variations of Total Suspended Solids (TSS) Mass Fluxes during Storm Events." *Hydrological Processes* 28(4):2419–2426.

R Development Core Team. 2008. *R: A Language and Environment for Statistical Computing*. Vienna, Austria: R Foundation for Statistical Computing. ISBN 3-900051-07-0.

Sivapalan, M., G. Blöschl, R. Merz, and D. Gutknecht. 2005. "Linking Flood Frequency to Long-Term Water Balance: Incorporating Effects of Seasonality." *Water Resources Research* 41(6):W06012.

Wagenbrenner, J.W., P.R. Robichaud, and W.J. Elliot. 2010. "Rill Erosion in Natural and Disturbed Forests: 2. Modeling Approaches." *Water Resources Research* 46(10):W10507.

Walling, E., and W. Webb. 1982. "Sediment Availability and the Prediction of Storm-Period Sediment Yields." In proceedings of the Exeter Symposium *Recent Developments in the Explanation and Prediction of Erosion and Sediment Yield.* Exeter, UK. 327–337.

Williams, G.P. 1989. "Sediment Concentration versus Water Discharge during Single Hydrologic Events in Rivers." *Journal of Hydrology* 111(1):89–106.

Wolman, M.G. 1967. "A Cycle of Sedimentation and Erosion in Urban River Channels." *Geog. Annaler* 49(A):385–395.

Zehe, E., and G. Blöschl. 2004. "Predictability of Hydrologic Response at the Plot and Catchment Scales: Role of Initial Conditions." *Water Resources Research* 40:W10202.

Zuzel, J.F., R.R. Allmaras, and R.N. Greenwalt 1993. “Temporal Distribution of Runoff and Soil Erosion at a Site in Northeastern Oregon.” *Journal of Soil and Water Conservation* 48(4):373–378.

Supplemental Data: Correlation Matrices for All Numerical Variables in Statistical Analysis

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Table 1. Correlation matrix for watershed outlet events.

	Event Load	t_d	t_r	t_r/t_d	Q_{max}	Q_{ave}	Q_{max}/Q_{ave}	B	CP	SC	V	D	t_p	P	i	P_7	A	S	M
Event Load	1																		
t_d	0.512	1																	
t_r	0.540	0.756	1																
t_r/t_d	0.197	0.157	0.633	1															
Q_{max}	0.807	0.511	0.460	0.124	1														
Q_{ave}	0.749	0.556	0.525	0.201	0.869	1													
Q_{max}/Q_{ave}	0.042	-0.112	-0.128	-0.181	0.266	-0.182	1												
B	0.184	0.326	0.165	-0.050	0.270	0.504	-0.371	1											
CP	-0.031	0.044	-0.054	-0.187	-0.018	0.092	-0.145	0.352	1										
SC	0.085	0.226	0.169	0.018	0.071	0.121	-0.107	0.174	0.052	1									
V	0.777	0.802	0.713	0.191	0.787	0.839	-0.072	0.350	0.047	0.152	1								
D	0.777	0.802	0.712	0.191	0.787	0.839	-0.072	0.350	0.047	0.152	1.000	1							
t_p	0.308	0.537	0.709	0.397	0.280	0.271	0.005	0.040	-0.066	0.066	0.418	0.418	1						
P	0.536	0.496	0.438	0.212	0.595	0.550	0.105	0.077	-0.090	-0.102	0.668	0.668	0.288	1					
i	0.141	0.113	0.042	-0.123	0.307	0.233	0.243	0.104	0.144	-0.140	0.201	0.201	0.048	0.411	1				
P_7	0.144	0.209	0.050	0.009	0.157	0.240	-0.153	0.408	0.045	0.032	0.198	0.198	-0.041	0.222	0.079	1			
A	0.459	0.577	0.530	0.243	0.531	0.520	0.016	0.022	-0.129	-0.041	0.669	0.669	0.366	0.833	0.418	0.176	1		
S	0.268	0.382	0.301	0.131	0.259	0.351	-0.160	0.084	-0.110	0.005	0.432	0.432	0.039	0.459	0.250	0.174	0.649	1	
M	0.194	0.440	0.424	0.183	0.252	0.283	-0.088	-0.047	-0.122	0.042	0.408	0.408	0.308	0.323	0.263	0.057	0.793	0.604	1

Notes: Total precipitation depth (P); snowfall snow water equivalent (S); snowmelt snow water equivalent (M); available inflow (A); time to maximum rainfall intensity (t_p); maximum rainfall intensity (i); peak discharge (Q_{max}); average discharge (Q_{ave}); event intensity (Q_{max}/Q_{ave}); streamflow depth (D); event water volume (V); antecedent baseflow (B); 7-day antecedent precipitation (P_7); water year cumulative precipitation (CP); time to runoff peak (t_r); event runoff duration (t_d); relative rising limb length (t_r/ t_d); stormflow coefficient (SC)

Table 2. Correlation matrix for rural events.

	Event Load	t_d	t_r	t_r/t_d	Q_{max}	Q_{ave}	Q_{max}/Q_{ave}	B	CP	SC	V	D	t_p	P	i	P_7	A	S	M
Event Load	1																		
t_d	0.436	1																	
t_r	0.414	0.752	1																
t_r/t_d	0.123	0.113	0.651	1															
Q_{max}	0.809	0.506	0.405	0.054	1														
Q_{ave}	0.658	0.399	0.337	0.077	0.859	1													
Q_{max}/Q_{ave}	0.298	0.303	0.230	-0.072	0.418	0.022	1												
B	0.121	-0.005	-0.026	-0.074	0.195	0.556	-0.399	1											
CP	-0.110	-0.273	-0.199	-0.151	-0.141	0.034	-0.313	0.382	1										
SC	0.033	0.167	0.069	-0.097	0.055	0.129	-0.102	0.165	-0.025	1									
V	0.778	0.719	0.610	0.128	0.809	0.798	0.180	0.267	-0.082	0.130	1								
D	0.778	0.719	0.610	0.128	0.809	0.799	0.179	0.268	-0.082	0.130	1.000	1							
t_p	0.194	0.566	0.645	0.359	0.232	0.161	0.170	-0.081	-0.158	0.052	0.339	0.338	1						
P	0.562	0.524	0.498	0.177	0.624	0.477	0.313	-0.005	-0.156	-0.173	0.687	0.687	0.297	1					
i	0.135	0.157	0.176	0.015	0.262	0.194	0.228	0.083	0.059	-0.251	0.208	0.208	0.146	0.540	1				
P_7	0.039	0.079	0.066	0.078	0.159	0.182	-0.007	0.236	0.054	-0.048	0.147	0.147	-0.065	0.294	0.262	1			
A	0.485	0.653	0.616	0.206	0.574	0.403	0.357	-0.095	-0.248	-0.077	0.663	0.663	0.424	0.873	0.455	0.267	1		
S	0.380	0.538	0.438	0.121	0.385	0.293	0.177	-0.008	-0.180	0.020	0.472	0.472	0.308	0.473	0.196	0.218	0.711	1	
M	0.189	0.561	0.525	0.162	0.279	0.143	0.272	-0.175	-0.268	0.080	0.365	0.365	0.420	0.355	0.160	0.125	0.766	0.739	1

Notes: Total precipitation depth (P); snowfall snow water equivalent (S); snowmelt snow water equivalent (M); available inflow (A); time to maximum rainfall intensity (t_p); maximum rainfall intensity (i); peak discharge (Q_{max}); average discharge (Q_{ave}); event intensity (Q_{max}/Q_{ave}); streamflow depth (D); event water volume (V); antecedent baseflow (B); 7-day antecedent precipitation (P_7); water year cumulative precipitation (CP); time to runoff peak (t_r); event runoff duration (t_d); relative rising limb length (t_r/ t_d); stormflow coefficient (SC)

Appendix B. Bacteria Data

South Fork Palouse River—ID17060108CL003_03			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
6/5/2014	1.434	21.5	—
6/11/2014	0.877	172.5	—
6/16/2014	1.12	112.6	—
6/19/2014	1.268	101.7	—
6/24/2014	1.005	46.4	72
9/24/2015	NA	95.9	—
9/28/2015	NA	60.5	—
10/1/2015	NA	39.9	—
10/7/2015	NA	17	—
10/13/2015	NA	11.5	34
South Fork Palouse River—ID17060108CL002_03			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
6/5/2014	1.404	185	—
6/11/2014	0.445	46.4	—
6/16/2014	1.476	90.5	—
6/19/2014	2.085	172.2	—
6/24/2014	0.866	83.9	102
9/24/2015	NA	435.2	—
9/28/2015	NA	110.6	—
10/1/2015	NA	133.4	—
10/7/2015	NA	16.4	—
10/13/2015	NA	101.4	101
Deep Creek—ID17060108CL032b_03			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
6/4/2014	1.883	16	—
6/10/2014	0.778	43.2	—
6/16/2014	1.156	105.4	—
6/19/2014	3.608	104.3	—
6/24/2014	0.623	34.1	48

Deep Creek—ID17060108CL032a_02			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
9/4/2013	NA	135.4	—
9/9/2013	NA	21.1	—
9/17/2013	NA	14.6	—
9/23/2013	NA	5.2	—
9/30/2013	NA	122.3	31
Flannigan Creek—ID17060108CL011b_03			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
6/4/2014	0.622	2,419.2	—
6/10/2014	1.023	2,419.2	—
6/16/2014	1.12	1,643	—
6/19/2014	1.753	2,419.2	—
6/24/2014	0.736	2,419.2	2,239
Flannigan Creek—ID17060108CL011a_02			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric mean**
6/4/2014	1.623	2,419.2	—
6/10/2014	1.193	2,419.2	—
6/16/2014	1.353	1,732.9	—
6/19/2014	1.365	1,119.9	—
6/24/2014	0.971	2,419.2	1,940
Gold Creek—ID17060108CL030_02			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
6/4/2014	0.82	76.3	—
6/10/2014	0.614	1,119.9	—
6/16/2014	0.676	218.7	—
6/19/2014	0.965	90.6	—
6/24/2014	0.434	325.5	223
Gold Creek—ID17060108CL029_03			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
6/4/2014	1.795	231	—
6/10/2014	0.847	365.4	—
6/16/2014	1.202	248.9	—
6/19/2014	3.071	139.6	
6/24/2014	1.099	238.2	234

Hatter Creek—ID17060108CL015b_03			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
6/4/2014	3.471	1,119.9	—
6/10/2014	2.036	1,046.2	—
6/16/2014	2.108	1,046.2	—
6/19/2014	2.728	260.2	—
6/24/2014	1.337	816.4	764
Hatter Creek—ID17060108CL015a_02			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
6/4/2014	1.556	178.9	—
6/10/2014	1.341	128.1	—
6/16/2014	1.02	72.8	—
6/19/2014	1.302	547.5	—
6/24/2014	0.984	272.3	190.2
Rock Creek—ID17060108CL012_03			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
6/4/2014	0.059	235.9	—
6/10/2014	0.033	129.6	—
6/16/2014	0.039	727	—
6/19/2014	0.155	69.1	—
6/24/2014	0.021	502.8	239
Rock Creek—ID17060108CL013a_02			
Sample Date	**Flow (cfs)**	***E. coli***	**Geometric Mean**
6/4/2014	0.032	58.1	—
6/10/2014	0.007	73.3	—
6/16/2014	0.053	178.5	—
6/19/2014	0.065	263.2	—
6/24/2014	0.02	275.5	141
Notes: cubic feet per second (cfs); not available (NA)			

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Appendix C. Phosphorus Data

Paradise Creek—ID17060108CL005_02					
Sample Date	**Time**	**Temp (^oC)**	**DO (mg/L)**	**Flow (cfs)**	**TP (mg/L)**
5/7/2014	12:50	12.8	10.91	2.2	0.122
5/15/2014	14:43	13.2	10.3	1.3	0.139
5/21/2014	11:53	14.8	9.97	0.9	0.153
5/29/2014	12:45	13.8	7.41	2.3	0.156
6/5/2014	15:00			0.31	0.203
6/11/2014	12:31	15.9	5.89	0.18	0.183
Average				1.20	0.16
Flannigan Creek PR16—ID17060108CL011b_03					
Sample Date	**Time**	**Temp (^oC)**	**DO (mg/L)**	**Flow (cfs)**	**TP (mg/L)**
5/8/2014	15:44	13.6	10.16	5.646	0.0996
5/14/2014	15:30	16.3	10.18	3.836	0.113
5/20/2014	12:06	13.2	10.33	3.223	0.0901
5/28/2014	11:13	14.4	9.07	2.669	0.134
6/4/2014	11:08	18.9	7.89	0.622	0.134
6/10/2014	10:45	16.3	8.25	1.023	0.133
Average				2.84	0.12
Flannigan Creek PR17—ID17060108CL011a_02					
Sample Date	**Time**	**Temp (^oC)**	**DO (mg/L)**	**Flow (cfs)**	**TP (mg/L)**
5/8/2014	16:26	12.1	10.74	7.264	0.0891
5/14/2014	16:00	15.7	10.64	5.329	0.077
5/20/2014	11:30	10.6	10.33	4.12	0.0725
5/28/2014	10:38	12.3	9.59	2.812	0.08
6/4/2014	10:35	15.3	8.21	1.623	0.0949
6/10/2014	9:55	15.6	7.91	1.193	0.103
Average				3.72	0.09

Hatter Creek PR12—ID17060108CL015b_03					
Sample Date	**Time**	**Temp (°C)**	**DO (mg/L)**	**Flow (cfs)**	**TP (mg/L)**
5/8/2014	13:08	9	10.62	18.22	0.0555
5/14/2014	12:35	15	9.36	10.61	0.061
5/20/2014	13:58	15.2	9.58	8.107	0.0647
5/28/2014	13:35	11.8	10.07	5.541	0.0614
6/4/2014	12:49	18.1	9.04	3.471	0.0673
6/10/2014	12:54	16	9.9	2.036	0.0636
Average				8.00	0.06
Cow Creek—ID17060108CL001_03					
Sample Date	**Time**	**Temp (°C)**	**DO (mg/L)**	**Flow (cfs)**	**TP (mg/L)**
5/7/2014	9:33	12.22	11.34	8.452	0.0793
5/15/2014	9:44	15.5	12.88	6.437	0.0835
5/20/2014	9:12	12.9	10.77	4.259	0.069
5/29/2014	9:35	12.1	11.6	4.336	0.105
6/5/2014	10:40	16.9	12	2.025	0.197
6/11/2014	8:46	14.3	8.45	1.593	0.132
Average				4.52	0.11
South Fork Palouse River SF1—ID17060108CL003_02					
Sample Date	**Time**	**Temp (°C)**	**DO (mg/L)**	**Flow (cfs)**	**TP (mg/L)**
5/7/2014	11:32	9.2	10.35	0.986	0.15
5/15/2014	12:47	13.1	10.06	0.596	0.132
5/21/2014	10:47	10.3	10.47	0.305	0.127
5/29/2014	11:15	10.4	10.53	0.239	0.135
6/5/2014	12:40	13.1	10.3	0.187	0.126
6/11/2014	10:44	13.1	9.59	0.087	0.123
Average				0.40	0.13
South Fork Palouse River SF2—ID17060108CL003_03					
Sample Date	**Time**	**Temp (°C)**	**DO (mg/L)**	**Flow (cfs)**	**TP (mg/L)**
5/7/2014	10:53	7.2	11.62	3.658	0.0893
5/15/2014	12:09	11.7	11.31	2.801	0.0919
5/21/2014	10:11	9.9	11.19	2.394	0.0886
5/29/2014	11:36	9.7	11.09	1.41	0.0925
6/5/2014	13:20	14.5	10	1.434	0.111
6/11/2014	11:06	11.6	10.33	0.877	0.107
Average				2.10	0.10

South Fork Palouse RiverSF4—ID17060108CL002_03					
Sample Date	**Time**	**Temp (^{o}C)**	**DO (mg/L)**	**Flow (cfs)**	**TP (mg/L)**
5/7/2014	12:11	11.4	11.35	7.4	0.0963
5/15/2014	13:35	17	12.7	3.509	0.11
5/21/2014	11:19	16.1	10.89	3.854	0.111
5/29/2014	12:14	13.5	10.64	3.405	0.113
6/5/2014	14:25	19.5	10.71	1.404	0.128
6/11/2014	11:54	17.5	11.55	0.445	0.109
Average				3.34	0.11