DEEP RIVER DAM
ENGINEERING FEASIBILITY STUDY

NORTHWESTERN INDIANA
REGIONAL PLANNING COMMISSION

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1. PROJECT INTRODUCTION

1.1 RIVERS

Rivers are like blood vessels in a body or branches on a tree. They form fractured or irregular patterns that repeat in shapes known as fractals. Fractals are complex mathematical formulas created by algorithms. In living things; fractal shapes allow them to maximize their surface area by exchanging energy or nutrients. In trees, a fractal structure allows a tree to maximize the sun's exposure to leaves. In rivers, the fractal structure creates the maximum efficient means to circulate water from the air (in rain) to the land to the stream to the river to the ocean or lake and back into the air. The fractal pattern of streams and rivers creates the ideal conditions for the uptake of water into plants; plants being the fourth most important ingredient to animal existence after sun, water and soil. The fractal pattern of rivers is what holds soil on the land while it transports unwanted elements and nutrients from the land to the oceans.

In geological time, river erosion is in a state of dynamic equilibrium. In human time, the anthropogenic modifications of streams to manage waters for power, irrigation, and recreation is a critical factor in modernization and city development. However, these anthropogenic modifications, including dams, destroy the river's natural state of equilibrium. If these modifications are removed or modified, a river has the ability revert back to a state of dynamic equilibrium. Left alone, rivers often by-pass constructed dams to reach equilibrium.

Humans will always be looking to find a more sustainable approach to river water management. Today, more river professionals look to mimic the natural river patterns. Natural dams (falls) are a rare and wondrous exception in the landscape (Niagra Falls for example). In North America, man-made dams appear to have reached maximum capacity. Today, people are examining the frequency, purpose, cost in ecology and money, and life-cycles of man-made dams that no long have a functional purpose.

It has been said that each generation will form its own relationship with the river. Some generations have harnessed the river for power; others for food; others for irrigation; others for transportation; and others for recreation and contemplation.

Since before the settlement of North America by Europeans, rivers were an important resource with European expansion. Rivers have been used for transportation highways, power, irrigation, industrial cooling sources, and sewer discharge points. Native Americans had great respect for rivers as a food and water source; they understood the annual flood flow cycles and the far reaching effect that waterways had on the landscape as well as plant and animal communities. They used the rivers to transport resources, travel during migration, or to reach neighboring tribes. Rivers were used by Lewis and Clark to explore the wilderness of the continent.

As settlements moved further inland, water transportation routes developed; some of these routes are still used today. The use of rivers as main thoroughfares for transportation shifted with the advent of railroad and automobile highways, allowing more dams to be built on waterways that formerly would have been used for transportation.

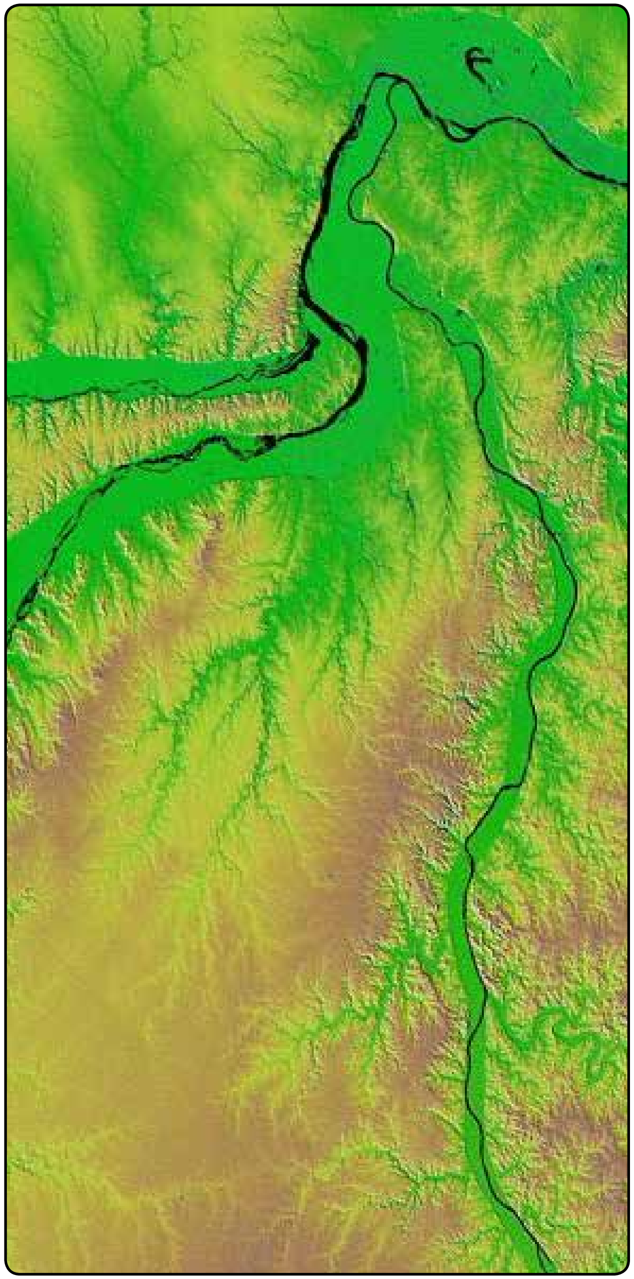

FIGURE 1.1-1 | River Fractal Patterns

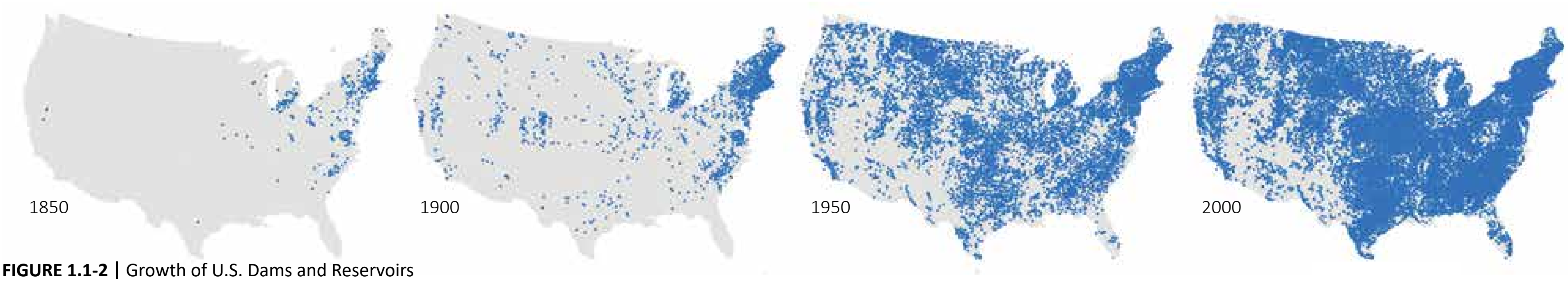

FIGURE 1.1-2 | Growth of U.S. Dams and Reservoirs

The harnessing of rivers for power and industrial cooling in virtually all instances required the construction of a dam. The dams created pools of impounded water used to create head pressure to propel turbines or mills. Mills processed goods such as grain, wood, paper, and textiles. Rivers as the source of energy generation to power gristmills, and later, electricity, waned as production moved to large-scale operations and the national electric grid provided more reliable electricity. During the industrial boom, the impounded water was used for cooling and cleaning processes in both factories and power plants.

The number of dams greatly increased in the 1900's to 2000 (Fig. 1.1-2). The H. John Heinz III Center for Science, Economics and the Environment has reported today that there are an estimated 2 million dams nationwide. However, as the purpose and function of many dams ceased due to industrial and agricultural centralization, the river landscape of America became dotted with defunct dams that have no societal benefit. Often, the abandoned factories have been demolished or reproposed but the dams remain with no defined ownership or operation. Questions continue to surface as to the best future use, if any, of these dams.

Dam removal and modification has become an emerging trend in the nation starting in the 1980's. Although there are many reasons why dams are removed/modified today, the start of the trend may be credited to the environmental movement that began in the 1960's (as the Clean Water Act helped save the nation's dirty rivers). As a result, people were drawn to river's for canoeing and fishing.

Wisconsin, Indiana, Illinois, and Michigan became a favorite river destinations in the Midwest throughout the 1970's and into the early 1980's due to many headwater streams being located in each state, with enough population densitiy from the surrounding major cities to support recreational business. More liveries and fishing guides were established and canoe racing became popular. The year after the canoe adventure movie Deliverance (1972), the Grumman Canoe Company reportedly sold 33,000 canoes, a record in the history of the company at the time (pineypaddlers.com). Peak canoe sales, at the time, was tied to high fuel costs during the 1970's energy crisis.

The cleaning of rivers and subsequent increases in recreational use brought to light obsolete dams that heretofore were largely forgotten and unnoticed. Often, an increase in fish leads to an increase in river water sports which leads to a desire to unleash dammed rivers to create longer free flowing riparian zones for expanded recreation.

A resurgance in water paddle sports has been documented since the great recession of 2008. As water recreation continues to be a growing trend, dam removal/modification has been an increasingly examined topic.

Organizations such as American Rivers; Heinz Center for Science, Economics, and the Environment; The American Association of State Highway and Transportation Officials, and The Association of State Dam Safety Officials have all contributed to our understanding of dam removal efforts. American Rivers and the Heinz Center are seminal resources to the nationwide dam removal efforts that have occurred over the last 20 plus years.

It is clear that there are many things for communities to consider when exploring dam removal. Dam removal is appropriate when there is a careful evaluation, public input, and overall understanding of the issue.

This report is a discussion of the proposed modification of the Deep River Dam, and will look at general reasons for dam removal/modification (ecology, safety, recreation, and economics), national and local trends, before giving an in depth history of the Deep River Dam, the dam modification process, and specific approaches and associated costs for modification of the dam.

1.2 **DEFINITIONS**

A few general definitions provided below are commonly used throughout the report.

BACKWATER
The term backwater refers to any water that is held or forced back; a dam, a flood, or a tide can cause this. As dams are the focus of this study, the definition of backwater used will refer to the impounded water held behind the dam. Nearly all dams create backwaters. Backwaters can extend only a few feet to several miles in length. Typically the taller the dam, the more extensive the backwater basin or water storage capacity. Large dams create reservoirs, which are typically thought of as lakes. These backwater basins drastically change the habitat and characteristics of the stream to be more like a lake or pond. There is a profound difference in the aquatic biology of a free-flowing stream versus a lake.

BANKFULL DISCHARGE (BFQ)
The bankfull discharge for most streams, is the flow that has a recurrence interval of approximately 1.5 years in the annual flood series. The empirical range of bankfull discharges have a recurrence range between 1.1 and 1.8 years.

Sometimes referred to as the effective flow or ordinary high water flow. Bankfull discharge is the channel-forming flow and transports the most sediment for the least amount of energy over time.

Bankfull is the elevation in all rivers at which the point of incipient flooding occurs. Bankfull is often confused with terms such as ordinary high water mark, the low flow or the flood elevation. It should be clairifed that bankfull is not any of these.

Bankfull is an elevation that occurs with enough annual frequencies that it creates a break in the land form and is repeatable and quantifiable. Bankfull measurements have been used to develop regressions based on drainage area and compared to cross-sectional area of the river compared to many other rivers of similarity.

Figure 1.2-3, shows the regional channel-dimension curves which are used for estimating bankfull-channel width, mean depth, and cross-sectional area of non-urban wadeable streams in the Northern Moraine & Lake physiographic region of Indiana (Robinson).

BEDLOAD
The part of a stream's sediment load that is moved on or immediately above the stream bed, such as the larger or heavier particles (boulders, pebbles, gravels) rolled along the bottom; the part of the load that is not continuously in suspension or solution.

DEPOSITIONAL FEATURES
Features built and typically maintained within the bankfull channel such as point bars, central bars and riffles. (Fig. 1.2-4)

FLOOD-PRONE AREA
An area bordering a stream that will be covered by stream waters at a flood stage of twice the maximum bankfull depth. (Fig. 1.2-4)

FLOOD-PRONE WIDTH
The stream width at which the discharge level is defined as twice the maximum bankfull depth. (Fig. 1.2-4)

HAZARD POTENTIAL RATING
A hazard potential rating system has been developed to assess the risk of dam failure.

A) Low Hazard Potential Dam:
Dams where failure or mis-operation will probably cause minimal damage, mostly on the dam owner's property. Damage is limited to farm buildings, agricultural land, and local roads.

B) Significant Hazard Potential Dam:
Dams where failure or mis-operation will probably cause damage to rural or agricultural lands. Rural roads, buildings, utilities or railroads may be damaged.

C) High Hazard Potential Dam:
Dams where failure or mis-operation will probably cause serious injury or loss of human life. Urban development, buildings, roads, railroads or utilities are seriously damaged.

LOW-HEAD DAM
A barrier constructed in a river with a hydraulic height (head water to tail water) not exceeding 25 feet. This definition encompasses run-of-river dams as well as other small dams but excludes industrial dams that do not create an impoundment in the river. Generally low head dams fall into two categories: overshot or undershot dams. While both impound water, the flow of the river is different.

OVERSHOT DAM
An overshot dam is designed to allow water to flow over the top of the dam. Overshot dams typically impound water of which a portion is often diverted from the dam reservoir of water for industrial, flood control, irrigation or drinking water supply. Some-

times overshot dams only impound water to create a larger body of water with no diversion.

Some overshot dams have a gate at the bottom of the dam that is opened periodically to release stored water (especially with flood control dams) or to release accumulated sediment. Most overshot dams do not have a way to release accumulated sediment from the storage reservoir.

In the Midwest, most overshot dams used for irrigation, drinking water supply and industrial uses have a diversion structure near the location of greatest vertical column of water storage. The diverted water is controlled with a gate to regulate the volume and or the velocity of the water being diverted. The diverted water is usually skimmed near the water surface of the reservoir. (Fig. 1.2-1).

POOL
An area of the stream that has greater depths and slower currents than riffles and runs.

RIFFLE
An area of the stream where the water breaks over cobbles, boulders and gravel or where the water surface is visibly broken. You can typically cross riffles to get to the other side without getting too wet.

RIGHT BANK/LEFT BANK
Right bank and left bank designations are used in hydrology, cartography, lithography and other related disciplines of geography. Right bank and left bank designations are determined based on the direction of the water's flow. When facing downstream, the right bank is on the right and vice versa. (Fig. 1.2-4)

RUN-OF-RIVER DAM
A constructed barrier where the river normally flows over the dam from one side of the waterway to the other. A run-of-river dam has short-term storage capacity.

SEDIMENT DROPOUT
Sediment dropout is the tendency of sediment that is suspended in the water column to settle and deposit on the river bed due to a decrease in the velocity of the water (Fig. 1.2-2). Sediment dropout is common upstream of a dam due to the slowed velocity of water caused by the dam.

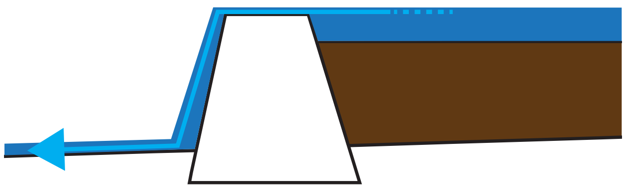

FIGURE 1.2-1 | Overshot Dam Diagram

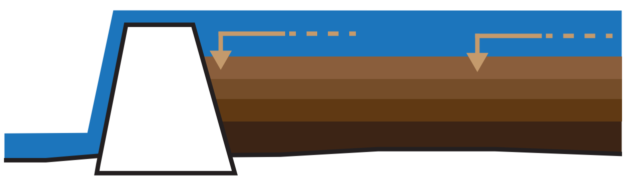

FIGURE 1.2-2 | Sediment Dropout Diagram

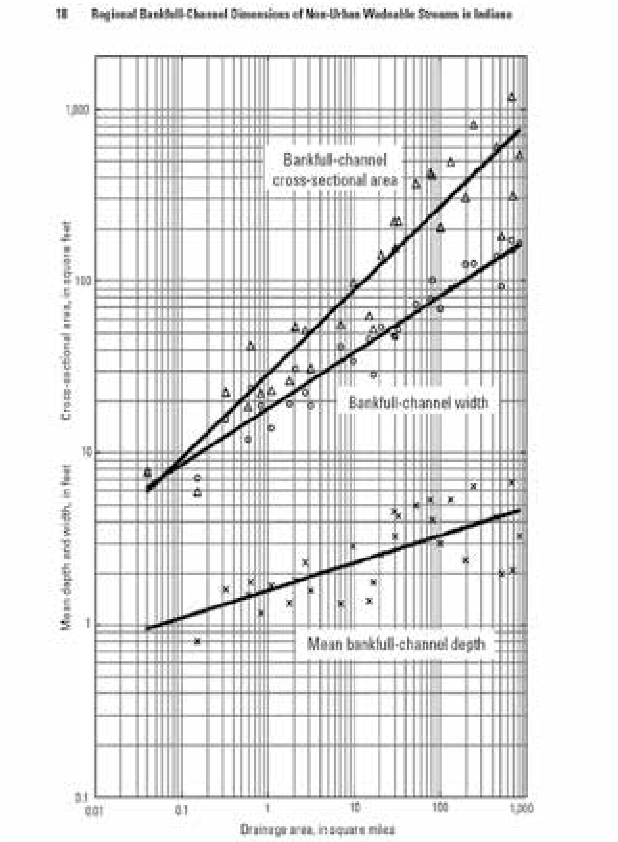

FIGURE 1.2-3 | Regional Curve Diagram

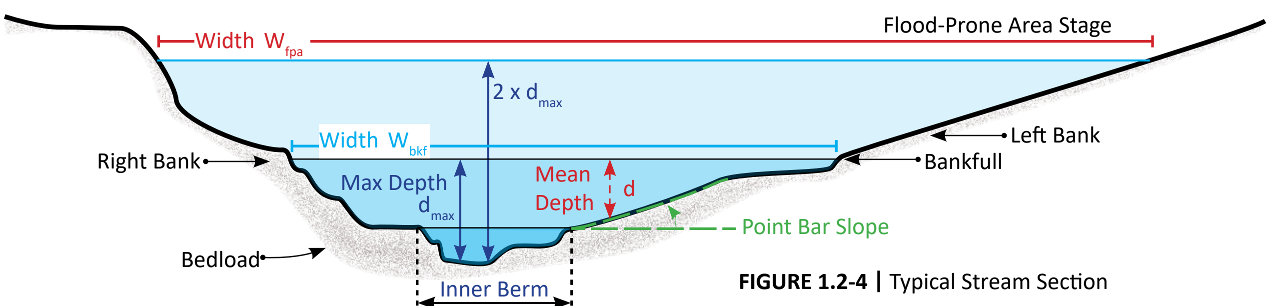

FIGURE 1.2-4 | Typical Stream Section


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2. REASONS FOR DAM REMOVAL/ MODIFICATION

2.1 **INTRODUCTION**

The five common reasons for dam removal/modification are: ecology, safety, recreation, economics, and geomorphology. Research shows that dams can be addressed for a number of reasons. Individually, or in combination, these reasons may propel a community to remove a dam.

PROPONENTS

Deciding whether or not to remove/modify a dam is not a simple matter. Taking action on a dam has both proponents and opponents. There are many proponents that favor dam removal/modification on a large scale. For example, most ecologists support and can rally funds towards dam removal for macro and micro biological gain (fish passage), chemical function (oxygen and temperature) and nutrient flow (sediment transport). Other proponents may be those who recreate on rivers or those who are aware of the safety hazards dams pose, both to those who enter the river and to those downstream of it. Other proponents recognize the economics of repair and operation of a dam far exceed the cost of removal.

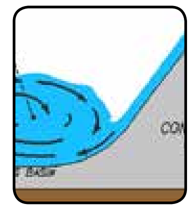
OPPONENTS

Opponents are most often vocal at the local community level. Opponents might like the dam's appearance or have historical or sentimental reasons. Another aspect that may cause disapproval on a local level is the fact that dam removal can be expensive, especially when river restoration of the backwater pool area of a dam is factored into the equation.

Eventually all dams will require financial investment, either through maintenance and repair, restoration or removal. Maintenance and repair expenses, so often without a revenue stream to fund the repairs, opens the local discussion about dam ownership and safety which opens the removal topic.

ECOLOGICAL

Science shows that dams cause considerable disruption and are detrimental to the ecology of the river.



SAFETY

Low-head dams have the ability to produce dangerous recirculating currents, hydraulic jumps, as well as other hazardous conditions.

RECREATION

Recreation along the river includes passive contemplation, and active recreation, such as fishing, paddle sports, tubing and exploring the river's edge.

ECONOMIC

Many cities are removing/modifying dams for the economic boosts that come with increasing land value.

GEOMORPHOLOGICAL

Dams disrupt the critical pool to riffle to pool rhythm that naturally occurs in rivers.

2.2 **ECOLOGICAL**

Science shows that dams cause considerable disruption and are detrimental to the ecology of the river. Dams change chemical, physical, and biological processes of rivers. Dams alter water temperature and oxygen levels, and can trap sediments, which are sometimes contaminated, in the backwater area.

Federal, state and local research indicate sediment is the critical pollutant in streams and rivers. Sediment pollution is a major contributor to the degradation of aquatic life and their associated habitats. Suspended solids increase water temperature and lower dissolved oxygen, harming sensitive aquatic animal species. This sediment pollution can block out sunlight in the water, reducing the available light for aquatic plants. It can cover spawning areas and food sources, reducing the populations of aquatic animals, such as fish and insects, over the long term. It can also clog fish gills, reduce resistance to disease and lower growth rates, affect development, disrupt the natural food chain, and decrease diversity.

PAST WATER QUALITY STUDIES

The water quality of Deep River has been monitored recently through efforts of the Indiana Department of Environmental Management (IDEM), the Indiana Department of Natural Resources (IDNR), and the Northwestern Indiana Regional Planning Commission.

TARGET CONCENTRATIONS

Below, average pollutant concentrations for the Deep River were compared to target concentrations for each parameter. The target concentrations are concentrations that, if exceeded, may cause detriment to aquatic life or pose a threat to human health. Target concentrations are based on standards set by IDEM or criteria identified through scientific research or by other agencies, such as the United States EPA. The following target concentrations were used: total Nitrogen, 10 mg/L, total Phosphorus, 0.3 mg/L, total suspended solids (TSS), 30 mg/L, and E. coli, 125 counts/100 mL.

TOTAL SUSPENDED SOLIDS

According to IDEM data from 2013-2014, the average TSS concentration near the Deep River dam was elvated above the target concentration.

Total suspended solids include sediment and organic matter suspended in the water column. Sediment can harm aquatic life directly by clogging fish gills, smothering fish and aquatic insect eggs, etc (Frankenberger 2012). According to a study published by the American Fisheries Society, concentrations above this target reduce fish concentrations (Waters, T.F., 1995). Sediment can also harm aquatic life indirectly by burying the rocky habitat required by some species. Sources of sediment and other suspended solids include: runoff from agricultural fields, stream bank erosion, and urban runoff (particularly construction activities). Forest and wetland riparian areas can trap sediment, thereby reducing TSS levels.

NITROGEN AND PHOSPHORUS

Sediment particles bind to nutrients, such as phosphorus. Excess phosphorus contributes to the formation of toxic algae blooms, which can degrade drinking-water supplies, negatively affect ecological health, and interfere with recreational activities. The EPA identifies nitrogen and phosphorus as the two most widespread stressors contributing to degraded biological conditions in lotic waters across the Nation (U.S. Environmental Protection Agency, 2006). Toxic algae blooms most commonly occur in ponds, lakes, reservoirs and slow-moving rivers (usually above dams).

Although a set concentration level was put in place for total Nitrogen, 10 mg/L, "The total nitrogen value of 10 mg/L was not used as target in the development of the Deep River-Portage Burns TMDL. IDEM is in the process of determining the appropriate water quality criteria for nitrogen based on toxicity and other harmful effects to aquatic communities. Therefore, nitrogen TMDL will not be completed for this watershed."

Nitrogen is a necessary element for plant growth. However, excess nitrogen in water can cause algae blooms, which can deplete dissolved oxygen to levels inadequate for supporting fish life, causing fish kills. These algae blooms occur more commonly in lakes and ponds than in rivers.

Sources of nitrogen include fertilizer runoff from agricultural fields and yards and waste from humans and animals. Models predict that livestock and row crops are the biggest land use contributors of nitrogen (Reckhow 1980). Local On-Farm Network®/ Infield Advantage data demonstrates that 85% of participating producers in Delaware County are applying optimal levels of nitrogen; excess nitrogen in waterways is likely driven by solubility, not over application of fertilizer by agricultural producers.

According to IDEM data from 2013-2014, the average total phosphorus concentration on the Deep River near the dam was below the target concentration.

Like nitrogen, phosphorus is a necessary element for plant growth and can also cause algae blooms and fish kills. Sources of phosphorus are similar to those of nitrogen. There are different forms of phosphorus present in the environment. Inorganic phosphorus is the most common form and does not leach through the soil. Dissolved Reactive Phosphorus (DRP), while less common, can leach through the soil and is the form of phosphorus most used by aquatic life. Therefore, it is often the cause of algae blooms in freshwater systems. DRP is found in lawn and agricultural fertilizers and enters waterbodies through runoff.

BIOLOGICAL RESULTS

As a part of the TMDL report completed in 2013-14, IDEM completed QHEI, OWQ/WAPB, and Fish Communities Assessments of the Deep River -- Portage Burns Watershed, of which the Deep River Dam is located (Figure 3.2-1).

One of the most significant threats to rivers and freshwater organisms is the damming of our rivers (Poff et al. 2007). Impoundments alter the physical, chemical, biological, and hydrological characteristics of a stream (Poff et al. 2007). These alterations result in modified flow, increased siltation and scouring, temperature alterations, decreased dissolved oxygen, and blocked passage for aquatic organisms (Watters 1996; Dean et al. 2002; Lessard & Hayes 2003; Tienmann et al. 2004; McLaughlin et al. 2006; Poff et al. 2007; Maloney et al. 2008).

Mussels

Freshwater mussels are considered the most imperiled group of organisms in North America (Lydeard et al. 2004; Strayer et al. 2004), and perhaps the world (Strayer 2008), and are declining at alarming and unprecedented rates (Neves et al 1997; Ricciardi & Rasmussel 1999; Vaughn & Taylor 1999; Strayer & Smith 2003; Poole & Downing 2004; Regnier et al. 2009). In North America alone, 72% of the native mussel fauna is either federally listed as endangered or threatened or considered to be in need of some protection (Haag 2009). Mussels are an essential part of the aquatic ecosystem; removing suspended particles through filter feeding, contributing to the food web, providing habitat for other organisms, and assisting in nutrient cycling (Vaughn & Hakenkamp 2004; Vaughn et al. 2004; Howard & Cuffey 2006; Spooner & Vaughn 2012; Vaughn et al. 2006; Vaughn et al. 2007; Vaughn et al. 2008; Christian et al. 2008; Vaughn 2010). Because of their imperiled state and contribution to the aquatic ecosystem,

Dams have been implicated as the leading cause of current-day decline in freshwater mussel populations in North America (Parmalee & Bogan 1998; Haag 2009). They have been cited as being responsible for the "local extirpation of 30-60% of the native freshwater mussel species in many United States rivers" (NRCS 2009). Studies have shown that the impacts of impoundments have resulted in reduced abundance, diversity, and species richness of mussel fauna (Dean et al. 2002; Baldigo et al. 2004; Tiemann et al. 2004; Santucci et al. 2005; Galbraith & Vaughn 2011: Tiemann et al. 2016).

One of the largest impacts to mussel communities is the movement restriction to fishes (Watters 1996; Box & Mossa 1999; Vaughn & Taylor 1999; Watters 1999; Hornbach 2001; Dean et al. 2002; Tiemann et al. 2007). In order to survive, mussel larvae (of

2.2 **ECOLOGICAL**

the family Unionidae) must temporarily attach to the gills or fins of a fish specific to each mussel species. If the specific fish host has limited mobility due to an impoundment, mussel dispersal is also limited. Impoundments as low as 1m in height have been found to restrict mussel dispersal (Watters 1996), and this effect is compounded when there are multiple dams on a system (Watters 1996; Cummings & Mayer 1997; Tiemann et al. 2007; Tiemann et al. 2016).

Exotic or Invasive Species

Although impoundments can create barriers to the movement of native and invasive species, they can likely harbor and escalate the spread of invasive species (Poff et al. 2007). Once over the impoundment, these species are free to reproduce uninhibited, often in conditions that are unfit for native species, such as backwater pools. One of the biggest concerns for the US Fish and Wildlife Service (USFWS) is the movement of the sea lamprey, from Lake Michigan into the streams and rivers of the United States. The impoundments, and therefore, the desire of the USFWS to maintain and or remove/modify each dam is based upon how many miles of rivers, streams, and tributaries flow to that impoundment. As seen in Figure 2.2-1, the Deep River Dam has approximately 46 miles of water free flowing to it. However, the Lake George Dam, (about 7 miles upstream of the Deep River Dam), has approximately 265 miles of river, streams and tributaries flowing to it. With this perspective, USFWS cares more about maintaining the Lake George Dam than the Deep River Dam, as potentially releasing sea lamprey into 5x the mileage of waters can have a much more drastic effect on the ecology and biology of the northwestern Indiana watershed system.

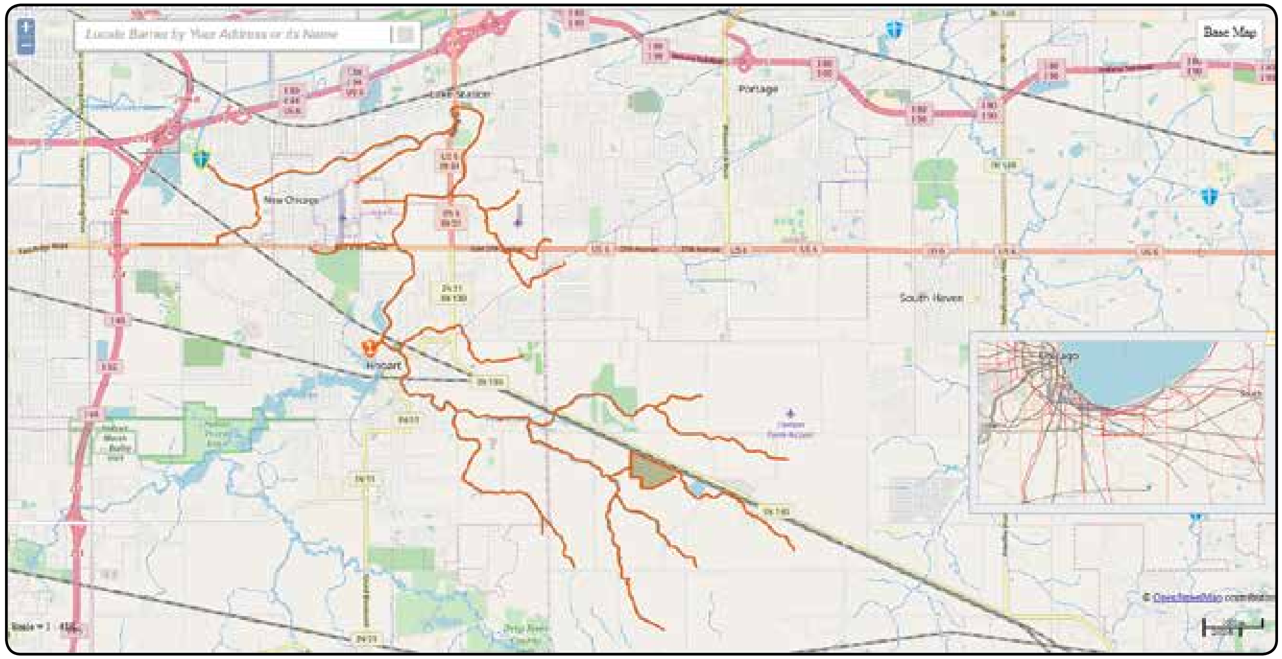


FIGURE 2.2-1 | River Access to Sea Lamprey Above Deep River Dam

Macroinvertebrates

Macroinvertebrates play an essential role in stream food webs and aquatic ecosystem function (Cummins & Klug 1979; Merritt et al. 1984). Healthy macroinvertebrate communities require the riffle-run-pool sequences found in natural, free-flowing streams (Santucci et al. 2005). A mixture of gravel, pebble, and cobble substrates and moderate, consistent water flow is also essential (Santucci et al. 2005). Impounded reaches alter these habitats and result in decreased abundance (Tiemann et al. 2004), evenness (Lessard & Hayes 2003; Tiemann et al. 2004), diversity, richness and biotic integrity of macroinvertebrate communities (Neves & Angermeir 1990: Dynesius & Nilsson 1994; Tiemann et al. 2004).

Ecological Impact of Dam Removal

Studies are lacking on long-term ecological effects of dam removal (Bednarak 2001; Hart et al. 2002; Thomson et al. 2005; Maloney et al. 2008; Gangolff et al. 2011), especially on systems with low-head dams (Benstead et al. 1999; Stanley et al. 2002; Santucci et al. 2005; Tiemann et al. 2004). As of 2014, only 9% of all dam removals have been scientifically evaluated (Bellmore et al. 2016). The desire to monitor fish migration and population after the project is complete could be an essential contribution to the science of dam removal/modification.

Full recovery and response of aquatic communities following dam removal/modification is not

2.2 **ECOLOGICAL**

immediate. Construction activities can often create unsafe habitat conditions, and push communities away temporarily. However, with appropriate planning, timing, and construction techniques, effects on aquatic communities fauna can likely be minimized (Heise et al. 2013).

Recolonization and recovery in macroinvertebrate communities has been reported to be fairly rapid; generally one to two years (Bushaw-Newton et al. 2002; Stanley et al. 2002; Maloney et al. 2008). While few long-term mussel studies have been performed post-removal, it is theorized that full mussel recolonization and recovery will likely take decades to occur (Gangloff et al. 2011; McCormick 2012; Tienemann et al. 2016) due to slower dispersal, reproduction, and recruitment rates.

HABITAT AND THE FOOD WEB

Poor chemical water quality is not the only thing that can decrease the diversity and abundance of aquatic animals like fish and mussels. Poor quality habitat surrounding the river also harms aquatic communities. A high quality habitat has many components, forest and wetland riparian areas are one important component. Riparian areas trap and filter sediment, nutrients, and pesticides from water before it enters streams. Too much sediment in streams can cover the rocky substrate that many organisms require. For example, some aquatic insects, collectively referred to as scrapers, feed on algae they scrape off of rocks in riffle areas.

Riparian forests are also a source of food material. Leaves that fall into streams and rivers are fed on by aquatic macroinvertebrates. The aquatic macroinvertebrates, in turn, are food for fish. Thus, a high quality habitat provides the base of the Deep River's food web.

Stabilizing streams using natural restoration methods can boost an area's visual appeal. Dams negatively affect the sustainability, health, and quality of a river community.

The free movement of a natural stream encourages genetic diversity of aquatic species; dams disconnect stream biological populations, limiting the genetic diversity. Indiana is home to several migrating fish (like American eel); dams are obstacles, limiting their access to spawning grounds. The change in flow behind the dam can also cause problems for juvenile fish trying to get downstream. Fish can sustain injuries as they go over the spillway. Dam modification will encourage diversification of genetics within aquatic species by restoring the natural flow.

The reduction of ecological habitat has a concurrent effect on wildlife. Many aquatic and terrestrial species have gone extinct from the region due to human impacts. Species that do remain span the gamut of native, non-native, invasive, or noxious.

The Indiana Natural Heritage Data Center database, maintained by the Indiana Department of Natural Resources Division of Nature Preserves, maintains a list of endangered, threatened, and rare species by county. The list includes both the federal and state status. Some of the species within Lake County that are on this list are: Lake Stugeon, Spotted Turtle, Blanding's Turtle, Blue-spotted Salamander, and the Sheepnose and Ellipse Mussel. Visit the Indiana Department of Natural Resources website for a complete list of species in each county.

2.3 **SAFETY**

Low-head dams have the ability to produce dangerous recirculating currents, hydraulic jumps, as well as other hazardous conditions adequate to trap and drown victims immediately downstream, posing the greatest safety risk to the public (Fig. 2.3-1). Documented research shows a significant increase in the past 15 years in the number of injuries and fatalities at low-head dams. Additionally, a higher percentage of the fatalities occurred in Illinois, Indiana, Maryland, Ohio, Tennessee, and Virginia relative to other states. The increase in dam victims might be tied to the increase in water paddle sports. (Fig. 3.1-2).

Dubbed "drowning machines," low-head dams are safety hazards for waterway users– boaters, kayakers, canoers, rafters, swimmers and anglers alike. People, and far too often emergency responders, are not familiar with the safety hazards of low-head dams. Dams are dangerous because of the recirculating waters below the dam, also known as the hydraulic jump. These recirculating waters will take an object (including people) to the bottom of the stream. The water forces will then release the object to the surface in, or near, the end of the boil, the danger zone. Once at the surface, the reverse flows of the stream drive the object back into the face of the dam. Once at the dam face, the process repeats endlessly. Adding to the risk are water adventurers who consciously go over the low-head dam, falling prey to the fast-moving water and currents. Although rivers often may look innocuous, the dam's tail water produces undertow that is exceptionally strong and can be impossible to escape.

Dams have resulted in an estimated 400 deaths since 1960 across the nation (Tschantz) with 50 occurring in the last two years (Association). The Midwest, and many eastern states, has begun to push for dam removals for safety reasons. As counter intuitive as it might seem, experienced waterway users wearing life vests caught in the hydraulic jump often drown. This is because of the large amount of air at the bottom of the stream. normally, life vests are buoyant relative to the mass of water. The large amounts of air within the dangerous recirculation zone prevent a life vest from becoming buoyant (Fig. 2.3-1).

For those fortunate enough to remain at the surface while wearing a life vest, they often drown from body concussions. Concussions occur from being slammed back into the dam repeatedly because of the recirculating nature of dam water hydraulics.

Recent research of dam drownings indicates that 40% of dam drowning victims were wearing life vests. Often, it is reported that the people rescuing others caught in the recirculating waters perish while attempting to save another.

Safety is also threatened by the possible failure of dams. The failure of a dam can release a wall of water that can cause destruction of life and property downstream. Dams have a design life expectancy of 50 years. The Natural Resources Conservation Service (NRCS) has reported that more than 400 dams failed in the US between 1985 to 1994. The American Society of Civil Engineers estimates that by 2020, 85% of the dams in America will be near the life expectancy threshold.

2.3 SAFETY

The NRCS, who has constructed over 10,450 dams nationwide with various functions, like flood and grade control, at a cost of an estimated $14 Billion, reports that more than 2,400 or approximately 23 percent are in need of repair (NRCS 2000). Many of these dams are flood control structures, meaning a failure could result in loss of life and property. Additionally, a surge of water caused by failure could injure and potentially kill anyone on the river or along it's banks. Indiana has an estimated 1100 dams. Inspection reports indicate that 90% of these dams are in need of repair to meet safety requirements. The Prince's Lake dam failed in Indiana in 2008 after it rained in Central Indiana about an inch an hour for several hours. Recently, the Oroville dam in California raised awareness of life loss threats if dams fail. Removal of obsolete dams eliminates the safety concern.

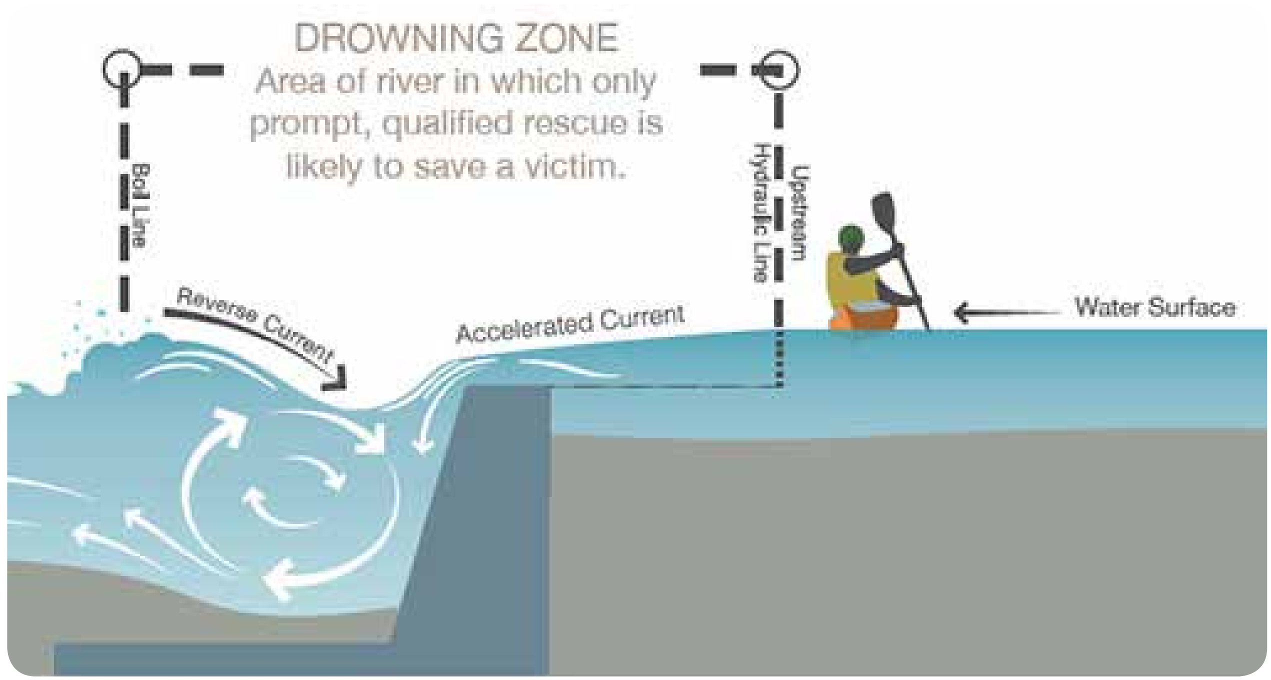


FIGURE 2.3-1 | Low-head Dam Safety, Iowa DNR

2.4 **RECREATION**

Recreation along the river includes passive contemplation, such as an escape from the busy city, and active recreation, such as fishing, paddle sports, tubing and exploring the river's edge. Today's fast-paced, technology-driven society has a distinct disconnect from nature. Richard Louv recognized this disconnect in his 2005 book, "Last Child in the Woods." He coined the term "nature-deficit disorder" to describe the human costs of alienation from the natural world. Several movements to reconnect with nature have sprung up across the country. Rivers often flow through urban areas, offering opportunities for large populations to rediscover nature. Dam removal/modification increases the safety of those reconnecting with nature, such as anglers, boaters, and explorers.

Recreation along the river's edge includes walking trails and park space. Rivers have a calming presence, their white noise reducing the sounds of cars. Fishing is a popular pastime. The ecology section described how dam removal will improve the aquatic habitat and therefore improve populations of fish and macroinvertebrates. The increased health of the river will in turn improve the quality, quantity, and diversity of species of the fish. Many cities and towns across the U.S. are currently working to eliminate combined sewer discharges as part of the MS4 program (Municipal Separate Storm Sewer System).

Paddle sports, including kayaking, canoeing and paddle boarding have increased across the nation in the last 10 years. The Outdoor Foundation released a special report on paddle sports in 2015. In 2014, 7.4% of the United States population were paddle sporters: kayak, canoe, raft, and stand-up users.

The east north central region (WI, OH, MI, IL, IN) make up 15% of all the paddle sport users in the nation, a majority of which are canoers. Paddle sport retailers and virtually all canoe liveries are not required to provide any explanation or training about paddle sport hazards along our blue water trails. With liveries, a renter typically signs a wavier form releasing the livery operator from any damages as a result of the paddler. The livery hands over a boat and paddles and off the novice goes into the water.

RIVER'S EDGE

The river's edge provides infinite educational opportunities for citizens, especially children. Interaction with the river, whether from a trail, the bank's edge, or in a boat, shapes individuals and communities. The memories shared along the river have lasting impressions and solidify relationships between people and nature. The river does not discriminate; all socioeconomic classes have access to the river.

The outdoor recreation economy grew approximately 5 percent annually between the years 2005 and 2011. Among the most popular activities are water-based recreation and trail-based recreation, both of which will continue to be expanded by a free-flowing Deep River. The recreational opportunities provided by a free-flowing river will offer residents and visitors a place to get healthier, by hiking, biking, or paddling. It will expand the opportunities for children and young people to get outside and gain valuable learning experiences from the outdoors.

2.5 **ECONOMIC**

Many cities are removing and or modifying dams for the economic boosts that come with increasing land value. Property in the area of a free-flowing stream has more value than similar property located in the area of a small impoundment (Provencher et. al. 2008). Properties adjacent and close to trails also show an increase in property values. There is a synergistic increase of values when trails are next to rivers that free flow.

An additional factor that often drives the dam removal/modification discussion is the long-term costs of rebuilding or maintaining aging low-head dams. In some cases, dam modifcation is less expensive than the cost of rebuilding or repairing a failing dam. Depending on the nature of the failure, all or most of the dam may need to be removed before reconstruction takes place. Aging dams likely have seen multiple repairs over the years, making failure more likely. Proper maintenance and operations of dams adds up over time.

When dams serve no functional purpose, dam removal or modification can have an economic benefit to a community by increasing recreation and land development opportunities. Once a city takes action on a dam, greenbelts, river walks, housing, and offices are often developed next to the rivers. Vibrant communities and life-style amenities like free flowing, natural looking, rivers are the currency that attracts businesses and developers to a town. A dam removal summary report created by Headwaters Economics (2016) found in their research that dam removal is often measured in cost-benefit economics but there is a cultural benefit that creates non market values. The net gain on a cultural benefit can lead to latent economic benefits by increased people at a river. With most obsolete low head dams, cultural benefits of dam removal/modification are gained by the free flowing of a restored stream and increase in life safety. A stream that allows a greater migration of fish is viscerally perceived as cleaner and safer, thereby increasing the river usage through recreation, be it paddle sport, angler or trail user (when a trail is next to a free flowing river). Clear data shows that post dam removal/modification, paddle sports increase while anglers have been measured to increase when the fishing experience includes more catch rates and higher species diversity.

As the health of American rivers continues to improve in response to the Clean Water Act and the Endangered Species Act, people respond equally with increased river usage and increased river access post dam removal.

A May 2014 survey of millennial and active baby boomers by the American Planning Association reported that "traditional business recruitment strategies are seen as less important than investing in local amenities and quality-of-life. Job prospects and economic health are not the overriding factors for choosing where to live. Quality of life features such as transportation options, affordability, parks, local vitality, health, and presence of friends and family are equally or often more important." Americans place a high priority on quality of life is also recognized by World Business Chicago, a non-profit economic development organization, which reports that, "[average wages, overall labor pool statistics or skills availability] are important, but the quality of life is what draws people to live and work in a particular region. Quality-of-life is as important today as wages, advancement, or stock options." Tourism impacts extend beyond outdoor recreation.

2.5 **ECONOMIC**

Tourism revenues come from visits to museums, historic sites and buildings, entertainment events such as concerts, plays, and sports, and the money that tourists spend on food, beverages and lodging.

The recreational opportunities provided by a free-flowing river will offer residents and visitors a place to get healthier, by hiking, biking, or paddling. It will expand the opportunities for children and young people to get outside and gain valuable learning experiences from the outdoors.

At least 56% of Indiana residents participate in outdoor recreation each year. Overall, outdoor recreation in Indiana generates over $9 billion annually in consumer spending, employs over 105,000 Hoosiers, and contributes over $700 million to state and local tax coffers, according to the Outdoor Industry Association. In addition, wildlife watchers spent $751 million in Indiana in 2011, on trip-related expenditures and equipment costs. Every year, Americans spend $646 billion on outdoor recreation — on gear, vehicles, trips, travel-related expenses and more. This creates jobs, supports communities, generates tax revenue and helps drive the economy.

2.6 **GEOMORPHOLOGY**

The Deep River has experienced many of the same anthropogenic hydro-modifications (i.e. dredging, straightening, vegetation removal, etc.) that other streams throughout the continental United States have experienced. Historically, streams were modified for flood protection or agricultural purposes. The straightening of channels to drain lands is an example of the classic struggle between man and nature.

Although man may think it is possible to overtake natural rhythms of a river, time eventually reverts mans impacts. For example, any dam left alone over time, will be breached, by-passed, as we have been seeing with the slow deterioration of the Deep River Dam.

Dams disrupt the critical pool to riffle to pool rhythm that naturally occurs in rivers. Free flowing streams and rivers develop a pool, riffle, pool pattern that manages the velocity of the water and grade changes. Pools in a stream are deep and slow while riffles are shallow and steep. The pools dissipate water speed while riffles control that gradient and increase water speed.

During some high water events, pools collect sediment while others flush sediment from the pools. Like stairs, pools act as the stair tread or landing pad while the riffle act as the stair riser, the place to move vertically up or down. It takes more energy to lift a leg up or down a stair riser than it does to stand on a stair tread.

Because of gravity, all water on land and in a river will move down gradient, or down valley. The downward motion of water in a river is a rhythmic pattern of pool, step, pool, step. Dams disrupt the natural river rhythmic pattern, creating long ponds of lakes or landing pads for sediment to dissipate, falling out by the gravity of the sediment relative to the velocity of the pool water (think of cleaning stairs; one has to clean/vacuum stair treads much more frequently than the stair risers or walking up stairs, long lengthy landings that do not repeat the previous stairs run and rise pattern can cause one to trip). Similarly, the backwater of a dam collects sediment; this slack water can become stagnant, store increased nutrients which can result in algae blooms.

The human modification of streams starts a cycle whereby the stream seeks a state of dynamic equilibrium. This means that a channel that is modified will always seek to revert to a stable form within a balanced meander, gradient and pool to pool spacing.

When a stream is modified, such as with dam installation and stream straightening, the result is an increase or decrease in the overall channel slope.

Increasing a channel slope disturbs the equilibrium pendulum by increasing the coarseness (size) of sediment that a channel can move (Fig. 4.6-1). The result is channel degradation and incision. The channel will not only erode vertically, but also laterally, until it once again finds its equilibrium state (Fig. 4.6-2).

The process of both vertical and lateral erosion increases sediment load to the water column, resulting in land loss. Decreasing channel slope will result in the deposition of suspended and bedload materials. As the deposited material accumulates, it forms a wedge shape that becomes wider which

2.6 GEOMORPHOLOGY

causes the channel to be wider than its natural state (while in equilibrium).

Backwaters of dams over time will accumulate a sediment wedge that eventually rises to the waters surface. The accumulation of sediment will eventually form mid channel islands. The sediment that accumulates in the backwater of a dam (those without a sediment release mechanism) will eventually return the total water volume of the dam storage area to the pre dam condition.

3. DAM REMOVAL/MODIFICATION TRENDS

3.1 **NATIONAL TRENDS**

NATION-WIDE

The 1960's and 1970's are considered the "golden age" of dam building. By the 1980's the number of dams being built in the nation had decreased and dam removal started to increase. Dam removal is still common today. It is estimated that 1,300 dams have been removed since 1912; sixty-two were removed in 2015 alone (American Rivers). Figure 3.1-1 shows the location of dams that have been removed in the United States. The vast majority of removed dams are less than 20 feet in height with most of them being less than 15 feet in height. Glines Canyon and Elwha Dams in Washington State, which were 210 and 105 feet tall, respectively, are two exceptions. Generally, larger dams are still functioning and therefore are maintained by the owner. Low head and small dams are left over from a time past. Often neglected, removal of these dams is more economical in the long run.

A study by AASHTO found that the most frequent removal reasons were ecology, economics, and safety, in that order. Removal funding has a tendency to lean more toward one of these three categories and is usually driven by the rallying organization that initiates the call for removal. In most dam deconstruction cases, it is a combination of these reasons that precipitate dam removal initiatives. Removal costs were also analyzed in the report, with the breakdown in costs being 22% environmental engineering, 30% deconstruction, and 48% sediment management.

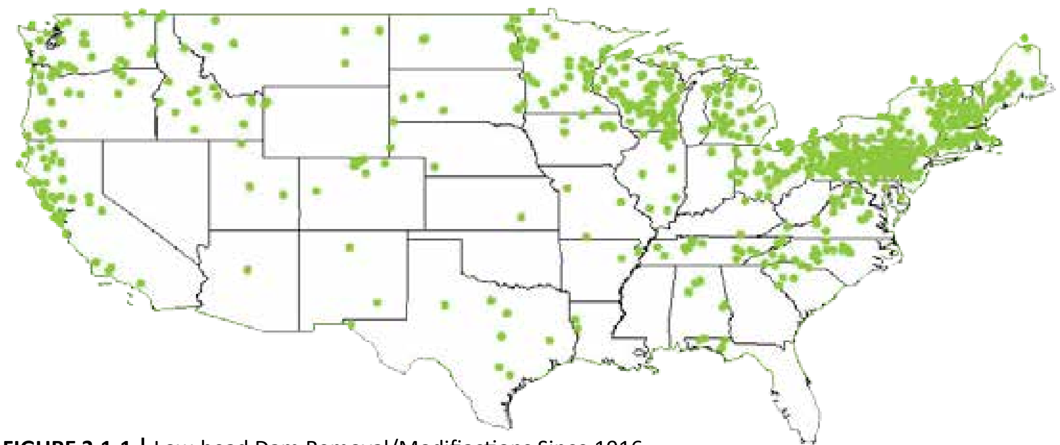


FIGURE 3.1-1 | Low-head Dam Removal/Modifiactions Since 1916

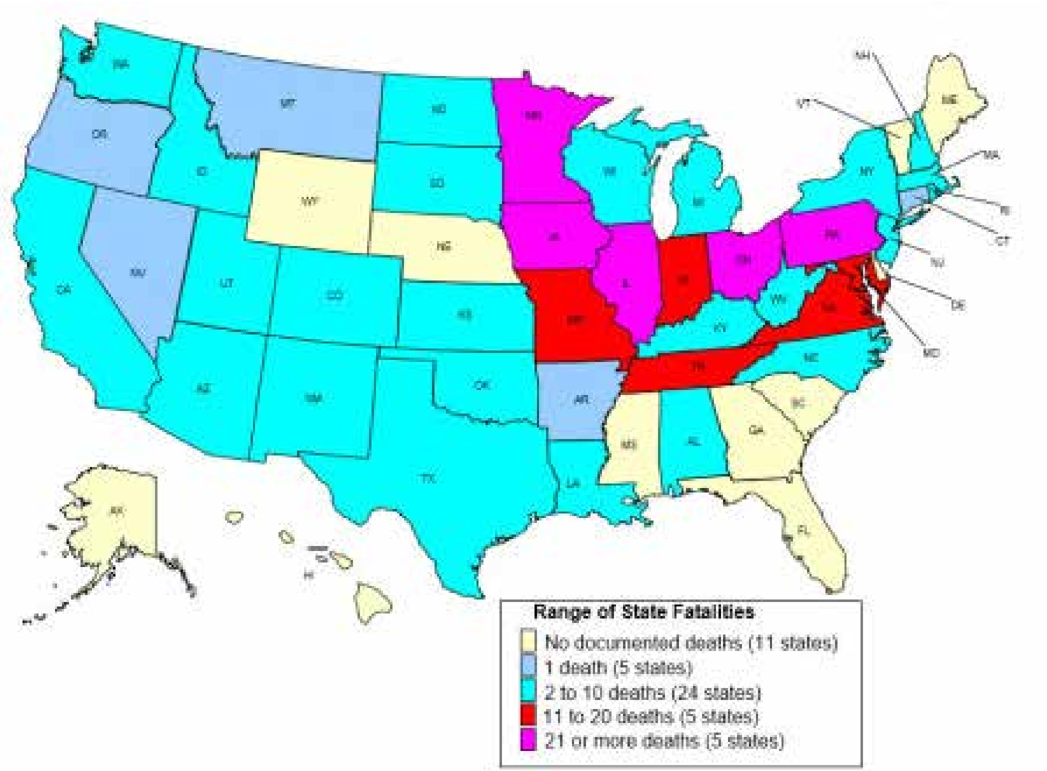


FIGURE 3.1-2 | Distribution of Low-Head Dam Casualities, 350 Total

3.2 **INDIANA TRENDS**

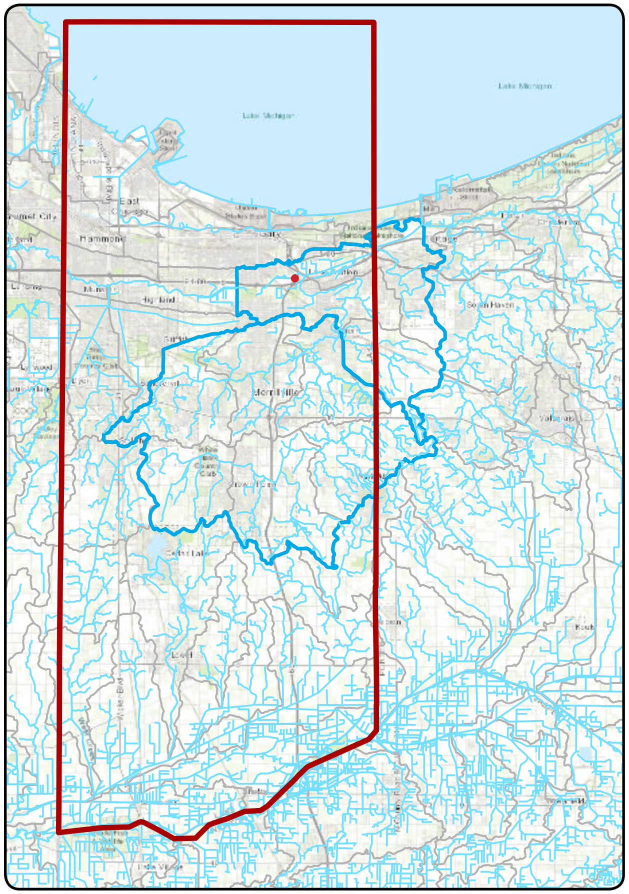


FIGURE 3.2-1 | Deep River -- Portage Burns Watershed

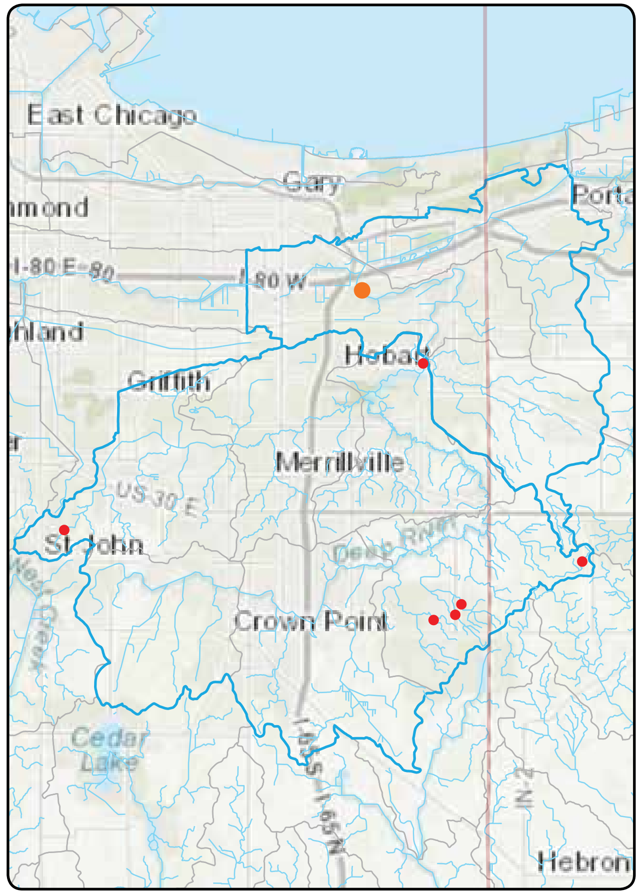


FIGURE 3.2-2 | Dams Within the Watershed

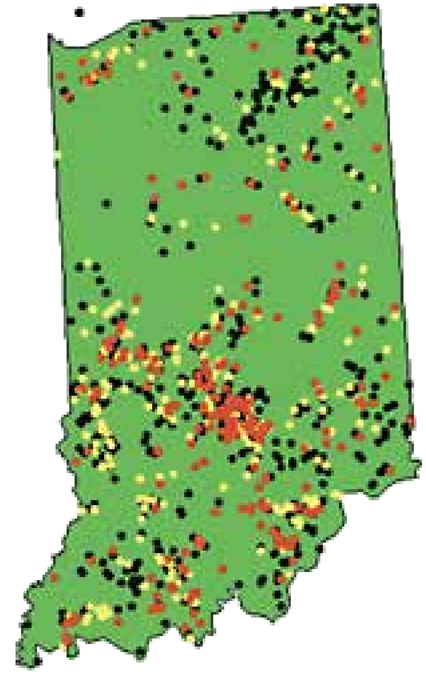


FIGURE 3.2-3 | Dams Within the State of Indiana

There are seven dams located within the Deep River – Portage Burns Watershed (Fig 3.2-2). Most of the dams can be found near the headwaters of the watershed, with the two exceptions being the Lake George Dam and the Deep River Dam.

The IDNR inspects the dams every few years. The latest reports for these dams range from 2012-2016 (See Appendix A.4 for most recent report). In Lake Station, as the river becomes an important economic driver as the cities greatest natural resource and prominent recreation opportunity, safety around any dam is a concern when recreational activities occur near the natural resource. In Indiana, somewhere between 11 and 20 fatalities have occurred because of low-head dams (Fig. 3.1-2).

Safety inspection reports, suggest that the Deep River Dam is in poor condition, and has been deteriorating slowly over the last 60+ years. If the dam were to fail, it would most likely happen one small section at a time, as the sheet piling gives way. As seen in Figure 3.2-4, the sheet piling on the wing walls is already seeping. This issue will only get worse as the water slowly eats away at the metal.

Based on dam removals reported to American River, Indiana has been slow relative to surrounding states and much of the nation in the removal process. This appears to be driven in part by the lack of local and state public funding mechanisms for stream projects and dam removal. Indiana is one of the ten states in the country that ranks highest for drowning due to dams (Fig 3.1-2).

The Association of State Dam Safety Officials has compiled extensive data on low-head dam associated deaths and encourages the removal of

3.2 **INDIANA TRENDS**

dams whenever possible to save lives.

Indiana has an inventory of more than 1,100 dams, of which 150, or 14%, are low-head dams. The Indiana Department of Natural Resources and Army Corps of Engineers records indicate that 60% of these dams were constructed during the national dam building blitz of the 1950's and early 1960's, meaning that the vast majority of Indiana dams are older than the estimated life expectancy of dams. The American Society of Civil Engineers gave Indiana a D- grade in a recent survey. Indiana tied with four other states for the lowest dam safety rating in the nation. The survey that was used to create the grade determined that 90 percent of all dams in Indiana have some type of deficiency (April 15th, 2015 WISHTV). It is estimated by the DNR that 150 of Indiana's dams are run-of-river low-head dams, of which many are in the significant or low hazard realm.

To date, only five dams have been removed in Indiana. Two dams; low hazard, low-head dams; were located on the Eel River in the towns of Liberty Mills and North Manchester. The third dam, located on the Little River in Huntington, was removed after it had failed. The fourth dam, located in LaPorte County at Red Mill County Park in the headwaters of the Little Calumet River, was replaced with a series of riffles. The fifth removed was located at the Fawn River Fish Hatchery in Orland.

The removal of the dams on the Eel River were due to the efforts of Manchester University students and Jerry Sweeten, associate Professor of Biology and Director of Environmental Studies. Funding was secured by the University through the Ohio River Basin Fish Habitat Partnership and the U.S. Fish and Wildlife Service. The dams were no longer functional and were extremely dangerous. "The dams at Liberty Mills and North Manchester are the first significant dams to be removed in Indiana for the National Fish Passageway Program" (Jerry Sweeten, Press release August 2010). The dams were removed in October 2012, reconnecting 190 miles of stream which were targeted to help increase habitat for the State Endangered greater redhorse (Moxostoma valenciennesi). Post removal monitoring shows that habitat has improved, with a 20% increase in the Qualitative Habitat Evaluation Index (QHEI) score upstream of the former dam location.

The Index of Biotic Integrity (IBI) score, which indicates the health of a fish community, also increased the first year after dam removal, with the qualitative description of the fish community improving from "Fair/Poor," prior to dam removal, to "Good," following dam removal. An eastern sand darter (Ammocrypta pellucida) was documented in the former backwater area of one of the dams the first summer after dam removal, the first record of this species at the site.

The Indiana Department of Natural Resources' Lake and River Enhancement Program (LARE) is one of the only State funding sources that can comfortably direct money to dam removal projects in Indiana. A LARE grant funded this dam removal feasibility study, as well as one on the White River in Muncie, Indiana. LARE also has funded the scheduled removal of two of the dams in Muncie, as well as a dam in Warsaw on the Tippecanoe river.

The DNR has under contract the removal of a dam on the Fawn River near Orland at the DNR Fawn River Fish Hatchery. This removal is unique in that the removal design protects the backwater area upstream from dewatering a very large riparian wetland complex. The project also has to preserve certain elements of the existing dam that was constructed by the post-depression era Civilian Conservation Corps. These dam components are on the national register of historic places.

The exploration of dam removal/modification in Indiana has recently been furthered by the first ever low-head dam removal conference held in December 2015. The conference was organized by the Indiana Water Monitoring Council and cosponsored by the Indiana Water Resources Association and the Indiana Silver Jackets. The Silver Jackets are a partnership between State and Federal agencies that anticipate needs during disaster events. Since the conference, the Silver Jackets furthered some of the outcomes of the conference by producing a documentary film, "Over, Under, Gone – The Killer in Our Rivers". The 30-minute 2016 film raises the awareness of dam deaths due to drowning. Profound segments of the film recounts the loss of life due to dam drownings, even the loss of a DNR conservation officer that was a member of the elite Indiana river rescue team. In this segment, three surviving officers describe becoming caught in the undertow of the Williams Dam in Lawrence County during a routine dam water rescue training exercise.

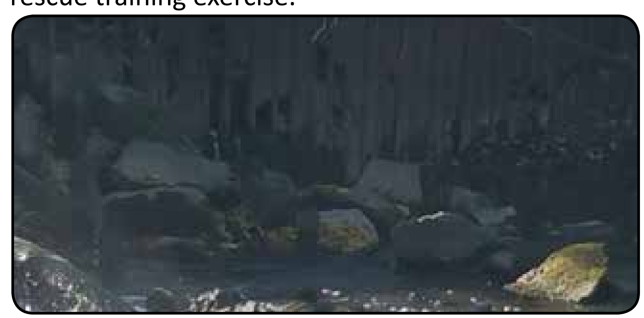
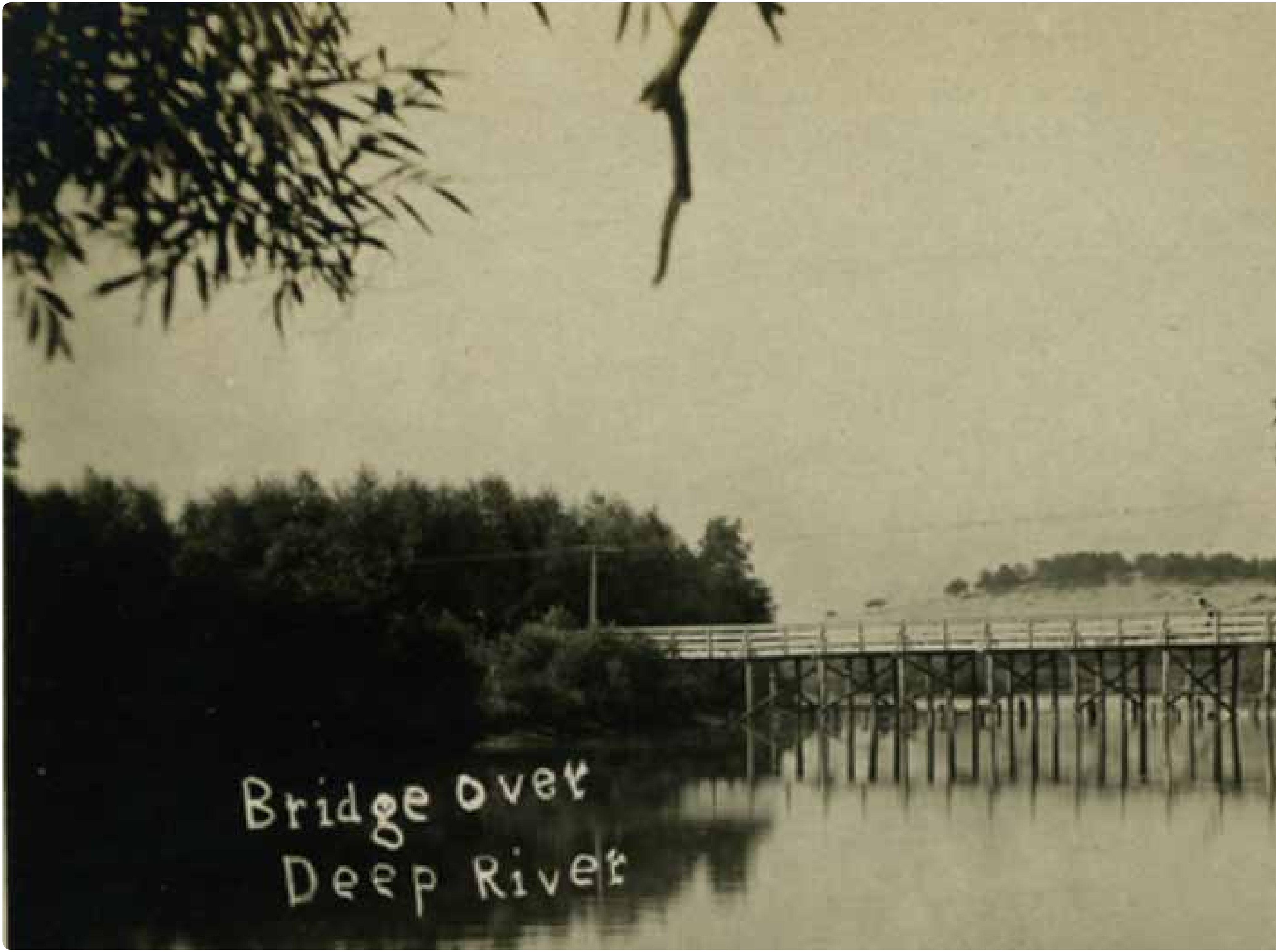


FIGURE 3.2-4 | Failng Sheet Piling on Deep River Dam

3.2 INDIANA TRENDS

DAM REMOVAL WITHIN THE STATE OF INDIANA


Bridge over
Deep River

4. **INVENTORY & ANALYSIS**

4.1 **DEEP RIVER DAM**

YEAR BUILT: 1930's
PURPOSE: BUILT BY USACOE/RECREATIONAL
HEIGHT: ~14'
HYDRAULIC HEAD: ~10'
OVERFLOW WIDTH: ~100'
DAM MATERIAL COMPOSITION: SHEET PILE & ROCK FILLED WOODEN CRIB
LENGTH OF BACKWATER: 6 – 6.5 MILES
SEDIMENT QUANTITY BEHIND DAM: ~790,000 – 1,000,000 CYS

4.1 **DEEP RIVER DAM**

4.2 **PUBLIC INPUT**

Three public meetings were held over the course of 5 months in the winter/spring of 2018. These meetings held a dual purpose: 1) Inform and educate the public about the project and the process of dam removal/modification and 2) gauge public perception of the dam and what residents of Lake Station and the region wanted to see happen with the project.

The following tactics were used to market and announce the meetings: Radio ads, newspaper ads, post cards mailed to residents that lived along the backwater, email to those who signed up for project alerts and announcements, and social media posts.

At the first meeting, held in the Lake Station City Hall Building, nearly 70 people showed up. This meeting was meant to be an introduction into the project and lay the groundwork for the rest of the project. The mood was contentious, as the perception was that the dam would be coming out. The Deep River Dam has played a significant role in the childhoods of many current Lake Station residents and plays a current role in how citizens recreate on the river. Removing the dam would take away the culture and identity so many had taken to.

The second meeting was held at the Lake Station – New Chicago Library Branch. This meeting had approximately 25 participants, many of whom attended the first meeting. The meeting focused on all the alternatives to the project and gave more direction to where the project was headed. Between the first and second meeting, there was much public interest, and action groups were formed in order for the public to maintain their voice as the project moved forward.

The third and final meeting was also held at the Lake Station – New Chicago Library Branch, with about 28 attendees. This meeting consisted of an overview of the whole project and the recommendation for action on the dam. The attendees had few questions, and seemed pleased that the dam would not be removed as a part of this feasibility study.

Figure 4.2-1 shows the location of all attendees to the three meetings.

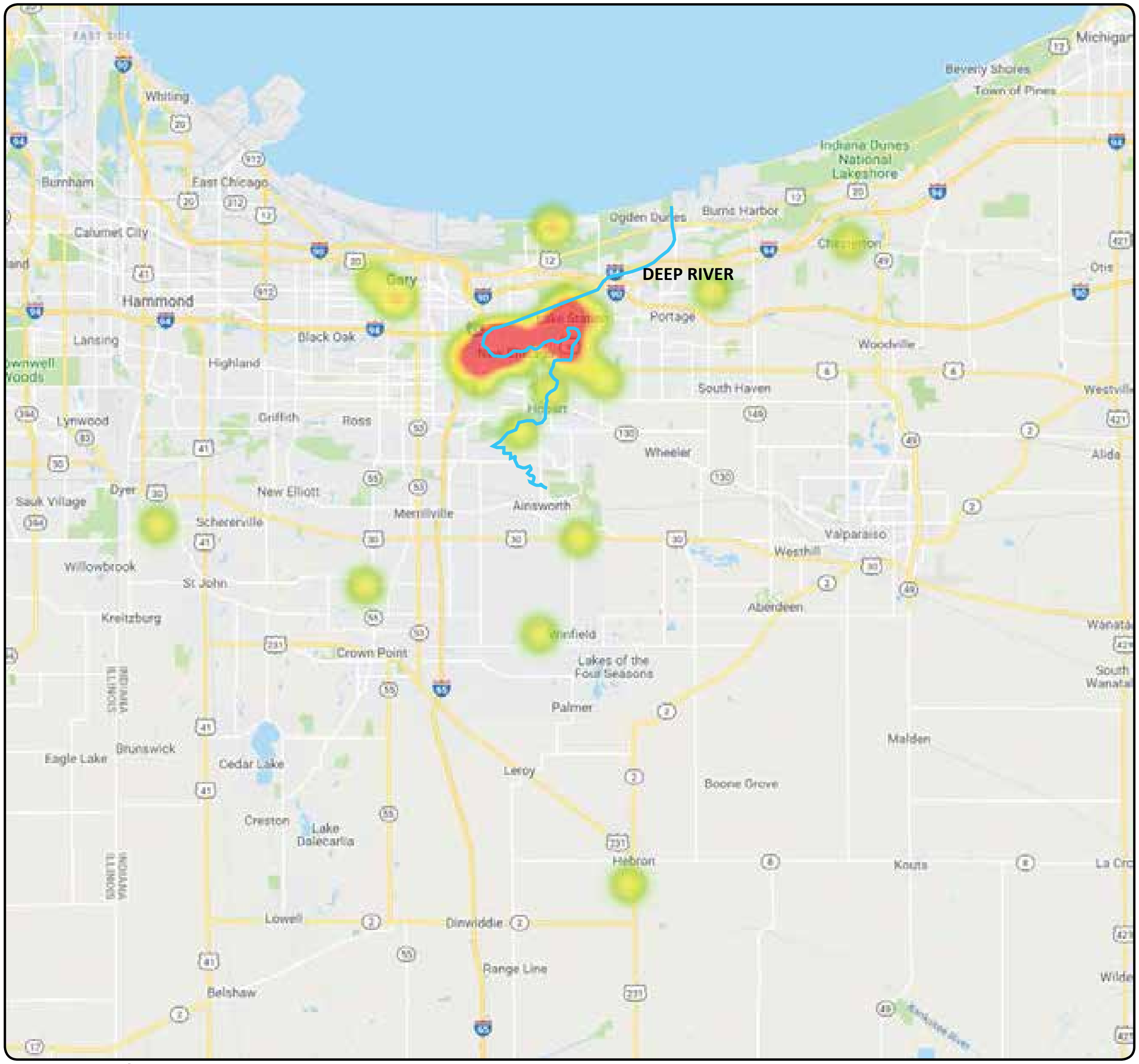


FIGURE 4.2-1 | Addresses of Participants of all Three Public Meetings

4.3 **WETLANDS**

Preliminary identification of wetland sites was completed using US Fish & Wildlife Service's National Wetlands Inventory Wetlands Mapper. Sites along the backwater were selected for the survey (Figure 4.3-1).

The ecological value of three wetlands found within the Deep River floodplain near Lake Station and New Chicago was assessed using field verification of the National Wetlands Inventory Wetlands Mapper. A vegetative survey was conducted on 12/21/2017 by Clair Burt and Kristin Riga. A full wetland delineation was not conducted as part of this project. Prior to construction activities, coordination with the Army Corps of Engineers should be completed to confirm whether or not a full wetland delineation report is required. Sites were identified as by USFWS Wetland Mapper as palustrine emergent (PEM1C) and palustrine scrub-shrub /palustrine emergent (PSS1/EM1C).

With nearly 200 acres of wetlands along the backwater of the dam, any removal or modification efforts that affected these wetlands could cause significant ecological and finacial costs.

Cost of wetland mitigation can range between $15 and $25k per acre, before the client gets into land acquisition. This cost includes permitting, plantings, and monitoring per the permitting agencies requests. To the right is ratio of wetland replacement required per type of wetland.

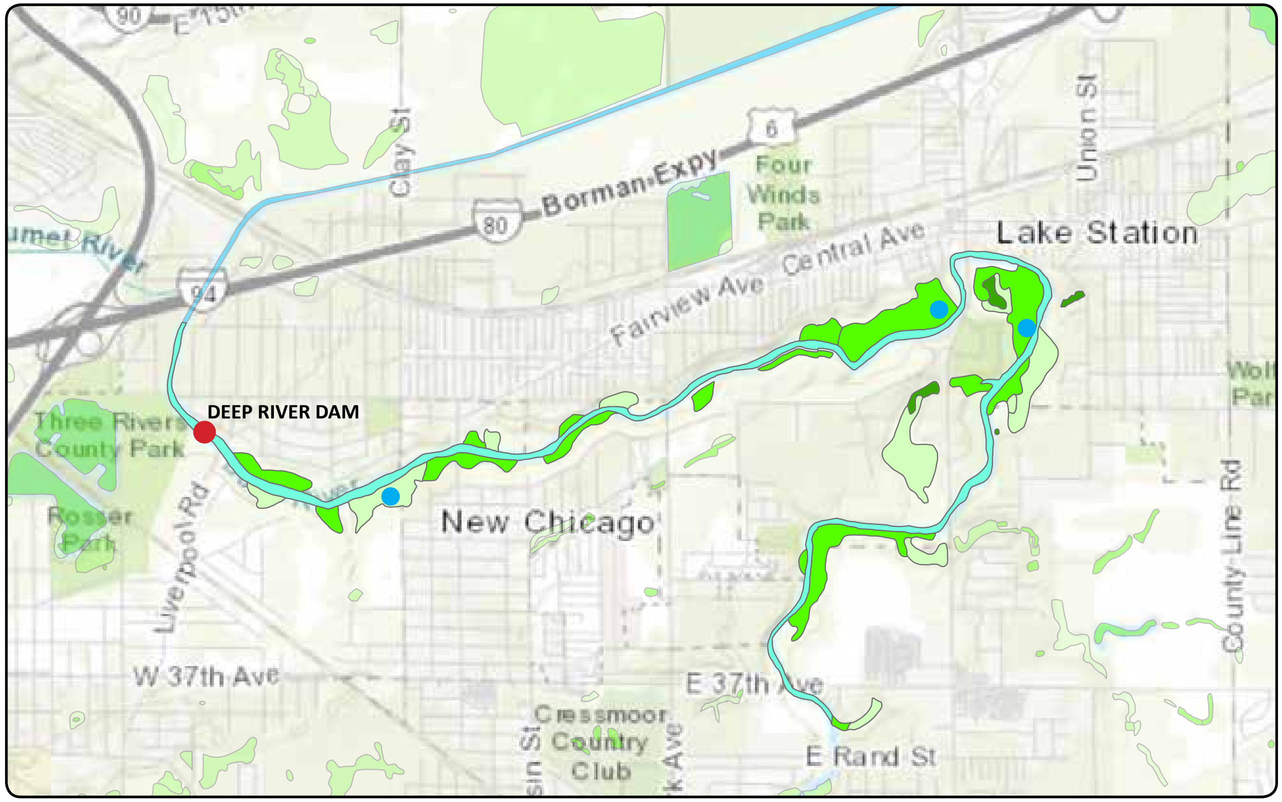


FIGURE 4.3-1 | Wetlands Along the Backwater of Deep River Dam

REPLACEMENT RATIO FOR WETLANDS

4:1 -- Forested Wetlands
~90ac along backwater

4:1 -- Bogs, & Fens

3:1 -- Scrub-Shrub Wetlands
~30ac along backwater

2:1 -- Emergent Wetlands
~72ac along backwater

1:1 -- Waters of the U.S.
~5ac along backwater

1:1 -- (foot) Stream Impacts

PROPOSED ACTION OPTIONS EFFECT ON WETLANDS

NO ACTION
No loss of wetlands

FISH LADDER
No loss of wetlands

BYPASS CHANNEL
No loss of wetlands

ROCK RIFFLE
No loss of wetlands

DAM REMOVAL
Loss of 70-90% of wetlands*

*Hydraulic studies would have to be completed in order to understand the full magnitude of wetland loss if the dam was removed. Many factors would play into this determination, such as proposed river profile, grade control structures, and various methods to maintain the existing water table for the wetlands.


FIGURE 4.3-2 | Wetland -- Bicentennial Park


FIGURE 4.3-3 | Wetland Conditions Along Deep River


FIGURE 4.3-4 | Wetland Conditions Along Deep River

SITE INFORMATION

Project/Site:	Bicentennial Park, Deepwater River
City/County:	Lake Station, Lake County
Sampling Date:	12/21/2017
State:	Indiana
Investigator(s):	Clair Burt, Kristin Riga
Landform:	floodplain
Local relief:	none
Lat:	41.570104°
Long:	-87.241928°
NWI Classification:	PFO1C
NWI Classification Decoded:	Palustrine, Forested, Broad-Leaved Deciduous, Seasonally Flooded
Are climatic/hydrologic condition on the site typical for this time of year?	Yes
Are Vegetation, Soil, or Hydrology significantly disturbed?	No
Are Vegetation, Soil, or Hydrology natually problematic?	No
Are normal circumstance present?	Yes

VEGETATION PRESENT

Species	Common Name	Wetland Indicator Status
Acer negundo	boxelder	FAC
Acer saccharinum	silver maple	FACW
Alisma subcordatum	subcordate water-plantain	OBL
Asclepius incarnata	milkweed	OBL
Bidens comosa	threelobe beggarticks	OBL
Boehmeria cylindrica	smallspike false nettle	OBL
Cephalanthus occidentalis	button bush	OBL
Cornus amomum	silky dogwood	FACW+
Iris pseudacorus	yellow iris	OBL
Leersia oryzoides	rice cut grass	OBL
Lysimachia nummularia	pennyroyal	FACW
Onoclea sensibilis	sensitivie fern	FACW
Phalaris arundinacea	reed canary grass	FACW
Phragmites australis	common reed	FACW
Prunus virginiana	chokecherry	FACU
Scutellaria lateriflora	mad dog skullcap	OBL
Symplocarpus foetidus	skunk cabbage	OBL
Toxicodendron radicans	poison ivy	FAC

HYDROLOGY INDICATORS PRESENT

Water-Stained Leaves
Surface Water
Water Marks
Buttressing on Trees

4.3 **WETLANDS**

FIGURE 4.3-5 | Wetland-- River Forest High School

FIGURE 4.3-6 | Wetland-- River Forest High School

FIGURE 4.3-7 | Wetland-- River Forest High School

SITE INFORMATION

Project/Site:	River Forest Community School, Deepwater River
City/County:	New Chicago, Lake County
Sampling Date:	12/21/2017
State:	Indiana
Investigator(s):	Clair Burt, Kristin Riga
Landform:	floodplain
Local relief:	none
Lat:	41.560276°
Long:	-87.279016°
NWI Classification:	PEM1C
NWI Classification Decoded:	Palustrine, Emergent, Persistent, Seasonally Flooded
Are climatic/hydrologic condition on the site typical for this time of year?	Yes
Are Vegetation, Soil, or Hydrology significantly disturbed?	No
Are Vegetation, Soil, or Hydrology natually problematic?	No
Are normal circumstance present?	Yes

VEGETATION PRESENT

Species	**Common Name**	**Wetland Indicator Status**
Caltha palustris	marsh marigold	OBL
Cornus amomum	silky dogwood	FACW+
Impatiens capensis	spotted touch-me-not	FACW
Iris pseudacorus	yellow iris	OBL
Lysimachia nummularia	creeping jenny	FACW
Onoclea sensibilis	sensitive fern	FACW
Phalaris arundinacea	reed canary grass	FACW
Phragmites australis	common reed	FACW
Symplocarpus foetidus	skunk cabbage	OBL

HYDROLOGY INDICATORS PRESENT

Water-Stained Leaves
Surface Water
Water Marks
Buttressing on Trees

FIGURE 4.3-8 | Wetland-- Riverview Park

FIGURE 4.3-9 | Wetland-- Riverview Park

FIGURE 4.3-10 | Wetland-- Riverview Park

SITE INFORMATION

Project/Site:	Riverview Park, Deepwater River
City/County:	Lake Station, Lake County
Sampling Date:	12/21/2017
State:	Indiana
Investigator(s):	Clair Burt, Kristin Riga
Landform:	floodplain
Local relief:	none
Lat:	41.568648°
Long:	-87.235687°
NWI Classification:	PFO1C
NWI Classification Decoded:	Palustrine, Forested, Broad-Leaved Deciduous, Seasonally Flooded
Are climatic/hydrologic condition on the site typical for this time of year?	Yes
Are Vegetation, Soil, or Hydrology significantly disturbed?	No
Are Vegetation, Soil, or Hydrology natually problematic?	No
Are normal circumstance present?	Yes

VEGETATION PRESENT

Species	Common Name	Wetland Indicator Status
Acer negundo	boxelder	FAC
Acer saccharinum	silver maple	FACW
Alisma subcordatum	subcordate water-plantain	OBL
Boehmeria cylindrica	smallspike false nettle	OBL
Crataegus mollis	downy hawthorn	FAC
Impatiens capensis	spotted touch-me-not	FACW
Iris pseudacorus	yellow iris	OBL
Lysimachia nummularia	creeping jenny	FACW
Penthorum sedoides	ditch stonecrop	OBL
Phalaris arundinacea	reed canary grass	FACW
Phragmites australis	common reed	FACW
Polygonum persicaria	lady's thumb	FACW
Toxicodendron radicans	poison ivy	FAC

HYDROLOGY INDICATORS PRESENT

Water-Stained Leaves
Surface Water
Water Marks
Buttressing on Trees

4.4 REGION 5 MODELING

The EPA Region 5 Model estimates pollutant reduction with the implementation of Best Management Practices (BMPs) in a given watershed or stream setting. Although the model has its limitations, it is widely used to provide a uniform system of estimating pollutant loads. With its ease of use in calculating pollutant reductions for sediment, sediment borne phosphorous and nitrogen, feedlot runoff, and commercial fertilizer, pesticides and manure utilization, the model can be utilized by citizens and professionals alike.

Within the Region 5 Model are different equations for specific situations. There are equations for gully erosion, channel erosion, and a universal soil loss equation. After choosing an equation based on the given site, sediment and nutrient reduction is estimated based on gross erosion at the site. This number is based upon many site specific factors such as soil type, bank height, length of bank, and the Lateral Recession Rate (LRR) (a subjective measure of the state of bank erosion). The LRR ratings are very similar to BEHI and NBS models.

After calculating gross erosion, the formula calculates sediment load reduction as well as phosphorous and nitrogen load reduction with 100% efficiency in the BMPs. However, the model also allows the user to assume lower rates of BMP efficiency. Expecting a 70-90% effectiveness of BMPs tends to be a more realistic expectation in the real world, as multiple factors (human error and Mother-Nature are a couple examples) can alter their effectiveness.

With regards to this project, the Region 5 model was run for the area downstream of the dam that would be affected by the installation of the proposed rock riffle. The soils within this area are generally sandy loam, Watseka Loamy Fine Sand (Figure 4.4-1), with extensive bank erosion occurring along the banks as the river turns to the north. Over the years, concrete rubble has been dumped on the right bank in an attempt to stabilize the erosion.

The model was run using a median height of six feet for the bank (the rock riffle would start at approximately +12’ elevation and run down to 0’ elevation). At 100% efficiency in reduction of erosion, it can be anticipated that roughly 24.3 less tons of sediment will be entering the river each year. Due to the proposed design of the rock riffle, it can be anticipated that a 90 – 100% reduction in erosion will occur. With most of the banks becoming a part of the rock riffle structure, potential erosion will be significantly reduced within the bankfull width.

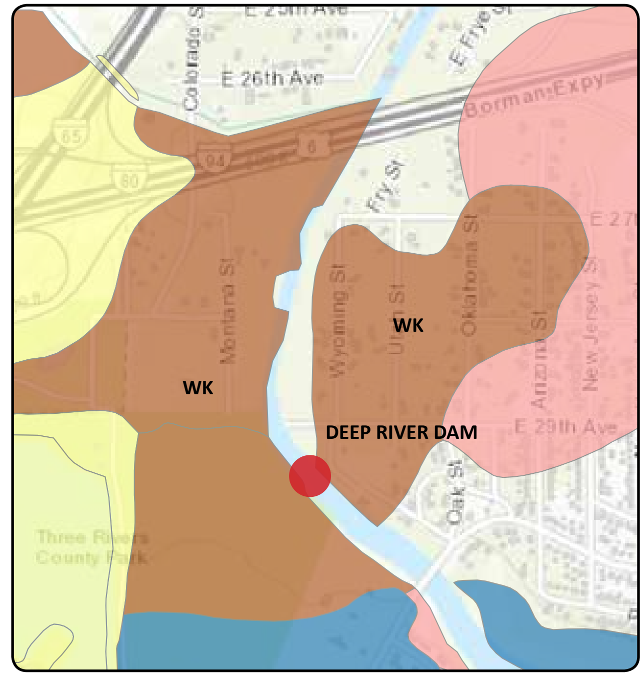


FIGURE 4.4-1 | Soil Map Around Dam

	EFFICIENCY OF BMP	80%	90%	100%
	RIGH BANK	14.4	16.2	18
	LEFT BANK	5	5.7	6.3
TOTAL SEDIMENT REDUCTION (TONS/YR)		19.4	21.9	24.3

FIGURE 4.4-2 | Sediment Reduction Calculations

Bank Stabilization

If estimating for just one bank, put "0" in areas for Bank #2.

Please select a soil textural class:

- ☐ Sands, loamy sands
- ☐ Sandy loam
- ☒ Fine sandy loam
- ☐ Loams, sandy clay loams, sandy clay
- ☐ Silt loam
- ☐ Silty clay loam, silty clay
- ☐ Clay loam
- ☐ Clay
- ☐ Organic

Please fill in the gray areas below:

Parameter		Bank #1	Bank #2	**Example**	
Length (ft)		300	300	**500**	
Height (ft)		6	6	**15**	
Lateral Recession Rate (ft/yr)*		0.2	0.07	**0.5**	
Soil Weight (tons/ft^3)		0.05	0.05	**0.04**	
Soil P Conc (lb/lb soil)**	DEFAULT	0.0005	0.0005	**0.0005**	**
Soil N Conc (lb/lb soil)**	DEFAULT	0.001	0.001	**0.001**	**

** If not using the default values, users must provide input (in red) for Total P and Total N soil concentrations

*Lateral Recession Rate (LRR) is the rate at which bank deterioration has taken place and is measured in feet per year. This rate may not be easily determined by direct measurement. Therefore best professional judgement may be required to estimate the LRR. Please refer to the narrative descriptions in Table 1.

Estimated Load Reductions

	BMP Efficiency* Bank #1	**BMP Efficiency* Bank #2**	**Bank #1**	**Bank #2**	**Example**
Sediment Load Reduction (ton/year)	1.00	1.00	18.0	6.3	**150**
Phosphorus Load Reduction (lb/year)			15.3	5.4	**150**
Nitrogen Load Reduction (lb/yr)			30.6	10.7	**300**

* BMP efficiency values should be between 0 and 1, and 1 means 100% pollutant removal efficiency.

Table 1

LRR (ft/yr)	**Category**	**Description**
0.01 - 0.05	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang.
0.06 - 0.2	Moderate	Bank is predominantly bare with some rills and vegetative overhang.
0.3 - 0.5	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross-section becomes more U-shaped as opposed to V-shaped.
0.5+	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross-section is U-shaped and streamcourse or gully may be meandering.

Source: Steffen, L.J. 1982. Channel Erosion (personal communication), as printed in "Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual," June 1999 Revision; Michigan Department of Environmental Quality - Surface Water Quality Division - Nonpoint Source Unit. EQP 5841 (6/99).

FIGURE 4.4-3 | Example of Region 5 Model Being Run for this Study

4.5 **EARLY COORDINATION MEETING**

An early coordination meeting with all agencies of jurisdiction including the Army Corp of Engineers (404 Permit), IDEM (401 Permit and Rule 5 Permit), IDNR (Construction in the Floodway Permit), and the US Fish and Wildlife Service occurred on site on May 9th, 2018. The purpose of this early coordination meeting was to get all agency comments and questions about the project addressed prior to the design/engineering/permitting phase of the project. This approach will allow for a more seamless and streamlined permitting process due to the agencies having knowledge of the project. However, project changes/amendments could occur upon final formal permitting to all agencies.

The general consensus of all permitting agencies was approval of the proposed project approach of building a constructed rock riffle. Once the permits are submitted, there may be more questions and concerns regarding the design, but based upon the feedback received, the project is headed in the right direction. Meeting minutes from the meeting can be found in Appendix A.3.

Overview of Comments per Agency

USACOE

- Public input and opinion will be extremely important
- Will be hesitant to permit a project that is seen as unfavorable in the eyes of the public
- Will project benefit aquatic species and fish passage as proposed?
- What do the sediment test results show?

IDNR

- Will design of rock riffle allow for fish passage for multiple species?
- Construction contractor will need to be cognizant of seasonal work requirements
- Footprint of impact will determine amount of mitigation required for project

USFWS

- Will the rock riffle be constructed bankfull width, or wider than the dam?
- What will the backfill material be composed of for the structure?

IDEM

- Will project adversely affect water quality and/or aquatic habitat?
- Minimize disturbance to riparian corridor for construction access and activities

4.6 **SEDIMENT SAMPLING**

The locations chosen for the sediment sampling behind the Deep River Dam were based upon the known dynamics of sediment falling out of the water and settling behind the dam. After the dam is built, the first place sediment begins to collect is directly behind the dam. As time goes on, sediment will begin to accumulate farther upstream, matching the elevation of the first dropout. At this point, a new layer of sediment is created, following the same pattern. This buildup creates a 'history book' of all the sediment behind the dam. By sampling closer to the dam, a snapshot is created of this entire 'book', instead of just the last half or quarter of it, giving a full history of any toxins or heavy metals that may be present in the sediment. See the Figure 4.6-1 for further explanation.

The results of the sediment analysis were compared to the IDEM Residential Closure levels, as well as the EPA's ESL Levels. The heavy metals and PCB's tested come from the IDNR's dredging projects required testing list. The reason for this is related to where the sediment can be relocated safely. If the results show all levels are below IDEM's requirement, then the sediment could be stored in a public location. If, however, the levels exceed the standards laid out by IDEM, then the sediment would have to be relocated to a place where the general public cannot come into contact with it.

Based on the results of the testing, there are currently no concerns with what was found. If the sediment had to be moved in the future or if the dam were to fail, it would be safe for the general public to come in contact with the sediment.

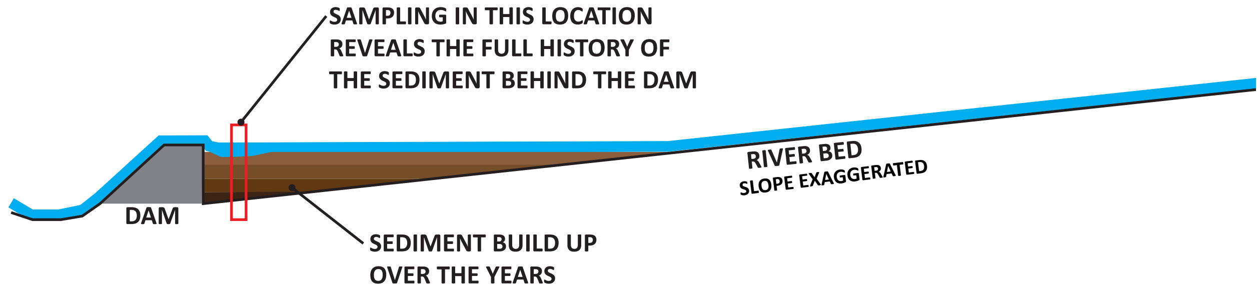
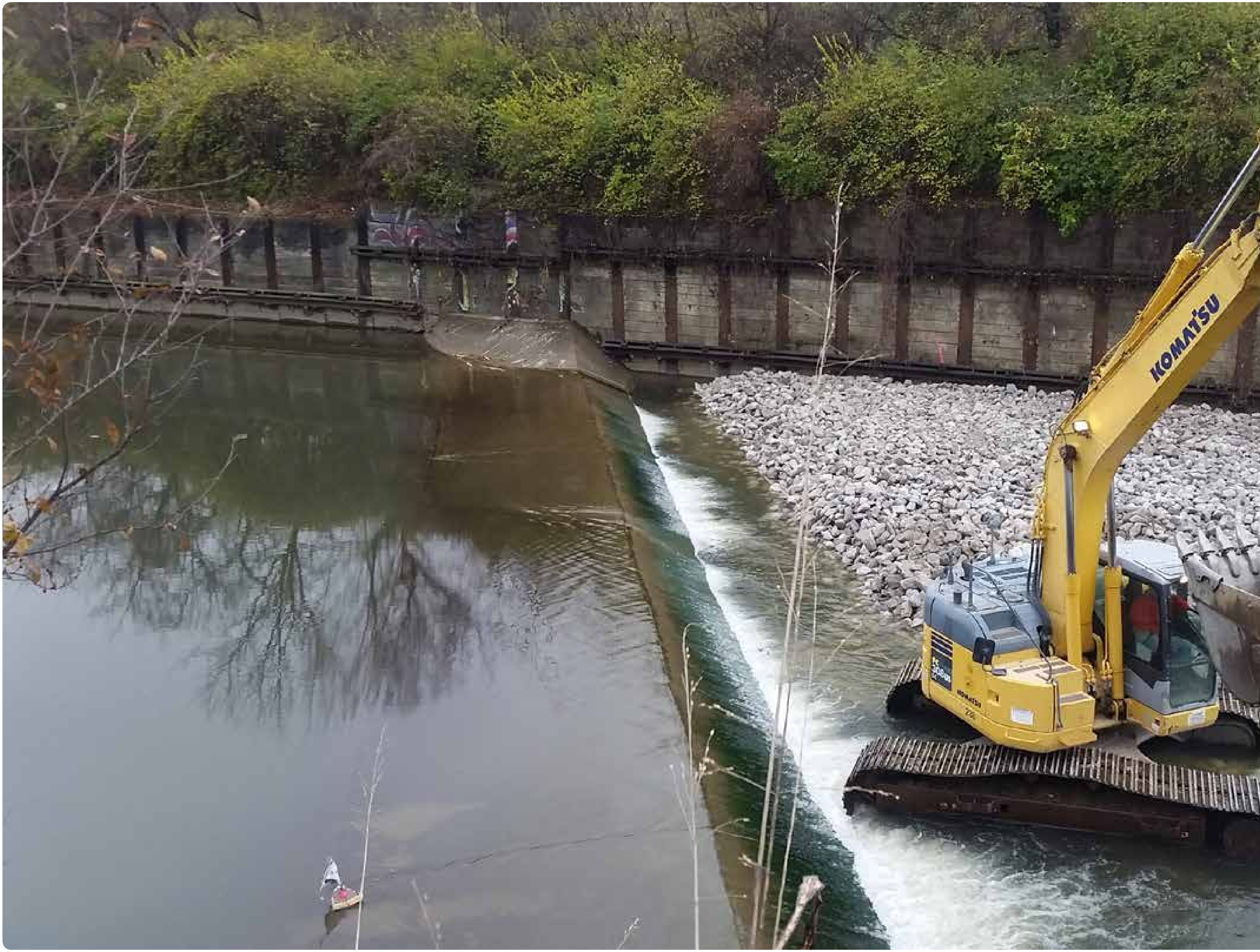


FIGURE 4.6-1 | Sediment Build Up Behind Dam

	ANALYTICAL PARAMETER	METHOD	UNITS	SAMPLE IDENTIFICATION SED:1	SED:2	SED:3	IDEM RCG RSL (MG/KG)	ESL ESV (MG/KG)	ESL RSV (MG/KG)
PCBs	AROCLOR 1016	EPA 8082	MG/KG	ND	ND	ND	5.7	--	--
	AROCLOR 1221	EPA 8082	MG/KG	ND	ND	ND	2.8	--	--
	AROCLOR 1232	EPA 8082	MG/KG	ND	ND	ND	2.4	--	--
	AROCLOR 1242	EPA 8082	MG/KG	ND	ND	ND	3.2	--	--
	AROCLOR 1248	EPA 8082	MG/KG	ND	ND	ND	3.2	--	--
	AROCLOR 1254	EPA 8082	MG/KG	ND	ND	ND	1.7	--	--
	AROCLOR 1260	EPA 8082	MG/KG	ND	ND	ND	3.4	--	--
	AROCLOR 1262	EPA 8082	MG/KG	ND	ND	ND	--	--	--
	AROCLOR 1268	EPA 8082	MG/KG	ND	ND	ND	--	--	--
	TOTAL PCB'S	EPA 8082	MG/KG	ND	ND	ND	--	0.0598	0.676
	DECACHLOROBIPHENYL	EPA 8082	MG/KG	70	90	45	620	--	--
	TETRACHLORO-M-XYLENE	EPA 8082	MG/KG	75	75	40	--	--	--
METALS	ARSENIC	EPA 6010	MG/KG	1.7	< 0.59	1.5	9.5	9.8	33
	BARIUM	EPA 6010	MG/KG	16	19	37.0	21,000	20	60
	CADMIUM	EPA 6010	MG/KG	< 0.23	< 0.24	< 0.29	99	1	5
	CHROMIUM	EPA 6010	MG/KG	5.1	7.5	7.1	100,000	43.4	111
	COPPER	EPA 6010	MG/KG	15.0	2.4	4.9	4,300	31.6	149
	LEAD	EPA 6010	MG/KG	4.8	4.7	6.0	400	35.8	128
	NICKEL	EPA 6010	MG/KG	4.2	3	7.3	2,100	22.7	48.6
	SELENIUM	EPA 6010	MG/KG	< 1.8	< 1.8	< 2.2	550	11	20
	SILVER	EPA 6010	MG/KG	< 0.59	< 0.59	< 0.73	550	1	2.2
	ZINC	EPA 6010	MG/KG	17	16	23	32,000	121	459
	MERCURY	EPA 7471	MG/KG	< 0.052	< 0.042	< 0.061	3.1	0.18	1.1
	CYANIDE, TOTAL	EPA 7472	MG/KG	0.32	0.58	ND	32	5.2	--

FIGURE 4.6-2 | Sediment Analysis Results


KOMATSU

5. DAM REMOVAL/MODIFICATION OPTIONS

5.1 **ACTION OPTIONS**

NO ACTION

The cheapest option available would be to do nothing. This could happen for a couple reasons: 1) lack of desire to take action by dam owner, and 2) cost of project becomes prohibitive to taking action. Although not a preferred route for any project, funding, and a willingness to act are the driving forces as to whether or not a project gets off the ground.

In the event of no action being taken, it is anticipated that the dam will fail over time, rather than in one single event. This is due to the way in which it was built, as the sheet piling that creates the main structure of the dam slowly breaks down. If this were to occur, the owner of the dam would be required to react to the emergency, which could cost more money and headache than dealing with the issue up front.

PROS

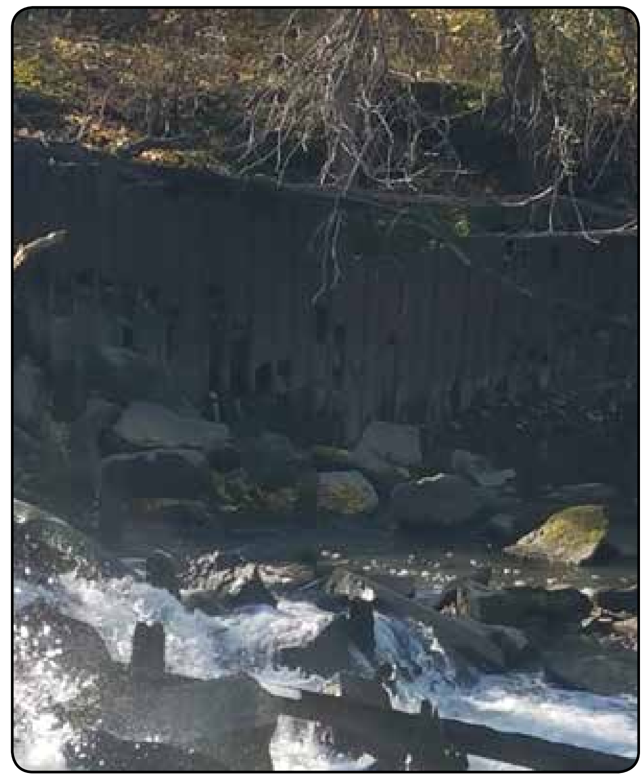
- No money spent
- Maintain current backwater pool and wetlands

CONS

- Continued deterioration of dam
- Potential for large release of sediment should dam fail
- Community forced into emergency restoration efforts & compliance issues with permitting agencies

RANKINGS

MAINTAIN BACKWATER	● ● ● ● ●
MAINTAIN WETLANDS	● ● ● ● ●
FISH PASSAGE	○ ○ ○ ○ ○
RECREATIONAL PASSAGE	○ ○ ○ ○ ○
BIOLOGICAL HEALTH	● ○ ○ ○ ○
ECOLOGICAL HEALTH	● ○ ○ ○ ○
COST	● ○ ○ ○ ○
COMPOSITE SCORE	● ● ○ ○ ○



5.1 **ACTION OPTIONS**

FISH LADDER

Fish ladders are small structures typically built on the downstream side of dams and mimic riffle/ boulder runs found in nature. These structures allow fish to migrate to waterways upstream of dams by creating step pools. Based on the species of fish that are trying to move upstream, the fish ladder is designed to allow fish to jump and rest, jump and rest, until they have reached the top of the dam and the backwater pool.

Fish ladders can be made up of nearly any material (wood, concrete, stone, etc) and take any form, some functional, some aesthetic.

Although this solution offers potential fish passage opportunities, it would still require canoers and kayakers to port around the dam and does not address the issue of the deteriorating dam. Unfortunately, fish ladders are often cookie cutter in design and implementation, meaning less aggressive and 'charismatic' fish tend to struggle mightily with traversing the fish ladder (Kessler, 2014). This has lead to a reluctance to use fish ladders where dams cannot be removed, in favor of more popular and successful rock riffles.

PROS

- Increased fish passage opportunities for certain species (Trout, Steelhead, etc.)
- Relatively cheap option compared to other options
- Maintain current backwater pool and wetlands

CONS

- No passage for boats, canoes, kayaks
- Would allow for migration of sea lamprey (although not a current concern of USFWS)
- Does not address deterioration of dam

RANKINGS

MAINTAIN BACKWATER	● ● ● ● ●
MAINTAIN WETLANDS	● ● ● ● ●
FISH PASSAGE	● ● ● ○ ○
RECREATIONAL PASSAGE	○ ○ ○ ○ ○
BIOLOGICAL HEALTH	● ● ○ ○ ○
ECOLOGICAL HEALTH	● ○ ○ ○ ○
COST	● ● ○ ○ ○
COMPOSITE SCORE	● ● ● ○ ○

5.1 **ACTION OPTIONS**

BYPASS CHANNEL

Bypass channels are small, man-made channels that are built off to one side of a dam. These 'natural' channels divert a small portion of the river or stream, creating a channel that allows for fish and recreational passage around the dam. These channels can be constructed out of concrete, but typically are designed and constructed to look like a stream found in a mountainous landscape, with large boulders, riffles, and white water.

Due the increased amount of space available and freedom to create a more natural system, bypass channels create a better environment for more species of fish and mussels to successfully migrate upstream of the impoundment.

Much like the previous two options, installing a bypass channel will not directly impact the structural integrity of the dam, as this would need to be addressed separately.

PROS

- Increased fish passage opportunities for certain species (Trout, Steelhead, etc.)
- Increased recreational opportunities for canoers and kayakers
- Relatively cheap option compared to other options
- Create a 'natural' channel
- Maintain current backwater pool and wetlands

CONS

- No passage for motor boats
- Would allow for migration of sea lamprey (although not a current concern of USFWS)
- Does not address deterioration of dam

RANKINGS

MAINTAIN BACKWATER	● ● ● ● ●
MAINTAIN WETLANDS	● ● ● ● ●
FISH PASSAGE	● ● ● ● ○
RECREATIONAL PASSAGE	● ● ● ● ○
BIOLOGICAL HEALTH	● ● ● ○ ○
ECOLOGICAL HEALTH	● ● ● ○ ○
COST	● ● ● ○ ○
COMPOSITE SCORE	● ● ● ● ○

5.1 **ACTION OPTIONS**

ROCK RIFFLE

A rock riffle is a series of boulder arcs stretching from bank to bank, creating a large riffle complex that greatly aids in the ability of fish to migrate above the dam. Much like the fish ladder and bypass channel, a rock riffle allows fish to jump and rest until clear of the impoundment. However, they are built at a 3-5% slope, much shallower than a fish ladder, which allows for more species to successfully navigate the riffle.

This alternative approach to dam removal gained popularity in the 1970's and '80's, and has become the go to option when a dam cannot be removed. This is due to: 1) their ability to stabilize the existing dam structure, 2) increased fish and recreational passage opportunities, and 3) their natural appearance.

Oftentimes the biggest hurdle in building rock riffles is finding natural stones large enough to withstand the force of floodwaters. Boulders upwards of six feet are routinely required to withstand these forces.

PROS

- Provide structural support for dam
- Improve recreational passage opportunities (canoes, kayaks, tubing)
- Increase fish passage opportunities
- Relatively cheap option
- Maintain current backwater pool and wetlands

CONS

- No passage for motor boats
- Would allow for the migration of thesea lamprey, although this is not a concern of the USFWS

RANKINGS

MAINTAIN BACKWATER	● ● ● ● ●
MAINTAIN WETLANDS	● ● ● ● ●
FISH PASSAGE	● ● ● ● ●
RECREATIONAL PASSAGE	● ● ● ● ◐
BIOLOGICAL HEALTH	● ● ● ○ ○
ECOLOGICAL HEALTH	● ● ● ○ ○
COST	● ● ● ○ ○
COMPOSITE SCORE	● ● ● ● ◐

5.1 **ACTION OPTIONS**

DAM REMOVAL

Removing the Deep River Dam would drastically change the landscape of Lake Station. Dam removal would increase the area floodplain along the length of the existing backwater pool. The channel would become about seventy feet wide at bankfull width; a third of its width near the dam. Not only would dam removal change the landscape, it would allow for the development of a healthy river system, with pools and riffle complexes that would support healthy ecological and biological systems.

However, removing the dam would also affect the landowners along the backwater of the dam, as well as those who grew up playing in and along Deep River. The 'lake culture' plays a significant role in lives and recreational activities of many residents and holds a dear spot in childhood experiences. Removing the dam would take away what Lake Station means to them.

The nearly two hundred acres of wetlands between the Lake George and Deep River Dam would also be affected by dam removal. If the dam were to be removed, the water table would be lowered, thus rendering the wetlands unable to maintain wet soils. Not all of the wetlands would be affected, but a majority would see their water reserves dry up.

PROS

- Greatly improved passage for fish and mussel species
- Restoration of riparian corridor
- Increased biological, ecological, and river health

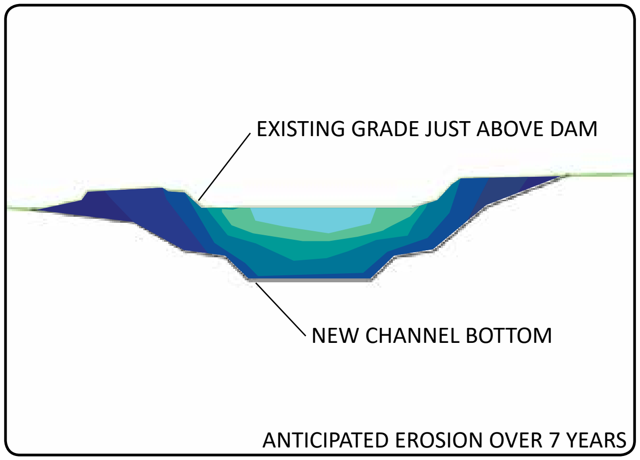
CONS

- Most expensive option, no matter how the sediment is handled
- Would allow for the migration of thesea lamprey, although this is not a concern of the USFWS
- Elimination of the culture of Lake Station, definition of recreation for town (the lake lifestyle)
- Loss of significant amount of wetlands upstream of dam due to drop in water table

RANKINGS

MAINTAIN BACKWATER	○ ○ ○ ○ ○
MAINTAIN WETLANDS	● ○ ○ ○ ○
FISH PASSAGE	● ● ● ● ●
RECREATIONAL PASSAGE	● ● ● ● ●
BIOLOGICAL HEALTH	● ● ● ● ●
ECOLOGICAL HEALTH	● ● ● ● ●
COST	● ● ● ● ●
COMPOSITE SCORE	● ● ● ◐ ○

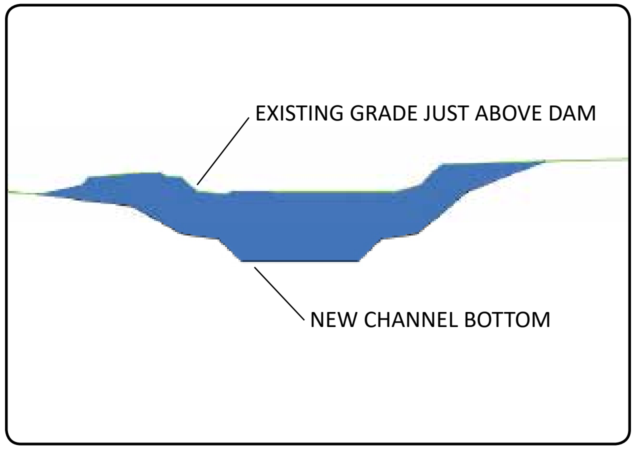
DEALING WITH THE SEDIMENT



NO SEDIMENT REMOVAL

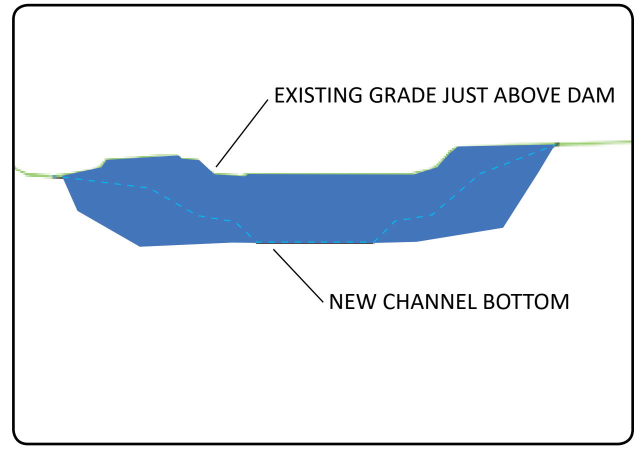
With the no sediment removal approach, the dam structure is taken out, and the sediment is left to wash downstream on its own timetable. This is the cheapest approach of the three, as the human factor is severely limited. A study completed by Duke Professor, Eli Manning, shows that typically, 10-14% of sediment that will mobilize after the removal of a dam does so each year (this number could be more or less, depending on the amount of rainfall and severe storm events that come through the area after dam has been removed).

This hands-off approach will allow the channel to determine its new meandering path but does take the longest amount of time to complete. If the dam were to fail or be removed, this would most likely be the approach taken, as moving upwards of a million cubic yards of sediment would be financially unfeasible.



PARTIAL SEDIMENT REMOVAL

With partial removal of the sediment, only the material within the newly constructed channel is removed or aided on its march to Lake Michigan. The banks will be sloped, stabilized, and revegetated. The sediment not removed during the construction process would become the new floodplain for Deep River. It is estimated, that with this approach, approximately 400 – 650k cubic yards of material would be removed from Deep River.



COMPLETE SEDIMENT REMOVAL

With complete removal of the sediment, the Deep River would begin anew. This approach is extremely expensive, as there is upwards of 750k – 1 mil cubic yards of material built up behind the dam that would have to be hauled off-site. Then, new material would have to be brought in to rebuild the banks and slopes to match the existing grades. Finally, the riparian corridor would be replanted with vegetation. All told, this approach would be unfeasible and unnecessary for the project to be considered a success.


DEERE

6. **RECOMMENDED OPTION**

6.1 **CONSTRUCTED ROCK RIFFLE**

After carefully weighing all options, the recommended course of action is to install a constructed riffle on the downstream side of the dam. What follows is a summary of the analysis that lead to this conclusion, in no particular order of relevance.

Wetlands

By leaving the dam in place, all of the wetlands along the backwater pool will not be affected or lost. This maintains a vital cog in the ecological and biological diversity of the Deep River. Not only does it benefit the environmental side, the Little Calumet River Basin Development Commission (currently in the process of acquiring the dam) will not have to go through mitigating for lost wetlands should the dam fail or be removed. Having to mitigate for over a hundred acres of wetlands would be an extremely costly consequence to either of those alternatives, both ecologically and financially. A more in-depth study of existing and proposed water tables would have to be completed to understand the full impact of wetland loss should the dam be removed.

Public Input

As stated previously, three public meetings were held regarding the feasibility study. The consensus among those that participated is to save the dam. Childhood memories of playing in Deep River and current lifestyle activities (boating, fishing, the lake lifestyle) are driving factors in their desire to see these activities continue in their current form.

The proposed solution will allow for those that enjoy the recreational benefits of Deep River as it currently exists, while also increasing the biological diversity and recreational opportunities of the river.

Permitting Agency Input

All permitting agencies, Indiana Department of Natural Resources, Indiana Department of Environmental Management, US Army Corps of Engineers, and the US Fish and Wildlife Service gave their general approval for the proposed project approach. No rock riffle of this size has been completed within the state, and it should be anticipated that the permitting agencies will have more questions about the proposed benefits once the design is complete. All agencies wanted to ensure that the installed structure would allow for fish passage for multiple species, as this will be one of the driving factors for measuring the success of the project.

Dam Structural Stability

The Deep River Dam is slowly failing, as the sheet piling that constitutes the primary structure has begun to rust out. The rock riffle will provide the necessary structural support to ensure the dam does not fail. The next phase of engineering would address whether or not the dam structure itself would need to be reinforced in addition to the installation of the rock riffle.

NIRPC & Watershed Plan

Addressing the Deep River Dam has been a priority of the Northwestern Indiana Regional Planning Commission and was listed as a priority action item in the Deep River – Portage Burns Waterway Watershed Plan completed in 2016. By modifying the dam, the following objectives would be met as proposed by the watershed plan: 12.2.4 – Improve Bedform Diversity and 12.2.5 – Improve Channel Stability.

LCRBDC

With the Little Calumet River Basin Development Commission working through the acquisition process of the dam, they are supportive of the feasibility study, and believe that taking action is an important step to maintaining the dam. However, addressing the dam is not current priority for the LCRBDC. Ongoing discussions between the development commission, NIRPC, and IDNR LARE program will be necessary to keep the project moving forward.

Next Steps – Short Term

Continued discussions between landowners (LCRBDC), NIRPC, and IDNR LARE representatives is critical in maintaining momentum of the project. The next phase will be to complete the design and engineering of the rock riffle structure and submit the design for the required construction permits. It is anticipated that permits will be required from the IDNR, IDEM, and the USACOE. As laid out in the proposed timeline in Section 7.4, the engineering/ permitting phase should be completed in the fall/ winter of 2019.

Until the rock riffle is complete, it is recommended that signage be installed upstream of the dam, warning users of the river of the dangers of the dam and the currents it creates. Although no death has been recorded from an individual from going over the dam, these proposed signs could serve as a deterrent for an individual who might otherwise decide to recreate too close to the structure. An example of what these signs could look like can be seen in Figure 6.1-1.

FIGURE 6.1-1 | Warning Sign of Dam Hazards

Next Steps – Long Term

It is the desire of both NIRPC and the Fish & Wildlife branch of the IDNR that extensive fish monitoring and tagging occur before and after the construction of the rock riffle in the Deep River. This data will help build evidence as to whether or not, and what species of fish are able to pass both up and down the structure.

Informal creel studies could also be completed of anglers that fish Deep River before and after construction. These studies often provide more data due the knowledge and understanding everyday fishermen bring to the table.

Acquiring funding for the construction of the rock riffle will be the greatest challenge to completing the project as proposed. Building and maintaining relationships at the local and national level would go a long way in closing the funding gap. It is anticipated that the construction and monitoring phase of the project could cost upwards of 1.5 million dollars, of which no monies have been committed yet.

FIGURE 6.1-2 | Typical Rock Riffle Structure

A rock riffle structure is composed of a step pool system, typically built at a 3-5% slope, depending on the space available and the species of fish that would attempt to move upstream through the riffle. The largest boulders (approximately 4-5' in diameter for this project), would be spaced about twenty feet apart and each ascending row would be about a foot higher than the one prior. These boulders are sized based upon flood flow velocities. It is critical that the main arch boulders do not tumble downstream during the first big rain event after the riffle is constructed. This twenty-foot spacing allows the jumping fish a place to rest as they move the riffle. These structures can also be designed in a way to allow for canoers or kayakers to pass through without having to portage around the side. This design often has a 'path' that does not require falling over boulders, but acts as more of a meandering ramp. This path is also an alternative route for fish who are not jumpers but can move effectively through faster currents.

Typically, the cheapest way to build the support base for the 'surface' portion of the riffle is to use concrete rubble. If accessible for a project, the rubble can help keep costs down, making the possibility of the project coming to fruition much greater.

6.2 CASE STUDIES

CAPE FEAR RIVER RIEGELWOOD, NC

RED RIVER GRAND FORKS, ND

CASS RIVER FRANKENMUTH, MI

Cape Fear River
Riegelwood, NC
Low head dam / lock system; Lock & Dam #1
Installed in 2012
12 rows of boulders
~250’ long
5% slope
Cost: ~$3,200,000.00

Ciritical Component: Fish passage; American Shad, Striped Bass, River Herring, Atlantic Sturgeon, Shortnose Sturgeon

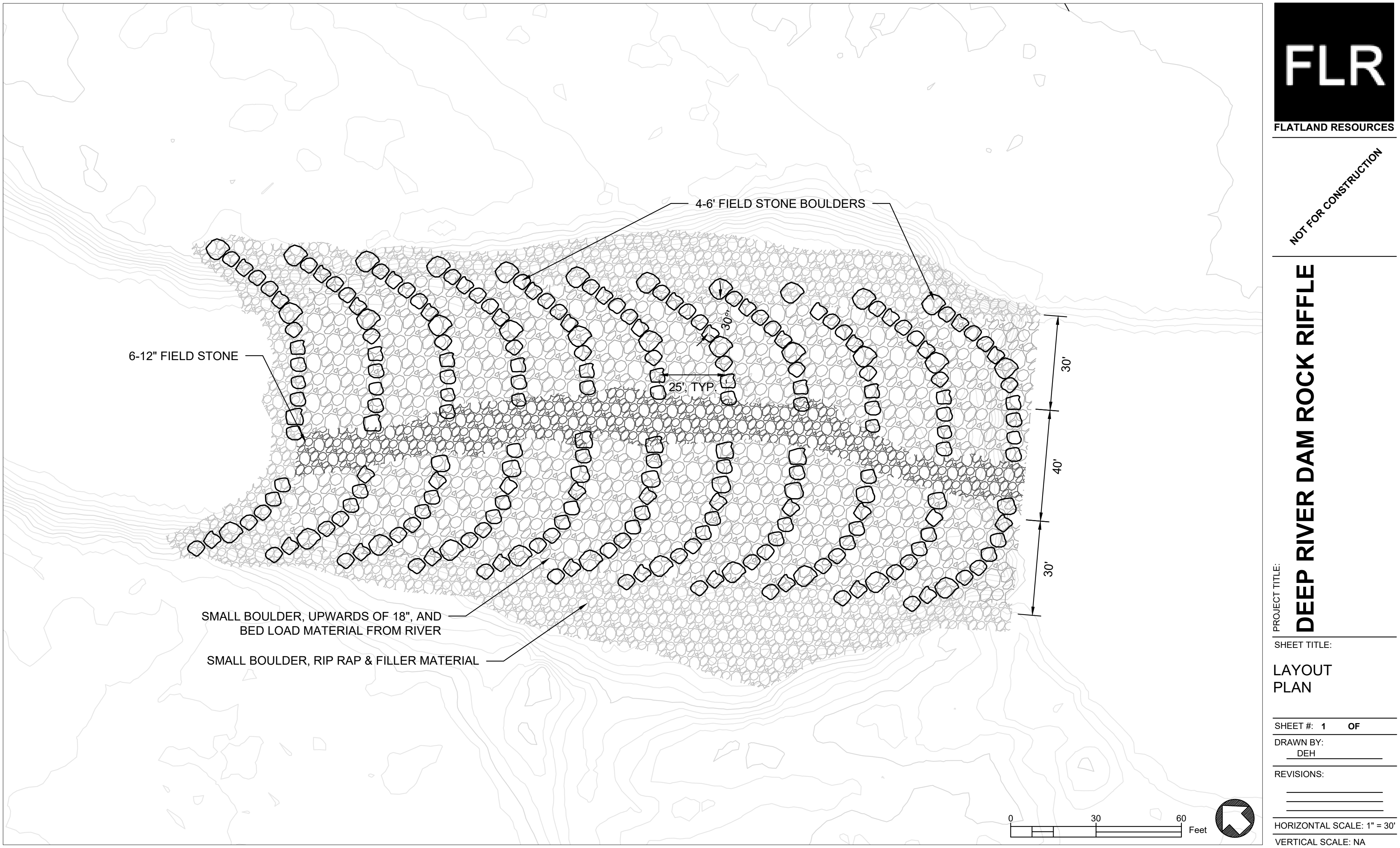
Red River
Grand Forks, ND
Low head dam
Installed in 2001
11 rows of boulders
~300’ long
5% slope
Cost: ~$750,000.00

Ciritical Component: Fish passage; Lake Sturgeon being the species considered most imporant

Cass River
Frankenmuth, MI
Low head dam
Installed in 2015
14 rows of boulders
~300’ long
5% slope
Cost: ~$3,500,00.00

Ciritical Component: Fish passage to and from Saginaw Bay; Northern Pike, White Sucker, Redhorse Suckers, Walleye, & Smallmouth Bass

6.3 **PRELIMINARY DESIGN**



6.4 **COST ESTIMATE**

FLR has developed cost estimates for the engineering, permitting, construction, and monitoring for the proposed rock riffle. Construction estimates are based on FLR's previous construction project experiences and current cost of materials. The estimates do not include increase in unit prices due to inflation or increases in fuel costs.

ITEM	DESCRIPTION	LOW END COST	HIGH END COST
1	ENGINEERING / PERMITTING	$ 30,000.00	$ 50,000.00
2	RIFFLE CONSTRUCTION	$ 975,000.00	$ 1,130,000.00
3	BANK RESTORATION/REVEGETATION	$ 25,000.00	$ 40,000.00
4	MONITORING	$ 10,000.00	$ 20,000.00
5	CONTINGENCY (20%)	$ 208,000.00	$ 248,000.00
	ESTIMATED TOTAL	**$ 1,248,000.00**	**$ 1,488,000.00**

POTENTIAL FUNDING PARTNERS

ENGINEERING/PERMITTING

Northwestern Indiana Regional Plan Commission (NIRPC)
IDNR LARE Program

CONSTRUCTION/MONITORING*

Northwestern Indiana Regional Plan Commission (NIRPC)
IDNR LARE Program
Northwest Paddlers Association
Great Lakes Restoration Initiative

*No organization has committed funds towards the project to date

6.5 **CONSTRUCTION TIMELINE**

FLR has developed a timeline, which if implemented, would address how the rock riffle would be designed and constructed. The construction would follow the construction timeline in Appendix A.2.

Engineering would begin in the fall of 2019, with the permitting to follow in the winter of 2020. Construction activities would have to be scheduled around two IDNR restrictions: 1) Tree removal between April - October for the Indiana Bat habitat, and 2) Fish spawning season (April - June). Any trees that have to be removed should be done so before April, and with the restriction of not working more than two consecutive days for fish spawning season, the earliest construction activities could feasibly start would be July.

As part of this timeline several assumptions have been made. First, it is assumes that all funding for the construction and monitoring phases of the project are in place. It is anticipated that NIRPC will pursue funding for the engineering and permitting through the IDNR LARE program. Second, the timeline does not assume any delays including, but not limited to, inclement weather (major floods, tornadoes, hurricanes, etc.), bidding delays, etc. that would disrupt the timeline proposed.


RC&D

A. APPENDICES

DEEP RIVER DAM | FEASIBILITY STUDY

DAM FACTS
- YEAR BUILT: 1930'S
- PURPOSE: BUILT BY ARMY CORP / RECREATIONAL
- HEIGHT: ~14'
- OVERFLOW WIDTH: ~100'
- DAM STYLE: SHEET PILING, TIMBER CRIB
- BACKWATER LENGTH: 6 -- 6.5 MILES
- SEDIMENT BEHIND DAM: ~1 MILLION CYS (±20%)
- ACTION PRIORITY FOR USFWS? NO
- ACTION PRIORITY FOR IDNR? YES

SUMMARY OF ANALYSIS
- HISTORY OF THE DEEP RIVER
- UNDERSTANDING RIVER DYNAMICS
- PUBLIC INPUT
- ECOLOGICAL ANALYSIS
- SEDIMENT SAMPLING/ANALYSIS
- EARLY COORDINATION W/ PERMITTING AGENCIES

WHY TAKE ACTION?

INCREASED SAFETY
- LOW HEAD DAMS CREATE DANGEROUS CURRENTS THAT CAN TRAP WATER USERS
- OVER 400 DEATHS HAVE BEEN RECORDED NATIONWIDE DUE TO LOW HEAD DAMS SINCE 1960
- https://goo.gl/1kb3Sr

RECREATIONAL ACCESS
- INCREASED FISH SPECIES AND QUANTITIES THROUGHTOUT RIVER REACH
- MILES OF RIVER OPENED TO CANOEING, & KAYAKING

INCREASED ECOLOGICAL DIVERSITY
- IMPROVED HABITATS CREATE HAVENS FOR DIVERSE FORMS OF FLORA, FAUNA, & AQUATIC SPECIES

INCREASED CULTURAL CONNECTIVITY
- GREATER SENSE OF CONNECTION WITH NATURE & THE ECOSYSTEMS SUPPORTED BY THE RIVER

ECONOMIC DRIVER
- RIVER RESTORATION/DAM MODIFICATION CAN DELIVER SHORT AND LONG TERM FINANCIAL GAIN FOR INDIVIDUALS AND THE COMMUNITY; FROM THE CONSTRUCTION CREWS TO THE SUSTAINED TOURIST REVENUE

DAM OPTIONS

OPTION 1 -- NO ACTION
- PROS: NO MONEY SPENT
- CONS: CONTINUED DETERIORATION OF DAM
  POTENTIAL FOR LARGE RELEASE OF SEDIMENT
  COMMUNITIES FORCED INTO ACTION
- WHY /WHAT?
  LACK OF DESIRE TO ACT BY DAM OWNER
  COST OF PROJECT BECOMES PROHIBITIVE TO ACT
  DAM FAILURE LIKELY TO PROGRESS SLOWLY

OPTION 2 -- FISH LADDER (DAM MODIFICATION)
- PROS: INCREASED FISH PASSAGE OPPORTUNITIES
  RELATIVELY CHEAP OPTION
- CONS: NO PASSAGE FOR BOATS/KAYAKS
  DOES NOT ADDRESS DETERIORATION OF DAM
- WHY/WHAT?
  MAINTAIN CURRENT BACKWATER POOL & WETLANDS
  TYPICALLY BUILT TO ONE SIDE OF DAM
  CAN BE MADE OF CONCRETE, AND OR STONE
  CREATING A BYPASS CHANNEL IS ANOTHER OPTION

OPTION 3 -- CONSTRUCTED RIFFLE (DAM MODIFICATION)

CHOSEN METHOD
- PROS: INCREASED FISH PASSAGE OPPORTUNITIES
  IMPROVE RECREATIONAL PASSAGE (KAYAKS, CANOES)
  PROVIDE STRUCTURAL SUPPORT FOR DAM
- CONS: NO PASSAGE FOR BOATS
- WHY/WHAT?
  MAINTAIN CURRENT BACKWATER POOL & WETLANDS
  LARGE BOUDLERS (3-5' DIA) PLACED IN 'ARC' SHAPE
  BUILT AT ~3-5% SLOPE
  SERIES OF 'FALLS & POOLS'

OPTION 4 -- DAM REMOVAL
- PROS: INCREASED FISH PASSAGE OPPORTUNITIES
  IMPROVE RECREATIONAL PASSAGE
  RESTORATION OF RIPARIAN CORRIDOR
  INCREASED RIVER HEALTH
- CONS: MOST EXPENSIVE OPTION
  ELIMINATION OF LAKE STATION CULTURE
- WHY/WHAT?
  ADD FLOODPLAIN BACK TO 37TH ST CROSSING
  (NO EFFECT ON 100 YEAR FLOOD MAP, HOWEVER)
  3 OPTIONS TO HANDLE SEDIMENT
  1) COMPLETE REMOVAL (MOST EXPENSIVE)
  2) PARTIAL REMOVAL (MODERATLEY EXPENSIVE)
  3) NO REMOVAL (LEAST EXPENSIVE)

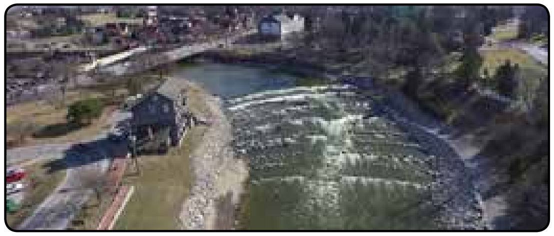
CONSTRUCTED RIFFLE

PERMITTING AGENCY FEEDBACK
- AGREE IN PRINCIPAL TO PROJECT APPROACH
- WILL VALUE PUBLIC INPUT DURING PERMITTING PROJECT
- PROJECT WILL BE FIRST OF ITS KIND/SCALE IN STATE

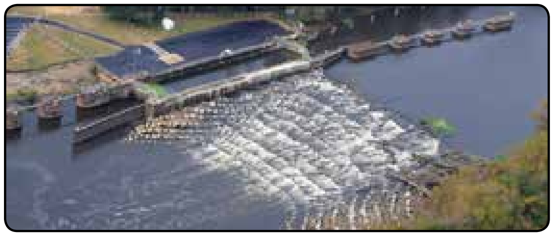
COST ESTIMATE

ENGINEERING/PERMITTING:	$30 - 50K
RIFFLE COSNTRUCTION:	$975K - 1.13 MIL
BANK RESTORATION:	$25 -40K
MONITORING:	$10 - 20K
CONTINGENCY (20%)	$200 - 250K
ESTIMATED TOTAL:	**$1.25 - 1.5 MIL**

PRECEDENT STUDIES



CASS RIVER | FRANKENMUTH, MI | FALL 2015



CAPE FEAR RIVER | RIEGELWOOD, NC | FALL 2012

RED LAKE RIVER | CROOKSTON, MN | FALL 2015

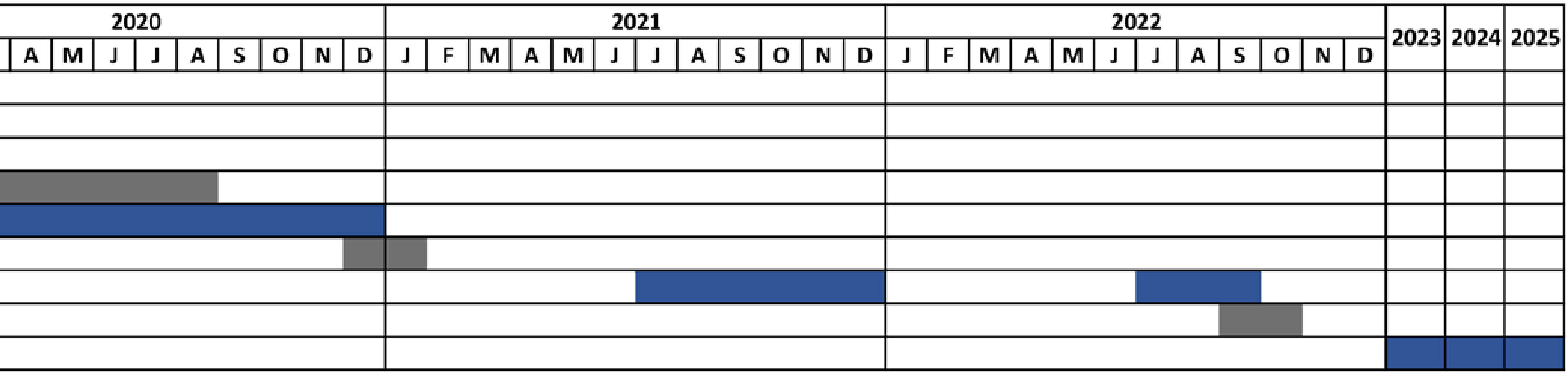
A.1 **PUBLIC HANDOUT**

A.2 **CONSTRUCTION TIMELINE**

DEEP RIVER DAM MODIFICATION

ESTIMATED ENGINEERING/CONSTRUCTION TIMELINE

		2018							2019														
ITEM	**DESCRIPTION**	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
1	COORDINATION BETWEEN NIRPC, LCRBDC, IDNR LARE																						
2	SUBMIT GRANT REQUEST FOR ENGINEERING TO IDNR																						
3	ENGINEERING/DESIGN SERVICES																						
4	PERMITTING																						
5	GRANT WRITING/SOURCE FUNDS FOR PROJECT																						
6	TREE REMOVAL																						
7	CONSTRUCT RIFFLE																						
8	BANK RESTORATION																						
9	MONITORING																						


2020
A M J J A S O N D
2021
J F M A M J J A S O N D
2022
J F M A M J J A S O N D
2023
2024
2025

A.3 **EARLY COORDINATION MEETING MINUTES**

DEEP RIVER DAM FEASIBILITY STUDY

EARLY COORDINATION MEETING

TIME:5/9/2018 11am CST
LOCATION: Deep River Dam

ATTENDEES:
USACOE -- Paul Leffler
IDNR FISH & WILDLIFE -- Sarah Ogden
IDNR LARE -- Doug Nusbaum
USFWS -- Elizabeth McCloskey
NIRPC -- Joe Exl
FlatLand Resources -- David Heilman

MEETING MINUTES:

1) David Heilman called the meeting to order at 11:10am
2) David Heilman introduced himself and began with a brief overview of the project
    a) IDNR LARE provided some funding for the project, in conjunction with NIRPC
    b) Why this study?
        i) Dam has poor structural integrity
        ii) IDNR has this dam ranked in top 25% of structures to be removed/modified per their internal ranking of all dams within the state
        iii) Action needs to be taken
            (1) Dam will soon be under ownership of the Little Calumet River Basin Development Commission making any action taken easier to coordinate
    c) Basic facts about the dam, and history of the river
    d) Four options of action for the dam:
        i) No action -- Dam will eventually fail, causing the owner to react to an emergency scenario
        ii) Fish ladder -- increase potential fish migration upstream of dam
            (1) Bypass channel -- increase potential fish migration upstream of dam as well as canoe and kayaking opportunities
        iii) Constructed rock riffle -- increase potential fish migration upstream of dam as well as canoe and kayaking opportunities
        iv) Remove dam -- most expensive but would create healthiest riparian corridor of all options considered
            (1) Don't do anything with sediment
            (2) Remove sediment where new alignment of channel would be
            (3) Removal of all sediment and bring in material to rebuild banks/floodplain
    e) FlatLand Resources will recommend a constructed rock riffle be built
        i) Maintains backwater pool, which is extremely important to residence of Lake Station
        ii) Creates opportunity to recreational and fish passage
        iii) Will not have to mitigate for loss of wetlands (~200 acres of wetlands are upstream of dam, and if the dam is removed, the water table will drop, these wetlands will disappear, and have to be mitigated for). This leads to additional costs and monitoring for the project
        iv) Minimal costs to meet goals of NIRPC and community of increasing recreational and ecological/biological health of river
        v) Rock riffle would extend about 300' downstream of the dam if built at a 5% slope
        vi) A project like this, on this scale would be new to the state of Indiana, and could set a precedent for future projects
3) What is the dam made of?
    a) Sheet piling along the width of the channel and wing walls, and rock & timber cribbing just downstream of the dam
4) What are some of the project aspects the permitting agencies will be looking at during the permitting process?
    a) USACOE
        i) Public input (so far, the public has rallied behind this approach)
            (1) It could aid the Corps if letters of support were submitted with the permit, showing a general public approval of the project
        ii) Will it be beneficial to aquatic species & fish passage?
        iii) What is in the sediment (we will have results of the sediment testing as a part of the final feasibility study, which will be shared with anyone who wants to see it)
    b) IDNR F&W
        i) Is design & slope of rock riffle is suitable for the fish species that would use it?
        ii) Ensure dam would not impede fish passage
        iii) What would the tree mitigation look like? (This would most likely be limited to construction access points, but would be finalized during the design/engineering process)
        iv) Are there any seasonal work requirements?
            (1) Can't cut down trees during bat habitat months (April -- Mid Oct)
            (2) Fish spawning season (April -- June). Cannot work for two (2) consecutive days
    c) USFWS
        i) How wide would the structure be? Would the eddy just downstream of the dam be backfilled with soil so that the rock riffle is built to bankfull width, or would it meet the existing edges of the channel?
            (1) This would come out in the design details
            (2) Partially based on what the DNR would allow (fill in the channel)

5) May be best for the success of the project to break out the engineering from the construction
    a) Engineering could possibly be funded through LARE in 2019
    b) Possible construction funding partners:
        i) LARE, NIRPC, LCRBDC, Northwest Paddling Assc., MS4, and GLRI
6) Permits required
    a) INDR CFW
    b) IDEM 401
    c) USACOE 404
7) Get IDNR biologists to do tagging studies of fish below and above dam before and after construction to understand what species, and how fast/far they are moving upstream
8) David asked if the agencies saw any major hurdles to getting this project through permitting
    a) All replied no, that there did not seem to be any glaring proposed issues with the project. There would be more questions and some back in forth with the agencies once the permits were submitted, which is to be expected.

David Heilman ended the meeting at 1215pm CST

A.4 **DNR REPORT -- DEEP RIVER DAM**

LOW HAZARD IN-CHANNEL DAM VISUAL INSPECTION REPORT
(Primarily non-embankment structures)

DAM NAME: HOBART DEEP RIVER DAM DATE: 2/8/2010 I.D.# 45-1

NEAREST TOWN OR LANDMARK: LAKE STATION COUNTY: LAKE

NW 1/4, NW 1/4, SEC. 24, T 36 (N)/S, R 8 E/(W) UTMN 4601482 UTME 475525

QUAD: GARY STREAM: DEEP RIVER

ACCESS NOTES: FROM I-65 EXIT 258, GO EAST ON 37TH AVE. TO LIVERPOOL Rd., THEN GO NORTH ≃ 3/4 MILE TO THE DEEP RIVER EDUCATION CENTER (SOUTH SIDE OF RIVER & WEST SIDE LIVERPOOL Rd.) TO ACCESS SOUTH END DAM. NORTH END ACCESS, GO ACROSS RIVER ON LIVERPOOL RD. & VEER NORTH ON OAK ST. AT "T" INTERSECTION WITH E. 29TH AVE. GO WEST TO END OF ROAD THEN SOUTH TO RIVER. DAM WILL BE ≃ 150' UPSTREAM.

OWNER'S NAME: GARY COMMUNITY SCHOOL CORPORATION & THE SMIT'S (1995) TELEPHONE: (219) 963-1579 FAX: (219) 980-6361

ADDRESS: 620 E. 10TH PLACE, GARY, IN 46402

OWNERSHIP HISTORY: ACCORDING TO AN 8/7/95 MEMO THE NORTH END IS OWNED BY LARRY & TRENA SMIT AND THE SOUTH END IS OWNED BY THE GARY COMMUNITY SCHOOL CORPORATION. THE SMIT'S OWN THE NORTH BANK DOWN TO THE WATERLINE & THE SCHOOL OWNS TO THE CENTERLINE OF THE RIVER.

DAM HISTORY HIGHLIGHTS: ACCORDING TO FILE MEMOS PAST INSPECTORS THOUGHT DAM WAS BUILT IN THE 1930's BY THE U.S. ARMY CORP OF ENGINEERS. NO PURPOSE FOR THE DAM COULD BE FOUND IN THE FILE.

DESCRIP. OF STRUCTURE: SHEET PILING ACROSS THE CHANNEL WITH LARGE RIPRAP & CONCRETE PLACED ON THE DOWNSTREAM SIDE FOR SUPPORT & ENERGY DISSAPATION.

LENGTH OF OVERFLOW: ≃ 100' TOTAL LENGTH: ≃ 150' OVERFLOW HEIGHT ≃ 14' TOP WIDTH N/A SHEET PILE WEIR

APPURTENANT WORKS: NONE

DESCRIP. OF ABUTMENTS: SANDY EARTHEN SOIL

FOUNDATION/ABUTMENT MATERIALS: ? LIKELY DUNE/BEACH MATERIAL.

- 1 -

FIELD CONDITIONS: COLD, ≃ 1" TO 2" SNOW COVER.

CONDITION OF OVERFLOW SECTION: SHEET PILING BADLY RUSTED OUT.

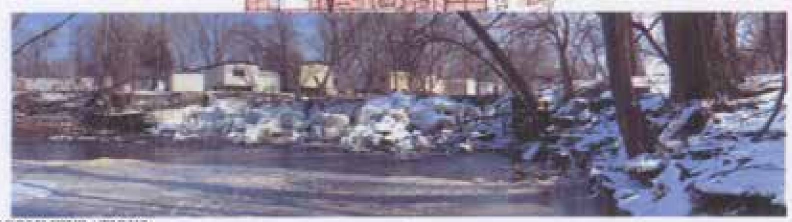
CONDITION OF ABUTMENTS: SHEET PILING BADLY RUSTED OUT. EROSION AROUND LEFT (SOUTH) END.

CONDITION OF APPURTENANT WORKS: NONE

MAINTENANCE: POOR

OVERALL CONDITION: POOR

SKETCH



RECOMMENDATIONS:

✓ CLEAR DEBRIS OFF OF STRUCTURE AS NEEDED.

__ REPAIR

__ HIRE A PROFESSIONAL ENGINNER TO DEVELOP RECONSTRUCTION PLANS

__ OTHER

INSPECTOR: Doug McKinney OWNER:

IMPORTANT: THIS REPORT NOTES THE OBVIOUS SURFICIAL CONDITIONS AT THE DATE OF THE VISUAL INSPECTION. WATER, DEBRIS, ICE, SNOW, ETC. FREQUENTLY COVER AND HIDE SERIOUS PROBLEMS WITH THESE DAMS. THE OWNER SHOULD OBTAIN A PROFESSIONAL ENGINEER EXPERIENCED IN DAMS OF THIS KIND TO MAKE A DETAILED INSPECTION AND EVALUATION OF THE ENTIRE STRUCTURE.

NOTE: ALTHOUGH FAILURE OF A LOWHAZARD IN-CHANNEL DAMS DOES NOT TYPICALLY PRESENT A SIGNIFICANT DOWNSTREAM FLOOD, THESE STRUCTURES ARE DANGEROUS DROWNING HAZARDS. THE OWNER SHOULD POST APPROPRIATE SINNAGE AND LIMIT ACCESS TO THE STRUCTURE TO PREVENT INJURY OR DEATH.

- 2 -

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