Restoration of the Kinnickinnic River through Dam Removal

Feasibility Report

SUBMITTED TO
Friends of the Kinni
315 North Fremont St.
River Falls, WI 54022

PREPARED BY
Inter-Fluve
2121 Randolph Ave, Suite 200
St. Paul, MN 55105

In association with:

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JANUARY 2017

TABLE OF CONTENTS

1. Executive Summary

Inter-Fluve was contracted by the Friends of the Kinni to complete a dam removal and river restoration feasibility study for the Junction Falls and Powell Falls Dams and impoundments in River Falls, Wisconsin. This feasibility study and report considers and evaluates potential construction methods and logistics, water management, sediment management and restoration outcomes for removing the two dams. The dam removal and river restoration feasibility study considers project goals of improvement of water quality, fish habitat, public safety, aesthetics, protection of infrastructure, and historic, cultural and recreational values. The scientific evidence supports dam removal as a cost-effective method of relieving concerns for public safety, achieving trout stream restoration goals, eliminating long-term dam repair and maintenance, and improving recreational opportunities.

To date, Friends of the Kinni and stakeholders, including the Kinnickinnic River Land Trust, the City of River Falls, Wisconsin Department of Natural Resources (DNR), the National Park Service, US Fish and Wildlife Service, and Trout Unlimited have expended significant time and energy to understand the issues surrounding hydropower generation and both the recreational and ecological impacts of the River Falls dams. Past studies include the following, copies of which are available on the City of River Falls website:

- Hydrologic Study of Lake George and Upper Kinnickinnic River Watershed (Swanson 1976)
- Kinnickinnic River Water Management Plan (1995)
- Lake George Management Plan (1996)
- Surface Water Resource Appraisal Report for the Kinnickinnic River WI DNR Priority Watershed (Schreiber 1998)
- Kinnickinnic Nonpoint Source Control Plan (1999)
- Kinnickinnic River Thermal Study (2003)
- Lake George Area Storm Water Treatment Concept Plan Report (Bonestroo and Assoc. 2005)
- Lake George Depth Survey (2006)
- West Side Stormwater Demonstration Project (2007)
- Community Report on the Kinnickinnic Priority Watershed Project (2016)
- Kinnickinnic River Watershed Strategic Action Plan (2016)

This document considers the results of this previous work, and is intended to provide a summary of updated regulatory input, structural engineering reconnaissance, construction logistics and next steps. This report complements previously conducted sediment sampling results and sediment management recommendations.

Current studies include the Friends of the Kinni Dam Removal Feasibility Study and the Kinnickinnic River Corridor Planning Project being conducted by the City of River Falls. In 2016, the Federal Energy Regulatory Commission (FERC) granted rehearing of their earlier denial of the City's request for a five-year license extension for the River Falls Hydroelectric Project to accommodate the Kinnickinnic River Corridor Planning Process. This action extends the license term to 2023 and delays any notice by the City to FERC until 2018.

Taking into account overarching project goals and solutions that have been tried to date, the recommended alternative is staged drawdown and removal of both dams using active sediment management, grading of a floodplain form, and restoration of the stream channel. Specifically, the recommendation for the River Falls removal approach considers downstream habitat and recreational fishing impacts which limit the amount of sediment that can be allowed to move downstream. The Kinnickinnic River is a Class 1 trout stream used extensively by both anglers and paddlers. Based on Inter-Fluve's previous dam removal experience, we recognize that significant impacts to both ecology and recreation need to be minimized.

Dam removal projects must weigh short term impacts versus long term benefits. The short-term impacts in this case include sand deposition in the channel downstream, noise from heavy equipment use, disturbance of nearby park access, traffic on haul roads, interruption of recreational land and water trail use, and dewatering of the impoundments. Long-term benefits include improved fish and wildlife habitat within the former impoundments, improved water quality, elimination of dam failure risk, improved public safety, improved trail connectivity, improved kayak and canoe passage, new fishing opportunities and the uncovering of a picturesque bedrock waterfall complex, gorge and cobble bed stream with bedrock outcrops.

Site access is good for both dam removal projects. Existing cleared trails and access roads are available both downstream of each dam and within the impoundment areas. Powell Falls Dam has direct access from downstream, and Junction Falls Dam can be accessed via a haul road and ramp over the lower falls and South Fork of the Kinnickinnic River. Haul routes are close to major city arteries that can quickly route haul trucks out of town if needed, although it may be possible to store all excavated sediment within the current impoundment footprint.

Sediment can be actively removed from the impoundments through mechanical excavation from upstream to downstream. The Lake Louise impoundment can be used as a sediment trap for the Lake George impoundment restoration, and additional sediment traps could be built downstream of Powell Falls (Lake Louise) to capture additional sediment. The Kinnickinnic River stream channel within the impoundments would be stabilized at the pre-dam bed elevation, and riffles, pools and depositional bars would be constructed. Banks would be stabilized with bioengineering methods and large wood applications. A floodplain of variable width can be excavated as funding allows. The floodplain and newly constructed streambanks can be stabilized further with active plantings of native grasses, forbs, shrubs and trees endemic to the Kinnickinnic River watershed.

Preliminary cost estimates were given in the sediment assessment (Inter-Fluve 2016). Updated preliminary cost estimates for the discussed alternatives are given in the table below. It should be noted that final design estimates for engineering and construction may vary. For concept level cost estimates, we typically assume costs are accurate to within 50% of the posted value, given assumptions. As design progresses through final design, the accuracy of the cost estimates improves.

Table 1. Concept level cost estimates*

	Junction Falls	Powell Falls	Combined
Engineering	$ 344,372	$ 264,895	$ 609,267
Permitting	$ 20,000	$ 20,000	$ 40,000
Construction	$ 1,229,899	$ 946,054	$ 2,175,954
Total Cost	$ 1,594,271	$ 1,230,949	$ 2,825,220

**Costs are +/- 50%*

For these estimates, we have assumed the following:

- Active removal of 90% of the sediment needed to construct a channel and minimal floodplain width. Additional floodplain width can be excavated based on final project goals and available funding. This type of detail will be developed fully in the final design stages.
- Sediment excavated from the channel can be stored and incorporated into the fringe of the impoundment areas. This action greatly lowers costs as it eliminates truck hauling through town to an approved disposal area (e.g. farm field or other fill area).
- The cost estimates do not include any large scale detention storage or stormwater best management practice treatment installation, as the viability of these treatments needs further investigation.
- The costs do not include additional trails or park amenities, as there are numerous iterations of trail locations, lengths, and types that need to be worked out before final costs can be included.
- Costs do not include removal or renovation and reuse of the powerhouse buildings or interior infrastructure. The fate of these buildings for public or private use involves too many variables, including ownership, removal of contaminants, and possible renovation costs.
- Engineering costs include hydrology, hydraulics, structural engineering, restoration engineering and stakeholder communication. Engineering costs listed here do not include planning and administration costs incurred by the Owner or stakeholders.
- Permitting costs assume no extraordinary permitting related to sediment management measures, contaminants or other.

1.1 CONCEPT PLANS

The Appendices includes concept drawings for the removal of Junction Falls and Powell Falls Dams. These drawings are preliminary but incorporate potential access routes and trails connecting with existing trails and roadways in the area. The exact location of trails and temporary access routes, kayak ramps, and other amenities will need to be determined through the final design process, and the decisions should include multiple stakeholder groups.

2. Introduction

Powell Falls and Junction Falls Dams impound the Kinnickinnic River (the "Kinni") within the City of River Falls, Wisconsin ("the City", "River Falls"), approximately 10 miles upstream of the river's confluence with the St. Croix River and 30 miles downstream from its headwaters in Erin Prairie Township, Wisconsin (National Hydrology Dataset, 2015). The dams create the downstream Lake Louise and the upstream Lake George, respectively (Figure 1). In addition to partially obscuring the City's namesake cascades, the River Falls dams impact water quality and fish habitat along the river, limit trout angling and paddling opportunities, and create potential safety hazards. The City of River Falls has been coordinating with the Federal Energy Regulatory Commission (FERC Project number P-10489-013) regarding relicensing, and has conducted a preliminary financial analysis related to the long term economic viability of maintaining the dams. Removal of the two dams and restoration of the Kinnickinnic River channel through River Falls has been proposed as one alternative to addressing these issues.

To further understand the benefits and limitations associated with the removal of Junction Falls and Powell Falls Dams, the Friends of the Kinni (FOTK) contracted with Inter-Fluve and teaming partners to complete a Dam Removal Feasibility Study. This feasibility study describes the following items:

1. Existing physical and ecological conditions along the river, including the impact of dams on the riverine environment, and adjacent infrastructure that might impact, or be impacted by, dam removal.
2. The planning and work required to complete dam removal and channel restoration, including access, staging, demolition, water management, and sediment management.
3. Costs that might be associated with the project and possible funding sources.
4. A set of recommendations for future analyses and work plans and goals (next steps).

Overall, the aim of the feasibility study is to present information and recommendations that will enhance local decision making for the FOTK and their partners, and provide a foundation for future engineering phases for removal of the River Falls dams. The project received funding from the St. Croix Valley Foundation, Patagonia, the LUSH Charitable Giving Program, and a Surface Water Grant from the Wisconsin Department of Natural Resources.

The work completed for this report included both field and desktop components, completed with input from stakeholders and partners. Fieldwork included an onsite evaluation of dam infrastructure, including spillways, adjacent buildings, penstocks, and other appurtenant structures, as well as adjacent trails, stormwater outfalls, utilities, and bridges. A brief geomorphic assessment was conducted as part of Inter-Fluve's 2016 sediment analysis (Inter-fluve 2016). A desktop analysis included a review of existing written reports and geo-spatial data covering Kinnickinnic River landuse, topography, fisheries, threatened and endangered species, water quality and hydrology, sediment contamination, and historical maps and photographs.

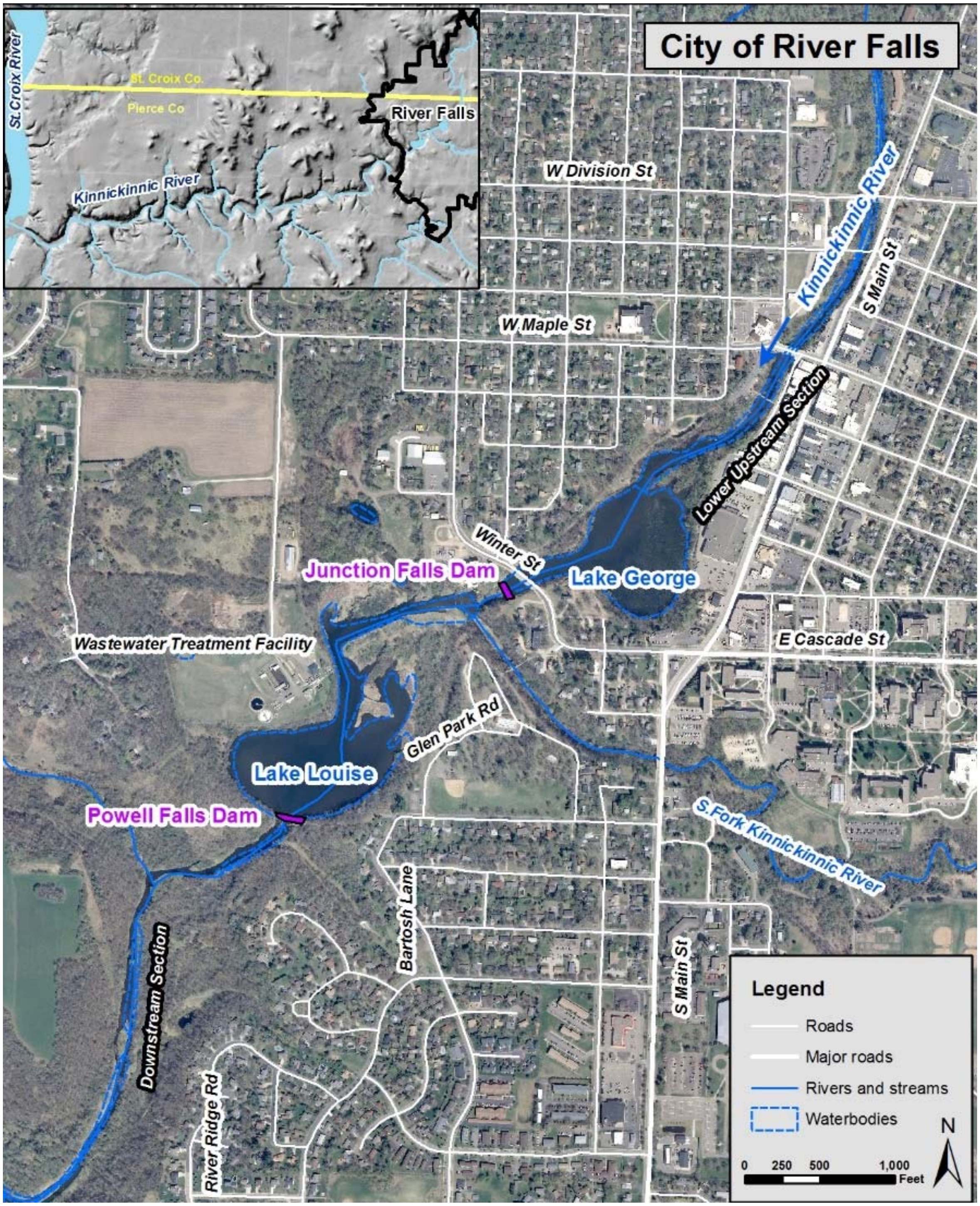

Figure 1: Powell Falls and Junction Falls Dams, River Falls, WI

3. Existing Conditions

Historically, small run of river dams powered saw and grain mills, fed irrigation canals, and provided electricity. They also often provide recreational opportunities, such as impoundment fishing, boating, and lakeside trails. However, as dams age, structural components begin to fail and their impoundments fill with sediment. Researchers have identified a number of physical and environmental concerns associated with dams. Dams cause dramatic changes to the physical and ecological riverine environment, the most pronounced occurring within the impoundment and downstream where flow regimes, sediment and nutrient transport, and temperatures are altered (e.g.; Baxter 1977, Ward and Stanford 1979, 1983; Armitage 1984; Petts 1984; Williams and Wolman, 1984; Brandt, 2000; Grant et al., 2003). In general, characteristics within the impoundment shift from a free-flowing stream that favors riverine processes, and the plants and animals adapted to them, to a lower energy, lake environment to which those species are not adapted. Additionally, many communities have identified safety and maintenance costs issues associated with their dams.

For River Falls, the dams have provided power and recreation, and many citizens associate the dams with the City's past and its picturesque setting. However, the dams have also impacted the physical and biological components of the system. The following sections describe the existing character of the Kinnickinnic River, the dams and their impoundments, and other physical and cultural aspects related to the river corridor. The effect of the dams on present conditions is also examined.

3.1 PHYSICAL ATTRIBUTES OF THE KINNICKINNIC RIVER

3.1.1 Channel Geomorphology and Floodplain Character

The Kinnickinnic River flows from groundwater-fed tributaries north of River Falls, passes through the heart of the City and over the dams, and exits the 174 square mile watershed through a confined valley on its way to the St. Croix River. The river passes through St. Croix and Pierce Counties on its approximately 40 mile course, dropping roughly 300 feet from its headwaters to the mouth- an average slope of 0.2 %. The segment of river between County Road M and the upper dam, through River Falls, has a slope around 0.13%. The Kinni falls 80 feet over both dams, and then, for the first 5 miles below Powell Dam, the channel maintains an average bed slope of 0.17%. The final downstream section flattens as the channel flows across the St. Croix River valley and floodplain.

Throughout its length, the upper Kinni Watershed has experienced human disturbance, including agriculture, dams, channelization, drain tiling, and industrial and residential development. The landuse in the upper watershed is primarily agricultural, with variably sized riparian buffers, wetlands, and forested headwater areas. From I-94 to County Road M, the stream is a highly meandering riffle-pool and run-pool stream coursing through primary growth floodplain forest. Significant streambank erosion along the upper Kinni and its tributaries contributes sediment to the channel, and some of that material moves downstream to the River Falls reach. In-stream wood density is low, and habitat primarily comprises bedforms, occasional boulders, and artificial and natural undercut bank habitat. The channel within 2500 feet of Lake George, through downtown

River Falls, is a straight riffle-pool channel. Early topographic and plat maps, including the 1850 General Land Office (GLO) map, show this segment being slightly more meandering (Figures 2 and 3)) however, these maps often depict unseen channel reaches with idealized planforms, which often do not represent true ground conditions. The lower portion of the river upstream of Lake George was at least partially channelized during the early history of the City. The channel bank toes through the city are stabilized with riprap while the riparian zone is a narrow primary and secondary growth riparian forest.

Dams reduce the water surface slope upstream of the spillway. This slope is a surrogate for what is called the energy grade line, which relates to the ability of the stream to transport sediment. The reduced energy grade line of the Kinnickinnic River just upstream of each of the River Falls dams reduces the channel's capacity to transport sediment in these segments. The resulting sediment deposition has buried the pre-dam river upstream of the dams. Before dam construction, the Lake George and River Falls reaches were likely sediment transport dominant, meaning that incoming sediment passed through to downstream reaches with little deposition. The lower reach, between the dams, may have had some depositional characteristics, but if in equilibrium, most of the finer materials would have also passed downstream. Once closed, the dams trapped coarser materials and sands and silts, leaving a wedge of deposited material in both ponds and upstream, past the downtown Maple Street Bridge.

An analysis of channel bed slopes through River Falls and recent coring of the impoundment sediments (Inter-Fluve 2016) suggest the pre-dam channel in the Lake George impoundment area was likely around 55 feet wide and 2 to 3 feet in mean depth. The river was likely a moderately sloped riffle pool channel with gravel, cobble and boulder bed material. Similar data indicate the channel in Lake Louise was likely 60-65 feet wide and 3-4 feet in mean depth. The larger channel would accommodate flow from the South Fork Kinnickinnic River, which joins the mainstem just downstream of Junction Falls, as well as any backwater effects created by the rock sill that forms Powell Falls. The Lake Louise channel appears to have been a gravel riffle-pool segment with a moderate gradient (0.2-0.6%). The banks were likely forested with common riparian forest trees such as black willow, cottonwood, silver maple, swamp white oak and elm, and a native shrub understory. Sediment deposition attributable to a dam failure along the South Fork Kinnickinnic River, along with natural transport, has created an alluvial fan deposit at the upstream end of Lake Louise. A small tributary channel from a spring pond to the north also enters the Kinni at the upper end of Lake Louise, but is not a significant source of water or sediment.

In addition to being buried by sediment trapped upstream of dams, river segments downstream of dams often become "sediment starved," where sediment is mobilized in the sections downstream of the dams but no new sediment is carried in to replace it (i.e., the sediment is trapped upstream). This process can result in channel widening and armoring immediately downstream of the dams (Kondolf 1997, Ligon 1995). However, the effect of sediment starvation is limited along the Kinni downstream of River Falls, as the channel was already armored by an existing bedrock and cobble-boulder bed. The channel downstream of the Powell Falls Dam and bedrock influence is a cobble-gravel, riffle-pool reach that runs through a narrow valley. The valley ranges in width from 80-200 feet and is approximately 40-150 feet below the surrounding farmland occupying the upper terrace. Roughly 7.0 miles from the St. Croix River, the Kinni channel transitions into a depositional reach, characterized by frequent depositional features including alternate gravel, sand and silt point bars, mid channel bars, and vegetated islands.

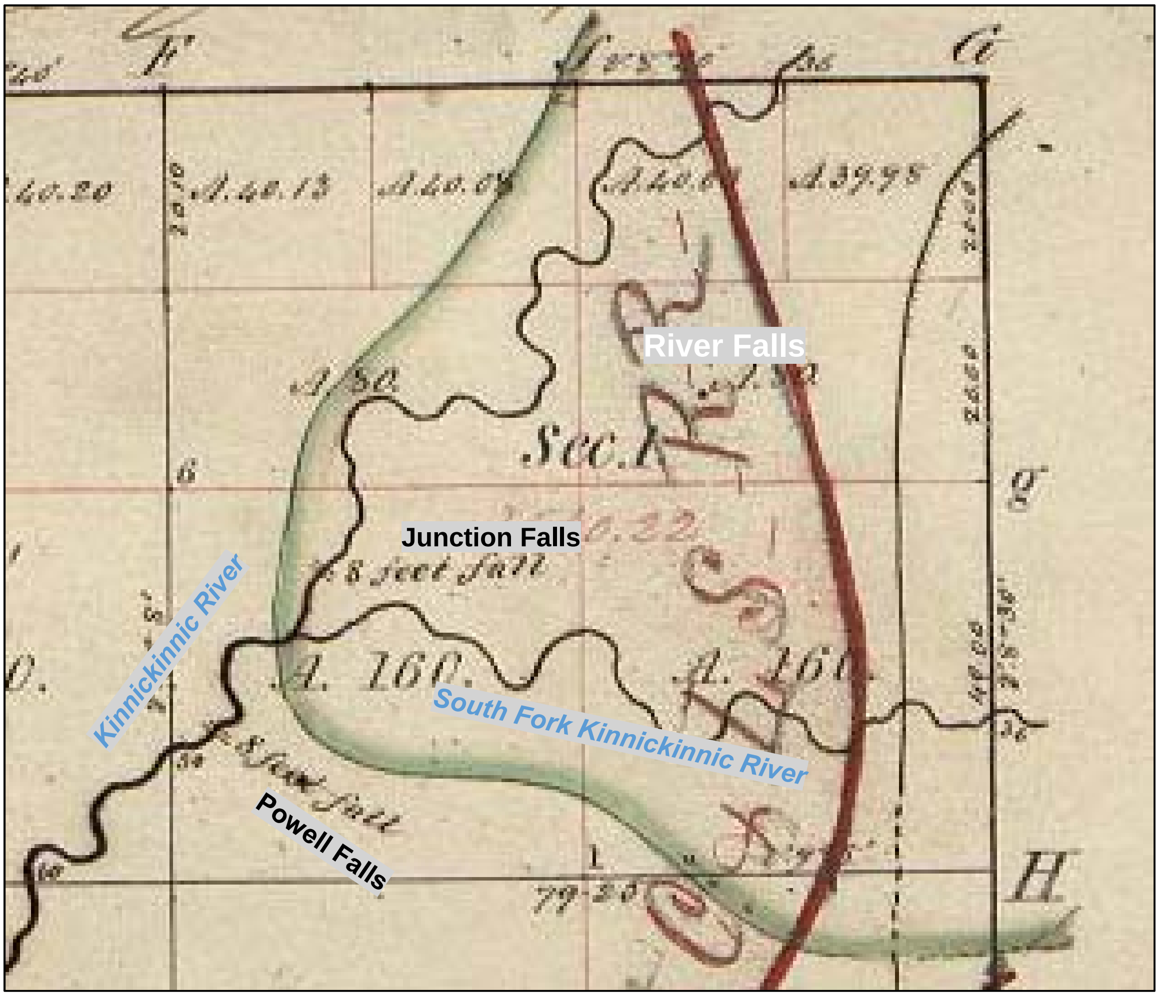

Figure 2: 1848 GLO Plat map for River Falls Township, Section 1, depicting "repeated" meanders along the Kinnickinnic River up- and downstream of the junction with the South Fork Kinnickinnic River.

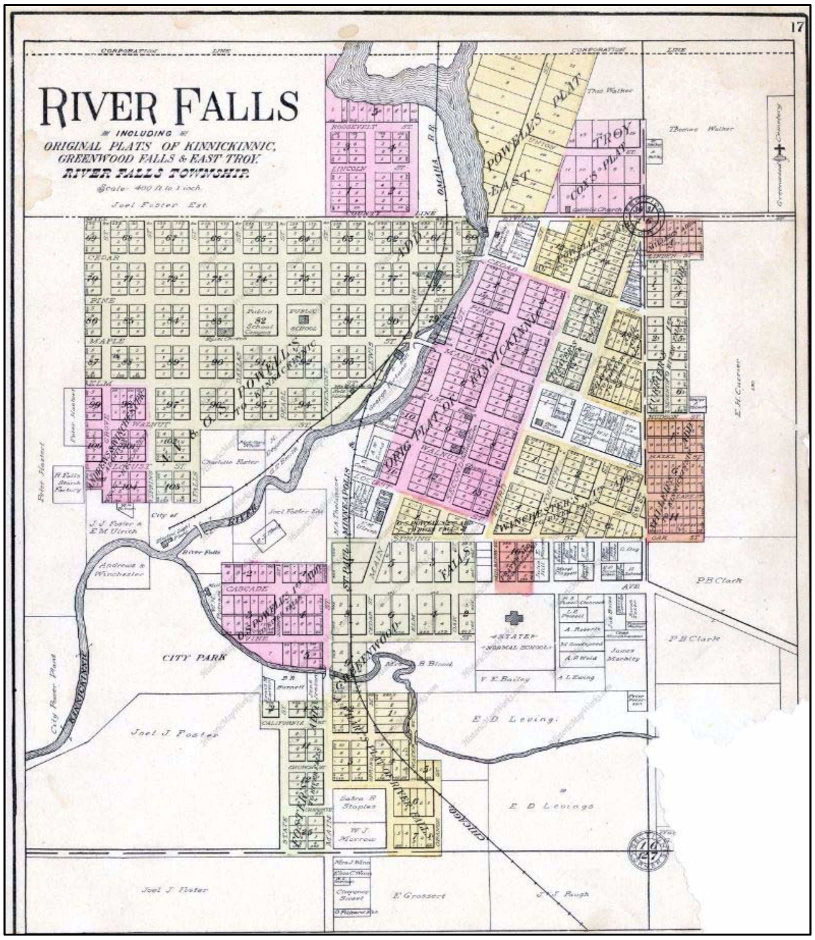

Figure 3: 1901 Plat Map of River Falls.

3.1.2 Dam and Impoundment

Various dams have occupied the channel through River Falls since the 1800s, and the two remaining dams were built on top of the natural waterfalls that provide the City's name (Figures 4 and 5). Prior to dam construction, the Kinni flowed over the upper part of Junction Falls, dropping roughly 10 feet before flattening out for 100 feet and then dropping an additional 16 feet over the lower falls. Eagle Rock, which was originally at the middle crest of the lower falls of Junction Falls, moved to river left, between the lower falls and the South Fork Kinnickinnic River.

Junction Falls Dam - Junction Falls Dam is a concrete gravity dam built in 1920 by the City of River Falls (Figure 6). The City replaced the previously rock filled timber dam constructed in the late 1800s. The powerhouse was built in 1948. Improvements to the dam include encasing the steel tube penstock in 1962, and drawdown and refacing in 1990. The general layout of the current dam is illustrated in Figures 7 and 8.

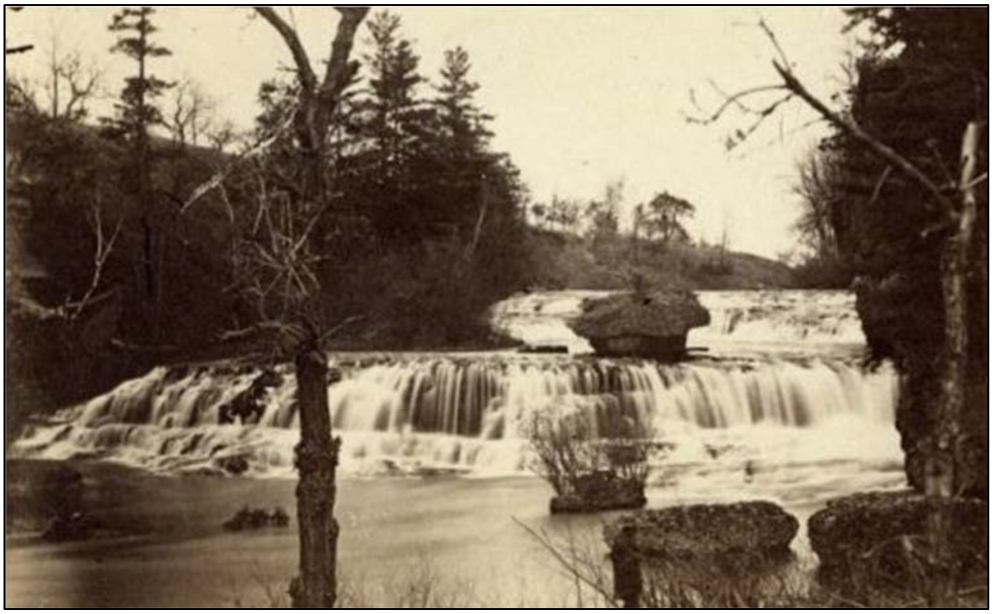

Figure 4: Pre-dam view of Junction Falls

Figure 5: Looking upstream along Junction Falls to pre-1920s dam and Falls Street bridge. Eagle Rock is visible above the lowest cascade.

Figure 6: Existing Junction Falls Dam with power house on right bank (left of photo). The dam sits on the upper cascade and the lower falls is in the center of the photograph (photo Inter-Fluve).

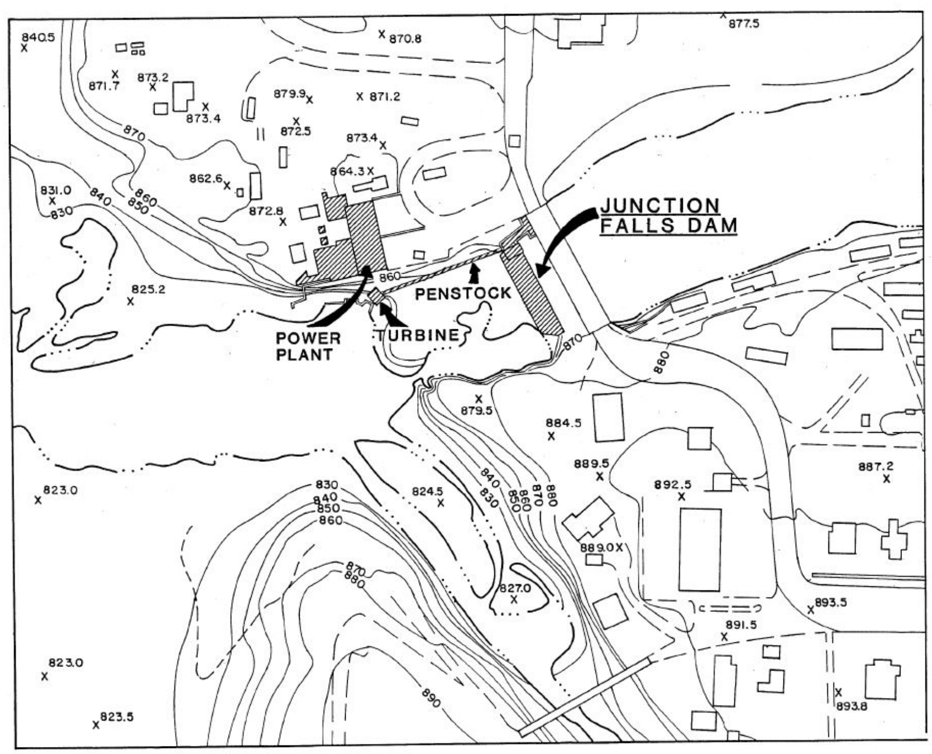

Figure 7: General Plan View Configuration of Junction Falls Dam (from Hatch 2013).

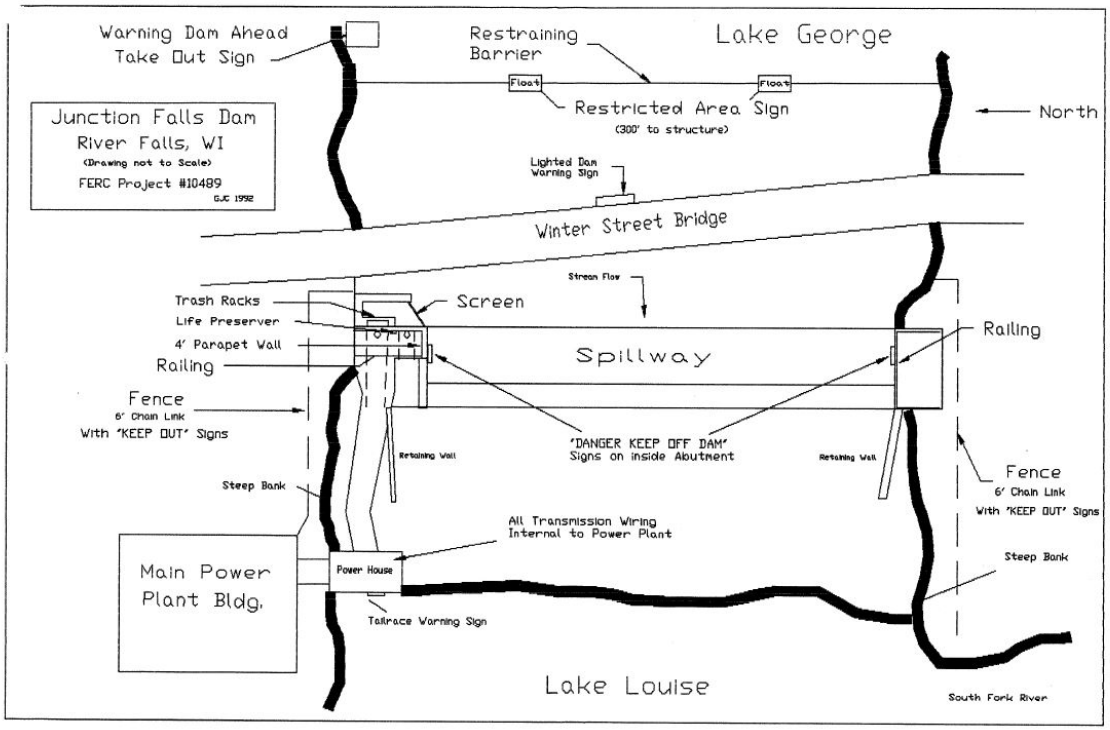

Figure 8: Detailed General Plan View of Junction Falls Dam (from Hatch 2013).

The Junction Falls spillway is approximately 32-feet high and 115-feet long, and has a 21-foot wide base. The spillway elevation and normal pool elevation is 865.3-feet. The design head is approximately 42-feet. The dam is currently operated as a run-of-the-river facility. A single, active turbine, with a power generation capacity of 250 kW, is housed in the power station on river right (Figures 5 and 6). Flows are controlled by three hydraulic devices including the ogee spillway, a 6-ft diameter by 200-ft long Penstock, and a 5-square foot gated water opening used to control excess flows. The Penstock opening, at elevation of 850.8 feet, has a maximum hydraulic capacity of approximately 80 cfs when pool elevations reach the top of dam (City of River Falls 1987). The 5 square foot opening, at an elevation of 845.3-feet, has a hydraulic capacity of approximately 880 cfs when pool elevations reach the top of the dam. (City of River Falls 1987).

At Junction Falls Dam, the Kinnickinnic River drains approximately 90 square miles. The dam creates Lake George, an approximate 16-acre impoundment with a storage capacity of 142 acre-feet at the top of the dam (Hatch 2013). Based on the Lake George and Lake Louise Sediment Assessment Report (Inter-Fluve, 2106), Junction Falls Dam has less than 10% of its original storage capacity, as approximately 103 acre-feet of sediment is currently stored within the Lake George impoundment.

Powell Falls Dam – Powell Falls Dam sits approximately 0.5-miles downstream of Junction Falls Dam. This dam is a concrete gravity dam built in 1966 by the City to replace a previously damaged timber dam (Figure 9). The hydroelectric equipment dates back to 1948. The general layout of the current dam is illustrated in Figures 10 and 11. A single, active turbine with a power generation capacity of 125kW is housed in the power station on river left.

The dam is 22-feet high and with an uncontrolled spillway at elevation of 821.8-feet, with a 108.25-feet long crest and a 21-foot wide base. The dam sits on bedrock within an existing sandstone gorge. The Powell Falls Dam is also a run-of-the-river dam with a normal pool elevation of 821.8-feet. The design head for the facility is 20-feet. Flows are controlled by three hydraulic devices including an ogee spillway, a 39-inch direct intake with a 6-foot by 6-foot outlet, and a 6-square foot gated water opening used to control excess flows. Both intakes are at an approximate elevation of 811-feet. At maximum pool, the discharge capacity of the 39-inch intake and 6-foot square waste gate is approximately 82 cfs and 530 cfs, respectively (City of River Falls, 1987).

The Kinnickinnic River drains approximately 110 square miles upstream of the Powell Falls Dam, which includes the South Fork Kinnickinnic River subwatershed. The associated impoundment, Lake Louise, covers roughly 15 acres. Based on the Lake George and Lake Louise Sediment Assessment Report (Inter-fluve, 2016), approximately 101.5 acre-feet of sediment is currently stored within the Lake Louise impoundment.

Figure 9: Existing Powell Falls Dam with power house on left bank (right of photo). The dam sits on bedrock (center of the photograph).

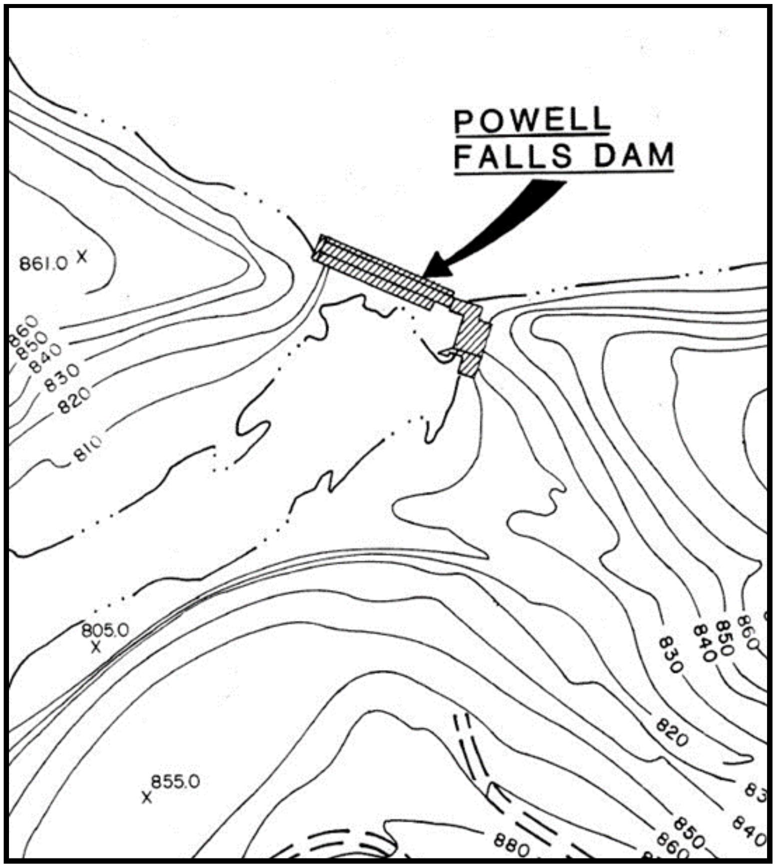

Figure 10: General Plan View Configuration of Powell Falls Dam (from Hatch 2013).

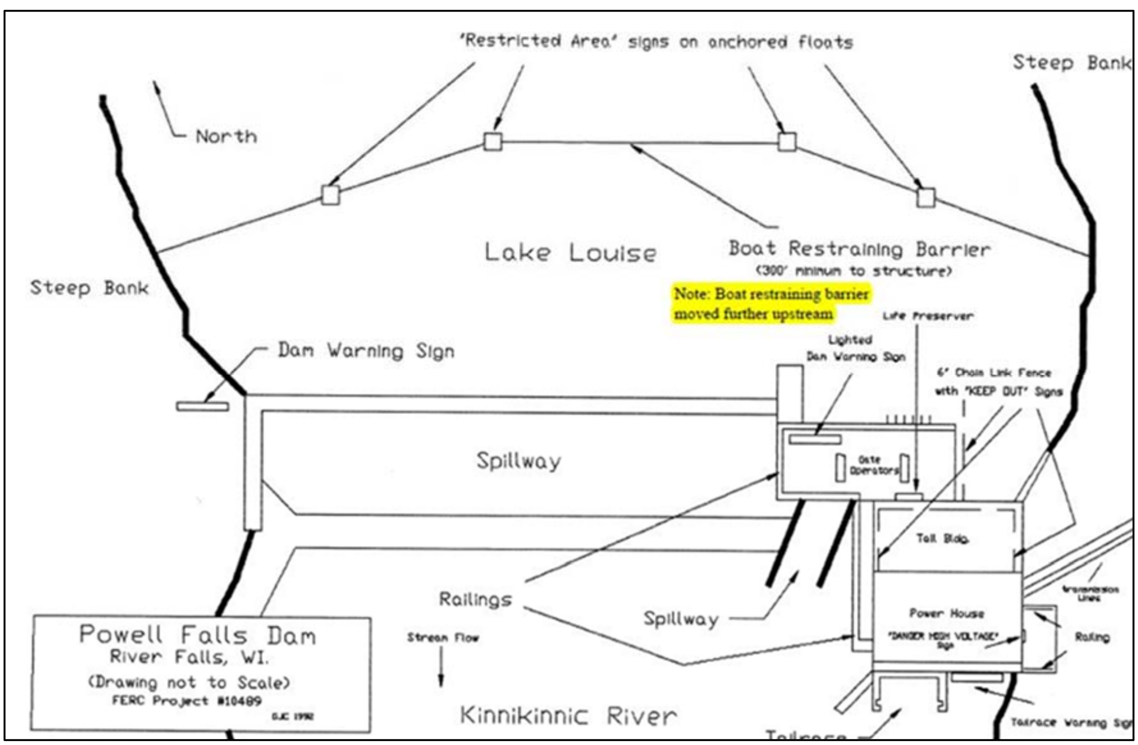

Figure 11: Detailed General Plan View of Junction Falls Dam (from Hatch 2013).

3.1.3 Impoundment Sediment and Sediment Contamination

The reduced energy in many dam impoundments creates areas where fine material, including silt, clay, and organics, can fall out of suspension and accumulate. Pollutants often adsorb to fine material, so contaminant concentrations may be elevated in dam impoundments where these fine sediments accumulate. Concerned about possible sediment contamination in the impoundments, the City of River Falls contracted Inter-Fluve to evaluate existing sediment conditions in the Lake George and Louise impoundments. The Lake George and Lake Louise Sediment Assessment (Inter-Fluve 2016) included depth-of-refusal probing throughout the impoundments and the collection of six sediment cores in each lake (12 total) for contaminant and physical property analyses (Figure 12). The samples were analyzed for a range of inorganic (e.g., metals) and organic (e.g., PCBs, PAHs) pollutants. The data indicated that Lake George stores approximately 166,800 cubic yards ("CY") of sediment and Lake Louise stores 163,800 CY. In both ponds, the dominant impoundment sediments are fine and medium sand (80% in Lake George and 65% in Lake Louise – Table 2). Silt, clay, and organic material were also observed. Sand-sized sediment and larger clasts typically do not retain contaminants, and it is likely that most of the noted contamination is bound up in the finer fractions.

Figure 12. Scientists sample sediment cores just upstream of the Junction Falls crest, Fall 2015 (photo Inter-Fluve).

In a dam removal scenario, sediment will either be allowed to transport downstream or will be actively excavated. In either case, the sediment must first be tested to determine if any of the sediment has contaminant concentrations that exceed any thresholds that might trigger special handling. If those thresholds are exceeded, rules may take effect that govern where or how excavated sediment may be stored. Federal and state pollution regulatory thresholds use *effects concentrations*, which are thresholds based on established research regarding the toxicity of compounds to biological organisms such as worms, insects or fish. The contaminant data from the impoundment samples suggest that the sediment within the ponds has contaminant concentrations either undetected or less than their respective effects concentrations. Some exceptions are noted below. More detail can be found in the Sediment Assessment Report (Inter-Fluve, 2016):

1. Samples collected along the main channel in Lake George were relatively uncontaminated. No PCBs were detected. Concentrations of two polyaromatic hydrocarbon (PAH) compounds exceed their respective effect concentrations (ECs) at one channel sample. PAHs result from oil and other petroleum products and are fairly common contaminants in urban

watersheds. In the off-channel historic floodplain sediments of Lake George, mercury exceeded the lowest WI state threshold in two samples, and lead in one sample. Arsenic exceeded EPA screening levels for ingestion, as did hexavalent chromium in three of six samples.

2. In Lake Louise, the upstream channel sediments were relatively uncontaminated. In one sample, the concentration of arsenic and cadmium were elevated above WI regulatory screening levels. Just downstream of the waste water treatment outlet, concentrations of 10 PAH-compounds exceeded their respective effects concentrations. In the Lake Louise floodplain sediments, mercury nickel exceeded the lowest WI screening thresholds at two sites. Arsenic exceeded the lowest threshold at three sites, and hexavalent chromium at one site. In addition, concentrations of seven PAH compounds exceeded their respective screening levels in the north floodplain area, downstream of the treatment facility.

Table 2. Approximate sediment composition of the impoundments

	Lake George	*Lake Louise*
Silt/clay	20%	40%
Fine sand	40%	20%
Medium to coarse sand	40%	40%

During final design, permit regulations will likely require resampling and testing of areas where contaminant concentrations exceeded thresholds of concern. During the pre-permitting meeting process, the WDNR will be consulted and a sediment sampling and testing plan will be developed. The results of the plan will help to dictate the permit conditions for sediment reuse. Early communication with the WDNR during the Sediment Assessment process suggests that sediment may be reused on site.

3.1.4 Hydrology and Hydraulics

The climate within the Kinnickinnic River Watershed is characterized by long and relatively cold and snowy winters and mostly warm summers with periods of hot humid conditions. Mean annual precipitation for the region is about 29 inches of rain and melted snow, with the majority falling during summer thunderstorms. Precipitation associated with less intense rainfall and snow melt seep into the glacially-derived sand and gravel deposits and eventually, into the underlying bedrock. Excess water, accumulated during intense storms, rain-on-snow events, and significant snow melt periods, runs into smaller channels, tributaries, stormwater mains, etc., and eventually flows down the Kinnickinnic River to the St. Croix River.

For most of the year, flow along the Kinni is primarily maintained by groundwater drainage to at least fifteen intermittent tributaries and several springs along the channel, as well as direct discharge through the river bed. The groundwater flows are significant and steady, producing relatively stable discharges. However, the watershed responds rapidly to snow melt and rainfall, in part because there are fewer wetlands and ponds within the system to attenuate higher flows (Swanson, 1976). Most large flows along the Kinnickinnic River are associated with snow melt in March and April, or with extreme thunderstorms during late spring. Several large floods with considerable damage have occurred, including a flood that destroyed Junction Falls Dam and two other River Falls dams (Prairie Mill and Green Wood Dams) in 1894 (Swanson, 1976).

The Application for Minor Hydroelectric Power Project Report (City of River Falls 1987) reported the annual average flow through the dams as approximately 95 cfs, based on 1916 – 1921 USGS stream gage data collected approximately 5 miles downstream of the City. Between 2003 and 2014, flow values were recorded at USGS stream gage 05342000 (Kinnickinnic River near River Falls, WI), approximately 7.5 miles downstream of Powell Falls Dam, at the road crossing of County Road F at the eastern edge of Kinnickinnic State Park. The gage includes inflows from three main tributaries at or below the dams: the South Fork of the Kinnickinnic River, Mann Valley Creek, and Rocky Branch. The watershed area upstream of the gage is 165 square miles compared to approximately 110 square miles at Powell Falls Dam and 90 square miles at Junction Falls Dam. Based on the daily mean flow data, the average daily flow over the year at this location is approximately 107 cfs. Average daily values by month at this site vary between 92 and 145 cfs (Table 3). When scaled by watershed area, the average daily flow for the year at Junction Falls Dam is 58 cfs and varies between an average of 50 cfs in January and 79 cfs in March. At Powell Falls Dam, the average daily flow for the year is 71 cfs, with a January average of 61 cfs and a March average of 97 cfs. The average daily flows indicate flow is higher during spring runoff and lowest during the winter, as expected, and the relative difference in the average daily flow data validate that flows are somewhat stable. However, some of the monthly differences could be associated with dam operations.

The WDNR's report on the Kinnickinnic Watershed (Schreiber 1998) described additional continuous streamflow measuring stations upstream and downstream of the City. Although the study only included data for two years, 1996 and 1997, the information showed that stream flows through the City are significantly influenced by stormwater, tributaries, and dam operation. Based on a 1997 baseflow survey, approximate baseflow of 68, 94, and 11 cfs were reported upstream of the City, downstream of the City and along the South Fork Kinnickinnic River, respectively. During monitored storm events, the South Fork Kinnickinnic River contributed approximately 90% of the peak flow recorded at the gage downstream of the City, indicating stormwater and impervious surface development within the associated area of River Falls have likely increased the magnitude of peak flows and flows-per-event within that system. The WDNR report (Schreiber 1998) also examined the hydrologic effect of dam operations, specifically during non-storm event periods. The study concluded that daily manipulation of dam gates and regular trash cleaning operations causes significant fluctuations in flow recorded at the downstream gage location.

Table 3: Monthly Average Flows at USGS Gage Station 05342000 (Kinnickinnic River near River Falls, WI). Powell and Junction Falls data are scaled by watershed area relative to USGS gage data.

Month	2003 – 2014 Average Daily Flow Data (cfs)		
	USGS Gage 05342000	Junction Falls	Powell Falls
Drainage Area	165	90	110
January	92	50	61
February	95	52	63
March	145	79	97
April	129	70	86
May	120	65	80
June	129	70	86
July	106	58	71
August	113	62	75
September	105	57	70
October	107	58	71
November	101	55	67
December	96	52	64
Annual	107	58	71

Schreiber (1998) does not include a period of record long enough for developing exceedance probabilities and associated flows that can be used for channel design, but it provides supportive evidence suggesting using downstream flow data may not be suitable for design upstream of the dams. Even though the current downstream gage includes a longer period of record, the data should be processed to account for the presence of existing upstream hydrologic impacts. The report also highlights the associated water quality and biological effects for a system with significant stormwater inputs and daily or routinely scheduled flow manipulations (Schreiber 1998).

In 2011, The Federal Emergency Management Agency (FEMA) published an effective Flood Insurance Study (FIS) for Pierce County, which covers past flooding issues, flood management actions, estimated flood flows (Table 4), and water surface profiles (55109C; FEMA, 2011). The River Falls reach of the Kinni was part of a more detailed study described within the 2011 FIS, which included hydrologic and hydraulic modeling performed by SEH consultants. This detailed evaluation included a HEC-2 model of the channel from Division Street, upstream of the dams, to the confluence of Rocky Run downstream of the dams. Due to the current, backwatered conditions, only one model cross-section was necessary for Lake George, and no cross-sections span Lake Louise. Flood Insurance Rate Maps (FIRMs) associated with the FIS studies, and subsequent modeling, have also been published by FEMA. FIRM panel 0482 covers the impoundments; panels

0482, 0501, and 0343 cover the Kinni through River Falls, and panels 0483 and 0484 include the Kinni downstream of the dam. The maps indicate all flooding is contained within the steep-sided valley through the reach.

The FIS's (FEMA 2011) peak flow values associated with standard flood recurrence intervals at each dam (Table 4) are evaluated with a focus on flood hazards; however, channel morphology is usually adjusted to carry smaller, more frequently occurring peak flows (e.g., 1.1 to 5 year recurrence interval floods). For refining the channel design along the Kinnickinnic River through the study reach, these smaller flood events were quantified using the USGS Streamstats application (https://water.usgs.gov/osw/streamstats/) and Walter and Krug's (2003) Flood-Frequency Characteristics of Wisconsin Streams. This analysis indicates bankfull flows for the Kinnickinnic River at Junction Falls is likely between 180 and 405 cfs (i.e., 1.2 to 5 YR recurrence interval flood), and at Powell Falls, bankfull is likely between 200 and 445 cfs (Table 5). However, flows predicted for larger flood events using this method, such as the 50, 100, and 500 year floods, are an order of magnitude or more less than the flows predicted by FEMA in the FIS.

Table 4. Peak Flows for the Kinnickinnic River through River Falls, WI, from the FEMA FIS (2011).

Location	Drainage Area (sq miles)	Annual Peak Flood (cfs)			
		10-Year Recurrence	50-Year Recurrence	100-Year Recurrence	500-Year Recurrence
Junction Falls Dam	90.0	3,350	7,050	8,700	13,000
Powell Falls Dam	109.7	6,800	11,000	12,800	16,900

As a general check on the channel sizing conducted in the Inter-Fluve (2016) sediment assessment, Manning's equation was used to calculate bank full flows for the field delineated channel (60-foot wide stream bed, 3:1 (horizontal: vertical) bank slopes, roughness (*n*) of 0.04, and a slopes of .0042 for Lake Louise and .007 ft/ft for Lake George (Inter-Fluve, 2016)). We assumed bankfull depths between 2.5 and 3 feet, corresponding to bankfull depths observed upstream. If the bankfull channel carries a flow between the 1.2 and 5 year recurrence interval annual flood, as research suggests (Wolman and Leopold, 1957), then the estimated bankfull flow based on the proposed rough channel dimensions should be between the average daily flows (Table 3) and the larger flood events (Table 3), and verify the streamstats flows. The estimated bankfull flows for the delineated channel range from 690 cfs to 1225 cfs (Table 5), which fall in the range of "acceptable" flows set by the broad criteria. The estimated bankfull flow for the delineated Lake George channel also matches the bankfull flow of 1221 cfs estimated for a cross-section surveyed upstream of the dam, near the intersection of Pine and Main Streets (slope = 0.005 ft/ft and depth = 3 feet) However, the flow estimates are considerably higher than the 1.2 to 5 year flows provided using streamstats. Bankfull flow estimates and channel depths will require refinement in future studies and design.

Table 5. Flood flows associated with standard return intervals as predicted using Walker and Krug (2003).

Recurrence Interval (YR)	Junction Falls Dam Flood Flow (cfs)	Powell Falls Dam Flood Flow (cfs)
1.01	74	82
1.1	149	162
1.2	186	202
1.5	248	266
2	305	327
5	417	443
10	479	506
25	558	588
50	611	641
100	659	690
500	743	775

Table 6: Preliminary Bankfull Estimates for Lake Louise Channel

Impoundment	Lake Louise	Lake George
Average Stream Slope	0.42%	0.70%
Water Depth (ft)	Bankfull Capacity (cfs)	Bankfull Capacity (cfs)
0.5	46	59
1	147	189
2	474	611
2.5	**690**	**891**
3	**949**	**1224**
4	1563	2017
5	2314	2986

Hydrology has obvious implications for designing channel and floodplain restoration. The hydrology of the Kinnickinnic River in this reach suggests that design must incorporate not only the stable base flow typical of trout streams, but also potentially flashy flood flows. Design hydrology is fairly complex and will need to consider upstream inputs, baseflow inputs from the spring pond, outfall inputs into Lake George, South Fork contributions, and outfalls from the Lake Louise area. Hydrology also has implications for construction period access routes and other temporary support. For instance, if a crossing is needed at the mouth of the South Fork, that crossing must be able to pass a defined flood flow or overtop safely without having to rebuild the crossing after each precipitation event. The size and materials used in the crossing must be designed with a risk analysis balancing the likelihood of a flood of particular size and the cost of the temporary treatment.

3.1.5 Stream Temperatures

In addition to the geomorphic changes caused by dam construction and operations, small dams often elevate water temperatures via flow stagnation, increased exposed water surface area and increased time of solar exposure (Horne 2001, Poole and Berman 2001, Walks et al 2000). Elevated water temperatures may directly impact biota by exceeding an organism's physiological tolerance, or indirectly, by decreasing concentrations of dissolved oxygen, a problem that intensifies during the summer months when air temperature is warmest and flows are low. Therefore, temperature often dictates aquatic community structure, productivity, and species distribution in rivers and impoundments (Mitro et al., 2010). With the exception of the Lake George and Lake Louise impoundments, the majority of the Kinnickinnic River is classified by the WDNR as cool-coldwater habitat. The *Surface Water Resource Appraisal Report* (WDNR 1998) recommends dam removal or modification as being important in improving water temperature conditions in the lower Kinnickinnic River (from STH 35 to CTH F).

Considerable effort has been made by the US Army Corps of Engineers (USACE), Trout Unlimited (TU), and the WDNR to monitor and model water temperature distributions and impacts along the Kinni. Water temperature data from the WDNR (1996-1997) and TU (1992-1997) indicate that under summer base flow conditions, the impoundments can increase downstream river temperatures by about 5°F. In the affected downstream reaches, recorded summer stream temperatures exceeded optimal brown trout conditions 21-48% of the time compared to just 3-10% of the time upstream of the two dams (Schreiber 1998). Data collected by TU's Kiap-Tu-Wish Chapter (Kiap-Tu-Wish, 2014; unpublished) corroborates the WDNR study. Over the 1993 to 2013 data collection period, July stream temperatures downstream of the dams are 4.7°F greater than upstream (Kiap-Tu-Wish, 2014).

These results are of concern considering that native brook trout and other cold water species are sensitive to changes in environmental conditions, particularly water temperature (Mitro et al. 2010). Although an increase in water temperatures occurs from upstream to downstream, it should be noted that other factors may influence the temperature changes within the study area, including treatment plant discharge, urban runoff, and groundwater spring input within the impoundments.

The Coldwater Fish and Fisheries Working Group (Mitro et al., 2010) incorporated the Kinnickinnic River stream temperature data set to develop climate change forecast models as it relates to available stream length for Wisconsin cold water species. Predictions from their statistical models for a best, moderate, and worst case climate warming scenario indicate a 7.9%, 33.1 % and 88.2% statewide loss in stream length for brown trout, respectively. The models show a more significant reduction in stream length for brook trout (43.6%, 94.4%, and 100%, respectively). These findings stress the importance of protecting and enhancing the coldwater system through River Falls.

In 2003, the USACE developed a CE-QUAL-W2 thermal model for the Kinnickinnic River to assist the City and stakeholders in evaluating stormwater management alternatives associated with managing their cold water fishery (Noren, 2003). The modeling tool appears promising for existing and future analysis, including dam removal assessment, but as of the report date, it lacked detailed input data including the impoundment bathymetry, continuous flow data, and others. If quantifying the temperature effects from the two impoundments, and their removal, is desired, the continued development of a comprehensive thermal model may be an option worth considering. However, anecdotal evidence and the broader assessments completed to date may suffice for generally identifying a source of thermal impacts and management or project outcomes.

3.2 ECOLOGICAL/BIOLOGICAL ATTRIBUTES OF THE KINNICKINNIC RIVER STUDY REACH

Negative impacts of dams on riverine systems are well documented and usually associated with the conversion of flowing to standing waters, modification of downstream flows, and blockage of up and (or) downstream passage (e.g., Winston et al. 1991, Martinez et al. 1994, ISG 1996). In general, intolerant *specialist* stream species within dam-impacted river segments are replaced by more tolerant or adaptable species (*generalists*) typically associated with reservoir or lake environments (Cole 1983, Kanehl et al., 1997).

The river segments impacted by the River Falls dams primarily provide a lake/pond environment. Because the impoundments are filled with sediment, much of the wetted area is relatively shallow (< 2ft deep during drawdown), with deeper areas occupied by the main channels. The bed materials primarily comprise sand and silt with little habitat variability or cover other than pockets of thick aquatic vegetation. Few fish were observed within the impoundments during past Inter-Fluve field visits, but various water fowl (e.g., Canadian geese, ducks), great blue herons, large pond snails, and river otters were noted.

The primary impact of the dams on Kinnickinnic River ecology is the conversion from a river system to a lake system upstream of each dam, and the sedimentation associated with the change to a lower energy environment. Stream ecological communities require a diversity of complex habitats for eating, hiding, resting, and spawning. Sediment accumulated behind dams covers course substrates, eliminating interstitial spaces in rocks, burying spawning gravel and attachment substrate, and filling over bedforms such as riffles and pools. Sediment upstream of both River Falls dams has filled pools, covered riffles, and simplified what were historically more complex lotic habitats.

3.2.1 Fisheries

The fish species that historically inhabited the Kinnickinnic River include brook trout, smallmouth bass, brook stickleback, fathead minnow, mottled sculpin, and white sucker. European brown trout have been introduced and managed as a game fish for the past century. The WDNR has determined that the Kinnickinnic River contains an exceptionally high quality and high density brown trout population throughout the main stem (WDNR 2015). According to the WDNR, the Kinnickinnic River and South Fork of the Kinnikinnic River are considered outstanding Class I trout waters, and the lower Kinni, downstream of Powell Falls Dam, is classified as an Outstanding Resource Water. The upper Kinni is also a Class I Trout Stream and a designated Oustanding Resource Water above

State Highway 35. The entire Kinnickinnic River outside of the impounded areas is designated as an Area of Special Natural Resource Interest (ASNRI). The receiving reach of the St. Croix River is classified as an Exceptional Resource Water. During the past decade, brown trout densities and the number of large size trout (12 inches and greater) have been consistently above the 95 percentiles for the State of Wisconsin. During the 2015 survey, the survey station just downstream of the River Falls dams ranked in the 78th percentile among Wisconsin streams for adult brown trout Catch Per Effort (CPE; 937 fish/mile). Longer term (1996 –2014) trend data from the lower Kinni show adult densities consistently greater than the 95th percentile.

Survey data has shown the prevalence of self-sustaining brook trout within the South Fork Kinnickinnic River and near the headwater of the Kinni, and considerable effort has been expended to restore trout habitat in these areas. Lake Louise and Lake George are currently managed for fishing and swimming, and although they are not considered impaired, they are also not listed as trout water. However, WDNR's 1971 Surface Water Inventory of Wisconsin, suggests brown trout inhabit Lake George, along with warm water species including crappie, green sunfish, black bullhead, and carp.

A fishery survey (Schreiber 1998) found that trout densities are generally higher above the two dams due to cooler water temperatures and more stable flows. In addition to temperature, hydrology, and habit issues, Powell Dam also directly impacts migratory fish production by preventing upstream access to upstream spawning grounds in the upper end of Lake Louise, and to downstream feeding areas for fish within the dam. Junction Falls Dam impacts downstream passage of fish and other wildlife; however, the Junction Falls cascades also likely prohibited fish passage prior to dam construction.

3.2.2 Macroinvertebrates

Besides fish, aquatic plants, insects, and other species depend on coarse substrate for attachment sites, hiding places, and stable nest material. Because benthic (i.e., bottom-dwelling) macroinvertebrate abundance correlates with substrate complexity and populations are more abundant in gravel and cobble matrices, deposition of sand and other fines can be detrimental to invertebrates such as insects and mussels (Cordone and Kelly 1961, Minshall 1984). With sediment aggradation behind dams, the abundance of mussels and less tolerant aquatic insects like mayflies, stoneflies and caddisflies decline, while more tolerant midges, blackflies, amphipods, snails, and worms increase in density (Allen 1995, Benke et al. 1984, Tiemann et al 2007, Hughes and Parmalee 1999, Waters 1995).

Upstream and downstream passage of invertebrates may also be an issue at dams. For instance, mussel larvae, or glochidia, develop in the gills of certain fish species particular to each mussel group. Dams are barriers to the passage of these host fish, so if the fish cannot migrate, neither can the mussels. However, at the River Falls sites, the Junction Falls cascades are a natural barrier to upstream migration of mussel host fish.

The literature review for understanding the current makeup of mussel communities within and below the two impoundments returned minimal results. The USACE has been actively completing mussel surveys along the St Croix River near Prescott, WI but the ability to transfer their findings to the smaller Kinnickinnic River system is limited. WDNR staff (pers. comm.; Heath, Karns, and Kitchel) confirmed that little mussel research has been conducted along the Kinnickinnic River, and one past survey, completed up- and downstream of River Falls, found no mussels being present.

In Schreiber (1998) several macroinvertebrate surveys were conducted in 1995 and 1997 at several locations above and below, but not within, the two impoundments. The survey samples were assessed for several biometrics to report on a species tolerance and general understanding of organic loading and water quality within the Kinnickinnic River. Biologic indices, including production and diversity, indicated the Kinni is "a generally healthy aquatic community ". However, the results cannot be applied to represent the health of the macroinvertebrate community within the impoundments, nor were impoundment impacts analyzed.

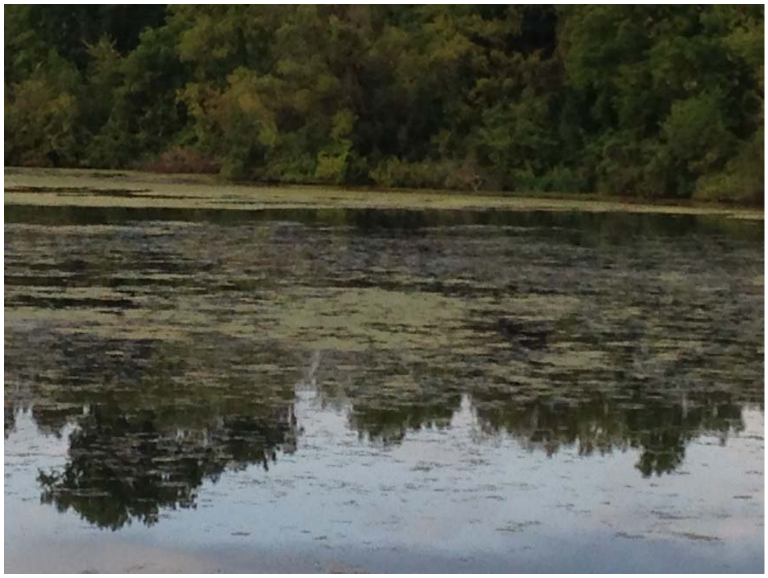

Figure 13: Surface algae and shallow water conditions at Lake George (above) and Lake Louise (lower).

3.2.3 Other Wildlife

Rivers are important green corridors for the migration of both terrestrial wildlife and birds. The open space bordering the two impoundments in River Falls support a number of common bird, mammal, and herptile species, and the ponds likely attract certain migratory bird species as layover points. The lower Kinnickinnic River is part of the Great Wisconsin Birding and Nature Trail, and the St. Croix Valley Bird Club is active in the area. Over 140 species are commonly observed in the area including Great Blue Herons, Turkey Vultures, Sedge Wrens, Bobolinks, Mourning Doves, Hummingbirds, various woodpecker species, Blue Jays, Chickadees, Cedar Waxwings, Indigo Buntings, Eastern Kingbirds, Clay-colored and Grasshopper Sparrows, Pine and Mourning Warblers, and Eastern Bluebirds, Common Mergansers, Canada Geese and Common Goldeneyes, and Bald Eagles. The WDNR lists wildlife species using the Kinnickinnic River State Park area as including white tailed deer, raccoons, mink, gray and red fox, squirrels, rabbits, weasels, and an occasional beaver.

The proximity of the ponds and the downstream ravine also creates a somewhat connected green corridor, albeit fragmented by roads and the dams. The River Falls dams are each over twenty feet high, and limit passage of any wildlife along the near-bank region. More importantly, the dams inundate what was historically a wide, forested riparian area, supporting a multitude of wetland and floodplain habitat types and communities. Bird and other wildlife species dependent on riparian habitat or certain stream-dependent food species were likely negatively impacted.

3.2.4 Threatened and Endangered Species Review

In the Fall of 2016, the WDNR conducted an official Endangered Resources Review (ERR) for the Kinnickinnic River through the impoundment reach, which includes the identification of state and federally listed endangered and threatened plant and animal species potentially impacted by a project (WDNR 2016). The review was completed using the Natural Heritage Information System. The review identified 6 habitat types, 12 plant species, and no animal species of concern. If dam removal is sought, the WDNR deemed no impact is anticipated to any of the listed species and, therefore, no actions will be required to protect them. Additional evaluation downstream of the dams to the Kinni-St.Croix River confluence indicated few species of concern, and stated that no fish and mussels would be impacted. However, the WDNR recommended drawdowns be completed between May 1 and September 30 to avoid impacts to overwintering herptiles. The WDNR also recommended conducting native mussel relocations prior to drawdowns. The ERR decision covers the project for the state and federally listed species, and therefore, additional ERR permits are not required. However, the review will need to be renewed at no charge (DNRERReview@wisconsin.gov, (ERR Log #16-536)).

3.3 Social and Cultural Attributes of the Kinnickinnic River Study Reach

3.3.1 Recreation

The Kinni currently provides ample opportunities for recreation, including hiking, paddling, and fishing (Figure 14). Heritage Park, the White Pathway, Swinging Bridge, and Glen Park, as well as more informal trails and access points bordering the impoundments, are frequently used by city residents, university students and tourists, and the access point downstream of Powell Falls Dam is a popular starting point for boaters. In the City, trails are currently blocked at Junction Falls Dam and impeded by Powell Falls Dam. The dams are also a potential hazard to paddlers, involving a takeout at each dam site.

In addition to walking and paddling, The Kinnickinnic River is one of Wisconsin's most popular trout fishing streams. Anglers typically do not fish in the impoundments, but fish the flowing sections upstream or downstream of the City of River Falls. Currently, the impoundments provide only suboptimal trout angling opportunities; the dams impound potential trout fishing habitat and access, including sections easily accessible from downtown.

3.3.2 Aesthetics/history

The River Falls dams span several generations, and many people have known the dams and ponds their entire lives. Park users walk, run, and bike along the riparian trails and thus, encounter the dams or the impoundments regularly. Aesthetics, however, are personal, and for every person that sees the dam as an amenity, there are likely people who view the dam as an intrusion into the natural aesthetic of the park and the river. Inter-Fluve can only provide objective scientific opinion, which is that the dams are man-made and negatively impact the pre-dam natural aesthetic by covering the falls and inundating the gorge and river habitat. The dams currently cover over 4,000 feet of gravel, cobble and boulder channel and a deep bedrock gorge. Bedrock outcrops throughout the impoundments are currently hidden from view, as are much of the natural cascades that gave River Falls its name.

3.3.1 Safety

Dams are defined as an attractive nuisance and represent a liability risk to the City of River Falls. People are attracted to the structure and the sound, and often congregate above or below dams, wading in the pools and playing on the rocks or even on the spillways themselves. Despite warning signs posted on the River Falls dam abutments, people still climb fences and injure themselves at the dam sites. Additionally, maintenance staff must climb the face of Junction Falls, risking dangerous falls or other accidents.

Figure 14. Recreational opportunities along the Kinnickinnic River include fly fishing along a Class 1 trout stream (upper photo) and kayaking the narrow valley below Powell Falls Dam (lower photo – Kayak the Kinni).

All dams, regardless of their design or construction, have the potential to fail during large storm events. Failure could impact adjacent infrastructure, habitat, and possibly result in loss-of-life. In the United States, dams fail every year, and the number of failures is increasing as dams age. Junction Falls Dam was stabilized in 1990 (HNTB). However, concrete has a typical design life of 30-75 years, and if no action is taken, the dam will eventually need to be repaired or replaced again. In the meantime, there will be a need for continual maintenance, inspection, design, and repair costs. As long as the dam exists, the risk of failure exists.

3.4 INFRASTRUCTURE ALONG THE KINNICKINNIC RIVER STUDY REACH

Because the dams impact a stretch of river within an urban environment, there are a number of bridges, sanitary sewers, and other infrastructure running along or across the channel. Many of these structures were designed and constructed based on existing conditions, with the dams in place. They have not necessarily been impacted by the dams, but any changes to the dams, including removal, could affect the impact; therefore this infrastructure was inventoried as part of the existing conditions analysis. The City of River Falls provided as-built and design utility information in paper and GIS format, including stormwater and sewer pipe information, outfall locations, pipe elevations, overhead and underground utilities, bridge design, and as-built plans.

Using these data, and a cursory field reconnaissance completed in the Fall, 2016, we identified a number of utility lines and roads that may be impacted by dam removal.
(Appendix and Figure 15)

3.4.1 Water Mains

The City's GIS data identifies four water mains that cross the river (Figure 16).

- Winter Street Bridge 10" water main (on bridge).
- West Cedar Street 8" Water main (not on a bridge). This water main is below ground. No information was available in GIS related to elevations; however, this section of the river is upstream of the impoundments.
- Division Street 12" water main (on bridge)
- North of Division Street 10" water main (not on a bridge). This water main is below ground. No information was available in GIS related to elevations; however, this section of the river is upstream of the impoundments.

None of these water mains are expected to be impacted by dam removal based on the available data and their location.

3.4.2 Sanitary Mains

There are three (3) sanitary mains that cross the Kinnickinnic River (Figure 17):

- The 24-inch main (RF_PIPE_ID 1044) spans between RF_MH_ID 1106 and 1115. RF_MH_ID 1106 has a rim elevation of 824.26 feet and a depth of 8.84 feet and RF_MH_ID 1106 has a rim elevation of 829.69 and a depth of 14.56. This puts the calculated top of pipe elevation of approximately 817.42 feet.
- The 18-inch main (RF_PIPE_ID 1255) is approximately 300 feet downstream of the toe of Junction Falls. It spans between RF_MH_ID 1250 which has a rim elevation of 826.29 and a depth of 8.07 feet and RF_MH_ID 1103 which has a rim elevation of 824.92 feet and a depth of 8.0 feet which puts the pipe invert at 818.22 and top of pipe at approximately 819.72 at RF_MH_ID 1250 and invert elevation at 816.92 and top of pipe at approximately 818.42. All elevations for this interceptor are surveyed (source: email from R. Wronski).
- The 14-inch main (RF_PIPE_ID 1283) is approximately 1,200 feet upstream of Division Street. It spans between RF_MH_ID 1273 (Rim elevation of 875.7) and RF_MH_ID 1262 which has a rim elevation of 874.37 feet. Depth is not provided for either sanitary manhole.

The three sanitary mains need to be further investigated to determine if they are below the expected river bed elevation post dam removal. The GIS data is inconclusive on this matter. The referenced depths and elevations indicate that the 24 and 18 inch mains are at or near the expected (historic) riverbed elevation. The 14-inch main is in a riverine section of the impoundment and may be outside of the influence of Junction Falls Dam.

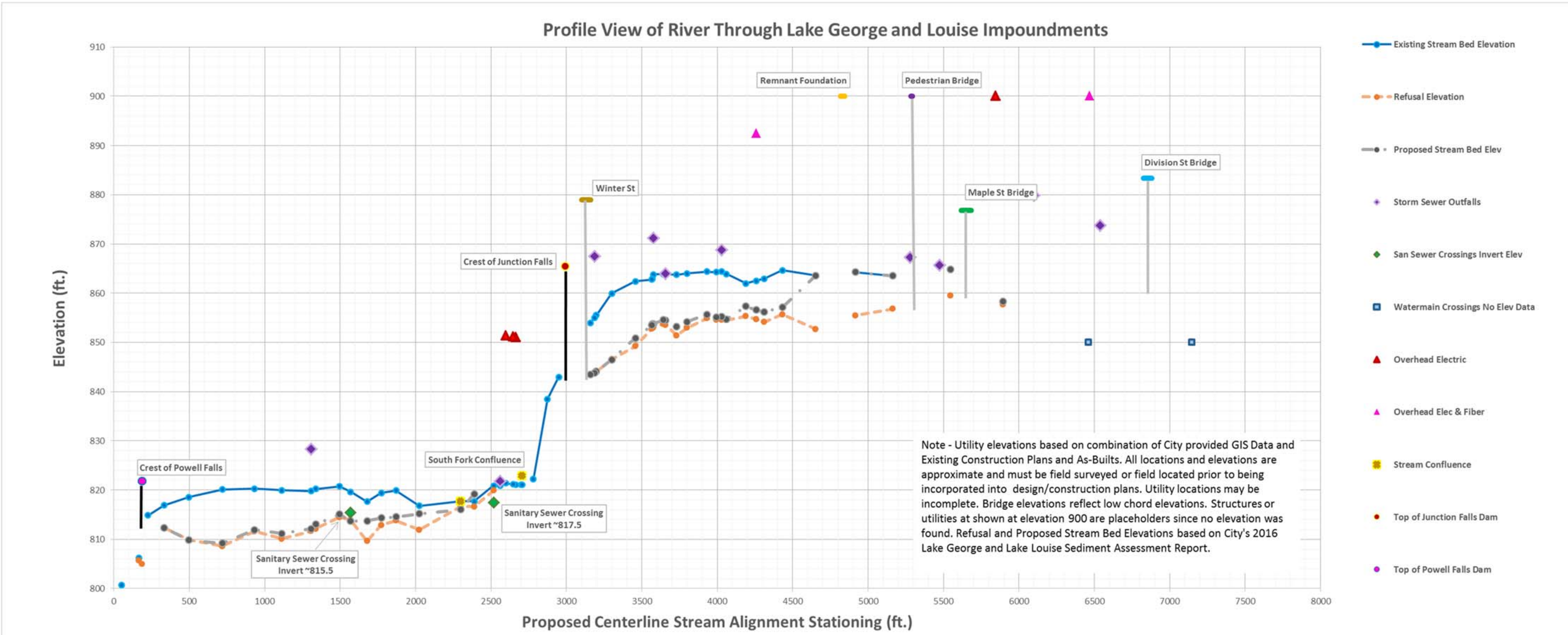

Figure 15: Channel profile with utility locations and elevations.

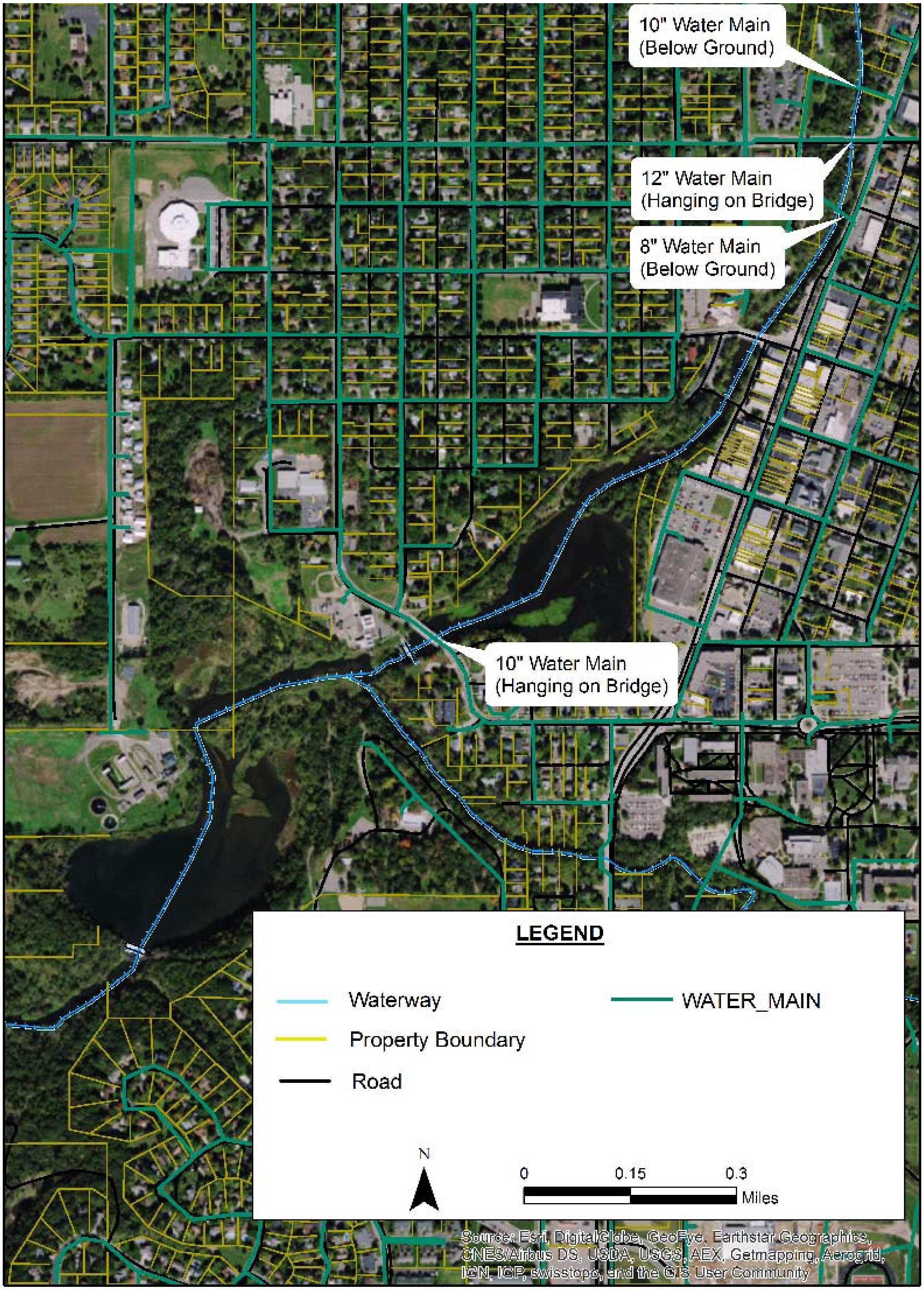

Figure 16: Water Main Locations

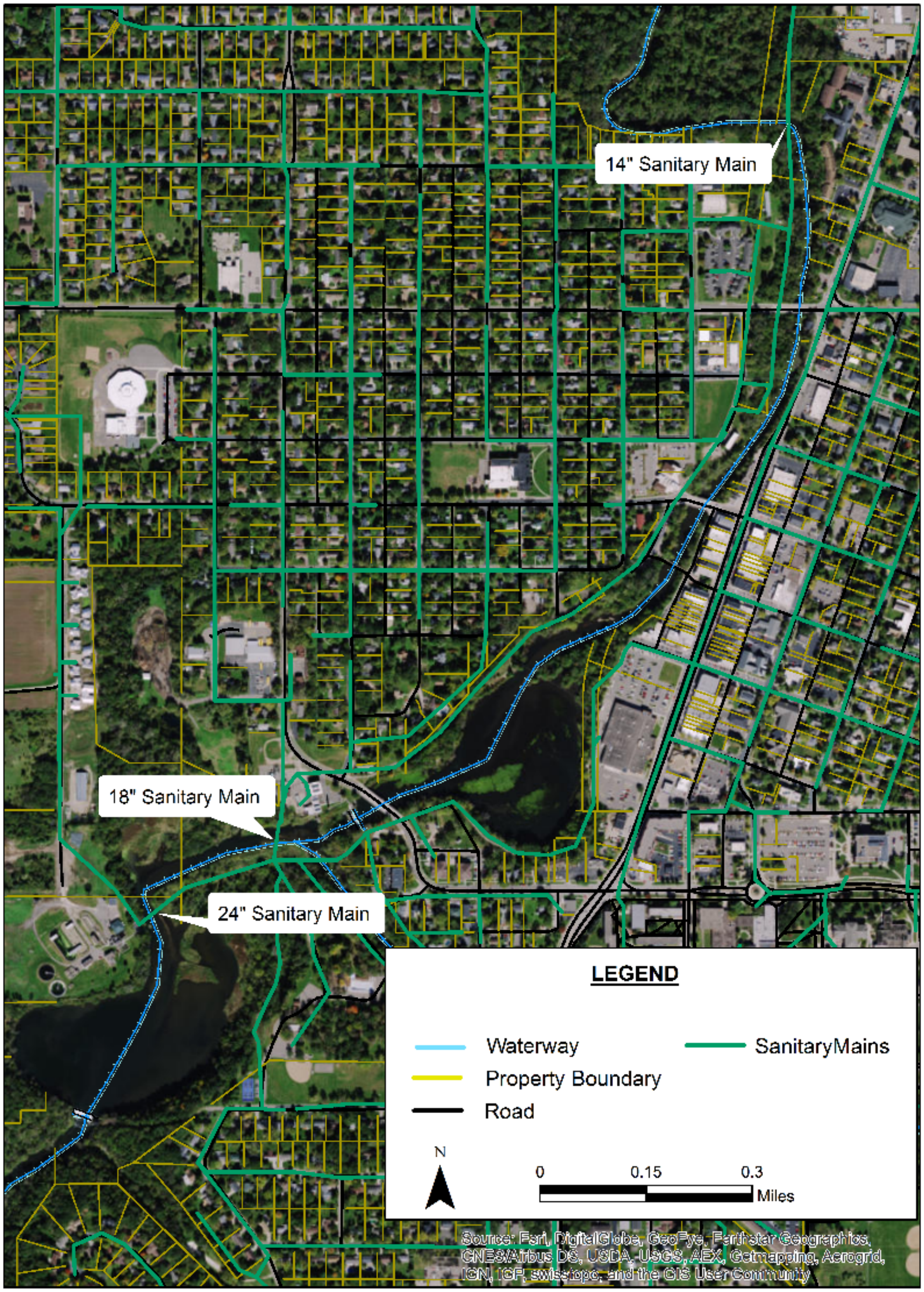

Figure 17: Sanitary Main Crossings

3.4.3 Stormwater Outfalls

Numerous storm water outfalls are located along the river and impoundments (Figure 18). Based on a review of the stormwater outfalls, some adjustment will likely be required to assure proper discharge function of particular outlets. In some cases, outfalls may need to be extended to the river's edge and other outfalls may need to be lowered to discharge to a new surface elevation (Table 7).

Table 7. Outfall Dam Removal Impacts

Outfall ID	Note on Dam Removal Impact
40	Downstream of Powell Dam along left bank of river. No expected impact related to dam removal.
61	Between Junction Falls and Powell Dam. Outfall appears to be set back from left bank of river. Some grading and channel development may be needed post dam removal.
17	Approximately 300 feet below Junction Falls on right bank. In riverine section of river. Likely little to no impact related to dam removal.
015 and 014	Outfalls at left and right bank at Winter Street Bridge. Water level will drop approximately 50 feet in this area. Outfalls will need to be modified to account for change in water levels.
013, 023, and 019	Outfalls along left bank of Lake George impoundment. These will need to be modified to convey flow to river post dam removal.
012, 049, 021, 020, 010, 011, 008, 009, 007, 006, 005, 004, 003, 002, 026, 025, 001, 024	These outfalls are upstream of Lake George. The river along this stretch will be faster moving post dam removal, but maintain essentially the same location and width. Thus, outfalls will likely not require major changes. However, some additional minor armoring or grading may be required.

3.4.4 Electric Lines

Overhead lines are not typically an issue for dam removal projects, except when they are within the immediate area of construction and may pose a safety hazard or require periodic shutdowns during construction activities. A map of overhead powerlines in the vicinity of the dams is provided in Figure 19. Overhead power lines that will need to be addressed via coordination exist at the following locations:

Immediately downstream of Junction Falls Dam:

- Transmission Line - Line number RF-6 (Voltage - 69,000); approximately 300 feet downstream of dam.
- Overhead Primary – Line number RF-6 (Voltage - 69,000); approximately 300 feet downstream of dam.
- Overhead Primary - no data in GIS; location is directly above dam crest.

Immediately upstream of Junction Falls Dam:

- Underground secondary lines are shown in alignment with Winter Street Bridge. The City Engineer indicated that these were hung on the bridge.

Across Lake George:

- Overhead primary lines at upstream end of Lake George.

Upstream of Lake George

- Overhead secondary line upstream of Market Street Bridge.
- Overhead Primary and City Fiber crossing near East Cedar Street
- Overhead Primary upstream of Division Street Bridge.

No underground lines were identified via the GIS data.

3.4.5 Gas Lines

No gas utility information was provided by the City via their GIS files. In addition, no known conflicts were identified by City of River Falls staff. A representative from St. Croix Natural Gas, the local provider, indicated there were no utility conflicts to disclose and if present, any gas mains would be hung under existing bridge crossings. The presence or absence of natural gas lines in the vicinity of the project will need to be verified with private pipeline companies and through Dig Safe during future design phases.

3.4.6 Bridges

There are five (5) bridges that fall within the backwater areas upstream of the River Falls dams (Figure 20). An exhaustive evaluation of bridge structural or geotechnical stability was not a component of this evaluation. However, the identified bridges were reviewed using the following approach:

- Each bridge was visited and photographed.
- Engineering design or as-built plans were reviewed (if available).
- Relevant foundation and geotechnical data from bridge design plans/ as-builts were compiled and compared to stream profiles and dam crest elevations to determine potential impact areas (Table 8).

The bridge comparison (Table 8) shows that the foundation designs for all five structures are similar. The abutment foundations are generally on steel sheeting driven to bedrock and the piers are set on the bedrock with a concrete cap or they are embedded a few feet into the bedrock. The similarity of bridge designs within the influence of the dams to those outside of the dam's influence would suggest that the bridge designs are adequate for a “dam out” scenario.

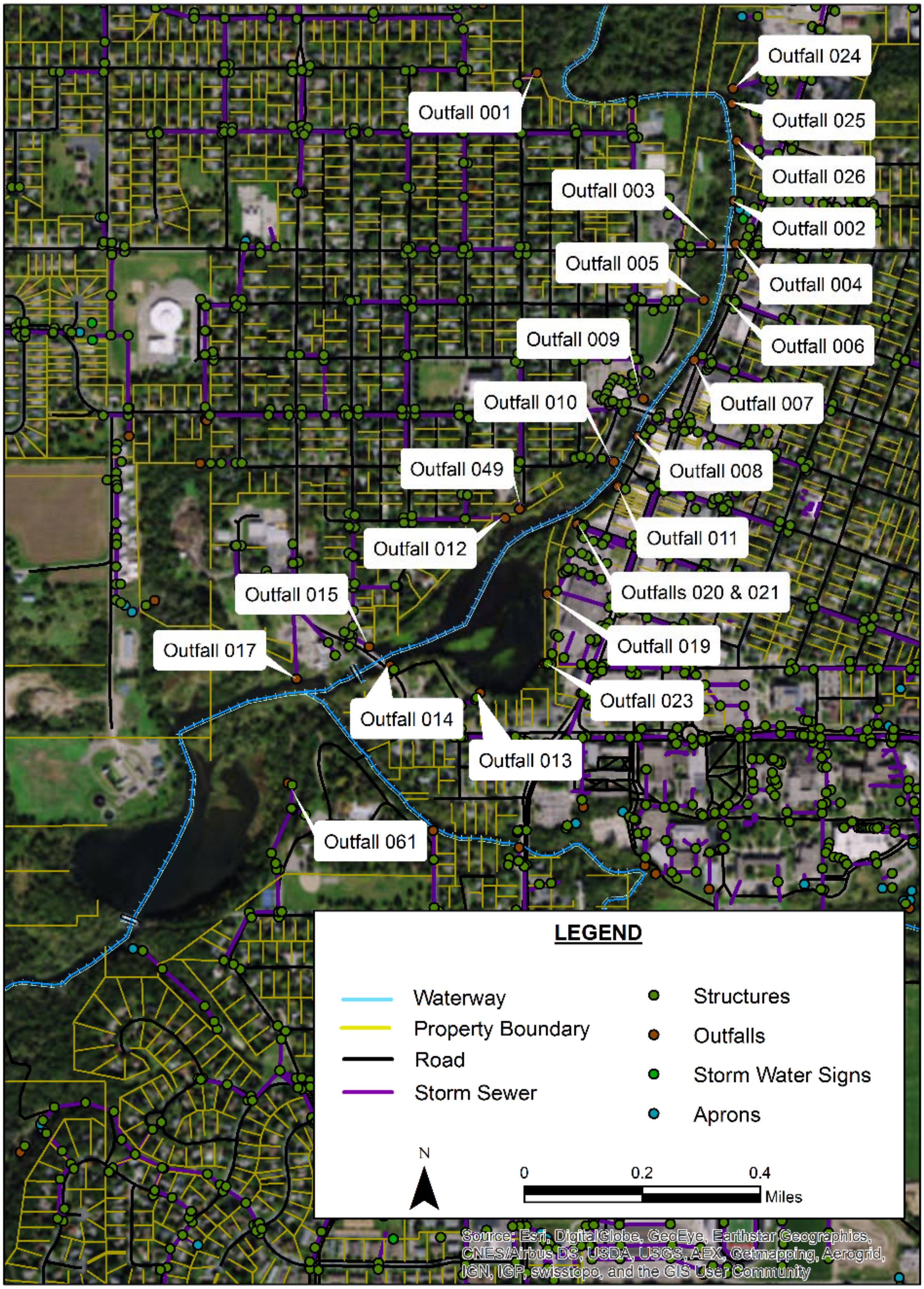

Figure 18: Storm Sewer Outfalls

Figure 19: Electrical Transmission Lines

Being directly upstream of Junction Falls Dam, the Winter Street Bridge will likely be the most impacted in a dam out scenario. The Winter Street Bridge Plans show the pier foundations are built on a nine-foot-thick seal that rests on dolomite bedrock. The seal is not anchored to the bedrock, nor are the pier foundations anchored to the seal. During the dam out scenario, the seal and pier foundations will be exposed, as they sit above the expected river bottom. It is recommended that the Winter Street Bridge be further evaluated for stability and scour under a dam removal scenario. This study would need to be conducted by a professional engineer and would require that the bridge be evaluated against current WisDOT and County Design Standards.

Table 8: Bridge elevations and abutment and pier attributes

Bridge	Abutment and Pier Elevations	Additional Information
Winter St.	South abutment: 862 ft North Abutment: 864.45 ft Deck: 886.42 ft Low Chord: 879 ft Pier in bedrock: 841.5 (bottom), 852.67 (top) Streambed: 850 (approx.)	South abutment on leveling concrete. North abutment on steel piling. Pier footing bottom is in bedrock. Scour critical code is 5.
Maple St	West Abutment: 865 ft Deck: 881.61 ft Low Chord: 876.87 ft Lowest Pier Footing: 855.27 ft	Abutments with steel piling to ~14 to 16 feet. Piers on bedrock.
Division St	24” Outlet: 870.5 ft Pier in Bedrock: 863.02 ft Low Chord: 883.30 ft Streambed: 865.5 ft	Abutments with steel piling. Piers on bedrock with concrete seal.
MM Bridge	Pier Footing: 873 ft Streambed: 876.5 ft	Pier foundations ~3.5 feet below bed. Limited Data.

Notes: Elevations per plans and assumed to be the same.

Figure 20: Bridge Crossings

4. Dam Removal

Removing Junction and Powell Falls Dams requires planning how the structures will be removed, including access to the dams, demolition and disposal, and how to manage the water during the project. The following methods and approaches recommended for tearing down the dams are based on preliminary information and have not been engineered to final design or approved by any municipal or other government entity. Final design recommendations may differ, and construction contractors often have novel approaches to improve efficiencies and reduce costs.

This report assumes a project involving removal of both dams concurrently or in immediate succession. It is assumed that the same sediment management approach will be used for both dams, or that the sediment management approach will be fully coordinated between the two dam removals.

4.1 STAGING AND ACCESS PLAN

Junction Falls Access - Junction Falls Dam is accessible at the top of the right abutment via City property and the area below the dam can be accessed along the gated access road from Glen Park (Figure 21). Materials and equipment can be moved along the latter access path, and it can be locked during off hours. Utilizing this proposed access route will require the following steps:

1. Improvements to the existing paved trail to allow vehicle clearance.
2. Addition of gravel construction access pad at the end of the pavement. The gravel pad would likely be built to a height that avoids impacts from moderately high flows. Exact elevation would be determined during final design.
3. Construction of a river crossing at the South Fork Kinnickinnic River. This crossing will need to include culverts to convey South Fork Kinnickinnic River flow and would likely be constructed of a cobble base and a gravel road base. Culvert sizing would be accomplished during final design.
4. Improved construction access up Junction Falls to a work pad to be used for demolition work. The South Fork road can transition to a ramp that brings equipment to the flat area below the spillway. A gravel pad can be installed to protect the bedrock from damage.
5. Staging for both Junction Falls Dam demolition and the upper Lake Louise restoration activity can be located both at the top of the incline road within Park entrance (e.g. parking lot, construction trailer), and at the bottom of the incline in the floodplain on river left (e.g., active equipment storage, parking). Weather can be monitored and equipment moved to higher ground as needed.
6. Upon finishing construction, the temporary construction ramp and road would be removed.
7. Signs and fencing should be posted at entrances to warn residents to keep out of the construction area.

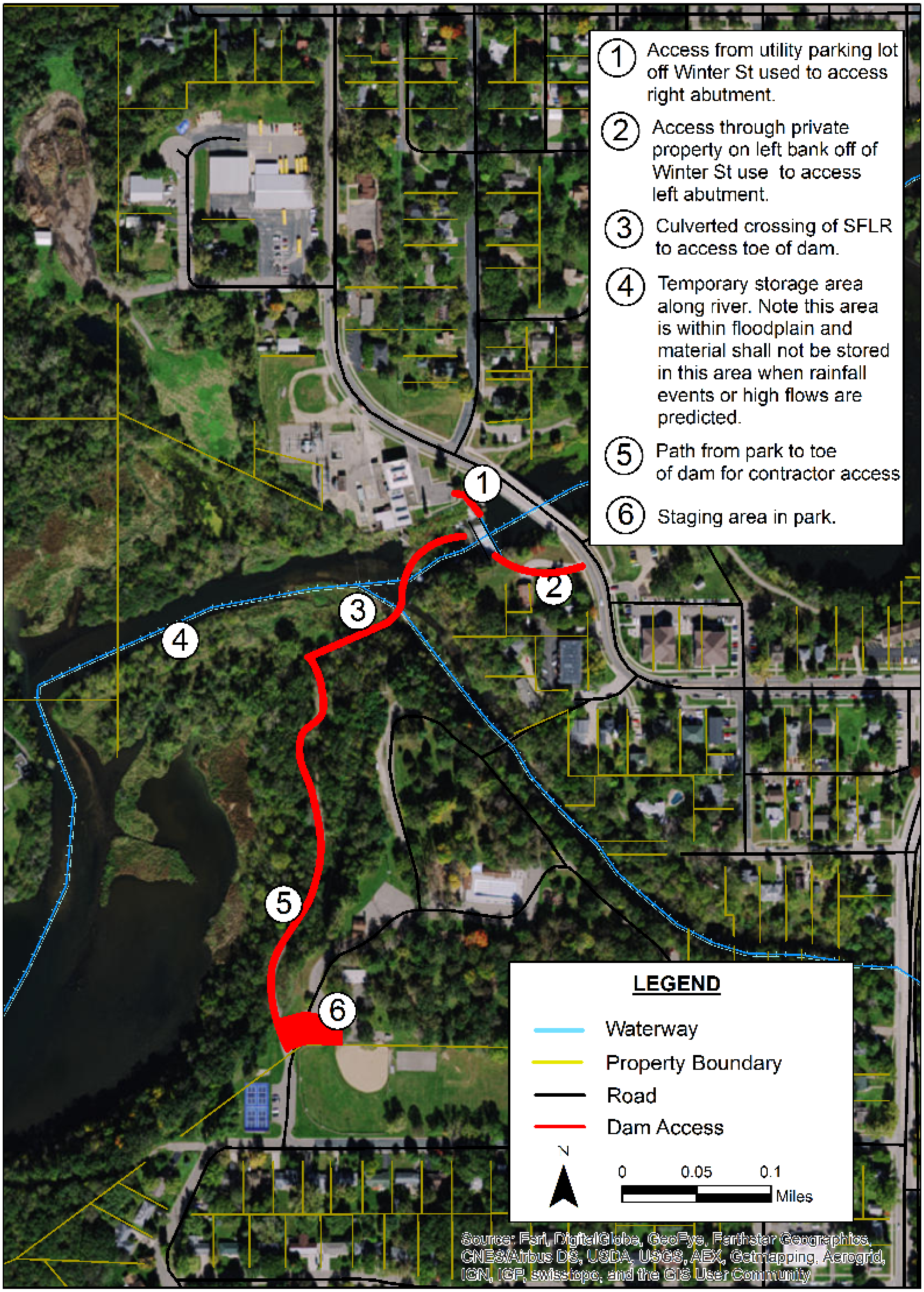

Figure 21: Junction Falls – Proposed Access Plan

Additional access may be accomplished from the top of the gorge wall on either the right or left bank. Right bank access would be on public property and left bank access would be through private property (including residence) at 407 South Winter Street.

The following access routes were considered, but deemed infeasible:

- Access from upstream of the dam via barge. This action was considered to be problematic due to clearance and size issues at the Winter Street Bridge. A barge may be able to navigate the river above Junction Falls Dam, but it may not fit between the bridge piers or under the bridge beams (with or without an excavator).
- Access via haul road from left bank of the gorge upstream of the dam.

Access to the Lake George impoundment area can be gained through either side of Winter Street Bridge. The East side of the bridge has an old mill access road on river left, while the existing walk path and parking area on right bank could be used as the main right floodplain entrance location. Temporary haul roads may need to be constructed as the sediment dries out upon drawdown.

Powell Falls Access - Access at Powell Falls is also targeted at the downstream side of the spillway. Haul trucks typically need an incline of less than 10% for effective and safe hauling, but the steep valley walls near the dam exceed 10% slope. Therefore, the most practical route to the base of the dam is the South Kinnickinnic River Trail, which connects Powell Dam to the intersection of Bartosh Lane and Foster Street on river right. The upper part of the left abutment can be accessed via a constructed paved or gravel path through Glen Park and the toe of the dam can be accessed via the South Kinnickinnic River Trail. Figure 22 shows the proposed access route for Powell Dam.

Steps for accessing the toe of the dam for demolition will follow these steps:

1. Improvements to the South Kinnickinnic River Trail to allow for vehicle clearance.
2. Add a gravel construction access to local road connections to limit turf and concrete damage and control erosion.
3. Construct a gravel access path along the left side of the river, possibly as far as 10 feet out into the channel margin. Elevations will need to be determined during final design to meet permit requirements and protect equipment.
4. Construct a crossing at the Bartosh Lane wastewater outlet, avoid damaging the newly installed stormwater outlet.
5. Improve construction access to the toe of Powell Falls Dam through construction of a work pad at the base of the dam.
6. Staging areas could be at the top of the path or in Glen Park. The southwest end of Glen Park offers a central staging area for both projects, thereby minimizing costs for mobilization and staging.

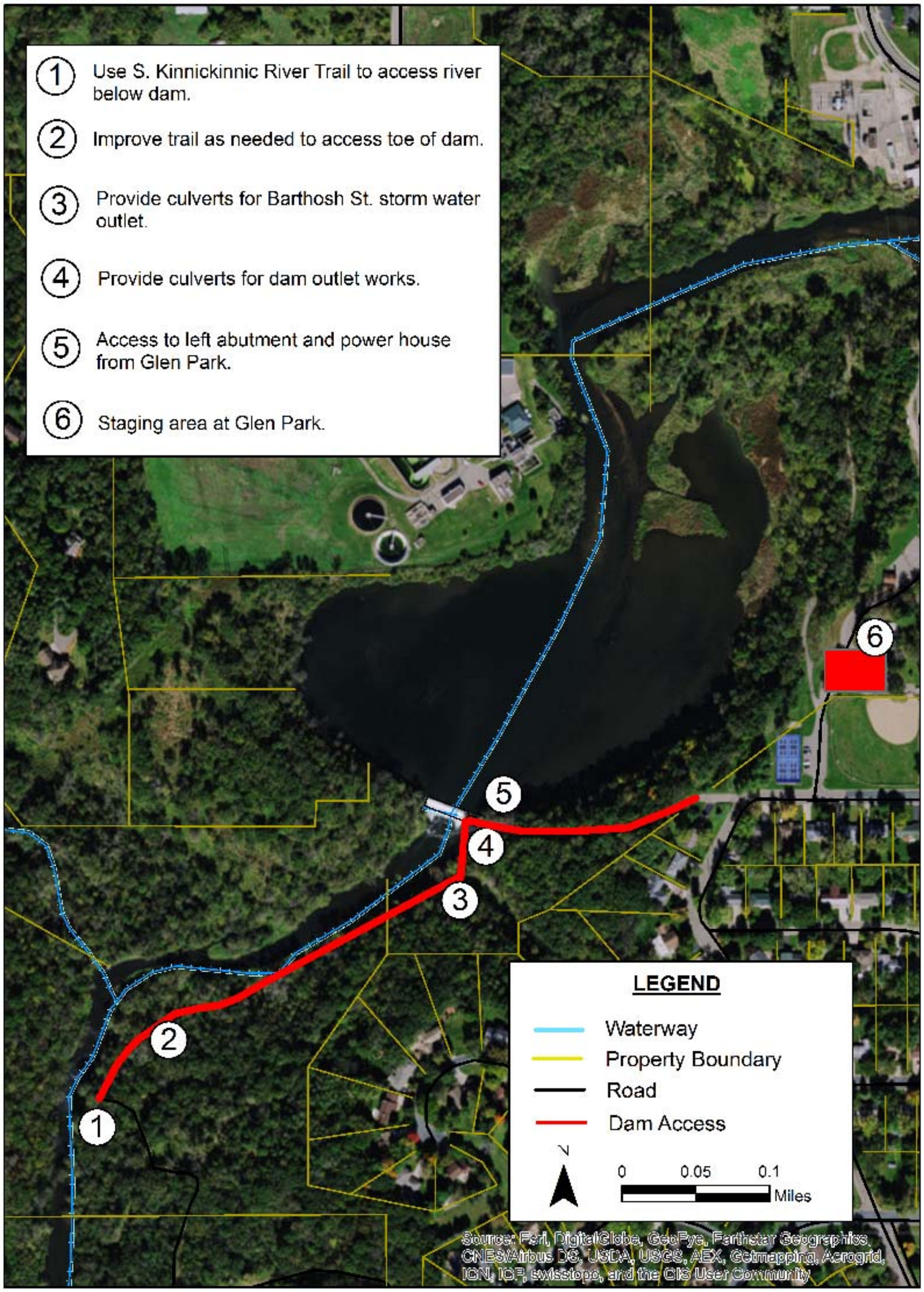

Figure 22: Powell Falls – Proposed Access Plan

4.2 PRELIMINARY DEMOLITION AND DEBRIS DISPOSAL PLAN

Demolition of the dams should begin once the impoundment water levels have been reduced using the wasteway bypass gates. The sequencing of removal should be determined during final design and with contractor input as staging area and equipment may play a role into the precise approach. However, in general, the demolition should proceed with the following concepts:

- Water flow through the wasteway gate and other temporary means of conveyance used during construction must be uninterrupted. Initial drawdown should minimize sediment transport in the impoundment areas. This can include managed output rates.
- Dam spillway notching from below the dam, starting at the top of the spillway and working down using either sawcut equipment or a hydraulic hammer mounted to a track excavator.
- Removed material will be transported away from the site via the construction access.
- The dam structures will need to be removed in a controlled fashion so that water flow is not interrupted and fine concrete debris washing into the river is minimized.
- Waste material will need to be removed on a continuous basis and should not be stored in the floodplain.

Traditionally, the "means and methods" for demolition are left to the contractor, however, for these cost estimates, it is assumed that the contractor will use a hydraulic hammer attached to an excavator to demolish the dam (Figure 23). Demolition rates can be relatively slow using this technique, depending on the density of steel reinforcement or the type of equipment used. Inter-Fluve recommends notching the spillway in 4 to 5 foot increments before hammering deeper on the dam face. This method allows for closing the gates if needed, but at a lower upstream pool volume to manage sediment excavation in the impoundment. Sediment immediately upstream of the spillway will likely need to be excavated to facilitate work. Once sections are demolished, hydraulic excavators and/or front end loaders will be required at the downstream base of the dam to load the debris onto trucks. The contractor may be required to salvage the reinforcing steel for recycling or disposal. Disposal can involve simple bulk loading of concrete and rebar, or secondary staging piles, divided into concrete and stripped rebar, can be generated prior to loading. Rebar can be partially stripped of concrete by having the jackhammer comb through the rebar and remove concrete. Additionally, vibration monitoring should be conducted to protect nearby buildings and other infrastructure such as Winter Street Bridge and the historic smoke stack on city property.

It may be feasible to leave the abutments intact if removing them causes the project to exceed available funds or if their removal would have a potential impact on nearby infrastructure. If this is a desired endpoint, a structural analysis of the portions of the dam that may be left would be required to verify that they are not under threat of collapse.

In lieu of a hydraulic hammer, saw cutting using a diamond wire saw is well-suited to demolishing sections of the reinforced concrete spillway and abutments. The saw consists of a hydraulic/electric drive unit and a series of pulleys designed to apply tension to and guide the diamond wire. The wires are then threaded through drilled holes and pulled in the direction of the cut as they circulate. The pulleys, guides, and wire are relatively light and can be set up by hand or lifted into place by a small machine. This method is more expensive, but limits the harmful vibrations, noise, debris, and dust associated with hammering. Holes would be drilled at the corners of the cut area in order to insert the saw bands. The diamond wire saw band is then threaded through the holes and attached to the saw. The cuts create well-defined sections, or blocks, of concrete. A crane would be required to remove and load the cut sections onto trucks.

Multiple demolition methods can be combined to complete the project. Hammering is the most efficient way to breach the spillway. However, the clean cuts of the diamond wire saw are likely preferred to demolish sections surrounding essential infrastructure. Finally, the inability to control debris, and the impact of the noise and possible shaking to the adjacent urban area, prohibits blasting as a removal method.

Demolition of Junction Falls and Powell Falls Dams will require extensive concrete removal, and may require removing the penstock and adjacent concrete and brick structures to fully expose the bedrock. Salvage and protection of any of these adjacent structures will be coordinated during the final design process. The location, dimension, and orientation of demolished spillway and abutment sections should be planned out so that the remaining portions of the dam are stable for anticipated loads. Concrete adhering directly to bedrock wall areas will require fine excavation, handwork or sandblasting.

Figure 23. Jackhammers comb through a rebar reinforced concrete spillway during dam demolition (photo Inter-Fluve).

Measurements taken from the 1990 dam reinforcement design plans suggest demolition of Junction Falls Dam will generate 1800 cubic yards of reinforced concrete including the removal of the penstock. At Powell Falls Dam, photograph and design plans suggest removal will generate an estimated 942 cubic yards of reinforced concrete. Reinforced concrete removal quantities assume both spillways are comprised of solid concrete. The removal of the two powerhouses may also be demolished and removed pending City input and the outcome of a recommended Phase 1 investigation. Due to the likelihood that asbestos and PCB material is present at the two powerhouses, required handling and disposal requirements for these and other materials, governed by state statues, may be defined in a Phase 1 investigation.

To minimize construction traffic through River Falls, it will be advantageous to locate off-site debris and sediment disposal sites south of the City. The preferred hauling route for sediment and demolition debris, such as concrete, rebar and other solid waste, will be via the inclined access road, Park Street, and southbound South Main Street. For northbound traffic, 830th Avenue can be used to access Hwy 65 north. Access for sediment removal and restoration of the Lake George impoundment can be via the old mill ramp on the east side of the river north of Winter Street, or from the park trail parking lot area on the west side of the river north of Winter Street. Truck traffic would be routed to South Main Street or 830th Avenue. Hauling of all removed concrete would require between 140 and 200 truckloads, depending on the haul volume per truck.

4.3 PRELIMINARY WATER ROUTING PLAN

4.3.1 Dewatering Methods

Dewatering of the impoundments (Lake Louise and Lake George) will benefit from the inclusion of a lake drain in the design of the structures. This component of the dams is referred to as the wasteway on the existing dam plans. At Junction Falls Dam, this outlet is controlled by a gate and the operator indicated that the gate is operable and has been used in the past for maintenance purposes. At the Powell Falls Dam, the wasteway gate is also operable by a controlling gate. However, the gate is aged and appears to not have been operated recently. The operator speculated that the gate could be opened but not closed.

Due to the presence of the wasteway openings, the dewatering approach can follow these general steps:

1. Lower the water to the minimum level possible using main opening to tailrace.
2. Clean any debris from screens and remove accumulated material from in front of the wasteway gate.
3. Open the wasteway gate in a controlled fashion to comply with drawdown permit requirements (typically 1’ or less per day or customized for notching and sediment management).
4. Install a debris boom in front of the wasteway opening to avoid clogging during dam demolition.
5. Remove the primary spillway in stages. Coordinate with sediment management upstream.
6. Install a cofferdam or other water control if needed (e.g. Supersacks or other means) to isolate the left abutment for removal in the dry or partial wet.
7. Remove the left abutment. Repeat for the right abutment.
8. Remove the cofferdam and construction access roads.

This approach will require heavy equipment to cross flowing water at the base of each dam to reach the right abutment. Alternatively, the contractor could remove the right abutment from the top of bank to avoid an additional cofferdam and river crossing.

Other considerations:

- Work should be scheduled for low flow periods, typically between July and February.
- Work must consider local haul road restrictions.
- The impoundment drawdown should be limited to a maximum of 1 foot per day or less. However, this assumption should be verified by a geotechnical investigation and through coordination with sediment management practices upstream.

- Sediment management activities need to be coordinated with drawdown activities to limit sediment mobilization beyond permitted levels. Sediment traps may need to be installed downstream of Powell Falls Dam and need to be designed with the haul/access road in mind.
- A Staged drawdown is typically the best way to lower impoundment levels for sediment removal and restoration. The drawdown can be done by opening gates incrementally.
- Fisheries restrictions may apply to the drawdown, and could limit work in the Fall and Winter due to the potential for trout spawning. However, since these reaches are not healthy trout waters, a variance may be appropriate. The WDNR ERR report (2016) recommends a spring/summer drawdown to protect overwintering herptiles.
- Work periods should be limited to daylight hours and possibly early evening hours to limit noise impacts. Such limits can be coordinated with stakeholders.

Alternative dewatering approaches that could be considered if the wasteway gates do not operate or the wasteway channel is otherwise inoperable include:

- It is possible for a contractor to remove sections of the dam using an excavator-mounted hydraulic hammer while water is flowing over the primary spillway (i.e., “in the wet”). Care would need to be taken to remove large pieces of concrete and to limit the downstream transport of fines. Controlling fines would be accomplished via rough notching of the dam and slowly lowering the water level in a controlled fashion. Because the dam is constructed of concrete this approach is the preferred alternative.
- Pumping / siphoning uses large diameter pipes and pumps to draw water out of the impoundment and discharge it downstream. Due to the relative small flows experienced at the sites during the preferred construction period, this method may be feasible and provide the contractor with flexibility on means and methods of removing the dam. Using a pump/ siphon system would make cofferdams unnecessary and make crossing the river less difficult (because it could be routed through a culvert under a construction access road. Negatives associated with pumps/ siphons are the cost of fuel and material.

5. Channel and Floodplain Restoration

5.1 SEDIMENT MANAGEMENT

The dams store a significant amount of sediment within their impoundments. With the dams removed, those sediments will be exposed to higher energy flows capable of eroding and transporting that sediment downstream. How the sediment is managed during the removal and restoration process is a major determinant of costs, site and downstream impacts, and resulting channel and floodplain form and process. Under any dam removal scenario, sediment removal can be accomplished either actively or passively. Under a passive sediment management alternative, the channel within the impoundment sediment is allowed to develop on its own, and the eroded sediment is transported downstream. Under an active sediment management alternative, the impounded sediment is excavated and the channel, floodplain, and any other features are constructed within the exposed space. These alternatives, and a third alternative utilizing a combination of active and passive management, are examined in more detail in the following sections.

5.1.1 Passive Sediment Management

Passive sediment management relies on the hydraulic forces of the river to erode sediment from the impoundment bed and transport the particles further downstream. As the water in the impoundment is drawn down, headcuts or small waterfalls will form and migrate upstream, developing a natural drainage pattern within the impoundment sediment. At the two dams, the main channels are still somewhat established within the reservoir, and initial channel formation will likely follow these channels. However, in the case of the River Falls impoundments, the cohesive bed materials could produce steep, unvegetated banks left behind as the channel cuts away the material, especially in the exposed floodplain areas. Over time, the channel will continue to erode and transport the stored material out of the reservoir, as it tries to balance its slope and form to handle the imposed sediment load and hydrology.

In a natural system (without the dam), the river would have transported sediment through the dammed reach to the lower end of the Kinni, and eventually into the St. Croix River. Sediment would have been moving continually, in relatively small volumes. Releasing stored sediment under a passive sediment management scenario generally results in a larger sediment pulse over a short time period, which could impact geomorphic and ecological processes. Once entrained, clay and finer sized particles will likely stay in suspension until they reach the larger St. Croix River. Silts are also easily entrained and could stay in suspension, but they will drop out of the water column during low flows or in lower energy areas, such as large pools, backwater areas, or overbank during floods. Sands evacuated from the impoundment will likely travel along the bed during lower flows, and possibly in the water column during larger floods, especially through steep sections of the river (e.g. riffles). Immediately following other dam removals relying on passive sediment management, sand has migrated slowly under lower flow conditions, moving as continuous and relatively homogenous, flat bedforms. At higher flows, pulses of sand advanced downstream, and deposited differentially in bars and as overbank sediment (Cui et al. 2014, Pearson et al. 2011).

To visualize the impact of transported sediment, we can conduct simple volume and area calculations. If we assume half of the impoundment sand from both impoundments is evacuated from the impoundments and transported downstream, and we assume the sediment deposits evenly within the channel over the first 5 miles of stream below the dam, the average deposited sediment depth would be 0.8 feet. Downstream transport of only 10% of the impoundment sediment yields an average depth of 0.2 ft. In reality, sediment deposition is influenced by local channel slope, obstructions, meander bends, and varying stream discharge, so deposition thickness will vary over time and space. Some sediment would also deposit in floodplain margins, but for streams with a high groundwater to surface water ratio, and limited flooding, much of the sediment remains in-channel. Over the short term, these finer sediments could bury bedforms (e.g., riffles and pools) along the downstream channel, or at least lower their effectiveness as ecological habitat. Contaminants in the impounded sediment would also be passed downstream under the passive management scenario, although contaminant concentrations would likely be diluted by additional clean sediment from the impoundment. The table below shows idealized sediment depths following various scenarios for sediment transport out of the Powell Falls impoundment.

Table 9: Idealized in-channel sediment deposit thickness downstream of Powell Falls Dam for varying sediment releases from both dams combined. These estimates of thickness depend on many variables, and are therefore very gross estimates.

% of Total Impounded Sediment Released Downstream	100%	50%	25%	10%
Volume allowed to transport (CY)	116,500	58,250	29,125	11,650
Sand fraction transported (assume 80%) - CY	93,200	46,600	23,300	9,320
Depth of sediment deposition over 1 mile (ft)	7.9	4	2	0.8
Depth of sediment deposition over 2 miles (ft)	4	2	1	0.4
Depth of sediment deposition over 3 miles (ft)	2.6	1.3	0.7	0.3
Depth of sediment deposition over 4 miles (ft)	2	1	0.5	0.2
Depth of sediment deposition over 5 miles (ft)	1.6	0.8	0.4	0.2

Inter-Fluve does not recommend a fully passive sediment management approach in this case. It is impossible to predict the amount of time it would take for the lower Kinnickinnic River to recover fully from large scale sediment release. Because sediment transport is dependent on flow and flow events are episodic and unpredictable, the impact of the transported sediment could last for decades depending precipitation. The lower Kinnickinnic is a popular angling and kayaking destination, and the impacts to these activities and to the available habitat render the passive sediment approach not feasible. A fully passive sediment management approach will probably not be allowed under a granted WDNR/US Army Corps of Engineers permit.

5.1.2 Active Sediment Management

The active sediment management alternative involves mechanical (active) removal of the impounded sediment for demolition and river and floodplain restoration activities, and relies on design and construction for determining final channel and floodplain form (Figure 24). Under this alternative, all of the sediment in Lake George and Lake Louise will be excavated to proposed channel bed and floodplain elevations, and the channel and habitat elements will be constructed to be fully functional, both geomorphically and ecologically, The channel and floodplains would be fine graded to the proposed lines and grades, and banks would be stabilized, likely through a combination of bioengineering approaches to minimize sediment loss and encourage plant growth. This can include fabric encapsulation of soils, placement of biodegradable fabrics and an aggressive planting plan.

Figure 24. Mechanical excavation was used to remove 20,000 CY of sediment from this impoundment. Streamflow is routed through the black pipe to dewater the site completely (photo Inter-Fluve).

Active management approaches along with bank stabilization and riparian corridor restoration will be looked upon more favorably than passive methods, which can leave exposed banks bare and can result in persistent erosion over decades. Active restoration in addition to sediment removal can jumpstart the riparian recovery process and produce quicker results.

The active sediment management method minimizes downstream sedimentation and contaminant issues within the newly restored system; however, it does not fully eliminate all sediment movement. Sediment removal would include in-water work, and thus some fine sediment will likely be entrained. Sediment traps can be employed to capture a significant portion of any released sand, generated from construction and dewatering activities, but some finer materials will still pass downstream.

Excavation of impoundment sediment is typically done with low pressure, wide track excavators mounted with large volume buckets. Occasionally, long arm excavators are used to access difficult areas. Bulldozers or scrapers do not work well in the fine, wet impoundment sediments typical of the River Falls dam sites, unless the movement distance is short and there is adequate room. Suction dredging is also an option for removing material. A bank or barge mounted suction unit can be worked in the downstream end of the impoundment, with the slurry pumped to a dewatering area. In the Lake George impoundment, the slurry could be pumped and gravity fed to a drying area in the upper part of the Lake Louise staging area or exposed impoundment surface, or alternatively, to a drying area in the Lake George impoundment once water levels are reduced. Because hauling of dredged material is expensive, cost savings can be gained by keeping as much of the material on site as possible, or by establishing nearby disposal sites. Sediment traps can be constructed downstream of work areas to trap courser fractions that escape the primary work area.

The full active approach bypasses the natural stabilization of the river that may take years to decades depending on flows. It also eliminates any issues with downstream sediment transport. A fully active or mostly active approach may be warranted depending on final design goals. Inter-Fluve recommends a mostly active approach, detailed below.

5.1.3 Combination of Active and Passive Sediment Management

The combined active and passive sediment management alternative (“combined alternative”) includes removing the bulk of the sediment mechanically, but allowing some controlled passive release of sediment at the beginning and/or end of the process.

Passive sediment management can be utilized at the beginning of the project, when the impoundment levels are reduced to a level conducive for exposed sediment to dry out and support equipment. We recommend drawing the impoundment levels down to the point where the upstream two thirds to three quarters of the impoundment surfaces are exposed, but before sediment is entrained in the main channel. Headcuts or localized bed perturbations that may contribute to significant entrainment of bed sediments can be managed by either raising or lowering the pool elevation. If done in spring or summer, this first drawdown stage allows temporary seeding and stabilization of exposed sediments, thus minimizing sediment losses from rainfall and rill erosion during construction. Exposing the impoundment bed also helps to dry out the upper sediments which can aid in developing construction and excavation access routes. Passive management can also be utilized at the end of the process, where unexcavated or partially excavated transition areas are allowed to naturally adjust. The volume of sediment allowed to mobilize downstream will depend on the amount allowed by regulatory agencies, which will, in turn, depend on the results of more detailed geomorphic assessment and/or sediment transport modeling included in further design phases.

The active management phase includes excavating the bulk of the impoundment sediment to construct the designed channel and floodplain surface, generally with less detail than in under the full active management alternative. Once upper sediments are temporarily stabilized, or in conjunction with that process, the water levels can be lowered incrementally, and excavation of the deepest sediment areas along the proposed channel alignment (i.e., within 300-400 feet of both dams) can commence. This approach creates additional work space behind the dams and also reduces the amount of sediment mobilized downstream. If the drawdown can be managed such that moisture content is low, sediment can be loaded directly onto trucks and hauled away to disposal locations. If the excavated sediment is wet, staging areas for sediment surcharge and drying piles can be created within the exposed impoundment.

Additionally, active sediment dredging and sediment trap construction at the upstream face of the dam, between dams or downstream of the lowermost dam may be required to meet downstream transport limits set by the regulatory agencies.

In general, sediment deposits form a wedge, with a thicker deposit at the downstream end of an impoundment that tapers off at the upper end. Under the combined alternative, much of the sediment in the thicker portion of the wedge observed along the downstream three quarters of each impoundment would be excavated to proposed channel bed and floodplain elevations. Excavation should start at the upstream end of these sections and proceed downstream, leaving the uppermost quarter undisturbed. The bed and banks along the unworked sections will be allowed to adjust naturally. Exposed banks in these sections will likely be relatively low and natural recovery will take less time because accumulated sediment volumes are lower than upstream of the dam.

For the cost estimate given in this report, we have assumed excavation of 90% of the impounded sediment and active stabilization of bed and banks in the lower three quarters of each impoundment. This approach assumes a conservative permit, and thus is the most expensive dam removal alternative. Assuming 90% excavation still allows for some fine sediment to be allowed downstream during construction, so that full dewatering will not be necessary during the entire project period. If a regulatory decision is made that allows for more sediment to passively transport, the amount of excavated material may decrease, thus lowering removal costs accordingly.

5.1.4 Sediment Disposal

Depending on the sediment management approach, between 120,000 and 130,000 CY of material could be removed from the impoundments, depending on the ultimate width of floodplain excavation. The two primary options for disposal of the excavated channel and floodplain sediment are 1) on-site wasting and 2) hauling off site.

Overall, dam removal and channel restoration will lower the water surface elevation and channel bed profile through the impoundment reaches. Lowering the channel may transition impoundment margins to upland areas, and therefore, it may be possible to dispose of excavated material on-site in these locations without mitigation since those areas may not be viewed as wetlands and available riparian wetland habitat quality may increase. For the Lake George impoundment, 60,000 CY of excavated sediment could be spread over the eastern edge of the impoundment, creating a wedge of sediment 140 feet wide at the base and matching the local grade roughly 15 feet up the adjacent slopes). The filled areas would be compacted and graded, and thus, incorporated into trail, stormwater, and/or recreational access plans.

Similarly, an equal volume of sediment could be spread within the Lake Louise impoundment area, either along the wastewater treatment plant bank, or the embankment along the north-south access road in Glen Park or both. On-site disposal is preferred from a cost standpoint, as the localized transfer of materials eliminates the need for road trucks. Removal and disposal can be completed entirely with 20 to 30 CY capacity off-road dump trucks and small, low pressure bulldozing equipment (Figure 25). It may also be possible to bury concrete on site. Our cost estimate assumes on site storage of sediment, but off-site hauling of concrete. In recent years, dam removal excavation with on-site reuse has varied from $5 - $8 per CY for local hauls within 300 feet.

If regulatory agencies or stakeholders determine on-site disposal is not permissible, then loading sediment to trucks and disposing of the material in an approved dump site will be required. Active removal and hauling of the full evacuation volume of 120,000 CY would require roughly 8,000 truckloads. Trucking of sediment can vary between $10 and $30 per CY, which would escalate sediment removal costs into the $1.2 – 2.5 million range. In addition to haul and disposal costs, extensive hauling may necessitate temporary traffic control (temporary stoplights, signage). Damage to local roads may require repair of paved surfaces, and these costs would need to be factored. Clearly, off-site hauling is economically undesirable and potentially prohibitive. It will be important to work with the WDNR on allowable practices. On site disposal will likely be allowed, but may require off site or on-site wetland mitigation.

Handling requirements are regulated by the State and based on feedback discussed in Section 3.1.3, the likelihood for special handling requirements on a mass level (i.e. impoundment scale) are low. WDNR staff reviewed the contaminant concentrations and made the following recommendations (Personal comm. WDNR):

- There is no need for additional sediment sampling in the River Falls impoundments (Lake George and Lake Louise) at this time.
- Additional impoundment sediment sampling may be required during final design (e.g. 30% submittal) to verify arsenic concentrations in Lake Louise downstream of the wastewater treatment facility (sample location LLC2).

Figure 25. A 30CY off-road dump truck moves excavated impoundment sediment 150 feet to nearby disposal (photo Inter-Fluve).

- The allowance for sediment to be released downstream will require a WDNR waters permit and WDNR fisheries input. Thresholds will be negotiated related to sediment volume and inundation of habitats, but contaminants concentrations found in Phase 1 (2015 sampling; Inter-Fluve 2016) do not trigger any thresholds related to chemical contamination, assuming additional sampling is completed at a later date in the area of LLC2 and those additional sampling results do not trigger additional provisions.
- For sediment excavated and reused on site (i.e., fill along floodplain margins, which will likely become uplands following removal), the project will need WDNR Waters permit and input and approval on potential wetland impacts. The WDNR Solid Waste Program will review plans and make a determination regarding any potential required special handling or treatments.
- For sediment excavated and stored off site, WDNR Solid Waste Program input and approval will be required.

The Solid Waste Program will look at the data collected for the initial 2015 investigation, and any results of follow-up sampling for design refinement purposes. Based on this information, and the desired disposal options, the Solid Waste Program may ask for leaching tests of the material. Therefore, a future sampling plan should include collection of enough material for lab and leaching analysis.

5.2 CHANNEL RESTORATION PLAN

In a low-cost scenario, habitat elements are expected to form on their own over time, and no active restoration of geomorphic based habitat elements such as pools, riffles, or other features is recommended. Habitat elements can be installed later, once the channel has stabilized, and additional funding becomes available. To provide a conservative picture of restoration costs, our estimate assumes a more aggressive restoration scenario, where habitat elements are built in place and function immediately. Habitat elements appropriate for this type of river include constructed geomorphic features (riffles, pools, and depositional features), boulders with pocket water pools, self-armoring banks, and large wood placement.

Geomorphic features – Riffles are constructed by excavating the existing channel bed to subgrade and backfilling with appropriately sized riffle material in layers (Figure 26). Compaction involves washing and packing of a wide gradation to mimic natural riffle formation and a controlled amount of hyporheic or throughflow. Pools are constructed by excavating sediment and casting the spoils on the opposite bank in the form of a depositional bar. This approach helps to maintain channel hydraulic stresses that prevent pools refilling with fines. Pools are often incorporated into large wood installations.

Figure 26. This constructed riffle and bar complex transitions into a pool and bar feature with large wood for trout habitat. This photo was taken one year following construction completion (photo Inter-Fluve).

Boulders – Large boulders in the 2-4 ft range can provide excellent mitigating habitat in steeper reaches. Pocket water pools downstream provide feeding stations and holding water for trout, and can provide excellent fishing opportunities.

Large wood – Large diameter (10-24 in.) wood can be used to protect banks from erosion, provide overhead cover for fish, provide visual separation for territorial trout, create local scour pools, provide flood refugia, reptile and amphibian basking areas, and perches and nesting habitat for birds (Figure 27). Large wood incorporation in the Kinnickinnic River can include small log jams, isolated pieces of wood, wood toes and crib bank structures. Wood must be designed with paddlers in mind to minimize trapping and pinning of boaters.

Self-armoring banks – Channel banks can be constructed with encapsulated soils containing cobble material that eventually falls into the channel and armors the toe. This allows the channel to move naturally, but controls the rate of bank retreat. Short term erosion control fabrics can be used to provide temporary stabilization (5-10 years) after which time, the bank cobble and gravel material is able to drop into the channel toe area.

Upper bank slopes are bioengineered, with either shaped or encapsulated soil combined with planting of native vegetation.

Unique features – Unique features such as the bedrock gorges can be cleaned of concrete and made to appear undisturbed. It may be possible to move Eagle Rock via crane back to its pre-dam location on top of the downstream cascade drop at Junction Falls.

Figure 27. Cedar Creek in Ione, WA 3 months after removal of a 20ft tall dam. Over 30,000 cubic yards of sand and gravel was removed. This photo shows the restored stream channel with constructed banks, large wood habitat, pools, riffles and bars, as well as a constructed floodplain. Both planted trees and shrubs as well as naturally recruited vegetation is present.

5.3 FLOODPLAIN REVEGETATION PLAN

Near bank areas in restored segments will be seeded prior to fabric placement, and shrubs, trees and plugs can be planted through the fabric. Once the drawdown and construction activities are completed, the floodplain areas should be actively seeded and planted to encourage native plant establishment and discourage invasion by non-native plants. Planting is critical to bioengineering, as the plant roots bind soils, minimize soil water pore pressure, and provide resistance to erosion. To avoid full coverage by invasive plants, long term management would need to include planting natives and spraying for invasive species such as reed canarygrass (*Phalaris arudinacea*) and Phragmites (*Phragmites australis; giant reed grass*). Lenhart (2002) found in a study of 15 dam removals in Wisconsin, that passive revegetation (i.e., no seeding or management) of drained impoundment surfaces resulted in a consistent pattern of 90-99% coverage by reed canarygrass, Phragmites, and stinging nettles. Revegetation of the near bank region should include planting of live stakes and potted stock from fast growing, flood tolerant, native, woody species such as black willow, eastern cottonwood, silver maple, dogwoods, and shrub willows (Figure 28). Other species can be used to create a successional plan that focuses on riparian diversity, but these core plants will help to provide short term bank stability. Vulnerable and exposed areas may require seeding and container planting with erosion control fabric for more short-term stabilization.

5.3.1 Stormwater Considerations

Stormwater concept design is not a major goal of this feasibility study, but we touch on the issue, as it has been addressed in previous work and is of concern to the Friends of the Kinni. Thirteen storm sewer outfalls currently discharge freely into the two impoundments, and so stormwater design will be a key element in final design. Stormwater designs will need to follow the City's 2002 initiative to enact and enforce the current stormwater management ordinance to protect the Kinnickinnic River from negative impacts of stormwater runoff. Stormwater design can also support the WDNR and Minnesota Pollution Contract Agency (MPCA) Total Maximum Daily Load (TMDL) requirements for controlling excess nutrients effecting Lake Saint Croix.

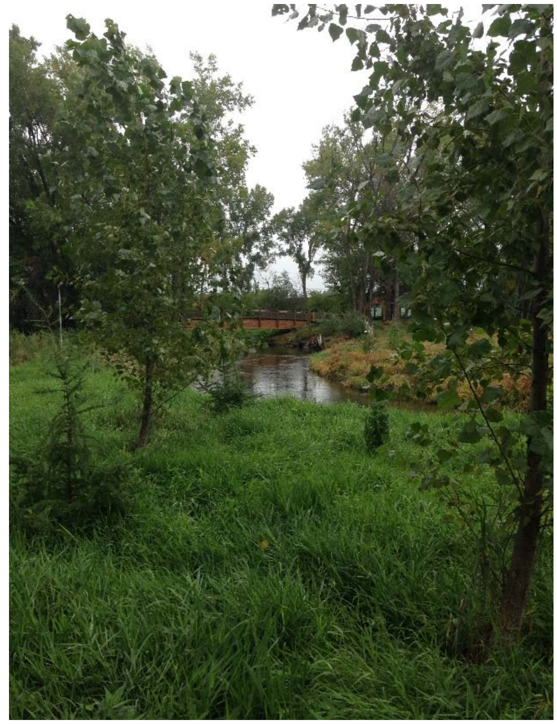

Figure 28. A mixture of seeding, bare root stock and potted stock was used in this riparian planting of a newly constructed stream. This photo was taken two years after construction (photo Inter-Fluve).

The City and stakeholders have completed several studies within the City and along the Kinnickinnic River charting stormwater issues and developing policies and proposed options to mitigate the thermal, chemical, biological, and hydrologic effects of non-point source pollution. Studies of note include Schreiber (1998) illustrating how, during a 1997 summer storm event, flows from the South Fork and City of River Falls urban area collectively contributed 69% and 75% of the total suspended solid and phosphorus load measured downstream of the City (Schreiber 1998). The 2005 Lake George Area Stormwater Treatment Concept (Bonestroo 2005) analyzed options that provide important information for future floodplain design elements. The Kinnickinnic River Monitoring Project (Short Elliott Hendrickson 2013) provides monitoring data that supports City stormwater policies.

Removal of the dams requires connecting the stormwater outfalls with the river, traversing newly exposed floodplain or uplands to do so. Upland solutions include design and maintenance of best management practices (BMP) capable of capturing and retaining organic compounds, floatable debris and liter, nutrients, sediment, salt and other pollutants as well as reducing conveyed stormwater peak flows. In addition, inclusion of BMPs that are designed to mimic natural hydrologic conditions, provide a source for groundwater recharge and buffer thermal impacts such as inclusion and maintenance of infiltration facilities are key elements to consider both upland and within a constructed floodplain. Determining the location and layout of BMPs within a constructed floodplain should include the following considerations:

- Outfall location – There are, as mentioned above, thirteen outfalls within the two impoundments. Floodplain space may allow some of these to be joined and routed to potential BMPs.
- Pretreatment controls – Coarse sediment from road runoff will need to be removed through pretreatment basins to ensure the longevity and function of any infiltration treatments.
- Residence time – The residence time of treated or controlled stormwater and the associated thermal impacts are a key design consideration. There is space for detention storage such as a pond or wetland, but if storage is exceeded, then warm water is discharged into the trout stream. Alternatives should focus on infiltration methods in addition to storage, since groundwater recharge can also lower discharging water temps. If infiltration is devised, the residence time underground will be important in lowering water temperatures before water discharges into the river.
- Elevations – Another key design element is the differential between groundwater elevation and BMP facility as it relates to hydraulic conductively and potential groundwater contamination. The change in channel bed elevation should improve the options for infiltration. Floodplain grading will need to consider the available subsurface slope between the outlet elevation or bottom of infiltration treatment areas (e.g. wetlands, rain gardens) and the channel bed. Discharging stormwater treatments will be most effective at the downstream end of the impoundments.
- Flooding – Final stormwater designs must consider the interaction of facility during high water conditions (e.g. prevent contained pollutants from being entrained in Kinni floodwaters). Again, infiltration versus detention storage partially solves this problem by reducing the likelihood of ponded water from entering the river. Sediment pretreatment basins will also need to be monitored and periodically dredged to ensure their long term function.
- Aesthetics – Design should consider integration into park or natural areas. In the concept plan, we have depicted stormwater treatment areas as floodplain wetlands. These features can be designed with infiltration rates that maintain wet soils between precipitation events, with underground conduits of coarse material for transfer of infiltrated water to the stream (Appendix). The size of these features will need to be balanced with storage needs and park or trail aesthetics in mind.
- Maintenance access – It will be important to establish light duty heavy equipment and truck access routes to sediment pretreatment basins. Vegetation maintenance goals should be defined prior to design, so that access routes can be designed for required vehicles. Trails can be designed to serve a dual purpose as both recreational and maintenance access routes.
- Permitting requirements - The WDNR (email correspondence, 10/26/2016) indicated there is no prohibition of ponds or stormwater ponds within 500 feet of a trout stream. However, the WDNR stated that thermal and water quality impacts from stormwater facilities

adjacent to a stream, especially those ponds with continuous surface water connections often make meeting state water quality standards difficult. Final design will need to consider the discharge frequency and volume from the pond to the cold-water stream (e.g. 25-year vs 50-year vs 100-year event).

Based on feedback from the WDNR and consideration of thermal impacts, the concept design (Appendix) incorporates an infiltration gallery and wetland complex within the constructed floodplains with a course aggregate subterranean outlet to the Kinnickinnic River.

6. Anticipated Dam Removal and Restoration Outcomes

Dam removal generally reduces or reverses many of the negative effects caused by the dam. The following subsections describe the changes that will occur following dam removal.

6.1 PUBLIC SAFETY

Public safety is improved with dam removal. The risk of dam failure is eliminated with removal of the dam. The liability risk to the City of River Falls for accidental injury, death or property loss due to dam failure is removed permanently. The liability risk of people injuring themselves on the dam spillways is also eliminated. The risk of injury on the waterfalls still exists, but the waterfalls are widespread, shallow, and have few large vertical drops. The risk of injury caused by climbing over fences, barriers, or on appurtenant structures still exists following dam removal, but the attraction of the dam is eliminated.

6.1 INFRASTRUCTURE

Outfalls will need to be connected to the stream to prevent undermining due to incision between the lowered river elevation and the outfalls. There are also buried pipes and possibly other old infrastructure within the Lake Louise and Lake George impoundments, as noted above. Any old, wooden dam remnants downstream of Winter Street will need to be removed. Any pipes near the proposed channel bed elevation may need to be moved or the river design adjusted to accommodate these conduits.

Bridge scour analysis will need to be conducted during final design, and shoring of the Winter Street Bridge abutments may need to be completed as part of the design. For the cost estimate, we have assumed that no significant stabilization beyond riprap placement will be needed.

6.2 KINNICKINNIC RIVER GEOCHEMISTRY

Removal of Junction and Powell Falls Dams will initiate a transformation of the physical, chemical, and biological processes of the lake environment to more of a riverine environments. Peak water temperatures in summer will decrease as residence time and solar exposure are decreased. The degree to which temperatures will decrease is not known at this time but can be studied in further design phases. This will improve as a forested riparian area matures and trees provide additional shading.

Spring connections will be routed directly to the river, including restoration of the stream connecting the current trout pond near the upstream end of Lake Louise. The spring pond channel, like all tributaries, will see a drop in bed elevation as the channel is restored to its pre-dam elevation. The spring pond channel represents an excellent opportunity to create a trout spawning and nursery area, potentially for brook trout if thermal refugia can be developed. Predatory fish passage will be limited by the falls, and so this area could be designed, as part of the dam removal, to encourage trout spawning and rearing.

Algal growth will decrease in the water column, and the nutrient inputs caused by geese and other waterfowl waste will be minimized. Nutrient pulsing during flooding, common in small dam impoundments, will be eliminated.

Once the dams are removed and the channel restored, the channel will roughly follow its old path through the City. It will flow over riffles and pools, and will flow unimpeded over the Junction Falls and Powell Falls cascades. A small pool area will remain just above the uppermost falls near the Winter Street bridge crossing. Sediment transport continuity will be restored, allowing incoming sediment to work its way through the system. Natural sediment sorting (i.e., self-organization) will build or reconstitute new bed forms such as riffles and depositional bars. The floodplain will be restored to include floodplain forest, ephemeral wetlands, spring ponds and other features common to regional riparian areas.

6.3 ECOLOGICAL OUTCOMES

Over the long term, the shift to normal riverine conditions should produce a general shift in aquatic communities, from the generalists currently using the impoundments to specialist species that are adapted to cold, flowing water and coarse substrates. Additionally, improved habitat complexity associated with flowing water and proposed design elements will also improve holding capacity and productivity for trout and other coldwater species. Following dam removal, improved water quality and an increase in the types of available habitat often increases overall macroinvertebrate abundance and diversity relative to impoundment communities (Bushaw-Newton et al. 2002, Calaman and Ferreri 2002). Additionally, riverine fish species generally respond quickly to increased sediment size, habitat complexity and decreasing temperature following dam removals (Maclin and Sicchio 1999, Kanehl 1997). Long term changes in physical habitat following dam removal should result in increased abundance and diversity of riverine fishes as newly available habitat is exploited (Born et al.1998, Stanley et al 2002).

Unlike most dam removals, upstream fish passage will not likely be greatly improved by this removal project. The waterfalls will still constitute a fish barrier at most flows. Downstream passage will likely be improved.

Although over the long term, fish and benthic macroinvertebrates should benefit from dam removal, there will be some negative short term impacts to these communities. Rapid drawdowns can strand fish and macroinvertebrates. Mitigation possibilities include rescuing fish by either removing them prior to dam breach using electrofishing, netting, or other techniques; or gathering stranded fish from exposed sediments. Mussels can also be captured and relocated or sequestered until conditions allow for their return. Rescuing these animals from a full impoundment is often not practical, and losses can be minimized through planned staged drawdown and rescue during low water conditions. If downstream sediment release is planned, mussel rescue may need to be scheduled for flowing water segments downstream of the dam, particularly in sediment trapping areas.

In addition to aquatic species, birds, reptiles, amphibians, and mammal species will gain available riparian habitat and will also have unimpeded passage through the river corridor following removal of the dams, with only minor, short-term disruptions due to noise and construction-related disturbances. With an improved natural riparian corridor featuring trees and shrubs, and decreased ponded water, Canada goose populations will decrease, and fewer geese will congregate and foul park lawns. This reduce goose population will help to reduce nutrient loading into the Kinni system. Riverine birds and waterfowl, including kingfishers, blue herons, Baltimore orioles, rose breasted grosbeaks, and wood ducks will likely be found in greater abundance following removal and restoration of the corridor.

6.4 SOCIAL AND CULTURAL OUTCOMES

If paired with trail system expansion, dam removal and river restoration can create better trail connectivity between the Lake George area, Lake Louise, falls, area parks and the Swinging Bridge area. For non-boaters, there is currently no efficient way to get from the Lake George trail system to Lake Louise. Trail construction at Junction Falls, including the portage, creates an opportunity for park users to move from one impoundment to the other without having to cross Winter Street or take a circuitous bypass route.

Enhanced kayak and canoe opportunities for this reach of the Kinni can be incorporated into trail connections. The post removal trail system could extend under the Winter Street Bridge with stair access down to the upper end of Lake Louise (Appendix A). A kayak portage ramp could be constructed alongside stairs to aid in boat transport across Junction Falls. With removal of Powell Falls, paddlers would have a relatively easy takeout spot and a small portage to the downstream put-in. Additional trails can be constructed within the Lake George and Lake Louise impoundments.

Removing the dams will uncover and accentuate the steep bedrock bluffs, cascades, and pools and riffles that once characterized the Kinni through River Falls. The exposed falls will create an attraction and an amenity to the City, and improved access will help to bring people close to these features. If a footbridge is installed along the river downstream of Junction Falls, a circular route could be devised linking UW-River Falls, River Falls downtown, City Hall, the White Pathway, and additional walking trails being planned and implemented by the City (Appendix A).

Trout angling opportunities within the impoundments and through downtown, which are currently hindered by sediment, temperature, and habitat issues, will increase significantly.

Figure 29. Following dam removal, the Milwaukee River in the former millpond at West Bend quickly reestablished natural riverine geomorphic and ecological function (Photo River Alliance of Wisconsin)

7. Dam Removal and Channel Restoration Costs

7.1 ENGINEERING AND PERMITTING COSTS

Dam removal engineering must address many potential issues, as noted in the sections above. In addition to typical civil engineering work, river restoration engineering involves unpredictable flows, variable sediments and soils, natural materials, and difficult access and working conditions. Each river is different, and requires a different set of complex topographic design data and proposed plans. Few standard designs exist such as those available for building or road construction. River restoration is often foreign to most contractors, and thus requires a high level of engineering oversight during construction. Permitting may involve sediment management coordination and mitigation, as well as no-rise certification or FEMA Letter of Map Revision work to establish altered 100-year flood elevations and extents. For these reasons, dam removal engineering costs can vary between 20-50% of projected construction costs. Ballpark engineering costs are given in the table below.

7.1 CONSTRUCTION COSTS

Preliminary cost estimates were given in the sediment assessment (Inter-Fluve 2016). Updated preliminary cost estimates are given in the table below. For concept level cost estimates, we typically assume costs are accurate to within 50% of the posted value, given assumptions. As design progresses through final design, the accuracy of the cost estimates improves.

As stated in the Executive Summary, this cost estimate comes with the following assumptions:

- Active removal of 90% of the sediment needed to construct a channel and minimal floodplain width. Addition floodplain width can be excavated, but the cost will vary depending on the ultimate width of the floodplain area. This type of detail will be developed fully in the final design stages, and the amount of sediment removed may vary depending on sediment allowed downstream or other factors.

- Sediment excavated from the channel can be stored and incorporated into the fringe of the impoundment areas. This greatly lowers costs as it eliminates truck hauling through town to an approved disposal area (e.g. nearby farm field or other fill area). Truck hauling off site could increase the cost of removal by $1 million or more.

- The cost estimates do not include any large scale detention storage or stormwater best management practice treatment installation, as the viability of these treatments needs further investigation.

- The costs do not include additional trails. There are numerous possible trail locations and combinations, and we have depicted some logical routes in the concept plans (Appendix A). Before costs can be estimated, preliminary trail locations would need to be agreed upon by stakeholders.

- Costs do not include removal or renovation and reuse of the powerhouse buildings or interior infrastructure. The fate of these buildings for public or private use involves too many variables, including removal of contaminants such as asbestos and PCBs, and possible renovation costs. We do not know what these buildings may be used for in the future, and so cannot estimate the cost of renovation. For instance, if the upper powerhouse would be converted to private commercial use, the cost of renovation would likely be borne at least partially by the private owner.

- These costs assume no road damage repair from hauling will be necessary. We assume truck hauling of concrete, but no road damage resulting.
- The cost of kayak or canoe launches is not included in the estimate below.

Junction Falls Dam (upper Lake George) - Feasibility Level Cost Estimate

Item	Description	Cost per	Unit	Number	Cost
Staging and mobilization	Assumes traffic control, construction site erosion control, staging, single mobilization, equal to 10% of remaining construction items	$111,809	LS	1.0	$111,809
General erosion control	Includes silt fencing, sediment trap construction and management, removal.	$15,000	LS	1.0	$15,000
Clearing and grubbing	Tree and shrub removal, salvage trees for channel restoration.	$7,000	AC	1.0	$7,000
Haul road/access	Temporary haul road construction.	$25	LF	1,000	$25,000
Flow management	Assumes diversion, but no full dewatering through pumping necessary. Assumes bypass or gravity only (no pumping).	$30,000	LS	1.0	$30,000
Demolition	Includes dam spillway removal, penstock removal but no powerhouse or remnant feature removal. Hydraulic jack access from below. Assumes off-site concrete disposal. Assumes cleaning to natural bedrock.	$200	CY	1,700	$340,000
Excavation	Assumes impoundment sediment excavation and active channel/floodplain restoration within the former impoundment. Assumes disposal of excavated sediment within the Lake George footprint.	$7.00	CY	66,600	$466,200
Channel stabilization	Assumes fine grading for bank reconstruction, fabric placement within 25 feet of water edge. Assumes 3,400 feet of active stabilization total.	$7.00	SY	3,400	$23,800
Fabric encapsulation	Assumes fabric encapsulated lifts on critical areas (1,000 feet), assumes 2 lifts x 1ft height each per LF of streambank.	$75.00	LF	1,000	$75,000
Channel restoration	Assumes riffle (3) and pool (3) construction, bar formation	$50.00	CY	556	$27,778
Large wood habitat	Assumes habitat jams, bank toe protection, includes furnish and install, ballast countermeasures.	$500	EA	50	$25,000
Seeding	Includes native seed mix, mulch. MNDOT metro riparian mix.	$130	LB	275	$35,813
Planting (Trees)	Assumes 5 gallon potted stock, natives, furnished installed. Includes protection via 4ft hardwire cloth cage and oak stakes. Count based on 25ft buffer x 20 ft grid spacing + 100 addnl for floodplain.	$150	EA	210	$31,500
Planting (Shrubs)	Assumes bare root stock, furnished and installed. Includes vispore mats and rodent protection. Count based on 25ft buffer, 10 ft spacing + 100 addnl for floodplain.	$20	EA	550	$11,000
Planting (Plugs)	Assumes native plugs furnished and installed.	$5.00	EA	1,000	$5,000

Estimated Construction Cost **$1,229,899** +/-50%

Engineering and Permitting

Engineering	Includes 30%, 60%, 90% and Final Plans, Specs and EOPC. Assumes designed in conjunction with Powell Falls Dam removal.	$344,371.86	LS	1	$344,372
Permitting	Includes all applicable permits and fees	$20,000	LS	1	$20,000

Estimated Engineering and Permitting Cost **$364,372** +/-20%

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Powell Falls Dam (lower Lake Louise) - Feasibility Level Cost Estimate

Item	Description	Cost per	Unit	Number	Cost
Staging and mobilization	Assumes traffic control, construction site erosion control, staging, single mobilization, equal to 10% of remaining construction items	$86,005	LS	1.0	$86,005
General erosion control	Includes silt fencing, sediment trap construction and management, removal.	$15,000	LS	1.0	$15,000
Clearing and grubbing	Tree and shrub removal, salvage trees for channel restoration.	$7,000	AC	1.0	$7,000
Haul road/access	Temporary haul road construction.	$25	LF	2,600	$65,000
Flow management	Assumes diversion, but no full dewatering through pumping necessary. Assumes bypass or gravity only (no pumping).	$30,000	LS	1.0	$30,000
Demolition	Includes dam spillway removal, penstock removal but no powerhouse or remnant feature removal. Hydraulic jack access from below. Assumes off-site concrete disposal. Assumes cleaning to natural bedrock.	$200	CY	942	$188,400
Excavation	Assumes impoundment sediment excavation and active channel/floodplain restoration within the former impoundment. Assumes disposal of excavated sediment within the Lake George footprint.	$7.00	CY	40,500	$283,500
Channel stabilization	Assumes fine grading for bank reconstruction, fabric placement within 25 feet of water edge. Assumes 3,400 feet of active stabilization total.	$7.00	SY	1,200	$8,400
Fabric encapsulation	Assumes fabric encapsulated lifts on critical areas (1,000 feet), assumes 2 lifts x 1ft height each per LF of streambank.	$75.00	LF	1,600	$120,000
Channel restoration	Assumes riffle (3) and pool (3) construction, bar formation	$50.00	CY	556	$27,778
Large wood habitat	Assumes habitat jams, bank toe protection, includes furnish and install, ballast countermeasures.	$500	EA	50	$25,000
Seeding	Includes native seed mix, mulch. MNDOT metro riparian mix.	$130	LB	327	$42,471
Planting (Trees)	Assumes 5 gallon potted stock, natives, furnished installed. Includes protection via 4ft hardwire cloth cage and oak stakes. Count based on 25ft buffer x 20 ft grid spacing + 100 addnl for floodplain.	$150	EA	210	$31,500
Planting (Shrubs)	Assumes bare root stock, furnished and installed. Includes vispore mats and rodent protection. Count based on 25ft buffer, 10 ft spacing + 100 addnl for floodplain.	$20	EA	550	$11,000
Planting (Plugs)	Assumes native plugs furnished and installed.	$5.00	EA	1,000	$5,000

Estimated Construction Cost **$946,054** +/-50%

Engineering and Permitting

Engineering	Includes 30%, 60%, 90% and Final Plans, Specs and EOPC. Assumes designed in conjunction with Powell Falls Dam removal.	$264,895.12	LS	1	$264,895
Permitting	Includes all applicable permits and fees	$20,000	LS	1	$20,000

Estimated Engineering and Permitting Cost **$284,895** +/-20%

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8. Conclusion

The River Falls Dams, including Junction Falls (Lake George) and Powell Falls (Lake Louise), like all dams, are aging and will ultimately need repair and eventual replacement. The removal of the dams offers an alternative to continued maintenance, and is an opportunity to improve public safety, reduce liability risk, improve recreation and restore the ecological and physical attributes of this segment of the Kinnickinnic River.

Fish passage is typically one of the main drivers for dam removal. In this case, fish passage will not be improved, but a significant amount of trout habitat can be restored within an urban area. This in itself is a rare opportunity. The motivating factors for dam removal in this case, as identified by Friends of the Kinni, are improved natural and historic aesthetic, improved public safety, water quality, fish habitat, angling and land and water trail opportunities. Inter-Fluve concludes that all of the aforementioned factors can be improved with removal of the two dams.

This is a feasibility project, intended to determine the feasibility of dam removal. The study goal is to answer the questions, “What is involved with removal of these dams, and how much will it cost?”. It is difficult to do a cost versus benefit comparison for natural resource restoration, because the intrinsic value of nature is variable from person to person. Someone who lives out of town may regard the river differently than someone who paddles and fishes the river weekly.

Inter-Fluve cannot comment on the social aspects of dam removal, and can’t place a monetary value on aesthetics or social importance, except to say that in our experience, the vast majority of people involved with dam removals are ultimately satisfied with their decision to remove. Most small towns and cities only have one dam, and the people of those towns have developed an emotional attachment to their impoundments, which are often the centerpiece of the community. In communities where dam removal has been adopted, however, the residents are often surprised by the positive transformation that takes place. In our experience, there is usually a realization that the restoration of natural features transforms the heart of these communities into something that is more fitting, more naturally suitable.

Dam removal in River Falls is feasible. Removal of both dams will cost approximately $2.8 million if conducted as described and with the assumptions noted in the previous section. Funding is perhaps the greatest hurdle. There are no grants available that offer such large sums of money, but such a project could be pieced together from multiple grant sources, or from special budget appropriation. American Rivers offers guidance and support for dam removal funding, and the Wisconsin DNR, NOAA, USFWS and NRCS have contributed funds to dam removals nationwide.

Socially, dam removal needs to be accepted by the community and agreed upon by multiple stakeholder groups, including most importantly, the owner of the dam, the City of River Falls who must take into account opinions for and against removal. Other major hurdles typical of small dam removals do not apply here. There are few private landowners on the impoundment. There are no significant contamination issues associated with the sediments in either impoundment. Access and staging are good, and there are few infrastructure issues such as buried pipes and cables. Bridge impacts are likely not an issue, and both dams and their abutments are seated on bedrock. Although the terrain is fairly complex, these dam removals can be accomplished with experienced science and engineering.

8.1 NEXT STEPS

Inter-Fluve has outlined below the steps necessary for removal of the Junction Falls and Powell Falls dams. This list is preliminary and based on what we know of the site and permit environment to date:

- The City of River Falls is conducting a corridor planning study in which the local citizenry is being engaged in planning the future of the River Falls river corridor. Part of this process will be to determine public opinion regarding the fate of the dams and the look and function of subsequent plans. Trails, recreation and aesthetics will all be discussed in some detail. This is a good first step toward a decision.
- If the City decides to remove the dams, the next step will be to generate funding for final design engineering. We have estimated a rough cost of approximately $600K for engineering design.
- Preliminary engineering includes the following:
    - Planning and design review meetings
    - Pre-permitting meetings
    - Project management
    - Detailed topographic surveying of the area surrounding the impoundments.
    - Detailed bathymetry was already collected by Inter-Fluve in 2015-16, and should not need to be repeated. Some additional bathymetry data may be warranted, but a full survey is not needed.
    - Additional sediment coring may be required by the WDNR.
    - Geotechnical engineering will need to be completed for the adjacent bedrock to ensure public safety during and after construction.
    - Underground utilities and other infrastructure will need to be located and their actual depths determined to gauge the impact of removal and the need for relocation or adjustment.
    - Structural engineering for interfaces between removed spillway/appurtenant structures and remaining infrastructure
    - Wetland delineation
    - Cultural resources investigation
    - Bridge scour analysis
    - Hydrology and hydraulic analysis
    - Detailed geomorphic assessment and river channel design
    - Plan drafting, including submittals at the 30%, 60% and 90% level of completion.

- After the 60% submittal level, permit applications will be submitted to the various regulatory agencies.
- Final Design - Upon receipt of permit comments, final design document preparation commences, including Project Manual preparation, specifications and Engineer's Opinion of Probable Costs, final 100% complete drawings stamped by a professional engineer licensed in Wisconsin.
- Bid period services – This includes pre-bid activities, responses to requests for information and bid award.
- Contracting – Once bids are awarded, the owner enters into contracting with the selected contractor. Contracting for a project of this size usually takes between one and three months to complete.
- Construction management, including construction observation, processing change requests and approvals.
- After the construction bid is awarded, mussel relocation, if required, should be completed prior to mobilization.
- *Mobilization* – This includes cordoning off staging and access areas, establishing traffic control measures such as temporary lights or signage, erosion control measures, and setup of job trailers and other support infrastructure.
- *Construction* - Preliminary estimates are 150 days (5 months) for clearing and grubbing, haul road installation, drawdown, demolition of the dam structures, and restoration of the river and floodplain areas. Drawdown and demolition of each spillway will take approximately 2 weeks from start of demolition. Total project time depends on whether the appurtenant structures will be removed, the level of sediment removal and restoration desired, and weather conditions. Construction can be done during any time of year, but river projects in the Midwest are usually best completed between June and August, or from September to February, avoiding spring runoff periods.
- *Monitoring* – Construction contracts typically include a monitoring period that includes watering and replacement of vegetation that does not meet success criteria established in the specifications. This period is typically 3 years. Engineers often monitor their work long term, but do not expend significant resources, nor should they, as success monitoring should be done by a third party. Monitoring funding has been historically difficult to obtain, but most large projects include at least a minimal amount of vegetation and channel stability monitoring.

9. Citations

Allen, J.D. 1995. *Stream ecology: structure and function of running waters.* Chapman and Hall, London, UK.

Armitage, P.D., 1984. Environmental changes induced by stream regulation and their effect on lotic macroinvertebrate communities. *Regulated rivers* 139: 204 – 217.

Baxter, R.M. 1977. Environmental effects of dams and impoundments. *Ann. Rev. of Ecol. and Systematics* 8:255-283.

Bednarek, A. 2001. Undamming rivers: A review of the ecological impacts of dam removal. *Envir. Mgmt*. 27(6): 803-814.

Bonestroo, Rosene, Anderlik, and Associates. 2005. *Lake George Area Stormwater Treatment Concept Plan*. Submitted to the City of River Falls, WI, April, 2005. 105p.

Born, S.M., K.D. Genskow, T.L. Filbert, N. Hernandez-Mora, M.L.Keffer, and K.A.White. 1998. Socioeconomic and institutional dimensions of dam removals: the Wisconsin experience. *Env. Mgmt.* 22:359-370.

Brandt, S.A., 2000. Classification of geomorphological effects downstream of dams. *Catena*, 40(4), 375-401.

Bushaw-Newton, K.L., Hart, D.D., Pizzuto, J.E., Thomson, J.R., Egan, J, Ashley, J.T., Johnson, T.E., Horwitz, R.J., Keeley, M, Lawrence, J., Charles, D., Gatenby, C., Kreeger, D.A., Nightengale, T., Thomas, R.L. and D.J. Velinsky. 2002. An integrative approach towards understanding ecological responses to dam removal: The Manatawny Creek Study. *J. Am. Wat. Res. Assoc.* 38(6) 1581-1599.

Calaman, H. and C.P. Ferreri. 2002. *Effects of dam removal on benthic macroinvertebrate diversity*. Pennsylvania State University School of Forest Resources.

Catalano, M.J., Bozek, M., and T. Pellett. 2007. Effects of dam removal on fish assemblage structure and spatial distributions in the Baraboo River, Wisconsin. *N. Am. J. Fish. Mgmt.* 27 (2) pp 519-530.

City of River Falls. 1987. *River Falls Municipal Hydroelectric Facilities: Application for License*. Prepared by HDR Technserve, Inc.

Cordone, A.J., and D.W. Kelly. 1961. The influences of inorganic sediment on aquatic life of streams. *California Fish and Game* 47:189-228.

Cui, Y., J.K. Wooster, C.A. Braudrick, and B.K. Orr. 2014. Lessons Learned from Sediment Transport Model Predictions and Long-Term Postremoval Monitoring: Marmot Dam Removal Project on the Sandy River in Oregon. *Journal of Hydraulic Engineering* 140.9. 10.1061

Cummins, K.W., 1979. The natural stream ecosystem, in: *The Ecology of Regulated Streams*, J.A. Sanford and J.W. Ward (Eds.), p. 7-24.

FEMA (Federal Emergency Management Agency). 2011. F*lood Insurance Study. Pierce County, Wisconsin.* FIS Number 55093CV000A. Effective November 16, 2011. 77pp.

Grant, G.E., Schmidt, J.C. and Lewis, S.L., 2003. A geological framework for interpreting downstream effects of dams on rivers. *A peculiar river*, pp.203-219.

Gray, L.J., and J.V. Ward. 1982. Effects of sediment release from a reservoir on stream macroinvertebrates. *Hydrobiologia* 96:177-184.

Hatch, B. 2013. *River Falls Hydroelectric Project: Pre-Application Document* Project No. P-10489 River Falls, Wisconsin.

HDR. 1987. *River Falls Municipal Hydroelectric Facilities: Application for License*. Prepared for the City of River Falls, WI.

Hughes, M.H., and P.W. Parmalee. 1999. Prehistoric and modern freshwater mussel (Mollusca: Bivalvia: Unionidae) faunas of the Tennessee River: Alabama, Kentucky, and Tennessee. *Regulated Rivers: Res. and Mgmnt.* 15: 25-42.

Independent Scientific Group (ISG). 1996. *Return to the river: restoration of salmonid fishes in the Columbia River basin*. Northwest Power Planning Council Document 96-6, Portland, OR.

Inter-Fluve. 2016. *Lake George and Lake Louise Sediment Assessment Report*. Submitted to City of River Falls, WI. March 14, 2016. 69p.

Kanehl, P.D., J. Lyons, and J.E. Nelson. 1997. Changes in the habitat and fish community of the Milwaukee River, Wisconsin, following removal of the Woolen Mills Dam. *N. Am. J. Fish. Mgmt* 17:387-400.

Kiap-Tu-Wish. 2014. *A Study to Assess the Water Resource Impacts of City of River Falls (WI)* Hydropower Facilities on the Kinnickinnic River. Chapter of Trout Unlimited.

Kondolf, G.M., 1997. Hungry water: effects of dams and gravel mining on river channels. *Envir. Mgmt.*, 21(4): 533-551.

Ligon, F.K., Dietrich, W.E., and W.J. Trush. 1995. Downstream ecological effects of dams: a geomorphic perspective. *Bioscience* 45(3) 183-192.

Maclin, E. and M. Sicchio, eds. 1999. *Dam removal success stories*. American Rivers, Friends of the Earth, and Trout Unlimited. Washington, DC.

Martinez, P.J., T.E. Chart, M.E. Trammell, J.G. Wullschleger, and E.P. Berggersen. 1994. Fish species composition before and after construction of a main stem reservoir on the White River, Colorado. *Envir. Biol. Fishes* 40:227-239.

Minshall, G.W. 1984. Aquatic insect-substrate relationships. Pages 358-400 in Resh and Rosenberg eds. *The ecology of aquatic insects*. Praeger Publishers, New York.

Mitro, M. et al. 2010. *Coldwater Fish and Fisheries Working Group Report*. In Wisconsin Initiative on Climate Change Impacts.

Noren, J.B. 2003. *Kinnickinnic River at River Falls, Wisconsin Thermal Study*. USACE St Paul District.

Pearson, A.J., N.P. Snyder, and M.J. Collins. 2011. Rates and processes of channel response to dam removal with a sand-filled impoundment. *Water Res. Res.* 47.8. 10.1029/2010WR009733.

Petts, G.E., 1984. *Impounded rivers, perspectives for ecological management*, John Wiley and Sons, New York, NY, 326p.

Poole, G.C. and C. H. Berman. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation. *Envir. Mgmt*. 27(6): 787–802.

R. Swanson. 1976. *A Hydrologic Study of Lake George and the Upper Kinnickinnic River Watershed*. University of Wisconsin-River Falls. 72p.

Schreiber, K. 1998. *Kinnickinnic River Priority Watershed Surface Water Resource Appraisal Report*. WDNR West Central Region.

Short Elliot Hendrickson. 2013. *City of River Falls North Kinnickinnic River Monitoring Project: 2013 Report*. Prepared for the City of River Falls, Wisconsin.

Stanley, E.H., Luebke, M.A., Doyle, M.W., and D.W. Marshall. 2002. Short-term changes in channel form and macroinvertebrate communities following low head dam removal. *J. N. Am. Benthol. Soc*. 21(1): 172-187.

Stillwater Sciences 2010. *Simulating Sediment Transport in the Patapsco River following Dam Removal with Dam Removal Express Assessment Model-1 (DREAM-1)*. Technical Report, prepared by Stillwater Sciences, Berkeley, California for Inter-Fluve, Madison, Wisconsin, and American Rivers, Washington, D.C., 32 pages, January.

Tiemann, J, Dodd, H.R., Owens, N. and D.H. Wahl, 2007. Effects of Lowhead Dams on Unionids in the Fox River, Illinois. *Northeastern Naturalist* 14(1):125-138.

Walker, J.F. and Krug, W.R., 2003. Flood-frequency characteristics of Wisconsin streams. US Department of the Interior, US Geological Survey.

Ward, J. V. and J.S. Stanford. 1983. The serial discontinuity concept of lotic ecosystems. Ch. 2 in T.D. Fontaine and S.M. Bartell (editors), *Dynamics of lotic ecosystems*. Ann Arbor Science Publishers.

Ward, J.V., and J.A. Stanford. 1979. Ecological factors controlling stream zoobenthos with emphasis on thermal modifications of regulated streams. Pages 35-55 in J.V. Ward and J. A. Stanford (eds) *The Ecology of Regulated Streams*. Plenum Press, New York.

Ward, J.V., and J.A. Stanford. 1989. Riverine ecosystems: the influence of man on catchment dynamics and fish ecology in Dodge, D/P. (Ed), *Proceedings of the International Large River Symposium. Can Spec. Publ. Fish Aquat. Sci.*, 106:56-64.

Waters, T.F., 1995. Sediment in streams: sources, biological effects, and control. *American Fisheries Society*.

WDNR 2015. Wisconsin Department of Natural Resources, *Fisheries Management Stream Classification Report – Kinnickinnic River*. 5p.

WDNR 2016. Wisconsin Department of Natural Resources, Bureau of Natural Heritage Conservation. *Endangered Resources Review Report. ERR Log #16-536. Proposed River Falls Dam Removal Feasibility Study*. Created for Inter-Fluve and the Friends of the Kinni, 8/24/2016.

WDNR. 1971. *Surface Water Inventory of Wisconsin*. Information made available at http://dnr.wi.gov/water/waterDetail.aspx?wbic=2603700

Williams, G.P., and M.G. Wolman. 1984. *Downstream effects of dams on alluvial rivers*. U.S. Geological Survey Professional Paper 1286.

Winston, M.R., C.M. Taylor, and J. Pigg. 1991. Upstream extirpation of four minnow species due to damming of a prairie stream. *Trans. Am. Fish. Soc.* 120:98-105.

Appendix

Concept Plans