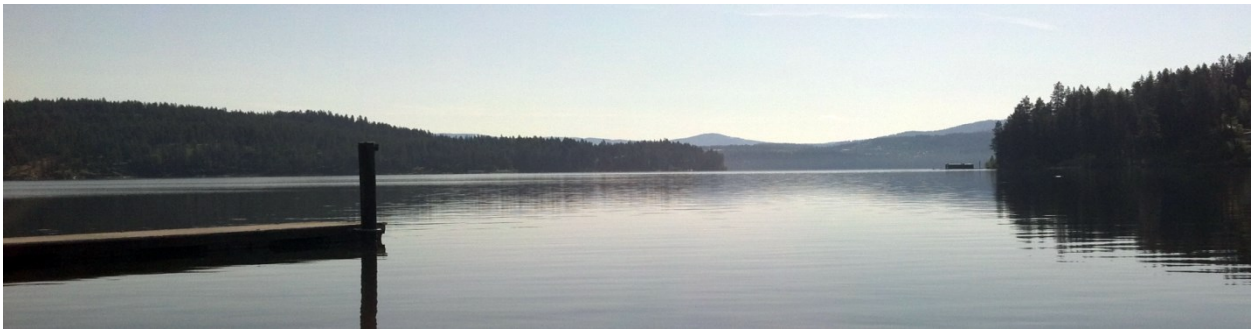
Coeur d'Alene Lake Management Plan: Total Phosphorus Nutrient Inventory, 2004-2013



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Coeur d'Alene Lake Management Plan: Total Phosphorus Nutrient Inventory, 2004-2013

May 2020

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Executive Summary

The Coeur d'Alene Lake Management Plan (LMP) is a collaborative effort among the Idaho Department of Environmental Quality, the Coeur d'Alene Tribe, and the region's many governmental and stakeholder groups to protect and improve water quality within Coeur d'Alene Lake (DEQ and Tribe, 2009). A core objective of this work is to maintain the lake in a low nutrient status, which will lead to high levels of hypolimnetic (deep water) dissolved oxygen and net burial of metal contaminants within lake-bed sediments. To achieve this, the LMP has established trigger criteria to compare the lake's status relative to water quality standards, historic data and the goal stated above. When water quality monitoring data indicate that the lake is trending toward or exceeding trigger criteria, then additional actions are taken to assess the cause and develop an appropriate response. A core component of this process is the development of a basin-wide nutrient inventory and nutrient management action plan. The LMP also mandates that the nutrient inventory and nutrient management action plan be developed.

This report provides a summary of phosphorus loading to Coeur d'Alene Lake across all major regions of the Coeur d'Alene Basin. These regions include the Coeur d'Alene River, the St. Joe River, and the many smaller ungauged watersheds that feed directly into Coeur d'Alene Lake.

Phosphorus levels are trending higher in the northern regions of Coeur d'Alene Lake, in the regions most impacted by the Coeur d'Alene River. This increase in phosphorus levels has potential influences on chlorophyll-a, and hypolimnetic oxygen demand (DEQ and Coeur d'Alene Tribe, 2015; 2017). These increases in phosphorus concentration within the lake also correlate with an apparent increase in phosphorus loading to the lake. These concurrent trends in phosphorus dynamics are a cause for concern, and emphasize the need to actively mitigate basin-wide phosphorus loading in order to (i) prevent Coeur d'Alene Lake from changing in ways that could reduce the ability of the lake to trap metals within the sediments, and (ii) preserve the lake's many beneficial uses that depend upon its current low productivity status. Managing phosphorus at the scale of the Coeur d'Alene Basin is a challenging task that requires many years of sustained effort. Consequently, protecting the lake from nutrient impacts requires that management actions be taken sooner rather than later.

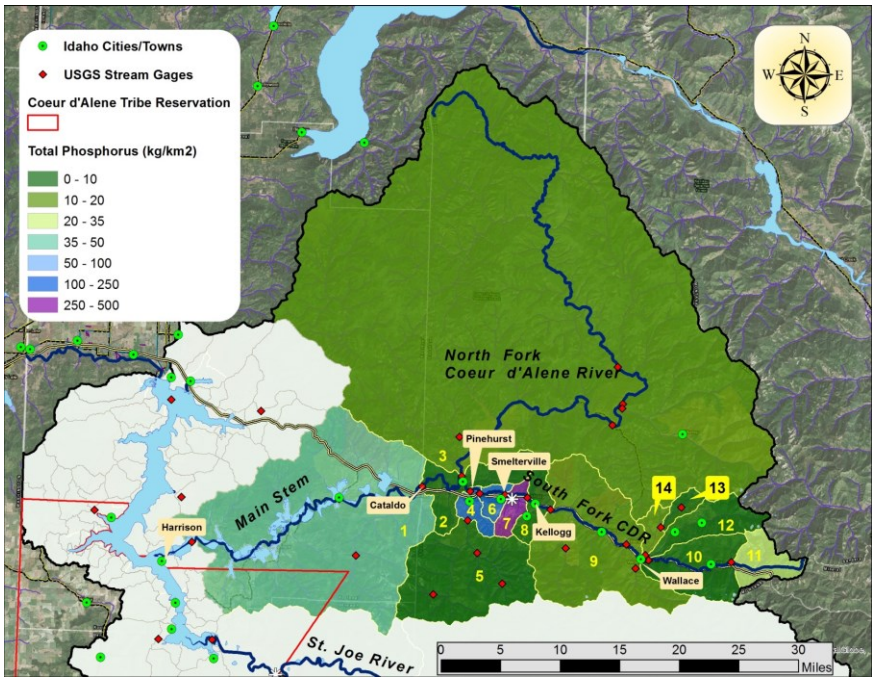
Most of the phosphorus that enters the lake originates in the Coeur d'Alene and St. Joe Rivers, which contribute over 75% of the total load to the lake. The smaller tributaries that drain into the lake are also important sources with seasonal and geographic influences that need to be better understood. Most phosphorus in the Basin arises from non-point sources, primarily from the forested watersheds along the Coeur d'Alene and St. Joe Rivers. Municipal wastewater treatment facilities comprise less than 10% of the total load to the lake. The contributions from permitted storm water discharges and other point source discharges have not been measured.

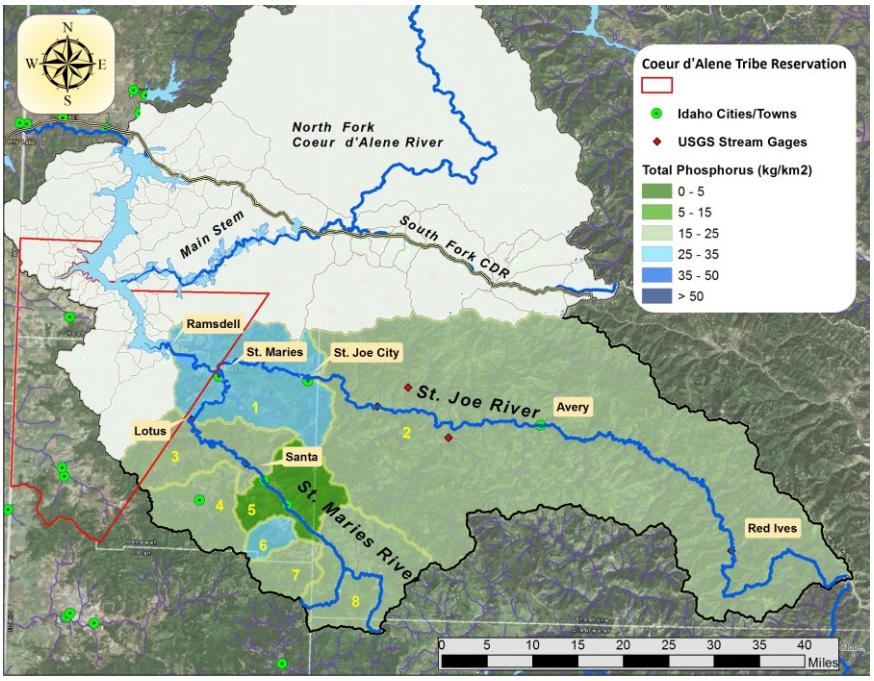
Important near-term opportunities for phosphorus mitigation occur along the South Fork of the Coeur d'Alene River and the main stem downstream from Cataldo. These regions have elevated phosphorus yields relative to the overall basin and also contribute much of the total load to the lake.

The strongest increasing trends for phosphorus in the lake occur north of the Coeur d'Alene River, where the river's influence is strongest.

In the Coeur d'Alene River subbasin, equivalent amounts of phosphorus originate in the North Fork, the South Fork, and the Main Stem below the confluence. The highest yields (load per unit area) occur along the South Fork, between the cities of Kellogg and Pinehurst. Several municipal wastewater treatment plants discharge into this stretch of the Coeur d'Alene River, and there are also important influences from surface/stormwater runoff and groundwater discharges from the Central Impoundment Area of the Bunker Hill Superfund site. The Main Stem also experiences elevated yield from unknown sources. Riverbed sediment load is likely to be an important contributor.

Phosphorous Yields from the Coeur d'Alene and St. Joe Rivers





In the St. Joe River subbasin, most phosphorus originates on the St. Joe River upstream from the confluence with the St. Maries River. The highest yields are found along Carpenter Creek in the St. Maries drainage, and in the confluence region between the St. Joe and St. Maries Rivers, downstream from the monitoring sites where nutrient loading data is available. The source(s) of the elevated phosphorus yield in the St. Joe River downstream from the confluence are unknown.

Other sources of phosphorus include drainage from the Lake's many smaller tributaries, direct atmospheric deposition to the Lake, shoreline erosion and nearshore runoff, septic systems, and non-municipal wastewater. There are few reliable measurements of these sources. Only indirect estimates can be made on the basis of numerical modeling, and/or extrapolation of regional data to the Coeur d'Alene Basin. These sources contribute less total phosphorus to the lake than do the rivers, but they are a significant component of the overall load and can have important localized effects. A summary of the overall load to the lake is shown in the table below.

Subbasin or Nutrient Source	Subbasin area (km2)	Average Phosphorus Load (tons/yr) [1]	Average Phosphorus Load (kg/yr) [2]	*average lower 95% confidence interval (kg/yr)* [2]	*average upper 95% confidence interval (kg/yr)* [2]
Coeur d'Alene River	3,755	75	67,800	*46,500*	*96,100*
St. Joe River	4,472	79	71,700	*55,200*	*91,700*
Coeur d'Alene Lake Tributaries	1,211	20 ± 8	estimated to 1 significant figure, see Section 2.4		
Atmospheric Deposition to Lake	129	7 ± 3	estimated to 1 significant figure, see Section 2.5		
Wastewater to Lake Watersheds	--	1 ± 0.5	estimated to 1 significant figure, see Section 2.5		
Input to Coeur d'Alene Lake		***180***	***139,500***	***101,700***	***187,800***
Spokane River	9,660	52	46,800	*37,500*	*57,560*
Groundwater outflow to Rathdrum Prairie Aquifer	--	3 ± 2	estimated to 1 significant figure, see Section 2.5		
Output to Spokane River		***55***	***46,800***	***37,500***	***57,600***
% of Phosphorus Retained within the Lake		***70%***			

The available data suggest that phosphorus loading to the lake has increased since the 1990's. Comparison of U.S. Geological Survey estimates of phosphorus load from the Coeur d'Alene and St. Joe Rivers in calendar years 1991-1992 to those for water years in the current period (2004 – 2013) suggest that flow-normalized phosphorus load to the lake may have doubled since the early 1990's. These changes are primarily associated with high flows during runoff events.

This potential for increased phosphorus load should be treated with caution. Historic data from 1991 – 1992 was recorded on a calendar year basis (January – December) over a relatively short period of time that is biased towards lower annual flows and is not fully representative of longer-term average conditions. The current dataset is recorded on a water year basis (October – September) and covers a longer time period that encompasses a broad range of flow conditions and is representative of longer-term average conditions. Additionally, the 1991 – 1992 data for the St. Joe River was collected upstream from the current monitoring location and is not directly comparable to data from the current monitoring location. Consequently, these potential changes in calculated loads cannot be reliably quantified with the existing data. However, there is corollary evidence that phosphorus loads to the lake have likely increased. Phosphorus concentration in Coeur d'Alene Lake has roughly doubled at core monitoring sites since 1991-1992. Additionally the in-stream concentration of phosphorus has become more sensitive to flow during high-flow events at some monitoring locations along the Coeur d'Alene River.

Note that the trends since 1991 – 1992 are different from those in the immediately prior decades. Nutrient loads to the lake and the resultant phosphorus concentrations in the lake declined from the 1970's to the 1990's, in response to regulatory and management actions. This report focuses on current conditions and trends since 1991 - 1992.

Priorities for Future Work

The Coeur d'Alene Basin is not a homogenous system. The lake exhibits different trends and in its different regions. The different subbasins all exhibit different influences on current nutrient loading, and different changes over time. The Coeur d'Alene Basin is a mosaic, with individual watersheds providing unique pieces. Future work needs to account for this and not apply a "one size fits all" approach. Each subbasin should have its own set of priorities and objectives.

Phosphorus in the lake is increasing in the lake regions north of the Coeur d'Alene River, but not significantly changing in other regions. The Coeur d'Alene River also shows the greatest indications of increased phosphorus loads since 1991 – 1992; and has the most robust nutrient monitoring network. Consequently, the Coeur d'Alene River subbasin is a high priority for early action. Benefits could be achieved through the following actions.

1. Conduct phosphorus monitoring to assess the impact of the upgrades to the Bunker Hill Central Treatment Plant on loading to the South Fork of the Coeur d'Alene River.
2. Collect phosphorus data for Coeur d'Alene River sediments and incorporate phosphorus transport analyses into future evaluations of remedial action.
3. Conduct effectiveness monitoring for restoration projects along the Coeur d'Alene River.
4. Construct a record of the historic influences of remedial action, restoration projects, and nutrient management actions on phosphorus transport along the Coeur d'Alene River.
5. Conduct a more detailed analysis of long-term trends in concentration and loads for multiple stations and reaches in the Coeur d'Alene River subbasin.
6. Further integrate phosphorus considerations into decision making on remedial action and restoration projects in this subbasin.
7. Elevate the priority of nutrient monitoring in the Basin Environmental Monitoring Program (BEMP).

Much less information is available to prioritize nutrient management actions in other subbasins. The lake monitoring record also suggests that the St. Joe River and Coeur d'Alene Lake tributaries subbasins have important influences on phosphorus levels within the lake. Management actions should be taken in these subbasins, but additional data is needed in order to better prioritize action and optimize effectiveness. The following actions are recommended.

1. Rigorously quantify nutrient loading from the Coeur d'Alene Lake tributaries in a manner that can inform future geospatial analyses and modeling.
2. Better assess the influence of forest management practices and recreational development on nutrient loading in the Coeur d'Alene Basin and integrate into geospatial analyses.
3. Better quantify the influence of atmospheric deposition, non-point wastewater, and recreational activities on nutrient loading in Coeur d'Alene Lake and Basin.

1 Purpose, Background, and Approach

The Coeur d'Alene Lake Management Plan (LMP) is a collaborative effort among the Idaho Department of Environmental Quality, the Coeur d'Alene Tribe, and the region's many governmental and stakeholder groups to protect water quality within Coeur d'Alene Lake (DEQ and Tribe, 2009). The United States Environmental Protection Agency (EPA) and United States Geological Survey (USGS) also provide technical support and historic data that help support program goals. *"The Lake Management Plan goal is to "protect and improve lake water quality by limiting basin-wide nutrient inputs that impair lake water quality conditions, which in turn influence the solubility of mining-related metals contamination contained in lake sediments".*

Metals contamination impacts virtually all the Lake's sediments north of Conkling Point. The impacts of this contamination are managed by maintaining the lake in a low nutrient status, which will lead to high levels of hypolimnetic (deep water) dissolved oxygen and low solubility of lake-bed metals. The LMP established "trigger criteria" to compare the lake's status relative to water quality standards, historic data and the goal stated above. These trigger criteria include metals levels, dissolved oxygen, trophic parameters such as phosphorus and chlorophyll *a*, and a suite of bioindicators that reflect changes in trophic status and may provide more sensitive indicators. When lake water quality monitoring data indicate that the lake is trending toward or exceeding trigger criteria, then additional actions are to be taken to assess the cause and develop an appropriate response. A core component of such a response is the development of a basin-wide nutrient inventory and associated nutrient reduction action plan (DEQ and Tribe, 2009).

> *"Development of a basin-wide nutrient source inventory is an essential first step to identifying and prioritizing management action for nutrient reduction. This inventory will focus on nutrient and sediment loading at key hydrologic locations across the basin".*

The LMP also mandates that this inventory be developed. Recent analyses indicate that nutrient levels and productivity are increasing in some parts of the lake (DEQ and Tribe, 2016; DEQ and Tribe, 2017). These changes heighten the need to obtain a rigorous accounting of nutrient sources and correlate them to trends within the lake to guide reduction efforts. The purpose of this report is to establish a baseline phosphorus inventory for the overall Coeur d'Alene Basin, identify trends, and help provide a foundation for establishing nutrient management priorities.

1.1 Objectives and Approach

The purpose of this report is to provide an inventory of total phosphorus loading to Coeur d'Alene Lake, for the purposes of helping establish priorities for nutrient management actions. This purpose will be achieved through the following objectives.

1. Characterize the relative contribution of phosphorus to Coeur d'Alene Lake from the major stream and river subbasins that flow into the lake.
2. Characterize the geographic distribution of these loads within each subbasin.
3. Characterize the relative contributions of point sources and non-point sources.
4. Characterize geographic and time trends and identify potential drivers of change.

These objectives will be achieved by enumerating sources of total phosphorus in the Coeur d'Alene Basin upstream of the lake, and comparing current data with prior reports to identify potential trends. Only total phosphorus is evaluated in this report. Sediment, nitrogen, and reactive phosphorus will be assessed in future studies, as appropriate. Total phosphorus loading estimates calculated by the USGS are used to the greatest extent possible. These loading estimates are derived from large, high quality datasets; and the loading calculations have undergone independent 3rd party review. These estimates provide the highest degree of confidence. Field data collected by DEQ and the Tribe are used to fill in data gaps, and geospatial modeling estimates are used when insufficient field data is available. Loading information on nitrogen and reactive phosphorus (sub-fraction of total phosphorus that is bioavailable) are not provided in this report. These factors will be assessed in future work. Information for sediment and temperature loading is available in the basin's TMDL reports.

Loading information is provided for the Coeur d'Alene River subbasin, the St. Joe River subbasin, and the many smaller ungauged tributaries that feed directly into Coeur d'Alene Lake. All watersheds and stream reaches for which a load is calculated are based on the location of a stream gauge where field data are available, or the "pour point" of a geospatial model (e.g. Section 2.4). This approach creates watersheds of unequal size. Estimates are also provided for atmospheric deposition of phosphorus directly to the lake and the overall contribution of phosphorus from wastewater sources. Loading information for watersheds and stream reaches within each subbasin is assessed independently for the three different subbasins; the Coeur d'Alene River, the St. Joe River, the sum of all the smaller tributaries and face drainages that feed into the Lake. A long-term record of published USGS annual loading estimates is available at the mouth of the Coeur d'Alene River and St. Joe River, as well as for the head of the Spokane River at the outlet from Coeur d'Alene Lake. A shorter-term record of USGS loading estimates is also available for watersheds and stream reaches within the Coeur d'Alene River subbasin (2004-2013). DEQ and the Tribe collected survey-level nutrient data for watersheds and stream reaches within the St. Joe River subbasin (WY 2010 – 2012) and developed preliminary loading estimates based on that dataset. Loading estimates for the Coeur d'Alene Lake tributaries are not based on field data. These estimates are derived from an evaluation of published studies, published loading estimates made with the USGS SPARROW model, and a qualitative comparison with a limited dataset of stream data. Wastewater data is compiled from the EPA Echo and ICIS databases and local records of septic sources and small community wastewater systems. Atmospheric input is estimated from literature reports on regional benchmarks.

1.2 Description of Study Area

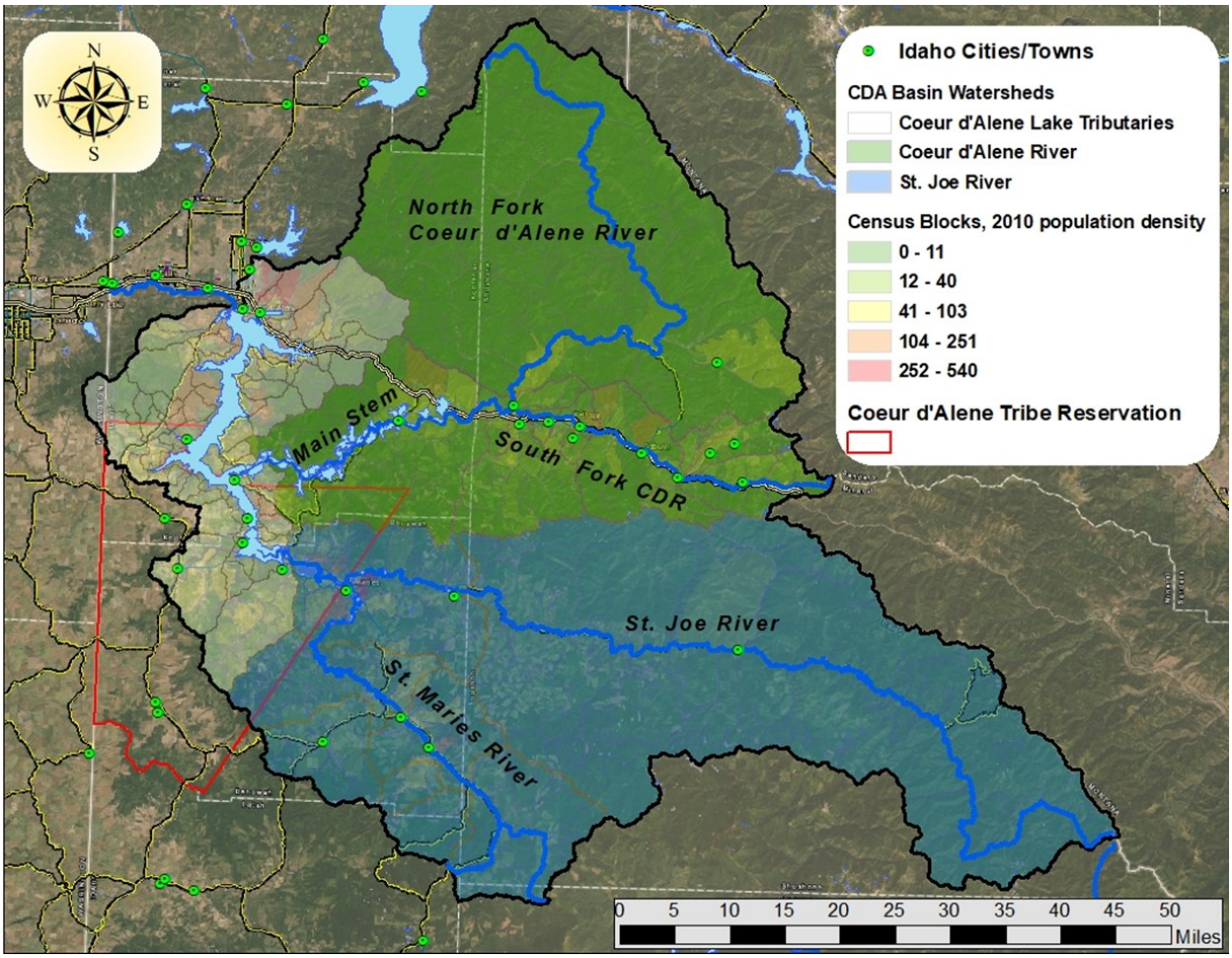
A map of the Coeur d'Alene Basin that drains into Coeur d'Alene Lake is provided in Figure 1. The Basin is a 9,580 km^2 watershed (including lakes) located within Kootenai, Benewah, Shoshone, and Latah counties in northern Idaho. The basin lies within the Bitterroot Range, and is dominantly characterized by steep, mountainous coniferous forests and deep intermontane valleys. Elevations range from 2,128 ft above sea level at full summer pool on Coeur d'Alene Lake to 6,845 ft above sea level along the Idaho-Montana border. The basin drains into Coeur d'Alene Lake (129 km^2) primarily through two large tributaries, the Coeur d'Alene River and the St. Joe River. An additional number of smaller tributaries feed directly into the lake. The northwest portion of Coeur d'Alene Lake provides the outlet to the Spokane River, which is a

tributary of the Columbia River. The boundaries and area of the region's subbasins have been defined differently, depending upon the context of the analysis. The subbasins may be defined in terms of their USGS HUC designation, or according to the stream network captured by a monitoring station. A summary of how this report defines the boundaries of the subbasins and watersheds within the Coeur d'Alene Basin is provided below.

The subbasins used in this report are shown in the map provided in Figure 1. These have been defined according to the current location of USGS gauging stations. All subbasins shown here drain to the Coeur d'Alene Basin upstream of the lake outlet to the Spokane River. The area and physical descriptions of these subbasins are as follows (~9,584 km^2).

- *Coeur d'Alene River* to the USGS gauging station at Harrison: 3,755 km^2
- *St. Joe River* to the USGS gauging station at Ramsdell: 4,472 km^2
- *Coeur d'Alene Lake tributaries* and face drainages that enter the lake downstream from these gauges and upstream from the USGS gauge at the lake outlet: 1,211 km^2

Figure 1. Map of the Coeur d'Alene Basin and major subbasins, with major geographic features.



The surface of Coeur d'Alene Lake (129 km^2) is part of the Coeur d'Alene Basin, but not the river and lake tributary subbasins. A number of smaller lakes that combine for ~15-20 km^2 of surface area are located within the Coeur d'Alene Basin. These include Chatcolet Lake, Round Lake, Benewah Lake, Hepton Lake, and the chain lakes along Coeur d'Alene River.

The subbasins within the Coeur d'Alene Basin can also be described according to their USGS HUC4 designations. These HUC4 boundaries do not coincide with USGS gauging stations. A map of these designations is given in Figure 2. The basin area according to HUC4's is approximately 9,584 km^2. This area includes the surface area of lakes.

- *St. Joe River* inclusive of Chatcolet Lake, and Round Lake: 4,780 km^2
- *Upper Coeur d'Alene,* North Fork of the Coeur d'alene River to the confluence with the South Fork of the Coeur d'Alene River: 2,322 km^2
- *South Fork Coeur d'Alene River* to the confluence with the North Fork: 774 km^2
- *Coeur d'Alene Lake,* region between the boundary with Round Lake and Chatcolate Lake, the confluence of the North Fork and South Fork of the Coeur d'Alene River, and the Lake outlet to the Spokane River: 1,708 km^2

Figure 2. Map of the Coeur d'Alene Basin, as defined by USGS HUC4.

Geology and Land Use

The history, geology, and ecology of Coeur d'Alene Lake and the surrounding basin have been summarized in numerous prior reports (e.g., DEQ, 2011a; DEQ, 2011b; DEQ, 2010; DEQ, 2007; NRC, 2005; DEQ, 2003; Woods and Beckwith, 1997). In general, the basin encompasses three primary drainage areas that have distinct geologic, historic, and land-use features. These drainages are the Coeur d'Alene River, the St. Joe River, and the smaller watersheds that flow directly into Coeur d'Alene Lake. From a social and economic perspective, the lake region is a resort destination with a diverse economy and rapidly growing population in Kootenai County, primarily in the cities of Coeur d'Alene, Hayden, and Post Falls (along northern shore and Spokane River), as well as many smaller communities along the lakeshore. The upstream regions of the Coeur d'Alene and St. Joe Rivers outside of Kootenai County are sparsely populated with economies that are a mix of agriculture, mining, timber, light industry, services, and recreational activities. Benewah County (along the southern tip of the lake) has experienced mild growth, while Shoshone County (upstream regions of the Coeur d'Alene and St. Joe River subbasins) has a declining population. The main stem of the Coeur d'Alene River and large portions of the South Fork of the Coeur d'Alene River have been heavily impacted by historic mining activities and are within the boundaries of the Bunker Hill Superfund site, which was is one of the United States' largest mining megasites. The site boundaries encompass most of Coeur d'Alene Lake and extend into the Spokane River (National Research Council, 2005).

The Coeur d'Alene River subbasin above the USGS gauge at Harrison is approximately 3,755 km^2 in size and can be divided into three general drainage regions; the North Fork above the City of Enaville (2,315 km^2), the South Fork above the City of Pinehurst (740 km^2), and the main stem stretching from the confluence of the North Fork and South Fork to the USGS gauge near the City of Harrison (710 km^2). Most of the subbasin is primarily underlain by schist and gneiss metasedimentary rocks of the Proterozoic Belt Supergroup. The lower floodplain is underlain by alluvium and lacustrine deposits. The North Fork largely consists of undeveloped mountainous forest land that hosts both logging and outdoor recreational activities with some historic mining (none current). The South Fork hosts the I-90 transportation corridor and small cities first founded as Silver Valley mining towns. The riparian zone in this region has been heavily impacted by historic mining activities. The North Fork and South Fork join just upstream from the City of Cataldo, which hosts the longest running flow record for the Coeur d'Alene River (1912 to present day). The main stem flows along a broad floodplain (0.25 – 1.75 miles wide) from this junction to the outlet to Coeur d'Alene Lake near the City of Harrison. Eleven lakes and numerous wetlands are located along the river in this region. These lakes are extensions of the high water table and are hydrologically connected to the river via natural and man-made channels. This region of lakes and wetlands supports a mix of agricultural, recreational, and light industrial activities and has also been heavily contaminated from historic mining.

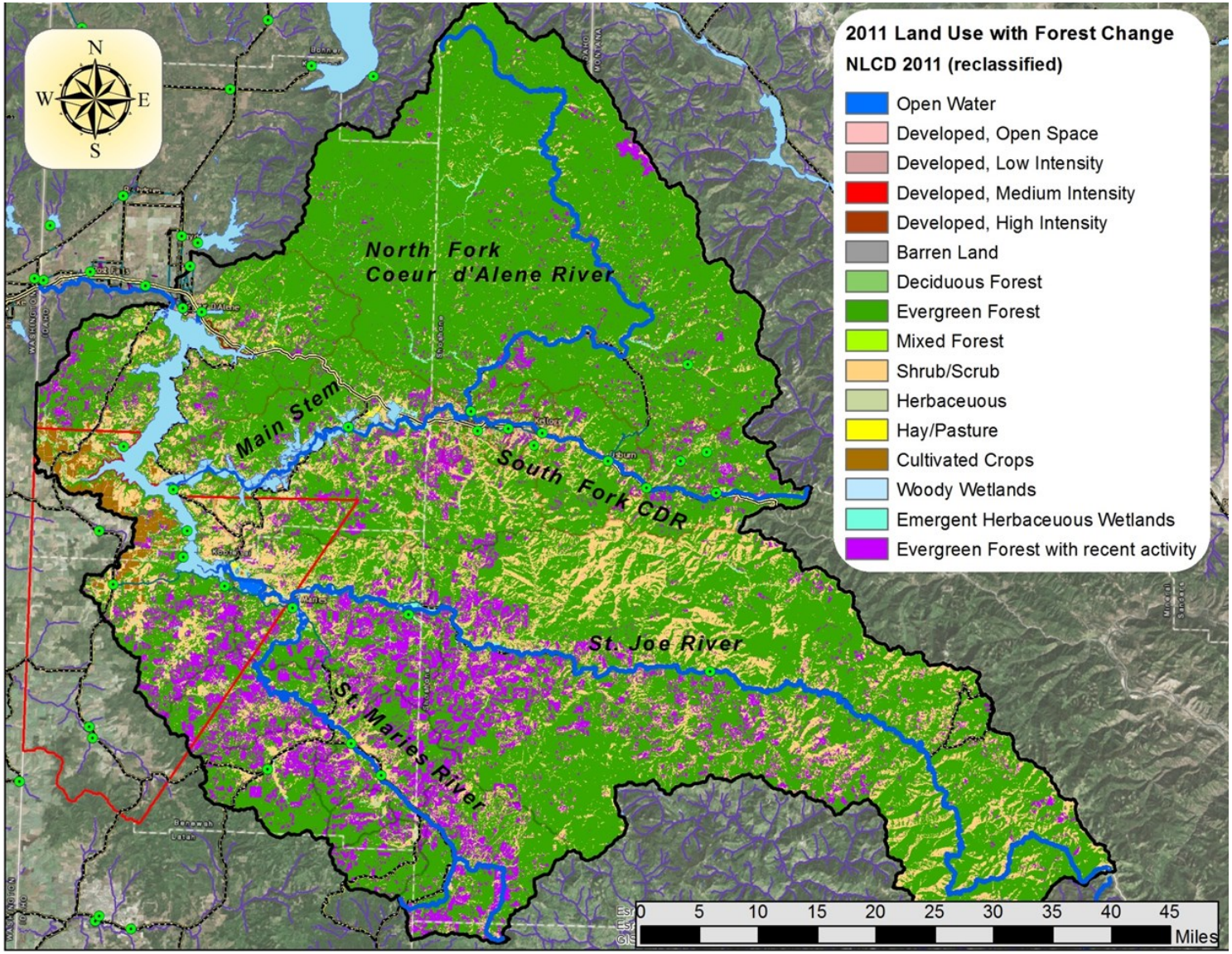
The tributaries to Coeur d'Alene Lake drain an aggregate area of approximately 1,211 km^2. There are significant differences in geology between the east and west side of the Lake. Most of the subbasin is primarily underlain by schist and gneiss of the Belt Supergroup metasediments. On the lower floodplain toward the mouth of the Coeur d'Alene River, the valley is underlain by alluvium and lacustrine deposits. The west side hosts most of the basin's agricultural activities and has geologic influences from the Palouse Hills. The Coeur d'Alene urban area is located along the northern shore of the lake. The lakeshore has numerous small residential and lake

resort communities that stretch up to the ridgelines surrounding the lake. The non-residential watersheds along the northern and southern lake host logging and agricultural activities. Most residential and recreational development along the lakeshore occurs north of the City of Harrison. The lake's larger tributaries are characterized by a wedge of water-deposited alluvium (deltaic sediments) found between 2,128- and 2,182- foot elevations. These wedges vary in length, influence, and hydrologic characteristics; and sustain subsurface flows into the lake for streams that become dry during the summer months. Perennial flow exists upstream of the deltaic sediments on most tributaries. The largest of these tributary systems is Wolf Lodge Creek (104 km^2) which combines with Cedar Creek (62 km^2) before draining into the northeastern region of the lake. Other notable tributaries include Benewah Creek (138 km^2), Plummer Creek (114 km^2), Lake Creek (100 km^2), Mica Creek (68 km^2), Fernan Creek (50 km^2), Cougar Creek (49 km^2), Fighting Creek (42 km^2), Carlin Creek (32 km^2), Beauty Creek (29 km^2), Blue Creek (21 km^2), and Turner Creek (17 km^2). There are also numerous small intermittent creeks that drain watersheds smaller than 15 km^2.

The St. Joe River subbasin above the USGS gauge at Ramsdell is approximately 4,470 km^2 and can also be divided into three drainages; the upper St. Joe River upstream from the confluence with the St. Maries River (3,090 km^2), the St. Maries River (1,265 km^2), and the lower St. Joe River stretching from the confluence with the St. Maries River downstream to the USGS gauge at Ramsdell (120 km^2). Note that the outlet of the St. Joe River into Coeur d'Alene Lake has been monitored by three different USGS gauges; the Ramsdell gauge (2010-current), the Chatcolet gauge (2004 – 09), and St. Maries gauge at the City of St. Maries, (1991-1992). The St. Joe subbasin is also primarily composed of the Proterozoic Belt Supergroup, with alluvial and lacustrine deposits in the lower floodplains. The upper St. Joe, upstream of the City of St. Joe, is predominantly undeveloped but roaded mountainous forest land that hosts logging, mining, and outdoor recreational activities. Most of the land in this region is under the stewardship of the U.S. Forest Service. The St. Maries drainage also hosts extensive tracts of undeveloped but roaded mountainous forest land. Additionally, large tracts of forest land in this basin are privately owned and more heavily logged. The region also hosts recreational and agricultural development, and large scale industrial garnet mining in the valleys. Agricultural activities are primarily along Santa Creek. The lower St. Joe is characterized by forested hillslopes that drain into a broad river valley that hosts a mixture of agricultural, recreational, and residential land covers interspersed among lakes and wetlands.

Land cover in the Coeur d'Alene Basin (Figure 3) is primarily evergreen forest (>70%), with open land comprising approximately 20% of the land (herbaceous, shrub/scrub). Agricultural land comprises less than 5% of the basin and less than 2% of the basin is developed urban and suburban land. Development is focused around small urban areas located near lakes, rivers, and streams, with the greatest development occurring in the cities of Coeur d'Alene, Hayden, and Post Falls along the northern shores of Coeur d'Alene Lake. Numerous homes occupy forested land in the urban-wildland interface along the shores of Coeur d'Alene Lake and many of the Lake's ungauged watersheds. Development pressure is greatest near the City of Coeur d'Alene and lessens to the south. Most development occurs north of the City of Harrison. There is also significant recreational and residential development in private land holdings along the St. Joe River, the South Fork of the Coeur d'Alene River and the lower portion of the North Fork of the Coeur d'Alene River (generally downstream from Pritchard).

Figure 3. Land Cover in the Coeur d'Alene Basin, 2011.



Climate and Hydrologic Characteristics

The climate of the Coeur d'Alene Basin is influenced by both moist maritime air masses moving east from the Pacific Ocean and cold continental air masses moving south from Canada. The cooling of moist Pacific air masses as they are forced up and over the Coeur d'Alene mountains leads to increasing precipitation with increasing elevation. The highest monthly precipitation typically occurs during winter months. Summers are typically dry, with some storm events. Much of the subbasin is located within the rain-on-snow zone, which locally occurs in the 3,300-4,500 foot elevation range (e.g., DEQ, 2001; DEQ 2007). Snowpack is transitory below the rain-on-snow zone, and more resistant to melting during winter rain-on-snow events at higher elevations. Snowpack has historically been in place from October to July at higher elevations, with peak snowpack typically occurring in March and April (SNOTEL data). Minimum temperatures in the City of Coeur d'Alene typically occur in December and January (20 ~ 30 °F), with maximum temperatures during July and August (80 ~ 90 °F). Average temperatures are typically ~5 °F cooler in the smaller cities along the Coeur d'Alene and St. Joe Rivers.

Annual and seasonal variability in climactic factors generate subsequent variability in discharge in the Coeur d'Alene and St. Joe Rivers, as well as the smaller tributary systems. Long-term averages of mean-daily flows for the Coeur d'Alene River at Cataldo and the St. Joe River at Calder are provided in Figure 4. Mean daily flows fluctuate in winter and early-spring in response to snowmelt and rain-on-snow events. The highest mean daily flows typically occur during the spring snowmelt season (April – June). Annual peak flows can occur either during rain-on-snow events or during spring snowmelt. Minimum flows typically occur in August and September. Peak flows can vary by up to 10-fold between extreme high and low flow years, but converge to a common range during summer low flows (Aug – Oct). Streams in the ungauged watersheds that flow directly into Coeur d'Alene Lake also experience high annual and seasonal variability in discharges and are subject to winter "rain-on-snow" discharge events. The lower elevation of these watersheds causes earlier maximum discharge compared to the majority of the watersheds of the Coeur d'Alene River and St. Joe River basins.

Backwater conditions exist during May through September on the St. Joe River downstream St. Joe City and along the Coeur d'Alene River from Cataldo to the mouth due to surface elevation control of Coeur d'Alene Lake by the Post Falls Hydroelectric Development (HED). The inundated channel during May through September attracts seasonal recreational boaters, and also enhances streambank erosion due to boat wakes. Backwater conditions also occur during spring high flows when the lake's surface elevation is not actively controlled by the Post Falls Hydroelectric Dam. These conditions arise from a combination of snowmelt, river geomorphology, and a natural sill at the lake outlet. They are not caused by the Post Falls Hydroelectric Dam. Spring runoff can also create flood conditions along both the Coeur d'Alene and St. Joe Rivers. These floods transport high levels of sediment and nutrients into the lake, as well as metal contaminants from the Coeur d'Alene River.

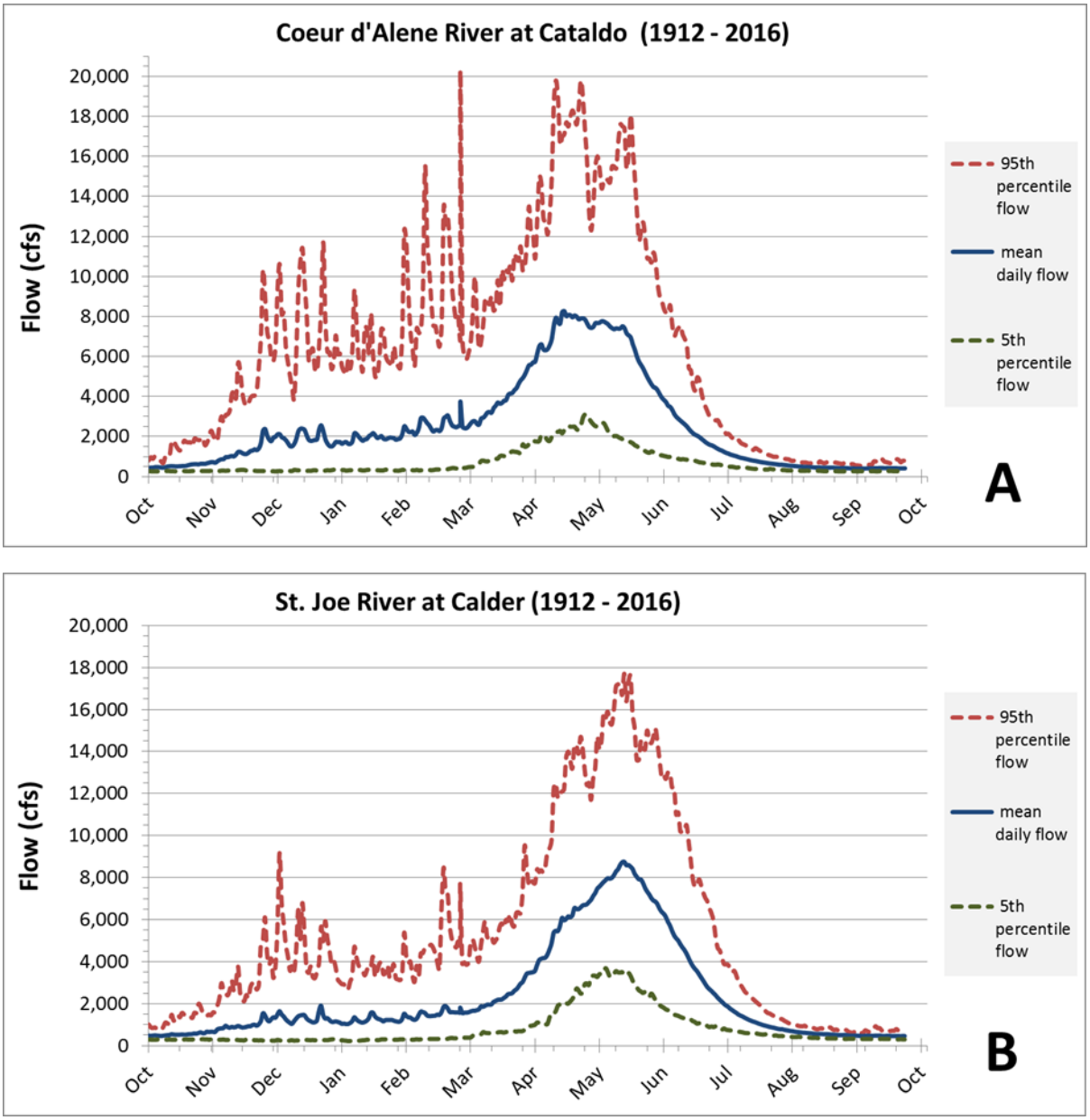


Figure 4. Long-term mean daily flows for the Coeur d'Alene (A) and St. Joe River (B).

1.3 Prior Studies of Nutrient Loading to Coeur d'Alene Lake

Prior analyses of nutrient loading to Coeur d'Alene Lake were conducted by the U.S. Geological survey in calendar years 1991 –1992 (Woods and Beckwith, 1997; Woods, 2004; Wood and Beckwith, 2008) and in water years 2004 – 2006 (Wood and Beckwith, 2008). Additional nutrient loading studies have been conducted for some parts of the basin, but are limited in geographic scope and hydrologic coverage. These USGS studies are the only ones that analyze nutrient loading to Coeur d'Alene Lake in a comprehensive manner. The different USGS studies provide different estimates of nutrient load to Coeur d'Alene Lake for the CY 1991 – 1992 time period. For example, Woods (2004) contradicts estimates for CY 1991 – 1992 that were reported by Woods and Beckwith (1997) while not providing an explanation. These different estimates confuse the historic record. A summary of these prior reports is provided here.

Woods and Beckwith (1997) measured nitrogen and phosphorus loads for the Coeur d'Alene River at Harrison, the St. Joe River at St. Maries (downstream from the confluence of the St. Joe and St. Maries Rivers), and the Spokane River near Post Falls (downstream from the wastewater outfalls of the cities of Coeur d'Alene and Post Falls). They also measured nutrient loading from four lake tributaries (Wolf Lodge Creek, Carlin Creek, Plummer Creek, Fighting Creek), and used those measurements to estimate nutrient loading from all lake tributaries. Additional estimates accounted for atmospheric deposition, wastewater, ground water outflow, and changes in lake volume. A subsequent report by Woods (2004) cites Woods and Beckwith (1997), but reports different loading estimates without explaining the reason(s) for the changes. Wood and Beckwith (2008) also provide revised estimates for Coeur d'Alene Lake nutrient loading for CY 1991 – 1992. These authors used a more recent statistical analysis software package, LOADEST (Runkel et. al., 2004), and normalized the gauging stations for the load estimates to reflect the St. Joe River at Chatcolet (outlet to lake) and the Spokane River at Lake Outlet (upstream from Post Falls and wastewater outfalls for Coeur d'Alene and Post Falls). These revised calculations did not consider the wastewater outfalls for Coeur d'Alene and Post Falls to be part of the Coeur d'Alene Lake system. Instead, these outfalls feed the Spokane River. Wastewater contributions for this analysis are lower and limited to facilities upstream of the lake outlet. The Plummer WWTP, the Harrison WWTP, and systems classified as "nearshore wastewater" are not captured by any stream gauges and this study categorizes them as feeding into Coeur d'Alene Lake.

The total phosphorus loading estimates for CY 1991-1992 reported by these three studies are given below. Inflows and outflows are the totals for all sources, as reported by each study.

1. Woods and Beckwith (1997), total phosphorus budget for Coeur d'Alene Lake
    - *CY 1991* — Inflow = 133,000 kg, Outflow = 54,000 kg, 59% retained in lake
    - *CY 1992* — Inflow = 55,000 kg, Outflow = 39,000 kg, 29% retained in lake
2. Woods (2004), total phosphorus budget for Coeur d'Alene Lake
    - *CY 1991* — Inflow = 115,000 kg, Outflow = 36,100 kg, 69% retained in lake
    - *CY 1992* — Inflow = 43,600 kg, Outflow = 27,600 kg, 37% retained in lake
3. Wood and Beckwith (2008), total phosphorus budget for Coeur d'Alene Lake
    - *CY 1991* — Inflow = 92,800 kg, Outflow = 47,800 kg, 48% retained in lake
    - *CY 1992* — Inflow = 39,400 kg, Outflow = 25,400 kg, 36% retained in lake

Each of these revisions for CY 1991 – 1992 is lower than the prior estimate. The estimate by Wood and Beckwith (2008) utilizes different inlet and outlet locations that exclude the wastewater treatment plant outfalls for the Cities of Coeur d'Alene, Hayden, and Post Falls. The estimates provided by Wood and Beckwith (2008) also utilize the same geographic boundary for Coeur d'Alene Lake that is used in follow-on studies for subsequent years (Clark and Mebane, 2014), and therefore provide more comparable estimates of nutrient loading for CY 1991 – 1992 than do prior reports. Wood and Beckwith (2008) also utilize the LOADEST model and have a longer model calibration dataset. The combination of comparable lake boundaries and model utilization support this study's assumption that the loading estimates provided by Wood and Beckwith (2008) provide the most reliable basis for comparing current loading estimates to historic loads. This report adopts the loading estimates of Wood and Beckwith (2008) for the CY 1991 – 1992 and WY 2004 – 2006 time periods. The loading estimates of Clark and Mebane (2014) are adopted for the period of WY 2009 – 2013. These USGS loading estimates are used to assess the long-term changes in nutrient loading from the Coeur d'Alene and St. Joe Rivers.

The nutrient loading estimates of Wood and Beckwith (2008) did not update estimates for tributary loading with new field data, atmospheric deposition, or non-municipal wastewater. Instead, they adopted the nutrient loading and land cover characteristics from Woods and Beckwith (1997) and adjusted for the hydrology of those years. Development patterns and land cover characteristics in the lakeshore watersheds changed significantly since the 1991 – 1992 time period and the tributary loading estimates for CY 1991 – 1992 are not likely to be representative of the system as it is today. Additionally, the estimates of nutrient loads from atmospheric deposition, and non-municipal wastewater provided by Woods and Beckwith (1997) and Wood and Beckwith (2008) are based on rough assumptions and extrapolations from datasets outside the Coeur d'Alene Basin that may or may not be representative of the system. Consequently, the estimates of loading from these non-river sources where there is no local data have limited interpretative value and should be treated with caution.

These considerations regarding the historic dataset limit the ability to compare historic conditions with those today. Historic data from 1991 – 1992 cover calendar years and not water years and there is disagreement in the literature as to what the estimated loads are. This historic dataset is also much shorter than the current dataset and less representative. There is not an internally consistent dataset to compare the changes in loading for the lake tributaries. There are no direct measurements of atmospheric loading to the lake or the basin at large. Current loading data can provide valuable information on the magnitude and location of current loading, but the current information can only be contrasted with historic data in a narrative and qualitative manner. The available historic data can be used to assess whether it is likely that loads have changed over time, particularly if there is consistency between multiple lines of evidence. However, there is insufficient information to quantify the magnitude of any potential change.

1.4 Influence of Hydrology on Nutrient Load

The historic variability in climactic conditions and discharges (e.g .Figure 4) also generates significant variability in nutrient loading from the Coeur d'Alene Basin's streams and rivers. This variability hinders efforts to develop a basin-wide nutrient inventory. Consider the following base equation, where nutrient load is the product of discharge and concentration.

Load (kg/day) = Concentration (kg/L) * Discharge (L/day)

Higher discharge equates to higher load. Additionally, historic data for the Coeur d'Alene Basin shows that nutrient concentration can also vary with flow; increasing the impacts of flow variability on loading. An example of these dual impacts is shown in Figure 5 and Figure 6.

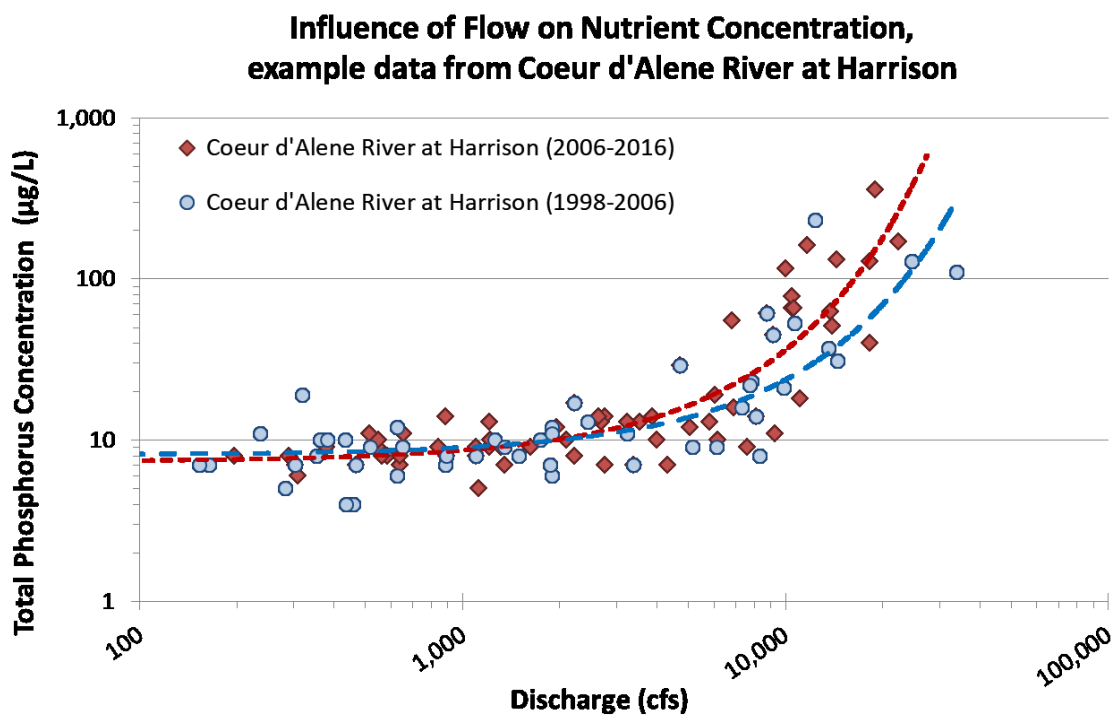


Figure 5. Influence of discharge (discharge) on phosphorus concentration. Example is from historic data for the Coeur d'Alene River at Harrison.

Example data provided in Figure 5 show that, at this monitoring location, the concentration of phosphorus is relatively constant below a flow of ~3,000 to 4,000 cfs. Above that flow, phosphorus concentration increases in an exponential relationship. Higher flow years, where peak flows are higher and elevated flows last for longer, will experience higher phosphorus concentrations and those elevated concentrations will last longer at higher flows – resulting in higher loads. An example of the combined influence of (i) discharge and (ii) the relationship between discharge and concentration on phosphorus loading is shown in Figure 6. These example data are for the Coeur d'Alene River at the USGS gauging station at Harrison, ID.

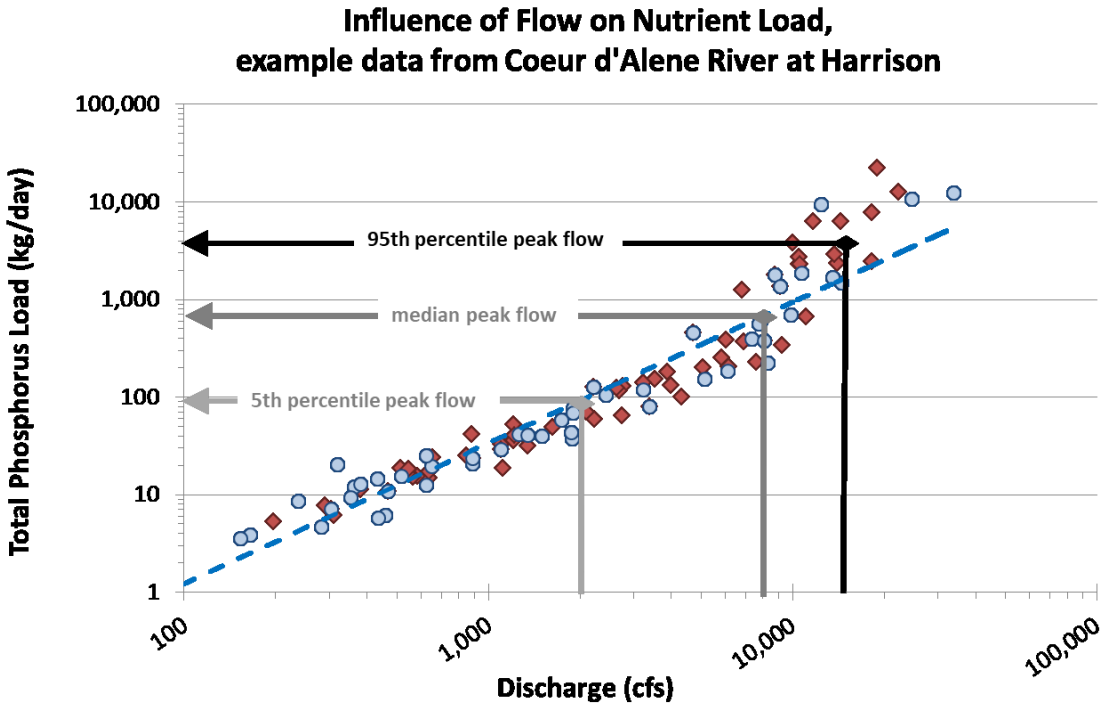


Figure 6. Influence of discharge (discharge) on main daily phosphorus load. Example is from historic data for the Coeur d'Alene River at Harrison.

Example data given in Figure 6 for the Coeur d'Alene River at Harrison show how mean daily load can vary greatly over the course of a water year at this location, in response the shifts in flow and the relationship between flow and phosphorus concentration. Comparable seasonal variability occurs at other locations throughout the basin. Daily loads at the Harrison gauge for typical years at base flow conditions (~500 cfs) are approximately 10 kg/day. At the long-term median peak flow (~8,000 cfs), mean daily load is higher by a factor of 50 – 100 (500 – 1,000 kg/day). That seasonal difference in daily load between base flow and peak flow can be as much as 1,000-fold for extreme high flow years where peak flow rises above 12,000 – 15,000 cfs. This influence of daily flow on daily load also translates to a variance in annual load between high-flow, mean-flow, and low-flow years. Higher flow years translate into higher flows for longer periods of time and higher annual loads. The reverse is true for lower flow years.

Historic Variability in Flow and Load

A summary of the historic variability in mean annual discharge on annual phosphorus loading for the most recent 10-year record of published phosphorus loads is provided in Table 1. Data are given for the St. Joe River at its outlet to the lake, the Coeur d'Alene River at its outlet to the lake at Harrison, and the Coeur d'Alene River at the Cataldo gauging station just downstream from the confluence of the North Fork and South Fork of the Coeur d'Alene River. The Cataldo gauge has the longest term flow record and provides the best basis for contrasting between

different flow years. A graphical comparison of how the load for the Coeur d'Alene and St. Joe Rivers compare when grouped according to the percentile ranking of flow years is provided in Figure 7. These data show that the mean annual load can vary up to 5-fold between extreme low-flow years (WY 2010) and high flow years (WY 2011). On average, annual load appears to vary by a factor of two between a "typical" flow year in the middle two quartiles and a higher or lower flow year for a year in the upper or lower quartiles of long-term flow. When compared within a flow grouping (e.g., mid-flow to mid-flow), the annual loads are comparable.

Table 1. Mean annual flow and published phosphorus loading data for the Coeur d'Alene and St. Joe Rivers for the period of 2004 - 2013.

Water Year	CDA River at Cataldo [1]			CDA River at Harrison		St. Joe River	
	%tile	flow [2]	TP load [2]	flow [2]	TP load [2]	flow [2]	TP load [2]
2004	20%	1,873	—	1,700	28	1,940	39
2005	25%	1,966	—	2,138	42	2,392	50
2006	59%	2,718	—	2,858	60	3,040	79
2007	46%	2,355	—	2,565	—	2,903	—
2008	63%	2,795	—	3,108	—	3,226	—
2009	35%	2,133	53	2,500	63	3,073	86
2010	12%	1,705	23	1,954	32	2,017	35
2011	94%	3,707	113	4,132	170	4,832	175
2012	75%	3,084	76	3,297	132	3,644	110
2013	42%	2,335	34	2,640	70	2,677	59
Low Flow	WY 2004, 2005, 2010 (≤ 25th percentile of flow record at Cataldo)						
average	19%	1,705	23	1,931	34	2,116	41
%RSD [3]	—	*WY 2010 only*		11%	21%	11%	18%
Mid Flow	WY 2006, 2009, 2013 (middle two quartiles of flow record at Cataldo)						
average	45%	2,395	44	2,666	65	2,930	74
%RSD [3]	—	12%	31%	7%	8%	8%	19%
High Flow	WY 2011, 2012 (≥ 75th percentile of flow record at Cataldo)						
average	85%	3,396	95	3,715	151	4,238	143
%RSD [3]	—	13%	27%	16%	18%	20%	32%

1. For Cataldo, use only WY 2010 for Low-flow and WY 2009, 2013 for Mid-flow
2. Mean annual flow (cubic feet per second), annual total phosphorus load (tons/yr)
3. % relative standard deviation

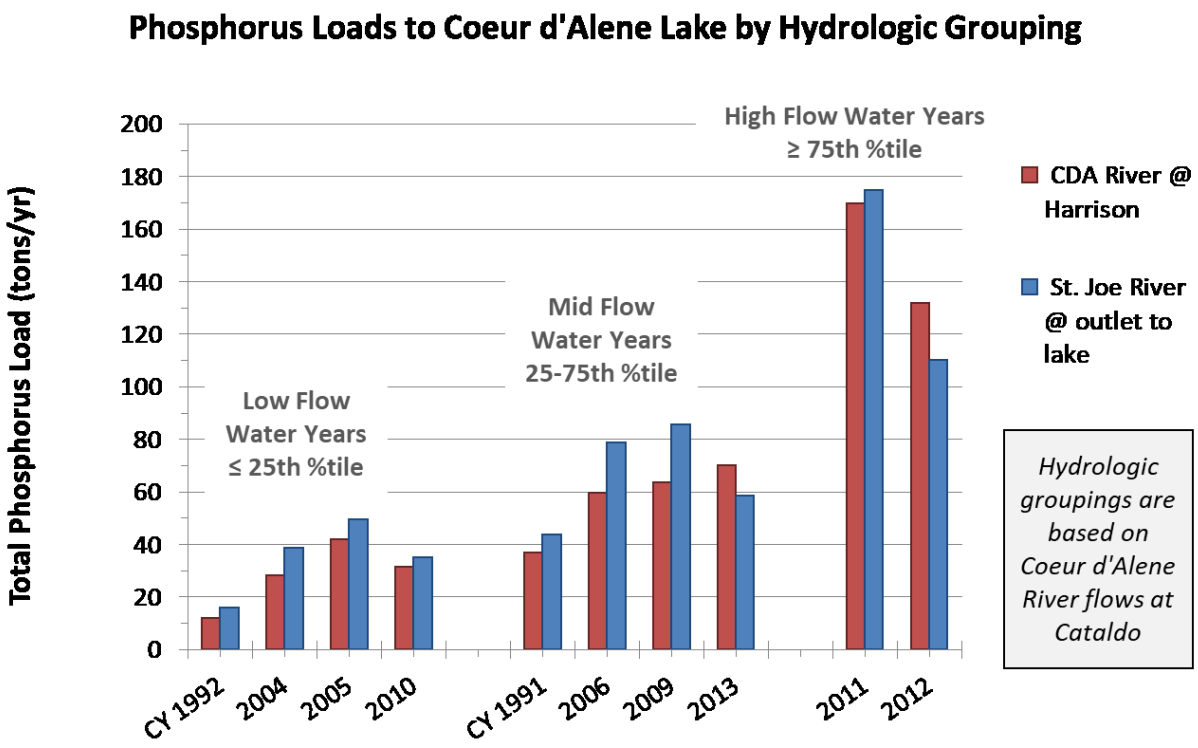


Figure 7. Annual total phosphorus loads by hydrologic grouping

The influence of flow variability on nutrient loading in the Coeur d'Alene Basin requires that hydrologic differences between years be taken into account. The relative importance of nutrient loading from different subbasins and watersheds can only be compared using an internally consistent dataset that is equally representative of variability in flow. The availability of these datasets is limited for the Coeur d'Alene Basin (e.g. Figure 8, following Section). This report will account for the impacts of hydrologic variability in two ways.

1. The overall budget for the lake is estimated as the average from the 10-year dataset from 2004 – 2013. This dataset is only available for the Coeur d'Alene, St. Joe, and Spokane Rivers. This dataset does not quantify all nutrient inputs (e.g. lake tributaries).
2. The watersheds within each of the three subbasins are evaluated independently, using the years where data is available in the data record. Watershed-to-watershed comparisons are conducted within each subbasin, but are not contrasted between subbasins due to limitations in the respective datasets.

Hydrologic variability also limits our ability to assess loading trends over time. The historic dataset is too short to fully represent variability for the early 1990's. Consequently, time trends will primarily be assessed qualitatively in terms of the flow-concentration relationship and how those changes relate to in-lake trends. The paucity of historic data forestalls a rigorous quantitative analysis of how loading trends may have changed over time.

A schematic summarizing the availability of internally consistent published nutrient loading reports and/or nutrient loading datasets for the different subbasins that drain into Coeur d'Alene Lake is provided in Figure 8. The most comprehensive dataset is for the St. Joe and Coeur d'Alene River outlets. Loading data is available for all years from 2004 – current for the Coeur d'Alene and St. Joe River outlets, but published reports do not include estimated loads for all years (i.e. WY2007, WY2008, WY2014 - current). For purposes of internal consistency, this study only uses published USGS loading estimates for the river outlets.

Limited internally consistent datasets are available for the watersheds and stream reaches of the Coeur d'Alene and St. Joe River subbasins. Differences in the representativeness of these datasets limit the ability to compare between upstream regions of these subbasins. A comprehensive, internally consistent dataset is not available for the tributaries that drain directly into the lake. Additional data is needed to develop a rigorous inventory for these watersheds.

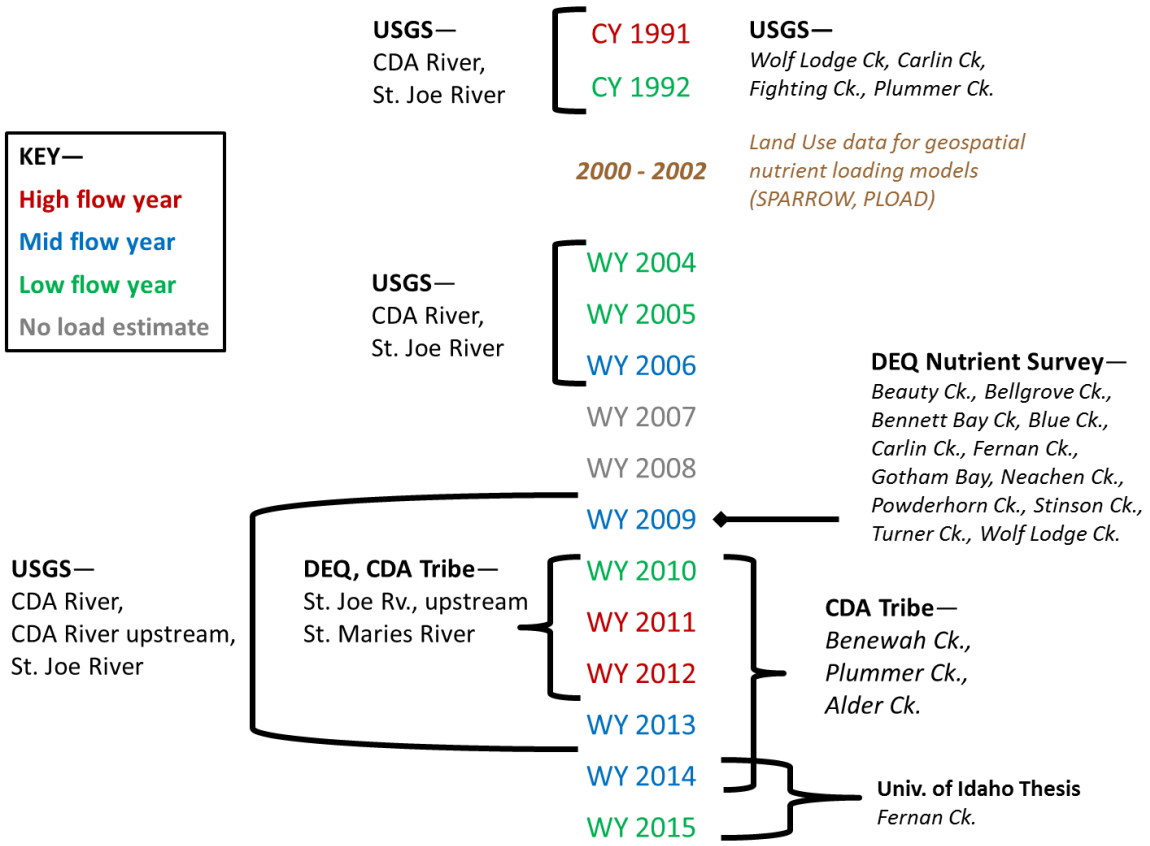


Figure 8. Summary of phosphorus data availability relative to discharges.

2 Current Phosphorus Loading, 2004—2013

This section provides an inventory of total phosphorus loading for the Coeur d'Alene Basin for water years 2004 – 2013. These years are chosen because the USGS has published loading estimates for the Coeur d'Alene River, St. Joe River and Spokane River and the available data cover a wide range of hydrologic conditions. Additionally, loading estimates for upstream watersheds along the Coeur d'Alene River and St. Joe River are available for a subset of years within this time frame. To the extent possible, loading estimates are from USGS studies. The USGS estimates are augmented by data from Idaho DEQ and Coeur d'Alene Tribe studies.

2.1 Phosphorus Inventory for Coeur d'Alene Lake

A total phosphorus budget for Coeur d'Alene Lake under average conditions for WY 2004 – 2013 is presented in Table 2. A corresponding map is provided in Figure 9. On average, the Coeur d'Alene and St. Joe River provide equivalent amounts of phosphorus to the lake, with the St. Joe contributing slightly more due to its greater drainage area. Combined, these two rivers provide over 75% of the total load to the lake, with < 10% of that load originating from municipal wastewater treatment plants (11 tons/yr). Phosphorus data is not available for other point sources such as storm drains, construction sites, and commercial/industrial discharges.

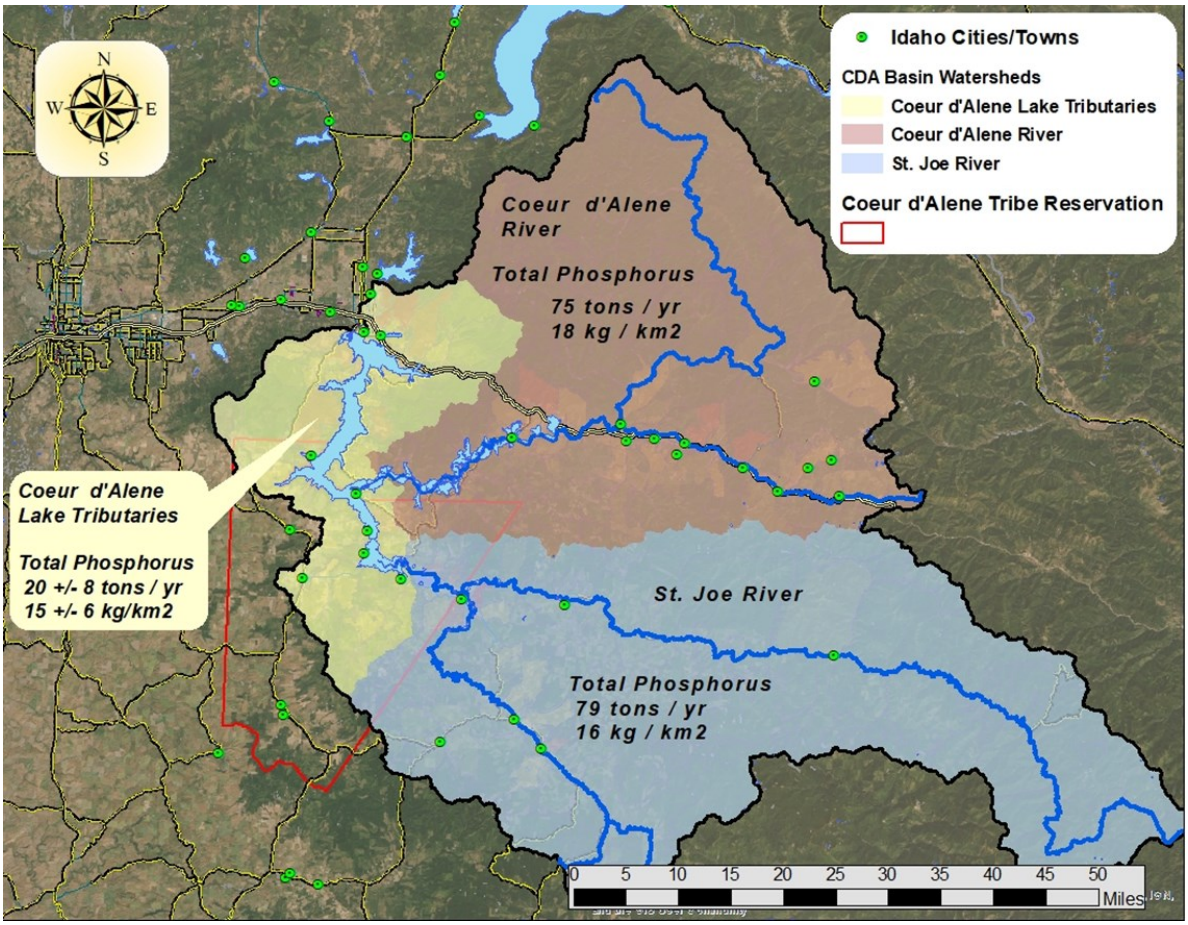


Figure 9. Map of average nutrient load to Coeur d'Alene Lake.

Table 2. Phosphorus Budget for Coeur d'Alene Lake (2004 – 2013).

Subbasin or Nutrient Source	Subbasin area (km2)	Average Phosphorus Load (tons/yr) [1]	Average Phosphorus Load (kg/yr) [2]	*average lower 95% confidence interval (kg/yr)* [2]	*average upper 95% confidence interval (kg/yr)* [2]
Coeur d'Alene River	3,755	75	67,800	46,500	96,100
St. Joe River	4,472	79	71,700	55,200	91,700
Coeur d'Alene Lake Tributaries	1,211	20 ± 8	estimated to 1 significant figure, see Section 2.4		
Atmospheric Deposition to Lake	129	7 ± 3	estimated to 1 significant figure, see Section 2.5		
Wastewater to Lake Watersheds	--	1 ± 0.5	estimated to 1 significant figure, see Section 2.5		
Input to Coeur d'Alene Lake		***180***	***139,500***	***101,700***	***187,800***
Spokane River	9,660	52	46,800	37,500	57,560
Groundwater outflow to Rathdrum Prairie Aquifer	--	3 ± 2	estimated to 1 significant figure, see Section 2.5		
Output to Spokane River		***55***	***46,800***	***37,500***	***57,600***
% of Phosphorus Retained within the Lake		***70%***			

1. Total phosphorus estimates given to two significant figures, unless otherwise noted.
2. Load estimates given to nearest 100 kg/yr
3. Phosphorus retention in the lake is calculated from a mass balance between the inputs and outputs listed here

Loading estimates for the Coeur d'Alene and St. Joe Rivers are based on field data collected by the USGS at the monitoring stations at the river outlets. Loading estimates for the Spokane River are based on field data collected by the USGS at the monitoring stations at the lake outlet. Data for the Coeur d'Alene River comes from the USGS monitoring station at Harrison (gauge # 12413860). Data for the St. Joe River comes from two different USGS monitoring stations located near the river mouth (Chatcolet, gauge #12415140, 2004 – 2009; Ramsdell, gauge # 12415135, 2009 - current). Data for the Spokane River comes from three different USGS monitoring stations located downstream from the lake outlet (Spokane River near Post Falls, gauge #12419000, 2004 – 2009; CDA Lake outlet near Coeur d'Alene, gauge # 12417160, 2010 – 2013; Spokane River near Blackwell Island, gauge# 12417650, 2014 - current). Annual load estimates for these rivers were calculated by the USGS with the LOADEST model, and are as reported in USGS technical reports (Wood and Beckwith, 2008; Clark and Mebane, 2014). Longer-term loads are the average over multiple years. Loading estimates for the Coeur d'Alene Lake tributaries are not based on direct field measurements. These are derived from model predictions reported in the literature (Woods and Beckwith, 1997; Wood and Beckwith, 2008; Geoengineers, 2011; Wise and Johnson, 2011; Wise and Johnson, 2014). These models are based on land use characteristics as they were in the 1990's and early 2000's; and are based on satellite data that does not fully capture the impacts of localized housing and recreational development (see Section 2.4). Kootenai County is one of the fastest developing regions in the Pacific Northwest, and these models do not capture all of the development impacts. Thus, the modeled load from the tributaries may underestimate the actual load.

The estimates of long-term average load from the Coeur d'Alene and St. Joe Rivers have considerable uncertainty that arises from two factors, (i) estimates of annual load provided by the USGS have statistical uncertainty, and (ii) loads can also greatly from year to year in response to varying hydrologic conditions. Tables of annual load and associated error provided in Appendix A show that annual load for low-flow or high-flow years can vary by a factor of 1.5 – 2x relative to the long-term average. There can be as much as a 5-fold difference between extreme low-flow and high-flow years. The year-to-year variability in annual flow and the resultant load constrains our ability to compare loads between the upstream watersheds within each subbasin. The available data for the upstream watershed along the rivers is not as comprehensive as for the river mouths, and is consequently less representative of long-term average loads. Consider the data presented in Table 3, which compares loads for the different subbasins for the different time periods where upstream loading estimates are available.

The long-term average load from the combination of the St. Joe and Coeur d'Alene Rivers for the decade from 2004 – 2013 is approximately 150 tons/yr (2 significant figures). However, the multi-year average rises for shorter time periods that are biased toward higher flows. For 2009 – 2013 when upstream information for the Coeur d'Alene River is available, that load increases to approximately 190 tons/yr. For 2010 – 2012, when upstream information for the St. Joe River is available, that combined load further increases to 220 tons/yr. The phosphorus yield (loading per unit area) increases correspondingly. This difference in load between the timeframes of the available datasets implies that, while the overall load from the different subbasins can be compared to one another, loading from upstream watersheds within a subbasin should only be compared within that subbasin. Thus, loads from subbasin watersheds can only be compared within a given subbasin and should not be compared across subbasin boundaries.

Table 3. Coeur d'Alene Lake Overall Nutrient Budget, comparison of loads for different time periods.

Time period	Hydrologic Representativeness	Subbasin	Average Annual flow (cfs)	Average Phosphorus Load (tons/yr)	Average Phosphorus Yield (kg/km2)	Average Phosphorus Load (kg/yr)	*average lower 95% confidence interval (kg/yr)*	*average upper 95% confidence interval (kg/yr)*
2004 - 2013 *excludes 2007, 2008*	**Long-term average.** Streamflow coverage is balanced between high flow, low flow, and mid-range flow years	Coeur d'Alene River	2,650	75	18	67,800	*46,500*	*96,100*
		St. Joe River	2,950	79	16	71,700	*55,200*	*91,700*
		Total River Inputs	***5,600***	***150***	***17***	***139,500***	***101,700***	***187,800***
		Spokane River	6,120	52	--	46,800	*37,500*	*57,560*
		Retained in Lake	--	***98***	--	***92,700***	***64,200***	***130,240***
2009 - 2013	**Biased toward higher flows and loads.** Years where loading data is available for watersheds in the Coeur d'Alene River Subbasin	**Coeur d'Alene River**	**2,900**	**93**	**22**	**84,800**	***55,000***	***125,900***
		St. Joe River	**3,250**	**93**	**19**	**84,300**	***61,500***	***112,900***
		Total River Inputs	***6,150***	***190***	***20***	***169,100***	***116,500***	***238,800***
		Spokane River	6,600	57	--	51,700	*40,300*	*65,400*
		Retained in Lake	--	***130***	--	***117,400***	***76,200***	***173,400***
2010 - 2012	**Biased toward higher flows and loads.** Years where loading data is available for watersheds in the St. Maries River and St. Joe River Subbasins	**Coeur d'Alene River**	**2,830**	**110**	**27**	**100,900**	***66,100***	***150,600***
		St. Joe River	**3,500**	**110**	**22**	**96,800**	***135,100***	***280,900***
		Total River Inputs	***6,330***	***220***	***24***	***197,700***	***200,200***	***431,500***
		Spokane River	7,170	64	--	58,200	*45,600*	*73,300*
		Retained in Lake	--	***160***	--	***139,500***	***154,600***	***358,200***

Total phosphorus load estimates are given to nearest 100 kg/yr.

Confidence intervals are estimated as the average of the upper and lower annual load confidence intervals reported by USGS.

2.2 Phosphorus Inventory for the Coeur d'Alene River

This section provides a breakdown of total phosphorus loading for the Coeur d'Alene River subbasin. Load estimates used in this analysis are from Clark and Mebane (2014). Estimates of average phosphorus loading for 2009 – 2013, and their 95% confidence intervals are provided for the phosphorus load at USGS sampling locations (Table 4) as well as the incremental load between those sites (Table 5, Table 6). Watershed demarcations are based on the location of these sampling locations. Information is given for both total phosphorus load (kg/yr) and yield by unit area (kg/km2). .Additional information is given in Appendix A.

A map of the Coeur d'Alene River study area is provided in Figure 10. The average long-term total phosphorus load (2004 – 2013) at the Coeur d'Alene River outlet is 75 tons/yr (Table 2). The 5-year average load for the shorter 2009 – 2013 time period for which upstream data is available is 93 tons phosphorus per year. The hydrology for 2009 – 2013 is biased towards higher flows. The 95% confidence intervals around the 2009 – 2013 average range from 60 – 140 tons/yr. Average annual loads for any given year between 2009 and 2013 ranged from 30 – 170 tons/yr depending upon discharges in the subbasin (see Appendix A).

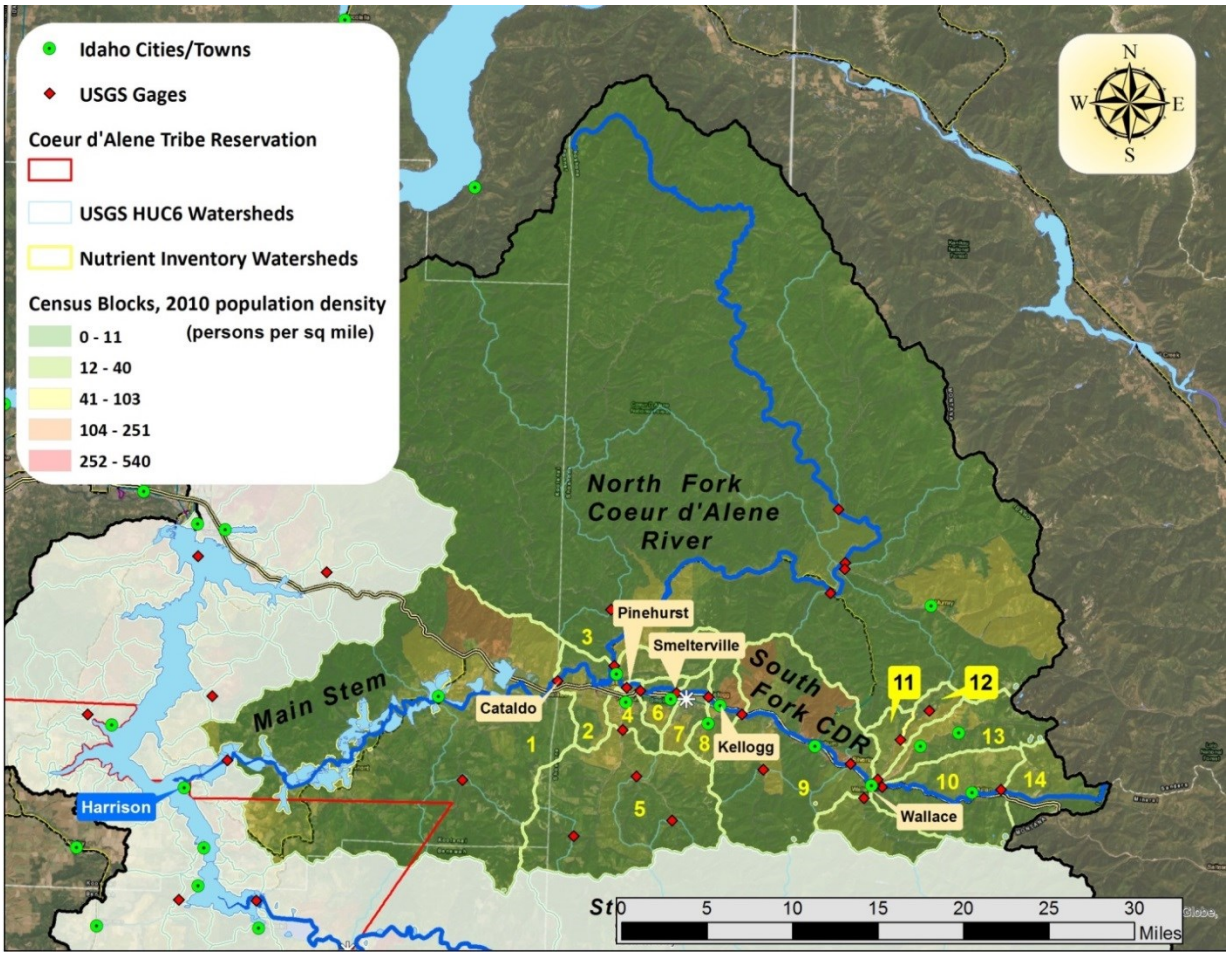


Figure 10. Map of USGS gauging stations, watersheds where loads can be calculated, and population density for the Coeur d'Alene River subbasin.

Table 4. Total phosphorus load and 95% confidence intervals at USGS stream gauges on the Coeur d'Alene River (kg/yr), average from 2009 – 2013.

Coeur d'Alene River Gauge	USGS Gauge #	area drained by gauge (km2)	Average Load 2009-2013 (tons/yr)	Average Load 2009-2013 (kg/yr)	lower 95% confidence interval (kg/yr)	upper 95% confidence interval (kg/yr)
Coeur d'Alene River near Harrison	**12413860**	**3,770**	**93**	**84,820**	**55,030**	**126,060**
Coeur d'Alene River near Cataldo	12413500	3,130	60	54,540	34,260	83,500
NFCDR at Enaville	**12413000**	**2,315**	**40**	**36,320**	**23,620**	**53,940**
SFCDR near Pinehurst	**12413470**	**744.6**	**27**	**24,570**	**14,580**	**39,150**
Pine Ck below Amy Gulch	12413445	189.6	1.2	1,130	330	2,950
SFCDR above Pine Ck near Pinehurst	12413355	492.3	22	19,690	9,330	36,900
SFCDR at Smelterville	12413300	522.0	18	16,120	9,390	26,000
SFCDR at Kellogg	12413250	501.7	7.6	6,890	3,750	11,800
SFCDR at Elizabeth Park	12413210	471.9	7.7	6,950	3,910	11,560
SFCDR above Placer Ck at Wallace	12413131	218.0	2.6	2,350	1,390	3,780
9-mile Ck above mouth near Wallace	12413130	86.6	0.4	360	170	680
EF Ninemile Ck above mouth near Blackcloud	12413127	15.8	0.2	140	90	200
Canyon Ck (above mouth at Wallace)	12413125	56.7	0.4	390	240	580
SFCDR above Deadman Gulch (Mullan)	12413040	44.8	1.1	970	430	1,940

Total phosphorus load estimates are given to the nearest 10 kg/yr.

Confidence intervals are estimated as the average of the upper and lower annual load confidence intervals reported by USGS

Table 5. Incremental total phosphorus load and 95% confidence intervals between USGS gauges on the Coeur d'Alene River, 2009 – 2013.

Watershed (River Reach)	Watershed ID	incremental area (km2)	Average Load 2009-2013 (tons/yr)	Average Load 2009-2013 (kg/yr)	lower 95% confidence interval (kg/yr)	upper 95% confidence interval (kg/yr)
Entire Coeur d'Alene River Basin	--	**3,770**	**93**	**84,820**	**55,030**	**126,060**
Main Stem CDR, Cataldo to Harrison	1	626	33	30,280	20,770	42,560
SFCDR, NFCDR confluence region	2	70.6	(7.0)	(6,350)	(3,940)	(9,590)
NFCDR at Enaville	**3**	**2,315**	**40**	**36,320**	**23,620**	**53,940**
SFCDR near Pinehurst	--	**744.6**	**27**	**24,570**	**14,580**	**39,150**
SFCDR and streams, Pine Ck to Pinehurst	4	18.0	4.1	3,750	4,920	(700)
Pine Ck above Amy Gulch	5	189.6	1.2	1,130	330	2,950
SFCDR and streams, Smelterville to Pine Ck	6	15.0	3.9	3,570	(60)	10,900
SFCDR and streams, Kellogg to Smelterville	7	20.3	10	9,230	5,640	14,200
SFCDR and streams, Elizabeth Park to Kellogg	8	29.8	(0.1)	(60)	(160)	240
SFCDR and streams, Wallace to Elizabeth Park	9	253.9	5.1	4,600	2,520	7,780
SFCDR and streams, Deadman Gulch to Wallace	10	86.6	0.7	630	550	580
WF Ninemile Ck, above mouth near Wallace	11	15.8	0.2	220	80	480
EF Ninemile Ck, above mouth near Blackcloud	12	14.1	0.2	140	90	200
Canyon Ck, above mouth at Wallace	13	56.7	0.4	390	240	580
SFCDR above Deadman Gulch (Mullan)	14	44.8	1.1	970	430	1,940

Total phosphorus load estimates are given to the nearest 10 kg/yr.

Negative loads indicate that phosphorus is removed from the river in that watershed.

Confidence intervals are estimated from the average of the upper and lower annual load confidence intervals reported by USGS

Table 6. Total phosphorus yield (kg/km2) and 95% confidence intervals for watersheds on the Coeur d'Alene River, 2009 – 2013. Based on data from Clark and Mebane (2014).

Watershed (River Reach)	Watershed ID	incremental area (km2)	Average Yield 2009-2013 (kg/km2)	lower 95% confidence interval (kg/km2)	upper 95% confidence interval (kg/km2)
Entire Coeur d'Alene River Basin	**--**	**3,770**	**22**	**15**	**33**
Main Stem CDR, Cataldo to Harrison	1	626	48	33	68
SFCDR, NFCDR confluence region	2	70.6	(90)	(56)	(140)
NFCDR at Enaville	**3**	**2,315**	**16**	**10**	**23**
SFCDR near Pinehurst	**--**	**744.6**	**33**	**20**	**53**
SFCDR and streams, Pine Ck to Pinehurst	4	18.0	210	270	(39)
Pine Ck above Amy Gulch	5	189.6	6.0	1.7	16
SFCDR and streams, Smelterville to Pine Ck	6	15.0	240	(4.0)	730
SFCDR and streams, Kellogg to Smelterville	7	20.3	450	280	700
SFCDR and streams, Elizabeth Park to Kellogg	8	29.8	(2.0)	(5.4)	8.0
SFCDR and streams, Wallace to Elizabeth Park	9	253.9	18	10	31
SFCDR and streams, Deadman Gulch to Wallace	10	86.6	7.3	6.4	6.7
WF Ninemile Ck, above mouth near Wallace	11	15.8	14	5.1	30
EF Ninemile Ck, above mouth near Blackcloud	12	14.1	9.9	6.4	14
Canyon Ck, above mouth at Wallace	13	56.7	6.9	4.2	10
SFCDR above Deadman Gulch (Mullan)	14	44.8	22	9.6	43

Total phosphorus yield estimates are given to two significant figures.
Negative loads indicate that phosphorus is removed from the river in that watershed.

A map of average phosphorus loads (tons/yr) over the 2009 – 2013 time period, for the watersheds listed in Table 5 is provided in Figure 11. The highest total loads come from the North Fork of the Coeur d'Alene River and the Main Stem between the confluence of the North Fork and South Fork near Cataldo and the outlet near Harrison. The sum of all the smaller watersheds along the South Fork of the Coeur d'Alene River is approximately 27 tons/yr, which is slightly less than the loads that originate in the North Fork and along the Main Stem.

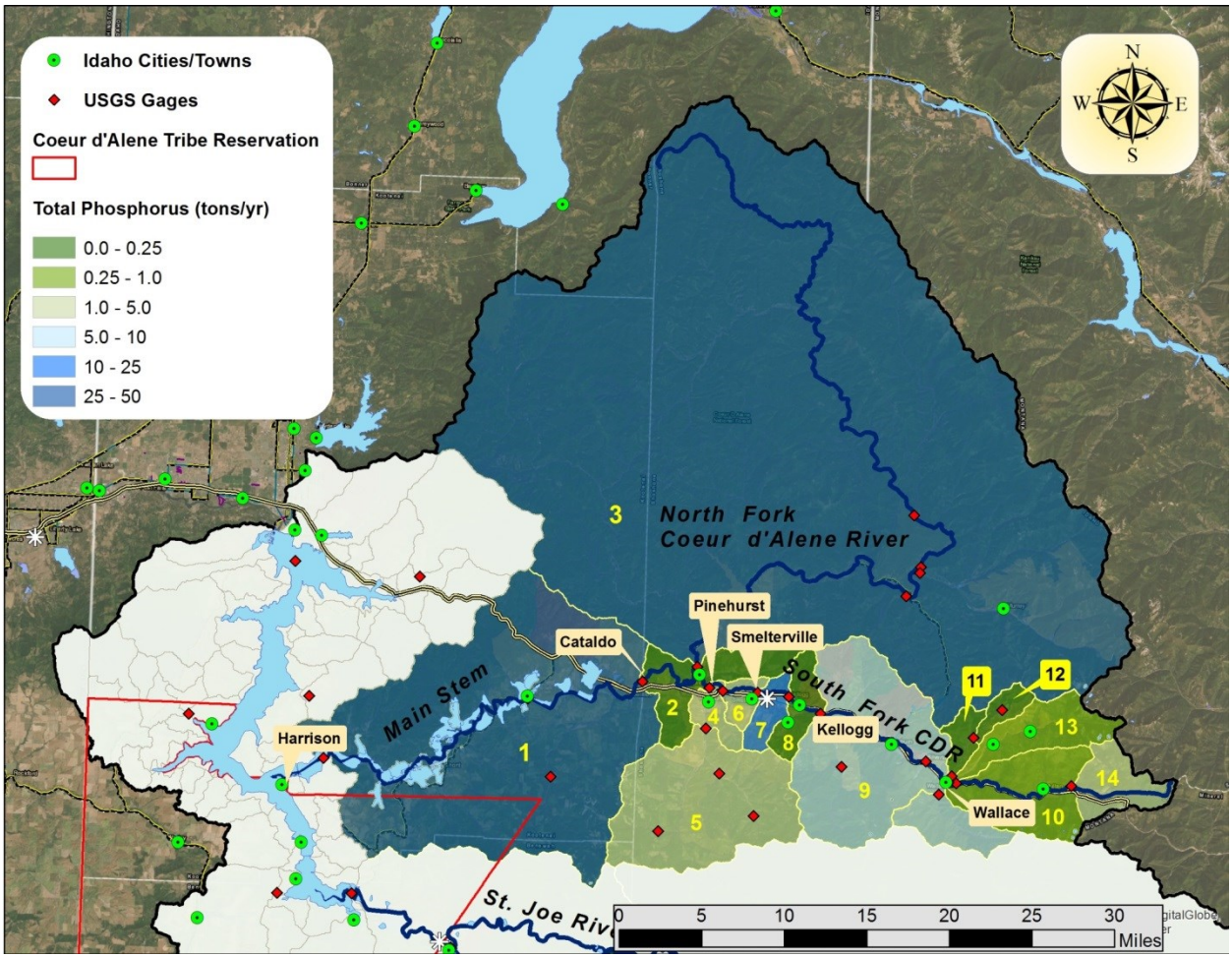


Figure 11. Map of total phosphorus loading (tons/yr) for watersheds in the Coeur d'Alene River subbasin for 2009 – 2013, as defined by USGS gauging stations.

The phosphorous loading in Figure 11 shows loading patterns that are biased towards larger watersheds. Larger watersheds collect more water, and thus inherently produce more load than a smaller watershed that collects less water. This map helps identify where in the Coeur d'Alene River subbasin phosphorus originates, at the scale for which loading estimates based on field data are available. However, due to the scale bias, it does not reflect local influences on phosphorus loading and the associated phosphorus mitigation opportunities. Phosphorus yield (kg/km2) provides a measure of how much load originates per unit area. This measure can help assess localized impacts and identify the watersheds where loading is less dispersed. A map of phosphorus yield is provided in Figure 12.

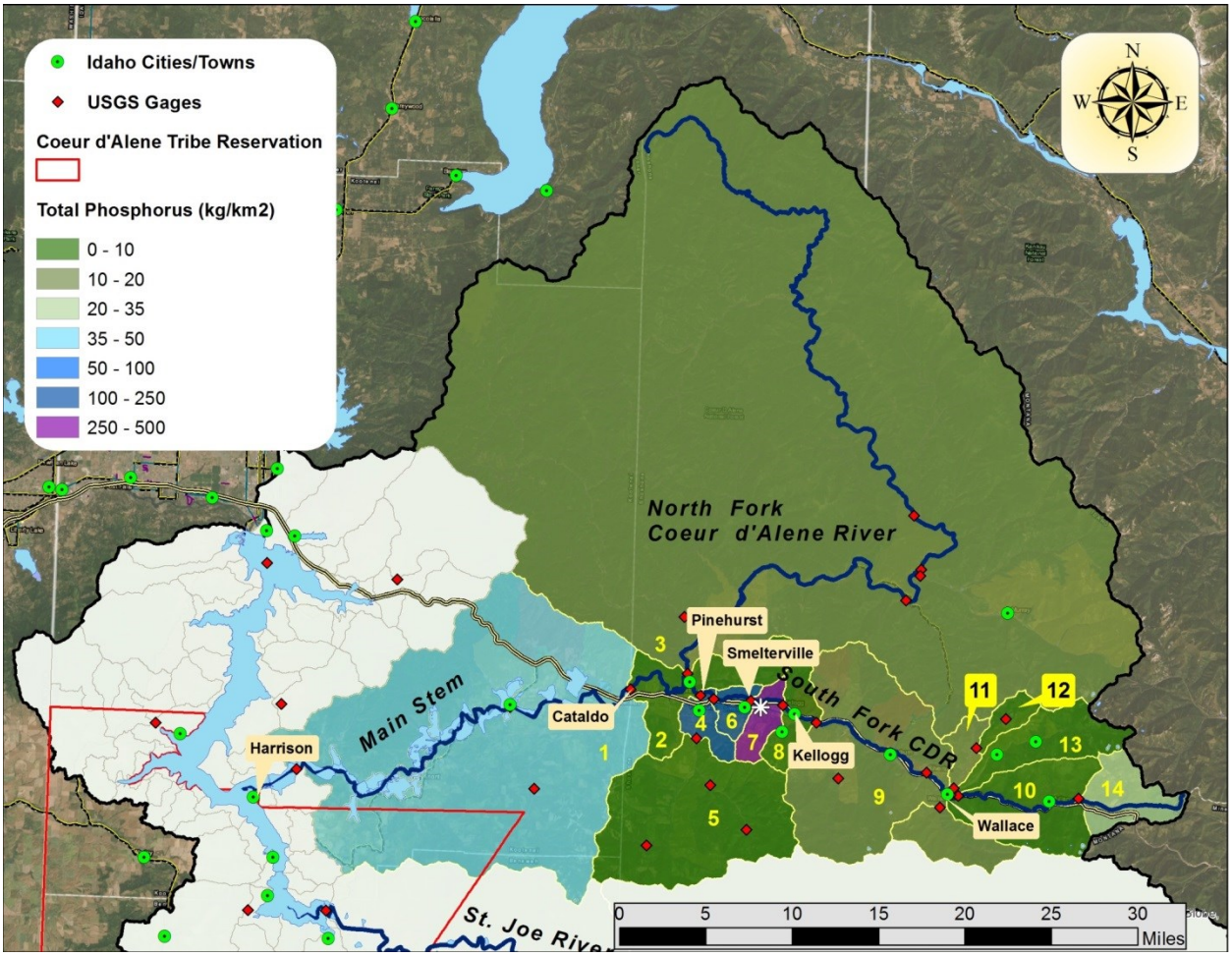


Figure 12. Map of total phosphorus yield (kg/km2) for watersheds in the Coeur d'Alene River subbasin for 2009 – 2013, as defined by USGS gauging stations.

The area-normalized loading map in Figure 12 (phosphorus yield) displays different trends than the total loading map. The North Fork and large swaths of the South Fork have relatively low phosphorus yields (< 10 – 20 kg/km2). Higher yields from more focused loads (> 100 kg/km2) originate in the developed corridor on the South Fork CDR from Pinehurst to Kellogg, with the highest loads occurring along the stretch from Kellogg to Smelterville (> 250 kg/km2). This stretch is adjacent to the Bunker Hill Central Impoundment Area, which is known to contain large amounts of phosphorus-rich gypsum waste produced from 1964 – 1970 as a waste byproduct of phosphoric acid production at the Phosphoric Acid/Fertilizer Plant located in Government Gulch (CH2MHill, 2009; Mullen, 2012). These regions of elevated load from Kellogg to Pinehurst also receive outfalls from regional wastewater treatment plants and urban storm water systems. Based on current monitoring data, most of the phosphorus load in this region of elevated yields likely originates from wastewater treatment plant discharges and groundwater sources in the Bunker Hill Central Impoundment Area.

Another area of elevated phosphorus yield occurs along the Main Stem of the Coeur d'Alene River between Cataldo and Harrison. US EPA studies have shown that the river picks up large loads of sediment along this stretch. Analyses of bank sediments and suspended sediments collected during flood events indicate that sediment phosphorus concentration along this stretch typically ranges from 250 – 550 ppm, and can be as high as 750 ppm in some areas (DEQ, 2009; CH2M Hill, 2018). The South Fork CDR upstream from Mullan also experiences moderately elevated phosphorus yield.

The maps in Figure 11 and Figure 12 are based on the 5-year average load for WY 2009 – 2013, as reported by Clark and Mebane (2014). These loads can vary greatly from year to year (Appendix A). From 2009 – 2013, the total annual phosphorus load from the Coeur d'Alene River at Harrison averaged 93 tons/yr, but varied from a minimum of 32 tons/yr in WY 2010 to a maximum of 170 tons/yr in WY 2011. This is an approximate 5-fold difference between the lowest and highest flow years. Also, the average load for 2009 – 2013 is biased upward by having more higher-flow years than lower-flow years in the period of record. The relative contribution from different watersheds in the Coeur d'Alene River subbasin also varies with flow. A summary of how flow variability impacts phosphorus loading is provided in Figure 13.

When only mid-flow years are considered (middle 50% of flows), the North Fork, South Fork, and Main Stem of the Coeur d'Alene River all contribute equivalent amounts of phosphorus. In low-flow years, the South Fork contribution grows, the Main Stem contribution shrinks, and the North Fork's contribution remains the same. In high-flow years, the North Fork's contribution increased to almost 50% of total load while the South Fork and Main Stem's contributions drop to less than 1/3rd of the total load each. The relative contribution of phosphorus from watersheds along the South Fork also varies with flow year. Here, the biggest change occurs in the area from Smelterville to Pine Creek, Pine Creek to Pinehurst, and Wallace to Kellogg.

- *Low-flow (2010)*— approximately 11 tons / yr (~90% of total SFCDR) originates between Kellogg and Pine Creek. Minimal loads originate elsewhere.
- *Mid-flow (2009, 2013)*— approximately 15 tons / yr (~70% of total SFCDR) originates between Kellogg and Pine Creek. ~2.5 tons originates in the region from Wallace to Kellogg (~10% of the SFCDR load). Other watersheds generate ~5% each.
- *High flow (2011, 2012)*— approximately 15 tons / yr (~40% of total SFCDR) originates between Kellogg and Pine Creek, with all originating between Kellogg and Smelterville. ~10 tons originates between Pine Ck and Pinehurst (~25% of SFCDR load), downstream from where the load occurs in lower flow years. Another ~10 tons originates between Wallace and Kellogg (~25% of the SFCDR load). Other watersheds generate < 5% each.

These shifts in loading suggest that the core drivers of nutrient loading in any given year shift in response to changing hydrologic conditions.

The watersheds of the Coeur d'Alene River subbasin with the most focused phosphorus yields are the Main Stem CDR from Cataldo to Harrison (watershed #1), the South Fork CDR from Kellogg to Pinehurst (watersheds #4, #6, #7), and the South Fork CDR above Mullan (watershed #11). Phosphorus sources are less dispersed within these watersheds. Higher total loads do occur in larger watersheds, but that loading is more dispersed.

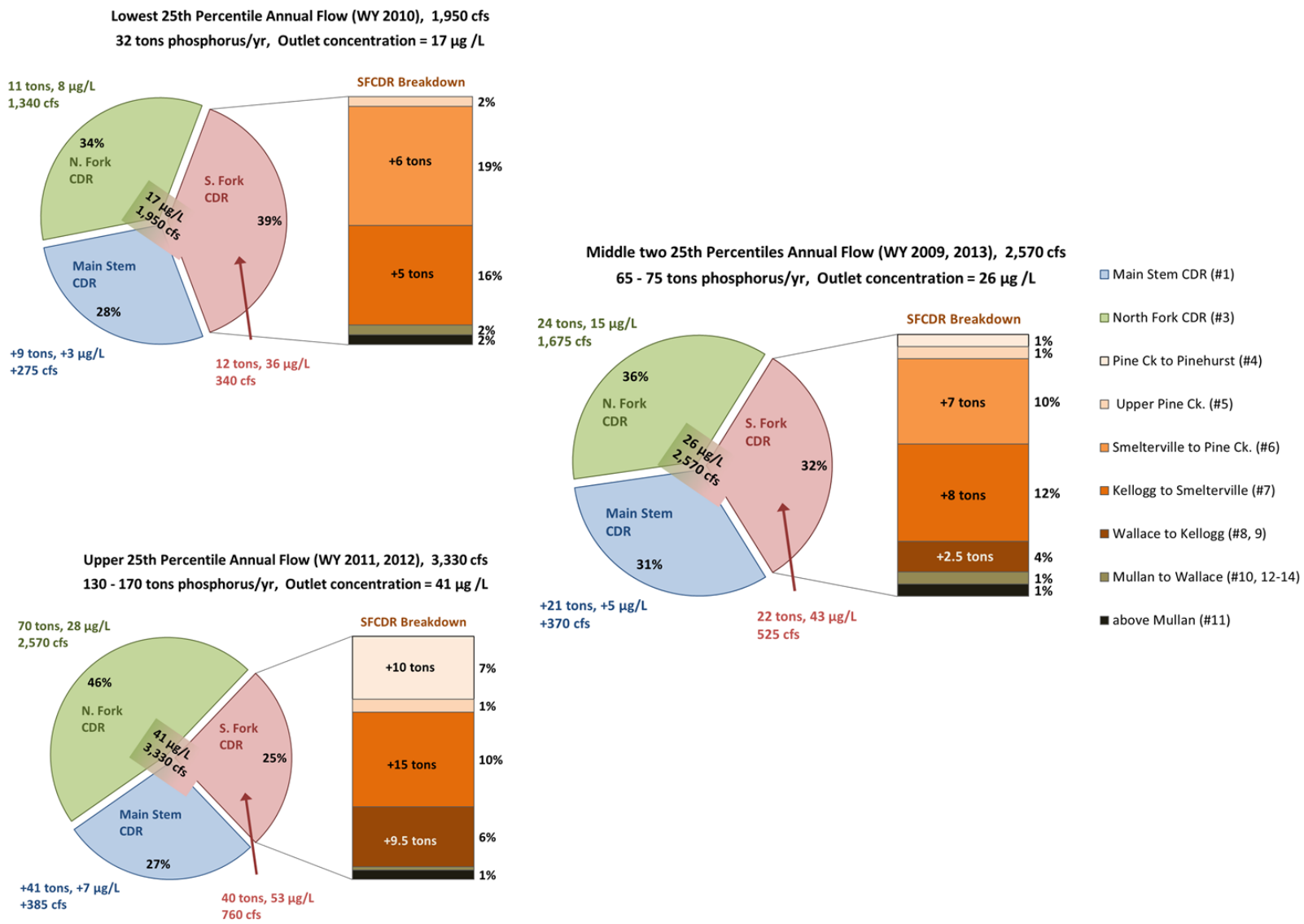


Figure 13. Phosphorus loading to the Coeur d'Alene River for low-flow, mid-flow, and high-flow years.

2.3 Phosphorus Inventory for the St. Joe River

This section provides a breakdown of total phosphorus loading for the St. Joe River subbasin. The data used in this section combine the overall St. Joe River loading estimates from Clark and Mebane (2014) with loads for WY 2010 – 2012 developed by DEQ and Tribe and reported in this study (Section 4). Estimates of average phosphorus loading for 2010 – 2012 are provided for the phosphorus load at sampling locations (Table 7), as well as the incremental load between those sample collection sites (Table 8, Table 9). Watershed demarcations are based on the location of these sampling locations. Information is given for both total load (kg/yr) and total yield (kg/km2). Additional information is provided in Appendix B.

A map of the St. Joe River study area with current and historic sampling and gauge locations is given in Figure 14. The average long-term total phosphorus load (2004 – 2013) at the St. Joe River outlet is 79 tons/yr (Table 2). The 3-year average load for the shorter 2010 – 2012 time period for which upstream data is available is 107 tons phosphorus per year. The hydrology for 2010 – 2012 is biased towards higher flows. The 95% confidence intervals around the 2010 – 2012 average range from 68 – 125 tons/yr. Average annual loads for any given year between 2010 and 2012 ranged from 35 – 175 tons/yr depending upon streamflows (see Appendix B).

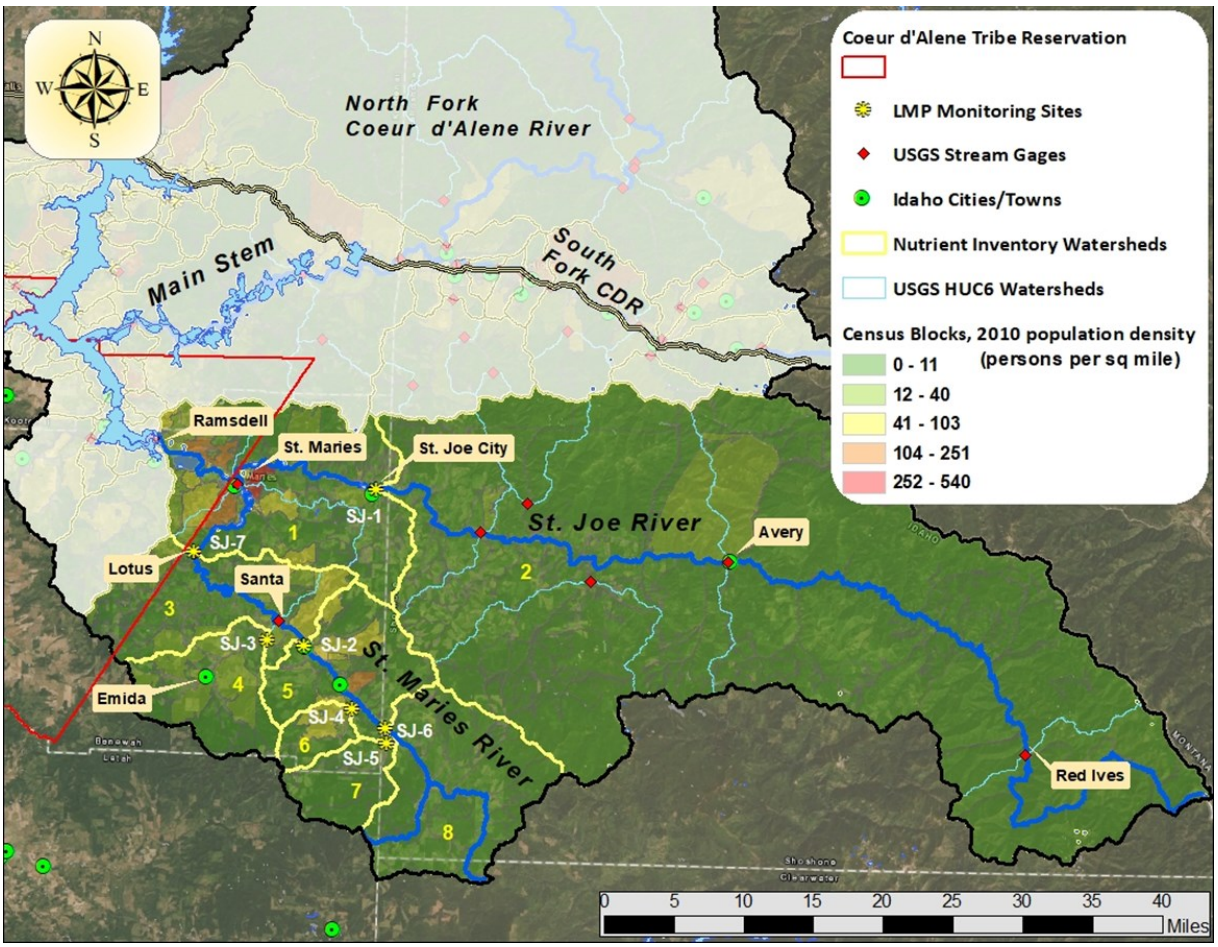


Figure 14. Map of sampling locations, watersheds where loads can be calculated, municipal areas, and population density for the St. Joe River subbasin.

Table 7. Total phosphorus load and 95% confidence intervals at sampling locations on the St. Joe River and St. Maries River (kg/yr), 2010 – 2012

River Gauge	USGS Gauge #	area drained by gauge (km2)	Average Load 2010-2012 (tons/yr)	Average Load 2010-2012 (kg/yr)	lower 95% confidence interval (kg/yr)	upper 95% confidence interval (kg/yr)
St. Joe River at Ramsdell	**12415135**	**4,480**	**107**	**96,770**	**70,000**	**130,300**
St. Joe River at St. Joe City (SJ-1)	--	2,860	65	58,870	41,720	80,590
St. Joe River at Calder	**12414500**	2,665	**--**	**--**	**--**	**--**
St. Maries River at Lotus (SJ-7)	[-12415000-] discontinued	1,125	23	21,280	17,980	24,900
Santa Ck (SJ-3)	--	180	4.0	3,620	3,030	4,280
St. Maries River at Santa	**12414900**	707	--	--	--	--
St. Maries River near Santa gauge (SJ-2)	--	675	15	13,190	12,300	14,100
Carpenter Ck (SJ-4)	--	49	1.4	1,260	910	1,610
Emerald Ck (SJ-5)	--	93	2.2	2,000	1,460	2,540
Upper St. Maries River (SJ-6)	--	330	7.3	6,640	5,680	7,610

Total phosphorus load estimates are given to the nearest 10 kg/yr.

Confidence intervals are estimated as the average of the upper and lower annual load confidence intervals.

Table 8. Incremental total phosphorus load and 95% confidence intervals between sampling locations on the St. Joe River and St. Maries River, 2010 – 2012.

Watershed (River Reach)	Watershed ID	incremental area (km2)	Average Load 2010-2012 (tons/yr)	Average Load 2010-2012 (kg/yr)	lower 95% confidence interval (kg/yr)	upper 95% confidence interval (kg/yr)
Entire St. Joe River Basin	**--**	**4,480**	**107**	**96,770**	**70,000**	**130,300**
St. Joe Confluence Region	1	495	18	16,620	10,300	24,810
St. Joe River above St. Joe City	**2**	**2,860**	**65**	**58,870**	**41,720**	**80,590**
St. Joe Maries River above Lotus	**--**	**1,125**	23	**21,280**	**17,980**	**24,900**
St. Maries River, Santa to Lotus	3	238	4.9	4,470	2,650	6,520
Santa Ck.	4	180	4.0	3,620	3,030	4,280
St. Maries River, Emerald Creek to Santa	5	202	3.6	3,290	4,250	2,340
Carpenter Ck.	6	49	1.4	1,260	910	1,610
Emerald Ck.	7	93	2.2	2,000	1,460	2,540
St. Maries River, above Emerald Creek	8	330	7.3	6,640	5,680	7,610

Total phosphorus load estimates are given to the nearest 10 kg/yr.

Confidence intervals are estimated as the average of the upper and lower annual load confidence interval

Table 9. Total phosphorus yield (kg/km2) and 95% confidence intervals for watersheds on the St. Joe River and St. Maries River, 2010 – 2012

Watershed (River Reach)	Watershed ID	incremental area (km2)	Average Yield 2010-2012 (lb/acre)	Average Yield 2010-2012 (kg/km2)	lower 95% confidence interval (kg/km2)	upper 95% confidence interval (kg/km2)
Entire St. Joe River Basin	--	**4,480**	**0.10**	**22**	**16**	**29**
St. Joe Confluence Region	1	495	0.15	34	21	50
St. Joe River above St. Joe City	**2**	**2,860**	**0.09**	**21**	**15**	**28**
St. Joe Maries River above Lotus	--	**1,125**	0.09	**19**	**16**	**22**
St. Maries River, Santa to Lotus	3	238	0.09	19	11	27
Santa Ck.	4	180	**0.09**	20	17	24
St. Maries River, Emerald Creek to Santa	5	202	0.07	16	21	12
Carpenter Ck.	6	49	0.12	26	19	33
Emerald Ck.	7	93	0.10	22	16	27
St. Maries River, above Emerald Creek	8	330	0.09	20	17	23

Total phosphorus yield estimates are given two significant figures.

Confidence intervals are estimated from the average of the upper and lower annual load confidence intervals

A map of average phosphorus loads (tons/yr) over the 2010 – 2012 time period, for the watersheds listed in Table 8 is provided in Figure 15. The highest total loads come from the large watershed of the St. Joe River upstream of St. Joe City (#2), followed by the confluence region downstream of the St. Joe City and St. Maries River at Lotus monitoring sites (#1). The sum of the smaller watersheds along the St. Maries River is approximately 23 tons/yr for 2010 – 2012, which is comparable to the 18 tons/yr that originates in the confluence region (#1).

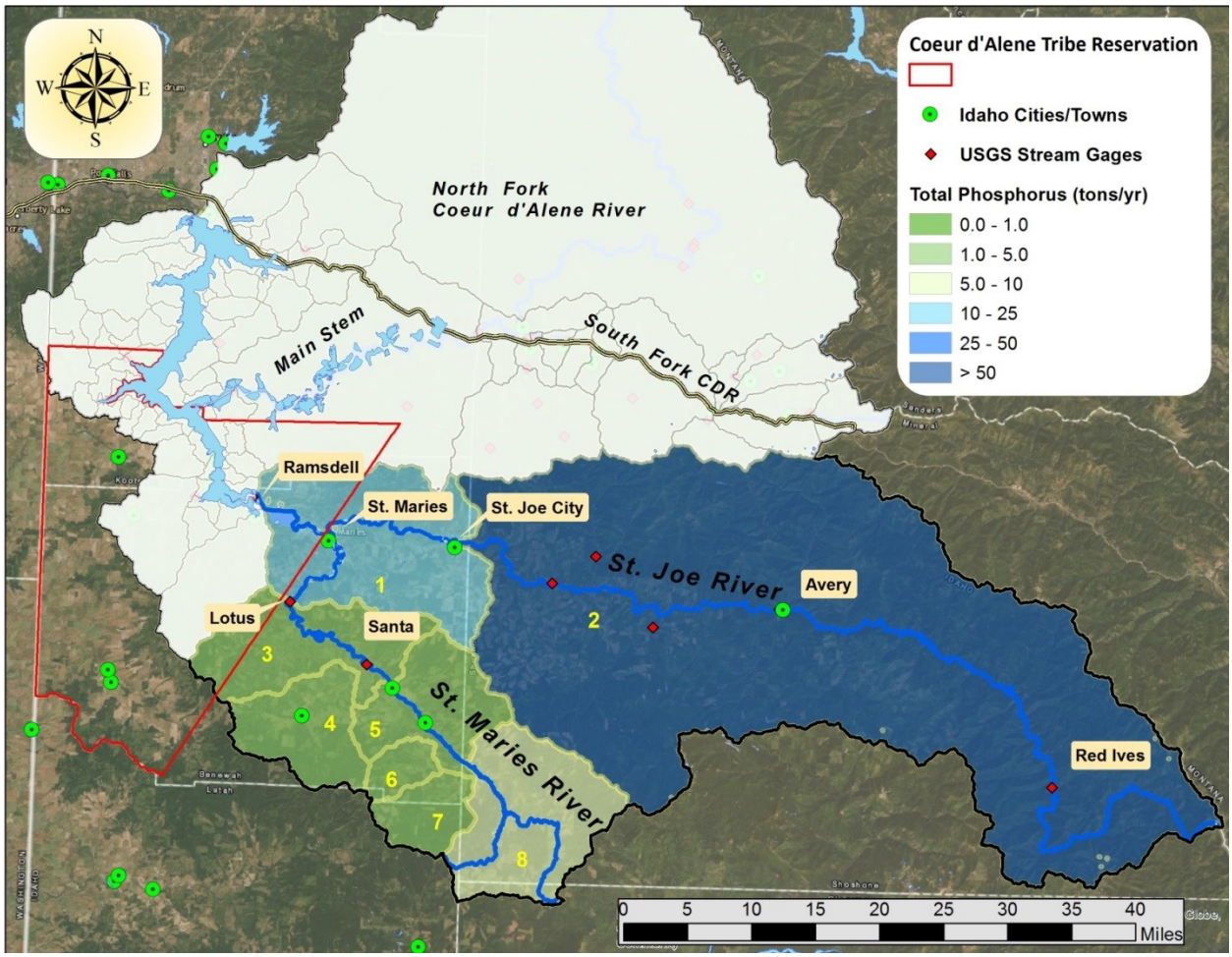


Figure 15. Map of total phosphorus loading (tons/yr) for watersheds in the St. Joe River Basin for 2010 – 2012, as defined by field sampling locations.

The phosphorous loading in Figure 15 also shows loading patterns that are biased towards larger watersheds. Larger watersheds collect more water, and thus inherently produce more load than a smaller watersheds that collect less water. This map helps identify where in the basin phosphorus originates, at the scale for which loading estimates based on field data are available. However, due to the scale bias, it does not reflect local influences on phosphorus loading and the associated phosphorus mitigation opportunities. Phosphorus yield (kg phosphorus/km2) provides a way to assess localized impacts and identify the watersheds with the best mitigation opportunities. A map of phosphorus loading per unit area, or yield, is provided in Figure 16.

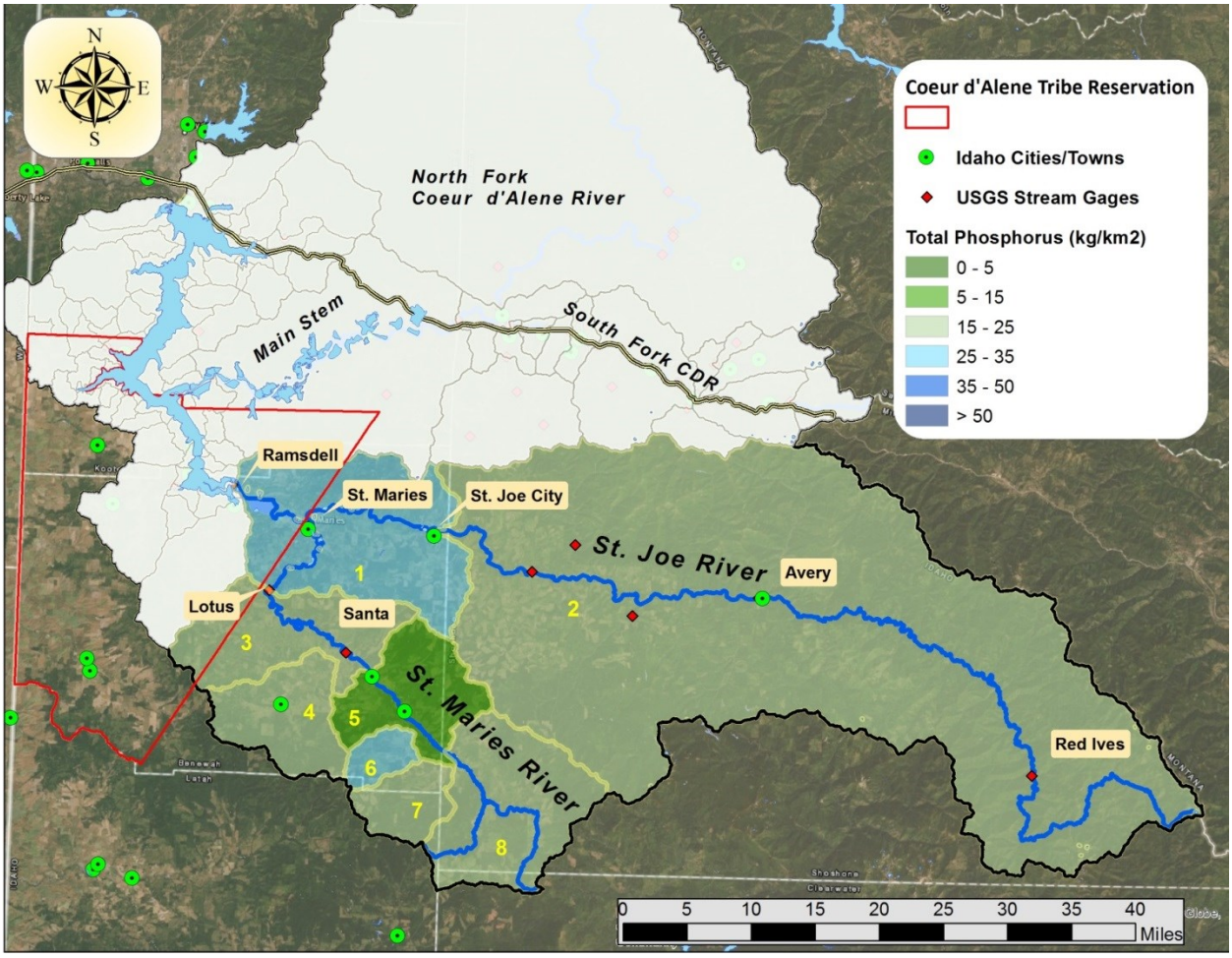


Figure 16. Map of total phosphorus yield (kg/km2) for watersheds in the St. Joe River subbasin for 2010 – 2012, as defined by monitoring locations.

The phosphorus yield map in Figure 16 displays a different set of trends than the total loading map. The yield per unit area is similar across most of the St. Joe River subbasin, averaging approximately 20 kg/km2 over the period of this study. Areas of relatively elevated area loading are observed in Carpenter Creek (#6, 26 kg/km^2) and the St. Joe River confluence region (#1, 34 kg/km2). The lowest yields are observed along the stretch of the St. Maries River extending from the confluence with Emerald Creek to the USGS gauge at Santa (#5). Note that, due to above average discharges during the period of this study; the estimated loads for WY 2010 – 2012 are likely biased high relative to the long-term record for the St. Joe River at Ramsdell (e.g., Table 1). Based on flow considerations, the long-term average phosphorus yield is likely to be lower than what is reported here for the 2010 – 2012 St. Joe study.

The overall pattern for the St. Joe River subbasin is consistent with that observed for the Coeur d'Alene River subbasin. The large swaths of forested uplands have lower phosphorus yields and the downstream regions near the river mouth have higher yields. Areas of high natural resource

development, such as Carpenter Creek (#6), can display higher phosphorus yields. The St. Joe River subbasin does not support the same level of urban and industrial development as the Coeur d'Alene River subbasin, and thus does not have comparable regions of highly focused loads. Additionally, the data coverage for the St. Joe subbasin does not isolate the more urbanized areas as is possible with the Coeur d'Alene River dataset.

The maps provided in Figure 15 and Figure 16 are based on the average load over the 2010 – 2012 time period evaluated by the St. Joe River study (see Section 4). These loads can vary greatly from year to year (e.g., Table 1; Appendix B). From 2010 – 2012, the total annual phosphorus load from the St. Joe River at Ramsdell averaged 107 tons/yr, but varied from a minimum of 35 tons/yr in WY 2010 to a maximum of 175 tons/yr in WY 2011. This is an approximate 5-fold difference between the lowest and highest flow years. The average load for 2010 – 2012 is biased upward by having more higher-flow years than lower-flow years in the period of record. In addition to this overall variance, the relative contribution from different watersheds within the St. Joe River subbasin also varies with flow. A summary of this variability is provided in Figure 17.

Only data for high-flow years (upper 25th percentile of flows) and low-flow years (lowest 25th percentile of flows) are available for upstream watersheds in the St. Joe River subbasin. Flow years within the middle two quartiles did not occur from 2010 – 2012 (e.g., Table 1). Significant differences in the relative contribution of upstream watersheds are seen between low-flow and high-flow years. These differences are outlined below.

- *Low-flow (2010)*— approximately 17 tons/yr (~50% of total St. Joe subbasin) originates upstream of St. Joe City. Approximately 1/3rd of the total originates in the St. Maries River, and the remaining ~1/5th originates in the St. Joe confluence region. Along the St. Maries River, most phosphorus originates upstream of Carpenter Ck. and downstream from Santa.
- *High flow (2011, 2012)*— approximately 90 tons / yr (~60% of total St. Joe subbasin) originates upstream of St. Joe City. Approximately 1/5th of the total originates in the St. Maries River, and the remaining ~1/5th in the St. Joe confluence region. Along the St. Maries River, Santa Creek and the watersheds between Emerald Creek and Santa yield a higher proportion of the total load.

These shifts in loading suggest that the core drivers of nutrient loading in any given year shift in response to changing hydrologic conditions.

The watersheds of the St. Joe River subbasin with the most focused phosphorus loading are the confluence region downstream from St. Joe City and the St. Maries River at Lotus (watershed #1) and Carpenter Creek (watershed #6). Higher total loads do occur in larger watersheds, but that loading is more dispersed at the scale of this analysis.

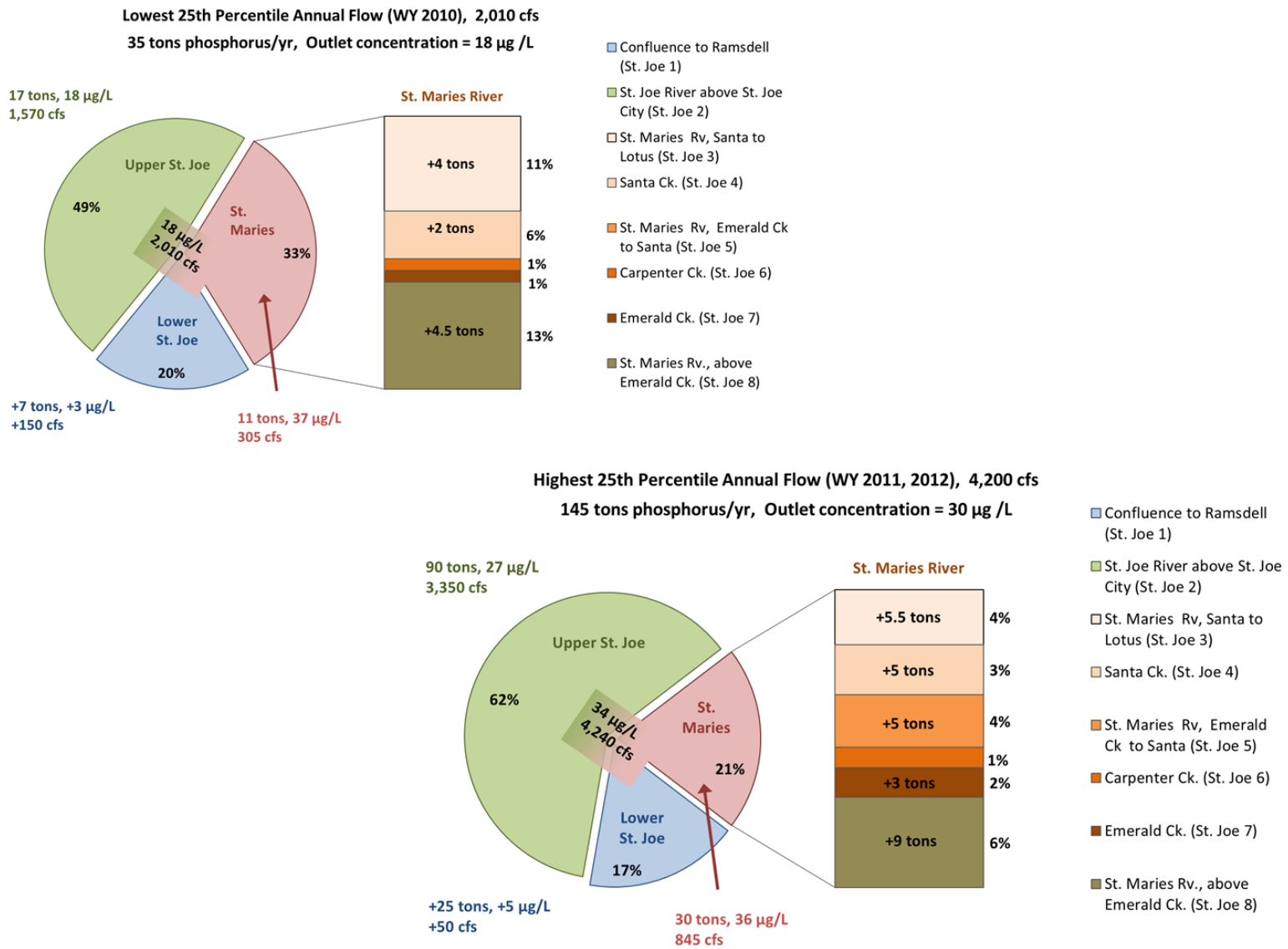


Figure 17. Phosphorus loading to the St. Joe River for low-flow and high-flow years.

2.4 Phosphorus Analysis for the Coeur d'Alene Lake Watersheds

This section provides a survey of the available phosphorus loading information for the tributaries and smaller ungauged watersheds that feed directly into Coeur d'Alene Lake, without passing through the gauging stations along Coeur d'Alene River (Harrison) and St. Joe River (Ramsdell). There is insufficient data to allow for a comprehensive and consistent phosphorus inventory for these watersheds, or for nearshore surface runoff. The available information is sufficient to provide a lower-end estimate of the potential load from the sum of all the lake tributaries.

A summary of available loading data for the Coeur d'Alene Lake tributaries is given in Figure 18 and Table 10. Watershed demarcations are based on the location of these sampling sites. A strong multi-year dataset is available to calculate current nutrient loads for Benewah Creek and Plummer Creek in Tribe Reservation lands along the southern reaches of the lake. A high quality 1-year dataset at stretches from April 2014 – April 2015 is available to calculate nutrient loads for Fernan Creek and the Fernan Lake watershed along the lake's northern pool. River discharge in the Coeur d'Alene Basin during the period of the Fernan Creek study falls within the middle 50% of the long-term record, and this dataset can be considered to be generally representative typical conditions. Historic data from 1991 – 1992 is available for Wolf Lodge Creek in the lake's northern pool; Carlin Creek and Fighting Creek in the central regions of the lake, and Plummer Creek in the southern lake. Limited, survey level nutrient loading data is available for 13 tributaries from a DEQ TMDL prioritization study conducted in 2009. This study was targeted to assess relative conditions at high flows and is not representative of the streams' overall condition. The dataset is too sparse to support reliable loading calculations. However, the data can be used to qualitatively describe the range of in-stream phosphorus concentration and daily loads that could be expected at high and low flow conditions.

Geospatial modeling studies have been conducted on regional watersheds that include the Coeur d'Alene Basin (Geoengineers, 2011; Wise & Johnson, 2011; Wise and Johnson, 2013). These studies utilize land use data from 2001 National Land Cover Database and other nutrient source information reflective of the late 1990's and early 2000's. These geospatial modeling studies use different methods and assumptions, cover different time periods, and are not directly comparable. However, these studies can provide insight into the potential influence of the Coeur d'Alene Lake tributaries and lakeshore drainages on nutrient loading to Coeur d'Alene Lake.

Trends from Field Data

Results from the available loading studies for Fernan Creek, Benewah Creek, and Plummer Creek suggest that total phosphorus loads from these watersheds range from 1,000 to 2,000 kg/yr (1-2 tons/yr), with phosphorus yields ranging from 10 – 30 kg/km^2. These three creeks drain larger watersheds with large swaths of forest land and areas greater than ~40 km^2 (15 mi^2). They can be considered to be representative of the lake's larger tributaries, but are not likely to be representative of the smaller watersheds around the lake that have different characteristics.

DEQ conducted a nutrient and sediment survey of 13 streams around the lake in 2009 (DEQ, 2010). The purpose of this study was to characterize the potential importance of nutrient and sediment loading from the smaller tributaries to Coeur d'Alene Lake and help establish nutrient and sediment management priorities. This study collected stream samples from each limb of the

hydrologic cycle, but the sampling plan was biased toward higher flows. These data were used to rank the streams according to the nutrient impact. The term of the study included base flows (minimum load) and peak flows (maximum load). The range of stream phosphorus conditions reported in this study are summarized in Table 10.

These survey data indicate that the tributaries exhibit highly variable nutrient conditions. Minimum in-stream total phosphorus concentrations ranged from 11 – 84 µg/L, and maximum in-stream concentrations ranged from 63 – 605 µg/L. Estimated daily loads ranged from a minimum of 0.1 kg/day to a maximum of 210 kg/day. The most impacted stream was Bellgrove Creek and the least impacted was Beauty Creek. Of the remaining creeks, the highest maximum phosphorus concentrations were found in Fernan Creek, Gotham Creek and Bennett Bay Creek. The Bellgrove Creek watershed was strongly impacted by an upstream elk farming operation. These data cannot be used to estimate reliable loads, but do provide an insight into the range of in-stream conditions and the potential for localized impacts.

The field data indicate that the lake's tributaries are an important source of phosphorus, but they do not provide enough data to calculate the total annual load from the tributaries. This is a critical data gap. In the absence of field data, the total contribution of the tributaries to the lake was estimated from geospatial modeling studies reported in the technical literature.

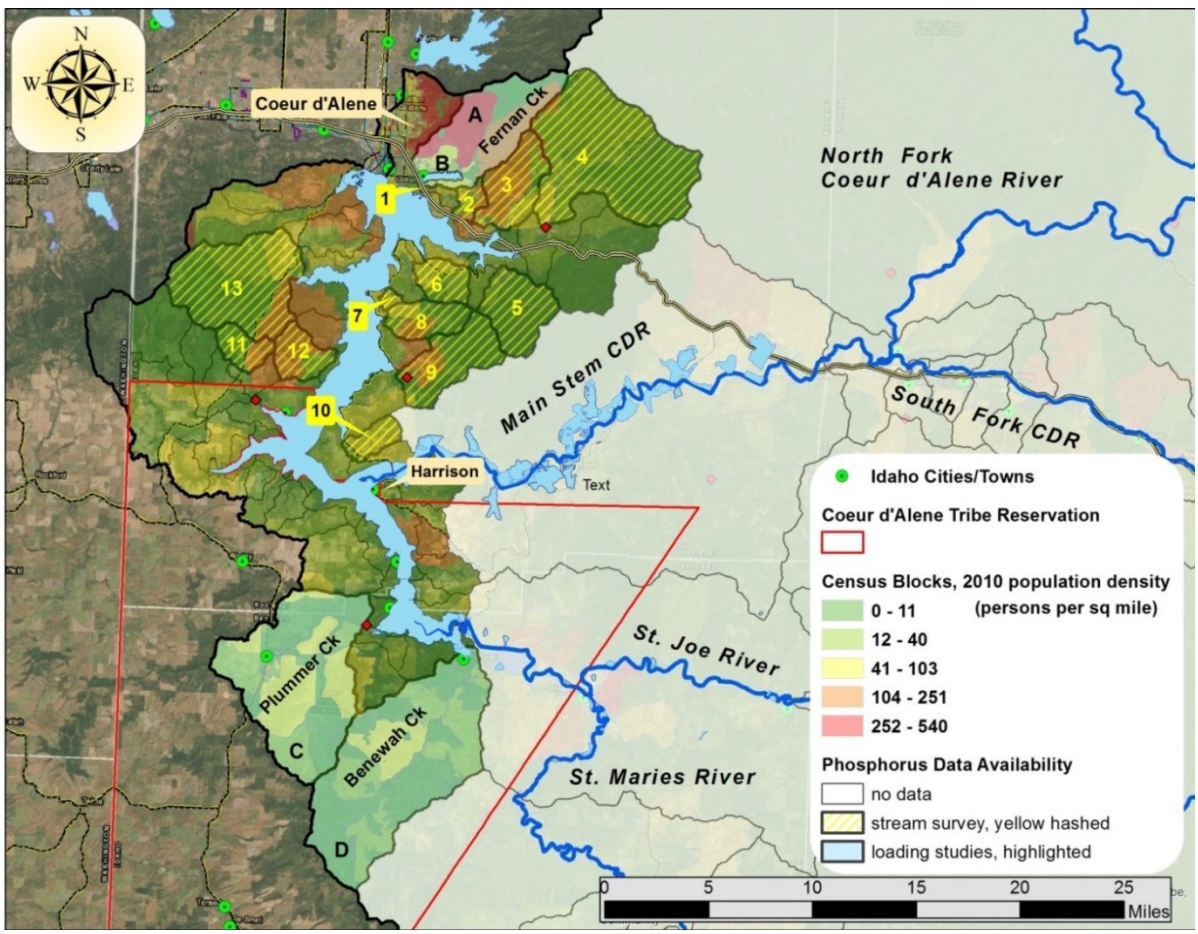


Figure 18. Map of sampling locations, watersheds with nutrient data, municipal areas, and population density for the Coeur d'Alene Lake Tributaries.

Table 10. Summary of phosphorus data for Coeur d'Alene Lake Tributaries and ungauged watersheds.

Lake Tributary or Watershed *total phosphorus data from WY 2009 - 2015*	Map ID	drainage area (km2)	number of samples	Annual Phosphorus Load (tons/yr)	Annual Phosphorus Load (kg/yr)	Annual Phosphorus Yield (kg/km2)	Lowest in-stream phosphorus concentration (µg/L)	Highest in-stream phosphorus concentration (µg/L)	Lowest observed daily load (kg/day)	Highest observed daily load (kg/day)
Fernan Creek above Fernan Lake [1]	A	39	24	1.2	1,130	29	19	690	–	–
Sum of all drainages to Fernan Lake [2]	B	49.5	67	1.3	1,160	23	19	690	–	–
Benewah Creek [3]	C	136	66	1.6	1,440	11	7	371	0.1	64
Plummer Creek [3]	D	110	40	2.3	2,090	19	18	268	0.1	140
Fernan Creek below Fernan Lake [4]	1	9.2	6	–	–	–	24	232	0.1	10
Bennett Bay Creek [4]	2	5.5	5	–	–	–	50	248	0.1	20
Blue Creek [4]	3	26	5	–	–	–	30	134	0.3	45
Wolf Lodge Creek [4]	4	102	8	–	–	–	11	110	0.2	210
Beauty Creek [4]	5	27	5	–	–	–	17	63	0.2	10
Neachen Creek [4]	6	11	5	–	–	–	50	145	0.2	15
Gotham Bay Creek [4]	7	1.9	5	–	–	–	84	250	0.0	5
Turner Creek [4]	8	16	7	–	–	–	31	139	0.1	20
Carlin Creek [4]	9	31	5	–	–	–	23	127	0.2	30
Powderhorn Creek [4]	10	8.9	5	–	–	–	79	174	0.1	20
Bellgrove Creek [4]	11	11	5	–	–	–	84	605	0.1	30
Stinson Creek [4]	12	14	5	–	–	–	47	145	0.2	10
Mica Creek [4]	13	64	5	–	–	–	33	147	0.4	70

1. Load estimate for April 2014 – April 2015, from Lacroix (2015). Data are for the MW site. Daily load calculations not provided.
2. Sum of all inflows to Fernan Lake from LaCroix (2015). Given values exclude direct atmospheric deposition to Fernan Lake.
3. Load estimates for WY 2010 – 2014, from Coeur d'Alene Tribe.
4. Stream Survey data for WY 2009, from DEQ (2009).

Geospatial Model Predictions of Phosphorus Loading

Model predictions for phosphorus loading for the Coeur d'Alene Basin are available from three sources, (i) USGS field and modeling studies of the Coeur d'Alene Basin, (ii) the Spokane River watershed non-point source phosphorus reduction plan, and (iii) USGS studies to model nutrient loading in the Pacific Northwest with the SPARROW model. Results from these studies provide the basis for the estimate of a minimum of 20 ± 8 tons of total phosphorus per year coming from the tributaries and lake facing (lakeshore) drainages that drain into Coeur d'Alene Lake.

Woods and Beckwith (1997) measured loading in four tributaries to the lake (Wolf Lodge Ck, Carlin Ck, Fighting Ck, Plummer Ck) for calendar years 1991 – 1992, and then extrapolated the yields measured for those tributaries to ungauged inflows based on similarities in hydrology, land cover, and land use. Wood and Beckwith (2008) provided updated estimates by developing a relationship between the 1991 – 1992 estimates and the annual flow in the closest gauged tributary for water years 2004 – 2006. Their estimated annual average loads from the sum of all tributaries ranged from 7,960 kg/yr (WY 2004) to 11,500 kg/yr (WY 2006). The 3-year average from WY 2004 – 2006 was 9,470 kg/yr (10 tons/yr). The 95% confidence intervals around that three year average are 7,500 – 11,500 kg/yr (8.3 – 13 tons/yr). This estimate of approximately 10 tons/year is derived from 1990's land use data normalized for hydrologic conditions, and represents a lower boundary for the current total phosphorus load from the lake tributaries.

A 2011 technical report to the Washington State Department of Ecology (Geoengineers, 2011) estimated nutrient loading to Coeur d'Alene Lake from the tributaries and small watersheds as part of a study of nutrient loading for the overall Spokane River watershed. This study utilized geospatial modeling based on local water quality data and land-use coefficients derived from 2001 satellite data (NLCD, 2001) to derive a nutrient budget. This study did not report a load for the Coeur d'Alene Lake tributaries. However, if their reported land cover coefficients for phosphorus yield are multiplied by the area of each land use type in the Coeur d'Alene Lake tributaries, then the resultant load is approximately 12 tons per year (10,700 kg/yr).

Wise and Johnson (2013) conducted a series of modeling studies with the USGS SPARROW model to characterize nutrient loading in the Pacific Northwest. Their studies focused on the overall Pacific Northwest and were calibrated and validated at that scale. Basin-specific results for the Coeur d'Alene Basin can be used if data limitations and scaling considerations are taken into account. Their study used satellite land use data from NLCD 2001, and estimates of agricultural inputs (manure and fertilizer), point source discharges, and natural phosphorus sources. They also factored in a number of other geologic, hydrologic, and human factors. Their models can assess the factors that influence nutrient loading across the region, but the published results were conducted at too large a scale to effectively capture localized effects in small watersheds (e.g., housing, storm water outfalls, urban development). Even so, the model can provide a preliminary estimate of phosphorus loading for the sum of all ungauged tributaries.

The load from the tributaries was calculated using published results from the SPARROW modeling studies of Wise and Johnson (2013) in three ways. These are (i) a mass balance between the major rivers, (ii) the sum of interconnected streams in the model (NHD24k national hydrography dataset), and (iii) extrapolating results from representative watersheds to the overall region. The SPARROW model is most accurate for watersheds where an interconnected stream

network connects to a lake or river. It is less reliable for lakeshore drainages where there is not an interconnected stream network. For Coeur d'Alene Lake, the SPARROW model predictions are best for the watersheds shown in Figure 19. These watershed boundaries are based on the NHD24k stream data layer used in SPARROW; and merged to describe either the entire watershed at the mouth to a larger water body or a connected set of lakeshore drainages. The green watersheds have interconnected stream networks that drain to the lake. The blue regions are lakeshore drainages. The grey regions are watersheds where the stream does not have a surface connection a larger waterbody. All but one of the shown watersheds drain into Coeur d'Alene Lake. Watershed S2 drains to Fernan Lake, which connects to Coeur d'Alene Lake via watershed S1. SPARROW phosphorus loads for the numbered watersheds are given in Table 11.

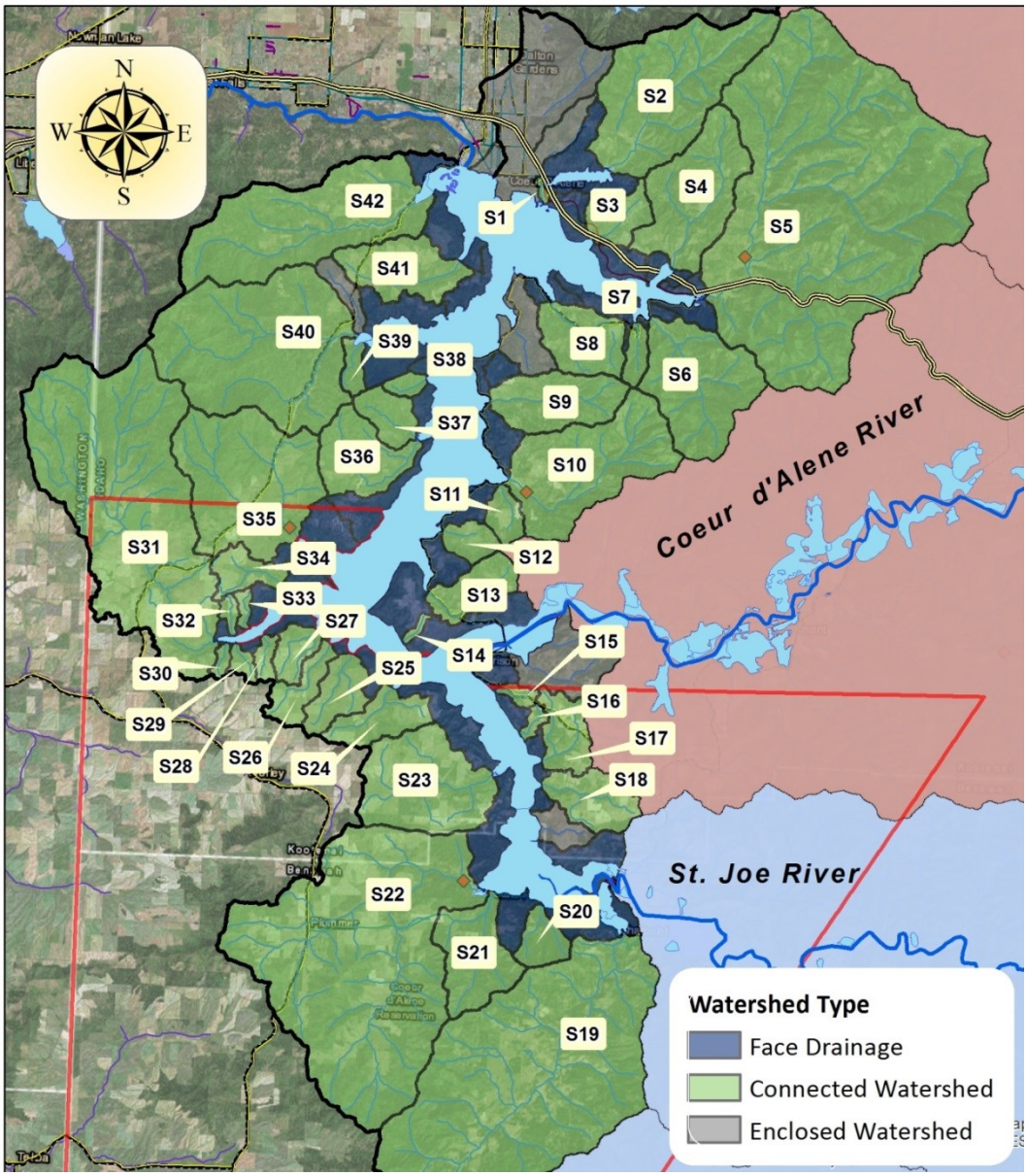


Figure 19. Map of tributary Coeur d'Alene Lake tributary phosphorus load predictions based on the USGS SPARROW model for the Pacific Northwest.

Table 11. SPARROW model predictions for Coeur d'Alene Lake Tributaries in watersheds with interconnected stream networks.

Watershed	Map ID	Drainage Area (km2)	SPARROW Reach Code	SPARROW TP Load (kg/yr)	SPARROW Yield (kg/km2)
Fernan Creek watershed	S1	55.1	17010303000109	1,350	25
Fernan Creek	S2	42.3	17010303000110	590	14
Bennett Bay Creek	S3	7.4	17010303000269	100	13
Blue Creek	S4	26.7	17010303000273	360	13
Wolf Lodge Creek	S5	162.4	17010303000090	2,690	17
Beauty Creek	S6	28.4	17010303000084	470	16
Beauty Bay - small stream	S7	3.08	17010303000165	40	14
Neachen Creek	S8	12.8	17010303000160	180	14
Turner Creek	S9	16.2	17010303000130	260	16
Carlin Creek	S10	34.7	17010303000146	570	16
Carlin Bay - south side	S11	4.07	17010303000181	70	16
Half Round Bay watershed	S12	4.46	17010303000183	60	13
Powderhorn Creek	S13	8.94	17010303000197	110	13
Harlow Point - southwest side	S14	0.82	17010303000368	10	13
South of Harrison - small stream	S15	1.60	17010303000375	20	15
North of Shingle Bay - small stream	S16	1.41	17010303000379	20	16
Shingle Bay watershed	S17	8.66	17010303000386	160	19
O'Gara Bay watershed	S18	10.6	17010303000241	200	19
Benewah Creek	S19	137.8	17010304000020	2,350	17
East of Rocky Point - small stream	S20	5.57	17010304000711	70	12
PeeDee Creek	S21	16.4	17010304000017	230	14
Plummer Creek	S22	114.2	17010304000005	2,330	20
Carey Bay watershed	S23	27.7	17010303000235	550	20
Cottonwood Creek	S24	9.31	17010303000216	130	14
Aberdeen Lodge Bay watershed	S25	7.99	17010303000208	100	13
Cave Bay watershed	S26	6.43	17010303000213	130	20
16-to-1 Bay watershed	S27	4.86	17010303000201	100	21
Windy Bay - south side - east	S28	2.09	17010303000209	40	21
Windy Bay - south side - center	S29	1.79	17010303000212	40	21
Windy Bay - south side - west	S30	1.25	17010303000210	30	21
Lake Creek	S31	93.4	17010303000030	1,870	20
Windy Bay - north side - west	S32	1.40	17010303000365	20	18
Windy Bay - north side - east	S33	1.29	17010303000364	30	21
Sun Up Bay watershed	S34	6.02	17010303000359	120	21
Fighting Creek	S35	41.7	17010303000023	670	16
Stinson Creek	S36	14.4	17010303000176	190	13
Lyle Creek	S37	6.34	17010303000313	80	13
Deldardo Creek	S38	1.99	17010303000426	20	12
Mica Bay - south side - west	S39	2.82	17010303000425	40	14
Mica Creek	S40	60.7	17010303000014	900	15
Kid Creek	S34	14.9	17010303000013	230	16
Cougar Creek	S35	45.6	17010303000009	620	14

The simplest calculation is to conduct a mass balance between the inputs from the Coeur d'Alene River and the St. Joe River; and the output to the Spokane River. This mass balance will capture the contributions from all watersheds and lakeshore drainages. SPARROW does not account for in-lake processes such as sedimentation, and thus this mass balance approximates the combined contribution from of the lakeshore drainages and ungauged tributaries. Using SPARROW model predictions as reported by Wise and Johnson (2013), this calculation is as follows.

- *Coeur d'Alene River at Harrison*, input to CDA Lake = 51,730 kg/yr (57 tons/yr)
- *St. Joe River at Ramsdell*, input to CDA Lake = 53,790 kg/yr (59 tons/yr)
- *Spokane River at Lake outlet*, output to Spokane River = 124,830 kg/yr (137 tons/yr)
- *Difference,* 19,310 kg/yr (21 tons/yr)

This mass balance yields a total input from the ungauged tributaries and lakeshore drainages along the lake shoreline of 19,310 kg/yr (21 tons/yr, 16 kg/km^2). If the loads from only the interconnected stream networks (green watersheds) in Figure 19 are summed together, then the total phosphorus load from this subset of streams is 17,590 kg/yr (19 tons/yr, 15 kg/km^2). At one significant figure, both of these methods yield a total of 20 tons/yr.

If only interconnected stream networks are considered (e.g. Figure 19, Table 11), then the phosphorus yields for the lake tributaries would be expected to range from 12 – 25 kg/km^2, with a median value of 16 kg/km^2. The watershed downstream from Fernan Lake (S1) is an outlier and not representative of the other tributaries. S1's behavior is influenced by complex nutrient cycling within Fernan Lake and stormwater inflows from French Gulch (La Croix, 2015; DEQ, 2010). However, the Fernan Creek watershed upstream of Fernan Lake (S2) is comparable to the other watersheds. Excluding S1, phosphorus yields for the CDA Lake watersheds range from 12 – 21 kg/km^2, with a median of 16 kg/km^2. If this range of potential yields is extrapolated to the entire 1,211 km^2 of the Coeur d'Alene Lake tributaries, then the resultant load ranges from 14,900 ~ 25,800 kg/yr (16 – 28 tons/yr) with a median of ~18,900 kg/yr (21 tons/yr).

Analysis of Geospatial Model Predictions

At one significant figure, all three methods for using the SPARROW predictions of Wise and Johnson (2013) to estimate the combined load from all the smaller, ungauged watersheds agree to an average load of 20 tons/yr. As with estimates from field data, these model predictions are also subject to considerable uncertainty. The model uncertainty can be calculated at the Pacific Northwest Region scale to which it was calibrated. However, the published model results were not calibrated and validated at the smaller scale of the Coeur d'Alene Lake tributaries, and thus the accuracy and precision of these estimates is unknown for this application of the model results. Even so, two general evaluations can be made.

1. Load estimates based on field data for the Coeur d'Alene and St. Joe Rivers have 95% confidence intervals of roughly ± 30 – 40% (e.g. Table 2). Locally, the SPARROW model predictions were calibrated to these river loads. The model is not likely to be accurate to better than this. At this precision, SPARROW would predict 20 ± 8 tons/yr.
2. The SPARROW model predicts ~60 tons/yr each for the Coeur d'Alene and St. Joe Rivers, while the field data from 2004 – 2013 estimate 75 ~ 80 tons/yr each (Table 2). The model under-predicts the observed loads from these rivers by 25 ~ 35%.

Given all of these considerations and the other published studies, it is reasonable to estimate that, as of 2001, the sum of the tributaries generated approximately 20 ± 8 tons/yr. The range of ± 8 tons/yr is equivalent to ± 40% (comparison #1), and is consistent with the range of phosphorus yields from the individual watersheds shown in Table 11. The lower end of this range (12 tons/yr) is consistent with the results predicted by Woods and Beckwith (2008) and Geoengineers (2011). The upper end of this range (28 tons/yr) is consistent with the value that would be calculated if the SPARROW model predictions were normalized to the long-term loads measured for the Coeur d'Alene and St. Joe Rivers (comparison #2).

These predictions of the phosphorus load from the lake's ungauged tributaries and lakeshore drainages are likely to be a minimum value. The SPARROW model is based on land use data representative of 2002. Kootenai County and the Coeur d'Alene Lake region have experienced a high level of growth and development since then. Land use practices have changed. The area now has more homes, roads, and people. Also, the SPARROW model predictions of Wise and Johnson (2013) did not account for the impacts of urban development because their prior study (Wise and Johnson, 2011) indicated that urban development was not a statistically significant source at the scale of the Pacific Northwest region. Urban development had localized impacts, but only contributed a very small percentage of the overall influences across the entire Pacific Northwest. Because of this, they did not include these factors in their follow-up study. Development pressure is known to increase phosphorus loading at a smaller scale than was analyzed by Wise and Johnson (2013), and thus the model is likely to under-predict phosphorus loading from watersheds that have experienced significant development pressure. Additional data is needed to address this information gap.

2.5 Atmospheric Deposition, Ground Water, and Point Sources

Phosphorus in the Coeur d'Alene Basin comes from two general types of sources, point sources that represent discrete discharges into surface waters and non-point sources that represent more general processes such as runoff, erosion, and ground water exchange. Point sources include municipal wastewater treatment plants, industrial and commercial discharges, storm water discharges, construction sites, and various other permitted discharges. Of these permitted discharges, consistent phosphorus data is currently only available for municipal wastewater treatment plants (WWTP). WWTP's are estimated to currently contribute approximately 11 tons phosphorus per year, comprising less than 6% of the total estimated load into the basin's watersheds. The contribution from the other types of permitted discharges is unknown. Even considering the potential contribution from the permitted discharges without phosphorus information, the majority of the phosphorus load most likely originates from non-point sources. Even so, these permitted discharges may provide some of the most cost effective phosphorus management options. The basin's non-point sources include atmospheric deposition, ground water exchange, stream bed load, stream bank erosion, and surface runoff.

This analysis considers point sources to be permitted discharges that are currently licensed by either the U.S. EPA National Pollutant Discharge Elimination System (NPDES) or the Idaho Pollutant Discharge Elimination System (IPDES). It is also acknowledged that the basin contains sources that can be termed "dense nutrient source areas" that are non-point sources but originate in discrete areas. These nutrient source areas would include groundwater from non-

municipal wastewater systems, as well as areas where there may be a high density of individual septic systems. Known areas of ground water discharges such as the gypsum waste at the Bunker Hill facility would also fall into this category. These "dense nutrient source areas" are discussed in this section even though they are not true point sources.

Permitted Discharges

IPDES and NPDES issue two categories of discharge permits, individual permits that govern direct waste discharges and general permits for systems that collect surface runoff into a point discharge. Individual permits are issued for industrial waste facilities and municipal waste facilities. General permits encompass Construction General Permits (CGP) for construction activities, MS4 permits for municipal storm water systems, and Multi-Sector General Permits (MSGP) for non-municipal storm water and surface runoff. These permitted discharges likely comprise a relatively small percentage of the basin's total load, but they also may provide some of the most cost effective nutrient management options. For example, Woods and Beckwith (1997) evaluated the effectiveness of various nutrient management strategies for the Coeur d'Alene Basin and concluded that eliminating wastewater discharges would be one of the more effective strategies. Thus, quantification of the contribution of these permitted discharges to phosphorus loading can facilitate phosphorus management activities.

Some phosphorus data exists for municipal wastewater treatment plants (WWTPs). No phosphorus data exists for General Permits and Individual Permits for industrial sites, other than the Enida WWTP and the storm water outfalls for the City of Coeur d'Alene. There are many active permits within the basin. A summary of the number of active permits in the basin is provided below. A list of permit ID's, operator, discharge location, and receiving waterbody is provided in Appendix F. Municipal WWTP's are discussed in the next section.

- *Muncipal WWTP*. 9 permits, this includes the Enida WWTP that operates under an industrial permit.
- *Individual Industrial Permit*. 8 permits, excludes the Bunker Hill Central Treatment Plant. Most of these are mine discharges along the South Fork of the Coeur d'Alene River.
- *Construction General Permits*. 35 permits
- *Multi-Sector General Permits*: 25 permits
- *MS4 Storm water Permits*: 4 permits

A limited set of survey-level phosphorus data is collected under the City of Coeur d'Alene's MS4 Storm water permit. The city has storm water outfalls that drain into the lake and its tributaries. A map of these is provided in Figure 20. Phosphorus data is collected at two outfall locations (Bellerive, 19th Street). Total phosphorus concentrations from data collected between 2013 and 2016 ranged from 80 – 1,100 µg/L at these monitoring sites. Nutrient data is not available for the additional storm water systems that serve other areas of the basin.

The Bunker Hill Central Treatment Plant is managed by EPA under Superfund authority and is not permitted by the NPDES or IPDES system. This facility is currently being upgraded to process both mine discharges and groundwater pumped from the Central Impoundment Area. This groundwater contains phosphorus waste from a historic fertilizer facility. The current influence of this phosphorus source is discussed in Section 2.5.3.

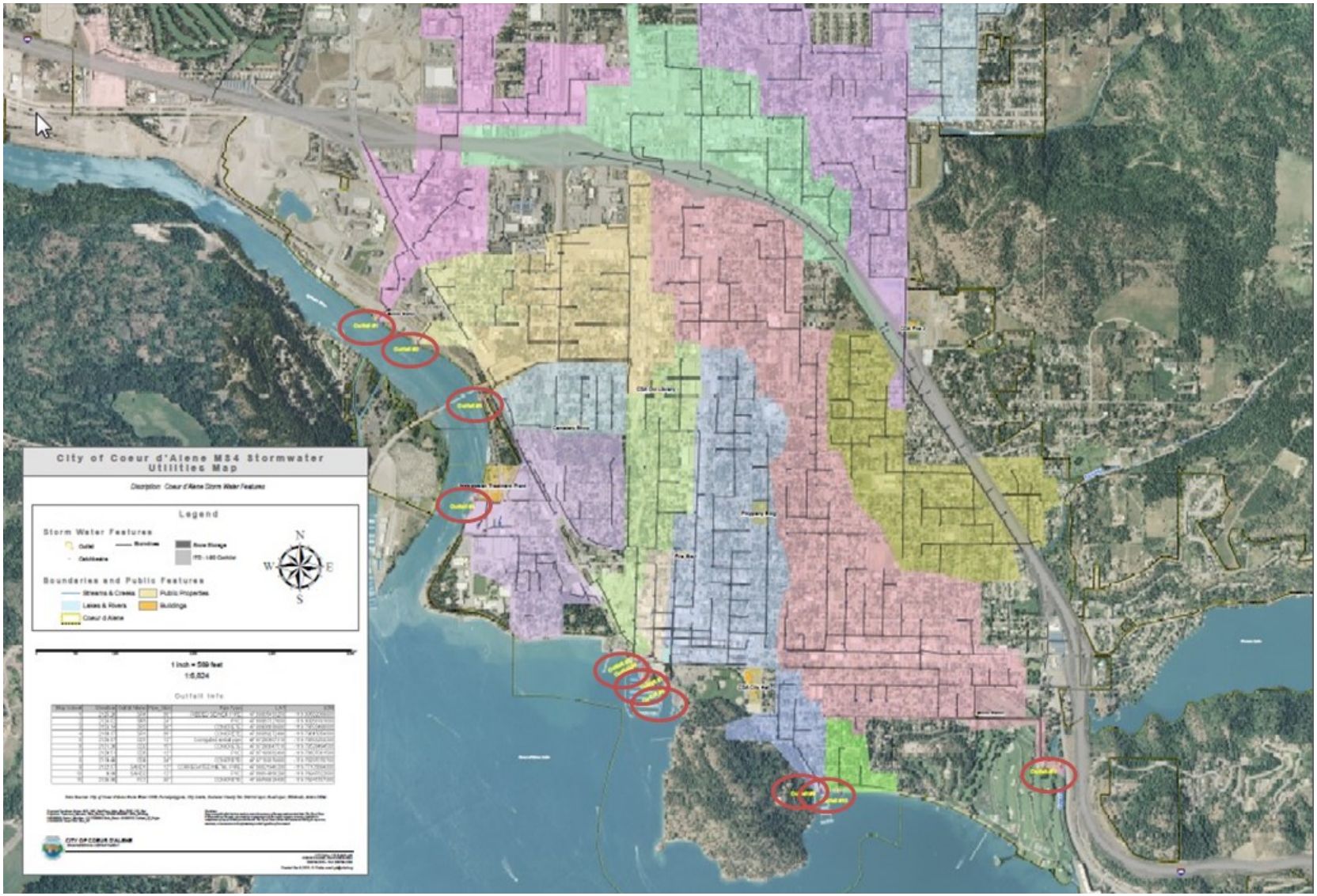


Figure 20. Map of storm water drainage for the City of Coeur d'Alene.

2.5.1 Municipal Wastewater Treatment Plants

A limited phosphorus dataset is available for municipal wastewater treatment plants. A summary of all municipal wastewater treatment facilities in the Coeur d'Alene Basin is provided in Table 12. For these sites, estimates are given for the multi-year average total phosphorus concentrations and total annual load as well as an estimated range of average monthly concentration and load and the subbasin they discharge into (i.e., Coeur d'Alene Lake, Coeur d'Alene River, St. Joe River). Direct measurements of phosphorus load are available for some sites, but not all. All load calculations for municipal WWTP's are based on data for effluent flow from the treatment plant (mgal/day) and total phosphorus in the effluent (mg/L) as reported in the EPA ICIS and ECHO databases. In cases where direct measurements of phosphorus concentration in the effluent are not available, an estimate is made based on total discharge (MGD) and an assumed average total phosphorus concentration of 2 mg/L. This assumed value is the average over all WWTP's within the Coeur d'Alene Basin where phosphorus data are available and rounded to one significant figure.

The estimated total discharge for municipal wastewater treatment plants is an average of 9 tons phosphorus per year basin-wide (all sources), with less than 0.1 tons total phosphorus per year contributing to the Coeur d'Alene Lake watersheds downstream from the monitoring gauges on the Coeur d'Alene and St. Joe Rivers (City of Plummer, City of Harrison). Woods and Beckwith (1997) estimated a total of 8.6 tons phosphorus per year from municipal wastewater treatment plans basin-wide, with 0.5 tons per year discharging into the Coeur d'Alene Lake watersheds downstream from the river monitoring gauges. Relative to 1991 – 1992, there has been only a minimal increase in basin-wide phosphorus discharges from municipal WWTP's. Discharge estimates provided in Table 12 show that increased discharges at some facilities have been offset by reduced discharges at other facilities. The largest WWTP discharges are at the Page facility along the Coeur d'Alene River and the St. Maries facility along the St. Joe River. Note that monthly phosphorus concentration, effluent discharge, and phosphorus load can vary by a factor of 10 – 100 depending on local conditions and demand; and a number of facilities do not have records of monthly data for the time period covered by this study.

All calculations were based on data reported to the EPA ICIS database as of 2018. The database has significant gaps. Monthly phosphorus data is only available for a few facilities. In some cases, no phosphorus data is available and an average basin-wide effluent phosphorus concentration had to be assumed. These estimates are only approximate long-term averages and actual discharges may vary significantly from year to year.

Table 12. Permitted Municipal Wastewater Treatment Plants (WWTP) in the Coeur d'Alene Basin.

Name	NPDES SYS ID #	Discharge Location	County	Average load 1991-1992 (kg/yr) [1]	Average load 2009-2017 (kg/yr) [2]	Average annual discharge (MGD) [2]	Average total phosphorus conc (mg/L) [2]	Range of total phosphorus concentration (mg/L) [2]	Range of monthly discharge (MGD) [2]	Range of annual load (kg/yr) [2]
Coeur d'Alene Lake										
Harrison WWTP	ID0021997	Anderson Slough	Kootenai	120	36	0.01	2	--	0 to 0.25	28 to 46
Plummer WWTP [3]	ID0022781	Plummer Ck.	Kootenai	290	25	0.23	0.07	0.0005 to 0.4	0.08 to 1.4	15 to 37
Coeur d'Alene River										
Mullan WWTP	ID0021296	SF CDR	Shoshone	310	260	0.10	1.8	0.3 to 3.7	0.04 to 290	190 to 360
Page WWTP	ID0021300	SF CDR	Shoshone	5,400	5,400	2.0	1.9	0.6 to 3.7	1.1 to 6.9	4,000 to 6,700
Smelterville WWTP	ID0020117	SF CDR	Shoshone	225	140	0.04	2.5	0.13 to 5.7	0.0075 to 0.26	60 to 260
St. Joe River										
Clarkia WWTP [4, 5]	ID0025971	St. Maries River	Shoshone	20	34	0.01	2	--	0 to 0.04	16 to 56
Santa-Fernwood WWTP [4]	ID0022845	St. Maries River	Benewah	60	190	0.07	2	--	0 to 0.2	90 to 300
St. Maries WWTP	ID0022799	St. Joe River	Benewah	1,400	2,200	1.3	1.3	0 to 3.9	0.2 to 3.9	1,700 to 2,900
Emida WWTP	ID0028487	Santa Ck.	Benewah	no data	no data	no data	no data	no data	no data	no data
TOTAL (kg/yr)	--	--	--	*7,800*	*8,300*	--	--	--	--	--
TOTAL (tons/yr)	--	--	--	*8.6*	*9.0*	--	--	--	--	--

1. From Woods and Beckwith (1997).
2. From average over all years within the period of record to 2 significant figures, unless otherwise noted.
3. Plummer data are for 2014 - 2017, after plant upgrades and process testing were completed.
4. Assumed total phosphorus concentration, based on average from other sites to 1 significant figure.
5. Average monthly data not available. Estimate based on monthly maximum flow.

2.5.2 Dense Nutrient Source Areas

Dense nutrient source areas are non-point source releases that come from a relatively small area but do not discharge into a discrete "point" (e.g. discharge pipe) or require an NPDES or IPDES permit. These can include large nearshore septic systems, community wastewater systems or other landscape features that release phosphorus into the environment from a focused region. These sources are discussed in the following subsections. Note that this enumeration is partial and primarily focuses on the Coeur d'Alene Lake ungauged tributaries and nearshore regions. The ungauged tributaries and nearshore regions of Coeur d'Alene Lake are experiencing rapid development. Nutrient releases from these areas are not captured by the monitoring stations on the Coeur d'Alene and St. Joe Rivers. Potential phosphorus release from ground water associated with the gypsum waste at the Bunker Hill Central Impoundment Area and associated facilities is also discussed. There is insufficient information to quantify the overall contribution of these sources and only a rough, order-of-magnitude approximation can be made at this time. The available information suggests that these sources may combine to produce an annual phosphorus load on the order of 5 – 20 tons/year. This estimate includes estimated phosphorus loads associated with groundwater flow through the Bunker Hill Central Impoundment Area.

Non-Municipal Wastewater Systems along Coeur d'Alene Lake

Non-municipal wastewater systems typically process much smaller volumes of wastewater than municipal systems. They gather discharges from multiple residences or places of business within a small community and jointly manage the wastewater. The wastewater can be put into a lagoon, a drain field, a large scale soil absorption system, or a land application system. Waste can also be pre-treated before release. Each of these types of systems has different performance parameters based on their size, age, and specific operations; and thus it is difficult to get a solid estimate for the combined contributions from these systems. However, a rough estimate can be derived by applying DEQ guidelines that assume an average phosphorus concentration in untreated wastewater of 9 mg/L, 90% soil retention factor, and an average effluent of 250 gal/day (per full time equivalent resident, assuming a 3-bedroom house). These values are comparable to assumptions made by Woods and Beckwith (1997) for their calculation of nearshore wastewater systems. An estimated potential contribution for each community wastewater system can then be generated from their estimated discharge maximum capacity design, and the type of waste management system they use.

A list of community wastewater systems that may release nutrients into the ungauged tributaries and nearshore regions that drain into Coeur d'Alene Lake is provided in Table 13. This list also gives rough estimates of potential phosphorus load based on the above assumptions and data from a survey conducted in CY 2008 (Glen Rothrock, unpublished data, March 2008), and updated with new information for this report. Less than 0.1 tons total phosphorus per year are estimated to currently enter Coeur d'Alene Lake from these community wastewater systems.

Additional supporting data for these calculations is provided in Appendix C.

Table 13. Non-discharging wastewater systems along Coeur d'Alene Lake.

Name	500 ft of Shore?	Location	County	Volume (MG/yr) [1]	Potential phosphorus Load (kg/yr) [2]	Type of Treatment [3]
Coeur d'Alene Lake						
Arrow Point Community Association and Gozzer Ranch Golf and Lake Club	No	Arrow Point, Gozzer Ranch	Kootenai	3.3	negligible [5]	RW with tertiary pre-treatment
Kidd Isl. Bay Sewer District and Harbor View Estates [4]	Yes	Kidd Isl. Bay	Kootenai	12.5	negligible [5]	RW
Black Rock Development [4]	No	Black Rock Bay	Kootenai	30	negligible [5]	RW
Roth's Black Rock [4]	Yes	Black Rock Bay	Kootenai	< 1.0	negligible [5]	RW
Delcardo Bay Property Owners	Yes	Delcardo Bay	Kootenai	0.06	0.2	LSAS
Camp Easton (Boy Scouts)	Yes	Gotham Bay	Kootenai	2.4	10	LSAS
Camp Lutherhaven	Yes	Mica, Everwell Bay	Kootenai	0.5	1.7	LSAS
Driftwood Point Co-op	Yes	Driftwood Point	Kootenai	0.9	3.1	LSAS
Kildare Effluent System [4]	Yes	Bennett Bay	Kootenai	< 1.0	< 3.5	Community Drainfield
Rockford Bay Store/Resteraunt, Boat Pump-out, and Dock [4]	Yes	Rockford Bay	Kootenai	< 1.0	< 3.5	Combo Septic Tanks and Drainfields
Rockford Bay, Summer Homes, Rockford Terrace Club [4]	Yes	Rockford Bay	Kootenai	< 1.0	< 3.5	Community Drainfield
Carlin Bay Sewer Association [4]	Yes	Carlin Bay	Kootenai	20	negligible [5]	RW
Heyburn State Park	Yes	Chatcolet Lake	Tribe Reservation	5.2	negligible [5]	RW
Sun Meadow Resort	No	near Carey Bay	Tribe Reservation	0.74	negligible [5]	RW
Pointe at Brown's Bay [4]	Yes	Brown's Bay	Tribe Reservation	2.3	10	LSAS
Cave Bay Community Sewer	Yes	Cave Bay	Tribe Reservation	10	negligible [5]	RW
Wildwood	Yes	near Chippy Pt.	Tribe Reservation	0.05	negligible [5]	LSAS/RW
TOTAL	--	--	--	*45*	*40*	--
TOTAL (tons/yr)	--	--	--	--	*< 0.1*	--

1. Estimated average annual input to wastewater system in million gallons per year.
2. Assume 9 mg total phosphorus/L, 250 gal/day per connection, 90% soil retention
3. LSAS = Large Soil Absorption System. RW = Recycled Wastewater via land application system
4. Based on maximum design capacity rather than annual discharge.
5. Land application for crop irrigation, nutrient addition not to exceed plant uptake during the growing season. Wastewater is stored during the remainder of the year.

Wastewater from septic systems along Coeur d'Alene Lake

Wastewater from septic systems is an established water quality issue for rural and semi-rural areas in the Inland Northwest (Idaho, Montana, Oregon, Washington), where rapid growth is occurring in areas with little water infrastructure (Tri-State Water Council, 2005). Kootenai County, Idaho, which hosts the majority of the shoreline of Coeur d'Alene Lake, is one of the fastest growing regions in the Inland Northwest. The population of Kootenai County has approximately doubled since the time of the 1991 – 1992 study of Woods and Beckwith (1997), growing from 69,795 in 1990 to 138,494 in 2010. Most growth has occurred in the cities of Coeur d'Alene, Hayden, and Post Falls that are served by municipal wastewater systems that discharge into the Spokane River downstream from the Coeur d'Alene Lake. However, the population of the unincorporated areas of Kootenai County and the Coeur d'Alene Lake watersheds has also grown significantly, with over ~12,000 acres of private waterfront property.

Much of the growth in the unincorporated areas of Kootenai County has occurred away from the nearshore region of Coeur d'Alene Lake. However, the lakeshore and lake front regions have experienced steady development pressure and the total number of septic systems has increased significantly. A prior study of nutrient loading to the Spokane River Basin (Tri-State Council, 2015) estimated that septic systems may have relatively small impacts to nutrient loading to the overall lake over the near term. However, other studies have found that septic systems can have important influences on the supply of phosphorus to lakes and streams (e.g. Arnscheidt et al., 2007; Kramer et. al., 2006; Gilliom and Patmont, 1983). These studies suggest that, unless mitigated, septic inputs will likely increase significantly in the future as soil retention capacity is reduced and a greater proportion of septic phosphorus is transported to the lake.

Woods and Beckwith (1997) estimated that nearshore wastewater systems within 150 meters of the lakeshore contributed approximately 390 kg/yr (0.4 tons/yr) of phosphorus to Coeur d'Alene Lake in CY 1991 – 1992. In a 2008 technical memorandum to the Kootenai County Commissioners (Rust, 2008; copy in Appendix C), a natural resource advisor to the Kootenai County Commissioners used long-term trends in septic system permits to provide an estimate for the total septic system contribution to Coeur d'Alene Lake for CY 2008. Rust estimated there were 3,696 septic systems within 1.0 miles of the lakeshore in 2008 that would generate approximately 1,380 kg/yr of total phosphorus. Rust used the same approach to back-calculate that there would have been 1,190 septic systems in 1991-1992, generating 444 kg/yr of total phosphorus. This value agrees to within 15% of the 390 kg/yr in 1991-1992, as estimated by Woods and Beckwith (1997). Rust's estimates are based on septic system performance assumptions used by the City of Spokane. If Idaho DEQ guidelines for evaluating nutrient impact of septic systems for a household of four people (9.0 mg/L, 300 gal effluent/day) are adopted for Rust's 2008 calculations, then the same value of 1,380 kg/yr (1.5 tons/yr) would be predicted. If these residences are assumed to house only three people (250 gal/day), then a lower phosphorus load of 1,150 kg/yr (1.3 tons/yr) is predicted.

Rust (2008) estimated septic loads for sources within 1.0 mile of the lakeshore, while Woods and Beckwith (1997) estimated septic loads only for homes within 150 m of the shore (0.1 mile). Septic sources further inland may influence the lake through loading to streams that drain into the lake, but should have less influence on nutrient loading to the Lake than systems along the lakeshore. A breakdown of how septic systems and their potential phosphorus loads are distributed according to distance from the lakeshore is provided in Table 14.

Table 14. Phosphorus from septic systems along the portions of Coeur d'Alene Lake that are in Kootenai County, as of 2008

Distance from Lakeshore [1]	System Age	Permit	Total Number	Volume (MG/yr) [2]	Potential Load (kg TP/yr) [2]	Volume (MG/yr) [3]	Potential Load (kg TP/yr) [3]	Range (tons/yr)
500 ft of Lake	pre-1972	no	799	73	250	87	300	0.28 - 0.33
500 ft of Lake	post-1972	no	526	48	160	58	200	0.18 - 0.22
500 ft of Lake	post-1972	yes	1,073	100	340	120	410	0.37 - 0.45
SubTotal	--	--	***2,398***	***220***	***750***	***270***	***910***	***0.83 - 1.0***
500 ft to 1.0 mile	no data	no data	1,298	120	410	140	480	0.45 - 0.53
TOTAL	--	--	***3,696***	***340***	***1,160***	***410***	***1,390***	***1.3 - 1.5***

1. 500 ft = 152 m = ~0.1 mile
2. Two significant figures. Assumes 3 year-round residents per home (9 mg phosphorus/L; 250 gal effluent/day; 90% soil retention)
3. Two significant figures. Assumes 4 year-round residents per home (9 mg phosphorus/L; 300 gal effluent/day; 90% soil retention)

GIS analyses using Kootenai County and Coeur d'Alene Tribe records of property development along the nearshore region of the Lake (as of 2009) estimate that there were 2,398 homes on septic systems within a 500 foot buffer of the lakeshore. There were also 704 homes served by non-municipal wastewater systems within the 500 ft buffer (as of 2009). Of the septic systems, 799 were installed prior to passage of the Clean Water Act in 1972. Applying DEQ guidelines to only the septic systems within 500 feet of the lakeshore yields a nearshore phosphorus load of approximately 750 – 900 kg phosphorus/yr (0.8 – 1.0 tons/yr), depending on whether the residences hold three or four people. Note that this count of septic systems only includes Kootenai County. There are additional shoreline septic systems in Benewah County that are not included in these estimates.

Comparison with the calculations of Rust (2008) that there were 3,696 septic systems within 1.0 mile of the shore as of 2008 and the GIS analyses of systems within 500 ft of the lakeshore (2,398) homes suggest that there were 1,298 septic systems between 500 ft and 1.0 mile of the Lake. Adding the contribution of these systems would generate 1.3 – 1.5 tons phosphorus per year, depending on whether the residences hold three or four people.

This estimate is a lower end estimate. It does not consider inputs from failing septic systems that are known to exist. Residential development has continued, and there are many more homes than there were in 2008. Soil retention in older systems has likely declined, generating increased loads to the Lake. There is not sufficient soil, ground water, and septic data to estimate the current load via ground water modeling. This is an important data gap. When considered into perpetuity, such that soil uptake capacity is reduced, the phosphorus load from current and future septic systems will increase significantly over time, unless mitigation measures are taken.

Bunker Hill Central Impoundment Area and Government Creek

The Central Impoundment Area at the Bunker Hill facility contains two sources of phosphorus bearing gypsum waste, the Gypsum Pond north of Bunker Creek and south of the Coeur d'Alene River and the Gypsum Pond A4 Closure Area south of Bunker Creek and adjacent to the Central Impoundment Area (CIA). These are shown on the map given in Figure 21. These source areas contain gypsum produced from 1964 – 1970 as a waste byproduct of phosphoric acid production at a former Phosphoric Acid/Fertilizer Plant located in Government Gulch (CH2MHill, 2009; Mullen, 2012). This plant was shut down in 1981 and subsequently demolished.

The available data suggests that phosphorus from the CIA gypsum ponds is an important source of phosphorus to the SFCDR. Annual average loading estimates from USGS studies (Clark and Mebane, 2014) indicate that this stretch of the SFCDR contributes 5 – 15 tons total phosphorus per year to the Coeur d'Alene River subbasin (loading intensity of 220 – 660 kg/km^2). This stretch also contributes approximately 20 – 30% of the 2009 – 2013 zinc and cadmium load to the Coeur d'Alene River. Surface water phosphorus concentrations in the upstream monitoring sites ranged from < 50 µg/L to 70 µg/L while downstream surface water concentrations ranged from < 50 µg/L to 300 µg/L over the same period (Mullen, 2012). The increased phosphorus in down-gradient surface water suggests that the CIA gypsum ponds are an important source of phosphorus, whereby phosphorus leaches into ground water and is then transported to the SFCDR via ground water exchange. This stretch also adjoins the cities of Kellogg and Smelterville, and surface runoff from these cities also likely contributes to the phosphorus load.

The groundwater in the CIA contains high phosphorus concentrations. Water quality monitoring in the main gypsum pond area of the CIA, north of Bunker Creek conducted in 2008 (CH2MHill, 2009) indicated phosphorus levels in ground water ranged from 8 – 370 µg/L. Total phosphorus levels in surface water in Magnet Gulch, Deadwood Gulch, and Bunker Creek ranged from 6 – 162 µg/L. Ground water and surface water total phosphorus at upstream sites along the Coeur d'Alene River ranged from 5 – 10 µg/L at that time. Ground water data from EPA databases for 2009 – 2015 show phosphorus levels ranging from 420 – 8,120 ug/L in the northwestern corner of the CIA, further downgradient from the wells sampled in the 2009 CH2MHill study. Water quality monitoring in the A4 Gypsum Pond Area conducted in 2012 (Mullen, 2012) indicated soluble phosphate levels in ground water that ranged from 330 – 5,400 µg/L. These ground water levels and phosphorus concentrations can vary significantly through the year. Ground water modeling (CH2MHill, 2018b) estimates that, depending on flow conditions, 27 – 56 lbs/d of phosphorus enters the SFCDR from the CIA (~ 5 – 10 tons/yr). Recent USGS data suggests that groundwater inputs from the CIA comprise most of the load along this stretch during low flow years, and that other sources (e.g. storm water) can also be important in higher flow years.

In addition to the CIA, there is the potential for phosphorus release from the former Phosphoric Acid/Fertilizer Plant formerly located along Government Gulch, and closed in 1981. Subsequent demolition, remediation, and restoration work was done in the mid 1990's. This work included extensive soil removal and stream reconstruction work on Government Gulch. These activities are believed to have substantially reduced the potential for phosphorus release from this location. Government Gulch drains into Government Creek, which drains into the SFCDR downstream from the CIA. Total phosphorus in Government Creek ranges from 6 – 75 µg/L (USGS gage #12413290). These concentrations fall within the range observed for the SFCDR upstream of the Bunker Hill CIA.

The A4 Gymspum Pond was closed in 2004 and is currently being maintained by Stauffer Management Company, LLC under a Consent Decree with Idaho DEQ and U.S. EPA. The work completed under the consent decree has focused on hazardous substances, such as toxic metals, and have not explicitly considered nutrient impacts. However, some metals management strategies could also reduce nutrient loading from sources in the CIA as a co-benefit. Ongoing remedial actions include building a groundwater cut-off wall and routing the retrieved groundwater through an upgraded wastewater treatment facility (Central Treatment Plant, CTP). The wastewater treatment process includes lime addition to increase pH, sludge recycle, and water filtration. Given the high levels of iron and other metals in the groundwater and mine effluent, lime addition and the associated pH increase could remove phosphorus from the system as a Ca/Fe phosphate mineral. Thus, the CTP may have the potential to be operated in a manner that reduces phosphorus load from this source area. US EPA has issued a change order to the CTP contractor to include phosphorus monitoring as part of the contract, to help assess the CTP's phosphorus removal capabilities in addition to the primary metals reduction objective.

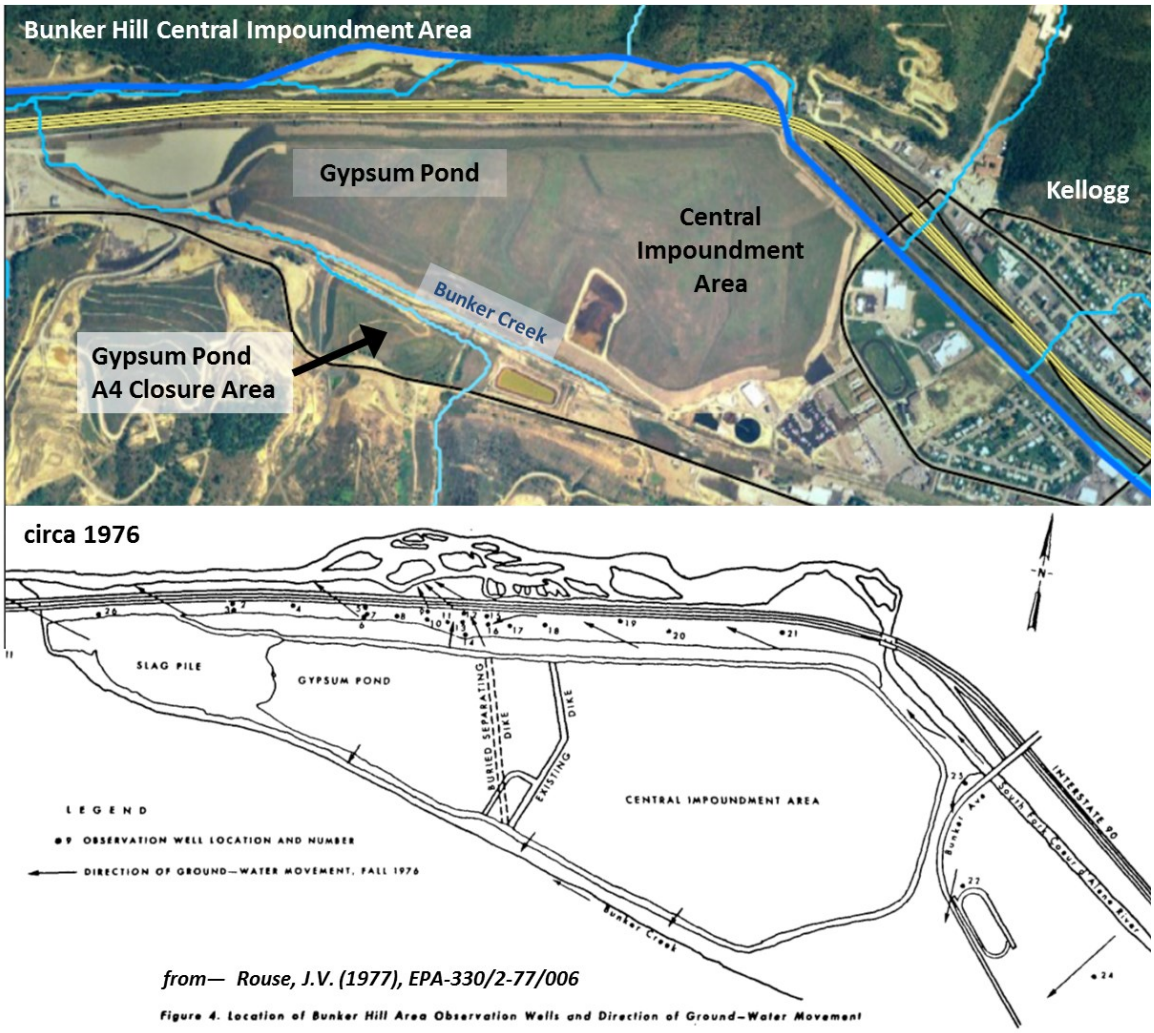


Figure 21. Map of phosphorus sources at the Bunker Hill Central Impoundment Area

2.5.3 Atmospheric Deposition

No direct measurements of atmospheric deposition of phosphorus to Coeur d'Alene Lake are available. However, measurements are available for Flathead Lake, MT for WY 1985 – 2004 (Ellis et. al., 2011) and estimates have been made for Fernan Lake (Harvey, 2001; LaCroix, 2015). Flathead Lake is a ~496 km^2 lake in western Montana, located approximately 180 miles west of Coeur d'Alene near Glacier National Park. Fernan Lake is a small lake (~1.65 km^2) located in a developed area adjacent to Interstate 90 a few miles north of Coeur d'Alene Lake. LaCroix (2015) used unpublished data from Harvey (2001) to estimate that Fernan Lake received 145 kg/yr of wet phosphorus deposition and 99 kg/yr of dry phosphorus deposition from the period of December, 1999 to December, 2000. This yields 244 kg/yr of total phosphorus deposited over a ~1.65 km^2 lake area (range = 1.60 km^2 at min pool, 1.69 km^2 at full pool, 1.75 km^2 at flood) for an average deposition rate of approximately 150 $kg/km^2 \cdot yr$ (2 significant figures). Fernan Lake is located immediately adjacent to US. Interstate I-90, and may experience greater impacts from auto traffic and local urban sources from the City of Coeur d'Alene.

Ellis et. al. (2011) collected long-term phosphorus deposition data for Flathead Lake, MT. They report total phosphorus deposition ranging from 0.2 – 4.2 g/ha·day, with a mean of 0.84 ± 0.93 g/ha·d. Inorganic phosphorus (SRP) ranged from 0.03-0.89 g/ha·d (0.32 ± 0.28 g/ha·d), and bioavailable phosphorus ranged from 0.12 – 3.2 g/ha·d (0.65 ± 0.71 g/ha*d). Ellis et. al. (2011) also noted a long-term trend of declining atmospheric deposition of total phosphorus, though the contribution of inorganic phosphorus remained unchanged over the period. This was attributed to the changing levels of fine dust particulates (PM10), which are a known source of atmospheric P deposition. If the mean deposition rate of total phosphorus for Flathead Lake (0.84 ± 0.93 g/ha*d) is converted to an average annual load, the resultant value is 30 ± 34 $kg/km^2 \cdot yr$. This value is consistent with the North American average of 42 ± 39 kg/km^2 (median = 32 kg/km^2) reported in a global compilation of phosphorus deposition datasets (Tipping et. al., 2014).

The estimated annual average deposition for Fernan Lake (150 $kg/km^2 \cdot yr$) is well above the range reported for Flathead Lake, which has an upper end of 64 $kg/km^2 \cdot yr$. In comparison, Woods and Beckwith (1997) estimated atmospheric phosphorus deposition to Coeur d'Alene Lake of 6,460 ± 1,050 kg/yr (50 ± 8 kg/km2*yr) based on regional atmospheric data collected in the mid-1980's. The range reported by Ellis et. al. (2011) overlaps with that reported by Woods and Beckwith (1997), and is likely to be more representative of Coeur d'Alene Lake than is unpublished data collected for the smaller, more urban Fernan Lake. Combining the two sets of published results for regional analogs for atmospheric deposition to Coeur d'Alene Lake yields a range of 30 – 70 $kg/km^2 \cdot yr$ with an average of 50 kg/km2·yr (1 significant figure).

The approximate surface are of Coeur d'Alene Lake is 129 km^2. Applying this range of deposition rates (30 – 70 kg/km^2, average = 50 kg/km^2) yields a load of 4,000 – 9,000 kg/yr (average = 6,500 kg/yr). At one significant figure, these equate to a range of 7 ± 3 tons/yr. The estimates of Woods and Beckwith (1997) equates to 7 ± 1 tons/yr. Lacking direct measurements, this report estimates that atmospheric deposition to the Lake lies between the estimates of Woods and Beckwith (1997) for Coeur d'Alene Lake and the range estimated by Ellis et. al. (2011) for Flathead Lake. This yields an estimate 7 ± 3 tons/yr. Local field data is needed to develop a more reliable estimate and quantify the sources of atmospheric influence.

3 Trends and Drivers of Change

Trend analyses of trophic parameters for Coeur d'Alene Lake have found that phosphorus levels are increasing in some portions of the Lake, and may be impacting the Lake's primary productivity (DEQ and Coeur d'Alene Tribe, 2015; DEQ and Coeur d'Alene Tribe, 2017). A summary of phosphorus trends, relative to river inputs, is provided in Figure 22. Phosphorus levels in the lake are increasing in the regions north of the Coeur d'Alene River. Phosphorus appears to be stable or decreasing south of the Coeur d'Alene River. The given trends for phosphorus in Coeur d'Alene Lake are relative to 2003. Phosphorus has increased lake-wide relative to 1991 – 1992, potentially by as much as two fold. The drivers behind this increase in phosphorus concentrations within Coeur d'Alene Lake are unclear. Increases in nutrient loading are one potential cause, though other factors could also influence in-lake trends. This section evaluates the potential for phosphorus loading into the lake to be increasing over time.

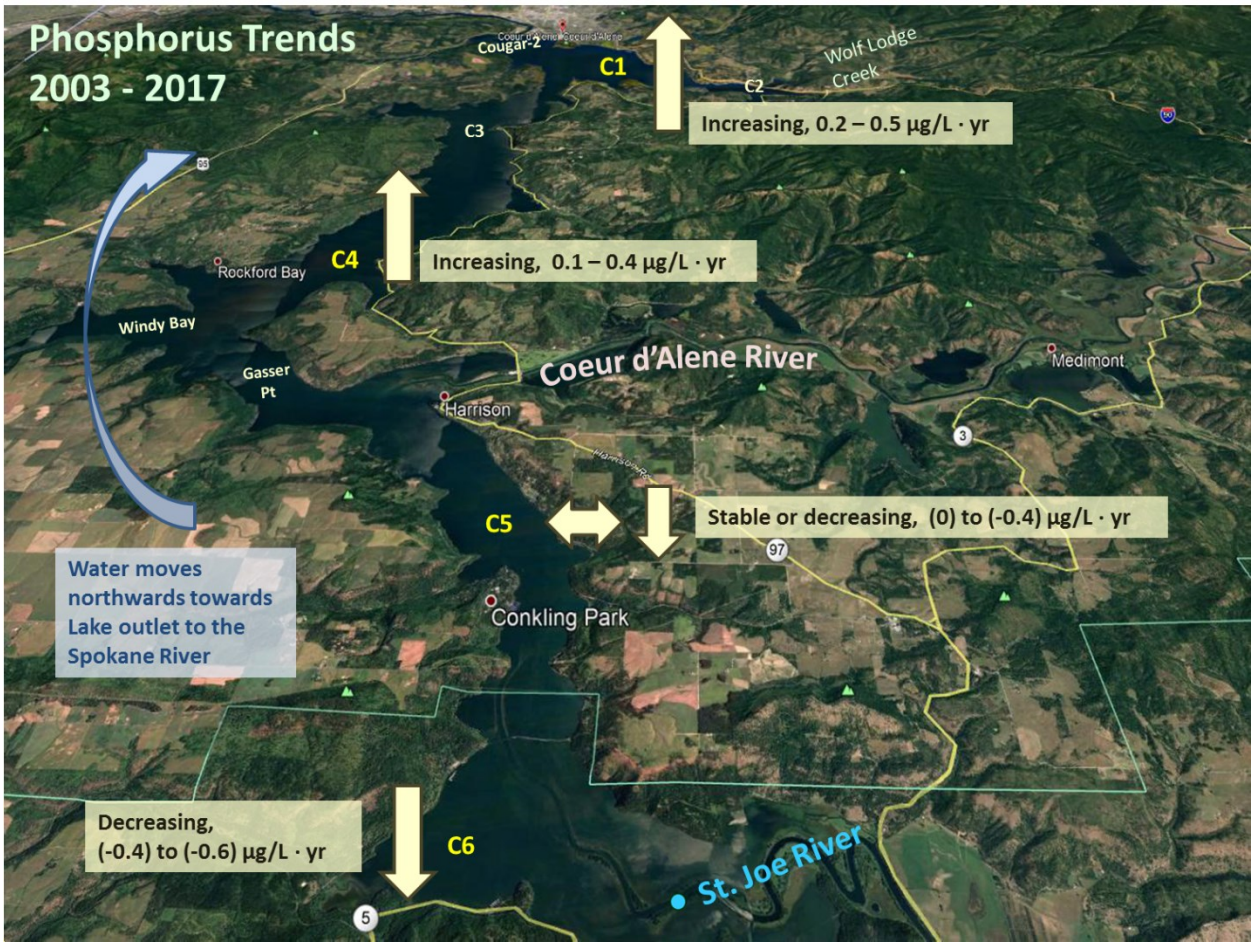


Figure 22. Trends in total phosphorus concentration (µg/L) over all depths at core monitoring locations within Coeur d'Alene Lake, 2003 – 2015.

3.1 Changes in Nutrient Loading

A summary of changes in the estimated total phosphorus load for the Coeur d'Alene and St. Joe Rivers between calendar years 1991 – 1992 and the current period is provided in Table 15. Annual load and discharge data are averaged over the given time period. These data show an apparent 3-fold increase in average annual total phosphorus loading from these rivers since CY 1991 – 1992. This increase is only 2-fold when load is normalized to the average annual river discharge and expressed in terms of an annual average phosphorus concentration. There is insufficient data to assess the potential for changes in loading from atmospheric deposition.

Table 15. Summary of change in estimated total phosphorus loading from the Coeur d'Alene and St. Joe Rivers from CY 1991-1992 to the current period (WY 2004 – 2013).

Watershed	Annual Average Discharge (cfs)	Annual Average Load (tons/yr)	Annual Average Yield (kg/km2)	Load / Discharge (kg/yr*cfs)
Coeur d'Alene River Basin (3,770 km^2)				
CY 1991 - 1992	1,945	25	6	11
WY 2004 - 2013	2,690	75	18	25
St. Joe River Basin (4,480km^2)				
CY 1991 - 1992	2,505	30	6	11
WY 2004 - 2013	2,975	79	16	24
Coeur d'Alene Lake Tributaries and Watersheds (1,160 km^2)				
CY 1991 - 1992	250 - 350	8	6	23
WY 2004 - 2013	estimate 50 - 550	estimate > 20	estimate > 15	*estimate > 40*

A summary of the changes in estimated phosphorus loading and in-stream concentration from the lake tributaries is provided in Table 16. Only limited data is available. Comparison of in-stream phosphorus concentrations for streams where there are comparable datasets show that observed minimum and maximum in-stream concentrations have increased. Medians cannot be compared, as the current datasets for Wolf Lodge Creek and Carlin Creek have too few data points and are not representative of typical stream conditions. Comparison of measured loads for CY 1991 – 1992 with modeled loads from the USGS SPARROW model (Wise & Johnson, 2011; Wise and Johnson, 2013) indicate a potential 2 – 4 fold increase in nutrient loading from the lake's northern tributaries, with only a moderate increase in loading from the southern tributaries. The SPARROW predictions are extrapolated to a smaller scale from a large regional study and are not directly comparable to historic data. Loads are only comparable qualitatively.

Total phosphorus in Coeur d'Alene Lake is reported to have increased approximately 2-fold since CY 1991 – 1992 (DEQ and Coeur d'Alene Tribe, 2015, 2017). Flow-normalized total phosphorus loading to Coeur d'Alene Lake, relative to 1991 – 1992, has potentially increased by approximately the same extent as phosphorus concentrations within the lake. These correlations suggest that a substantial portion of the increased phosphorus concentration in the lake may be attributable to increased phosphorus load from both the rivers and lake tributaries.

Table 16. Summary of change in total phosphorus in-stream concentrations (A) and annual loading (B) for the Coeur d'Alene Lake tributaries from CY 1991-1992 to the current period.

A Lake Tributary or Watershed	drainage area (km2)	USGS Data, CY 1991 - 1992 [1]		Current Data, WY 2009 - 2015	
		Minimum In-stream (µg TP/L)	Maximum In-stream (µg TP/L)	Minimum In-stream (µg TP/L)	Maximum In-stream (µg TP/L)
Wolf Lodge Creek above Cedar Creek [4]	102	3	28	10	110
Carlin Creek	30.9	7	44	25	140
Plummer Creek	110	23	190	18	268
Fighting Creek	41.6	21	170	--	--
CDA Lake, all tributaries	1,211	--	--	--	--

B Lake Tributary or Watershed	drainage area (km2)	USGS Data, CY 1991 - 1992 [1]		USGS SPARROW Model, 2002 [2]		Current Dataset, WY 2009 - 2015	
		Average Annual Load (kg TP/yr)	Average Annual Yield (kg TP/km^2)	Estimate of Minimum Annual Load (kg TP/yr)	Estimate of Minimum Annual Yield (kg TP/km2)	Average Annual Load (kg TP/yr)	Average Annual Yield (kg TP/km2)
Wolf Lodge Creek above Cedar Creek [4]	102	400	4	1,730	17	--	10 - 70 [3]
Carlin Creek	30.9	160	5	570	18	--	15 - 50 [3]
Plummer Creek	110	1,600	15	2,340	21	2,100	19
Fighting Creek	41.6	510	12	630	15	--	--
CDA Lake, all tributaries	1,211	7,270	6	17,570	15	--	--

1. Load and yield estimates from Woods and Beckwith (1997). Field data was collected at the given locations.
2. Model estimates are based on 2002 land use and exclude the impacts of urban development (Wise and Johnson, 2013).
3. Range of potential yields based on data from WY 2009 and simulated discharges using multiple discharge estimates.
4. Given data are for the sub-watershed of Wolf Lodge Creek, as defined by the USGS sampling station for the 1991-1992 study.

3.2 Influences of Hydrology

The trend summary presented in Table 15 suggests that annual average phosphorus load from the rivers has increased since 1991 – 1992, even when variability in annual average discharges is taken into account. Consequently, the observed increases in estimated phosphorus loading between CY 1991 – 1992 and the current period cannot be solely attributed to differences in annual average discharge. However, differences in discharge are still an important consideration. The loads for 1991 – 1992 are provided in terms of calendar years (Jan-Dec), while the current loads are expressed in terms of water years (Oct-Sep). This difference limits our ability to compare these datasets. Also, there are important seasonal differences that cannot be assessed by comparing annual loads and mean annual flows from these dissimilar datasets.

Mean daily flow data for "typical years" (middle two quartiles of flow) is provided here for the Coeur d'Alene River (Figure 23) and the St. Joe River (Figure 24). Corollary data for flows in the Coeur d'Alene Lake tributaries is not available. These comparisons show that there are important differences in the flow profiles for each year, particularly for short-term runoff events in the winter and early spring (Nov- Mar). The magnitude and duration of peak flows from March thru June are broadly comparable, as are base flows in summer and fall. Peak flows in CY 1991 are higher than any year for the current period, suggesting that loads for CY 1991 should be higher than for the current period if discharge were the sole driver of change. Taken together, these data show that variability in discharge is an important factor. However, differences in discharge cannot account for the apparent increase in estimated phosphorus load between the early 1990's and the current period.

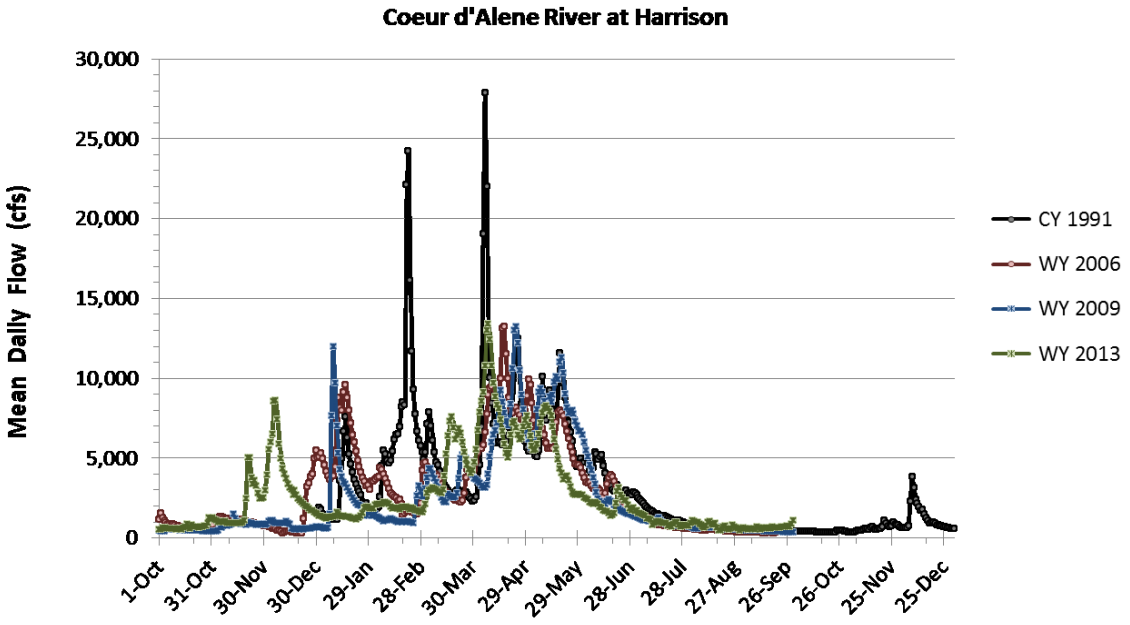


Figure 23. Mean daily flow for the Coeur d'Alene River at Harrison for "typical flow years" in the middle two quartiles of the long-term record (CY 1991, WY 2006, 2009, 2013).

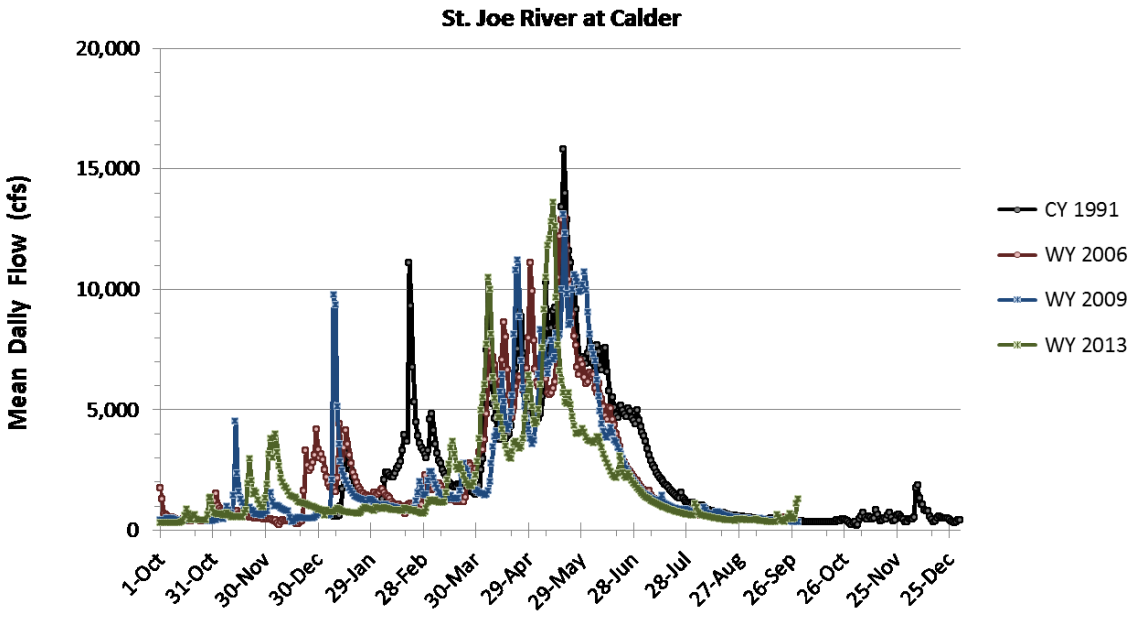


Figure 24. Mean daily flow for the St. Joe River at Calder for "typical flow years" in the middle two quartiles of the long-term record (CY 1991, WY 2006, 2009, 2013).

3.3 Phosphorus Concentration and Discharge

Loading is also influenced by the relationship between phosphorus concentration and discharge. This relationship can vary between streams and within a stream over time and lead to increases or decreases in loading. This section evaluates the potential for the relationship between phosphorus concentration and discharge to have changed over time. The ability to contrast the relationship between in-stream phosphorus concentrations and discharge between the early 1990's and the current period is constrained by the noted limitations in the historic dataset.

Coeur d'Alene River

A plot of how in-stream total phosphorus concentration varies with flow in the Coeur d'Alene River at its mouth near Harrison is provided in Figure 25. These data show that there is no relationship between concentration and flow in CY 1991 – 1992, and that concentration increases rapidly with flow above ~4,000 cfs for the 2004 – 2016 dataset. Concentration also increases with flow for the 1998 – 2006 dataset for the Harrison gauge (Section 1, Figure 5).

This increase in the sensitivity of total phosphorus concentration to flow also translates into a greater sensitivity of phosphorus load to flow (Figure 26). Phosphorus concentrations at flows less than 4,000 cfs are statistically equivalent between CY 1991 – 1992 and the current period. Phosphorus concentrations at flows above 4,000 cfs are much higher now. This difference in how phosphorus concentration responds to flow could account for the entirety of the observed increase in phosphorus loading from the Coeur d'Alene River relative to CY 1991 – 1992. However, limitations in the historic dataset constrain our ability to make this comparison (term of dataset, sparse data at high flows). Only a qualitative comparison is possible.

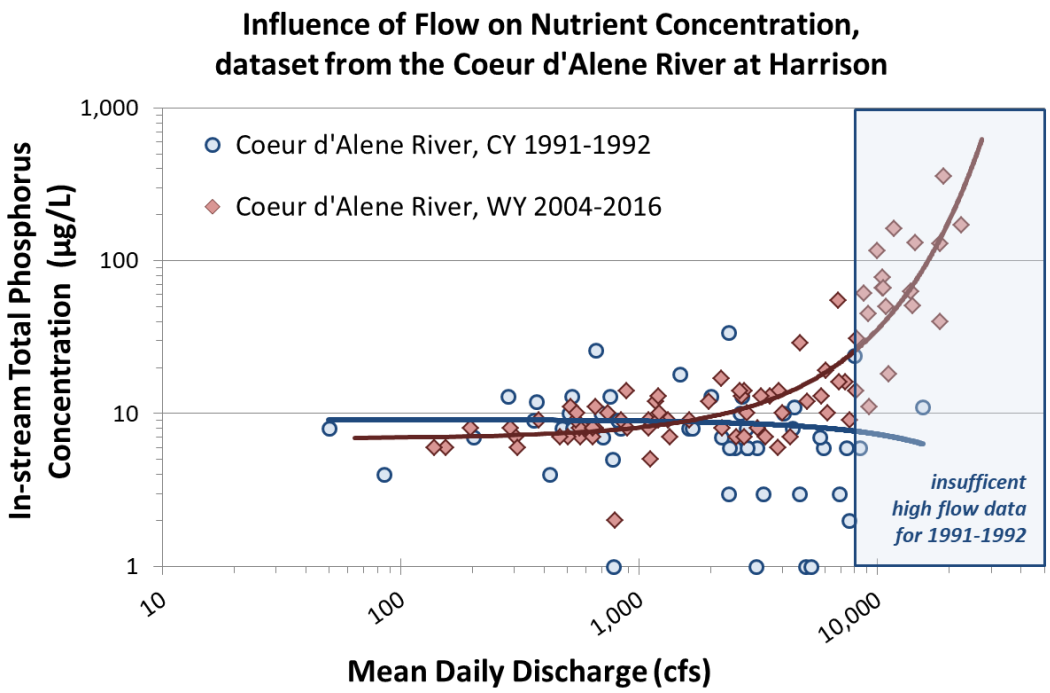


Figure 25. **Comparison of in-stream total phosphorus concentration (µg/L) vs mean daily flow (cfs) for the Coeur d'Alene River at Harrison.**

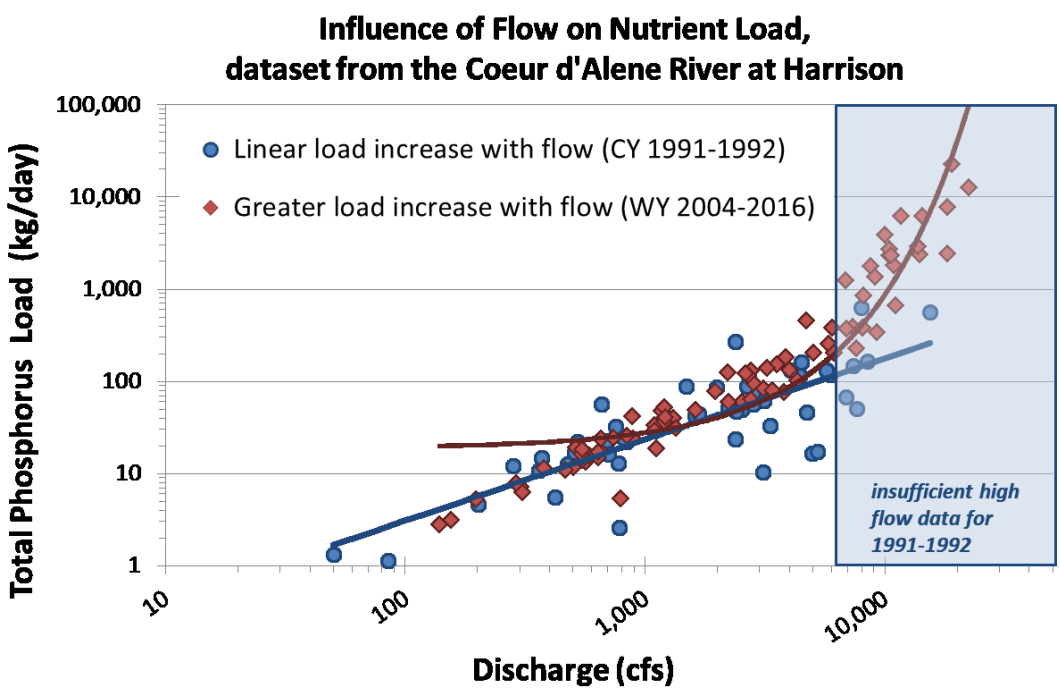


Figure 26. **Comparison of mean daily phosphorus load (kg/day) vs mean daily flow (cfs) for the Coeur d'Alene River at Harrison.**

The observed change in the response of phosphorus concentrations to changes in flow is remarkable and occurred over a short time interval, between 1992 and 2004. They suggest rapid change in a riverine system whose land use patterns and population have not changed to a similar degree. These changes should be treated with caution. Much of the observed differences could arise from limitations in the historic dataset. Data from 1991 – 1992 is for calendar years rather than water years, covers a relatively short time period, and is not fully representative of high flows. It is unclear to what extent the differences are real or an artifact from weaknesses in the historic dataset. Also the concentration versus flow relationship for phosphorus for CY 1991 – 1992 is unusual for streams whose phosphorus load is dominated by non-point sources.

One factor that is unique about the Coeur d'Alene River subbasin is its history of mine waste contamination. The subbasin is home to one of our nation's largest Superfund sites. Sediments and floodplain soils of the Coeur d'Alene River are contaminated by mine tailings and airborne particles from smelters that contain lead and other metals. Remedial actions have been completed in the Coeur d'Alene River subbasin, and many more are underway and planned for decades to come. The extensive deposits of mine waste and associated remedial actions affect the physical and biogeochemical functions of the Coeur d'Alene River, its tributaries, and its floodplain. Combined with other factors such as regulation of flow by Post Falls Dam, constriction of the floodplain by the historic railway, bank armoring, ditches and dikes, the Coeur d'Alene River cannot be expected to behave as other more natural rivers would.

There are a number of factors that could influence phosphorus dynamics and transport along the Coeur d'Alene River in the manner observed. These include remedial actions, recovery of natural ecosystems as a result of metals remediation, improved productivity arising from reduced sediment loading and corollary increases in water clarity, increased internal loading along lakes and wetlands, influences of climate change on runoff and summer temperatures, changes in atmospheric deposition, agricultural and forestry activities, and increased development and recreation within the riparian zone. This report cannot provide insight into the likelihood or magnitude of any potential drivers. We only note that there are many factors that could alter the dynamics of the system relative to phosphorus, and thus it is reasonable that a significant portion of the observed changes are real and not an artifact of limitations in the historic dataset.

Factors that suggest the observed changes in the relationship between flow and suspended phosphorus concentrations are real and not a sampling artifact include, but are not limited to;

- Differing trends for the phosphorus concentration versus flow relationships for upstream regions of the Coeur d'Alene River with different environmental characteristics.
- Consistency over time in this relationship for both lead and suspended sediment.
- The record of environmental remediation actions in the Coeur d'Alene River system.
- Land use changes in the Coeur d'Alene River subbasin.
- Corollary increases in phosphorus concentration within the regions of Coeur d'Alene Lake most impacted by the Coeur d'Alene River.

The different monitoring sites on the Coeur d'Alene River have different relationships between flow and total phosphorus. Some show a change over time, others do not. These sites have different geomorphological characteristics and environmental histories. They would not be expected to behave similarly, or show the same changes over time. If the observed changes

were a data artifact, then all sites would be expected to show a similar pattern of change over time. The diversity of site behavior (i.e., lack of similarity) suggests that the observed changes at the river outlet are real. Plots of the relationship between flow and phosphorus at multiple locations along the Coeur d'Alene River are provided in Figure 27. The lightly developed North Fork of the Coeur d'Alene River (24C) shows a relationship where the concentration of phosphorus increases with discharge, and where the nature of the relationship has not changed. The South Fork of the Coeur d'Alene River (24D), which has been influenced by development, mining, and subsequent remedial actions, shows a change over time. Phosphorus concentration decreased with flow in the 1990's, but increases with flow now. The main stem of the Coeur d'Alene River at Cataldo, downstream from the confluence, shows a mixed pattern where there is no clearly distinguishable difference between the 1990's and the current period. These patterns are different than is observed for the outlet at Harrison. Note that the different historical reporting limits constrain data interpretation. The reporting limit for phosphorus in the 1990's was 4 µg/L for the upstream monitoring sites (data from 1986 – 1996) and 1 µg/L for the 1991 – 1992 study at the Harrison site. Detection levels are 1 µg/L for the current dataset at all sites. Values less than reporting limits are shown here as equal to the reporting limit.

Another line of support is that the observed changes in the phosphorus-flow relationship for the Coeur d'Alene River at Harrison are not seen for suspended sediment or total lead (Figure 28). This lack of a change in the concentration-flow relationship over time for lead and suspended sediments, when one was observed for phosphorus, suggests that the data record describes real changes over time. Lead and phosphorus have very different biogeochemical cycles and are subject to different sets of physical processes in the Coeur d'Alene River system. They also have different sources. Lead is primarily associated with mining waste in riverbed sediments, while phosphorus comes from a diversity of particles; including point source discharges, agricultural operations, storm water, fine grained aerosols, lower density organic detritus, and a different set of riverine sediments. Phosphorus also co-cycles with iron in reducing riverine and lacustrine sediments while lead does not. Consequently, phosphorus dynamics and time trends should be quite different from those of lead. If historic sampling bias were the sole cause of the observed changes, then a comparable discrepancy should exist for all parameters. Phosphorus and lead behave differently, providing further evidence that the observed changes are real.

With respect to remedial actions, a number of actions were completed between 1992 and 2004 as part of the ongoing basin cleanup. A partial list of actions during that time period includes removal of 1.3 million cubic yards of waste materials at Smelterville Flats along the SFCDR (1997 – 1998), stabilization of contaminated soils on Bunker Hill hillsides (1995 – 1999), capping of the Bunker Hill Central Impoundment Area (1999 – 2000), and an ongoing program of property remediation and infrastructure protection. Remediation activities are a factor that could alter the nature of sediment and particulate transport, and also the bioavailability and physical forms of phosphorus. There is not sufficient data to quantitatively evaluate the potential impacts of these activities on the transport of phosphorus, which is predominantly particulate transport. However, qualitative assessments can be made. Actions that remove and/or sequester sediments and soils that are contaminated by lead will likely alter what sediments are transported by the river, where they originate from, and their phosphorus composition. Activities that harden surfaces and reduce ground water infiltration in the riparian zone may also increase particulate phosphorus transport during runoff events. Beneficial reduction of metals contamination could increase ecosystem productivity and enhance the nutrient cycling and bioavailability needed to

support that increased productivity. Thus, the history of beneficial remedial actions on the Coeur d'Alene River could also alter phosphorus transport in this unique system and contribute to the observed changes in the relationship between phosphorus concentration and stream flow. This history provides another line of evidence that the observed changes are real and not largely an artifact of bias in the historic dataset.

Land use in the Coeur d'Alene River subbasin, and the associated influences on water management, has also changed in the decades since 1991 – 1992. Beneficial remedial actions could potentially alter the composition of storm water; for example shifting the balance of phosphorus versus lead in runoff from urban lawns and roads. Land use patterns have changed in previously contaminated areas, potentially altering surface runoff. However, it is unclear if there has been a net change in urban runoff or the composition of that runoff since the 1990's. In addition to potential influences from property development and remediation, large areas of private forest lands that drain to the Coeur d'Alene River and its tributaries have experienced extensive forest harvest activities (see Figure 31, Figure 32; evergreen forest with recent activity). These changes would be expected to alter the dynamics of phosphorus transport, likely increasing the phosphorus load at higher flows. This history also provides another qualitative line of evidence that the observed changes in phosphorus dynamics could be real.

Taken together, these considerations provide multiple lines of evidence that phosphorus dynamics in the Coeur d'Alene River has likely changed in important ways since 1991 – 1992. The comparisons between the phosphorus, lead, and sediment data in the historic dataset are consistent with what would be expected if the changes are real. Additionally, there are important changes to land use and river dynamics (physical and biogeochemical) that are consistent with the observed change in phosphorus dynamics. These considerations indicate that some fraction of the observed increases in phosphorus loading from the Coeur d'Alene River is likely real and not an artifact of sampling bias towards lower flows in the historic dataset. Consequently, it can be concluded that phosphorus loads from the Coeur d'Alene River have likely increased since 1991 – 1992.

The magnitude of the increase in estimated load cannot be firmly established with the available data. But, the change is likely to be significant. Phosphorus concentrations in Coeur d'Alene Lake have also increased two-fold since 1991 – 1992 (DEQ and Tribe, 2017; DEQ and Tribe, 2015). While there are multiple factors that could contribute to the increased phosphorus concentrations in the lake, including ecological response to reduced metal levels in the lake, it is likely that increased loading is an important influence. A more detailed understanding of why the relationship between in-stream phosphorus concentrations and flow has changed (leading to increased phosphorus loading) is needed to better inform and prioritize nutrient management activities; including remedial and restoration actions. Future analyses should account for seasonal factors, and be conducted for all USGS and U.S. EPA monitoring sites for which there is a sufficient long term nutrient record.

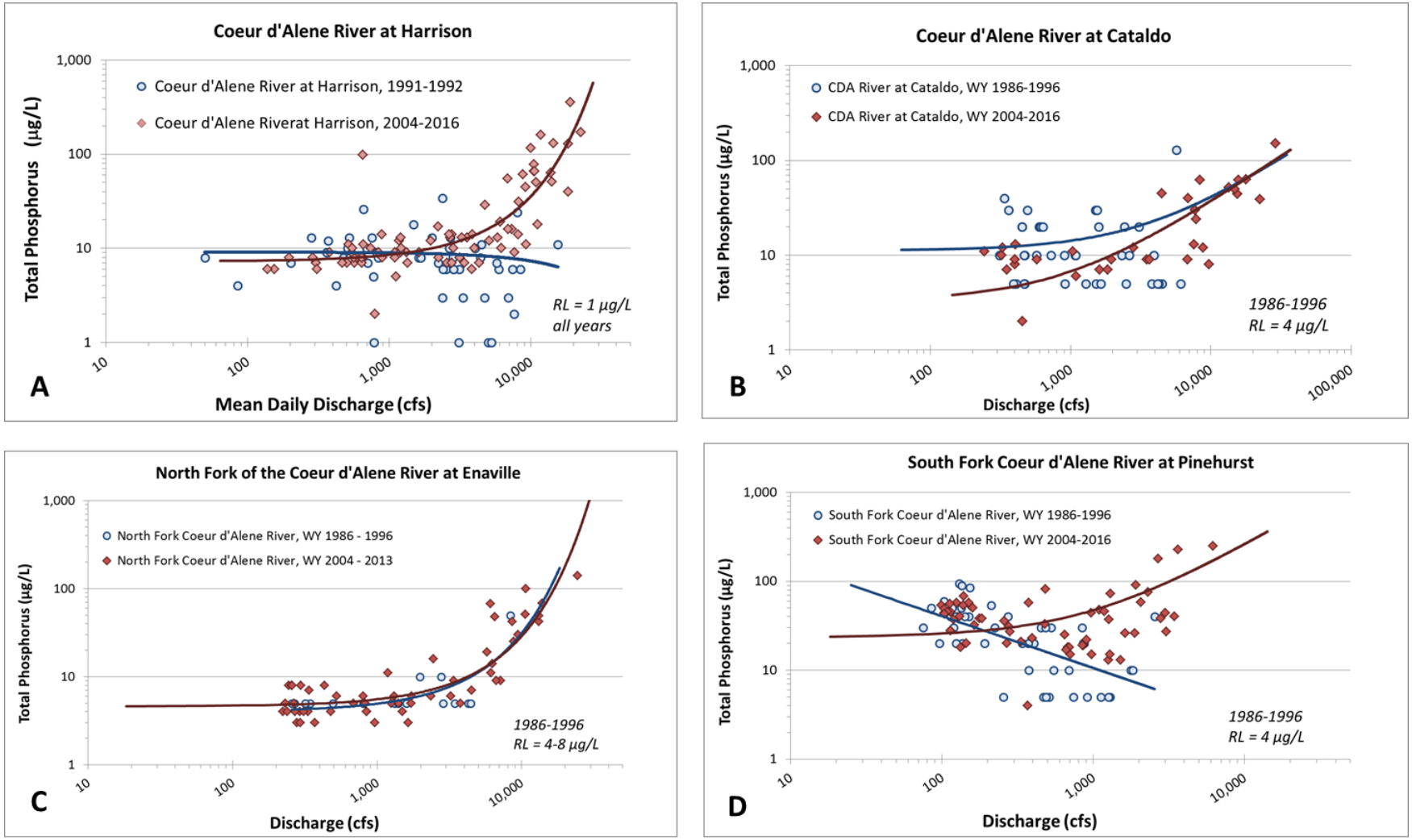


Figure 27. Plot of discharge versus total phosphorus for the Coeur d'Alene River at Harrison (A), the Coeur d'Alene River at Cataldo (B), the NFCDR at Enaville (C), and the SFCDR at Pinehurst (D) for the historic versus the current period.

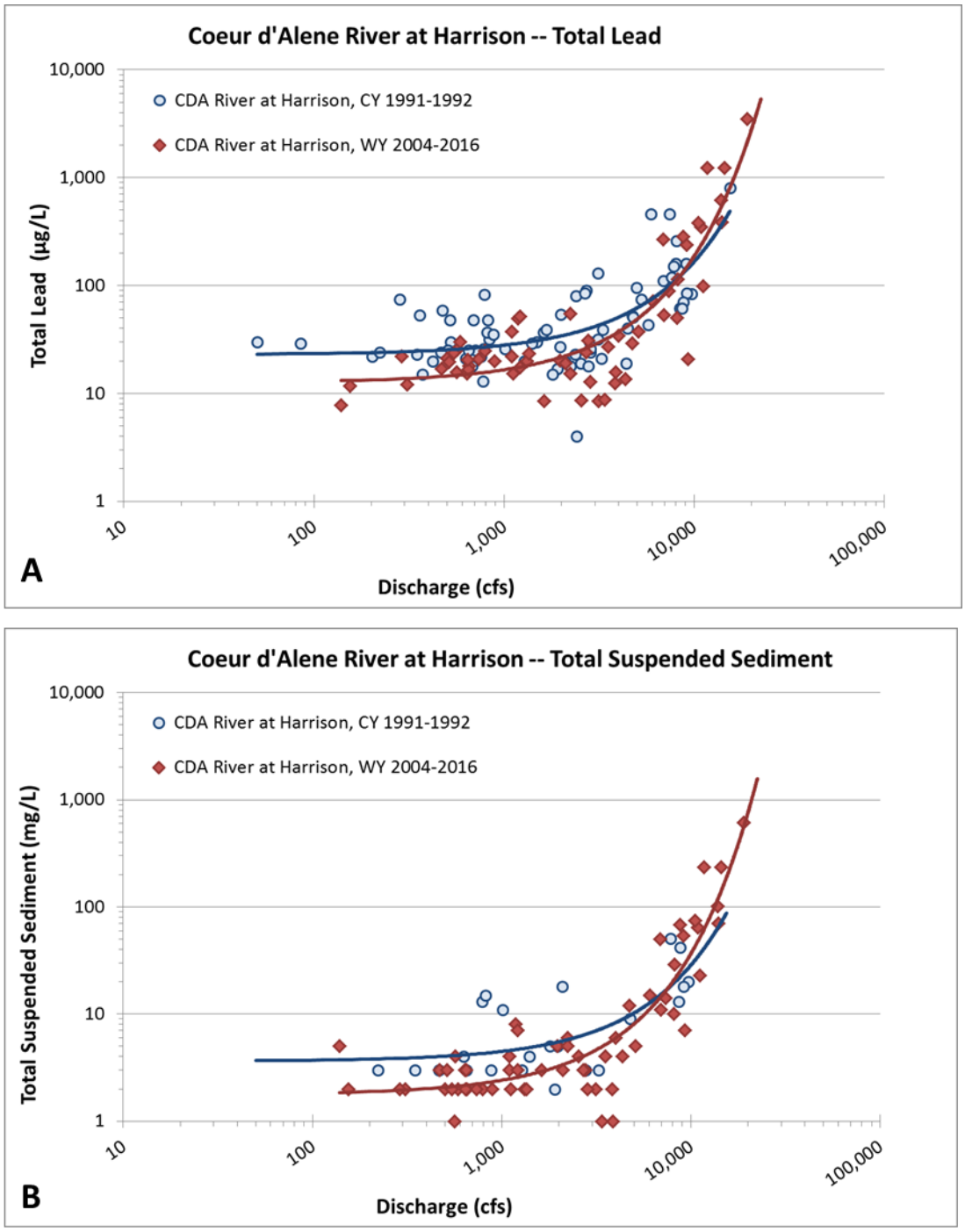


Figure 28. Plot of discharge versus total lead (A) and total suspended sediment (B) for the Coeur d'Alene River at Harrison for the historic versus the current period.

St. Joe River

A plot of how in-stream total phosphorus concentration varies with flow in the St. Joe River at the monitoring station closest to the outlet to Coeur d'Alene Lake is provided in Figure 29. Similar to the Coeur d'Alene River, the data show that there is no significant relationship between concentration and flow in CY 1991 – 1992. Total phosphorus concentration increases rapidly with flow above ~4,000 cfs for the 2004 – 2016 dataset. Phosphorus concentrations at lower flows appear to be higher now than in the 1990's. However, the 1990's data was collected at a different upstream site and are not directly comparable. There is no historic phosphorus data available at the current site, and data is not currently available at the CY 1991 – 1992 site.

The St. Joe River data for CY 1991 – 1992 was collected at the City of St. Maries, approximately 12 – 14 miles upstream from the river mouth. The 2004 – 2016 dataset was established at two different USGS gauging stations (Chatcolet, Ramsdell) located ~3 – 5 miles upstream from the river mouth. This region of the St. Joe River subbasin is a river valley containing agricultural lands, wetlands, and developed stream fronts backed by steep hills that are only partially forested. It also has the highest phosphorus yields in the St. Joe River subbasin and contributes significant phosphorus load (Section 2.3). The St. Maries station of CY 1991 – 1992 is not likely to be representative of this stretch of the St. Joe River, and thus the two stations can only be compared qualitatively. The data do suggest that phosphorus loads from the St. Joe River may have increased over time. However, it is unclear if this change is real or arises from dataset bias from (i) differences in geographic coverage, and (ii) insufficient data at higher flows.

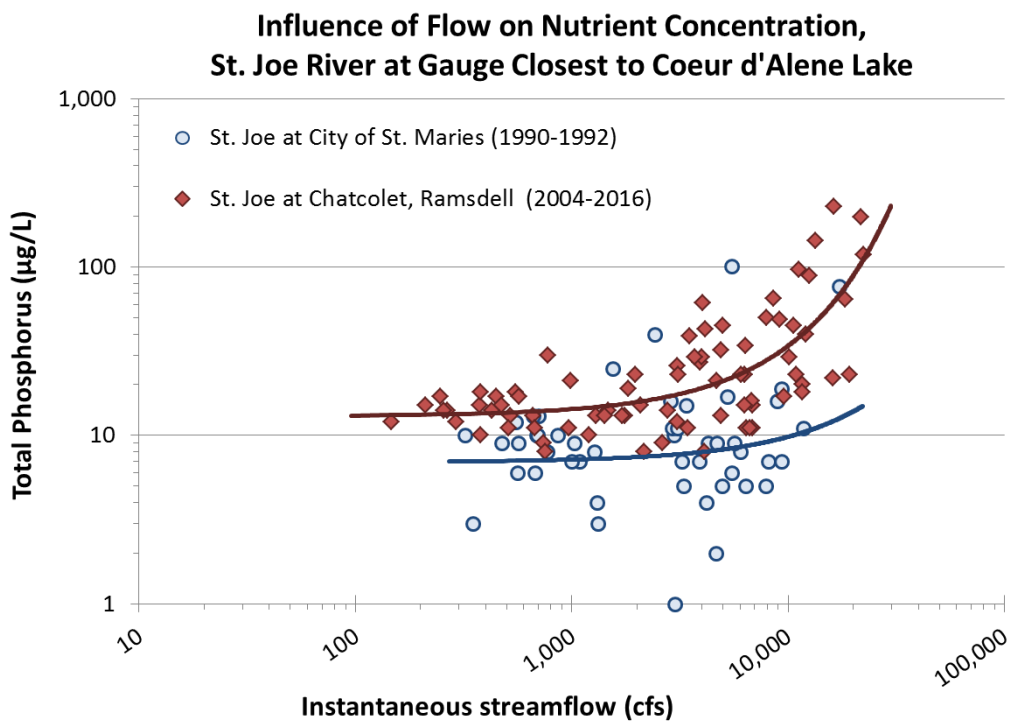


Figure 29. Comparison of in-stream total phosphorus concentration (µg/L) vs mean daily flow (cfs) for the St. Joe River at the outlet to Coeur d'Alene Lake.

3.4 Municipal and Non-Municipal Wastewater

The Coeur d'Alene Basin has experienced significant population growth since the early 1990's, leading to an increase in wastewater production. Wastewater load has increased for both municipal wastewater treatment plants (WWTP's) and non-municipal wastewater (e.g., septic, community systems). A summary of the observed changes is provided in Table 17. Note that the CY 1991 – 1992 study of Woods and Beckwith (1997) included wastewater from the cities of Coeur d'Alene and Post Falls, whose wastewater discharges into the Spokane River downstream from Coeur d'Alene Lake. A monitoring station has since been installed upstream of these discharges. This analysis excludes these WWTP's, as they do not discharge into Coeur d'Alene Lake and monitoring data is now available upstream of their discharges.

Table 17. Estimated annual phosphorus discharge from municipal and non-municipal wastewater in the 1990's and the current period.

Wastewater Source	1991-1992 Annual Load (tons/yr)	Current Annual Load [1] (tons/yr)	Percent change
Coeur d'Alene River			
Page WWTP	6.0	7.6	30%
Mullan WWTP	0.34	0.30	-10%
Smelterville WWTP	0.25	0.21	-20%
St. Joe River			
Clarkia WWTP [2]	0.02	0.06	150%
Santa-Fernwood WWTP	0.07	0.22	230%
St. Maries WWTP	1.5	2.1	40%
Coeur d'Alene Lake tributaries and smaller watersheds			
Harrison WWTP	0.1	0.04	*-70%*
Plummer WWTP	0.3	0.02	-90%
"Nearshore" [3]	0.4	1.4	230%
TOTAL	***8.9***	***12***	***30%***

1. Data from the most recent 5-yr period where data are available (2009 - 2014).
2. Estimated from maximum monthly flow
3. As per Woods and Beckwith (1997), the sum of private, community, and commercial wastewater systems within 150 m of the lake shore.

The data in in Table 17 indicate that there has been an overall 30% increase in wastewater sources since the 1990's (approximately 3 tons total phosphorus per year). The largest percent increases appear to be in the Santa-Fernwood WWTP in the St. Maries River and the estimated load from non-municipal wastewater sources within 1.0 miles of the lake shore. The apparent increase at the Clarkia WWTP may arise from the fact that these estimates are based on maximum monthly flow data as opposed to average daily flow. The Page WWTP and St. Maries WWTP have also increased phosphorus discharges. Note that some portion of these increases may be related to changes in service areas. Phosphorus discharges from the Harrison WWTP and the Plummer WWTP have decreased.

3.5 Factors that Could Influence Phosphorus Loading

The prior analyses suggest that a major driver behind the observed increases in phosphorus loading to Coeur d'Alene Lake is a shift in how total phosphorus concentration in the stream varies with flow. The changes are most pronounced for the Coeur d'Alene River, at high flows. Phosphorus concentrations are now higher at higher flows than they were in the early 1990's along the South Fork of the Coeur d'Alene River and the Main Stem below the confluence at Cataldo. There is insufficient historic data to similarly evaluate potential changes in the St. Joe River and the Coeur d'Alene Lake tributaries.

Identifying the cause(s) of this change could facilitate nutrient management. The potential for sampling bias resulting from a historic dataset that is not sufficiently representative of historic high flows is one possibility that could explain some, but not all, of the observed changes. Some additional potential causes could include the following.

1. Human and natural changes could alter sediment transport in the rivers so that the transported sediments are more phosphorus rich. For example, reducing the supply of metal contaminants, potentially increasing the supply of natural particulate matter.
2. Human and natural changes to the floodplain region could enhance the supply of phosphorus transported via surface runoff or ground water exchange. .
3. Human and natural changes to the overall drainage basin, including the floodplain region, could reduce the soil's capacity to bind phosphorus – leading to greater release of phosphorus from soils to surface runoff.
4. Human and natural changes could combine to alter the system's productivity and alter biogeochemical cycling of nutrients in rivers and streams, such that phosphorus is now more mobile during runoff events.
5. Human and natural changes could alter the amount of phosphorus that enters the basin via atmospheric deposition, and how much is transported into surface waters each year.

Some insights can be gained by evaluating whether increases in flow affect only particulate phosphorus, or whether soluble reactive phosphorus (dissolved bioavailable fraction) is also affected. Concentration versus flow data for total, total dissolved, and soluble reactive phosphorus (e.g. dissolved ortho-phosphate) is provided in Figure 30. These data show that only total phosphorus concentrations increase with increasing flow. This suggests that the changes in the relationship between phosphorus and flow arise from phosphorus bound to particulate matter.

Aqueous, water soluble phosphorus strongly sorbs to sediments and other forms of particulate matter (e.g. airborne dust, alluvial dust and soils, plankton, organic matter). Soluble phosphorus that enters a river system in a dissolved form, via ground water exchange or surface runoff, can rapidly bind to suspended matter in the river water. Such chemical sorption could mask differences in the source of phosphorus. Consequently, both phosphorus that originates as particle-associated and some fraction of phosphorus that originates in a soluble form could appear to be particle-associated by the time it reaches a downstream gauging station. Attenuation of soluble reactive phosphorus in streams via sorption and dilution is reported in the technical literature (e.g., Riemersma et. el., 2006). This chemistry could mask some changes in the ultimate sources of phosphorus to the basin's waters.

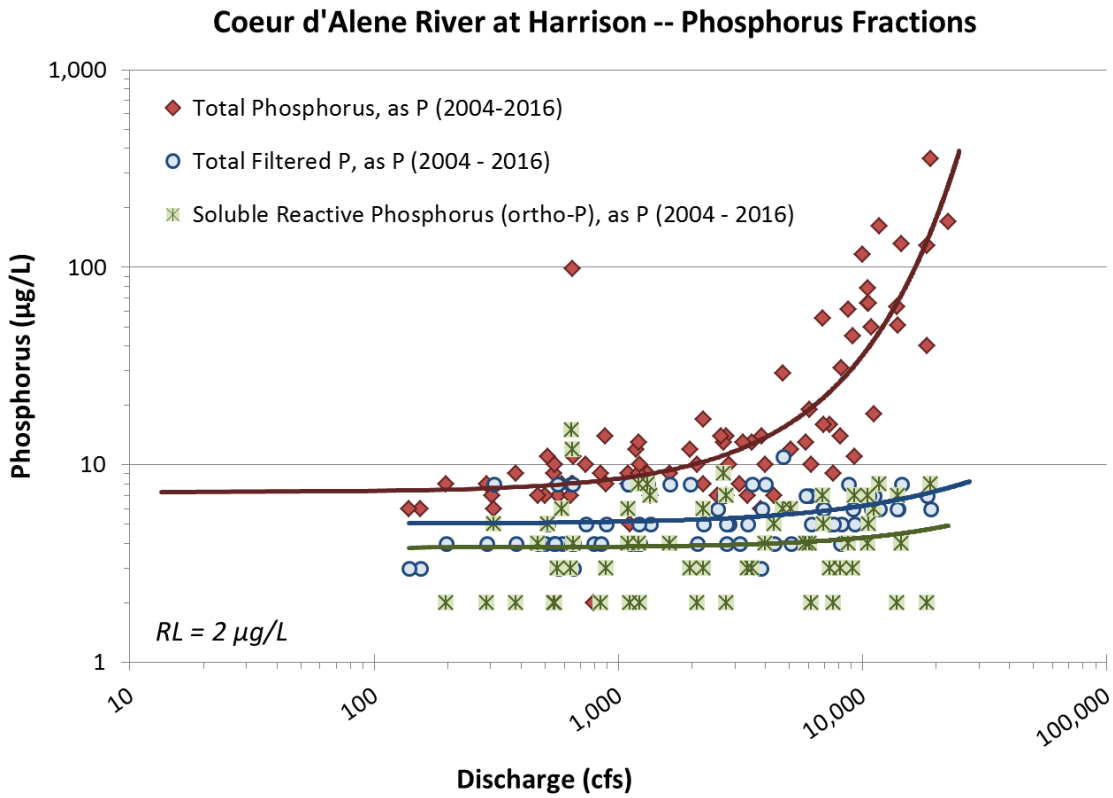


Figure 30. Plot of discharge versus total phosphorus, total dissolved phosphorus, and dissolved ortho-phosphate for the Coeur d'Alene River at Harrison.

The data in Figure 30 indicate that the changes in the phosphorus concentration versus flow relationship along the Coeur d'Alene River primarily arise from processes that influence particulate phosphorus. There are a number of factors that could impact transport of particulate phosphorus in streams and the near-stream riparian zone. These can include the following.

- Increases in the extent of impervious surfaces in the nearshore and upland watersheds.
- Changes in forest cover, road density and forest road density.
- Changes in streambank and streambed stability.
- Changes in flood frequency and timing.
- Changes in river dynamics, chemistry, and ecology; including potential influences from remedial actions and beneficial metals reduction.
- Changes in land management practices, including conversion of undeveloped forest and open land to residential, commercial, and industrial areas.
- Increased addition of phosphorus containing fertilizer and pesticides.
- Changes of the dynamics of water exchange between streams, lakes, wetland, and ground water in river delta regions.
- Changes in productivity, and carbon/nutrient cycling in wetlands, lakes, and rivers.
- Changes in atmospheric deposition of phosphorus to the basin.
- Changes in soil properties and erosion due to fire and forest management practices.

This is only a partial list. There is insufficient data available to quantify the impact of these factors in the Coeur d'Alene Basin. However, there is sufficient information available to evaluate some of these potential causes for purposes of prioritizing future nutrient management actions. Brief analyses of some of these factors are provided in the following sub-sections.

Development Pressure and Changes in Land Use

Land cover patterns are known to influence nutrient loading into aquatic systems. Agricultural land cover adds nitrogen and phosphorus fertilizer to soils and can enhance erosion. Ranching practices can denude streambeds, introduce high levels of animal waste, and enhance erosion while also reducing the ability of vegetation to absorb nutrients. Logging activities and road building can enhance erosion. Transformation of undeveloped land into residential and urban areas can add fertilizer and other phosphorus-containing chemicals into the system while also increasing the proportion of water that runs over the surface as opposed to percolating through ground water. Regional restrictions on the use of phosphorus in fertilizer in Liberty Lake, WA and Spokane County have led to the introduction of more benign fertilizers and reduced the supply of phosphorus bearing fertilizer to northern Idaho. However, the extent of these potential reductions and the impact on water quality in Coeur d'Alene Lake is unknown. Human waste management practices also impact phosphorus loading. Many studies have shown that agricultural and residential/urban lands typically have significantly higher phosphorus loading rates than natural undeveloped land (e.g. EPA, 2009; Smith, 2003; Bennett et. al., 2001; Smith et. al., 1999). These studies report that transformation of land from its natural state into a human-use state will typically increase nutrient loading.

River and stream floodplains and riparian areas are particularly susceptible to land use influences. Human development of these sensitive zones is generally more impactful to water quality than upland development. Significant residential, recreational, and economic development has occurred in the Coeur d'Alene Basin since the 1990's; with much of the change occurring in the floodplains and riparian zones. This development has changed the permeability of land surfaces through such activities as tree removal, landscaping, road building, and property development. These types of changes typically reduce ground water infiltration, alter floodplain capacity, increase flood heights and flood water velocities, divert water to surface run-off, impact waste systems, and enhance transport of phosphorus to streams during run-off events (e.g., Withers and Jarvie, 2008). Upland influences that include property development, forest management activities, road construction, and expansion of storm water management systems that drain to surface waters can also have important influences on nutrient loading. These factors can greatly increase the supply of soluble and particulate phosphorus, with the largest influences being associated with runoff events.

A summary of land cover changes between the early 1990's and the current period is provided in Figure 31 and Figure 32 for the Coeur d'Alene Basin. Data for 1992 is from the1992 National Land Cover Database (NLCD, 1992). All data for the current period is from the 2011 National Land Cover Database (NLCD, 2011), modified to account for forest change using the forest change dataset (Hansen et. al., 2013) as described in Appendix D. Note that the different datasets use different terminology for different land types and the satellite data processing algorithms are different for historic and current datasets. Consequently, land cover types are not directly comparable. Only a qualitative comparison is possible.

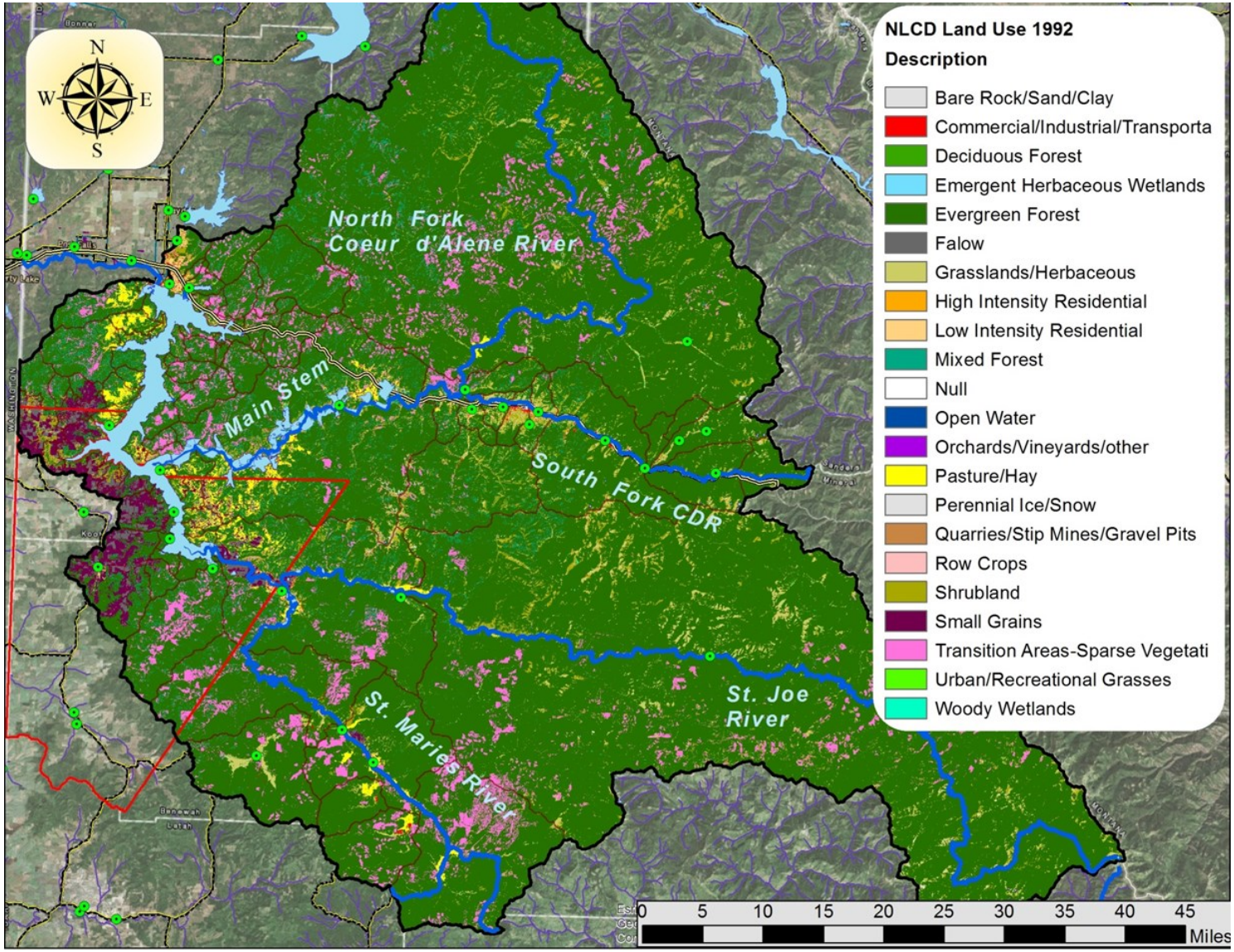


Figure 31. Map of land use in the Coeur d'Alene Basin in 1992 (NLCD 1992).

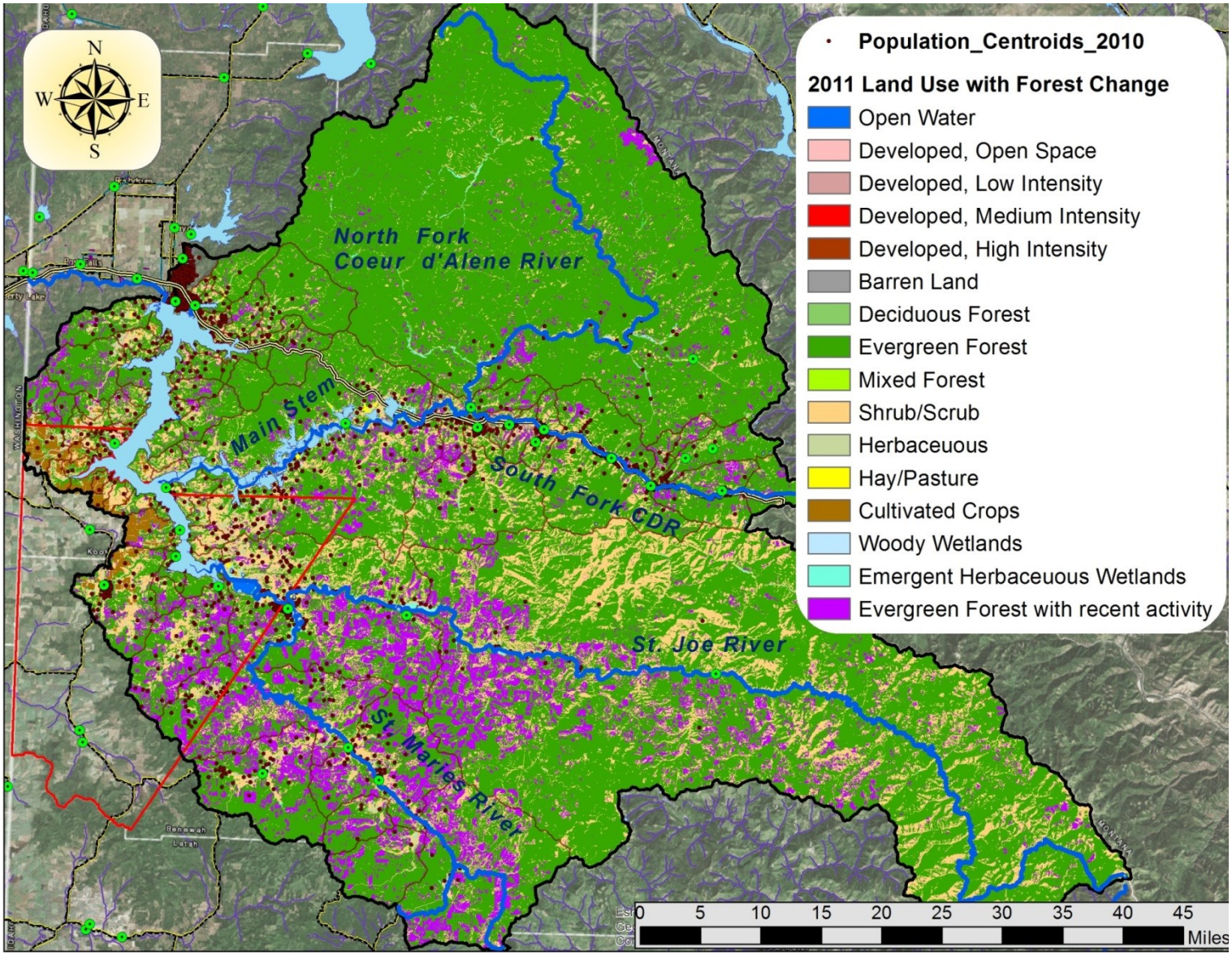


Figure 32. Map of land use in the Coeur d'Alene Basin in 2011, with forest change (NLCD 2011).

These maps suggest that forest harvest activity has increased in the basin from 1992 – 2011. Most of this activity has occurred in the St. Joe River subbasin. Intense forest harvest activity has also occurred in some parts of the Coeur d'Alene River subbasin, particularly in the watersheds that drain into the main stem downstream from Cataldo. Forest harvest activity has also occurred along Mica Creek and Lake Creek, which drain directly into Coeur d'Alene Lake. There also may be an increase in the amount of open, "shrub/scrub" land along watersheds in the northern regions of the lake (north of the Coeur d'Alene River mouth at Harrison). This potential difference is difficult to assess due to the different land use categorizations used in 1992 and 2011. A large increase in the proportion of land that is developed as urban and suburban areas is not apparent in these maps. However, much of the nearshore residential development has been in forested land at the wildland urban interface and may not be classified as developed in satellite imagery.

Atmospheric Deposition

Atmospheric dust and wet deposition is an important process for transporting phosphorus into a watershed (e.g. Zhang et. al., 2018). Neff et. al., (2008) reports that dust deposition rates in the American West have increased by 500% in response to increased settlement of the American West during the 19th and 20th centuries. This increased rate of dust deposition has resulted in more than a five-fold increase in inputs of phosphorus into mountainous ecosystems. Inputs of calcium, magnesium, potassium, and nitrogen have also increased. These increases have accelerated over the past 17 years due to a combination of factors that includes increased aridity, climate change, and expansion of upwind human activities (Brahney et. al., 2013). Forest fire smoke has been observed to increase phosphorus deposition in downwind areas (e.g., Ellis et. al., 2014, Tipping et. al., 2014; Vicars et. al., 2010; Ranalli, 2004). No atmospheric deposition data for phosphorus is available for the Coeur d'Alene Basin, and thus the potential for increased atmospheric deposition cannot be assessed at this time.

Soil Chemistry Change Associated with Forest Processes

One factor that could influence basin-wide phosphorus transport is forest aging in response to fire and forest management practices. DeLuca et. al. (2006) report that forest fires creates a biochar layer that binds phosphorus. This biochar has a limited sorption capacity that can become exhausted if it is not replenished via a natural fire cycle. For western U.S. forests, biochar sorption persists for a time period on the order of 100 years. The last large fire in the Coeur d'Alene Basin was the 1910 fire, which was approximately 100 years ago. If biochar becomes exhausted, then soluble phosphorus transport in forested land could increase.

Iron and Nutrient Cycling within Lakes, Rivers, and Wetlands

Aquatic sediments commonly become anoxic within the first foot below the sediment-water interface. The biogeochemical processes associated with anoxia can transport iron and phosphorus from larger particles and deeper sediment layers that are anoxic to smaller, more mobile particles in oxic sediment layers located closer to the surface. Phosphorus is dominantly

adsorbed to iron oxide minerals when oxygen is present. When systems become anoxic, iron oxides dissolve and release phosphorus into the water. Both iron and phosphorus move through the water to areas where oxygen is present. Iron then oxidizes and forms small, fine-grained, higher mobility iron oxide sediments that scavenge phosphorus from the water and can also themselves sorb onto other particles (e.g. Filippelli, 2002; Horowitz et. al., 1993). If this process has become more pronounced due to a combination of climate change, reduced metals concentrations and associated toxicity, and ecosystem recovery; then river sediment erosion could transport more phosphorus. Increased ecosystem productivity could also increase the portion of particulate phosphorus associated with organic matter, which also may be more mobile than soils and sediments. Recent studies by the Coeur d'Alene Tribe have documented anoxia in the chain lakes that adjoin the main stem of the Coeur d'Alene River and the deep meander bends within the Coeur d'Alene River itself (Coeur d'Alene Tribe, 2014).

Climate Change

Relatively little is known about the impact of climate change on lake and stream water quality. Climate change is known to impact the timing, amount, and temperature of water run-off within a basin; and a warming climate will also increase stream temperatures. The science of how these factors impact water supply is well established and water supply agencies are beginning to incorporate climate change into their water forecasts and long-range planning. However, the impact of climate change on surface water quality is difficult to predict. The nature, magnitude, and rate of water quality changes is largely unknown.

Abatzaglou et. al. (2014) reports that climate conditions in the Pacific Northwest and Idaho Panhandle region have changed significantly since the 1990's. Annual mean temperature has increased by 0.6 – 0.8 °C (~1.0 – 1.5 °F) from 1901 – 2012, with longer freeze-free seasons, warmer winter temperatures, and higher summer evapotranspiration rates. A long-term trend of increased spring precipitation has been observed, with lower summer and fall precipitation. These trends generally translate into higher summer stream temperatures, reduced or "wetter" snowpack, and more precipitation falling as rain and rain/snow mix rather than snow. The total amount of annual precipitation is approximately the same, and may be higher. However, less of this precipitation is falling as snow and the timing of snowmelt tends to come earlier in the season. This translates into changes in the timing, magnitude, and duration of peak flows; progressively drier summer conditions; and progressively warmer summer stream temperatures. Climate variability and the El Niño-Southern Oscillation make it difficult to quantify the actual amount of change. However, it can be concluded that temperatures and hydrologic cycling has changed in the Pacific Northwest, and is continuing to evolve in response to human greenhouse gas emissions. These historic changes are small and unlikely to have altered the cycling and transport of phosphorus in the Coeur d'Alene Basin to a degree that is measurable with current data. The largest impact of climate change on phosphorus transport, relative to historic conditions, is likely to be associated with atmospheric deposition arising from increased forest fires and greater dust transport due to desertification (e.g., Neff et. al., 2008; Brahney et. al., 2013; Running, 2006; Westerling et. al., 2006). Forest fires can also increase runoff through deforestation and changes to soil properties. These historic impacts are anticipated to continue and accelerate in the future in response to projected changes in global climate.

3.6 Summary of Trends

Comparison of current phosphorus loading with reported values for CY 1991 – 1992 indicate that phosphorus loading to Coeur d'Alene Lake has increased significantly. Flow-normalized loads from the Coeur d'Alene River and St. Joe River appear to have increased approximately two fold since the early 1990's. The load estimates for both the current and historic data are subject to considerable uncertainty, and thus the magnitude of the observed change is also uncertain. Even so, much of the observed change is likely real. The observed increases in phosphorus loading are consistent with trends in phosphorus concentrations in Coeur d'Alene Lake, which have also increased by approximately two fold since calendar years 1991 – 1992.

There is insufficient data to assess changes over time for the smaller tributaries that flow directly into Coeur d'Alene Lake. Comparison of area-normalized loads reported for the Coeur d'Alene Lake tributaries by Woods and Beckwith (1997) with estimates based on modeling studies representative of the early 2000's (Wise and Johnson, 2010; 2013) suggest that loading from the tributaries has increased from an average of 5 – 10 kg/km^2 to 10 – 20 kg/km^2 over that time period. This potential change is comparable in magnitude to that estimated for the rivers.

The potential causes driving this substantial increase in phosphorus loads are unclear. Variations in river discharge influence load calculations, but are not likely to be a major cause of the apparent increases in estimated phosphorus loading. Comparison of the relationship between stream phosphorus concentration and discharge show that the response of in-stream phosphorus concentration to changes in flow appears to have changed dramatically at some locations in the basin. Phosphorus concentrations at high flows are much greater now than in the decade spanning the CY 1991-1992 USGS study (1986 – 1996) at some locations in the basin, but not all. This historic dataset does not have sufficient data to be fully representative of conditions at high flows or lower phosphorus concentrations (< 10 µg/L). This data gap increases uncertainty and limits the extent to which historic data can be compared to current conditions.

There are a variety of basin-wide environmental factors that could contribute to the observed increase in phosphorus loading estimates. There has been a small increase in phosphorus from wastewater discharges within the basin, but this change can account for less than 5% of the observed increase in estimated phosphorus loads. Land use changes could alter phosphorus runoff, but land use as measured by satellite observations has only experienced minimal change as a basin-wide average. Significant development has occurred along the shorelines and watersheds that drain into the more northern reached of Coeur d'Alene Lake, but this would not influence loading from the Coeur d'Alene and St. Joe Rivers. Significant forest harvest activities have occurred in the Coeur d'Alene and St. Joe River subbasins.

Along the Coeur d'Alene River, remedial and restoration actions have reduced the transport of lead bearing sediments, improved water quality, and improved habitat. These changes could also combine with other factors to alter the physics and chemistry of suspended particles in ways that influence phosphorus transport. These activities could also have altered the physical properties of the floodplain in ways that influence net ground water infiltration and surface run-off, altering phosphorus transport. Also, reductions in the supply of metal contaminated sediments could increase the proportion of natural soils and sediments transported by the river. River down-cutting could also alter the phosphorus chemistry of transported sediments. Reductions in metals pollution could alter ecology in ways that influence phosphorus transport. Other possible factors

include changes in human additions of phosphorus to the land, alteration of the river floodplains with resultant influences on flood dynamics, and impacts from increased forest fires and dust deposition due to climate change and human development in upwind areas. These factors are poorly understood, and could have many competing influences.

The apparent increase in estimated phosphorus loads may not be consistent with the significant amount of remediation and restoration work that has been done along the Coeur d'Alene and St. Joe Rivers, activities which should help reduce the load of phosphorus entering the lake. However, only a fraction of the basin's streams have been restored. Also, remediation and restoration activities have been targeted on metals, sediments, temperature, and wildlife habitat. Nutrient control has been considered to be an additional, yet unquantified benefit. It is possible that remediation and restoration activities along the most heavily contaminated regions of the Coeur d'Alene River could influence phosphorus transport in response to declining toxic impacts of metals contamination on the river ecosystem, as the system progresses towards being less impacted by historic mining waste. Additional data collection and analysis is needed to evaluate this potential for change, and gain a better understanding of how the combination of remedial and restoration actions influence phosphorus transport in the Coeur d'Alene Basin.

4 Conclusions, Data Gaps, and Path Forward

This section provides a summary of the conclusions from this study as well as data gaps identified during the development of this nutrient inventory. Also provided are some preliminary recommendations for follow-on work. The recommendations are provided as a discussion point in response to stakeholder feedback and are not considered to be a commitment to future actions.

4.1 Conclusions

This report has established an updated total phosphorus budget for Coeur d'Alene Lake that reflects loading for 2004 – 2013 and presents long-term average load estimates for all the major source areas. Some load estimates are stronger than others. Additional work is needed to fill data gaps. Conclusions made on the basis of existing data include the following.

1. Phosphorus loading to the lake has likely increased since the 1991 – 1992 study for some, but not all, watersheds within in the Coeur d'Alene Basin.
2. The increases in estimated phosphorus loads are likely associated with changes in the mobility of phosphorus during high flow events. The cause(s) of this change are unknown.
3. Most loading to the lake is from non-point sources. Wastewater sources are estimated to contribute less than 10% of the overall nutrient load. Septic systems are estimated to currently be a minor contributor whose influence could grow significantly over time, as development continues and these systems continue to age.
4. The Coeur d'Alene River likely has the greatest influence on the observed trend of increasing phosphorus in the northern portions of the lake, as phosphorus concentrations are increasing immediately north of its outlet to the lake, but not to the south.
5. Within the Coeur d'Alene River, the greatest phosphorus yields (load per unit area) are found along the South Fork of the Coeur d'Alene River and the Main Stem downstream from Cataldo. These watersheds also show the greatest evidence of increases in estimated phosphorus loads since 1991 – 1992.
6. Within the St. Joe River, the greatest phosphorus yields (load per unit area) are found along Carpenter Creek and the combined load from the watersheds and river reaches downstream from the USGS gauge at Lotus on the St. Maries River and the City of Avery on the St. Joe River. This region includes the City of St. Maries.
7. The available data suggests that phosphorus load has likely increased significantly in the many smaller tributaries that drain directly into Coeur d'Alene Lake. However, there is very little data for these streams and collecting robust nutrient data is a priority to fill this data gap. The relative influence of these streams is likely to be greatest in the lake's northern pool, which is furthest from the outlet of the Coeur d'Alene River.
8. There is evidence of significant changes in land use associated with forest management and recreational development in all subbasins, which likely results in increased nutrient loading. However, there is currently insufficient data to rigorously assess the impacts of forest practices and development pressure on phosphorus loading.

Based on current data, the Coeur d'Alene River should be a high priority for nutrient management action. This subbasin has a marked influence on phosphorus trends within the lake and has shown the greatest evidence for increased phosphorus load since 1991 – 1992. This subbasin also has many opportunities for synergy between remedial, restoration, and nutrient management actions. The Coeur d'Alene Lake tributaries should also be a high priority for nutrient management action. Little data is available for these watersheds, and additional nutrient loading data is needed to better inform management actions. Nutrient loading studies to collect this data have been initiated and are ongoing. There have been intense forest harvest activities in the St. Joe subbasin that can potentially influence nutrient loading, and a rigorous assessment of the role of forest management on nutrient loading in this region would help establish future nutrient management priorities in subbasins impacted by forest harvest and forest management.

4.2 Data Gaps

This analysis has revealed a number of data gaps that limit our ability to effectively manage nutrient inputs into the lake. These gaps include lack of information of nutrient loading from geographic areas, as well as from specific types of sources (e.g., storm water, septic, WWTP inside a geographic region). More information on the timing and seasonality of nutrient additions is needed to help prioritize management actions. Corollary information on nitrogen and the more bioavailable forms of phosphorus is also needed. These gaps are discussed below.

Nutrient Source Areas

Only minimal information is known about nutrient loading from the tributaries and lakeshore drainages that drain directly into Coeur d'Alene Lake (Section 2.4). These tributaries are experiencing rapidly increasing development pressure and provide numerous opportunities for both prevention and restoration approaches to nutrient management. The individual contribution of each tributary may be relatively small, but their combined influence is significant. This is particularly important for the lake's northern pool, which is most removed from the Coeur d'Alene and St. Joe Rivers and experiencing the greatest development pressure. Loading information for the lake's tributaries is a high priority data gap. Sediment-based prioritization from the most recent 5-year TMDL review is serving as an interim surrogate for project ranking.

There are no direct measurements of atmospheric deposition to Coeur d'Alene Lake, or to the surrounding basin. The contribution of this source is inferred primarily from studies outside the Coeur d'Alene Basin. Precipitation and dry deposition of aeolian dust is a major vector for addition of more reactive and more mobile nutrients to both the lake and surrounding basin. Atmospheric sources can be managed via air quality management techniques, and the proportion of atmospheric phosphorus that deposits onto the land and is subsequently transported to the lake can be influenced through land management activities. Atmospheric deposition via both "wet" and "dry" deposition is changing across the northwest due to climate change and development influences, and shifts in this deposition could mask or enhance the effects of localized nutrient management actions. Lack of information on atmospheric deposition is an important data gap.

Additional nutrient loading information for the St. Joe River subbasin would facilitate nutrient management there. This document reports the results from a preliminary survey. A larger dataset would allow more rigorous evaluation of the effects of forest management practices and identify potential sources along the St. Joe River upstream from St Joe City. Additional information on nutrient sources within the St. Joe River confluence region (Section 2.3) would also be valuable.

Additional nutrient loading information for the Coeur d'Alene River subbasin would also be helpful. Priority needs include improved enumeration of phosphorus loading from the watershed encompassing the Central Impoundment Area and higher resolution information for the Main Stem of the Coeur d'Alene River, both geographically and temporally. The Main Stem of the Coeur d'Alene River contributes approximately one-third of the river's total load, and there is little information available to identify sources and establish management priorities. There is also insufficient information to separately account for the multiple sources in the watershed encompassing the Central Impoundment Area. These sources include potential runoff from the cities of Kellogg and Smelterville. An updated understanding of these multiple sources and loading mechanics will be needed once the Bunker Hill Central Treatment Plant (CTP) and groundwater collection system is operating. Understanding the relative contributions of groundwater and surface water runoff in this watershed would help to better assess the benefits and/or impacts of CTP operations and planned future remedial and restoration activities.

Nutrient Source Types

This study is primarily a geographic budget for only total phosphorus. Minimal information is available for the actual source of total phosphorus loading within the watersheds assessed in this study. The best available information is for the municipal WWTP's. These facilities comprise less than 10% of the total phosphorus load to the basin, but do produce a larger fraction of the load of bioavailable phosphorus. Even here, historic monthly nutrient load data is not available for many of the facilities. There is no reliable data for assessing phosphorus loads from storm water sources that drain into the lake, and the estimates for septic and community wastewater sources are based on very general assumptions that may or may not reflect actual conditions. Notable data gaps for nutrient source types include the following.

- Monthly nutrient load information for municipal WWTP's in the basin.
- Quantification of nutrient loading from the City of Coeur d'Alene storm water system.
- Preliminary surveys of nutrient loading from other storm water systems in the basin.
- Preliminary surveys of localized septic influences.

Most of the nutrient load to Coeur d'Alene Lake originates from non-point sources. While there are many factors that contribute to non-point source loading, the proportion of impermeable surfaces in a watershed and the health of the associated riparian area are key factors. The influences of recreational development (e.g. road, home construction) and forest management activities on non-point source loading within the basin have not been rigorously assessed, though they are expected to increase phosphorus loading to the basin and lake. Additional information to help establish, demonstrate, and prioritize improved best management practices for these land development activities would help to enhance the effectiveness of nutrient management actions.

Seasonality of Nutrient Addition

Nutrient loading to Coeur d'Alene Lake has important seasonal influences. This report excluded these influences, focusing instead on getting a longer-term understanding of the many source areas within the basin. Seasonality is acknowledged as an important factor, but one that requires more detailed analysis that would be appropriate at a finer scale. Data quality varies widely across the different subbasins, and there is insufficient information to conduct seasonality analyses for all subbasins and priority watersheds at this point. An improved understanding of seasonal influences will improve the efficacy of nutrient management actions. Such analyses, including potential future monitoring studies, would help fill this information and data gap.

Nitrogen and Reactive Phosphorus

Total phosphorus is only one piece of the nutrient management puzzle. Nitrogen is an important nutrient that has also been identified by the 2009 Lake Management Plan (LMP), and the LMP also requires that an inventory for nitrogen also be developed. It is also important to note that not all phosphorus that enters the lake is utilized by plankton and aquatic vegetation. A significant (and unquantified) fraction of total phosphorus that enters the lake settles into the sediments. Loading of the more bioavailable phosphorus fractions (e.g. the fraction that is soluble in water and/or available for plankton uptake) is expected to have a larger direct influence on productivity and subsequent biologic processes than loading of total phosphorus.

This report excluded analyses of nitrogen and reactive phosphorus (bioavailable fraction), focusing instead on the higher priority need to develop a basin-wide inventory for total phosphorus. An understanding of the sources that produce nitrogen and/or reactive phosphorus (bioavailable) is also needed help to prioritize nutrient management actions so that they more directly address key lake processes. Additional analyses, including both statistical analysis of existing data and potential future monitoring studies, would help fill this information gap.

Calibration and Validation Data for Geospatial Modeling

It is infeasible to measure all of the nutrient sources in the Coeur d'Alene Basin in a manner that is both geographically comprehensive and allows appropriate intercomparison between subbasins and their watersheds. Geospatial models are required. These models are also needed to forecast future conditions and evaluate various management scenarios. DEQ currently lacks sufficient field data to team with our partners to develop and test these models at an appropriate scale that accounts for localized influences. Additional data collection at the watershed and subbasin scale can help to develop models and further inform nutrient management actions.

4.3 Recommendations

This nutrient inventory is only one step in the adaptive management approach to managing nutrients in the Coeur d'Alene Basin. Additional nutrient loading assessments, including potential future field work, will need to be done in the future as part of this process. Such assessments should be made as new data becomes available for the respective source(s) and/or subbasin. The inventory should be updated regularly to support adaptive management.

A number of data gaps have been identified. It will also be important to assess the influences of ongoing remedial, restoration, and water quality management activities; to better inform nutrient management decisions. This subsection provides some preliminary recommendations for future work. These preliminary recommendations have been developed in response to stakeholder input, and are presented only as considerations for future nutrient management actions. This list is not comprehensive or exclusive, and should be treated only as a preliminary summary. These recommendations are presented according to the subbasins to which they apply.

Coeur d'Alene River subbasin

This inventory has identified the Coeur d'Alene River as a priority for nutrient management action. Trend analyses of Coeur d'Alene Lake show a clear demarcation in trend directions north of the Coeur d'Alene River outlet. This subbasin has some of the highest phosphorus yields in the basin and shows the greatest evidence for potential increases in nutrient loading relative to calendar years 1991 – 1992. Work in this subbasin should focus on both addressing data gaps and conducting nutrient reduction activities in alignment with current findings.

There are five primary data gaps for the Coeur d'Alene River subbasin, encompassing both preventative and restorative needs. These data needs are enumerated below.

1. Identification and quantification of nutrient sources on the main stem of the Coeur d'Alene River downstream of Cataldo, including seasonal influences.
2. Identification and quantification of the relative influences of the Bunker Hill Central Impoundment Area, Government Creek, surface runoff, storm water, and all point source discharges on nutrient loading along the stretches of the South Fork of the Coeur d'Alene River (SFCDR) with high nutrient yields, including seasonal influences and influences of wastewater management and remedial actions at the Bunker Hill site.
3. Improved nutrient loading information from municipal wastewater sources.
4. Preliminary assessment of the relative impact of nutrient loading from surface run-off and storm water outflows along the urbanized regions of the SFCDR.
5. Preliminary assessment of the potential influence of continued recreational development along the North Fork Coeur d'Alene River and Main Stem Coeur d'Alene River. Watersheds in this drainage are experiencing growing development pressure, potentially increasing phosphorus yields over the historic baseline. Only minimal nutrient information is available for the large North Fork Coeur d'Alene River watershed upstream of the USGS monitoring site at Enaville.

Extensive remediation, restoration, and streambank protection work is being conducted within the Coeur d'Alene River subbasin through a broad array of programs and authorities. Much of this work likely has a beneficial impact on nutrient dynamics. This report recommends that these actions continue, and that additional effort be taken to assess the nutrient management benefits. There is currently insufficient knowledge to assess the relative benefits of ongoing and proposed actions along the Coeur d'Alene River. This report recommends that nutrient monitoring be conducted to assess the influences of these efforts, and that monitoring plans help discriminate between sources that are and are not associated with remediation and restoration actions. Priority monitoring needs include net phosphorus discharge from the Bunker Hill Central Treatment Plant, monthly nutrient reporting from municipal WWTP's in this subbasin, assessment of the nutrient benefits of sediment control activities, and assessment of the nutrient reduction benefits of stream and wetland restoration projects. Additional beneficial information needs include analysis of potential storm water contributions to nutrient loading to the SFCDR and assessment of the nutrient impacts of recreational development throughout the subbasin.

St. Joe River subbasin

This inventory has identified the St. Joe River as a major contributor of nutrients to Coeur d'Alene Lake; but has not clearly identified nutrient loading "hotspots". However, elevated yield has been reported for Carpenter Creek and the confluence region of the St. Joe River, between LMP monitoring stations and the USGS gage at the St. Joe River outlet. Extensive forest harvest activities have occurred along numerous watersheds in this subbasin, but current data cannot yet clearly quantify what influence those activities have on nutrient loading. Restoration and bank protection activities are also ongoing in the St. Joe River subbasin, and likely also supporting nutrient reduction objectives. Though, as with the Coeur d'Alene River, there is insufficient information to assess the nutrient benefits of these activities.

This report recommends that these restoration and bank protection activities continue, that greater emphasis be placed on quantifying their nutrient reduction impacts; and that municipal WWTP's in this subbasin report monthly nutrient loads. It is also important to better quantify the influence of forest management activities on nutrient loading within this subbasin.

Coeur d'Alene Lake tributaries subbasin

This inventory has identified the Coeur d'Alene Lake tributaries as a major data gap. These tributaries have an important influence on the lake, but there is insufficient information to adequately quantify their nutrient load and prioritize nutrient management activities. This report recommends that these loads be quantified as expeditiously as is practicable. Also, there are a number of proposed and ongoing stream restoration and bank protection projects that likely provide nutrient reduction benefits. This report recommends that these projects continue, and that greater emphasis be placed on quantifying their nutrient reduction benefits.

The lake is experiencing rapid development pressure, and nutrient additions can originate from a different mix of sources than for a river and stream system. Recreational boating can produce "grey water" waste, enhance bank erosion, and even disturb lake sediments in shallow bays. These can impact nutrient levels in the lake. Higher housing density along the lake watersheds

and lakeshore drainages can lead to greater influences from roads, lawns, roofs, and other impermeable surfaces; and also provide opportunities to transition from older wastewater systems to more protective modern wastewater systems; for both individual septic and larger scale community systems. This report recommends developing innovative solutions that help account for these unique lake-based influences as well as more traditional projects. Additional monitoring may be needed. Also, continued effort should be made to upgrade community wastewater systems and transition homes away from older, less protective septic systems.

Basin-wide influences

In addition the influences on nutrient management that are specific to a subbasin or watershed, there are also more general basin-wide influences. These include atmospheric deposition, land use, roads, septic systems, and fire risk. Little information is available about the influences of these factors on nutrient management within the basin, yet the magnitude of their potential impacts could outweigh the beneficial effects of many smaller projects. This report has identified atmospheric deposition as an important data gap. Additionally, the influence of atmospheric deposition on the lake and surrounding basin could be changing in response to climate change and recreational development. Continued uncertainty in this parameter will make it more difficult to assess progress in nutrient management goals.

This report has also noted that the impacts of housing and recreational development around the lake may not be captured by satellite imagery that is typically used to assess land use influences. More localized information on nutrient loading from watersheds with a range of land uses can help to better understand and manage this influence. This report recommends that future analyses of tributary loading assess influences of land use, roads, and impermeable surfaces.

This report has not assessed the potential influence of wildfire on nutrient loading to the lake, but it is generally accepted that large wildfires can severely degrade water quality and alter the nutrient dynamics of impacted watersheds. This report also recommends that efforts be taken to assess the potential influences of wildfire on nutrient loading to the lake, and that mitigating future wildfire impacts to the lake be appropriately incorporated into nutrient management plans.

5 Additional Information

This section provides a summary of the data and calculations used to develop the loading estimates for the St. Joe River subbasin, and also a summary of internal loading from Coeur d'Alene Lake sediments. Internal loading is an important source of nutrients to the overlying waters, but originates within the Lake. This inventory assesses loading from sources outside the Lake.

5.1 Internal Loading

This report conducts a basin-scale analysis of how nutrients are entering the lake-sediment system. The flux of nutrients from the sediments is treated as an internal response rather than an external load. Internal loading from lake sediments is an important contributor to nutrient concentrations in the overlying waters, particularly in the southern regions of the Lake where summer oxygen levels in the bottom waters routinely drop below 5 mg/L. This sub-section assesses the relative magnitude of nutrient loading from lake sediments relative to other inputs. The potential impacts of reduced oxygen levels that may result from eutrophication and climate change are also briefly discussed.

Kuwabara et. al. (2000) conducted a study measuring the benthic flux of metals and nutrients from Coeur d'Alene Lake sediments using both *in situ* chamber and laboratory sediment incubation techniques. The implications of these measurements toward Coeur d'Alene Lake nutrient management is discussed in a subsequent paper (Kuwabara et. al., 2003). The objective of these studies was to evaluate the potential importance of nutrient and metal release from the sediments, not to quantify actual lake-wide flux under current conditions. Consequently, these studies' methods were only partially representative of in-lake conditions and results were not contrasted with internal loading estimates that could be calculated from changes in bottom water concentrations using field monitoring data. Results from these incubations with respect to the benthic flux of phosphorus are summarized in Table 18.

Kuwabara et. al. (2000, 2003) concluded that benthic flux from the sediments is an important source of nutrients to the overlying waters. They also report that this conclusion is consistent with observed depth profiles of total phosphorus in the overlying water at these two sites. The *in situ* chamber measurements are considered to be more reflective of the true system than the laboratory cores. If the estimated annual load from these incubations is used, then they would be equivalent to approximately 5 – 10% of the estimated annual load of total phosphorus, from all sources, for a "typical" year in the current period. The flux from shallower, warmer sediments in the southern lake that experience seasonal hypoxia may be higher than in the *in situ* sites and more comparable to the sediment core values. This conclusion arises from the observation that phosphorus flux from the core incubations was much greater in anoxic (argon-purged) incubations than in oxic (aerated) core incubations.

Kuwabara et. al. (2000, 2003) also report that the magnitude of the annual load of soluble ortho-phosphorus from the St. Joe River and Coeur d'Alene River is less-than or equivalent-to the flux from the benthic sediments. This report does not evaluate the loading of reactive phosphorus. This conclusion of Kuwabara et. al. (2000, 2003) is consistent with the results of this study, assuming that ortho-phosphorus typically ranges from 10% – 35% of total phosphorus in the St.

Joe and Coeur d'Alene Rivers. Kuwabara et. al. (2000, 2003) also report that the sediments of Coeur d'Alene Lake are a net sink for phosphorus. Phosphorus is released from the sediments into the overlying water; but it is dominantly captured by the lake's biological cycling and subsequently returned to the sediments or otherwise retained within the Lake system.

Internal loading from lake sediments is not a process that can be easily managed at the scale of Coeur d'Alene Lake. Active intervention is not likely to be feasible at this large a scale. Consequently, this aspect of the lake's phosphorus balance may best be viewed as a potential accelerant of change. If oxygen levels decline to a low enough level, then additional phosphorus will be released. This will tend to elevate productivity, increase carbon supply, and accelerate eutrophication. This process has been observed in isolated locations within the lake – where unique local conditions create lake microcosms that go anoxic during the stratified summer months. These microcosms have elevated phosphorus levels and elevated productivity relative to the adjacent regions of the lake (unpublished data, Craig Cooper Idaho Department of Environmental Quality; Dale Chess, Coeur d'Alene Tribe). Internal loading is currently a small part of the overall phosphorus load in the regions of the Lake where bottom water oxygen remains high, roughly equivalent to the magnitude of atmospheric deposition or total municipal wastewater. However, internal loading may contribute a much larger proportion of the total load to regions of the lake and lower rivers where bottom water oxygen drops below 3 – 5 mg/L during summer stratification. This load is a part of the lake's phosphorus balance that can grow rapidly if bottom water oxygen levels drop to sufficiently low levels.

Table 18 Range of phosphorus benthic flux rates from the studies of Kuwabara et. al. (2000, 2003) and estimates of load from sediments into Coeur d'Alene Lake.

	Incubation Data (ortho-phosphorus) [4]			Associated Annual Load [5]	
	Average (µg P/cm^2*yr)	standard error	# samples	Average load (tons/yr)	Range (tons/yr)
***In Situ* Chamber Incubations**					
Mica Bay [1]	20	20	2	25	0 - 50
Main Channel [2]	7	2	3	9	5 - 11
Laboratory Core Incubations [3]					
Mica Bay cores - aerated	50	30	3	60	20 - 100
Mica Bay cores - argon purged	150	10	3	180	170 - 200
Main Channel cores - aerated	90	30	3	110	60 - 130
Main Channel cores - argon purged	140	120	3	170	20 - 320

1. Located in the central region of Mica Bay, 17 km from the mouth of the Coeur d'Alene River, 27 m of water.
2. Located in the in main lake off of University Point near Rockford bay, 7 km from the mouth of the Coeur d'Alene River, 33 m of water.
3. Aerated cores continuously had oxygen in the overlying water, argon-purged cores went anoxic.
4. Units of µg/cm2*yr are equivalent to units of metric tonnes/km2*yr, 1 metric tonne = 1.1 US short ton.
5. Based on lake area of 334 km2 (129 mi2) and assumes rate is constant across the entire lake for the summer stratified period.

5.2 Load Estimates for the St. Joe and St. Maries Rivers

This section describes the calculations used to estimate nutrient loading from the St. Joe River subbasin nutrient loading study conducted by DEQ and the Tribe for water years 2010 – 2012. The methods used for this study are described in the Work Plan (DEQ and Tribe, 2010). Supporting data, LOADEST model inputs, and LOADEST model output are provided in Appendix E.

In summary, water samples were collected at the stations shown in Section 2.3 (Table 7, Figure 14) at 10 – 12 sampling events during water years 2010 – 2012. The samples were analyzed for nutrient concentration (N, P), suspended sediments, and standard water quality parameters. Some flow measurements were also made during sampling events. Mean daily flow for each monitoring site was estimated by indexing to flows reported by the USGS at the closest USGS gauge. Nutrient loads were then estimated using nutrient data and estimated flows with the USGS LOADEST model (Runkel et. al., 2004). Responsibility for field sampling was split between DEQ and Tribe staff as follows (see map in Section 2.3, Figure 14).

- **Tribe sites**— Carpenter Ck (SJ-4), Emerald Ck (SJ-5), Upper St. Maries River (SJ-6)
- **DEQ sites**— St. Joe River at St. Joe City (SJ-1), St. Maries River at Lotus (SJ-7), St. Maries River near Santa (SJ-2), Santa Ck (SJ-3)

Active USGS gauges are located along the St. Joe River at Calder, upstream from the St. Joe City monitoring site and on the St. Maries River at Santa, slightly upstream of the confluence with Santa Creek. Tribe staff collected more flow measurements at their monitoring sites than DEQ, and are better able to verify the accuracy of their flow estimates.

This project had a number of logistical constraints associated with sampling in remote, mountainous terrain under challenging weather and field conditions. The resultant dataset is sparse and subject to potential error and bias. However, the phosphorus dataset encompasses a wide range of field conditions; including a representative range of stream flows at both high- and low- flow conditions to the maximum extent that is logistically feasible. Special efforts were made to collect samples during high flow conditions during spring runoff and rain-on-snow events. LOADEST calculations were also cross-checked by contrasting with results from direct calculations that use an average phosphorus stream concentration for a specific range of stream flows at each monitoring site. These cross-check calculations yielded similar results to LOADEST calculations.

5.2.1 Load Calculations at Coeur d'Alene Tribe Monitoring Sites

Daily loading estimates were calculated for the St. Maries River above Fernwood (SJ-6), Emerald Creek (SJ-5) and Carpenter Creek (SJ-4). These sites were not gauged and required estimation of daily discharge (Q) to estimate phosphorus loading for the 2010-2012 water years. Methods to estimate loading at the above-mentioned sites are described below. The first part of the method consisted of estimating the daily Q, and the second part consisted of applying the USGS, LOADEST software (Runkel et al. 2004) to estimate daily phosphorus loading. Discharge (Q) was measured and nutrient samples were collected at each stream/river site on 10

sample dates from 3/24/2010 through 4/27/2012. Sampling dates were selected based on a combination of rain-on-snow events, high spring discharge (ascending and falling limb) and late summer base flow using methods described in the project work plan (DEQ and Tribe, 2010).

Discharge Estimation at Coeur d'Alene Tribe Monitoring Sites

Daily discharge was estimated for the St. Maries River above Fernwood (SJ-6) using the discharge relationship between site SJ-6 and the gauged St. Maries River at Santa (USGS gauge# 12414900), (Figure 33). The relationship of SJ-6 with gauge 12414900 was not linear at the lowest discharges (<41 CFS), creating estimated discharges at SJ-6 that were consistently greater than the discharge at the downriver gauge 12414900 at Santa. To correct for this bias, estimated discharges at SJ-6 were multiplied by the mean proportion of discharge at SJ-6 to gauge 12414900 at Santa when discharges were >40 CFS. This adjustment was done for the 20 lowest discharges of the total 1,096 estimated daily discharges for SJ-6.

Daily discharge of the non-gauged Emerald Creek (SJ-5) and non-gauged Carpenter Creek (SJ-4) were estimated by the drainage-area ratio method. First, the estimated daily discharge at Upper St. Maries river (SJ-6) was subtracted from the daily discharge at the gauge 12414900 at Santa. The difference in discharge was then multiplied by the proportion of sub basin area of Emerald Creek and Carpenter Creek in relation to all of the sub basins between gauge 12414900 at Santa and the upper St Maries River at SJ-6.

The estimated vs. measured discharge results for SJ-6, SJ-5 and SJ-4 from the above-mentioned methods are presented in Figure 34. In Figure 34, the estimated results are on the x-axis and the measured results on the y-axis, following the recommendations of Piñeiro (2008). In the same figures the red dashed line is the 1:1 ratio (slope=1) providing visual assessment of positive or negative bias. To evaluate the regression model's ability to estimate Q the estimated vs. measured Q results for SJ-4, SJ-5 and SJ-6 were each tested to determine if their slopes were equal to 1 (Warton et al. 2012). Summary results for this test (Table 19), reveal the relationship for Emerald Creek (SJ-5) produces a slope significantly different (P=0.023) than a slope of 1, indicating more estimation bias from SJ-5 compared to the St. Maries River (SJ-6) and Carpenter Creek (SJ-4).

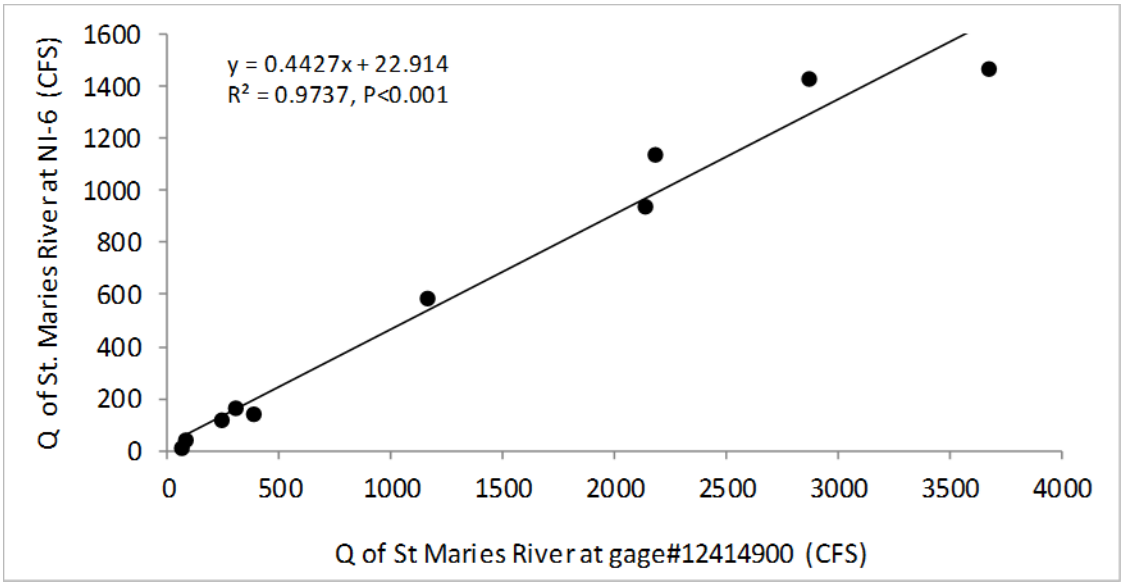


Figure 33. Discharge relationship between upper St. Maries River at site SJ-6 and the gauged St. Maries River at Santa (USGS gauge# 12414900).

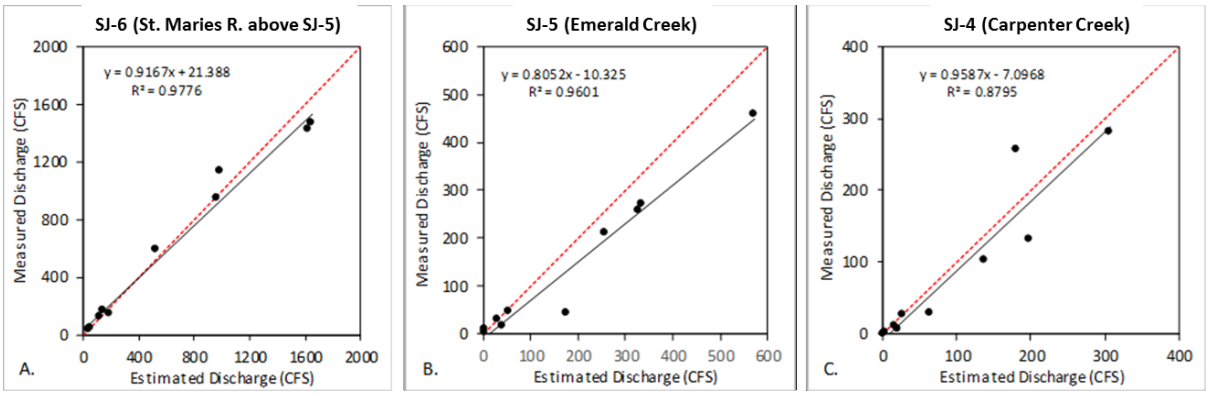


Figure 34. Estimated versus measured discharge for the upper St. Maries River SJ-6 (A), Emerald Creek SJ-5 (B) and Carpenter Creek SJ-4(C), (Red dashed line is the 1:1 ratio line).

Table 19 Summary statistics from the test of the regression slope is equal to 1 (1:1 ratio between estimated and measured discharge (Bold P-values are significant at α= 0.05).

	St. Maries River above Fernwood (SJ-6)	Emerald Creek (SJ-5)	Carpenter Creek (SJ-4)
n	10	10	10
r^1	-0.452	-0.704	0.064
P-value	0.190	**0.023**	0.862

Total Phosphorus Load Estimation at Coeur d'Alene Tribe Monitoring Sites

The USGS loading estimation software, LOADEST (Runkel et al. 2004) was used to calculate the daily loads from the estimated daily discharge (Q), and the measured Q and total phosphorus (TP) concentration relationships from sites SJ-6, SJ-5 and SJ-4. LOADEST requires at least 12 observations of concentration and Q in the calibration data set. Total phosphorus and Q were measured ten times at SJ-6, SJ-5 and SJ-4, not enough to run LOADEST. To increase the sample size from 10 to the minimum of 12 samples required by LOADEST, we used the TP versus Q relationship with 95% confidence intervals to estimate new TP and associated Q values for each site (Figure 35). The new TP and Q values were produced by randomly selecting Q values from the range of Q measured during sampling events at each site. The randomly derived Q values were then used to predict new TP values from the regression relationship (Figure 35). The predicted TP values were randomly selected from the distribution of values within the 95% confidence intervals (prediction intervals), (Bowerman and O'connell 1990). Multiple sets of two new TP and Q observations were added to the original 10 measured TP and Q values producing unique calibration files for each site. Multiple calibration files for each site were produced to support multiple loading estimation runs with LOADEST.

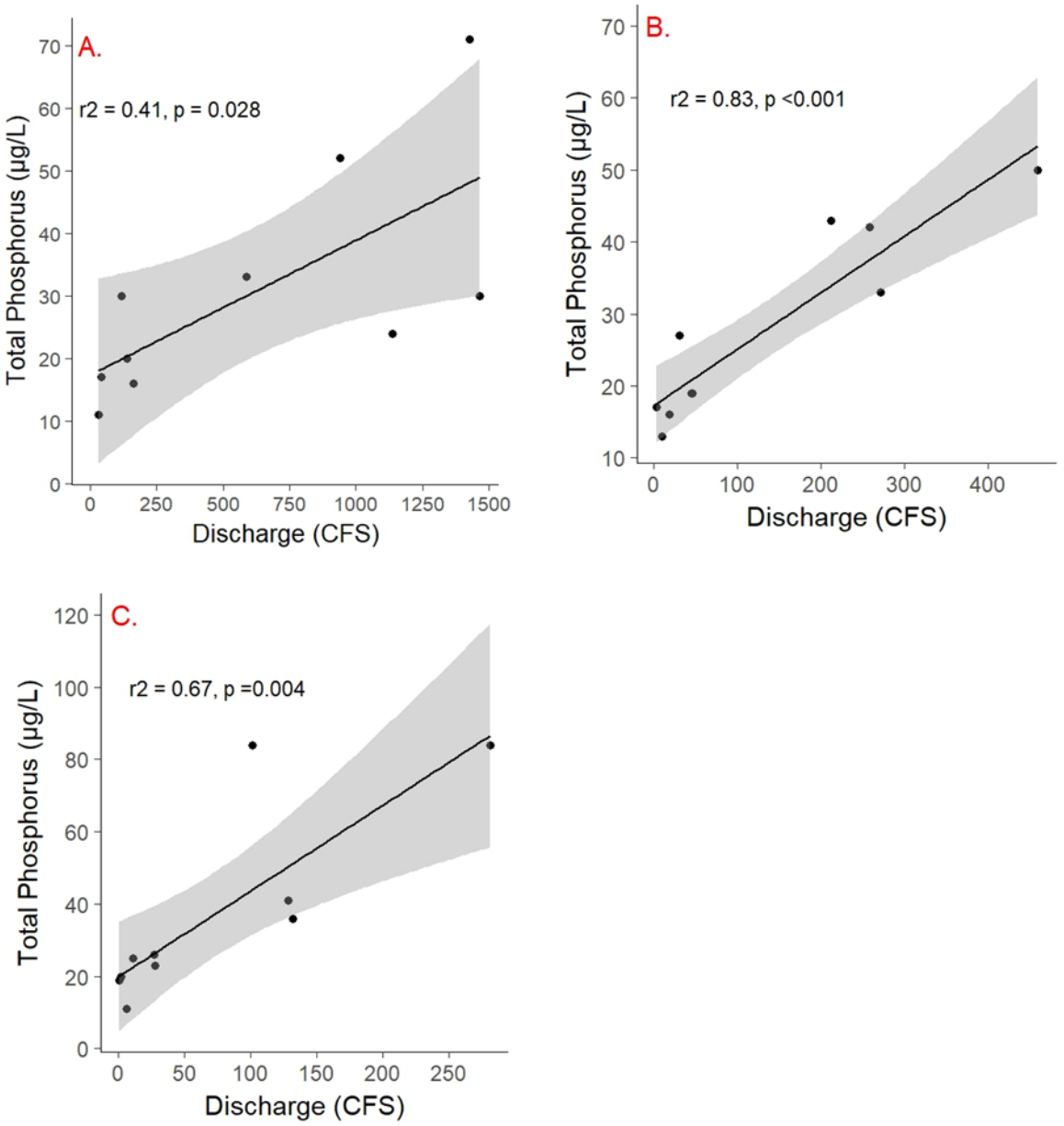


Figure 35. Total phosphorus versus discharge for the upper St. Maries River SJ-6 (A), Emerald Creek SJ-5 (B) and Carpenter Creek SJ-4 (C), (shaded area is the 95% confidence interval for predicted total phosphorus).

5.2.2 Load Calculations at DEQ Monitoring Sites

To the extent possible, loads at DEQ monitoring sites were calculated using the same methods as for the Coeur d'Alene Tribe monitoring sites. However, a representative set of discharge measurements was not taken at DEQ monitoring sites. There is insufficient field data to either (i) develop a linear index between the monitoring site and a USGS stream gauge, or (ii) validate the assumption that flow at a field monitoring location can be reliably estimated by an area ratio to the nearest USGS stream gauge. Consequently, the discharge estimation method used for Tribe monitoring sites cannot be utilized at DEQ monitoring sites.

Discharge Estimation at DEQ Monitoring Sites

A limited set of five discharge measurements was taken at Santa Creek (SJ-3). These measurements were all taken in WY 2010, which was a low-flow year that is not representative of stream conditions over the 3-year study period (WY 2010 – 2012). A comparison between field discharge measurements and discharge predictions from an area ratio between Santa Creek (SJ-3) and the USGS stream gauge for the St. Maries River at Santa (gauge# 12414900) is provided in Figure 36. This comparison shows the following.

- The field discharge measurements taken at Santa Creek (SJ-3) are consistently lower than those predicted by the area ratio method (Figure 36 A)
- The discharge measurements at Santa Creek (SJ-3) all occurred at lower flows. No flow measurements were collected during the higher flow years of 2011-2012 (Figure 36 B), and thus this field discharge dataset is not representative of the study period.

These results show that the area ratio method cannot be reliably used to estimate mean daily flows for Santa Creek. This finding, combined with the lack of discharge measurements for the other DEQ monitoring sites (SJ-1, SJ-2, SJ-7), suggests that the area ratio method may not be reliable at some or all of these sites. The DEQ work plan for this study was predicated on the assumption that an area ratio between DEQ monitoring stations and the nearest USGS stream gauge would predict discharge to the level of accuracy needed for this study. The results for Santa Creek (SJ-3) suggest that this assumption cannot be made for all sites (though it may be accurate for some), and that another method for estimating mean daily discharge is needed.

The area ratio method for correlating watersheds assumes that the difference in discharge between two watersheds is only dependent on watershed area. Other geomorphic factors, such as differences in slope and ground water infiltration, are assumed to be insignificant. An alternate method that better accounts for these differences would generate a better correlation. One option is to use a statistical correlation that accounts for watershed area and other geomorphic factors.

The USGS StreamStats model (*http://streamstats.usgs.gov/*) provides estimates of discharge statistics for user-defined watersheds. Predictions of discharge at ungauged sites can be made using regression equations between the site and gauged streams, using a broad range of geomorphic factors (Ries et. al., 2008; Ries et. al., 2004). Comparing StreamStat flow statistics for the monitoring site to those for the nearest USGS stream gauge provides an alternate method to index mean daily flow at an ungauged site to that at a gauged site. A summary of the discharge statistics available for the DEQ monitoring sites from StreamStats v4 is provided in Table 20.

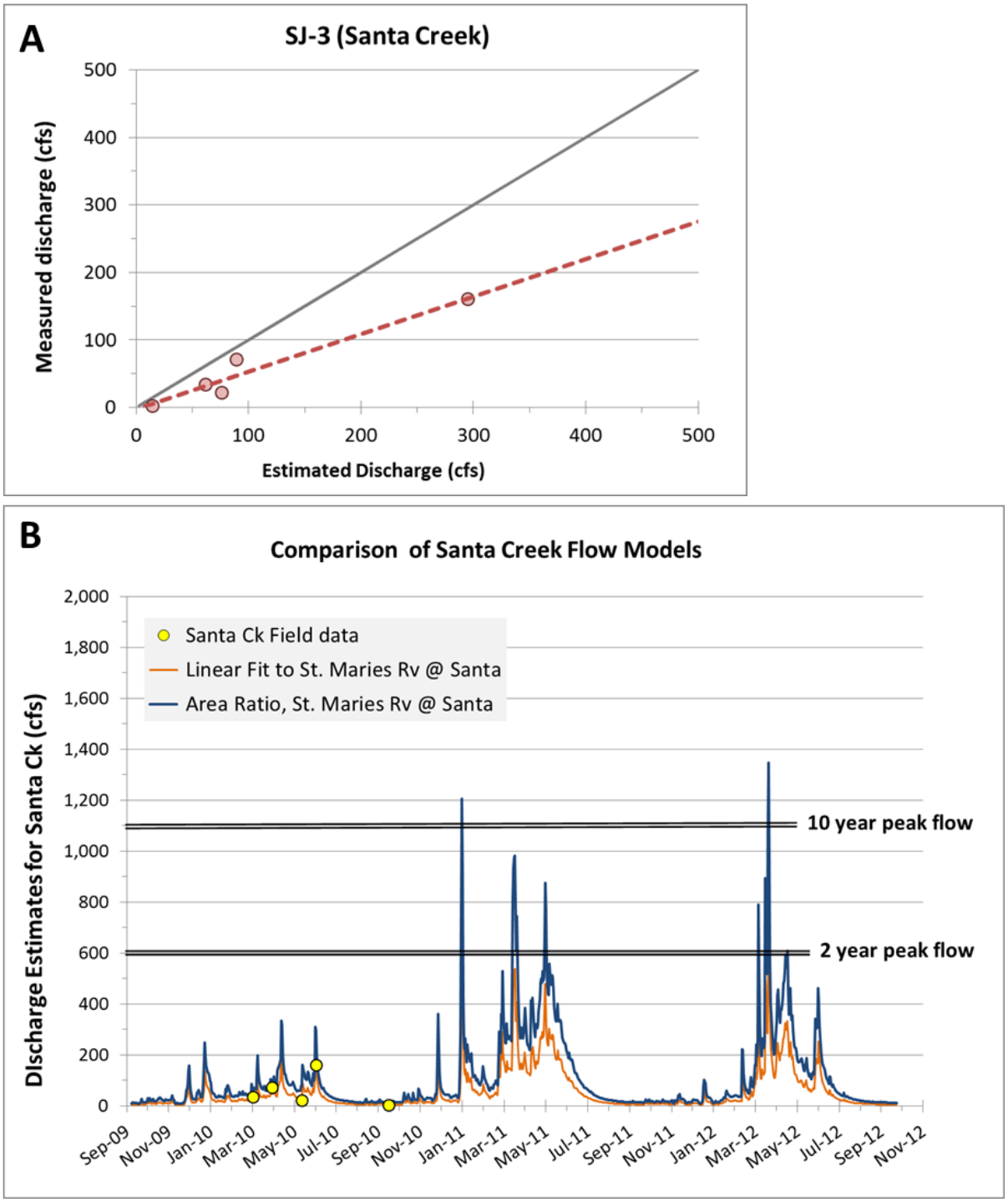


Figure 36. Santa Creek discharge measurements versus discharge estimated from area ratio to USGS gauge for the St. Maries River at Santa (A), and comparison of discharge estimates for the period of the St. Joe study (B).

Table 20 StreamStats v4 flow predictions for DEQ monitoring sites (SJ-1, SJ-2, SJ-3, SJ-7) and USGS stream gauges for the St. Joe River at Calder (#12414500) and the St. Maries River at Santa (#12414900).

Streamflow Statistic	USGS Gauge #12414500 St. Joe River at Calder (cfs)	USGS Gauge #12414900 St. Joe Maries at Santa (cfs)	DEQ Monitoring Site SJ-1 St. Joe River at St. Joe City (cfs)	DEQ Monitoring Site SJ-2 St. Maries River near Santa gage (cfs)	DEQ Monitoring Site SJ-3 Santa Creek (cfs)	DEQ Monitoring Site SJ-7 St. Maries River at Lotus (cfs)
High Flows						
1.25 yr flood	10,400	2,080	10,900	2,030	403	2,790
1.5 yr flood	11,900	2,450	12,400	2,390	489	3,280
2 yr flood	13,700	2,930	14,300	2,850	601	3,900
2.33 yr flood	15,000	3,220	15,600	3,140	670	4,290
5 yr flood	18,700	4,210	19,500	4,100	914	5,570
10 yr flood	21,300	4,950	22,200	4,830	1,110	6,520
25 yr flood	25,000	5,950	26,000	5,810	1,370	7,800
50 yr flood	27,600	6,700	28,700	6,540	1,570	8,740
Low Flows						
1day 10 yr	179	28.7	188	27.7	5.76	41.5
7 day 2 year	337	56.0	354	54.0	11.5	81.2
7 day 10 year	232	37.1	244	35.7	7.36	54.0
30 day 5 year	298	50.1	313	48.3	10.3	72.7

The ratio between the discharge predicted by StreamStats v4 between the ungauged watershed (i.e. SJ-1, SJ-2, SJ-3, SJ-7) and the closest corresponding gauge can be used to estimate discharge similarly to a watershed area ratio. The StreamStats ratios for the DEQ monitoring sites are given in Table 21. Watershed area ratios are also given. Note that the StreamStats ratio can vary with discharge while the watershed area ratio does not. Also, the StreamStats ratio is similar to the watershed area ratio for SJ-1 and SJ-2, but not for SJ-3 and SJ-7.

Mean daily flows for DEQ monitoring sites were estimated from the StreamStat ratios using the same approach as is used for a watershed area ratio.

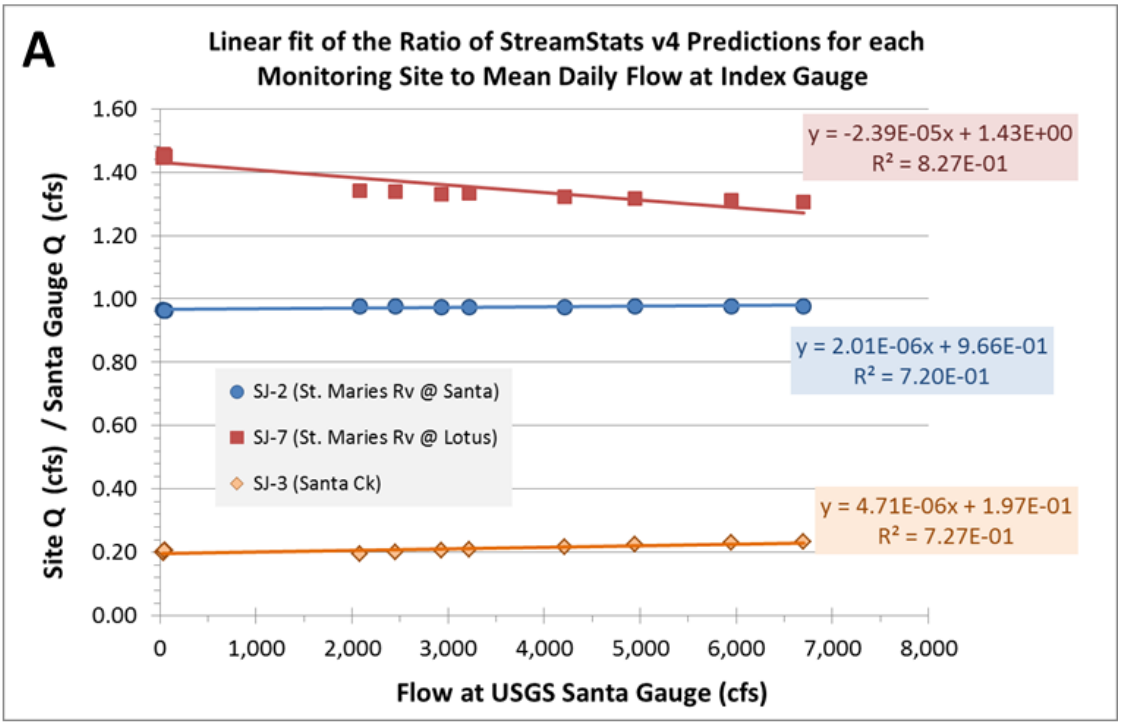
mean daily flow at ungauged site = mean daily flow at index gauge * StreamStat ratio

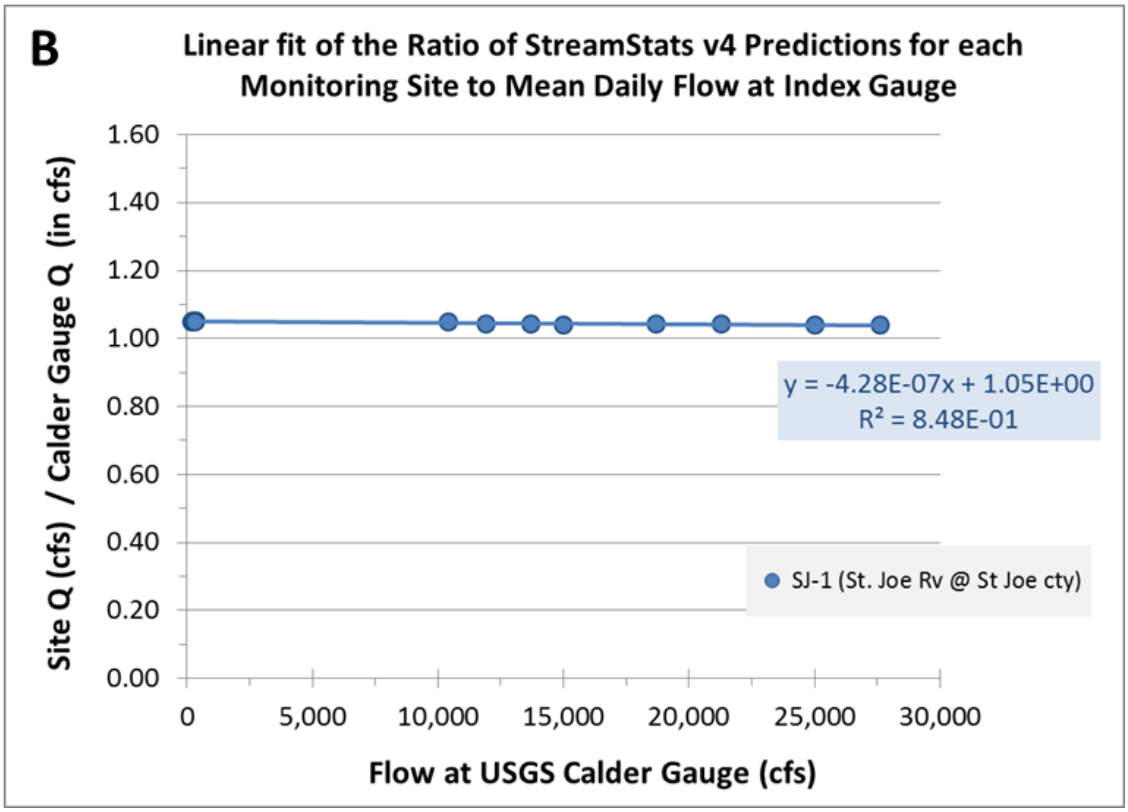
This StreamStat ratio in this equation varies with flow at the index gauge, and is derived from the StreamStats v4 predictions for each monitoring site (Table 20, Table 21) as a function of flow at the index gauge. These regressions are given in Figure 37 for sites SJ-1, SJ-2, SJ-3, and SJ-7.

Table 21 Ratio of StreamStat flow prediction to that of the reference gauge for DEQ sites (SJ-1, SJ-2, SJ-3, SJ-7). The watershed area ratio is also given as a reference.

Streamflow Statistic	StreamStat Flow Ratio cfs at SJ-1 / cfs at Calder gauge	StreamStat Flow Ratio cfs at SJ-2 / cfs at Santa gauge	StreamStat Flow Ratio cfs at SJ-3 / cfs at Santa gauge	StreamStat Flow Ratio cfs at SJ-7 / cfs at Santa gauge
High Flows				
1.25 yr flood	1.05	0.98	0.19	1.34
1.5 yr flood	1.04	0.98	0.20	1.34
2 yr flood	1.04	0.97	0.21	1.33
2.33 yr flood	1.04	0.98	0.21	1.33
5 yr flood	1.04	0.97	0.22	1.32
10 yr flood	1.04	0.98	0.22	1.32
25 yr flood	1.04	0.98	0.23	1.31
50 yr flood	1.04	0.98	0.23	1.30
Low Flows				
1day 10 yr	1.05	0.97	0.20	1.45
7 day 2 year	1.05	0.96	0.21	1.45
7 day 10 year	1.05	0.96	0.20	1.46
30 day 5 year	1.05	0.96	0.21	1.45
Area Ratio	1.07	0.95	0.25	1.59

Figure 37. Linear regression of the ratio between the StreamStats v4 prediction of discharge at an ungauged site and discharge at the index gauge.

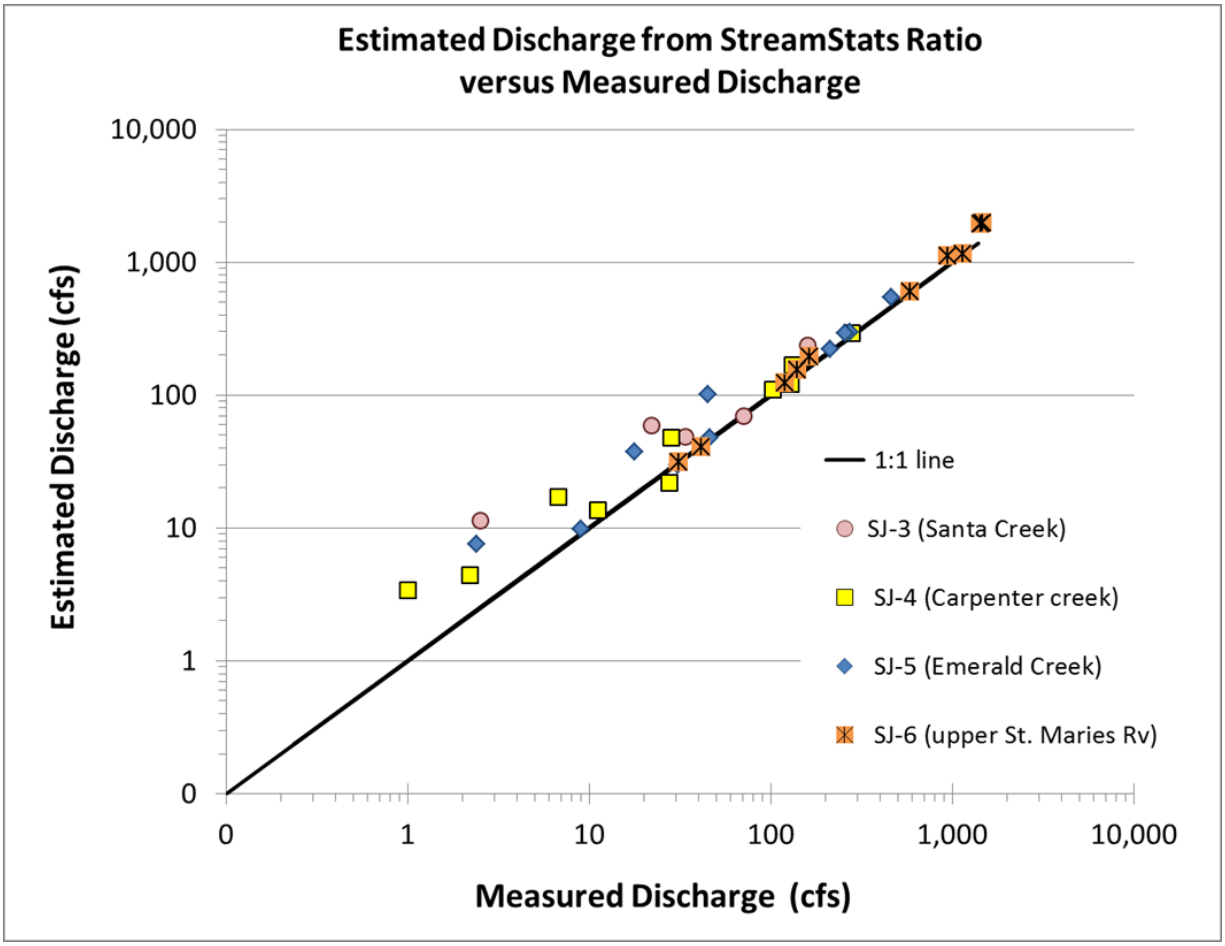




Discharge at each ungauged site was estimated from discharge at the index station and the StreamStat ratio, as calculated from a linear regression between the ratio of StreamStats v4 predictions and discharge at the index site. Sites SJ-2, SJ-3, and SJ-7 were indexed to the USGS gauge for the St. Maries River at Santa (#12414900). Site SJ-1 was indexed to the USGS gauge for the St. Joe River at Calder (#12414500). For sites SJ-1 and SJ-2, the StreamStat ratio varies very little with discharge and has a value equivalent to the watershed area ratio. For sites SJ-2 and SJ-7, the StreamStat ratio varies with discharge and is consistently less than the area ratio.

All discharge estimates for DEQ monitoring sites were made using the StreamStat ratio. Discharge estimates based on the StreamStat ratio were also made for Tribe monitoring sites for purposes of evaluating this approach for discharge estimation. A comparison of measured discharge to discharge estimates based on the StreamStat ratio for all sites where discharge measurements were taken is provided in Figure 38. The StreamStat ratio estimates generally fall along the 1:1 line for all sites, except for low discharges (less than ~10 cfs).

Figure 38. Comparison of estimated discharge from the StreamStats ratio method versus measured discharge for Santa Creek (SJ-3), Carpenter Creek (SJ-4), Emerald Creek (SJ-5), and the upper S.t Maries River (SJ-6).



Total Phosphorus Load Estimation at DEQ Monitoring Sites

The USGS loading estimation software, LOADEST (Runkel et al. 2004) was used to calculate the daily loads from (1) the estimated daily discharge (Q), and (2) the relationship between measured total phosphorus (TP) and estimated Q from the StreamStat ratio method for sites SJ-1, SJ-2, SJ-3, and SJ-7. LOADEST requires at least 12 observations of concentration and Q in the calibration data set. Total phosphorus and Q were measured 12 times at sites SJ-1, SJ-2, and SJ-3; but only nine times at site SJ-7. To reach the minimum number of 12 data points needed for LOADEST, three additional data points were modeled using methods previously described in Section 4.2.1.

Load estimates for this study are dependent on discharge estimates and the relationship between discharge and total phosphorus concentration. Discharge for this study was estimated from modeled flow data, and only minimal field measurements are available to verify model predictions. Load predictions are made using a minimum of phosphorus concentration data, with much of that data being biased toward higher flows. Consequently, estimates from this study are subject to considerable error, much of which is unquantifiable. Results from this study can only provide survey level data and should be used with caution. These estimated loads are of sufficient quality to estimate the relative magnitude of nutrient loading and prioritize watersheds for follow-on work. They are of insufficient quality to establish formal loads or load allocations.

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Appendix A. Supporting Information for the Coeur d'Alene River

Table A1. Total Phosphorus Load at Gauging Stations along the Coeur d'Alene River

CDA River Watersheds, total load (kg/yr) average (2009-2013)

Coeur d'Alene River Gauge	USGS Gauge #	area drained by gauge (km2)	Average Load 2009-2013 (tons/yr)	Average Load 2009-2013 (kg/yr)	lower 95% confidence interval (2009-2013)	upper 95% confidence interval (2009-2013)	TP Load SPARROW (kg/yr)
Coeur d'Alene River near Harrison	**12413860**	**3,770**	**93**	**84,820**	**55,030**	**126,060**	**51,730**
Coeur d'Alene River near Cataldo	12413500	3,130	60	54,540	34,260	83,500	39,550
NFCDR at Enaville	**12413000**	**2,315**	**40**	**36,320**	**23,620**	**53,940**	**27,930**
SFCDR near Pinehurst	**12413470**	**744.6**	**27**	**24,570**	**14,580**	**39,150**	**20,000**
Pine Ck below Amy Gulch	12413445	189.6	1.2	1,130	330	2,950	2,690
SFCDR above Pine Ck near Pinehurst	12413355	492.3	22	19,690	9,330	36,900	20,650
SFCDR at Smelterville	12413300	522.0	18	16,120	9,390	26,000	10,320
SFCDR at Kellogg	12413250	501.7	7.6	6,890	3,750	11,800	10,140
SFCDR at Elizabeth Park	12413210	471.9	7.7	6,950	3,910	11,560	9,830
SFCDR above Placer Ck at Wallace	12413131	218.0	2.6	2,350	1,390	3,780	5,370
9-mile Ck above mouth near Wallace	12413130	86.6	0.4	360	170	680	410
EF Ninemile Ck above mouth near Blackcloud	12413127	15.8	0.2	140	90	200	210
Canyon Ck (above mouth at Wallace)	12413125	56.7	0.4	390	240	580	950
SFCDR above Deadman Gulch (Mullan)	12413040	44.8	1.1	970	430	1,940	770

Table A1 (continued 1). Total Phosphorus Load at Gauging Stations along the Coeur d'Alene River

CDA River Watersheds, total load (kg/yr)			mid-flow			low-flow		
Coeur d'Alene River Gauge	**USGS Gauge #**	**area drained by gauge (km2)**	**TP Load 2009 (kg/yr)**	lower 95% confidence interval 2009	upper 95% confidence interval 2009	**TP Load 2010 (kg/yr)**	lower 95% confidence interval 2010	upper 95% confidence interval 2010
Coeur d'Alene River near Harrison	**12413860**	**3,770**	**57,610**	**38,920**	**82,370**	**28,760**	**19,600**	**40,820**
Coeur d'Alene River near Cataldo	12413500	3,130	48,440	30,840	73,120	21,320	14,240	30,840
NFCDR at Enaville	**12413000**	**2,315**	**22,680**	**15,690**	**32,020**	**10,250**	**7,440**	**13,880**
SFCDR near Pinehurst	**12413470**	**744.6**	**19,690**	**12,340**	**30,210**	**10,520**	**6,680**	**15,880**
Pine Ck below Amy Gulch	12413445	189.6	1,370	435	3,520	405	120	1,020
SFCDR above Pine Ck near Pinehurst	12413355	492.3	18,780	8,650	35,920	11,430	5,300	21,770
SFCDR at Smelterville	12413300	522.0	11,160	7,100	16,870	6,010	3,800	9,050
SFCDR at Kellogg	12413250	501.7	4,610	2,780	7,290	1,470	915	2,250
SFCDR at Elizabeth Park	12413210	471.9	4,820	2,960	7,480	1,710	1,070	2,590
SFCDR above Placer Ck at Wallace	12413131	218.0	3,140	1,610	5,540	1,480	770	2,670
9-mile Ck above mouth near Wallace	12413130	86.6	330	180	580	90	50	140
EF Ninemile Ck above mouth near Blackcloud	12413127	15.8	140	100	190	60	50	90
Canyon Ck (above mouth at Wallace)	12413125	56.7	340	340	510	290	130	320
SFCDR above Deadman Gulch (Mullan)	12413040	44.8	740	350	1,400	520	230	1,020

Table A1 (continued 2). Total Phosphorus Load at Gauging Stations along the Coeur d'Alene River

CDA River Watersheds, total load (kg/yr)

Coeur d'Alene River Gauge	USGS Gauge #	area drained by gauge (km2)	high-flow TP Load 2011 (kg/yr)	lower 95% confidence interval 2011	upper 95% confidence interval 2011	high-flow TP Load 2012 (kg/yr)	lower 95% confidence interval 2012	upper 95% confidence interval 2012
Coeur d'Alene River near Harrison	**12413860**	**3,770**	**154,220**	**98,880**	**232,240**	**119,750**	**76,840**	**178,710**
Coeur d'Alene River near Cataldo	12413500	3,130	102,510	62,320	162,390	69,220	44,810	102,510
NFCDR at Enaville	**12413000**	**2,315**	**73,570**	**46,270**	**112,490**	**53,800**	**34,650**	**80,380**
SFCDR near Pinehurst	**12413470**	**744.6**	**38,830**	**22,680**	**62,600**	**33,660**	**19,600**	**54,340**
Pine Ck below Amy Gulch	12413445	189.6	1,770	530	4,600	1,640	455	4,320
SFCDR above Pine Ck near Pinehurst	12413355	492.3	27,400	13,520	49,890	23,310	11,520	42,370
SFCDR at Smelterville	12413300	522.0	26,940	15,420	44,270	23,680	13,240	39,190
SFCDR at Kellogg	12413250	501.7	13,150	6,960	23,220	10,700	5,650	18,600
SFCDR at Elizabeth Park	12413210	471.9	12,520	6,910	21,320	10,800	5,870	18,330
SFCDR above Placer Ck at Wallace	12413131	218.0	3,470	2,200	5,230	2,440	1,600	3,570
9-mile Ck above mouth near Wallace	12413130	86.6	640	300	1,220	560	240	1,120
EF Ninemile Ck above mouth near Blackcloud	12413127	15.8	240	160	350	150	110	220
Canyon Ck (above mouth at Wallace)	12413125	56.7	560	330	880	460	260	730
SFCDR above Deadman Gulch (Mullan)	12413040	44.8	1,570	720	3,050	1,210	540	2,370

Table A1 (continued 3). Total Phosphorus Load at Gauging Stations along the Coeur d'Alene River

CDA River Watersheds, total load (kg/yr) mid-flow

Coeur d'Alene River Gauge	USGS Gauge #	area drained by gauge (km2)	TP Load 2013 (kg/yr)	lower 95% confidence interval 2013	upper 95% confidence interval 2013
Coeur d'Alene River near Harrison	**12413860**	**3,770**	**63,770**	**40,910**	**96,160**
Coeur d'Alene River near Cataldo	12413500	3,130	31,210	19,050	48,620
NFCDR at Enaville	**12413000**	**2,315**	**21,320**	**14,060**	**30,930**
SFCDR near Pinehurst	**12413470**	**744.6**	**20,140**	**11,610**	**32,750**
Pine Ck below Amy Gulch	12413445	189.6	450	110	1,290
SFCDR above Pine Ck near Pinehurst	12413355	492.3	17,510	7,690	34,560
SFCDR at Smelterville	12413300	522.0	12,790	7,390	20,590
SFCDR at Kellogg	12413250	501.7	4,510	2,450	7,650
SFCDR at Elizabeth Park	12413210	471.9	4,910	2,760	8,080
SFCDR above Placer Ck at Wallace	12413131	218.0	1,220	765	1,880
9-mile Ck above mouth near Wallace	12413130	86.6	190	90	360
EF Ninemile Ck above mouth near Blackcloud	12413127	15.8	100	60	160
Canyon Ck (above mouth at Wallace)	12413125	56.7	280	160	480
SFCDR above Deadman Gulch (Mullan)	12413040	44.8	830	300	1,880

Table A2. Incremental Phosphorus Load for Watersheds along the Coeur d'Alene River

CDA River Watersheds, incremental load (kg/yr) average (2009-2013)

Watershed (River Reach)	Watershed ID	incremental area (km2)	Average Load 2009-2013 (tons/yr)	Average Load 2009-2013 (kg/yr)	lower 95% confidence interval (2009-2013)	upper 95% confidence interval (2009-2013)	TP Load SPARROW (kg/yr)
Entire Coeur d'Alene River Basin	**--**	**3,770**	**93**	**84,820**	**55,030**	**126,060**	**51,730**
Main Stem CDR, Cataldo to Harrison	1	626	33	30,280	20,770	42,560	12,180
SFCDR, NFCDR confluence region	**2**	**71**	(7.0)	(6,350)	(3,940)	(9,590)	(8,380)
NFCDR at Enaville	**3**	**2,315**	**40**	**36,320**	**23,620**	**53,940**	**27,930**
SFCDR near Pinehurst	--	744.6	**27**	**24,570**	**14,580**	**39,150**	**20,000**
SFCDR and streams, Pine Ck to Pinehurst	4	18.0	4.1	3,750	4,920	(700)	(3,340)
Pine Ck above Amy Gulch	5	189.6	1.2	1,130	330	2,950	2,690
SFCDR and streams, Smelterville to Pine Ck	6	15.0	3.9	3,570	(60)	10,900	10,330
SFCDR and streams, Kellogg to Smelterville	7	20.3	10	9,230	5,640	14,200	180
SFCDR and streams, Elizabeth Park to Kellogg	8	29.8	(0.1)	(60)	(160)	240	310
SFCDR and streams, Wallace to Elizabeth Park	9	253.9	5.1	4,600	2,520	7,780	4,460
SFCDR and streams, Deadman Gulch to Wallace	10	86.6	0.7	630	550	580	3,240
WF Ninemile Ck, above mouth near Wallace	11	15.8	0.2	220	80	480	200
EF Ninemile Ck, above mouth near Blackcloud	12	14.1	0.2	140	90	200	210
Canyon Ck, above mouth at Wallace	13	56.7	0.4	390	240	580	950
SFCDR above Deadman Gulch (Mullan)	14	44.8	1.1	970	430	1,940	770

Table A2 (continued 1). Incremental Phosphorus Load for Watersheds along the Coeur d'Alene River

CDA River Watersheds, incremental load (kg/yr)

Watershed (River Reach)	Watershed ID	incremental area (km2)	mid-flow TP Load 2009 (kg/yr)	mid-flow lower 95% confidence interval 2009	mid-flow upper 95% confidence interval 2009	low-flow TP Load 2010 (kg/yr)	low-flow lower 95% confidence interval 2010	low-flow upper 95% confidence interval 2010
Entire Coeur d'Alene River Basin	**--**	**3,770**	**57,610**	**38,920**	**82,370**	**28,760**	**19,600**	**40,820**
Main Stem CDR, Cataldo to Harrison	1	626	9,170	8,080	9,250	7,440	5,360	9,980
SFCDR, NFCDR confluence region	**2**	**71**	6,070	2,810	10,890	550	120	1,080
NFCDR at Enaville	**3**	**2,315**	**22,680**	**15,690**	**32,020**	**10,250**	**7,440**	**13,880**
SFCDR near Pinehurst	--	744.6	**19,690**	**12,340**	**30,210**	**10,520**	**6,680**	**15,880**
SFCDR and streams, Pine Ck to Pinehurst	4	18.0	(460)	3,255	(9,230)	(1,315)	1,260	(6,910)
Pine Ck above Amy Gulch	5	189.6	1,370	435	3,520	405	120	1,020
SFCDR and streams, Smelterville to Pine Ck	6	15.0	7,620	1,550	19,050	5,420	1,500	12,720
SFCDR and streams, Kellogg to Smelterville	7	20.3	6,550	4,320	9,580	4,540	2,885	6,800
SFCDR and streams, Elizabeth Park to Kellogg	8	29.8	(210)	(180)	(190)	(240)	(155)	(340)
SFCDR and streams, Wallace to Elizabeth Park	9	253.9	1,680	1,350	1,940	230	300	(80)
SFCDR and streams, Deadman Gulch to Wallace	10	86.6	1,730	740	3,050	580	360	1,190
WF Ninemile Ck, above mouth near Wallace	11	15.8	190	80	390	30	0	50
EF Ninemile Ck, above mouth near Blackcloud	12	14.1	140	100	190	60	50	90
Canyon Ck, above mouth at Wallace	13	56.7	340	340	510	290	130	320
SFCDR above Deadman Gulch (Mullan)	14	44.8	740	350	1,400	520	230	1,020

Table A2 (continued 2). Incremental Phosphorus Load for Watersheds along the Coeur d'Alene River

CDA River Watersheds, incremental load (kg/yr)

Watershed (River Reach)	Watershed ID	incremental area (km2)	TP Load 2011 (kg/yr)	lower 95% confidence interval 2011	upper 95% confidence interval 2011	TP Load 2012 (kg/yr)	lower 95% confidence interval 2012	upper 95% confidence interval 2012
			high-flow			high-flow		
Entire Coeur d'Alene River Basin	**--**	**3,770**	**154,220**	**98,880**	**232,240**	**119,750**	**76,840**	**178,710**
Main Stem CDR, Cataldo to Harrison	1	626	51,710	36,560	69,850	50,530	32,030	76,200
SFCDR, NFCDR confluence region	**2**	**71**	(9,890)	(6,630)	(12,700)	(18,240)	(9,440)	(32,210)
NFCDR at Enaville	**3**	**2,315**	**73,570**	**46,270**	**112,490**	**53,800**	**34,650**	**80,380**
SFCDR near Pinehurst	--	744.6	**38,830**	**22,680**	**62,600**	**33,660**	**19,600**	**54,340**
SFCDR and streams, Pine Ck to Pinehurst	4	18.0	9,660	8,630	8,110	8,710	7,625	7,650
Pine Ck above Amy Gulch	5	189.6	1,770	530	4,600	1,640	455	4,320
SFCDR and streams, Smelterville to Pine Ck	6	15.0	460	(1,900)	5,620	(370)	(1,720)	3,180
SFCDR and streams, Kellogg to Smelterville	7	20.3	13,790	8,460	21,050	12,980	7,590	20,590
SFCDR and streams, Elizabeth Park to Kellogg	8	29.8	630	50	1,900	(100)	(220)	270
SFCDR and streams, Wallace to Elizabeth Park	9	253.9	9,050	4,710	16,090	8,360	4,270	14,760
SFCDR and streams, Deadman Gulch to Wallace	10	86.6	700	850	80	210	560	(650)
WF Ninemile Ck, above mouth near Wallace	11	15.8	400	140	870	410	130	900
EF Ninemile Ck, above mouth near Blackcloud	12	14.1	240	160	350	150	110	220
Canyon Ck, above mouth at Wallace	13	56.7	560	330	880	460	260	730
SFCDR above Deadman Gulch (Mullan)	14	44.8	1,570	720	3,050	1,210	540	2,370

Table A2 (continued 3). Incremental Phosphorus Load for Watersheds along the Coeur d'Alene River

CDA River Watersheds, incremental load (kg/yr) mid-flow

Watershed (River Reach)	Watershed ID	incremental area (km2)	TP Load 2013 (kg/yr)	lower 95% confidence interval 2013	upper 95% confidence interval 2013
Entire Coeur d'Alene River Basin	**--**	**3,770**	**63,770**	**40,910**	**96,160**
Main Stem CDR, Cataldo to Harrison	1	626	32,560	21,860	47,540
SFCDR, NFCDR confluence region	**2**	**71**	(10,250)	(6,620)	(15,060)
NFCDR at Enaville	**3**	**2,315**	**21,320**	**14,060**	**30,930**
SFCDR near Pinehurst	--	744.6	**20,140**	**11,610**	**32,750**
SFCDR and streams, Pine Ck to Pinehurst	4	18.0	2,180	3,810	(3,100)
Pine Ck above Amy Gulch	5	189.6	450	110	1,290
SFCDR and streams, Smelterville to Pine Ck	6	15.0	4,720	300	13,970
SFCDR and streams, Kellogg to Smelterville	7	20.3	8,280	4,940	12,940
SFCDR and streams, Elizabeth Park to Kellogg	8	29.8	(400)	(310)	(430)
SFCDR and streams, Wallace to Elizabeth Park	9	253.9	3,690	1,995	6,200
SFCDR and streams, Deadman Gulch to Wallace	10	86.6	(80)	215	(840)
WF Ninemile Ck, above mouth near Wallace	11	15.8	90	30	200
EF Ninemile Ck, above mouth near Blackcloud	12	14.1	100	60	160
Canyon Ck, above mouth at Wallace	13	56.7	280	160	480
SFCDR above Deadman Gulch (Mullan)	14	44.8	830	300	1,880

Table A3. Phosphorus Yield for Watersheds along the Coeur d'Alene River

CDA River Watersheds, yield (kg/km2) average (2009-2013)

Watershed (River Reach)	Watershed ID	incremental area (km2)	Average Yield 2009-2013 (lb/ha)	Average Yield 2009-2013 (kg/km2)	lower 95% confidence interval (2009-2013)	upper 95% confidence interval (2009-2013)	TP Yield SPARROW (kg/km2)
Entire Coeur d'Alene River Basin	**--**	**3,770**	**0.10**	**22**	**15**	**33**	**14**
Main Stem CDR, Cataldo to Harrison	1	626	0.22	48	33	68	19
SFCDR, NFCDR confluence region	**2**	**71**	(0.41)	(90)	(56)	(140)	(120)
NFCDR at Enaville	**3**	**2,315**	**0.07**	**16**	**10**	**23**	**12**
SFCDR near Pinehurst	--	744.6	**0.15**	**33**	**20**	**53**	**27**
SFCDR and streams, Pine Ck to Pinehurst	4	18.0	0.95	210	270	(39)	(190)
Pine Ck above Amy Gulch	5	189.6	0.03	6.0	1.7	16	14
SFCDR and streams, Smelterville to Pine Ck	6	15.0	1.09	240	(4.0)	730	690
SFCDR and streams, Kellogg to Smelterville	7	20.3	2.04	450	280	700	8.9
SFCDR and streams, Elizabeth Park to Kellogg	8	29.8	(0.01)	(2.0)	(5.4)	8.0	10
SFCDR and streams, Wallace to Elizabeth Park	9	253.9	0.08	18	10	31	18
SFCDR and streams, Deadman Gulch to Wallace	10	86.6	0.03	7.3	6.4	6.7	37
WF Ninemile Ck, above mouth near Wallace	11	15.8	0.06	14	5.1	30	13
EF Ninemile Ck, above mouth near Blackcloud	12	14.1	0.05	9.9	6.4	14	15
Canyon Ck, above mouth at Wallace	13	56.7	0.03	6.9	4.2	10	17
SFCDR above Deadman Gulch (Mullan)	**14**	**45**	0.10	22	9.6	43	17

Table A3 (continued 1). Phosphorus Yield for Watersheds along the Coeur d'Alene River

CDA River Watersheds, yield (kg/km2)

Watershed (River Reach)	Watershed ID	incremental area (km2)	mid-flow TP Yield 2009 (kg/km2)	mid-flow lower confidence interval 2009	mid-flow upper confidence interval 2009	low-flow TP Yield 2010 (kg/km2)	low-flow lower confidence interval 2010	low-flow upper confidence interval 2010
Entire Coeur d'Alene River Basin	**--**	**3,770**	**15**	**10**	**22**	**7.6**	**5.2**	**11**
Main Stem CDR, Cataldo to Harrison	1	626	15	13	15	12	8.6	16
SFCDR, NFCDR confluence region	**2**	**71**	86	40	154	7.8	1.7	15
NFCDR at Enaville	**3**	**2,315**	**9.8**	**6.8**	**14**	**4.4**	**3.2**	**6.0**
SFCDR near Pinehurst	--	744.6	**26**	**17**	**41**	**14**	**9.0**	**21**
SFCDR and streams, Pine Ck to Pinehurst	4	18.0	(26)	181	(513)	(73)	70	(384)
Pine Ck above Amy Gulch	5	189.6	7.2	2.3	19	2.1	0.6	5.4
SFCDR and streams, Smelterville to Pine Ck	6	15.0	507	103	1,267	361	100	846
SFCDR and streams, Kellogg to Smelterville	7	20.3	322	212	471	223	142	334
SFCDR and streams, Elizabeth Park to Kellogg	8	29.8	(7.0)	(6.0)	(6.4)	(8.0)	(5.2)	(11)
SFCDR and streams, Wallace to Elizabeth Park	9	253.9	6.6	5.3	7.6	0.9	1.2	(0.3)
SFCDR and streams, Deadman Gulch to Wallace	10	86.6	20	8.5	35	6.7	4.2	14
WF Ninemile Ck, above mouth near Wallace	11	15.8	12	5.1	25	1.9	0.0	3.2
EF Ninemile Ck, above mouth near Blackcloud	12	14.1	9.9	7.1	14	4.3	3.6	6.4
Canyon Ck, above mouth at Wallace	13	56.7	6.0	6.0	9.0	5.1	2.3	5.6
SFCDR above Deadman Gulch (Mullan)	**14**	**45**	17	7.8	31	12	5.1	23

Table A3 (continued 2). Phosphorus Yield for Watersheds along the Coeur d'Alene River

CDA River Watersheds, yield (kg/km2)

Watershed (River Reach)	Watershed ID	incremental area (km2)	TP Yield 2011 (kg/km2)	high-flow lower confidence interval 2011	high-flow upper confidence interval 2011	TP Yield 2012 (kg/km2)	high-flow lower confidence interval 2012	high-flow upper confidence interval 2012
Entire Coeur d'Alene River Basin	**--**	**3,770**	**41**	**26**	**62**	**32**	**20**	**47**
Main Stem CDR, Cataldo to Harrison	1	626	83	58	112	81	51	122
SFCDR, NFCDR confluence region	**2**	**71**	(140)	(94)	(180)	(258)	(134)	(456)
NFCDR at Enaville	**3**	**2,315**	**32**	**20**	**49**	**23**	**15**	**35**
SFCDR near Pinehurst	--	744.6	**52**	**30**	**84**	**45**	**26**	**73**
SFCDR and streams, Pine Ck to Pinehurst	4	18.0	537	480	451	484	424	425
Pine Ck above Amy Gulch	5	189.6	9.3	2.8	24.3	8.6	2.4	23
SFCDR and streams, Smelterville to Pine Ck	6	15.0	31	(126)	374	(25)	(114)	212
SFCDR and streams, Kellogg to Smelterville	7	20.3	678	416	1,035	638	373	1,013
SFCDR and streams, Elizabeth Park to Kellogg	8	29.8	21	1.7	64	(3.4)	(7.4)	9.1
SFCDR and streams, Wallace to Elizabeth Park	9	253.9	36	19	63	33	17	58
SFCDR and streams, Deadman Gulch to Wallace	10	86.6	8.1	9.8	0.9	2.4	6.5	(7.5)
WF Ninemile Ck, above mouth near Wallace	11	15.8	25	8.8	55	26	8.2	57
EF Ninemile Ck, above mouth near Blackcloud	12	14.1	17	11	25	11	7.8	16
Canyon Ck, above mouth at Wallace	13	56.7	9.9	5.8	16	8.1	4.6	13
SFCDR above Deadman Gulch (Mullan)	**14**	**45**	35	16	68	27	12.1	53

Table A3 (continued 3). Phosphorus Yield for Watersheds along the Coeur d'Alene River

CDA River Watersheds, yield (kg/km2) mid-flow

Watershed (River Reach)	Watershed ID	incremental area (km2)	TP Yield 2013 (kg/km2)	lower confidence interval 2013	upper confidence interval 2013
Entire Coeur d'Alene River Basin	**--**	**3,770**	**17**	**11**	**26**
Main Stem CDR, Cataldo to Harrison	1	626	52	35	76
SFCDR, NFCDR confluence region	**2**	**71**	(145)	(94)	(213)
NFCDR at Enaville	**3**	**2,315**	**9.2**	**6.1**	**13**
SFCDR near Pinehurst	--	744.6	**27**	**16**	**44**
SFCDR and streams, Pine Ck to Pinehurst	4	18.0	121	212	(172)
Pine Ck above Amy Gulch	5	189.6	2.4	0.6	6.8
SFCDR and streams, Smelterville to Pine Ck	6	15.0	314	20	929
SFCDR and streams, Kellogg to Smelterville	7	20.3	407	243	636
SFCDR and streams, Elizabeth Park to Kellogg	8	29.8	(13)	(10)	(14)
SFCDR and streams, Wallace to Elizabeth Park	9	253.9	15	7.9	24
SFCDR and streams, Deadman Gulch to Wallace	10	86.6	(0.9)	2.5	(9.7)
WF Ninemile Ck, above mouth near Wallace	11	15.8	5.7	1.9	13
EF Ninemile Ck, above mouth near Blackcloud	12	14.1	7.1	4.3	11
Canyon Ck, above mouth at Wallace	13	56.7	4.9	2.8	8.5
SFCDR above Deadman Gulch (Mullan)	**14**	**45**	19	6.7	42

Appendix B. Supporting Information for the St. Joe River

Table B1. Total Phosphorus Load at Gauging Stations along the St. Joe River

St. Joe River Sampling Sites (kg/yr)			average (2009-2013)			Total Phosphorus, average (2010-2012)				
River Gauge	**USGS Gauge #**	**area drained by gauge (km2)**	**Average TP Load 2009-2013 (kg/yr)**	lower 95% confidence interval 2009-2013	upper 95% confidence interval 2009-2013	**Average Load 2010-2012 (tons/yr)**	**Average Load 2010-2012 (kg/yr)**	lower 95% confidence interval (2010-2012)	upper 95% confidence interval (2010-2012)	**TP Load SPARROW (kg/yr)**
St. Joe River at Ramsdell	**12415135**	**4,480**	**84,300**	**61,500**	**113,400**	**107**	**96,770**	**70,000**	**130,300**	**54,010**
St. Joe River at St. Joe City (SJ-1)	--	2,860	--	--	--	65	58,870	41,720	80,590	22,080
St. Joe River at Calder	**12414500**	2,665	**--**	**--**	**--**	**--**	**--**	**--**	**--**	**19,900**
St. Maries River at Lotus (SJ-7)	[-12415000-] discontinued	1,125	--	--	--	23	21,280	17,980	24,900	20,790
Santa Ck (SJ-3)	--	180	--	--	--	4.0	3,620	3,030	4,280	3,430
St. Maries River at Santa	**12414900**	707	--	--	--	--	--	--	--	13,150
St. Maries River near Santa gauge (SJ-2)	--	675	--	--	--	15	13,190	12,300	14,100	11,080
Carpenter Ck (SJ-4)	--	49	--	--	--	1.4	1,260	910	1,610	1,080
Emerald Ck (SJ-5)	--	93	--	--	--	2.2	2,000	1,460	2,540	1,780
Upper St. Maries River (SJ-6)	--	330	--	--	--	7.3	6,640	5,680	7,610	4,490

Table B1 (continued 1). Total Phosphorus Load at Gauging Stations along the St. Joe River

St. Joe River Sampling Sites (kg/yr)

			mid-flow			low-flow		
River Gauge	**USGS Gauge #**	**area drained by gauge (km2)**	**TP Load 2009 (kg/yr)**	lower 95% confidence interval 2009	upper 95% confidence interval 2009	**TP Load 2010 (kg/yr)**	lower 95% confidence interval 2010	upper 95% confidence interval 2010
St. Joe River at Ramsdell	**12415135**	**4,480**	**77,850**	**58,050**	**102,500**	**31,750**	**24,300**	**40,750**
St. Joe River at St. Joe City (SJ-1)	--	2,860	--	--	--	15,825	--	--
St. Joe River at Calder	**12414500**	2,665	**--**	**--**	**--**	**--**	**--**	**--**
St. Maries River at Lotus (SJ-7)	[-12415000-] discontinued	1,125	--	--	--	9,760	--	--
Santa Ck (SJ-3)	--	180	--	--	--	1,800	--	--
St. Maries River at Santa	**12414900**	707	--	--	--	--	--	--
St. Maries River near Santa gauge (SJ-2)	--	675	--	--	--	4,590	--	--
Carpenter Ck (SJ-4)	--	49	--	--	--	440	--	--
Emerald Ck (SJ-5)	--	93	--	--	--	620	--	--
Upper St. Maries River (SJ-6)	--	330	--	--	--	3,965	--	--

Table B1 (continued 2). Total Phosphorus Load at Gauging Stations along the St. Joe River

St. Joe River Sampling Sites (kg/yr)

River Gauge	USGS Gauge #	area drained by gauge (km2)	high-flow TP Load 2011 (kg/yr)	lower 95% confidence interval 2011	upper 95% confidence interval 2011	high-flow TP Load 2012 (kg/yr)	lower 95% confidence interval 2012	upper 95% confidence interval 2012
St. Joe River at Ramsdell	**12415135**	**4,480**	**158,750**	**112,500**	**216,800**	**99,800**	**73,200**	**133,350**
St. Joe River at St. Joe City (SJ-1)	--	2,860	93,380	--	--	67,390	--	--
St. Joe River at Calder	**12414500**	2,665	**--**	**--**	**--**	**--**	**--**	**--**
St. Maries River at Lotus (SJ-7)	[-12415000-] discontinued	1,125	34,850	--	--	19,230	--	--
Santa Ck (SJ-3)	--	180	6,130	--	--	2,920	--	--
St. Maries River at Santa	**12414900**	707	--	--	--	--	--	--
St. Maries River near Santa gauge (SJ-2)	--	675	21,450	--	--	13,530	--	--
Carpenter Ck (SJ-4)	--	49	2,090	--	--	1,255	--	--
Emerald Ck (SJ-5)	--	93	3,030	--	--	2,350	--	--
Upper St. Maries River (SJ-6)	--	330	8,990	--	--	7,660	--	--

Table B1 (continued 3). Total Phosphorus Load at Gauging Stations along the St. Joe River

St. Joe River Sampling Sites (kg/yr) mid-flow

River Gauge	USGS Gauge #	area drained by gauge (km2)	TP Load 2013 (kg/yr)	lower 95% confidence interval 2013	upper 95% confidence interval 2013
St. Joe River at Ramsdell	**12415135**	**4,480**	**53,250**	**39,200**	**70,850**
St. Joe River at St. Joe City (SJ-1)	--	2,860	--	--	--
St. Joe River at Calder	**12414500**	2,665	**--**	**--**	**--**
St. Maries River at Lotus (SJ-7)	[-12415000-] discontinued	1,125	--	--	--
Santa Ck (SJ-3)	--	180	--	--	--
St. Maries River at Santa	**12414900**	707	--	--	--
St. Maries River near Santa gauge (SJ-2)	--	675	--	--	--
Carpenter Ck (SJ-4)	--	49	--	--	--
Emerald Ck (SJ-5)	--	93	--	--	--
Upper St. Maries River (SJ-6)	--	330	--	--	--

Table B2. Incremental Phosphorus Load for Watersheds along the St. Joe River

St. Joe River Watersheds, incremental load (kg/yr) average (2009-2013) Total Phosphorus, average (2010-2012)

Watershed (River Reach)	Watershed ID	incremental area (km2)	Average TP Load 2009-2013 (kg/yr)	lower 95% confidence interval 2009-2013	upper 95% confidence interval 2009-2013	Average Load 2010-2012 (tons/yr)	Average Load 2010-2012 (kg/yr)	lower 95% confidence interval (2010-2012)	upper 95% confidence interval (2010-2012)	TP Load SPARROW (kg/yr)
Entire St. Joe River Basin	**--**	**4,480**	**84,300**	**61,500**	**113,400**	**107**	**96,770**	**70,000**	**130,300**	**54,010**
St. Joe Confluence Region	1	495	--	--	--	18	16,620	10,300	24,810	11,140
St. Joe River above St. Joe City	**2**	**2,860**	**--**	**--**	**--**	**65**	**58,870**	**41,720**	**80,590**	**22,080**
St. Joe Maries River above Lotus	**--**	**1,125**	**--**	**--**	**--**	23	**21,280**	**17,980**	**24,900**	**20,790**
St. Maries River, Santa to Lotus	3	238	--	--	--	4.9	4,470	2,650	6,520	6,280
Santa Ck.	4	180	--	--	--	4.0	3,620	3,030	4,280	3,430
St. Maries River, Emerald Creek to Santa	5	202	--	--	--	3.6	3,290	4,250	2,340	3,730
Carpenter Ck.	6	49	--	--	--	1.4	1,260	910	1,610	1,080
Emerald Ck.	7	93	--	--	--	2.2	2,000	1,460	2,540	1,780
St. Maries River, above Emerald Creek	8	330	--	--	--	7.3	6,640	5,680	7,610	4,490

Table B2 (continued 1). Incremental Phosphorus Load for Watersheds along the St. Joe River

St. Joe River Watersheds, incremental load (kg/yr) mid-flow low-flow

Watershed (River Reach)	Watershed ID	incremental area (km2)	TP Load 2009 (kg/yr)	lower 95% confidence interval 2009	upper 95% confidence interval 2009	TP Load 2010 (kg/yr)	lower 95% confidence interval 2010	upper 95% confidence interval 2010
Entire St. Joe River Basin	**--**	**4,480**	**77,850**	**58,050**	**102,500**	**31,750**	**24,300**	**40,750**
St. Joe Confluence Region	1	495	--	--	--	6,165	--	--
St. Joe River above St. Joe City	**2**	**2,860**	**--**	**--**	**--**	**15,825**	**--**	**--**
St. Joe Maries River above Lotus	**--**	**1,125**	**--**	**--**	**--**	**9,760**	**--**	**--**
St. Maries River, Santa to Lotus	3	238	--	--	--	3,370	--	--
Santa Ck.	4	180	--	--	--	1,800	--	--
St. Maries River, Emerald Creek to Santa	5	202	--	--	--	0	--	--
Carpenter Ck.	6	49	--	--	--	440	--	--
Emerald Ck.	7	93	--	--	--	620	--	--
St. Maries River, above Emerald Creek	8	330	--	--	--	3,965	--	--

Table B2 (continued 2). Incremental Phosphorus Load for Watersheds along the St. Joe River

St. Joe River Watersheds, incremental load (kg/yr) high-flow high-flow

Watershed (River Reach)	Watershed ID	incremental area (km2)	TP Load 2011 (kg/yr)	lower 95% confidence interval 2011	upper 95% confidence interval 2011	TP Load 2012 (kg/yr)	lower 95% confidence interval 2012	upper 95% confidence interval 2012
Entire St. Joe River Basin	**--**	**4,480**	**158,750**	**112,500**	**216,800**	**99,800**	**73,200**	**133,350**
St. Joe Confluence Region	1	495	30,520	--	--	13,180	--	--
St. Joe River above St. Joe City	**2**	**2,860**	**93,380**	**--**	**--**	**67,390**	**--**	**--**
St. Joe Maries River above Lotus	**--**	**1,125**	**34,850**	**--**	**--**	**19,230**	**--**	**--**
St. Maries River, Santa to Lotus	3	238	7,270	--	--	2,780	--	--
Santa Ck.	4	180	6,130	--	--	2,920	--	--
St. Maries River, Emerald Creek to Santa	5	202	7,340	--	--	2,265	--	--
Carpenter Ck.	6	49	2,090	--	--	1,255	--	--
Emerald Ck.	7	93	3,030	--	--	2,350	--	--
St. Maries River, above Emerald Creek	8	330	8,990	--	--	7,660	--	--

Table B2 (continued 3). Incremental Phosphorus Load for Watersheds along the St. Joe River

St. Joe River Watersheds, incremental load (kg/yr) mid-flow

Watershed (River Reach)	Watershed ID	incremental area (km2)	TP Load 2013 (kg/yr)	lower 95% confidence interval 2013	upper 95% confidence interval 2013
Entire St. Joe River Basin	**--**	**4,480**	**53,250**	**39,200**	**70,850**
St. Joe Confluence Region	1	495	--	--	--
St. Joe River above St. Joe City	**2**	**2,860**	**--**	**--**	**--**
St. Joe Maries River above Lotus	**--**	**1,125**	**--**	**--**	**--**
St. Maries River, Santa to Lotus	3	238	--	--	--
Santa Ck.	4	180	--	--	--
St. Maries River, Emerald Creek to Santa	5	202	--	--	--
Carpenter Ck.	6	49	--	--	--
Emerald Ck.	7	93	--	--	--
St. Maries River, above Emerald Creek	8	330	--	--	--

Table B3. Phosphorus Yield for Watersheds along the St. Joe River

St. Joe River Watersheds, Yield (kg/km2) average (2009-2013) average (2010-2012)

Watershed (River Reach)	Watershed ID	incremental area (km2)	Average TP Yield 2009-2013 (kg/km2)	lower 95% confidence interval 2009-2013	upper 95% confidence interval 2009-2013	Average Yield 2010-2012 (lb/acre)	Average Yield 2010-2012 (kg/km2)	lower 95% confidence interval (2010-2012)	upper 95% confidence interval (2010-2012)	TP Yield SPARROW (kg/km2)
Entire St. Joe River Basin	**--**	**4,480**	**19**	**14**	**25**	**0.10**	**22**	**16**	**29**	**12**
St. Joe Confluence Region	1	495	--	--	--	0.15	34	21	50	23
St. Joe River above St. Joe City	**2**	**2,860**	**--**	**--**	**--**	**0.09**	**21**	**15**	**28**	**8**
St. Joe Maries River above Lotus	**--**	**1,125**	**--**	**--**	**--**	0.09	**19**	**16**	**22**	**18**
St. Maries River, Santa to Lotus	3	238	--	--	--	0.09	19	11	27	26
Santa Ck.	4	180	--	--	--	**0.09**	20	17	24	19
St. Maries River, Emerald Creek to Santa	5	202	--	--	--	0.07	16	21	12	18
Carpenter Ck.	6	49	--	--	--	0.12	26	19	33	22
Emerald Ck.	7	93	--	--	--	0.10	22	16	27	19
St. Maries River, above Emerald Creek	8	330	--	--	--	0.09	20	17	23	14

Table B3 (continued 1). Phosphorus Yield for Watersheds along the St. Joe River

St. Joe River Watersheds, Yield (kg/km2)			mid-flow			low-flow		
Watershed (River Reach)	**Watershed ID**	**incremental area (km2)**	**TP Yield 2009 (kg/km2)**	lower 95% confidence interval 2009	upper 95% confidence interval 2009	**TP Yield 2010 (kg/km2)**	lower 95% confidence interval 2010	upper 95% confidence interval 2010
Entire St. Joe River Basin	**--**	**4,480**	**17**	**13**	**23**	**7.1**	**5.4**	**9.1**
St. Joe Confluence Region	1	495	--	--	--	12	--	--
St. Joe River above St. Joe City	**2**	**2,860**	**--**	**--**	**--**	**5.5**	**--**	**--**
St. Joe Maries River above Lotus	**--**	**1,125**	**--**	**--**	**--**	**9**	**--**	**--**
St. Maries River, Santa to Lotus	3	238	--	--	--	14	--	--
Santa Ck.	4	180	--	--	--	10	--	--
St. Maries River, Emerald Creek to Santa	5	202	--	--	--	0.0	--	--
Carpenter Ck.	6	49	--	--	--	9.0	--	--
Emerald Ck.	7	93	--	--	--	6.6	--	--
St. Maries River, above Emerald Creek	8	330	--	--	--	12	--	--

Table B3 (continued 2). Phosphorus Yield for Watersheds along the St. Joe River

St. Joe River Watersheds, Yield (kg/km2)

Watershed (River Reach)	Watershed ID	incremental area (km2)	high-flow TP Yield 2011 (kg/km2)	lower 95% confidence interval 2011	upper 95% confidence interval 2011	high-flow TP Yield 2012 (kg/km2)	lower 95% confidence interval 2012	upper 95% confidence interval 2012
Entire St. Joe River Basin	**--**	**4,480**	**35**	**25**	**48**	**22**	**16**	**30**
St. Joe Confluence Region	1	495	62	--	--	27	--	--
St. Joe River above St. Joe City	**2**	**2,860**	**33**	**--**	**--**	**24**	**--**	**--**
St. Joe Maries River above Lotus	**--**	**1,125**	**31**	**--**	**--**	**17**	**--**	**--**
St. Maries River, Santa to Lotus	3	238	31	--	--	12	--	--
Santa Ck.	4	180	34	--	--	16	--	--
St. Maries River, Emerald Creek to Santa	5	202	36	--	--	11	--	--
Carpenter Ck.	6	49	43	--	--	26	--	--
Emerald Ck.	7	93	32	--	--	25	--	--
St. Maries River, above Emerald Creek	8	330	27	--	--	23	--	--

Table B3 (continued 3). Phosphorus Yield for Watersheds along the St. Joe River

St. Joe River Watersheds, Yield (kg/km2) mid-flow

Watershed (River Reach)	Watershed ID	incremental area (km2)	TP Yield 2013 (kg/km2)	lower 95% confidence interval 2013	upper 95% confidence interval 2013
Entire St. Joe River Basin	**--**	**4,480**	**12**	**9**	**16**
St. Joe Confluence Region	1	495	--	--	--
St. Joe River above St. Joe City	**2**	**2,860**	**--**	**--**	**--**
St. Joe Maries River above Lotus	**--**	**1,125**	**--**	**--**	**--**
St. Maries River, Santa to Lotus	3	238	--	--	--
Santa Ck.	4	180	--	--	--
St. Maries River, Emerald Creek to Santa	5	202	--	--	--
Carpenter Ck.	6	49	--	--	--
Emerald Ck.	7	93	--	--	--
St. Maries River, above Emerald Creek	8	330	--	--	--

Appendix C. Supporting Information for the Coeur d'Alene Lake Tributaries, Atmospheric Deposition and Wastewater Sources

March-2008 Glen Rothrock Survey on Community Wastewater Systems

March 28, 2008
To: PHD & CdA Tribal GIS Department
RE: Glen Rothrocks' Initial Survey of Wastewater System Records in the DEQ Office
Preliminary & Incomplete as of 3-28-08

1. Community Wastewater Treatment Plants (WWTP) – EPA NPDES Permit

a. City of Coeur d'Alene WWTP
i. Services the lake shoreline from west at Blackwell Island RV Park (T50 N – R4W – S14 to east at CdA Resort Gold Course and new Condos, T50N – R3W – S19.

b. City of Harrison WWTP
i. System built in 1978 – septic tank effluent to lagoon treatment – outfall discharge to Anderson Lake with NPDES.
ii. As or 2007, 170 connections, system has capacity of 300 connections.
iii. Harrison Heights subdivision (150 homes) recently annexed, will be hooked up down the road.
iv. Northern boundary of service = T47N – R3W – NW Quad S6
Southern boundary of service = T47 – R4W – NE Quad S1 (along Tribal Reservation boundary line).

2. Sewage Lagoon – Land Application Systems – DEQ Permit

a. Arrow Point Community Association
i. Up to 2007, a LSAS.
ii. In 2004 report, 125 connections, 3.26 mg/year effluent.
ii. In 2007 – 2008, effluent will be piped up to Gozzer Ranch Class A Treatment – Land Application system, operated by North Kootenai Water & Sewer District.
iii. North end - T50N – R4W – SE Quad Section 36:
South end: T49N – R4W – NE Quad of Section 6 (looks like the southern boundary of the service area is right at the southern line of the NE Quad of S6).

b. Gozzer Ranch Golf and Lake Club
i. Development and WWTP east of Hwy 97
ii. Vast majority of this development is >500 feet from lakeshore

c. Kidd Island Bay Lots Sewer District + Harbor View Estates
i. North end- T50N – R4W – SW Quad of S26 (north tip of bay): to south end- T49N – R4W – NW Quad of S1 (to Cellar Point)
ii. Constructed in the mid to late 1970s'
iii. Estimated 350 ERs (hookups); 80% capacity = 12.5 mg/year

iv. Many additions since first constructed

c. Black Rock
i. From 2004 report – 375 potential residential hookups + Clubhouse (6 ERs)
ii. Vast majority of this development is >500 feet from lake shore

3. Lagoon Treatment Only – DEQ Permit

a. Carlin Bay Sewer Association
i. Lagoon approved in 1981 with a maximum capacity of around 200 ERs (60,000 gpd)
ii. Suspicion that the lagoon leaks (2008 DEQ letter).
iii. as of 2004, 40 homes plus Carlin Bay Resort.
iv. T48N – R3W – in the middle of Section 6
v. Boundaries of sewer service are unknown at this time (probably enters around the Resort).
vi. PHD should have on file, 20 individual permits for Johnson Meadows Subdivision, NE Quad of S6, 28 acre subdivision with 20 individual septic tank – drainfields, that was denied hookups to the Carlin Bay Lagoon.

b. Cave Bay Community Sewer
i. Built in 1976/77
ii. Designed to handle every platted & proposed lot within Cave Bay through 5th addition.
iii. As of 2001 – 135 residential connections – design capacity = 205 connections
iv. T48N – R4W – NE Quad S32 and SE Quad S29

4. Large Soil Absorption Systems (LSAS) – >2,500 gpd: PHD Permit – DEQ Engineering Review

a. Delcardo Bay (North Shore) Property Owners – LSAS
i. LSAS installed in 1995
ii. Currently 7 connections (60,000 gp/year) – design capacity = 18 residences
iii. T49N – R4W – NW quad S23

b. Camp Easton (Boy Scouts) LSAS, Gotham Bay
i. Two drainfields with design capacity = 6,500 gpd.
ii. T49N – R3W – SW Quad S7.

c. Camp Lutherhaven

d. Driftwood Point Coop - LSAS
i. Constructed in 1985; 10 current connections (2207), expand to 12.
ii. T49N – R4W – NE Quad S13

e. Pointe at Browns Bay
i. Services a 25 unit development – design capacity 6,250 gpd.
ii. T47N – R4W – NE Quad S13

5. Community Drainfield Systems <2,500 gpd, 3 – 9 Homes Connected – PHD Permit

a. Kildare Effluent System (Formerly Bennett Bay)
i. In 2001 authorized for 9 hookups
ii. T50N – R3W – either Section(s) 29, 28, and/or 33

b. Roth's Black Rock (Bay) Community Sewer System
i. 8 residents
ii. T48 – R4W – NW Quad S10

c. Rockford Bay Store/Restaurant "Shooters", 16 RV sites, and Boat Pump-out & Dock Bathrooms.
i. Combination septic tanks and drainfields
ii. Site investigations by PHD and DEQ in 2007
iii. T48N – R4W – NE Quad S18

d. Rockford Bay Summer Homes, Rockford Terrace Club

Technical Memorandum by Bill Rust (2009) on Nearshore Septic Systems

Memorandum to: Kootenai County

From: W. C. Rust

Date: November 23, 2008

Regarding: The Contribution of the Nearshore Septic Systems to the Coeur d'Alene Lake Total Phosphorus Load

Nearshore Septic Systems can contribute total phosphorus to a Lake causing adverse water quality impacts. Management Actions 2 through 9 of the 2008 Draft LMP, Coeur d'Alene Lake Management Plan are actions to reduce the impact of nearshore septic systems. This memorandum attempts to quantify how important those actions are to maintaining the quality of the water in Coeur d'Alene Lake.

The total phosphorus load to the Lake from nearshore wastewater was estimated at 390 kilograms per year by the USGS as part of the 1991 – 1992 studies. A description of the methodology says Panhandle Health surveyed homes within 150 meters of the Lakeshore to determine the associated populations. The surveyed population numbers were then converted to equivalent full time residents. Transient populations, such as those at the camps of various organizations, were also included. A per capita effluent of 55,000 liters per person per year was multiplied by an average concentration of 15 milligrams per year of total phosphorus to get a potential phosphorus load. Since most of the phosphorus is associated with particulates that get retained in soil around the septic system drainfield, a retention factor of 90% was used and 10% was assumed to be discharged into the Lake. This works out to a potential load of 0.825 kilograms per year per capita and a discharge to the Lake of 0.0825 kilograms per person per year. To get a discharge of 390 kilograms per year would require an equivalent full time population of 4,727 people within 150 meters of the Lake.

In order to produce a more current estimate the Kootenai County Building Permits Department produced a map on May 7, 2008 showing all the septic systems within 0ne mile of the lakeshore. Their count showed 2,443 systems before 2000, 696 systems from 2000 to 2004, 466 systems from 2005 to present and 91 systems proposed. This adds up to 3,696 systems although the map legend shows a total of 3,386 systems. I have no explanation for the 310 system difference. Using the above numbers we get 1,253 systems from 200 to present or about 157 per year. If we assume a relatively constant rate of construction, then the same number would have been installed from 1991 – 1992 to 2000 and there would have been about 1,190 systems in 1991 – 1992.

I used an estimated effluent of 180 gallons per day per residence which is what Spokane is using for their planning. With a total phosphorus concentration of 15 milligrams per liter this gives 3.73 kilograms per year per system as potential effluent with 0.373 kilograms per year per system discharged to the Lake. Using this methodology I get 444 kilograms per year for 1991 – 1992 which is comparable to the 390 kilograms per year estimated by the USGS. Using the same methodology I get 1,379 kilograms per year as the current load from nearshore septic systems.

According to Table 4 of the recently released USGS Report the total phosphorus load to Lake Coeur d'Alene averaged about 90,000 kilograms per year for the five years of the two studies. My estimate of nearshore septic systems is about 1.5% of that load. Although nearshore septic systems need to be managed, that management is unlikely to have a significant effect on the total phosphorus load to the Lake.

GIS Analysis of Structures around Coeur d'Alene Lake within 500 feet of the shore line as of 11/17/2009

	Served by Community System Treatments	**Served by Non-Community System Treatments**	***TOTAL***
Drain Field	10		*10*
LSAS	31		*31*
STEP	420		*420*
WWTP	243		*243*
Permitted Structures		1073	*1073*
Built before 1972 – No permit / Data		799	*799*
Built after 1972 – No permit / Data		526	*526*
TOTAL STRUCTURES	*704*	*2398*	*3102*

This information and additional updated information is available in a nutrient inventory geodatabase that was created tas part of this study. Geodatabase fields are available from Idaho DEQ.

Appendix D. Supporting Information for the Trends Assessment

Methods Used to Generate Forest Change Data for Land Use Analyses

For satellite data, NLCD land cover datasets were collected for 1992, 2001, 2006, and 2011. The NLCD 2011 dataset was also adjusted for forest change, in order to reclassify shrub/scrub and herbaceous areas to a forest classification, with timber harvest activity and wildfire, that was modified with a reclassification of land cover identified by a gain or loss of forest using the global forest change data (e.g., Hansen et. al., 2013). These areas have had timber harvest activity, forest regeneration, or wildfire within the period of 2001 to 2014. The reflective wavelength of these areas classified them as either shrub/scrub, herbaceous, or evergreen forest in the NLCD 2011. The gains and losses were combined into a raster layer and given a cell value of 100. The cells with no change were given a value of 0 in the grid. This layer was then added to the NLCD 2011 using Spatial Analyst/Math/Plus tool. The output added a value of 100 to the land cover code (2 digit number) of NLCD 2011 where forest change occurred, creating three new classifications: Forest Change/Evergreen Forest, Forest Change/Shrub, and Forest Change/Herbaceous. They could all be grouped into a new classification in the modified NLCD 2011 as "evergreen forest with recent activity" (This may have been left ungroup into Forest Change/Evergreen Forest, Forest Change/Shrub, and Forest Change/Herbaceous in the summary tables). The modification was to enhance the classification of forest land cover.

Estimate of Land Cover Changes in the Coeur d'Alene Basin from the 1990's to the current period

Land use Type	Carlin Creek		Wolf Lodge Creek		Overall Coeur d'Alene Basin [1]		
	NLCD 1992 (%) [2]	2011 (%)	NLCD 1992 (%) [2]	2011 (%)	USGS 1990's (%) [3]	NLCD 1992 (%) [2]	2011 (%)
Water and Barren Land	**0.0%**	**0.02%**	**0.1%**	**0.0%**	**1.8%**	**2.1%**	**1.7%**
Cloud cover	--	--	--	--	**4.2%**	--	--
Mined Land	--	--	--	--	**0.1%**	--	--
Total Forested	**77%**	**81%**	**90%**	**90%**	**78%**	**82%**	**74%**
"Mature" Forest [4]	--	*74%*	--	*88%*	*75%*	*82%*	*68%*
"Recovering" Forest	--	*7.0%*	--	*2.3%*	*3.8%*	--	*6.3%*
Total Shrub/Herbaceous	**23%**	**19%**	**9.8%**	**9.1%**	**9.0%**	**12%**	**21%**
"Mature" Herbacous	0.1%	*4%*	*0.1%*	*0.2%*	--	*2.5%*	*1%*
"Mature" Shrub/Scrub [5]	23%	*13%*	*9.7%*	*8.1%*	--	*9.3%*	*16%*
Rangeland	--	--	--	--	*6.8%*	--	--
"Forest Harvest"	--	*3%*	--	*0.8%*	*2.2%*	--	*4.8%*
Total Developed	**0.3%**	**0.0%**	**0.1%**	**0.1%**	**0.8%**	**0.7%**	**0.8%**
Developed open space	*0.1%*	*0.0%*	*0.04%*	*0.04%*	--	*0.0%*	*0.4%*
Developed low intensity	*0.0%*	*0.0%*	*0.00%*	*0.05%*	*0.3%*	*0.3%*	*0.3%*
Developed medium intensity [6]	*0.2%*	*0.0%*	*0.07%*	*0.00%*	*0.5%*	*0.3%*	*0.1%*
Total Agricultural	**0.0%**	**0.0%**	**0.1%**	**0.0%**	**5.4%**	**3.2%**	**0.8%**
Hay/Pasture [7]	0.02%	0.0%	*0.1%*	*0.01%*	*3.5%*	*1.8%*	*0.1%*
Row Crops [8]	0.00%	0.0%	*0.0%*	*0.00%*	*1.9%*	*1.4%*	*0.7%*
Total Wetlands	**0.0%**	**0.3%**	**0.0%**	**0.8%**	**0.0%**	**0.1%**	**1.0%**
Woody Wetlands	0.0%	0.28%	*0.0%*	*0.5%*	--	*0.1%*	*0.3%*
Herbaceous Wetlands	0.0%	0.05%	*0.0%*	*0.3%*	--	*0.0%*	*0.7%*
TOTAL	***100%***	***100%***	***100%***	***100%***	***100%***	***100%***	***100%***

1. Entire Coeur d'Alene Lake watershed, including rivers and ungauged tributaries.
2. Estimate from NLCD 1992, not corrected for forest change.
3. As reported by Woods & Beckwith (1997).
4. Coniferous, sparse, deciduous forest from Woods & Beckwith (1997). Current dataset includes evergreen, mixed, deciduous forest
5. Sum of "Shrubland" and "Transitional Barren" from NLCD (1992).
6. Dense urban or built-up land from Woods & Beckwith (1997).
7. Dryland Ag and pasture from Woods & Beckwith (1997). Fallow and Pasture/Hay for NLCD 1992.
8. Irrigated Ag and pasture from Woods & Beckwith (1997). Row crops, small grains for NLCD 1992.

Future Climate Change

Mote and Salathé (2010) report that climate conditions in the Pacific Northwest and Idaho Panhandle region will likely continue to change in the coming years, and that the pace of warming may accelerate. Current models predict that temperature will increase by 1.1 °C by the 2020's, 1.8 °C by the 2040's, and 3.0 °C by the 2080's. All changes are relative to the 1970 – 1999 mean. The models also predict a small increase in precipitation (+1% to +2%), with some models predicting wetter autumns and winters and drier summers. The warming temperature is expected to progressively shift precipitation towards more rain and rain/snow mixes – leading to smaller and less durable winter snowpack and a shift in the timing, magnitude, and duration of winter and spring runoff. Summer stream temperatures are also expected to increase (Mote et. al., 2014).

The impact of these changes on nutrient loading and the lake's response to nutrient loads are unknown. The anticipated higher temperatures and associated changes in runoff are expected tend to shift ecologic balances, accelerate oxygen loss in the bottom waters of regional lakes, and alter nutrient dynamics in aquatic systems. Jeppesen et. al. (2009) report that climate change is anticipated to enhance phosphorus loading in Danish streams, while also enhancing eutrophication pressure. The land-use around the Danish streams is primarily agricultural, and the increased phosphorus loading there is anticipated to result from greater winter rains that inundate more fields. The Coeur d'Alene Basin is a mountainous forest system that is markedly different from Danish lowland agricultural soils, and it is unclear whether the anticipated shifts in runoff will significantly alter the nutrient loading dynamics in this system. It is possible that the region's ecologic systems may change in response to higher temperatures, less summer water, and increased fire hazard – potentially leading to higher nutrient loads. However, the extent and impact of such potential changes is still unknown. The best current information suggests that the primary impacts of climate change on nutrient loading in streams loading will arise from differences in the timing and magnitude of spring runoff. If the shift from snow to rain and rain/snow mix leads to more intense run-off events, then climate change would tend to enhance nutrient loading. However, it is also possible that this shift to more winter rains could lead to a more gradual runoff profile with fewer flash flows.

Jeppesen et. al. (2009) also report that climate change will lead to a stronger eutrophication response within lakes. Warmer temperatures will tend to decrease the mass of oxygen in lakes (warmer water holds less oxygen), increase the period of stratification, increase the rate of temperature-dependent microbial activity, and enhance rates of phosphorus release from sediments. The combination of nutrient dynamics and temperature change may also shift the ecological balance of lakes to fish species that are more effective grazers of zooplankton. This would then shift the abundance and species distribution of phytoplankton towards a more eutrophic system. A change in temperature-driven stratification would alter the nutrient dynamics of the lower reaches of the Coeur d'Alene River and St. Joe River; where the bottom waters of the riparian lakes and the Rivers' deep meander bends already become seasonally anoxic. This seasonal anoxia releases reactive phosphorus from the sediments and increases loads to Coeur d'Alene Lake (Dale Chess, Coeur d'Alene Tribe, personal communication, 2016). Enhanced phosphorus release from these sediments would increase the net load of reactive phosphorus into Coeur d'Alene Lake and increase eutrophication pressure.

Overall, the effect of climate change on nutrient loading into Coeur d'Alene Lake is unknown. Current information suggests that it is unlikely that climate change will reduce nutrient loading and/or the response of the region's waters to nutrients. It is more likely that climate change will tend to increase both nutrient loading and eutrophication pressure. The degree of impact is unknown, but there will likely be significant loading and eutrophication pressures that nutrient management activities will need to consider.

Appendix E. Additional Supporting Information

This Appendix provides supporting information from the St. Maries/St. Joe field study. Only information is provided for DEQ sites. The purpose for providing this information is to give a record of data and calculations for analyses to support this nutrient inventory. Data and calculations from the St. Joe study (2010 – 2012) have not been previously reported.

Data are provided for Stations SJ1 (St. Joe @ St. Joe City), SJ2 (St. Maries River at Santa), SJ3 (Santa Creek), and SJ-7 (St. Maries River at Lotus. Data for the remaining stations was collected by the Tribe. These are SJ-4 (Carpenter Creek), SJ-5 (Emerald Creek, and SJ-6 (Upper St. Maries River.

Area Ratio Discharge Estimate and Comparison with Measured Data for Santa Creek

The field plan for the St. Joe nutrient study assumed that discharges for all streams could be estimated from an area ratio. Analyses presented in Section 4 indicated this was not true for the DEQ site at Santa Creek, and thus could not be extended to other sites without confirmatory data. Confirmatory data was available for Tribe monitoring sites, but not DEQ sites. Area ratio constants for nutrient inventory sites are provided below, as is discharge data for Santa Creek.

- NI-1, St. Joe River at St. Joe City = (St. Joe River at Calder gauge) * (1.1)
- NI-2, St. Maries River at Santa = (St. Maries River at Santa gauge) * (0.96)
- NI-3, Santa Creek = (St. Maries River at Santa gauge) * (0.25)
- NI-4, Carpenter Creek =
- NI-5, Emerald Creek =
- NI-6, Upper St. Maries River at Emerald Creek =
- NI-7, St. Maries River at Lotus = (St. Maries River at Santa gauge) * (1.6)

Discharge Comparison for Santa Creek (NI-3)

Date	Measured Discharge (cfs)	Area Ratio Discharge (cfs)	%RPD
3/24/2010	33.9	62	59%
4/20/2010	70.9	89	23%
6/2/2010	22.4	76	109%
6/22/2010	160	293	59%
Average	--	--	**62%**

Point measurements for Santa Creek are provided on the following pages.

Point Measurements of Streamflow (2010 – 2012)

Stream Name	Santa Creek		Trib To St Maries River	NI-3
Sample Date	3/24/2010		Time: 10.00 AM	
Device	Marsh BacBirney		Sample station at Chuck Husky bridge	
Total Flow (cfs)	33.86			
Avg. Velocity (fps)	1.25			
Max. Velocity (fps)	2.72			
Starting Stage (ft)	8.60	Ending Stage (ft)	8.60	
Crew menbers	G. Rothrock	G.Pettit		
Method	wading	.6d		

Initial Pt. (ft)	Width (ft)	Depth (ft)	Vel. (fps)	Area (sq. ft.)	Discharge (cfs)
0.00	0.25				
0.50	0.75	0.10	0.00	0.08	0.00
1.50	1.00	0.60	0.00	0.60	0.00
2.50	1.00	0.90	0.04	0.90	0.04
3.50	1.00	0.90	0.05	0.90	0.05
4.50	1.00	1.00	0.93	1.00	0.93
5.50	1.00	1.20	2.08	1.20	2.50
6.50	1.00	0.80	2.63	0.80	2.10
7.50	1.00	1.20	2.72	1.20	3.26
8.50	1.00	1.50	2.72	1.50	4.08
9.50	1.00	1.70	2.48	1.70	4.22
10.50	1.00	1.60	2.20	1.60	3.52
11.50	1.00	1.40	2.29	1.40	3.21
12.50	1.00	1.35	1.94	1.35	2.62
13.50	1.00	1.30	1.63	1.30	2.12
14.50	1.00	1.25	1.32	1.25	1.65
15.50	1.00	1.25	0.95	1.25	1.19
16.5	1.00	1.15	0.92	1.15	1.06
17.50	1.00	0.95	0.79	0.95	0.75
18.5	1.00	0.90	0.46	0.90	0.41
19.50	1.00	0.90	0.18	0.90	0.16
20.50	0.75	0.05	0.00	0.04	0.00
21.00	0.25				

Point Measurements of Streamflow (2010 – 2012) – continued

Stream Name	Santa Creek		Trib To St Maries River	NI-3
Sample Date	4/20/2010		Time: 09.30 AM	
Device	Marsh BacBirney		Sample station at Chuck Husky bridge	
Total Flow (cfs)	70.92			
Avg. Velocity (fps)	1.75			
Max. Velocity (fps)	3.97			
Starting Stage (ft)	8.03	Ending Stage (ft)	8.03	
Crew menbers	G. Rothrock	G.Pettit		
Method	wading	.6d		

Initial Pt.	Width (ft)	Depth (ft)	Vel. (fps)	Area (sq. ft.)	Discharge (cfs)
0.00	0.25				
0.50	0.75	0.10	0.00	0.08	0.00
1.50	1.00	0.50	0.00	0.50	0.00
2.50	1.00	0.80	0.00	0.80	0.00
3.50	1.00	1.00	0.42	1.00	0.42
4.50	1.00	1.30	1.42	1.30	1.85
5.50	1.00	1.50	2.26	1.50	3.39
6.50	1.00	1.70	2.88	1.70	4.90
7.50	1.00	1.80	2.71	1.80	4.88
8.50	1.00	2.00	2.34	2.00	4.68
9.50	1.00	2.00	3.58	2.00	7.16
10.50	1.00	2.10	3.97	2.10	8.34
11.50	1.00	2.00	3.11	2.00	6.22
12.50	1.00	2.00	2.74	2.00	5.48
13.50	1.00	1.90	3.00	1.90	5.70
14.50	1.00	1.80	2.63	1.80	4.73
15.50	1.00	1.70	2.51	1.70	4.27
16.5	1.00	1.80	1.59	1.80	2.86
17.50	1.00	1.60	1.57	1.60	2.51
18.5	1.00	1.60	1.15	1.60	1.84
19.50	1.00	0.90	1.23	0.90	1.11
20.50	1.00	0.60	0.57	0.60	0.34
21.50	1.00	0.50	0.46	0.50	0.23
22.50	0.90	0.20	0.10	0.18	0.02
23.30	0.40				

Point Measurements of Streamflow (2010 – 2012) – continued

Stream Name	Santa Creek		Trib To St Maries River	NI-3
Sample Date	6/2/2010		Time: 12.00 PM	
Device	Marsh BacBirney		Sample station at Chuck Husky bridge	
Total Flow (cfs)	22.44			
Avg. Velocity (fps)	1.13			
Max. Velocity (fps)	2.16			
Starting Stage (ft)	NT	Ending Stage (ft)	8.80	
Crew menbers	G. Rothrock	B Witherow		
Method	wading	.6d		

Initial Pt.	Width (ft)	Depth (ft)	Vel. (fps)	Area (sq. ft.)	Discharge (cfs)
1.10	0.20				
1.50	0.60	0.25	0.00	0.15	0.00
2.30	0.80	0.35	0.00	0.28	0.00
3.10	0.80	0.70	0.00	0.56	0.00
3.90	0.80	0.75	0.00	0.60	0.00
4.70	0.80	0.80	0.46	0.64	0.29
5.50	0.80	1.00	0.88	0.80	0.70
6.30	0.80	1.10	1.13	0.88	0.99
7.10	0.80	1.25	1.46	1.00	1.46
7.90	0.80	1.10	2.01	0.88	1.77
8.70	0.80	1.30	1.99	1.04	2.07
9.50	0.80	1.30	1.84	1.04	1.91
10.30	0.80	1.30	2.16	1.04	2.25
11.10	0.80	1.25	1.59	1.00	1.59
11.90	0.80	1.10	2.03	0.88	1.79
12.70	0.80	1.20	1.76	0.96	1.69
13.50	0.80	1.05	1.29	0.84	1.08
14.3	0.80	1.15	1.47	0.92	1.35
15.10	0.80	1.00	1.41	0.80	1.13
15.9	0.80	1.00	1.35	0.80	1.08
16.70	0.80	0.90	0.96	0.72	0.69
17.50	0.80	0.80	0.90	0.64	0.58
18.30	0.50	0.20	0.10	0.10	0.01
18.50	0.10				

Point Measurements of Streamflow (2010 – 2012) – continued

Stream Name	Santa Creek		Trib To St Maries River	NI-3
Sample Date	6/22/2010		Time: 12.00 PM	
Device	Marsh BacBirney		Sample station at Chuck Husky bridge	
Total Flow (cfs)	160.00			
Avg. Velocity (fps)	2.62			
Max. Velocity (fps)	4.80			
Starting Stage (ft)	6.92	Ending Stage (ft)	6.92	
Crew menbers	T Clyne	G.Pettit		
Method	wading	.6d and.2d .8d		

Initial Pt.	Width (ft)	Depth (ft)	Vel. (fps)	Vel. (fps)	Area (sq. ft.)	Discharge (cfs)
0	0.50					
1	1.50	1.00	1.89		1.50	2.84
3	2.00	1.90	2.83		3.80	10.75
5	2.00	2.40	2.90		4.80	13.92
7	2.00	2.50	1.67	2.75	5.00	11.05
9	2.00	2.50	1.51	2.64	5.00	10.38
11	2.00	2.70	2.37	3.17	5.40	14.96
13	2.00	2.60	0.87	2.72	5.20	9.33
15	2.00	2.50	2.54	4.8	5.00	18.35
17	2.00	2.70	3.60	4.6	5.40	22.14
19	2.00	2.60	2.95	4.42	5.20	19.16
21	2.00	2.00	1.84		4.00	7.36
23	2.00	1.80	2.16		3.60	7.78
25	2.00	1.30	1.59		2.60	4.13
27	2.00	1.10	2.03		2.20	4.47
29	1.75	1.10	1.76		1.93	3.39
30.5	0.75					

Station SJ-1 (also NI-1), Field data from St. Maries/St. Joe Nutrient Loading Study (2010 – 2012)

Use Area Ratio to estimate discharge. StreamStat Ratio **is** Equivalent to Area Ratio.

St. Joe at St. Joe City (SJ-1, also NI-1)

Date	Sample Type	Modeled Discharge Using Area Ratio (cfs)	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)	Dissolved Ortho-Phosph. (µg/L)	Total Nitrogen (µg/L)	Dissolved NO3, NO2 (µg/L)	Dissolved Ammonia (µg/L)	TSS - Total Susp. Solids (mg/L)	Coarse Susp. Sediment (mg/L)	Fine Susp. Sed., < 62.5 µm (mg/L)	pH	T (C)	DO (mg/L)	Spec. Cond. (mS/cm)	Turb. (NTU)
3/23/2010	Field	1,112	5.8	<5	<3	56	<15	50	<5.0	--	--	--	4.7	12.3	ND	1.3
4/21/2010	Field	5,627	33.5	<5	<3	85	<15	<30	19	10	11	7.5	6.7	11.3	39.8	6.8
6/4/2010	Field	7,571	15.2	<5	--	70	<15	40	6	--	--	7.4	8.1	11.4	40.3	2.6
6/4/2010	Replicate	--	15	<5	--	62	<15	<30	7	--	--	--	--	--	--	--
6/23/2010	Field	5,778	9.6	<5	<3	70	16.7	<30	5	--	--	7.6	9.9	12.1	52.1	2.7
10/5/2010	Field	503	<5	<5	<3	<50	27.6	<30	<5.0	--	--	--	12.4	9.1	--	0.6
10/5/2010	Blank	--	<5	<5	<3	<50	<15	<30	<5.0	--	--	--	--	--	--	--
1/18/2011	Field	15,984	53	12.8	8.2	99	45	40	44	5	41	6.7	3.9	11.4	37.7	29.0
4/1/2011	Field	15,552	52.9	9.3	--	98	--	--	54	18	45	8.0	3.8	13.0	41.4	40.1
4/1/2011	Blank	--	<3	<3	--	<50	--	--	<5	<5	<5	--	--	--	--	--
5/16/2011	Field	21,492	60	6.3	5.4	90	42	<10	59	7.2	41	7.7	5.2	12.3	38.8	45.9
11/2/2011	Field	558	6.7	3.3	<3	<50	<10	<10	<5	<5	<5	7.5	4.3	14.6	64.1	--
4/4/2012	Field	5,065	15.7	5.8	3.9	51	18	<10	6	<5	<5	7.6	4.4	--	55.4	2.5
4/17/2012	Field	6,350	9	5.9	<3	<50	10	<10	5	<5	<5	7.9	7.6	--	46.8	1.9
4/24/2012	Field	21,276	72.5	11.6	7	98	36	<10	63	21.9	58.2	7.6	10.2	--	--	37.4

Station SJ-2 (also NI-2), Field data from St. Maries/St. Joe Nutrient Loading Study (2010 – 2012)

Use Area Ratio to estimate discharge. StreamStat Ratio **is** Equivalent to Area Ratio.

St. Maries at Santa
(SJ-2, also NI-2)

Date	Sample Type	Modeled Discharge Using Area Ratio (cfs))	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)	Dissolved Ortho-Phosph. (µg/L)	Total Nitrogen (µg/L)	Dissolved NO3, NO2 (µg/L)	Dissolved Ammonia (µg/L)	TSS - Total Susp. Solids (mg/L)	Coarse Susp. Sediment (mg/L)	Fine Susp. Sediment, <62.5 mm (mg/L)	pH	T (oC)	DO (mg/L)	Spec. Cond. (mS/cm)	Turb. (NTU)
3/24/10	Field	233	23.7	10.2	5.3	138	<15	57	<5.0	--	--	7.8	6.8	11.1	54.1	4.6
4/20/10	Field	336	21.6	11.1	5.8	179	59	31	6	6	3.0	7.9	12.2	10.9	54.1	5.1
6/2/2010	Field	287	21.4	9.9	6.2	126	<15	<30	<5.0	--	--	8.2	10.5	10.8	66.4	2.8
6/22/2010	Field	1,109	41.3	13.7	9.5	241	40.2	33	8	15	8.0	7.4	10.7	10.2	56.7	12.7
10/4/2010	Field	55	17.6	11.4	4.6	95	<15	<30	<5.0	--	--	8.3	14	8.0	63.8	1.7
1/18/2011	Field	163	76.2	22.4	11.5	248	66.2	<30	31	3	27.0	6.8	1.3	12.5	36.4	29.8
4/1/2011	Field	3,509	69.6	--	--	129	--	--	23	12	20.0	7.7	3	12.6	33.2	23.4
5/16/2011	Field	3,289	71	--	--	173	55	<10	28	<5	14.0	7.6	6.3	11.0	33.5	26.2
11/1/2011	Field	84	20.1	--	--	87	<10	15	<5.0	6.7	<5	6.9	4.6	15.3	62	2.3
4/3/2012	Field	1,511	33	--	--	129	39	<10	14	<5	11.5	7.1	3.5	--	38.8	11.4
4/17/2012	Field	1,434	34.1	--	--	116	27	<10	9	<5	9.7	7.6	6.4	--	39.7	8.1
4/23/2012	Field	1,989	46.4	--	--	107	38	<10	16	5.4	19.6	7.6	12.6	--	--	12.0
4/23/2012	Replicate	--	44.9	--	--	114	38	<10	18	<5	20.7	--	--	--	--	--

Station SJ-3 (also NI-3), Field data from St. Maries/St. Joe Nutrient Loading Study (2010 – 2012)

Use StreamStat Ratio to estimate discharge. StreamStat Ratio **not** Equivalent to Area Ratio.

Santa Creek
(SJ-3, also NI-3)

Date	Sample Type	Modeled Discharge Using StreamStat Ratio (cfs)	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)	Dissolved Ortho-Phosph. (µg/L)	Total Nitrogen (µg/L)	Dissolved NO3, NO2 (µg/L)	Dissolved Ammonia (µg/L)	TSS - Total Susp. Solids (mg/L)	Coarse Susp. Sediment (mg/L)	Fine Susp. Sediment, <62.5 mm (mg/L)	pH	T (oC)	DO (mg/L)	Spec. Cond. (mS/cm)	Turb. (NTU)
3/24/10	Field	48	26.3	9.3	4.4	183	<15	49	26.3	--	--	7.5	4.7	12.1	51.8	8.1
4/20/2010	Field	70	41.9	16.8	9.1	178	16	<30	41.9	2.4	2.4	7.3	9.4	11.9	46	9.8
6/2/2010	Field	60	31.8	10.8	7.5	149	<15	72	31.8	--	--	7.5	12.5	10.0	53.9	ND
6/22/2010	Field	235	61.4	22.4	15.1	455	47.5	44	61.4	5	5.0	7.3	11.4	10.8	52.6	17.9
10/4/2010	Field	11	42.2	20.5	11	144	36.1	<30	42.2	--	--	8.0	14.2	10.0	60.4	3.1
1/18/2011	Field	777	105	22.6	20.3	320	110	<30	18	3	23.0	7.3	2.7	--	36.4	31.2
1/18/2011	Replicate	--	90.3	22	20.1	274	90.7	36	18	8	22.0	--	--	--	--	--
3/30/2011	Field	385	86.7	42	14.9	246	40	<10	72	12	48.0	7.3	3.7	13.2	39.2	59.8
5/17/2011	Field	636	49.5	17.5	11.5	127	<10	<10	13	<5	6.0	7.5	7.1	11.1	33.1	14.3
11/1/2011	Field	17	32	17.1	6.5	120	<10	<10	<5.0	5.8	<5	7.7	4	15.6	52	2.7
11/1/2011	Blank	--	1.2	1	0.25	<50	<10	<10	<5.0	5.9	<5.0	--	--	.	--	--
4/3/2012	Field	323	53	26	16	162	22	<10	11	<5	10.0	7.0	3	--	37.9	16.9
4/17/2012	Field	306	42.6	20.9	10.8	120	10	<10	7	<5	7.7	7.2	6.5	--	37.1	11.3
4/23/2012	Field	430	31.8	19.6	11.8	103	<10	<10	6	<5	7.5	7.4	11.7	--	--	10.4

Station SJ-7 (also NI-7), Field data from St. Maries/St. Joe Nutrient Loading Study (2010 – 2012)

Use StreamStat Ratio to estimate discharge. StreamStat Ratio **not** Equivalent to Area Ratio.

St. Maries at Lotus
(SJ-7, also NI-7)

Date	Sample Type	Modeled Discharge Using StreamStat Ratio (cfs)	Total Phosphorus (µg/L)	Total Dissolved Phosphorus (µg/L)	Dissolved Ortho-Phosph. (µg/L)	Total Nitrogen (µg/L)	Dissolved NO3, NO2 (µg/L)	Dissolved Ammonia (µg/L)	TSS - Total Susp. Solids (mg/L)	Coarse Susp. Sediment (mg/L)	Fine Susp. Sediment, <62.5 mm (mg/L)	pH	T (oC)	DO (mg/L)	Spec. Cond. (mS/cm)	Turb. (NTU)
6/2/2010	Field	347	26.7	12.6	6.7	148	<15	<30	6	--	--	--	--	--	--	5.1
6/22/2010	Field	1627	70	26.9	17.1	380	40.7	<30	19	11	12.0	7.2	10.35	9.8	53.3	20.9
10/4/2010	Field	83	15	9.7	4.8	139	<15	<30	<5.0	--	--	7.4	13.8	8.8	69.4	1.6
4/1/2011	Field	4,306	74.5	18.2	--	198	--	--	28	12	19.0	7.6	4.2	13.3	34.3	26.9
5/17/2011	Field	4,088	45.5	16	12.2	136	32	<10	18	<5	9.0	7.7	6.1	12.6	34.4	17.5
5/17/2011	Replicate	--	48.4	16.7	11.6	126	33	<10	18	<5	7.0	--	--	--	--	--
11/1/2011	Field	126	14.1	8.1	<3	86	<10	<10	<5	10.6	<5	7.3	4.8	14.7	61.2	1.5
4/3/2012	Field	2,200	46	15	11	149	30	<10	10	<5	9.5	7.2	4.3	--	39.3	12.8
4/17/2012	Field	2,091	35.3	14.2	7.7	122	16	<10	10	<5	8.6	7.6	8.8	--	39.1	9.8
4/17/2012	Blank	--	<3	<3	<3	<50	<10	<10	<5	<5	<5	--	--	--	--	--
4/23/2012	Field	2,871	41.4	15.5	8	99	22	<10	9	<5	13.9	7.6	14.1	--	--	12.0
Simulated flow data using "bootstrapping" technique. Data provided by Tribe																
10/10/2011	simulated time = 12:01	1,844				152										
10/10/2011	simulated time = 12:02	5,390				135										
10/10/2011	simulated time = 12:03	1,046				101										
10/10/2011	simulated time = 12:04	331	42													
10/10/2011	simulated time = 12:05	5,846	55													
10/10/2011	simulated time = 12:06	2,045	39													

Appendix F. Supporting Information for Permitted Discharges

This Appendix provides a list of permitted discharges in the Coeur d'Alene Basin, other than those for wastewater treatment plants (WWTP's).

Individual Permits for Industrial Facilities

Facility Name	Owner	Permit #	Outfall Location
Lucky Friday Mine	Hecla Limited	ID0000175	3 outfalls-all discharge to SFCDAR
Star Mine	Hecla Limited	ID0000167	Outfall 001- Canyon Ck. Outfall 002- SFCDAR
Sunshine Mine	Silver Opportunity Partners, LLC	ID0000060	SFCDAR
Sunshine Mine East	Silver Opportunity Partners, LLC	ID0000159	SFCDAR
Caladay Mine	U.S. Silver Corporation	ID0025429	Outfall 001-Daly Ck. (SFCDAR)
Coeur/Galena Mine	U.S. Silver Corporation	ID0000027	Outfall 001-Lake Ck. Outfall 002- SFCDAR
St. Maries Complex	Potlatch - Deltic Corporation	ID0000019	St. Joe River
Bunker Hill Central Treatment Plant	USEPA and State of Idaho	no permit, operated under Superfund authority	SFCDAR

MS4 Permits for Municipal Stormwater and Surface Runoff

Owner	Permit #	Outfall Location
City of Coeur d' Alene	IDS028215	CDA Lake and Spokane River
Lakes Highway District	IDS028207	CDA Lake Watershed
East Side Highway District	IDS028207	CDA Lake Watershed
Idaho Transportation Dept.	IDS028223	CDA Lake Watershed

Construction General Permits (CGP) for Stormwater and Surface Runoff

Operator	Permit ID	Receiving Waterbody	Location
Big Sky ID Corp	IDR1001YS	Rockford Bay, CDA Lake	47.5076°N, 116.9056°W
Big Sky ID Corp	IDR1001YJ	Rockford Bay, CDA Lake	47.5159°N, 116.8872°W
International Line Builders	IDR10I019	Cottonwood Bay, CDA Lake	47.4452°N, 116.8268°W
Kootenai Electric Cooperative	IDR10I018	Cottonwood Bay, CDA Lake	47.4452°N, 116.8268°W
Robinson Bros. Construction, Inc	IDR1001Y0	CDA Lake	47.6011°N, 116.8577°W
International Line Builders	IDR10I015	CDA Lake	47.5365°N, 116.8331°W
Kootenai Electric Cooperative	IDR10I013	CDA Lake	47.5365°N, 116.8331°W
Kootenai Electric Cooperative	IDR1001XH	CDA Lake	47.6011°N, 116.8577°W
Earthworks Northwest, Inc (Kootenai County Landfill)	IDR1001YE	CDA Lake	47.5327°N, 116.9367°W
Kootenai Electric Cooperative	IDR10I011	CDA Lake	47.5017°N, 116.8937°W
C.L. Heilman Company, Inc	IDR1001VN	Pine Creek	47.5192°N, 116.2419°W
Potelco, Inc	IDR10I010	CDA Lake	47.5101°N, 116.9071°W
Local Highway Technical Assistance Council	IDR1001VF	Pine Creek	47.5191°N, 116.2417°W
Potelco, Inc	IDR1001TH	Hayden Lake	47.7882°N, 116.7017°W
Kootenai Electric Cooperative	IDR1001TG	Hayden Lake	47.793°N, 116.7021°W
Eric Aschenbrenner	IDR1001TY	Mica Bay, CDA Lake	47.6116°N, 116.858°W
Joe Parzych	IDR10I00R	St. Joe River	47.341°N, 116.6146°W
Verdis	IDR1000ZJ	Lower Twin Lakes	47.8855°N, 116.8648°W
Concrete Placing Co Inv	IDR10013I	Boulder Ck, Willow Ck, SFCDAR	47.4692°N, 115.8°E
ITD	IDR10013D	Boulder Ck, Willow Ck, SFCDAR	47.4692°N, 115.8°E
Amec Foster Wheeler Environment and Infrastructre	IDR1000XF	SFCDAR/Bunker Ck.	47.5405°N, 116.1393°W
Idaho Central Credit Union	IDR1000PO	Claims to infliltrate/no receiving water	47.7018°N, 116.8037°W
James Burggraf	IDR1000OP	St. Joe River	47.3162°N, 116.5623°E
ITD	IDR1000ON	St. Joe River	47.3162°N, 116.5623°E
City of Kellogg	IDR1000KO	SFCDAR	47.538°N, 116.129°W
Waldo Construction, inc	IDR1000LO LEW		47.6867°N, 116.9143°W

Multi-Sector General Permits (MSGP) for Industrial Stormwater and Surface Runoff

Operator	ID#	Facility Location	Receiving Waterbody
Stimson Lumber - Plummer Mill	IDR05I304	Benewah County 47.3303 -116.8893	Plummer Creek
Young Living Farm	IDR051314	Benewah County 47.3044°N, 116.7369°W	North Fork Coon Creek
Potlatch Deltic	IDR05I310	Benewah County - St. Maries Complex 47.3292°N, 116.5917°W	St. Joe River
Potlatch Deltic	IDR053018	Benewah County - Lumber Drying Division 47.3256°N, 116.5558°W	Swan Lake
Emerald Creek Garnet	IDR05J005	Benewah County - 47.0719°N, 116.3314°W	St. Maries River
Emerald Creek Garnet?	IDR053226	Benewah County 47.070696 -116.327793	St. Maries River
Emerald Creek Garnet	IDR053233	Benewah County 47.041679 -116.327019	Emerald Creek
Emerald Creek Garnet	IDR053232	Benewah County 47.086892 -116.380518	Carpenter Creek
Emerald Creek Garnet	IDR053234	Benewah County 47.056905 -116.434218	Carpenter Creek
Emerald Creek Garnet	IDR053228	Benewah County 47.09674 -116.369163	Olson Creek - St. Maries River
Emerald Creek Garnet	IDR053254	Benewah County 47.075676 -116.340206	Olson Creek - St. Maries River
Emerald Creek Garnet	IDR053227	Benewah County 47.083437 -116.348973	Olson Creek - St. Maries River
Emerald Creek Garnet	IDR053235	Benewah County 47.034054 -116.324207	Emerald Creek
Kootenai County Landfill	IDR053195	Kootenai County 47.530833 -116.936667	Fighting Creek/Bellgrove Creek
Peak Sand and Gravel	IDR05IA00	Kootenai County - Fighting Ck. Quarry. 47.5208°N, 116.9333°W	Fighting Ck.
Waste Management CDA	IDR053085	Kootenai County 47.725466 -116.836542	Spokane River
Potlatch Deltic	IDR05J003	Shoshone County - Clarkia Landing 47.0059°N, 116.2576°W	west fork st. maries river
Coeur Galena	IDR05C299	Shoshone County - Galena Mine 47.478248 -115.968354	Lake Creek
Coeur Galena	IDR053039	Shoshone County - Coeur Mine 47.48948 -115.990017	SFCDAR
Crescent Mine	IDR053080	Shoshone County - 47.5046 -116.0742	Big Creek - SFCDAR

Multi-Sector General Permits (MSGP) for Industrial Stormwater and Surface Runoff – *continued*

Operator	ID#	Facility Location	Receiving Waterbody
Hecla Lucky Friday	IDR053139	Shoshone County 47.4706 -115.778508	SFCDAR
Hecla Lucky Friday	IDR05C290	Shoshone County 47.470472 -115.782147	SFCDAR
Hecla Carlisle	IDR053161	Shoshone County 47.562424 -115.870579	carbon creek
Hecla Hercules	IDR053160	Shoshone County 47.549895 -115.841214	canyon creek
Hecla Interstate	IDR053159	Shoshone County 47.54489 -115.852383	ninemile creek
Hecla National	IDR053158	Shoshone County 47.491131 -115.766773	deadman creek
Hecla Snowstorm	IDR053157	Shoshone County 47.479167 -115.740833	daisy creek
Hecla Stanley	IDR053156	Shoshone County 47.538889 -115.812222	canyon creek
Hecla Limited Star/Morning	IDR053153	Shoshone County 47.464444 -115.8125	canyon creek
Hecla Limited Tamarack	IDR053155	Shoshone County 47.8125 -115.83111	East Fork Nine Mile Creek
Hecla Limited Tiger/Poorman	IDR053154	Shoshone County 47.520833 -115.8125	Canyon creek
Hecla Limited Vienna	IDR053152	Shoshone County 47.425 -115.875	Placer creek
US Silver - Osburn Tailings Pond	IDR053040	Shoshone County 47.501514 -115.982859	SFCDAR/Argentine Ck
Smelterville Pit	IDR053201	Shoshone County 47.5491 -116.1737	SFCDAR
Sunshine Silver Mine	IDR053001	Shoshone County 47.502538 -116.071176	Big Creek