

GREAT MIAMI RIVER DAM REMOVAL FEASIBILITY STUDY

TROY AND PIQUA, OHIO

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FOREWORD

It has been stated that nationwide infrastructure of roads, bridges, utilities and similar structures are aging at a rate greater than the funds exist to make necessary repairs. Dams are a part of this aging infrastructure, and most cities, utilities, and private owners do not have ongoing maintenance plans or funding in place to maintain them. The typical life of a dam is 50 years, after this time major upgrades and repairs are needed to maintain the safe operation of the dam. The American Society of Civil Engineers has stated that 70% of the dams in America are 50 years or older (American Society of Civil Engineers, 2017).

A vast majority of dams are obsolete and without function; many are also without clear ownership, maintenance revenue means, or safe operation procedures. Dams are generally categorized as “low or high hazard”. Failure of low hazard dams could cause property damage, but not a loss of life.

Miami County, Ohio, has three dams. All are in the low hazard category as failure of any of the dams would not cause significant downstream property damage or the loss of life. The City of Troy owns the low-head dam within city limits, and the City of Piqua owns the former power plant dam in town. Both of these dams no longer serve any functional purpose, but the Piqua dam remains operational (adjustable floodgates) for flood protection purposes. The third dam, also owned by the City of Piqua, maintains the backwater pool for the city’s backup water intake. Therefore, this dam cannot be removed.

Troy’s low-head dam last underwent repairs in the late 1990s, and will require inspection and likely minor repairs within the next decade. Piqua is required to maintain the adjustable gates that control the water level in the dam’s backwater for flood control purposes. If these floodgates were to remain fully elevated during an extreme high water event, flooding would occur upstream. As the dam ages, minor repairs (which almost always require a large crane) occur more frequently. Costs can quickly accumulate, sometimes reaching more than \$100,000 yearly, due to the high expense of crane mobilization and operation. The water intake dam in Piqua is slightly more stable due to being shorter, but modification in the form of a constructed riffle could virtually eliminate future maintenance needs.

Loss of life around the river in Miami County is most likely to occur by drowning at one of the dams. Low-head dams create a churning backwash in which people become trapped, and drown, in the recirculating current. Ohio is one of the states with the most low-head dam related drownings over the last 70 years, with at least 18. In 2015, two brothers lost their lives at a low-head dam in Columbus. Two years later, three individuals lost their lives in Marion County, and just last year Sidney lost two of four individuals in a boating party when they went over the dam.

Miami County’s greatest natural resource is the Great Miami River. Most of the recreational opportunities available here either connect to or lie alongside the river, and the history of this region is inexplicably tied to the river. Cities across the nation are turning towards their rivers as the place to engage community recreation and new economic development. The Great Miami River Trail is an important characteristic of southwestern Ohio communities, and the people crave more access to the river itself. Many cities across the country are discovering the measurable economic gains of low-head dam removal in regard to recreation, both on the water and nearby. Access to the water’s edge is something many cities along the Miami are trying to prioritize, including Troy and Piqua.

Troy and Piqua already have extremely accessible riverfronts, by removing the dams they would reduce the drowning risk of tubing or kayaking in town and open up longer reaches of river to these recreators, not just observers or trail users. Removal of the dams in Miami County would also increase the wadable fishing reaches by several miles within city limits, making fishing even more widely accessible to the local population. Dam Removal will benefit the local tackle shops and fly fisherman, in addition to the biological gains of the local fish population.

Dam removal would also significantly benefit habitat connectivity for fish and invertebrate species within the Great Miami River. As dam backwater is eliminated, appropriate habitat for a wider variety of species is reopened, which results in more fishing opportunities, improved water quality, and a healthier ecosystem. Especially important are the positive impacts dam removal would have on endangered and threatened species such as the freshwater mussel and American eel.





FIGURE 0.0-1 | Treasure Island Lagoon



FIGURE 0.0-2 | Old Lock, Former Miami - Erie Canal



FIGURE 0.0-3 | Eldean covered bridge, located North of Troy



FIGURE 0.0-4 | Multi-use trail and former Miami-Erie Canal, Piqua



FIGURE 0.0-5 | Pedestrian bridge over Great Miami River, Piqua



FIGURE 0.0-6 | Kayakers on the Great Miami River



FIGURE 0.0-7 | Great Miami River, winter
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FIGURE 0.0-8 | Kayakers on the Great Miami River, Troy



FIGURE 0.0-9 | Fishing on the Great Miami River

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1. INTRODUCTION

1.1 RIVERS

As the purpose and function of many dams ceased in America, the river landscape has become dotted with defunct dams that have no societal benefit.

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 and irrigation 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, a river will eventually revert to a state of dynamic equilibrium. Left alone, rivers eventually and 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 (waterfalls) are a rare and wondrous exception in the landscape (Niagara 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 longer 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. Rivers have been used for transportation highways, power, irrigation, industrial cooling sources and sewer discharge points.

Rivers have been an important resource since the beginning of civilization, as evidenced by the locations of the world's largest and oldest cities. Settlement throughout North America has been no different. 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 camps and tribes.

Rivers remained an important mode of transportation during the westward expansion, when Lewis and Clark used waterways to explore the wilderness of the continent. As western European settlements moved further inland, water transportation routes were developed to supply the westward expansion. Railroads, and later automobile travel eventually negated the need for waterways as transportation; However, major rivers like the Mississippi and its tributaries like the Missouri and Ohio remain important to shipping routes across the middle part of the continent.

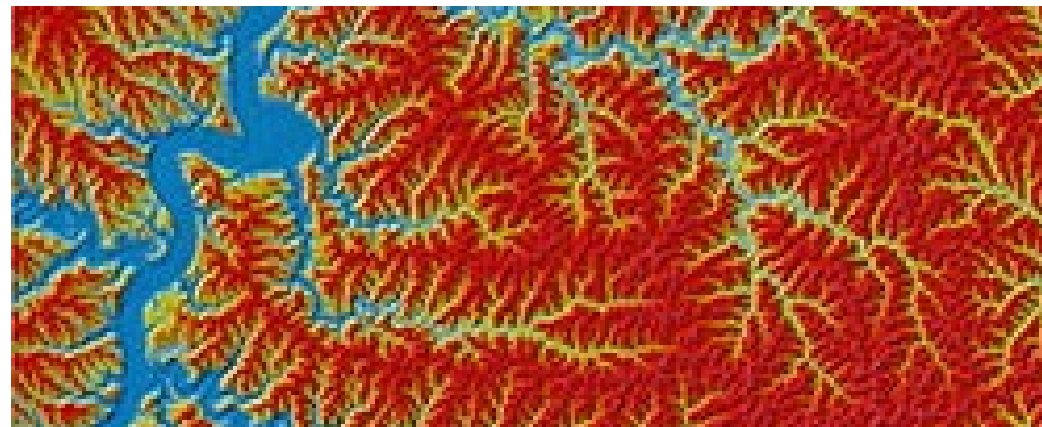


FIGURE 1.1-1 | River Fractal Patterns

1.1 RIVERS (cont.)

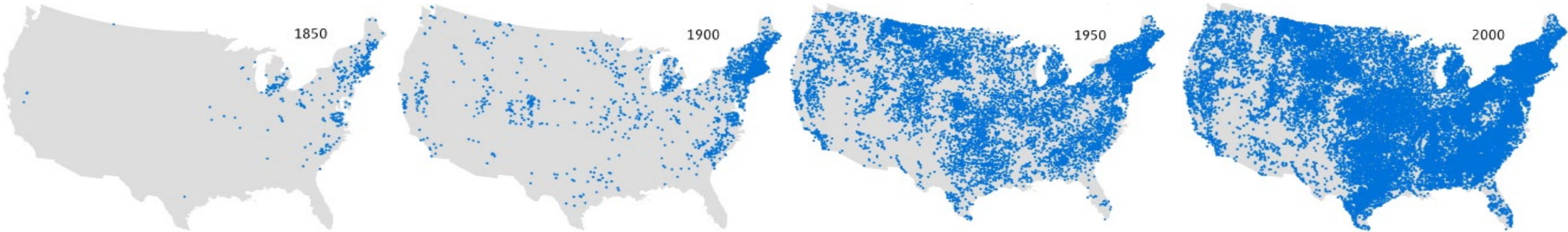


FIGURE 1.1-2 | Growth of U.S. Dams and Reservoirs (Syvitski & Kettner 2011)

The harnessing of rivers for power, industrial cooling, and water intake, in virtually all instances, requires the construction of a dam. Dams create pools of impounded water, which is then used to create head pressure to propel turbines, mills, or stored for cooling and irrigation.

The number of dams greatly increased between 1850 and 2000 (Fig. 1.1-3). 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 were demolished or repurposed, but the dams were left untouched, with no defined ownership or means of operation. Questions continue to surface as to the best future use, if any, of these dams.

Dam removal has become an emerging trend in the nation, beginning in the 1980’s, although there are records of dams being removed as early as 1918. There are many reasons why dams are removed today, but recent upticks in dam removal 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 rivers for canoeing and fishing.

Cornbelt states Illinois, Indiana, Iowa, Michigan, Minnesota, Ohio, and Wisconsin became river destinations in the Midwest throughout the 1970’s and into the early 1980’s due to the many

headwater streams located in each state, and the increasing population density of surrounding major cities. 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 time¹. Peak canoe sales were also tied to high fuel costs during the 1970’s energy crisis.

A resurgence in water paddle sports has been documented since the great recession of 2008, similar to the response during the 70’s energy crisis. As water recreation continues to be a growing trend, dam removal has been an increasingly examined topic. Recently, the social distancing required by our worldwide response to the COVID-19 pandemic has also increased the popularity of localized outdoor recreation, and rivers provide ideal locations for physical distancing while experiencing the benefits of nature and exercise.

Rivers are a significant driver of the American GDP. America’s “Outdoor Recreation Industry” values the expenses tied to travel, products, and services associated with outdoor recreation at \$887 Billion (Bie, 2017). This dollar amount is now being tracked by the Commerce Department as a result of the 2016 passage of the Outdoor Recreation Jobs and Economic Impact Act (Rec Act).

In addition to expanding the local and regional recreational economy, dam removals also provide monetary benefits by eliminating the cost of maintaining dams. Many dams are at least

50 years old, and are in dire need of significant repairs. In many cases, functionality (electricity production, flood control, etc) cannot be restored even with extensive repairs. Repairing a dam often costs up to three times as much as removal. Organizations such as American Rivers; Heinz Center for Science, Economics, and the Environment; The American Association of State Highway and Transportation Officials; Headwaters Economics; 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 for 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 careful evaluation, public input, and overall understanding of the issue.

In Miami County, the Piqua Power Plant dam is nearing the end of its lifespan, barring imminent major repair work. Troy’s low-head dam underwent major renovation work about 20 years ago, extending its lifespan by anywhere from 30 - 50 years. This report is a discussion of the proposed removal of these two dams. Additionally, the report will look at general reasons for dam removal (ecology, safety, recreation, and economics), national trends, and Ohio trends, before giving an in-depth history of the dams themselves, the general dam removal process, and specific approaches and costs for removing the two existing dams. Additionally, potential modification to the Piqua Water Intake dam will be explored.

¹ pineypaddlers.com

1.2 DEFINITIONS

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

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.

SMALL DAM

A constructed barrier with a structural height not exceeding 50 feet.

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: overshoot or undershot dams. While both impound water, the flow of the river is different.

OVERSHOT DAM

An overshoot 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 for industrial, flood control, irrigation or drinking water supply. Sometimes overshoot dams only impound water to create a larger body of water with no diversion (Fig. 1.2-1).

Some overshoot 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 overshoot dams do not have a way to release accumulated sediment from the storage reservoir.

In the Midwest, most overshoot dams used for irrigation, drinking water supply and industrial uses have a diversion structure near the location of the 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.

UNDERSHOT DAM

In contrast, an undershot dam is designed to release water with a great deal of head pressure near the toe or lower elevations of the dam. Undershot dams are most often used for power generation, but are also used for irrigation and drinking water supplies as well. Most undershot dams have a means of releasing reservoir accumulated sediment. (Fig. 1.2-2).

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. 1.2-3). Sediment dropout is common upstream of a dam due to the slowed velocity of water caused by the dam.

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.

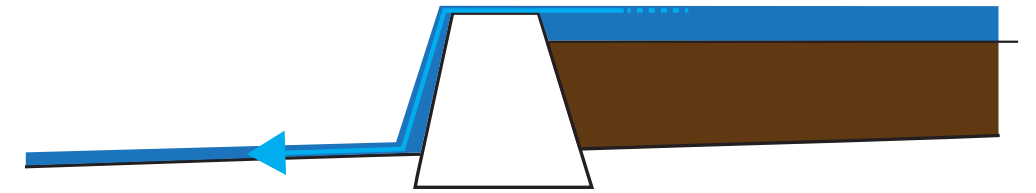


FIGURE 1.2-1 | Overshot Dam Diagram

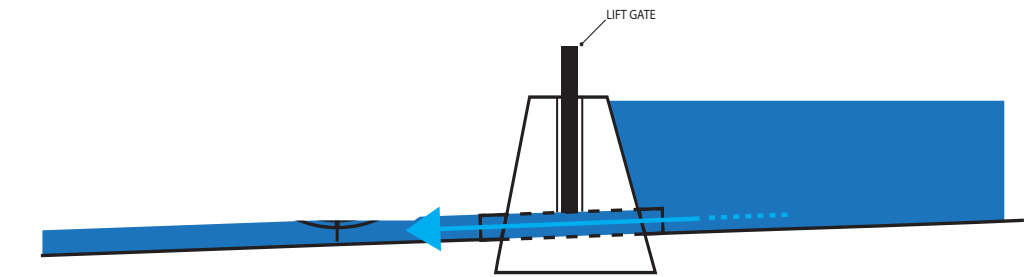


FIGURE 1.2-2 | Undershot Dam Diagram

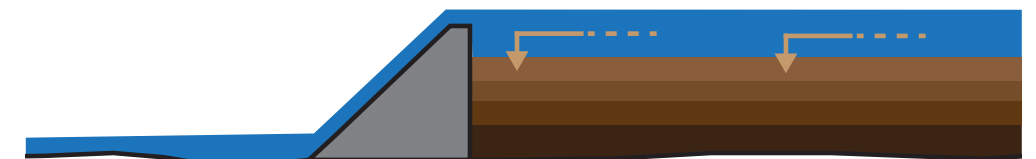


FIGURE 1.2-3 | Sediment Dropout Diagram

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 left bank is on the left. (Fig. 1.2-4)

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.¹ (Fig. 1.2-4,5)

¹ https://jornada.nmsu.edu/files/geomorph_terms.pdf

1.2 DEFINITIONS (cont.)

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. 1.2-5)

FLOOD-PRONE WIDTH

The stream width at which the discharge level is defined as twice the maximum bankfull depth. (Fig. 1.2-5)

POOL

An area of the stream that has greater depths and slower currents than riffles. The bottom of this area is comprised of fine materials. Pools are typically 5 - 6 times the length of the bankfull width (Fig. 1.2-4).²

RIFFLE

The bottom areas of the stream that are shallow and steep, composed of the coarsest materials. It's the area that controls the vertical drop of the channel bottom and also the area of the stream which creates the greatest amount of oxygen. It is located about every 5 - 6 times the bankfull width of the channel (Fig. 1.2-4).

THALWAG

A line connecting the lowest point of the channel.

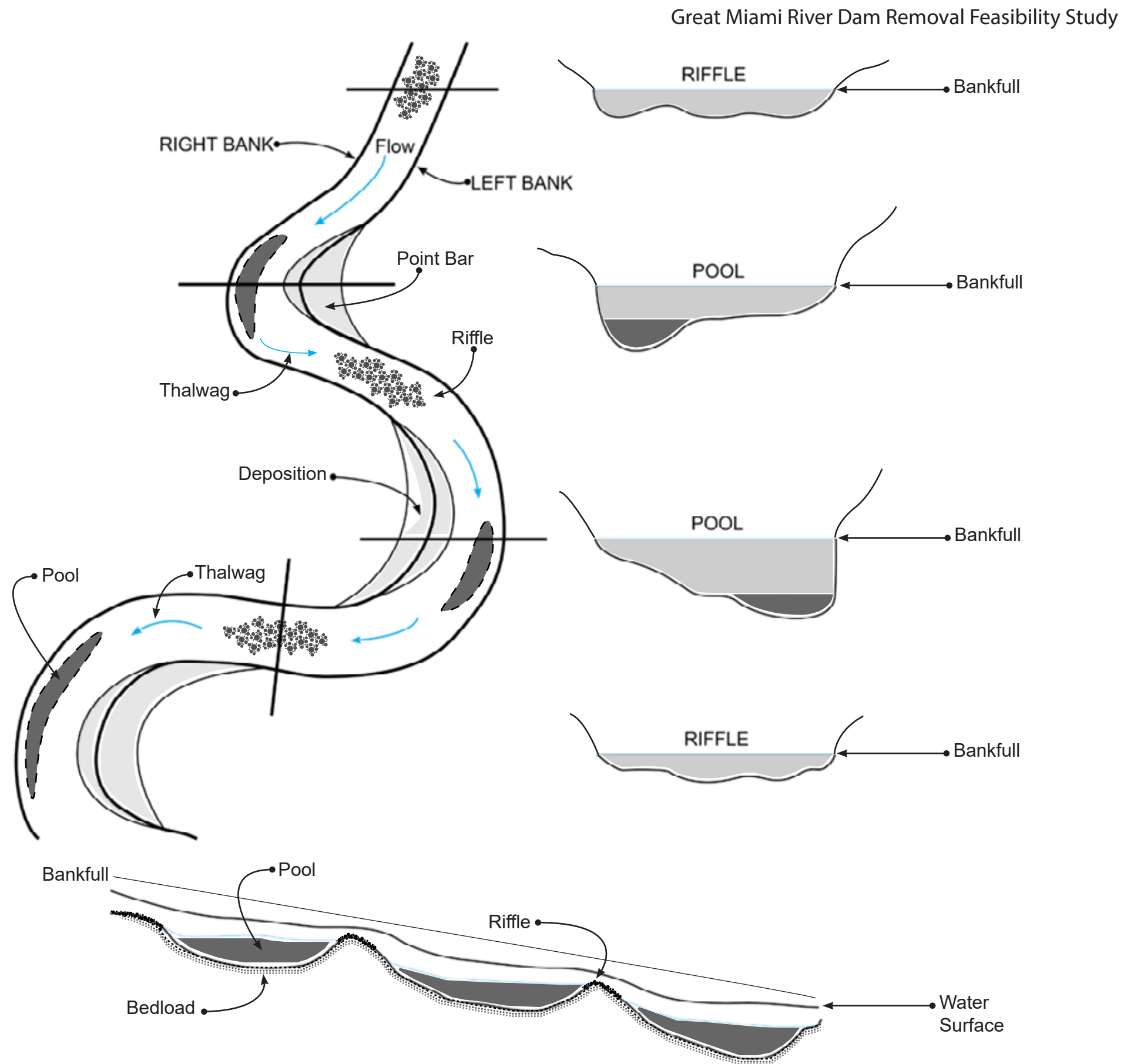


FIGURE 1.2-4 | Riffle-Pool Relationship Diagram

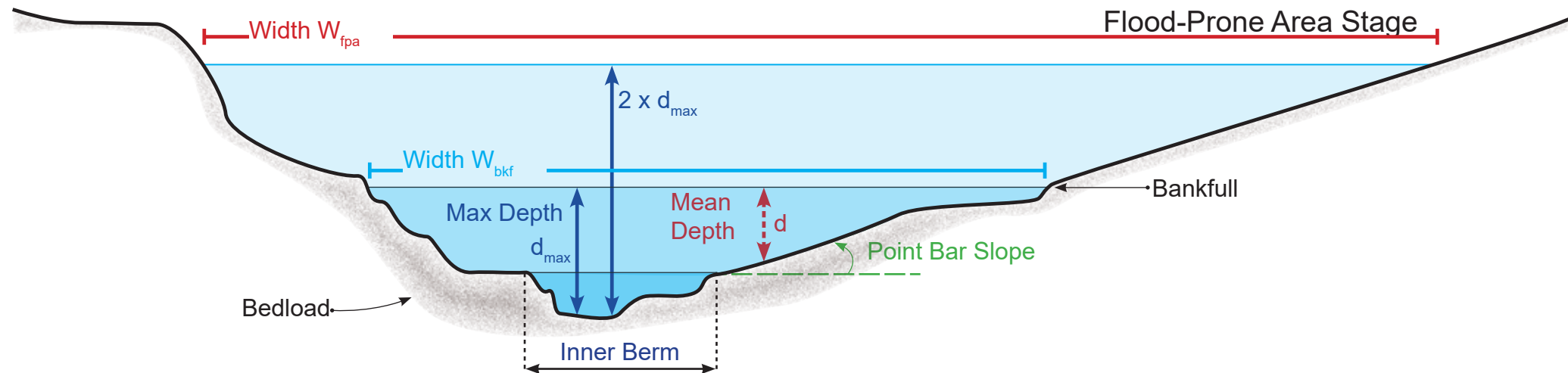


FIGURE 1.2-5 | Channel Dimensions

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 clear that bankfull is not any of these.

Bankfull is an elevation that occurs with enough annual frequencies that it creates a break in the landform and is repeatable and quantifiable. Bankfull measurements have been used to develop regressions based on drainage areas, and compared to cross-sectional areas of similar rivers.

Figure 1.2-6, shows the regional channel-dimension curves which are used for estimating bankfull-channel width and cross-sectional area (Fig. 1.2-5) of Ohio streams (Sherwood, Huitger). The Great Miami River is part of Region A.

HAZARD POTENTIAL RATING

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

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.

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.

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.

LEVEE

A levee is an elongated embankment, stopbank, naturally occurring ridge, or artificially constructed fill or wall, which regulates water levels. It is usually earthen and often parallel to the course of a river in its floodplain. Levees typically protect low lying areas from high water events of the river during certain flood events (Fig. 4.4-1).

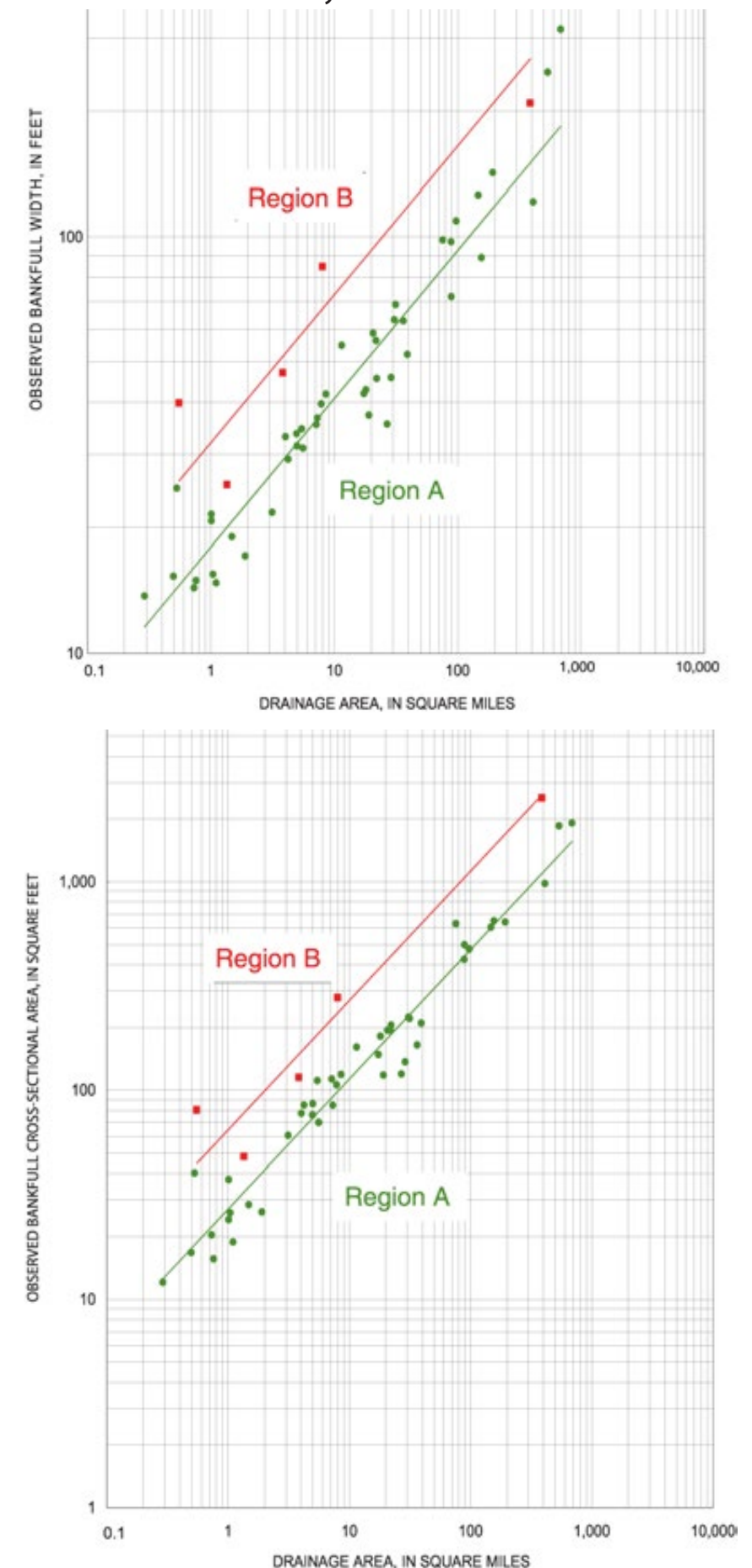
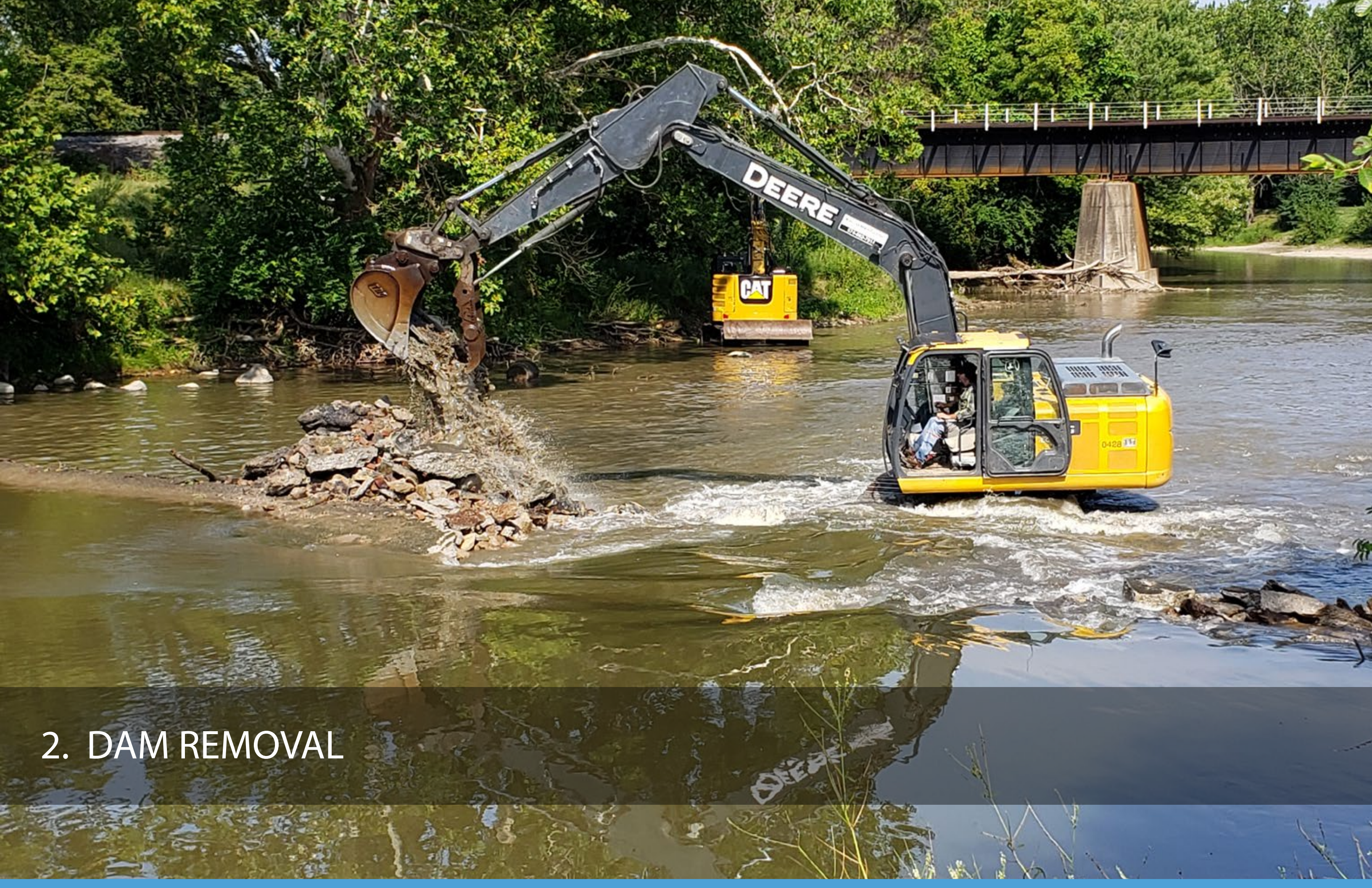


FIGURE 1.2-6 | Regional Channel-dimension Curves



2. DAM REMOVAL

2.1 REASONS FOR DAM REMOVAL

Research shows that dams can be removed for multiple reasons.

The five common reasons for dam removal are: ecology, safety, recreation, economics, and geomorphology. Individually, or in combination, these reasons may propel a community to remove a dam.

PROPOSONENTS

Deciding whether or not to remove a dam is not a simple task. Dam removal has both proponents and opponents. There are many proponents that favor dam removal 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, to both 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 and streambank 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 consistent revenue stream to fund the repairs, often opens the local discussion about dam ownership and safety. The Miami River in southwest Ohio is unique in that there is an extensive system of flood protection levees and “dry” dams throughout the watershed, all owned and operated by the Miami Conservancy District (MCD). The dams examined by this study are not operated by the MCD, but Troy’s low-head dam is within two of these levees, and much of the backwater of Piqua’s dam is within a leveed reach as well. Some of the dam back water areas within these reaches are without a levee toe or floodplain terrace. The lack of levee toes or bankfull benches alludes to fluvial geomorphic effects that translate into long term maintenance costs. When weighed in combination with dam repair costs, removal can quickly become a more cost effective approach than maintenance.

The following sections give a general look at each reason for dam removal (and gives examples of dam removal projects for each). Unauthorized dams (as a reason for removal) are not applicable to the dams looked at in this study and is not explored in the following section.



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.



ECONOMICAL

Many cities are removing 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. This generally causes the river to erode it’s banks, attempting to re-establish its equilibrium.

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 a 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. 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, lower growth rates, affect development, disrupt the natural food chain, and decrease diversity.

PAST WATER QUALITY STUDIES

The Ohio EPA has conducted various biological assessments on the Great Miami River in Miami County. Fish sampling, observation, and macroinvertebrate sampling has led the EPA to grade all free-flowing sections of the Upper Great Miami as Exceptional Warmwater Habitat. However, the impounded section of river behind the Piqua Power Plant Dam is graded as partially attaining Warmwater Habitat status (State of Ohio, 2009). This means that the impounded section of the river is significantly less suitable as habitat for marine animals than the free-flowing sections. The free-flowing sections of the Great Miami are among the cleanest, most vibrant riverine habitats in the State of Ohio.

HABITAT AND THE FOOD WEB

A habitat assessment is done because 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 physical habitat (stagnant water, lack of plant life, low oxygenation, etc.) 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. Examples of scrapers include: Water Penny, Snails, Flatheads, Riffle beetles, and Caddisfly larva.

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 Great Miami 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 by impounding water which reduces flow, increases sedimentation, and eliminates riffle habitat (Figure 2.2-1).

The free movement of a natural stream encourages genetic diversity of aquatic species; dams disconnect stream biological populations, limiting the genetic diversity. Additionally, the impounded sections of dammed rivers increase evaporation and pollutant accumulation, reduce available habitat and oxygenation levels, and inhibit the river's ability to adjust horizontally and vertically (See Figure 2.2-1). Ohio is home to several migrating fish (like American Eel) to whom 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 removal 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 Midwest Region Endangered Species list, maintained by the United States Fish and Wildlife Service (USFWS), maintains a list of endangered, threatened, and rare species by county in Ohio. The list

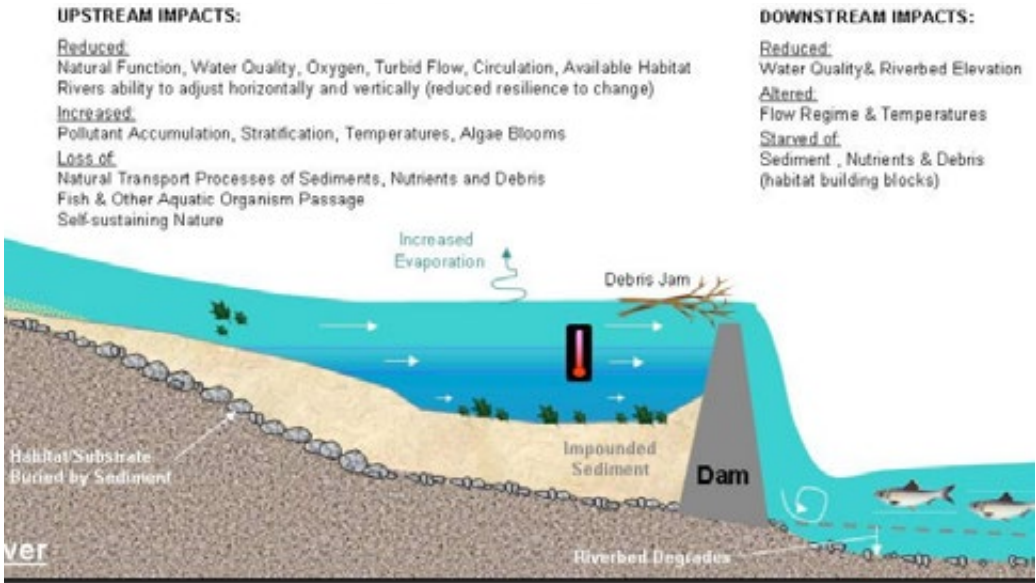


FIGURE 2.2-1 | Negative effects of a dam's backwater

ECOLOGICAL

includes both the federal and state status. Table 2.2-3 lists species that spend all or part of their lives in water and are endangered, threatened, rare, or of special concern in Miami county. Visit the USFWS website for a complete list of endangered and threatened species in each county.



FIGURE 2.2-2 | Water Penny Larva

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. A mixture of gravel, pebble, and cobble substrates with 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 essential macroinvertebrate communities (Neves & Angermeir 1990; Dynesius & Nilsson 1994; Tiemann et al. 2004).

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

TABLE 2.2-3 | Endangered and Threatened Species (excl. Birds & Mammals) in Miami County, OH (USFWS - August 2017)

Species Name	Common Name	Federal Status	State Status
Mussels			
<i>Villosa fabalis</i>	Rayed Bean	Endangered	Endangered
<i>Pleurobema clava</i>	Clubshell / Ohio Pigtoe	Endangered	Endangered
<i>Epioblasma triquetra</i>	Snuffbox	Endangered	Endangered
<i>Cyprogenia stegaria</i>	Fanshell	Endangered	Endangered
<i>Alasmidonta marginata</i>	Elktoe		Species of Concern
<i>Cyclonaias tuberculata</i>	Purple Wartyback	--	Species of Concern
<i>Lampsilis fasciola</i>	Wavy-rayed Lampmussel	--	Species of Concern
<i>Lasmigona compressa</i>	Creek Heelsplitter	--	Species of Concern
<i>Ptychobranchus fasciolaris</i>	Kidneyshell	--	Species of Concern
Fish			
<i>Etheostoma exile</i>	Iowa Darter	--	Endangered
<i>Etheostoma microperca</i>	Least Darter	--	Species of Concern
<i>Moxostoma carinatum</i>	River Redhorse	--	Species of Concern
<i>Hybognathus nuchalis</i>	Mississippi Silvery Minnow	--	Extirpated
Amphibians			
<i>Cryptobranchus alleganiensis alle.</i>	Eastern Hellbender (Salamander)	Species of Concern	Endangered
<i>Acris crepitans crepitans</i>	Eastern Cricket Frog (Frog / Toad)	--	Species of Concern
Insects			
<i>Catocala maestosa</i>	Moth	--	Special Interest

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 2001; 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).

Dams have been implicated as the leading cause of current-day decline in freshwater mussel populations in North America (Parmalee & Bogan 1998; Haag 2009). Dams 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 2007). 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 that occurs because of dams (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 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).

Freshwater mussels filter the water of a river by removing and storing toxins and other impurities as they constantly absorb and release the water of the stream. They are an essential part of the riverine ecosystem and provide a valuable ecological service, improving the quality of our drinking water by their very existence.

2.2 ECOLOGICAL (cont.)

American Eel

Once common throughout the eastern United States, the American eel in most of the Eastern and Ohio River Valley states has been extirpated as a result of dam construction, habitat degradation, and overfishing. Dams block the eel’s ability to migrate between their breeding grounds in the Sargasso Sea, as well as their feeding grounds in estuaries, fresh water lakes and streams (American Eel Conservation).

The life cycle of an eel is unique in that they are born in the ocean, live in freshwater streams, and return to the ocean to spawn and die. Once eels reach the Sargasso Sea (a region of the Atlantic just off the Eastern seaboard), a single female can lay over two and a half million eggs. The young eel in the larva stage are called leptocephalus, a flat transparent leaf like worm with a small pointed head and large teeth. These larva float in ocean currents for the first year of their lives, at which time the surviving members, known as the glass eel, move into the fresh, or benthic, water systems (American Eel Conservation). These become elvers as more color becomes present on the eel. The elvers become yellow eel, which is the immature American eel sexual adult. Yellow eel eventually become silver eel, the adult form. As the eel migrate into fresh waters, they feed on the bottom of the lakes or streams. They eat crustaceans and aquatic insects. Once mature, they return to the Saragossa Sea to lay eggs and die. The American eel live in fresh water systems for 10-25 years, depending on the length of their journey from the ocean and back, which can last many years and thousands of miles, making an eel’s entire lifespan upwards of 30-35 years (US Fish and Wildlife Service).

According to the Ohio Nature Conservancy, The Ohio Fish Commission (the predecessor to the Ohio Department of Natural Resources), once stocked Ohio rivers and streams with elvers for about a decade in the late 1800s. These efforts made eels common in Ohio until about 1910, when overfishing and an increase in the number of man-made obstacles began to take its toll on eel populations.

Eels are most likely to be found in moderate or large rivers with continuous flow and relatively clear water. They are nocturnal, and typically hide in large pools with lots of cover during the day, feeding at night using their acute sense of smell.

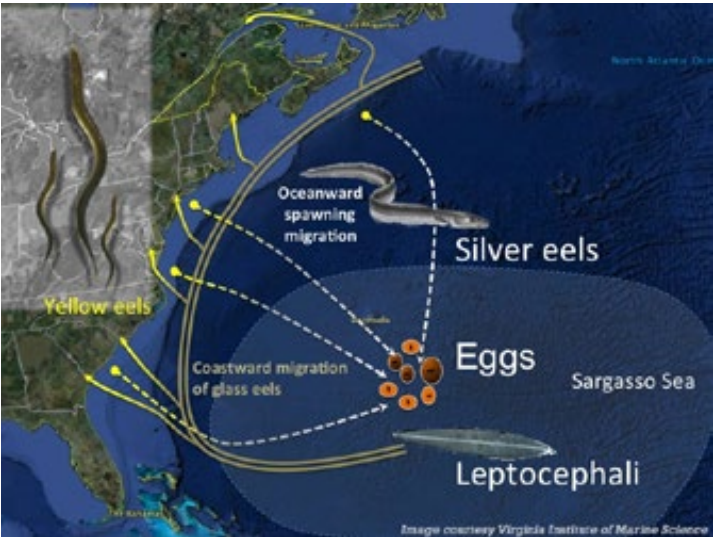


FIGURE 2.2-4 | Life Cycle of the American Eel



FIGURE 2.2-5 | American Eel caught in 2013 by the Muncie BWQ.

Exotic or Invasive Species

Impoundments, like the backwater of a low-head dam, in addition to being less suitable for native species habitat, are more likely to harbor and escalate the spread of invasive species (Poff et al. 2007; Johnson et al. 2008), specifically zebra mussels (Mackie 1995; Horvath et al. 1996; Allen & Ramcharan 2001; Smith 2014; Smith et al. 2015). This is of increased concern in the Miami River and in the rest of Ohio, as the lower Ohio River (downstream of Louisville) is already heavily infested with this invasive species. The zebra mussel is well known for its ability to attach to hard surfaces, and are economically devastating (Pimental et al. 2005; Nakano & Strayer 2014), recreationally, and biologically - especially in terms of their impacts on native mussels (Ricciardi et al. 1998; Strayer 2009). Zebra mussels thrive in warm waters with little flow, making the altered habitat upstream of impoundments ideal as “stepping stones” for population growth and recruitment, allowing downstream dispersal (Smith et al. 2015).

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; Gangloff 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 Ohio EPA’s long-term data on biological communities in the Great Miami River, pre- and post- dam removal, could be an essential contribution to the science of dam removal.

Over the last 30 years over 50 low-head dams in Ohio have been removed, some of which have been monitored pre- and post- dam removal by the Ohio EPA. Two removals near Delaware, Ohio resulted in an overall increase of invertebrate species of over 50%, and a 30% increase in fish species sampled after three years. Five of the species found following dam removal were pollution-intolerant fish species, a primary indicator of water quality improvement (State of Ohio, October 2013).

Full recovery and response of aquatic communities following dam removal is not immediate. Some studies have shown a temporary negative response likely due to initial sediment release and drop in water levels (Heise et al. 2013; Maloney et al. 2008; Orr et al. 2008). However, with appropriate planning, timing, and removal techniques, effects on aquatic communities’ fauna can likely be minimized (Heise et al. 2013). In the case of Troy and Piqua’s two low-head dams on the Miami River, gates or spillway pipes have been opened regularly for maintenance, helping to periodically flush out sediment. This results in less of a sedimented backwater pool than a typical low-head dam with no means of bypass.

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; Doyle et al. 2005; 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.

2.3 SAFETY

Low-head dams have the ability to produce dangerous recirculating currents, hydraulic jumps, and 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 these 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 sport popularity over this same time frame (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, repeating the process 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 can be impossible to escape.

Dams have resulted in an estimated 400 deaths since 1960 across the nation (Tschantz) with 50 occurring in 2016 and 2017 (Association of State Dam Safety Officials 2017). The Midwest, and many eastern states, have begun to push for dam removals for safety reasons. As counterintuitive as it might seem, experienced waterway users wearing life vests caught in the hydraulic jump often drown. 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 repeatedly slammed back into the dam 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. On the lower Great Miami River, a dam at Middletown collapsed in 1993, releasing sediment downstream and filling in the town’s efforts to widen the river for recreation. 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.

The NRCS, having 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). At least 1,680 of these dams are categorized as “high danger”, 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 its banks. Ohio has between 200 and 1,000 low-head dams, often in remote locations and on a mix of public and private property, making it difficult to regulate these structures. Many of these dams are inventoried by the State of Ohio, but a lack of funding to actually inspect them makes it impossible to do so on the intended five year intervals. The Prince’s Lake dam, located in central Indiana, failed in 2008 after it rained about an inch an hour for several hours. More recently, the collapse of Michigan’s Edenville dam raised awareness of the potential for loss of life and property due to dam failure. Removal of obsolete dams eliminates this safety concern.

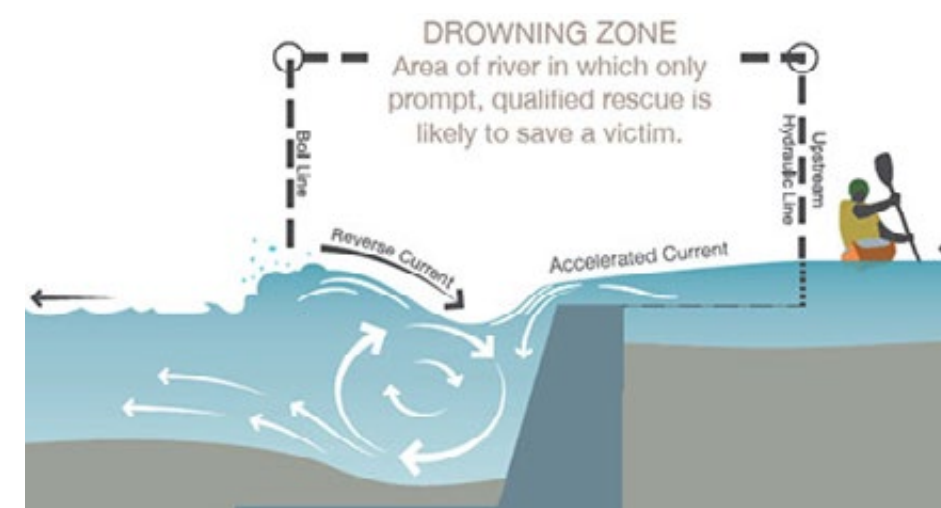


FIGURE 2.3-1 | Low-head Dam Safety, Iowa Department of Natural Resources.

SAFETY

2.4 RECREATION

Rivers have a calming presence. Their white noise reduces the sounds of cars, and they provide pastoral opportunities like fishing, wading, or observing the birds, fish, and other visitors. By investing in our waterways and their ecological health, we are ensuring the ability for current and future generations to enjoy the many recreational opportunities provided by the Great Miami River.

The ecology section described how dam removal will improve the aquatic habitat and therefore increase the populations and quality of fish and macroinvertebrates. The City of Piqua is currently in the latter stages of working to eliminate combined sewer discharges as part of an ongoing wastewater project. Troy has recently completed a similar project. These efforts will help to further improve aquatic health and result in a cleaner, more vibrant river as it pertains to wildlife and vegetation.

Recreation along the river includes passive contemplation, such as exploring the river’s edge or nature-watching; and active recreation, such as fishing, paddle sports, or tubing. Walking trails, public park space, and other improvements help promote a human connection with nature, but today’s fast-paced, technology-driven society distracts the passerby from his or her surroundings. Richard Louv recognized this disconnect between man and nature 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 so often experienced by urban-dwellers. Rivers often flow through urban areas, offering opportunities for large populations to rediscover nature, but many of these rivers are inaccessible to the people who live nearby. Dam removal increases the safety of those reconnecting with rivers, such as anglers, boaters, and explorers.

The Great Miami River has long served as an important regional asset for river recreation. However, dams limit the ability for kayakers and canoers to enjoy the river through urban areas. Large swaths of open river exist between urban centers, but paddlers are forced to portage around dams in Quincy, Sidney, Piqua, Troy, Vandalia, Dayton, West Carrollton, Middletown, and Hamilton. Rather than face a portage, many paddlers will just avoid these downtown areas entirely, a missed opportunity for regional visitors.

Paddle sports, including kayaking, canoeing and paddle boarding, have increased in popularity across the nation over the past 10 years. Consequently, the number of people participating in motor

sports (water-skiing, motorboating, etc.), has decreased, especially on rivers. Between 2006 and 2015 the Ohio DNR’s revenue from paddlesport registration fees increased by more than 50%, allowing for \$7 million in investments across the state such as small boat ramps, paddling publications and safety education programs (State of Ohio, 2016).

The Outdoor Foundation released a special report on paddle sports in 2015. In 2014, 7.4 percent 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. A renter typically signs a waiver form releasing the livery operator from any liability. The livery hands over a boat and paddles and off the novice goes into the water. This makes it increasingly important to educate the general public about hazards, and remove them when possible. Furthermore, many people who participate in watersports do so occassionally and must rent their equipment. Even some enthusiasts must rent, as canoes and kayaks take up a lot of storage space that some people don’t have.

RIVER’S EDGE

The river’s edge provides endless educational opportunities for citizens, especially children. Interaction with the river, whether from a trail along the river’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.

Often built with grants and other funding opportunities through ODOT, the Great Miami River Trail bike path is one of the most impressive pedestrian trails in the country. One can hike, bike, or paddle 99 continuous miles of open river (other than the dams) or paved multi-use paths through each of the bustling communities that call the banks of the Miami home. The MCD supports and helps to maintain this infrastructure along with individual communities and a slate of local and statewide organizations working to improve the trail and its surrounding assets.



RECREATION

The multi-use trail is built on top of what is called the “bankfull bench” of the Great Miami River. This part of the floodway is high enough above the normal water elevation to stay dry in a 2 yr frequency rain event (recently, these rain events have occurred on an annual basis). More importantly, part of this bankfull bench often serves as the toe of earthen levees intended to protect inhabited areas from flooding. In leveed reaches where near bank stress erosion occurs (erosion that affects the toe of the levee, brought on by brisk currents along the riverbank), a bankfull bench can sometimes be artificially constructed. This earthen bench would shift the bulk of the river’s current back towards the center of the channel and provide a reinforced barrier between the new thalweg and the previous river bank/levee toe. This new bench will then serve two functions, as it also makes this part of the river more naturalized and accessible to humans.



FIGURE 2.4-1 | Bike riders on the Miami River Trail in Troy.

LOCAL ACTIVITIES

In the past, Troy and Piqua have been known for their watersports, made possible by the increased river depth provided by their low-head dams. While an important part of the two town histories and culture, general participation in these activities have decreased over recent years. Furthermore, to maintain the necessary backwater depth, expensive dredging (which is no longer done) and dam maintenance activities are required. Without these maintenance activities the backwater will fill with additional sediment and continue to become too shallow for power or wind-driven watercraft. With a limited season and few access points for these larger watercraft to enter and exit the river, an increasingly smaller group of river users carry on this decades-old tradition.

Plentiful fishing opportunities exist along the Great Miami, and a wide variety of species are commonly found in the river; including smallmouth, largemouth, and spotted bass, white and rock bass, sunfish, and channel and flathead catfish (State of Ohio, 2009). As you get further North in the watershed (Miami County area), smallmouth bass become more and more common. Many people fish from the banks of the river, where they benefit from the access provided by the Great Miami Recreational Trail and the many public parks that dot the river’s shorelines. Some fishermen take small vessels onto the river, allowing for greater mobility. These boaters are able to access the river through the numerous small boat ramps and public spaces located along the river, many of which are maintained by local municipalities and trail partners.

The Great Miami Riverway also sponsors many events throughout the year intended to benefit the local communities and businesses along the river, spur community interaction, and promote the numerous recreational opportunities that the river and local parks provide. In June 2020, the Riverway sponsored an app-based fishing tournament for smallmouth bass. This socially distanced community event spurred from Barry Puskas of the MCD, and his realization that the Great Miami River is the best river in the state for smallmouth bass fishing. With some fish up to 24 inches long, the river is a popular destination for fly fisherman and anglers of all ages (Rutledge 2020). In 2020, the initial year of this month-long challenge, local anglers caught more than nine smallmouth bass bigger than 18 inches in length (Figure 2.4-2). The winner, Aaron H., caught the five largest fish during the month.

LOCAL IMPROVEMENTS

In order to capitalize on the river as a recreational resource, both Troy and Piqua have identified opportunities to make the river more accessible to their downtown environments (Figures 2.4-3, 2.4-4). A nationwide trend, riverside development, and additional park space have helped communities to attract younger families and couples of all ages to live in urban areas. Proximity to natural, recreational attractions has become a priority for many people, and both towns have an opportunity to provide this in their downtown spheres. Troy and Piqua will both be developing a new live-work environment in their riverfront and Lock Nine Park areas of the city, respectively.



FIGURE 2.4-2 | Smallmouth bass caught in the Great Miami River.



FIGURE 2.4-3 | Proposed improvements to Lock Nine Park, Piqua.



FIGURE 2.4-4 | Proposed Troy downtown riverfront development improvements.

2.5 ECONOMIC

Many cities are removing dams for the economic boost of 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 to, 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 are free flowing.

An additional factor that often drives the dam removal discussion is the long-term costs of rebuilding or maintaining aging low-head dams. In some cases, dam removal 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 can have an economic benefit to a community by increasing recreation and land development opportunities. Once a city removes a dam, greenbelts, river walks, housing, and offices are often developed next to the free flowing rivers. Vibrant communities and life-style amenities like free flowing 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 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). Data from studies across the country show that following dam removal paddle sports increase in popularity and anglers are happier because the fishing experience includes higher catch rates and improved species diversity.

As the health of American rivers continues to improve, commercial fishing guides and outdoor retailers/services benefit immensely. Oftentimes, even with larger dams, job growth in the outdoor industry will outpace job loss from dam maintenance/operations once a dam is removed.

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 (Investing in Place, 2014). In other words, the study concluded that 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.”²⁴

Americans placing a high priority on quality of life has also been 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, and good K-12 education often is as important today as wages, advancement, or stock options.” Tourism impacts extend beyond outdoor recreation. Tourism revenue comes 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.

PRECEDENTS

In 1999, the USACE released a draft feasibility report/environmental impact statement including an estimate of the economic effects of breaching (or removing part of) the four dams on the lower Snake River. Bioscience Magazine and ECONorthwest subsequently provided their own interpretations and expansions upon the ACOE report, highlighting a number of omissions and overlooked benefits and/or consequences of breaching these dams that were not considered in the USACE report.

The Snake River report, like a typical USACE dam removal study, uses the Principles and Guidelines developed by the US Water Resources Council in the 1970s, and last updated in 1983. These guidelines recommend that a cost-benefit analysis include the following socioeconomic factors for consideration:

- 1) National Economic Development (NED) effects, or a change in the output of goods and services on the national level.
- 2) Regional Economic Development (RED) effects, or a change in the distribution of regional economic activity such as jobs and income.
- 3) Environmental quality effects, or nonmonetary effects on natural and cultural resources; and other social effects.



According to the ACOE’s Environmental Impact Assessment however, “the NED account (1) is the **only** account required under the WRC (Water Resources Council) guidelines.” While economic effects were once paramount when it came to the analysis of a dam, social and ecological considerations are becoming increasingly important and not necessarily secondary to economic benefits (Whitelaw, Macmullen). According to the National Research Council (NRC), the Corp’s overall analytical approach should be modified to consider contemporary analytical techniques, changes in public values, and federal agency programs.

MIAMI VALLEY DAMS

The NRC recommends six principles to guide (Figure 2.5-1) the analysis of keeping or removing a dam. They are intended to ensure a broader, more inclusive approach in analyzing the impact of a dam on the surrounding region, as opposed to limiting focus to traditional, large-scale economic considerations. While these principles were developed primarily to consider removal of large, power-producing dams like those along the Snake River in the Northwest United States, they can be applied to smaller dams and dams with obsolete purposes as well.

For example, local expenditures related to dam maintenance and operation, while not a frequent concern in Troy, would steadily rise within the next 10-15 years as Troy’s low -head dam ages (last major construction - 1998). These expenditures would rapidly outpace construction costs for dam removal, which likely could be paid for through a variety of grants and state/federal programs.

Furthermore, the removal of Troy’s low-head dam would likely lessen the effects of erosion present along the city’s floodwall; as well as provide an opportunity to create a more stable bench at the base of that bank. The excessive width of the Miami through this stretch (double the natural bankfull width throughout the dam’s backwater) combined with the natural tendency of the river to migrate, has pushed the Miami’s natural thalwag up against Troy’s floodwall between the Adams St and Market St bridges.

By removing the dam, the river would be reduced to its normal bankfull width, allowing an opportunity to construct a naturalized bench along the existing floodwall to prevent erosion there. While an expensive initial investment, this earthen bench (and opportunity for a pedestrian walk), would outlast “patchwork” repairs currently utilized to maintain the levee toe and floodwall.

In Piqua, the gates utilized by the dam to control backwater level and flow must be maintained in working conditions, per MCD instructions, and require a great amount of capital to raise and lower the structures on a yearly, or sometimes more frequent basis. Furthermore, when a gate breaks a large crane needs to be mobilized in order to fix it, which incurs a significant financial cost. From a maintenance and public safety standpoint, the complex structure of Piqua’s unique dam is just not economically sustainable.

Dam removal isn’t just about savings when it comes to costs over time, rivers that are more “naturalized” tend to be more therapeutic for people and increase recreation on these waterways. In Troy’s Riverfront Development Plan, an increase in the population of young professionals has been identified as a driver for economic development. Traditionally, this demographic is more likely to participate in paddlesports, wade-fishing, and other watersports; and they will be attracted to communities that provide ample aquatic resources. In Muncie, Indiana, following dam removal, a significant increase in the number of people kayaking, fishing, tubing and wading has occurred. These waterway users sometimes purchase their tubes, kayaks, and fishing gear locally; and the asset of the river as a recreational resource helps to increase property values.

PRIMARY ANALYTICAL PRINCIPLES	SECONDARY ANALYTICAL PRINCIPLES
1) Benefits as well as costs Removing or keeping a dam would generate economic benefits as well as economic costs. Consider them both to understand the full effect on the value of goods and services derived from streams, forests, and other resources. 2) Positive as well as negative impacts on jobs Dealing with a dam would have both positive and negative effects on job opportunities. Consider them both to understand the full effect on workers, their families, and their communities.	3) Distribution of consequences and fairness Those who enjoy the benefits or jobs of a decision on a dam would not necessarily be the same as those who would bear the costs or job losses. Consider the full distribution of economic consequences to understand who wins, who loses, and the fairness of this distribution. 4) Rights and responsibilities With any decision on a dam, property owners and resource users behave differently than they otherwise would. Consider whether these changes represent infringement of their rights or enforcement of their responsibilities. 5) Uncertainty and sustainability Any decision on a dam would rely unavoidably on information insufficient to guarantee the outcome. Consider fully the potentially high costs from decisions yielding undesirable outcomes that are irreversible or extremely difficult to reverse. 6) More than just salmon (fish) conservation Removing or keeping a dam would have a variety of ecological and economic effects, such as changes in the quality of streamwater used for other purposes, that may seem peripheral. But consider all the effects.

FIGURE 2.5-1| NRC’s six principles to analyze dam removal. An exerpt from a 1998 letter by concerned economists regarding the economic issues of dam removal, salmon conservation, and local indigenous interests within the Snake River watershed.



2.6 GEOMORPHOLOGY

The Great Miami River has experienced many of the same anthropogenic hydro-modifications (i.e. dredging, straightening, levee construction, 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.

The detached oxbow immediately downstream of Troy's low-head dam is a perfect example of this (Figures 2.6-1, 2.6-2), although when first constructed there was an ability for floodwaters to reach the oxbow through a culvert. By replacing the culvert with an earthen levee, we have eliminated important habitat, increased the slope and velocity of the river's flow, and negatively affected the floodplain's capacity.

Although man may think it is possible to overtake natural rhythms of a river, time eventually reverses man's impacts. For example, any dam left alone over time, will be breached, by-passed, and/or the back water pool of the dam will be filled with sediment as the river returns to its dynamic balance.

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-moving while riffles are shallow and steep. The pools dissipate water speed while riffles control that gradient and increase water speed. Pools collect and release sediment with each high water event.

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 acts 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 this natural rhythmic pattern, creating unnaturally long pools, or landing pads, for sediment to dissipate, falling out of suspension as the water slows its velocity traveling through these "landing pads" (think of cleaning stairs; one has to clean/vacuum stair treads much more frequently than the stair risers). Through this process, the backwater of a dam collects sediment that would normally travel downstream. This slack water can become stagnant and store increased nutrients, chemicals, and minerals, 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, channelization, and/or re-routing, 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. 4.2-1). 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.

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 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 water's 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.

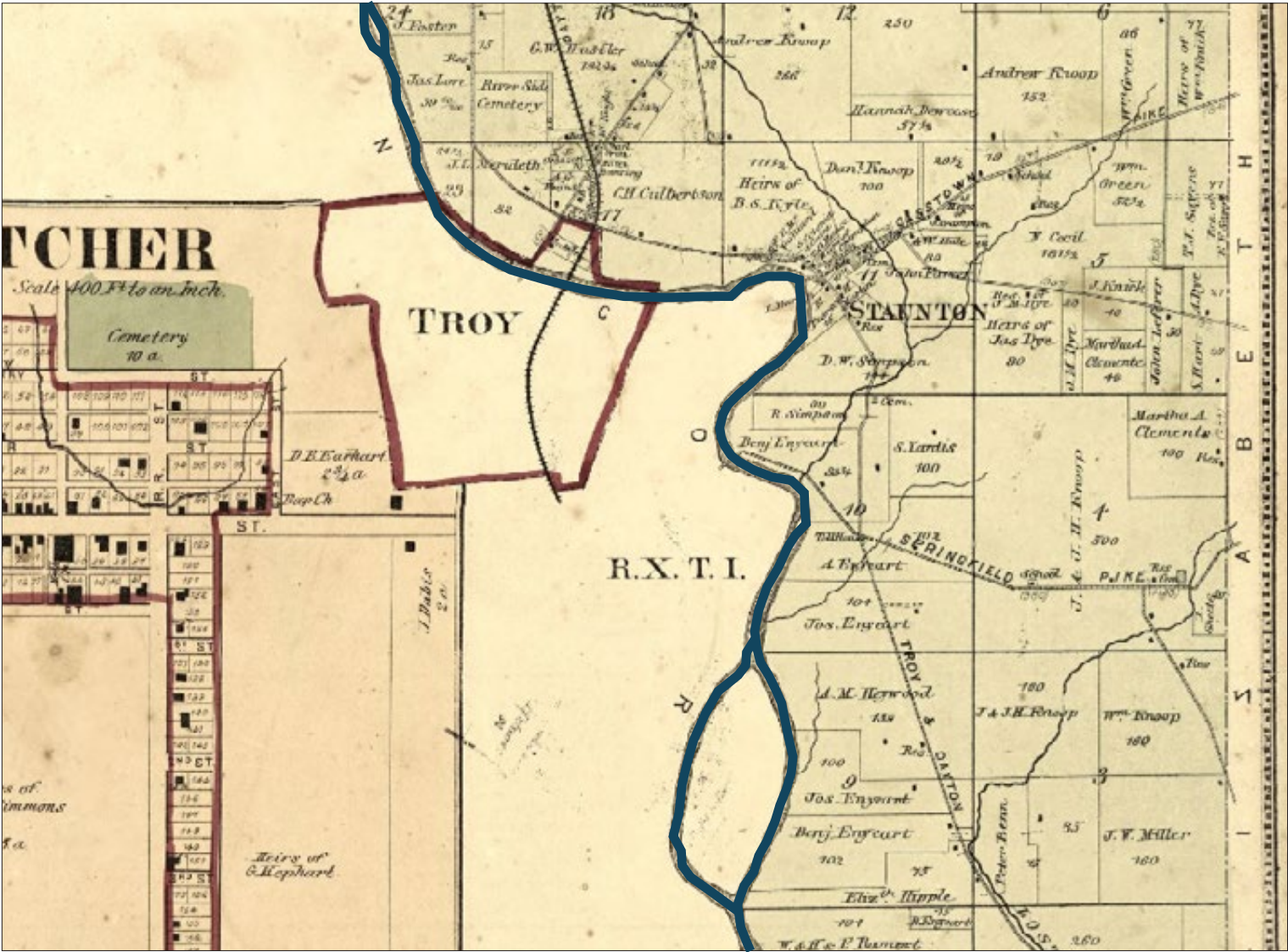


FIGURE 2.6-1 | Troy, Ohio. 1871.
Lake, D. J, et al. Atlas of Miami Co., Ohio. Philadelphia: C.O. Titus, 1871. Map.
Retrieved from the Library of Congress, <www.loc.gov/item/2008627035/>



FIGURE 2.6-2 | Troy, Ohio. 2018.
— CURRENT ALIGNMENT - GREAT MIAMI RIVER
— HISTORICAL ALIGNMENT - GREAT MIAMI RIVER

2.7 REMOVAL APPROACH

Complete removal of a dam is recommended for dams that no longer have an industrial function or benefit. It is the most economically sound and environmentally comprehensive solution as it eliminates the need for maintenance costs or liability due to risk of failure and drowning and, if done correctly, it restores the river to its natural state (Aadland 2010). There is almost always stream restoration needed after a dam removal, but this cost is significantly less than dam operation and maintenance. There are four options to removing a dam: an abrupt removal, incremental removal, dredging sediments before removal, or removal with river restoration (Aadland 2010). A fifth option is dam modification, or a constructed rock riffle.

ABRUPT REMOVAL

Abrupt removal with no restoration or sediment management is going to be the simplest form of removal. It is the least expensive and the only work involved is physically removing the dam; However it only works well if there is little accumulated sediment around the dam, or channel recovery rates will likely be rapid (Aadland 2010). Recovery rates for a channel depend on the type of sediment that would be released, stream gradient, hydrology, and the rate at which vegetation is likely to become established on deposited sediments. Heavy organic laden systems do not respond well to abrupt removal.

Abrupt removal often requires limited movement of the impounded sediment to prevent the stream from forming a mid-channel bar/ island as it works to re-establish it's equilibrium. The likelihood of this occurring is influenced by the amount of accumulated sediment in the dam's sediment-laden impoundment.

INCREMENTAL REMOVAL

Incremental removal of a dam suggests that the dam be removed over a period of several months or years. This diminishes the possibility of overwhelming the downstream channel with a more rapid sediment release and has the possibility to match the natural sediment transport capacity of the downstream channel (Aadland 2010). This method works best with dams that have predominantly fine sediment and little gravel. Larger materials cannot mobilize easily with incremental removals.

DREDGING

Dredging a reservoir or new stream channel prior to removal is recommended for dams with contaminated sediments. Dredging is the process of removing the accumulated sediment to reduce the negative effects of contaminated sediment as it washes downstream

when the dam is removed (Aadland 2010). This option is the most expensive, but in some cases the dredged material can be sold to offset the cost. Dredging without channel design and restoration does not always ensure stable channel morphology (Aadland 2010).

DREDGING AND RESTORATION

Removing a dam and then restoring the river after the dam is removed is probably the best method to ensure that the channel will recover (Aadland 2010). In some cases, abrupt removal without any dredging and/or restoration will result in the formation of a mid-channel sandbar, and increase future bank erosion (see Section 5.5).

The sediment that forms around the dam can be allowed to consolidate and vegetate while the channel is designed to use the sediment elevation to create a new floodplain. Constructed riffles, a topographic high point in a river that forms where the river bends, can help establish a new profile until the river reverts back to its natural state (Aadland 2010). Using this approach allows sediments to be stabilized, encourages a stable channel and diverse habitat, and advances the recovery process.

CONSTRUCTED ROCK RIFFLE

A constructed rock riffle is a dam modification technique that converts a low-head dam to a more natural drop in elevation, rapids. The dam is still in place, however its impact on the environment, aesthetics, and safety ratings are improved (Aadland 2010). Rock Arch Rapids are best suited for low-head dams; if it were applied to higher head dams, the quantity of materials might be too costly and stability of rapids would go down (Aadland 2010). The design works by creating a wedge on the downstream side of the dam with rocks and weirs. The wedge is usually constructed out of fieldstone, as it has proven to be stable, but not too angular and if the wedge is built at a slope of 7% or less, it allows fish passage over the dam and provides kayakers a way to pass over the dam without the risk of getting caught in a hydraulic roller (Aadland 2010).

This method requires the efforts of many to stabilize the riverbank around the rapids and to create the best shape for the Rock Arch Rapids, however, is considered to be one of the best options if a dam can't be removed and river restoration is a goal. It is a way to design a seemingly natural river that will aid in stabilizing the dam, cut down future maintenance costs, allow for the passage of native fish species, and lower the risks involved when using a river near a dam for recreational uses (Aadland 2010).



REMOVAL

2.8 CASE STUDIES

Hofmann Dam, Lyons, IL

Des Plaines River

Removed in 2012

Project Cost: \$ 2.5 Million

Height: 13'

Span: 258'

Type: Concrete Ogee Dam

Reason for Removal:

Fish passage

Safer recreation opportunities

Project Funding:

U.S. Army Corps

Illinois Department of Natural Resources

Project Included:

Removal of 150' of the dam (notched removal)

Removal of two older dam structures discovered during construction

Restoration of approximately 2,500 liner feet of stream bank

Installation of a culvert

Construction of a 12-foot wide asphalt path

Tree installation

Project Partners/Permitting Agencies:

Village of Riverside

Cook County Forest Preserve District

U.S. Army Corps

Illinois Department of Natural Resources

Illinois Environmental Protection Agency

Hofmann Dam River Rats

Observed Benefits:

Illinois DNR biologists observed an increase in the number of fish species found both upstream and downstream post dam removal



FIGURE 2.8-1 | Hofmann Dam before removal, March 12, 2012



FIGURE 2.8-2 | Hofmann Dam after removal



FIGURE 2.8-3 | Hofmann Dam before removal, April 7, 2017



FIGURE 2.8-4 | Hofmann Dam after removal

Armitage Dam, River Grove, IL
Des Plaines River
Removed in 2012
Height: 5’ + apron?
Span: 115’
Cost: \$ 400,000
Type: Concrete Ogee Dam

Reason for Removal:
Safety
Ecosystem improvements

Project Funding:
U.S. Army Corps
Illinois Department of Natural Resources

Project Included:
Removal of the dam

Project Partners/Permitting Agencies:
Forest Preserves of Cook County
U.S. Army Corps
Illinois Department of Natural Resources
Illinois Environmental Protection Agency

Observed Benefits:
Fish Passage
Elimination of a Safety Hazard



FIGURE 2.8-5 | Armitage Dam before removal.



FIGURE 2.8-6 | Armitage Dam after removal.



FIGURE 2.8-7 | Armitage Dam before removal.



FIGURE 2.8-8 | Armitage Dam after removal.

White Rock Dam, Stonington CT, and Westerly RI

Pawcatuck River
Removed in 2015
Project Cost \$ 1 Million
Height: 7.5’
Span: 130’
Type: Concrete
Watershed: 290 Square Miles

Reason for removal:
 Increase flood storage
 Improve river connectivity/fish migration

Project Funding:
 U.S. Fish and Wildlife Service (Superstorm Sandy recovery grant)

Project Included:
 Dam removal
 Closure of a millrace
 Channel work
 Bank stabilization
 Collection and Transplanting of mussels

Project Partners/Permitting Agencies:
 Connecticut Department of Energy and Environmental Protection
 Rhode Island Department of Environmental Management
 Rhode Island Historical Preservation and Heritage Commission
 Advisory Council on Historic Preservation
 U.S. Army Corps of Engineers

Observed Benefits:
 Elimination of a safety hazard
 Fish passage & aquatic biodiversity benefits



FIGURE 2.8-9 | White Rock Dam before removal, May 2015



FIGURE 2.8-10 | White Rock Dam after removal, April 2016



FIGURE 2.8-11 | White Rock Dam before removal



FIGURE 2.8-12 | White Rock Dam after removal

Liberty Mills Dam, Liberty Mills, IN

Eel River
Removed in 2012
Project Cost \$ 120,000
Height: 5’
Span: 115’
Type: Crib Dam
Watershed: 356 Square Miles

- Reasons for Removal:
- Obsolete / damaged
 - Safety
 - Fish passage
 - Improve recreational use
 - Watershed improvements

Project Funding:
Ohio River Basin Fish Habitat Partnership program
U.S. Fish and Wildlife Service

Project Partners/Permitting Agencies:
Manchester College
Natural Resource Conservation Service, Mississippi River
Basin Initiative

Project included:
Dam Removal
Post removal monitoring

Observed Benefits:
Natural riffle, pool complexes where forming, visible in two
new riffles
QHEI habitat scores increase 20% directly upstream of the
dam location
Increase in fish diversity upstream
An eastern sand darter (*Ammocrypta pellucida*) was
observed upstream of the dam for the first time since
removal.



FIGURE 2.8-13 | Liberty Mills Dam before removal, March 12, 2012



FIGURE 2.8-14 | Liberty Mills Dam after removal, 2016



FIGURE 2.8-15 | Liberty Mills Dam before removal, April 7, 2010



FIGURE 2.8-16 | Liberty Mills Dam after removal

North Manchester Dam, North Manchester, IN

Eel River
Removed in 2012
Project Cost \$ 120,000
Height: 6’
Span: 140’
Type: Concrete
Watershed: 419 Square Miles

- Reasons for Removal:
- Obsolete / damaged
 - Safety
 - Fish passage
 - Improve recreational use
 - Watershed improvements

Project Funding:
Ohio River Basin Fish Habitat Partnership program
U.S. Fish and Wildlife Service

Project Partners/Permitting Agencies:
Manchester College
Natural Resource Conservation Service, Mississippi River
Basin Initiative

Project included:
Dam Removal
Post removal monitoring

Observed Benefits:
Natural riffle, pool complexes where forming, visible in
three new riffles
QHEI habitat scores increase 20% directly upstream of the
dam location
Increase in fish diversity upstream



FIGURE 2.8-17 | North Manchester Dam before removal, March 30, 2005



FIGURE 2.8-18 | North Manchester Dam after removal, August 23, 2013



FIGURE 2.8-19 | North Manchester Dam before removal.



FIGURE 2.8-20 | North Manchester Dam after removal

Fawn River Fish Hatchery Dam, Orland, IN

Fawn River
Removed in 2018
Project Cost \$ 320,000
Height: 11’
Span: 188’
Type: Earthen Dike
Watershed: 88 Square Miles

- Reasons for Removal:
- Obsolete / damaged
 - Safety
 - Fish passage
 - Improve recreational use
 - Watershed and ecosystem improvements

Project Funding:
Lakes and Rivers Enhancement Program, IDEM
U.S. Fish and Wildlife Service Fish Passage Program

Project Partners/Permitting Agencies:
Indiana DNR
Town of Orland
Indiana Department of Environmental Management (IDEM)
National Register of Historic Places

Project included:
Dam Removal
Silt/Sediment Removal from backwater
Streambank Restoration
Installation of in-stream structures

Observed Benefits:
Increase in fish diversity
Elimination of safety hazard
Signs of historic wetland returning to natural state



FIGURE 2.8-21 | Fawn River Fish Hatchery Dam before removal.
April 23, 2017



FIGURE 2.8-22 | A check dam was used to dewater the dam's backwater
as the earthen portion of the dam was removed.



FIGURE 2.8-23 | Former backwater of the Fawn River Dam, following
removal, March 15, 2018.



FIGURE 2.8-24 | Former dam backwater after seeding has
begun to establish itself, June 19, 2018.

Fox Farm Road Dam, Warsaw, IN

Tippecanoe River
Removed in 2017
Project Cost \$ 80,000
Height: 3'
Span: 29'
Type: Concrete
Watershed: 177 Square Miles

Reasons for Removal:

- Obsolete / damaged
- Safety
- Fish passage
- Improve recreational use
- Watershed improvements

Project Funding:

- Lakes and Rivers Enhancement Program, IDEM
- National Fish Passage Program, USFWS

Project Partners/Permitting Agencies:

- City of Warsaw
- Center for Lakes and Streams, Grace College
- Indiana Department of Natural Resources
- Indiana Department of Environmental Management (IDEM)

Project included:

- Dam Removal
- Post removal monitoring

Observed Benefits:

- Elimination of a hazard to waterway users
- Increase in fish diversity upstream
- Elimination of Tippecanoe River diversion into Center Lake



FIGURE 2.8-25 | Fox Farm Road Dam before removal, July 25, 2018



FIGURE 2.8-26 | Initial dam breach during removal process. August 10, 2018.



FIGURE 2.8-27 | Concrete and rebar is piled next to former dam location following removal. August 14, 2018.



FIGURE 2.8-28 | Fox Farm Road dam after removal. August 15, 2018

West Milton Dam, West Milton, OH

Stillwater River
Removed in 2012
Project Cost \$ 1,500,000
Height: 13’
Span: 150’
Type: Concrete Low-Head Dam
Watershed: 356 Square Miles

- Reasons for Removal:
- Obsolete / damaged
 - Safety
 - Fish passage
 - Improve recreational use
 - Watershed improvements

Project Funding:
Ohio River Basin Fish Habitat Partnership program
U.S. Fish and Wildlife Service

Project Partners/Permitting Agencies:
Ohio DNR
Ohio EPA
USFWS - Fish Passage Program
Village of West Milton

Project included:
Dam Removal
Bank Restoration
Freshwater Mussel relocation
Post removal monitoring

Observed Benefits:
Increase in fish diversity upstream



FIGURE 2.8-29 | Algae blooms due to nutrient loading upstream of the existing West Milton Dam



FIGURE 2.8-30 | The West Milton Dam is breached, or lowered 3 feet, to gradually release silt and save mussels upstream.



FIGURE 2.8-31 | Freshwater Mussels are harvested for relocation after breaching the West Milton dam.



FIGURE 2.8-32 | West Milton Dam after removal

Indiana Steel & Wire Dam Removal, Muncie, IN

White River
Removed in 2019
Project Cost \$ 72,000
Height: 4'
Span: 140'
Type: Concrete Rubble Masonry
Watershed: 227 Square Miles

- Reasons for Removal:
- Obsolete / damaged
 - Safety
 - Fish passage
 - Improve recreational use
 - Watershed improvements

Project Funding:

- Indiana Lakes and Rivers Enhancement Program (LARE)
- U.S. Fish and Wildlife Service Fish Passage Program
- Community Enhancements, Inc.

Project Partners/Permitting Agencies:

- Indiana Department of Natural Resources
- Indiana Department of Environmental Management
- Army Corps of Engineers
- City of Muncie
- Community Enhancements, Inc.
- USFWS

Project included:

- Dam Removal
- Post removal monitoring

Observed Benefits:

- Natural riffle, pool complexes have formed
- Increase in fish diversity upstream
- Increase in local aquatic recreation in and around the site



FIGURE 2.8-33 | Indiana Steel & Wire Dam before removal.
March 16, 2017



FIGURE 2.8-34 | Indiana Steel & Wire Dam during removal.
August 19, 2019



FIGURE 2.8-35 | Former Indiana Steel & Wire dam site following removal
September 16, 2020



FIGURE 2.8-36 | Riffle upstream of former dam, exposed following dam removal. September 16, 2020

George Dale Dam, Muncie, IN
White River
Removed in 2019
Project Cost \$ 96,500
Height: 8’
Span: 120’
Type: Concrete Sloped Weir
Watershed: 229 Square Miles

Reasons for Removal:
 Obsolete / damaged
 Safety
 Fish passage
 Improve recreational use
 Watershed improvements

Project Funding:
 Indiana Lakes and Rivers Enhancement Program (LARE)
 U.S. Fish and Wildlife Service Fish Passage Program
 Community Enhancements, Inc.

Project Partners/Permitting Agencies:
 Indiana Department of Natural Resources
 Indiana Department of Environmental Management
 Army Corps of Engineers
 City of Muncie
 Community Enhancements, Inc.
 USFWS

Project included:
 Dam Removal
 Post removal monitoring

Observed Benefits:
 Natural riffle, pool complexes have formed
 Increase in fish diversity upstream
 Increase in local aquatic recreation in and around the site



FIGURE 2.8-37 | George R. Dale Dam (McCullogh Park) prior to removal. March 15, 2017.



FIGURE 2.8-38 | The formerly clogged spillway pipes were cleared prior to removing the center of the dam.



FIGURE 2.8-39 | The ends of the concrete dam were left in place, to maintain stability of the levee toe.



FIGURE 2.8-40 | Former site of the George R. Dale dam October 2, 2019

White River Sewer Interceptor Modification, Muncie, IN

White River
Constructed Riffle built in 2019
Project Cost \$ 90,000
Height: 6’
Span: 100’
Type: Concrete Box Culvert
Watershed: 243 Square Miles

Reasons for Removal:

- Safety
- Fish passage
- Improve recreational use
- Watershed improvements

Project Funding:

- Indiana Lakes and Rivers Enhancement Program (LARE)
- U.S. Fish and Wildlife Service Fish Passage Program
- Community Enhancements, Inc.

Project Partners/Permitting Agencies:

- Indiana Department of Natural Resources
- Indiana Department of Environmental Management
- Army Corps of Engineers
- City of Muncie
- Community Enhancements, Inc.
- USFWS
- Muncie Sanitary District

Project included:

- Construction of a rock riffle
- Post modification monitoring

Observed Benefits:

- Increase in fish diversity upstream
- Increase in local aquatic recreation in and around the site



FIGURE 2.8-41 | Boulders are piled near dam prior to modification.
October 3, 2019.



FIGURE 2.8-42 | An excavator is used to construct the riffle.
October 10, 2019.



FIGURE 2.8-43 | Completed constructed riffle. October 10, 2019.



FIGURE 2.8-44 | Completed constructed riffle. October 11, 2019.

Olentangy River, Delaware, OH
Olentangy River
6 dams removed between 2004 and 2010
Project Cost \$ 120,000
Height: 5’
Span: 115’
Type: Concrete Low-head Dams
Watershed: 432 Square Miles

- Reasons for Removal
- Obsolete / damaged
 - Safety
 - Fish passage
 - Improve recreational use
 - Watershed improvements

- Project Funding:
- City of Delaware
 - Delaware County General Health District
 - Preservation Parks
 - Ohio Scenic Rivers
 - Ohio EPA - WRRSP Program

- Project Partners/Permitting Agencies:
- Ohio EPA, DNR, ODOT

- Project included:
- Dam Removal
 - Pre and Post removal monitoring
 - High Quality Habitat protection (conservation easement)
 - Home septic replacement
 - More stringent stormwater requirements for construction

- Observed Benefits:
- Increase in fish species biodiversity and addition of pollution intolerant fish species
 - Elimination of drowning risk from dams
 - Increase in macroinvertebrate diversity
 - Achievement of full warmwater habitat aquatic life use designation (WWH) following dam removal. Prior to removal all sites were at non- or partial- WWH designation



FIGURE 2.8-45 | Dennison Dam before removal, 2003.

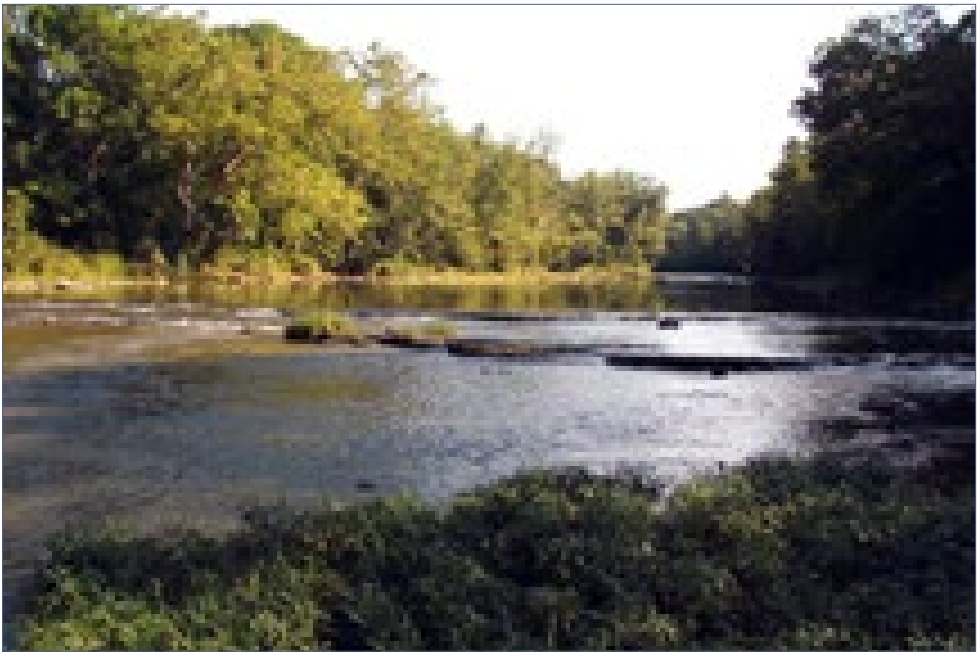


FIGURE 2.8-46 | Dennison Dam after removal, 2005.



FIGURE 2.8-47 | Central Avenue Dam before removal, 2007



FIGURE 2.8-48 | Water is diverted around a low-head dam in Delaware during removal.

Fifth Avenue Dam Removal, Columbus, OH

Olentangy River
Removed in 2013, Restoration completed in 2014
Project Cost \$ 6,900,000
Height: 6’
Span: 140’
Type: Concrete
Watershed: 537 Square Miles

- Reasons for Removal
- Obsolete / damaged
 - Safety
 - Fish passage, Water Quality & Aquatic Habitat
 - Improve recreational use
 - Watershed improvements / River Restoration

- Project Funding:
- Ohio EPA
 - The Ohio State University
 - Friends of the Lower Olentangy Watershed
 - City of Columbus

- Project Partners/Permitting Agencies:
- Ohio EPA
 - USACE
 - ODNR
 - OHPO
 - US Fish & Wildlife
 - ODOT

- Project included:
- Design and Permitting
 - Dam Removal
 - Freshwater Mussel relocation
 - River and Wetland Restoration
 - Pre and Post removal monitoring

- Observed Benefits:
- Restored waterway and wetlands
 - Increased aquatic biodiversity



FIGURE 2.8-49 | 5th Avenue Dam before removal, October, 2011.



FIGURE 2.8-50 | Removal of the 5th Avenue Dam begins. August 30, 2012.



FIGURE 2.8-51 | Former site of 5th Avenue dam.



FIGURE 2.8-52 | Former Site of the 5th Avenue dam following restoration.



3. DAM REMOVAL TRENDS

3.1 NATIONAL REMOVAL TRENDS

In the 1980's, the number of dams being removed started to increase. Dam removal is still common today. It is estimated that between 1995 and 2005, more than 600 dams were removed.

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 1,605 dams have been removed since 1912; ninety-nine were removed in 2018 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 generally left over from a time past. Often neglected, removal of these dams is more economical than maintaining them.

A study by American Association of State Highway & Transportation Officials (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 3.2-2).

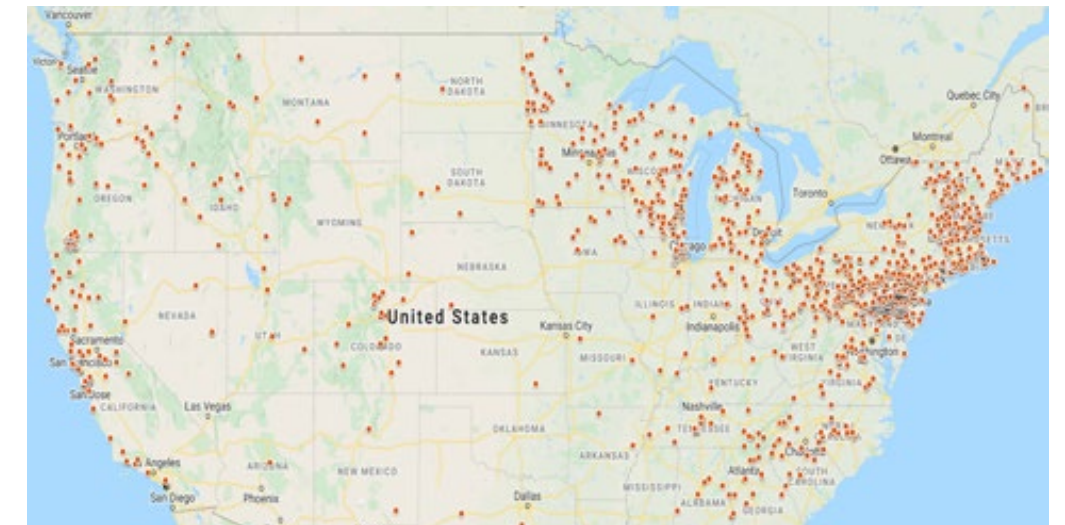


FIGURE 3.1-1 | Dam Removal Projects Since 1916.
Generated from American Rivers Data.

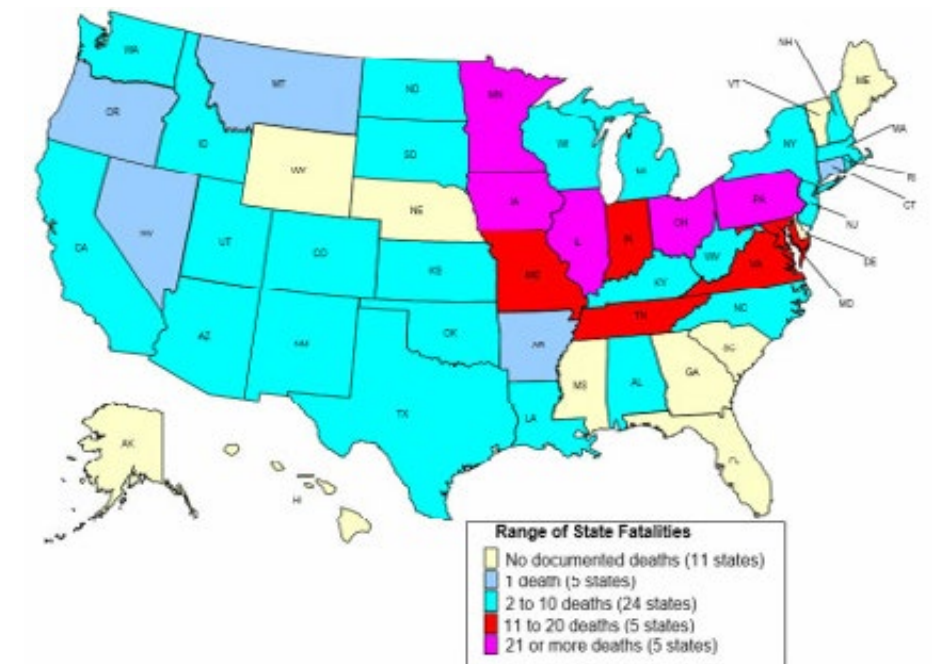


FIGURE 3.1-2 | State Distribution of Fatalities
350 total deaths at low-head dams from 1960s-Aug 2015,

3.2 OHIO REMOVAL TRENDS

The Great Miami River originates at Indian Lake, which was originally a 640 acre region of smaller lakes and wetlands fed by the North and South forks of the Miami River, Blackhawk Run, and Van Horn Creek. In 1860 work was completed on the levee and spillway, forming the 6,334 acre lake we see today. Initially called “Lewistown Reservoir”, Indian Lake served as the water source for the Miami-Erie Canal, connecting Toledo and Cincinnati (See Map 4.3-1). The canal did not remain an important source of transportation, but the lake remained as an important tourist attraction, easily accessible via railroad beginning in the late 1800s. It was officially renamed Indian Lake in 1898, and became an official state park with the advent of the Ohio Department of Natural Resources in 1949.

The main stem of the Great Miami River begins at the spillway for Indian Lake, and is obstructed by seventeen dams (not including the spillway): eight in Montgomery County (Dayton); one each in Shelby, and Logan Counties; three in Miami County (Troy & Piqua); and four in Butler County (Hamilton & Middletown) (Figure 3.3-3).

Ohio is estimated to have between 200 and 1,000 low-head dams. It is difficult to determine exactly how many due to several factors. Many of these dams are located in remote locations, on private land, or have simply been abandoned with no record of ownership to be found. Although the Ohio Department of Natural Resources inspects over 350 dams a year, inspections are not required for most low-head dams because they don’t meet the minimum size requirement. This means that a vast majority of Ohio’s dams are not overseen by any governmental agency, and any removal or modification efforts must be undertaken by private landowners or community organizations. As of 2014 only three states had laws regulating public safety at and around low-head dams; Pennsylvania, Illinois, and Virginia (Low-Head Dams: Danger Below).

The Association of State Dam Safety Officials has compiled extensive data on low-head dam associated deaths and encourages the removal of dams whenever possible to save lives.

Ohio has 14 recorded fatalities related to low-head dams, among the highest in the nation. Although there are a plethora of reasons for dam removal, stories like the two brothers who perished in Columbus’ Olentangy River in July 2015 seem to be the most likely reasons for people to support dam removal. Columbus had removed several dams in the city, and put up warning signs around others, but it wasn’t enough. Unfortunately, two brothers lost their lives near a low-head dam on the Olentangy River in Columbus (Low-Head Dams: Danger Below).

Ohio, as a whole, has removed at least 81 dams since 1973 (American Rivers). Most of these projects are funded in part by the Ohio EPA, DNR, USFWS, and other government agencies, but the burden of dam removal projects is almost always on local non-profit organizations or municipalities. Fortunately, many communities in Ohio today are learning to take action before tragedy strikes.

Thanks to efforts from the Ohio River Foundation, the Ohio EPA’s Water Resource Restoration Sponsor Program, and many local cities and municipalities more and more low-head dams are removed from Ohio’s rivers every year. These projects eliminate dangerous drowning hazards and improve water quality and fish habitat. Proponents hope to bring back species that have been largely eliminated from their natural habitats, like lake sturgeon, which were spotted in the Sandusky River for the first time in decades following a dam removal there.

On the Great Miami there have been two dam removals on the river itself, and at least five on tributaries to the Great Miami, two of which occurred on the Stillwater River (Englewood Reserve, 2009 and West Milton, 2014). On the Lower Great Miami River, the City of Middletown (Butler County) removed the Middletown Hydraulic Dam in 1993, formerly used to impound water for nearby factories. In 2018, the Tait Station dam in Dayton was removed and a constructed water feature was built for watercraft users.

In Miami County, the West Milton Dam was removed in 2014, with restoration efforts concluding in 2015. The dam was removed with the help of the USFWS WRRSP program, Ohio EPA, Ohio DNR, US Army Corp of Engineers, and the Stillwater River Watershed Council; at no cost to the city of West Milton.

Just north of Columbus, the City of Delaware, located on the Olentangy River, has removed seven low-head dams with financial assistance from the Ohio EPA and other agencies. The Olentangy Watershed Alliance has spearheaded many of these efforts, resulting in the repopulation of many pollution-intolerant species; a direct indicator of improved water quality. Additionally, this project sought to replace or remove 126 failing septic systems and protect over 200 acres of high-quality riparian and headwater areas by either easement or acquisition.

In Columbus itself, the Fifth Avenue dam was removed in 2012 as part of a large project to remove several of the city’s dams along the Olentangy river. This removal is part of a large movement to remove dams, restore the river’s natural floodplain, and improve the safety of water users.

Prior to the removal of Delaware’s low-head dam structures and the additional conservation work, the four Ohio EPA monitoring sites in and around the city were not in attainment of the river’s warmwater habitat designated aquatic life use. The fish (Index of Biological Integrity; IBI) and macroinvertebrate (Invertebrate Community Index; ICI) communities were not up to Warmwater Habitat standards, and the physical habitat (Qualitative Habitat Evaluation Index, QHEI) conditions were relatively poor (State of Ohio, 2009). Following dam removal, all of these evaluative scores increased for the Olentangy. Fish communities improved enough to achieve warmwater habitat standards, with two of the four test sites qualifying for exceptional warmwater habitat status. The macroinvertebrate (ICI) scores improved the most, 40% or more at some sites, and the quality of habitat (QHEI) increased at every test site.

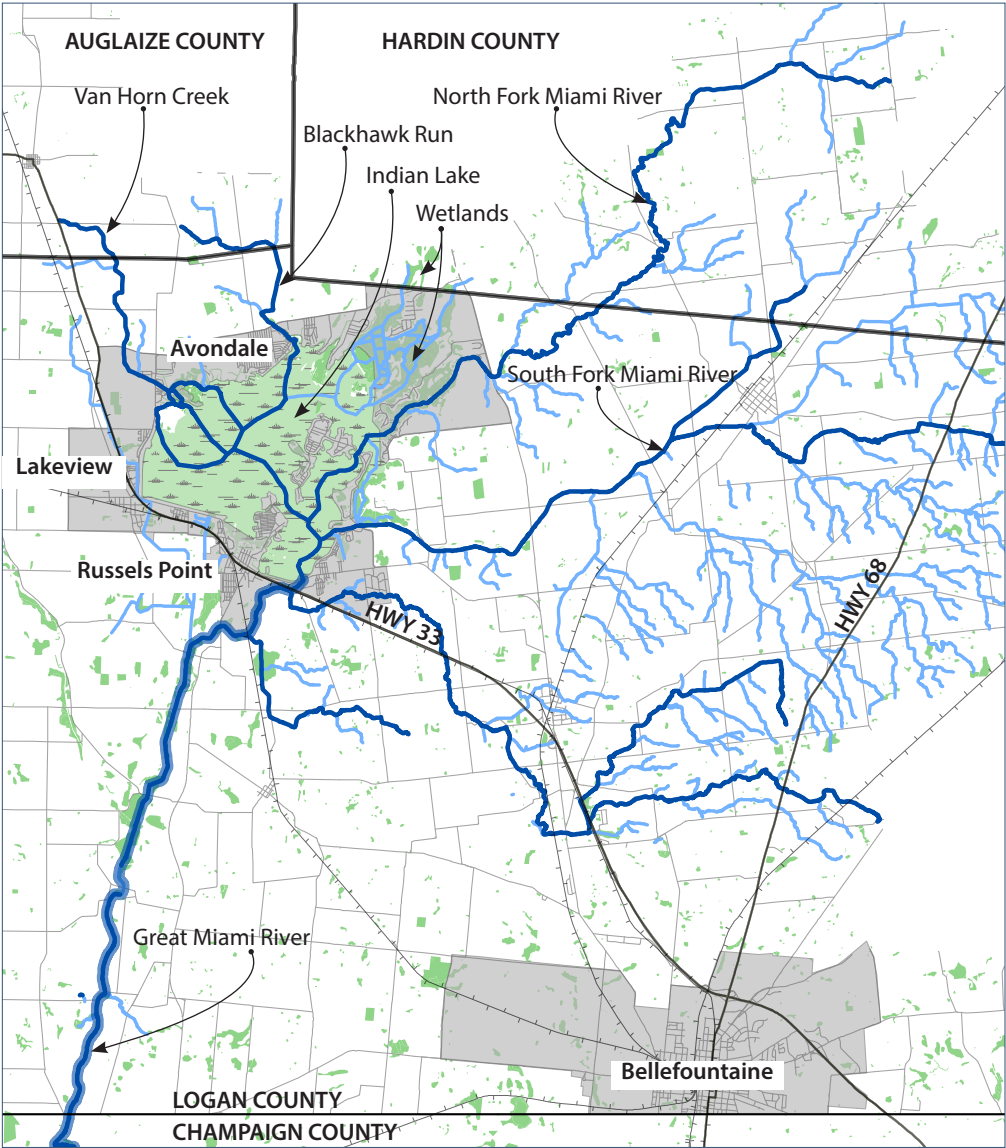


FIGURE 3.2-1 | Indian Lake was created from a wetland area fed by four small streams.

3.3 GREAT MIAMI RIVER DAMS

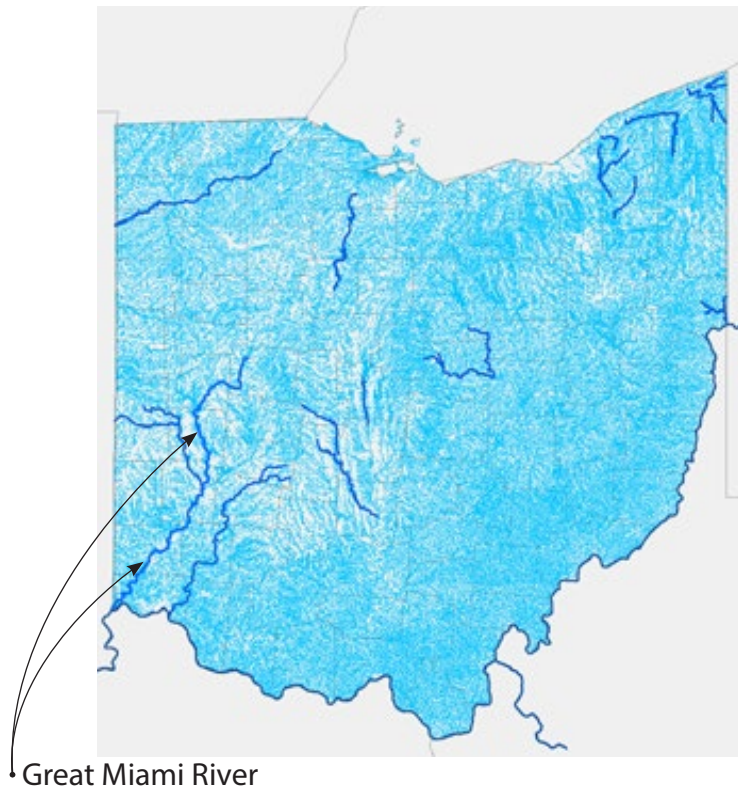


FIGURE 3.3-1 | Outstanding Rivers in Ohio

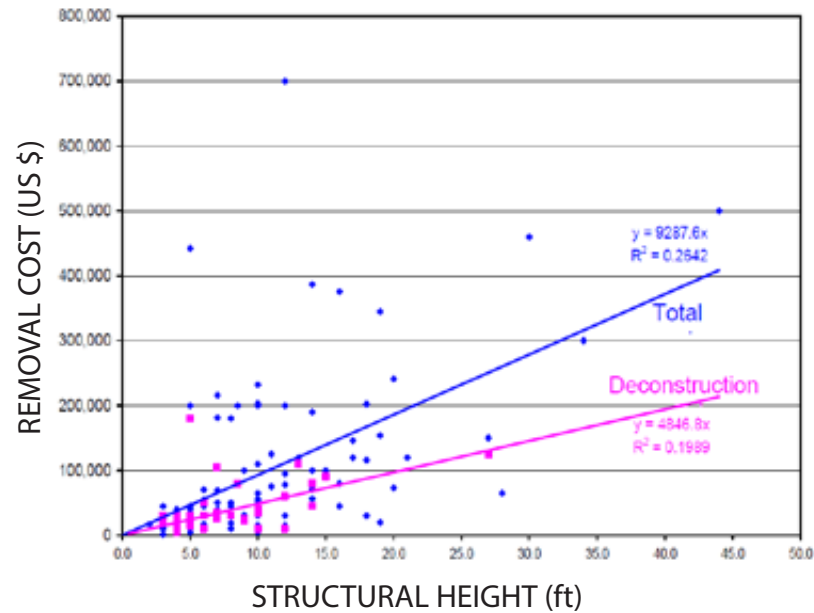
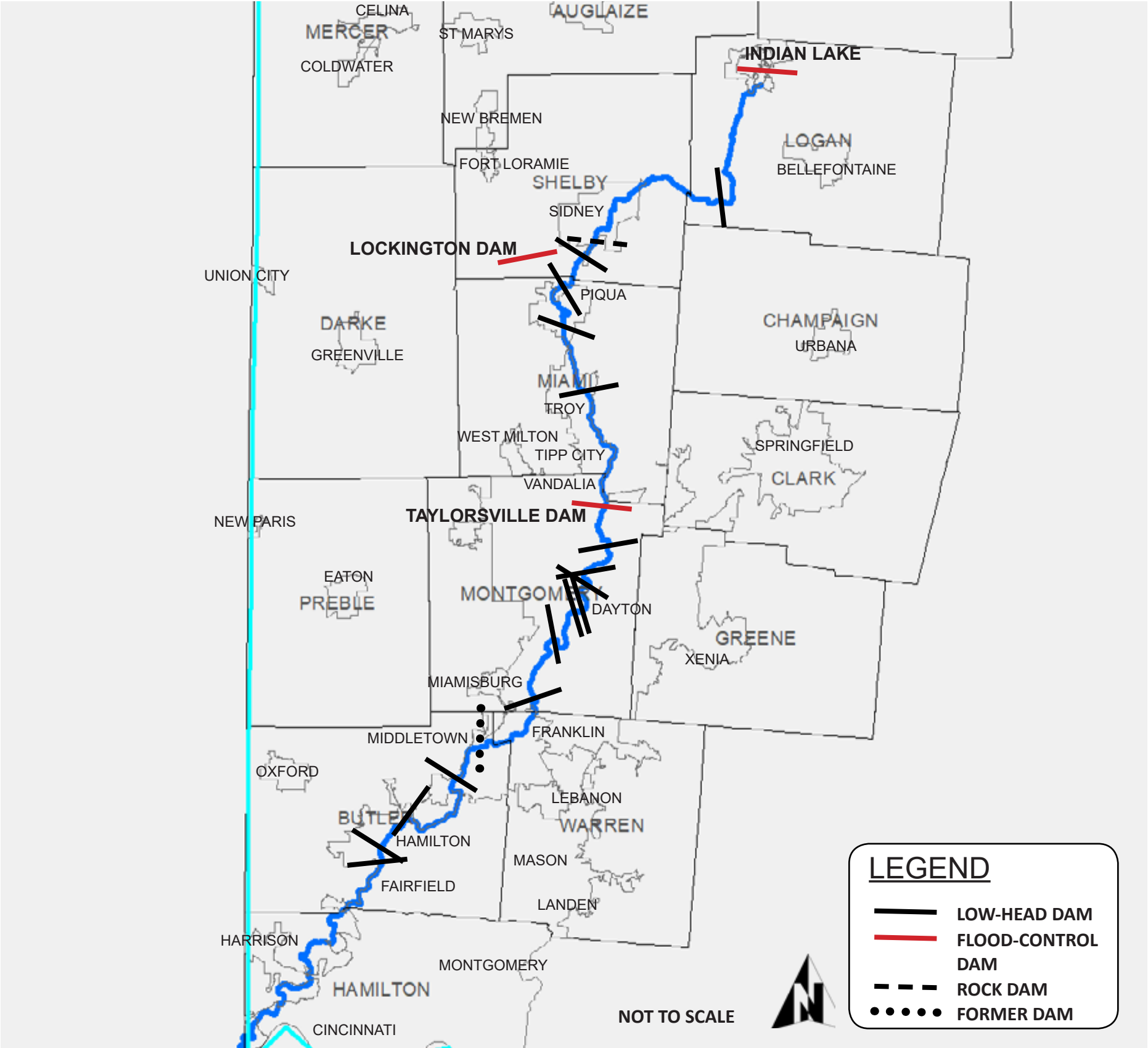
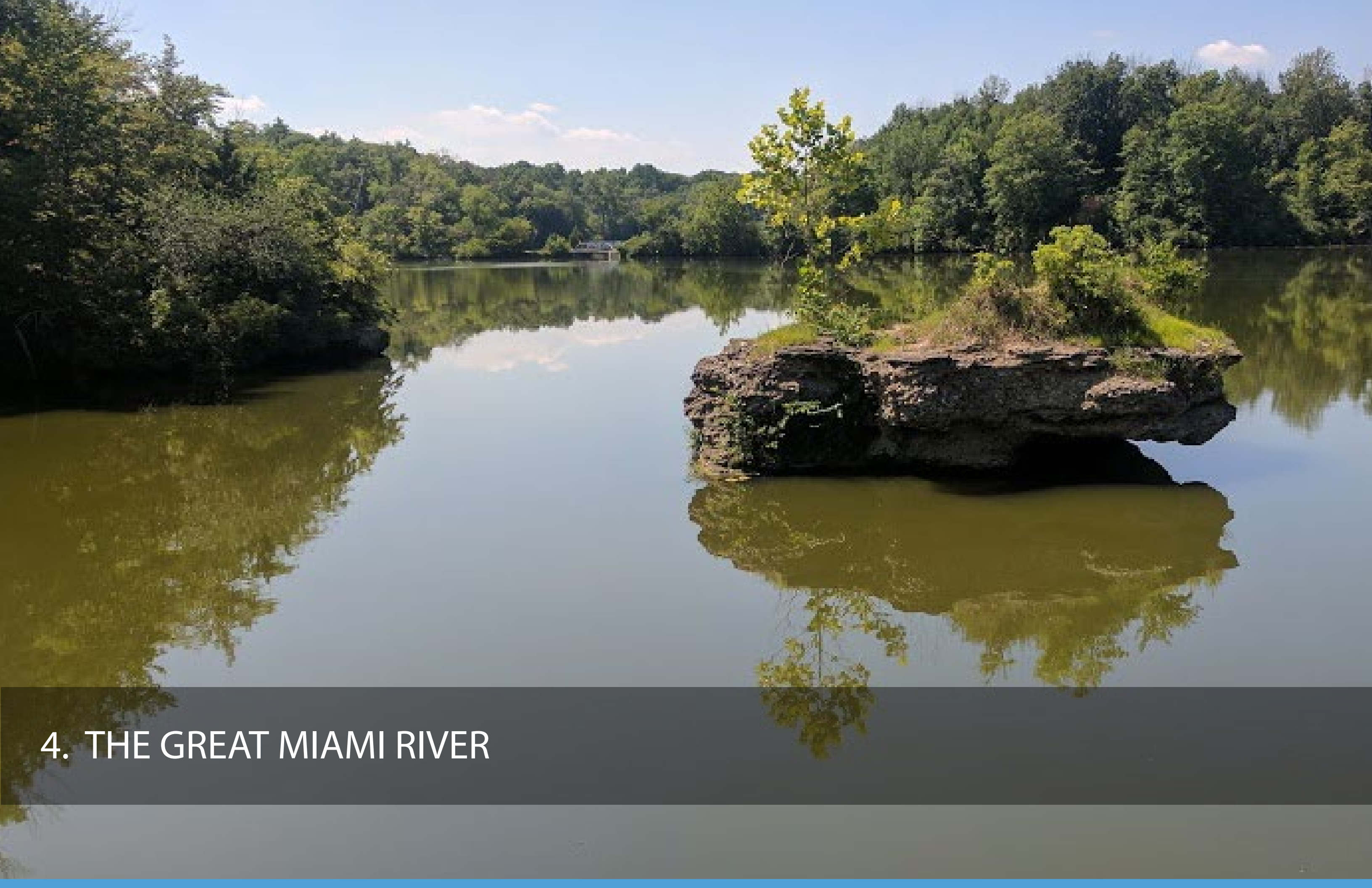


FIGURE 3.3-2 | Removal cost of low-head dams or small dams of different structural heights.



MAP 3.3-3 | Dam Locations on the Great Miami River



4. THE GREAT MIAMI RIVER

4.1 THE GREAT MIAMI RIVER

The Great Miami River is one of Ohio's largest rivers. It is listed as an Outstanding River by the Natural Resource Commission, with significance as a Scenic Waterway, for its ecological importance.

The Great Miami River is an approximately one hundred and seventy (170) mile long major tributary of the Ohio River. The upper region of this waterway forms at the confluence of the Great Miami's North and South forks, at Indian Lake in Logan County, approximately 15 miles southeast of Lima. From here the Loramie Creek joins the river as it flows South through Piqua, Troy, and on to Dayton. This section of the Great Miami, known as the upper Great Miami, is illustrated in pink to the right. In Dayton the Upper Miami joins the Stillwater (Blue) and Mad River (Green) before continuing onto Cincinnati and Hamilton, joining the Ohio River just inside the Indiana state line.

The Great Miami drains about 5,267 square miles of land; 66% of that is agricultural, 15% developed, and 19% undeveloped. Today, many of the Great Miami's ecological issues relate to fertilizer and pesticide runoff throughout the watershed, particularly agricultural. The northern portions of the watershed are primarily agricultural, while the southern and eastern portions are either heavily forested or pasture, outside of the major urban areas (Dayton, Cincinnati, etc.).

The Great Miami River is of particular cultural and historical importance, particularly to the people of the upper Miami watershed (North of Dayton), often called the "Miami Valley". In the 1850s a canal was completed along the Miami connecting Cincinnati with Toledo and the Great Lakes. Although railroads soon replaced the canal as the primary form of transportation, many local families today can trace their roots to the German, Irish, and French laborers who toiled along the canal.

Swimming in and eating fish from the Great Miami River can pose a threat to human health. With cautious use, the Great Miami River can and is used for recreation. Several different entities work to inform the public how to best protect their health when recreating in the Great Miami River, including the Great Miami Riverway.

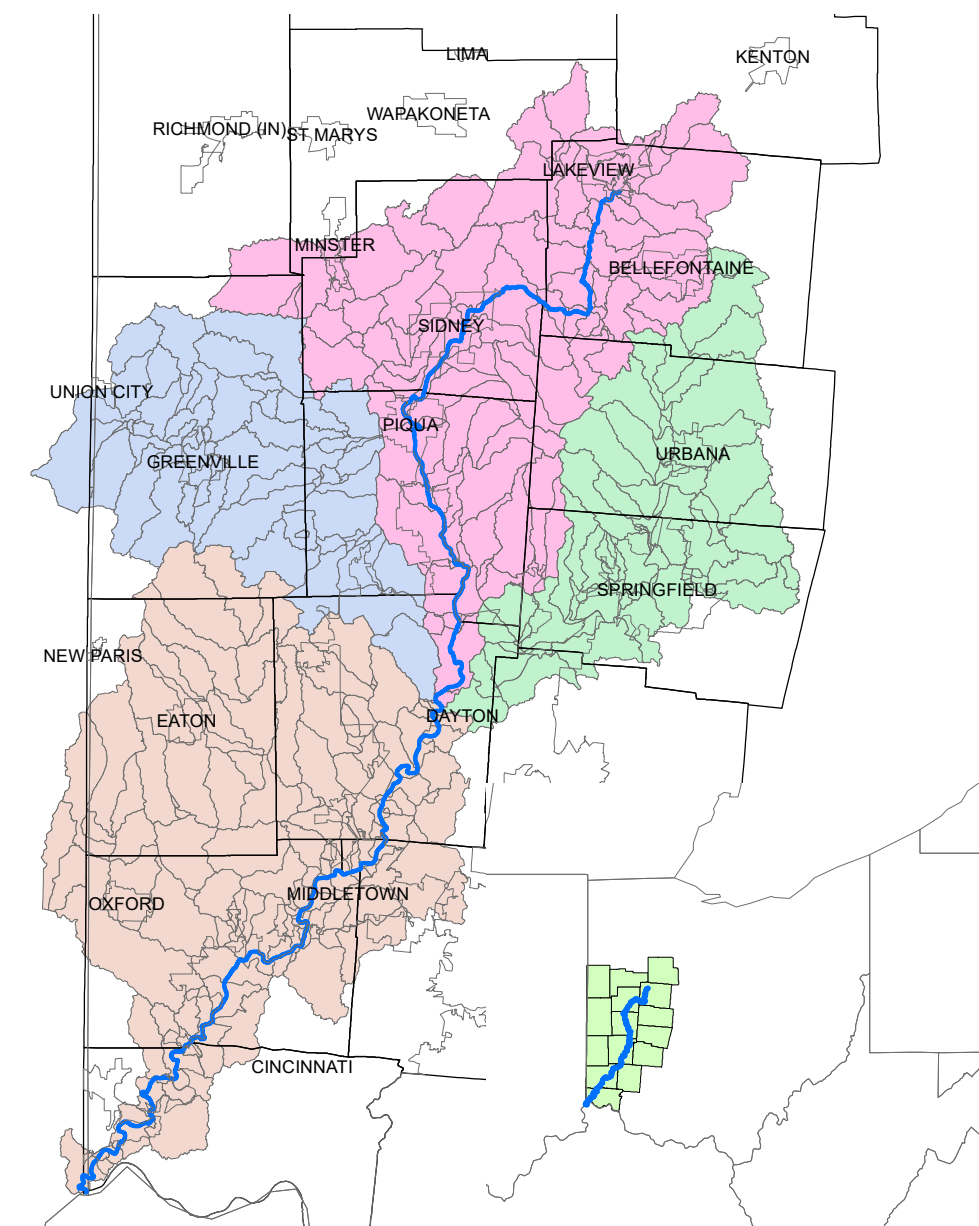


FIGURE 4.1-1 | Great Miami River Watershed

The MCD recommends avoiding swimming in the river within 48 to 72 hours after recent rainfall. During high water combined sewer outflows (CSO) discharge, public notices are issued by communities with combined sewer to warn people of possible E. coli threats.

4.2 HYDROLOGIC FEATURES

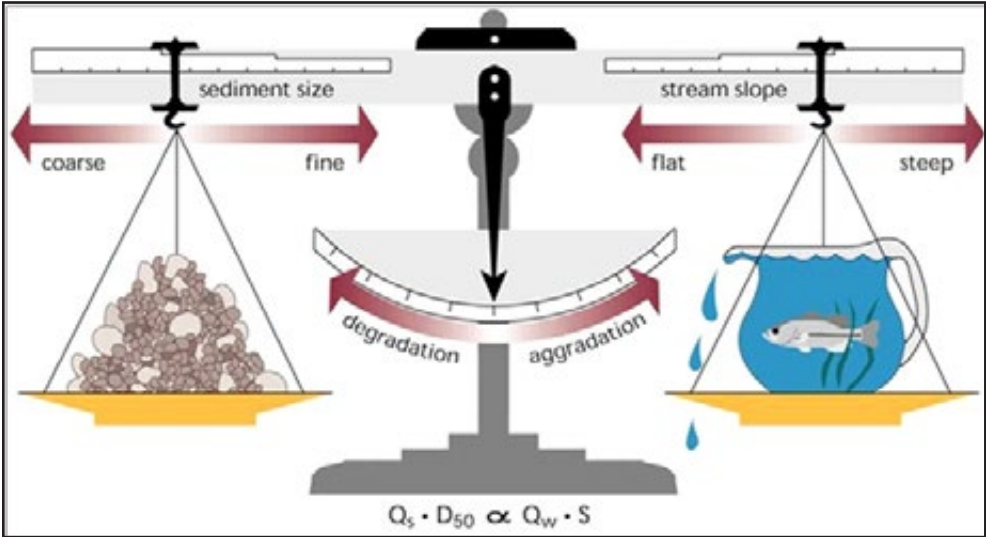


FIGURE 4.2-1 | Lane Diagram

RIVER GRADIENT

Rivers are steepest at the point of beginning and flattest at the confluence of the next largest body of water, with the joining of lakes and oceans being the shallowest river gradient location. Rivers at the headwaters need speed and energy to rush through the landscape. They are v-shaped channels, narrow and deep, with higher velocities, while at the lower elevations rivers become a wide u-shaped and shallow, with slower velocities.

In most rivers, high moisture in the form of rain or snow, flush from the steep gradients of a river’s beginning with limited access, if any, to the adjacent lands. As a stream transitions from steep grades near the headwater to more gradual grades as it moves down valley, it is able to overflow onto adjacent lands during high rains, causing flooding. While this flooding is an inconvenience to humans, in reality it has important consequences in terms of reducing erosion. The more gradual grade of the floodplain, together with the trees, grass, and other materials found there, dissipate the water’s energy, which ultimately prevents large scale erosion. In flat regions, rivers often begin in wetland depressional areas, that during high moisture events exit the wetlands, forming a stream.

Indian Lake, the modern source of the Upper Great Miami River, was once a large wetland fed by four smaller streams. While now a spillway controls flow into the Great Miami, it originally flowed from these 640 acres of wetland. From here to the Ohio River, the Miami has a natural gradient of nearly 3 feet per mile, much greater than the Ohio River’s six inches per mile.

CULTURAL GEOGRAPHY OF THE GREAT MIAMI RIVER

The Great Miami River is named for the Native-American Miami tribe, who inhabited this area when white settlers first arrived. An Algonquian tribe, they were related to the Delaware, Ottawa, and Shawnee people. The French bestowed the name Miami upon these natives, however they were also known as the Twigtwees or Tweechtwee. The earliest known British trading post in Miami County was known as Pickawillany (the French name was Piqualee), and was located North of present-day Piqua, at the mouth of Loramie Creek. This village was an important trading post established by the Miami and east-coast traders, and its presence spurred the establishment of smaller villages and branch tribes throughout Indiana, Illinois, southern Michigan and western Ohio. However, this settlement was destroyed in 1752.

When British settlers first attempted to colonize Ohio they were ousted by the French, and the Miami tribe allied themselves with the French until their defeat in the French and Indian War. Following this war, the Shawnee established two villages known as Upper Piqua and Lower Piqua. These settlements were named for the Shawnee’s ancestral home, Piqua, which was located on the Mad River until it was destroyed by a group of frontiersman led by George Rogers Clark. These tribes allied with the British during the Revolutionary War, and continued to fight against the newly formed United States until their defeat at the hands of General Anthony Wayne. After the Battle of Fallen Timbers, the Miami people were forced to sign the Treaty of Greenville and were ousted from their ancestral homelands, most of them moving to Indiana. Later, in the 1850s, the federal government forced many of the Miami to relocate again, this time to Kansas.

The first structures to occupy present day Piqua were built in 1796, and the Town of Washington was laid out in 1807. The settlers were unhappy with this name, and petitioned the State Legislature to return the town to it’s Indian name, Piqua, in 1816. Miami County was, at that time, a dense forest of generally rolling topography, with the occasional lowland and accompanying bluff. From 1811 until 1829 Colonel John Johnston operated an Indian agency in Piqua to ensure the Native Americans who were left in the area would trade with the Americans, and not the British. He recorded much of what we know about the Native Americans in this area, and his former farm (Johnston Farm and Indian Agency) is operated today by the Ohio Historical Society.



FIGURE 4.2-2 | Painting depicting the Treaty of Greenville

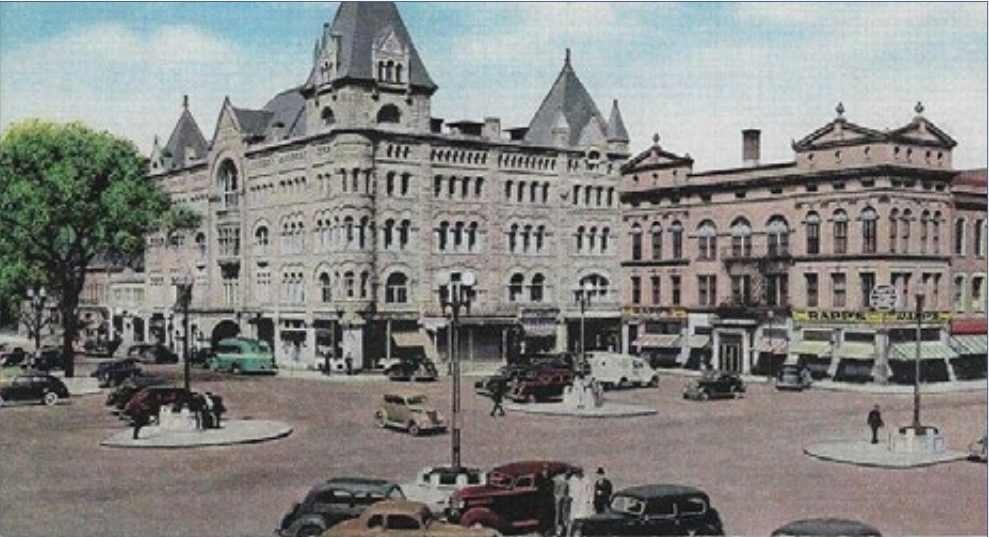


FIGURE 4.2-3 | Postcard image of early 1900s Piqua town square, library



FIGURE 4.2-4 | Postcard image of early Troy town square

4.3 THE MIAMI-ERIE CANAL

THE MIAMI-ERIE CANAL

During the early 1800s Ohio governor Ethan Allen Brown championed the creation of the Ohio Canal Commission, a board formed by the Ohio legislature for the express purpose of realizing internal improvements, particularly the construction of transportation canals. The board eventually settled on two canals; The Ohio and Erie Canal served the eastern and central portions of the state, and the Miami and Erie Canal served the western half from 1840 to 1860.

Canal construction began in July of 1825, and the Ohio-Erie Canal was finished in 1833. The northern half of the Miami-Erie canal (Dayton-Lake Erie) received funding in 1830, and wouldn't be completed until 1845. The state government funded the project with loans from East Coast businessmen, and private contractors bid on sections of canal across thirty-three (33) of Ohio's eighty-eight (88) counties. Once completed, farmers could ship their goods along the canal for a fifth of the price as horseback, and passengers could safely cross the state in a little over two days for \$1.70.

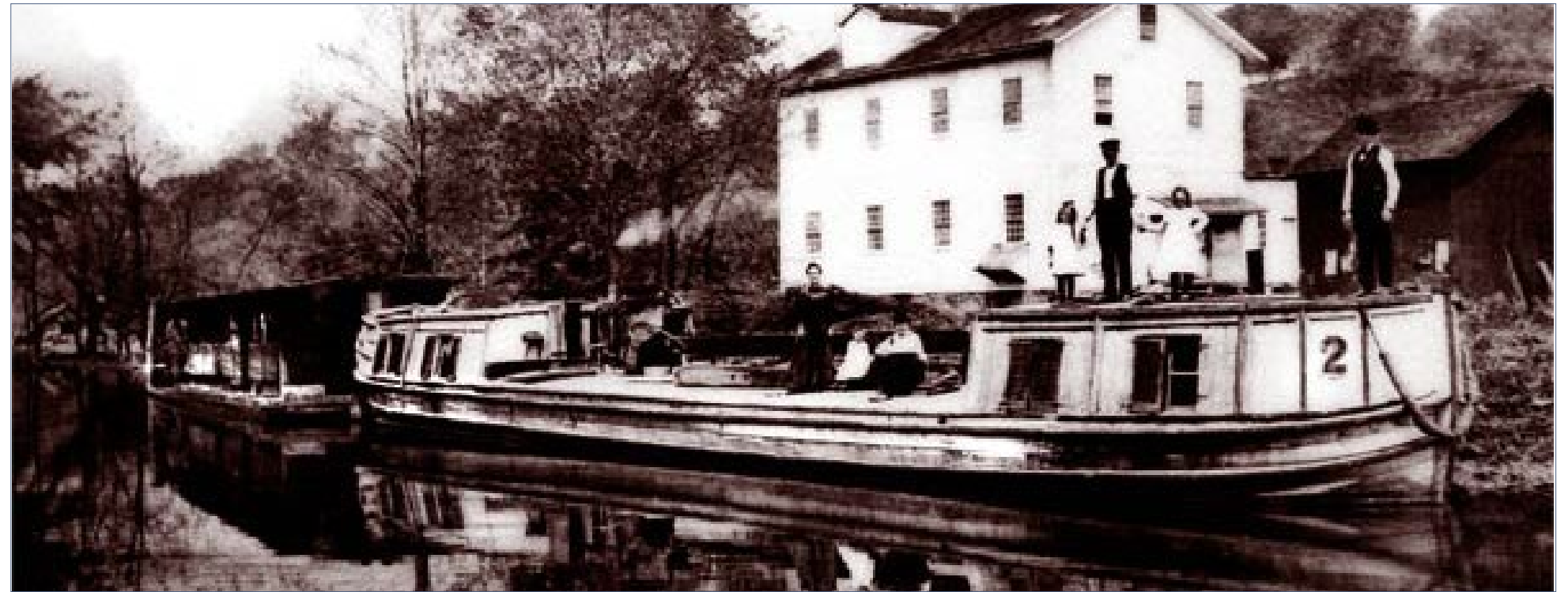


FIGURE 4.3-2 | A typical flat bottomed canal boat



MAP 4.3-1 | Ohio Canals Map (from Ohio DNR)



FIGURE 4.3-3 | North of Piqua, a portion of canal is still operational today.

4.4 GREAT MIAMI RIVER FLOOD PROTECTION

HISTORIC FLOODING IN OHIO

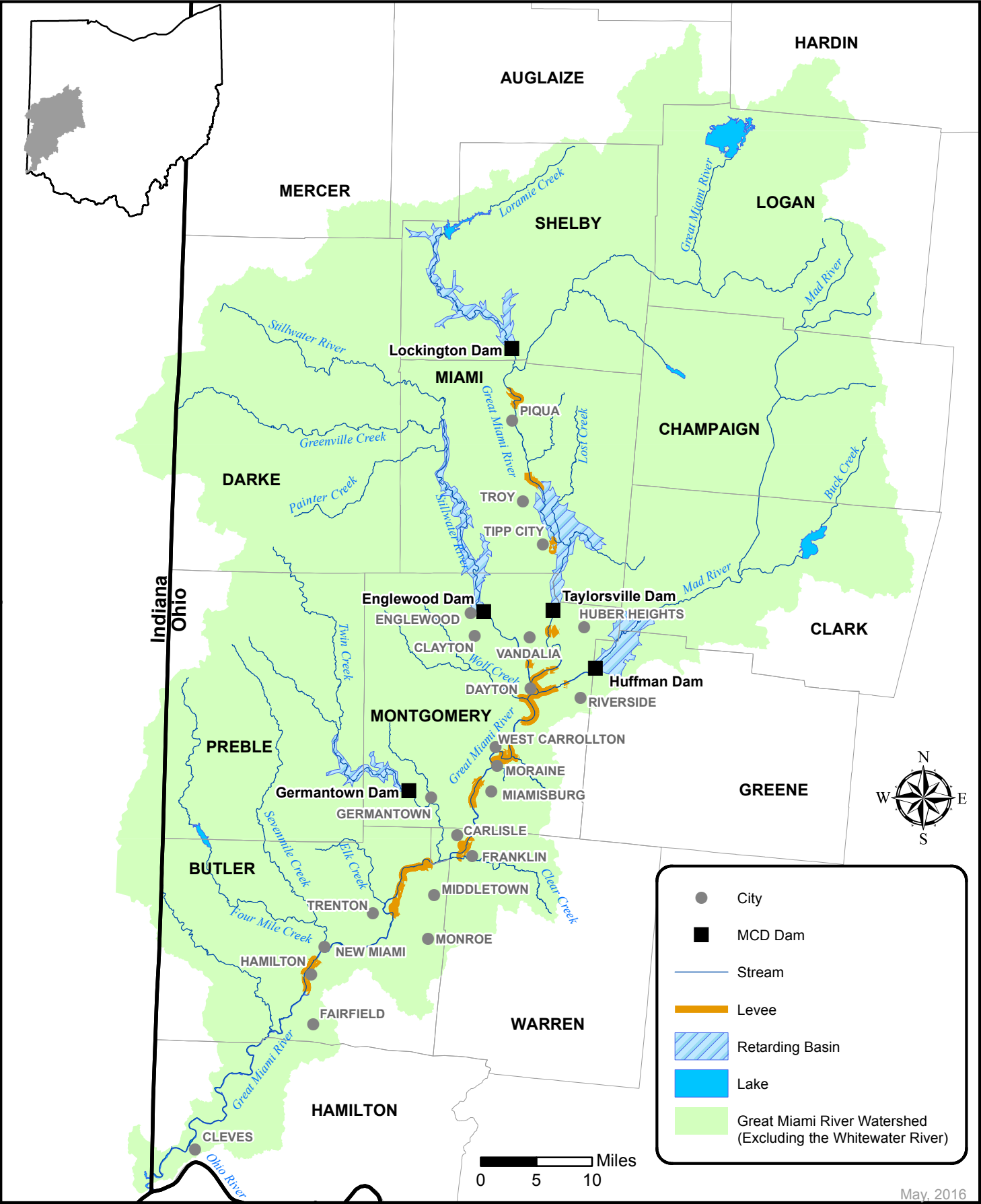
During the industrial revolution, land throughout Western Ohio was denuded of trees and cleared for larger farm sizes. The combination of tree removal, which allowed rain water to move more quickly over the land and into the river, and development near rivers created the perfect storm for flood water impacts. Additionally, the ground may have been frozen during the heavy rain and snow melt that occurred in early March, 1913, preventing the ground from being able to soak up any of the precipitation. Like much of the Miami River basin, Troy and Piqua were severely impacted by the floods of 1904 and 1913, an event classified by modern standards as a 500 year flood, or a flood event likely to occur about once every 500 years. The 1913 flood was commonly labeled during its time as the “Great Flood.” These two events drove a state-wide effort to build levees and dams throughout each Ohio watershed in order to keep river flood waters out of urbanized areas.

LEVEE CONSTRUCTION IN THE MIAMI WATERSHED

The severity and damage caused by the 1913 Flood, particularly in Dayton and Hamilton, demonstrated the need for a flood protection system. At the time, there was no way for a single agency to work across city and county boundaries in Ohio, so the Ohio Assembly passed the Conservancy Act of Ohio. This act allowed the formation of the Miami Conservancy District, which went on to construct a vast flood protection system between 1918 and 1922. At the time this system of earthen dams and levees was the largest public works project ever undertaken, with a total cost of more than 30 million dollars (about \$430 million today).

The Great Miami River’s flood protection system is made up of five large retarding basins, each consisting of largely undeveloped land and made possible by large earthen dams. A river’s ability to access floodplain lands during high water events will dissipate high water energies, ultimately preventing large scale erosion. The presence of large swaths of undeveloped land along the Miami allows for the flood protection system to use these areas as basins to temporarily retain stormwater.

The Miami River’s major earthen dams are located at Germantown, Englewood, Lockington, Taylorsville, and Huffman. These basins have successfully held stormwater over 1,800 times since their original completion in 1922. Downstream of these dams, levees protect developed land in Piqua, Troy, Tipp City, Dayton, West Carrollton, Miamisburg, Franklin, Middletown, and Hamilton. The levee system does not allow much river access to the floodplains by design. The levees compress water, increasing velocity in flood conditions.



MAP4.4-1 | Miami Conservancy District - Flood Protection System



FIGURE 4.4-2 | Piqua, just after the 1913 flood



FIGURE 4.4-3 | High water mark from 1913 flood in Piqua's downtown



FIGURE 4.4-4 | Piqua, OH on March 25, 1913



FIGURE 4.4-5 | NCR tent community, post-flood



FIGURE 4.4-6 | an NCR flat-bottomed boat is used to rescue people



FIGURE 4.4-7 | Gap where the levee was prior to the 1913 flood, Troy, OH

4.5 MIAMI RIVER NATURAL CHANNEL ALIGNMENT

HYDROMODIFICATION

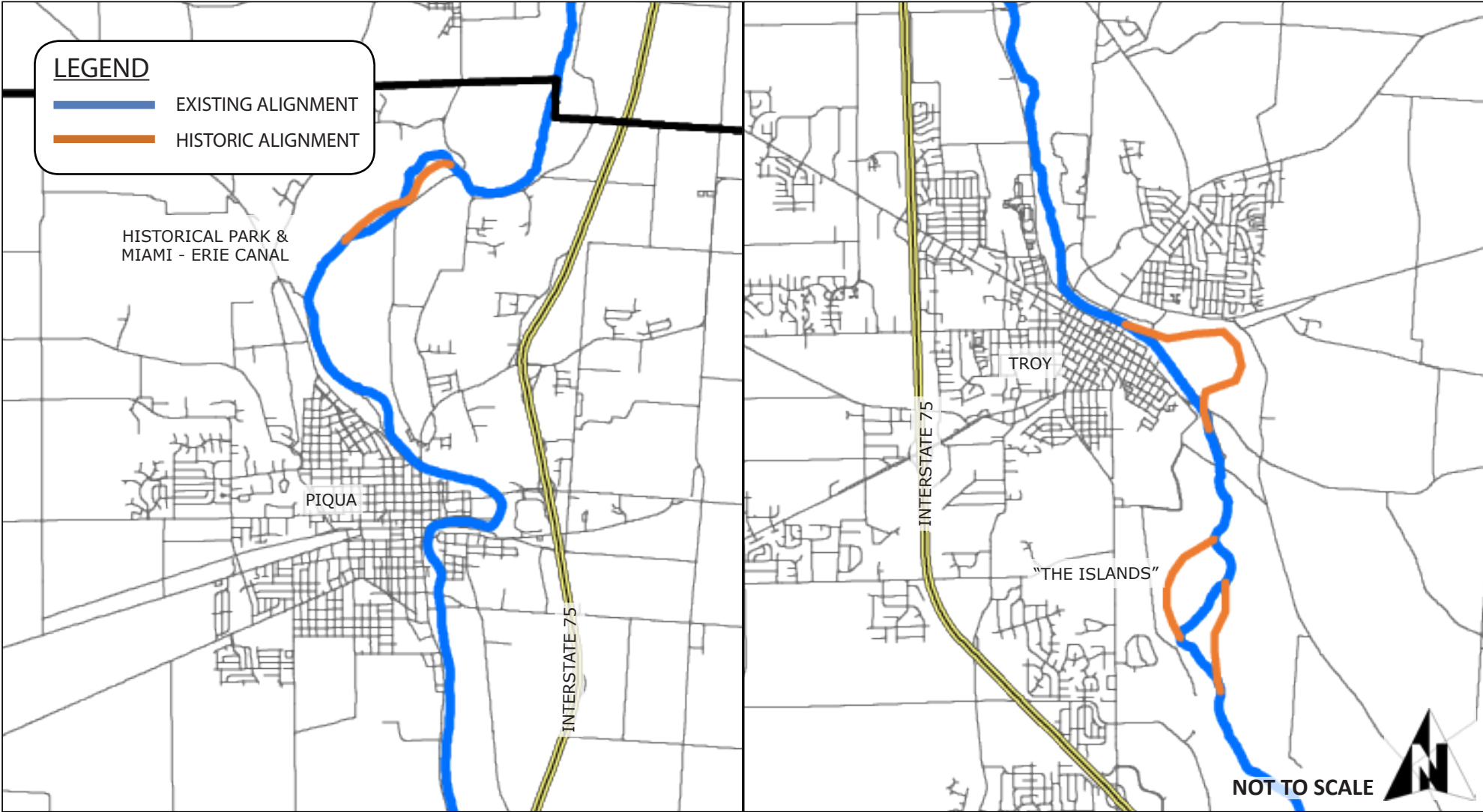
Over the last 120 years the Miami River has been utilized and altered in many different ways. Throughout Miami County the river has been used for boating, irrigation, as a municipal water source, and as a power source.

Through natural movement and human exploitation, the river, as it runs through Troy and Piqua, has shifted over the last few hundred years. The bend in the river just North of Piqua seems to have grown northwards, a result of the stream’s own efforts to find equilibrium. As Ohio expanded the Miami-Erie Canal from Dayton to Toledo during the 1840s, the river just past this bend was shifted slightly southwards for the new waterway, which is still in use today as part of the Johnston Farm and Indian Agency.

Piqua’s Power Plant came online in 1933, and it’s removable crest dam was completed 3 years later, replacing the original stone structure. The town once utilized the dam’s backwater for a water skiing competition and other boating activities, however dredging the river year after year to maintain these recreational opportunities proved too cost prohibitive. Furthermore, the buildup of sediment behind the dam has led to intensifying maintenance costs associated with the dam’s mechanical gates. Even though the gates no longer function, the city is required to inspect and maintain them on a yearly basis.

In Troy, the Great Flood in 1913 spurred the installation of a dam in the middle of town (bottom right) and the straightening of the Miami through Troy’s great bend. The floodplain within the former bend is now a golf course, and serves as a basin to dissipate floodwaters in extreme storm events. South of town, former islands within the river have disappeared as part of a large rock quarry. Throughout the city the Miami is lined with earthen Levees that have reinforced and heightened the natural riverbank.

As a result of the dam being built, many city residents desired boating and recreational opportunities along the riverbanks, and began clearing the banks of woody debris. This effort was hastened by the Hobart brothers, who brought in heavy equipment to accelerate the process and constructed a restaurant, lagoon, and festival space at Treasure Island. This park was donated to the city in the 1960s as part of a request for river improvement funds, and has served as a valuable community asset since then.



MAP 4.5-1 | Channel Hydromodification.



FIGURE 4.5-2 | Original Troy, OH dam (pre 1913). This dam existed between modern-day Treasure Island and Adams St.

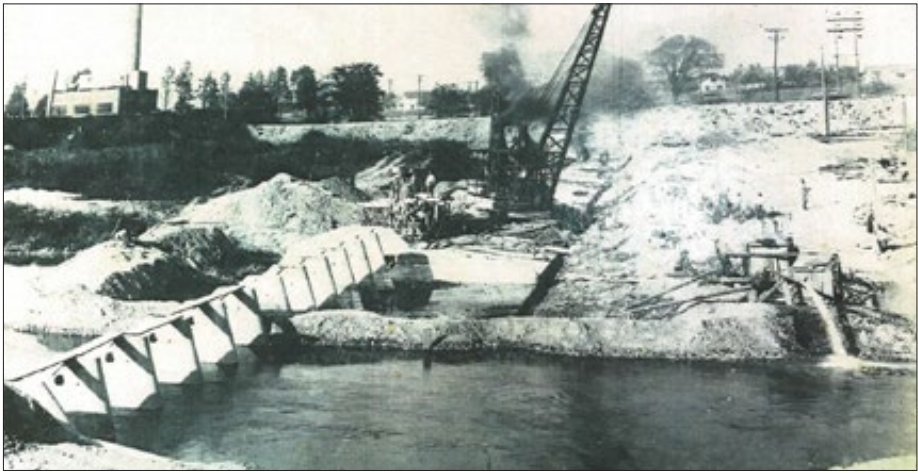


FIGURE 4.5-3 | Construction of Troy low-head dam in present-day location. ca. 1923.

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4.6 MIAMI COUNTY DAMS

MIAMI COUNTY DAMS

In Miami County there are about eight low-head dams, three of which are located on the Miami river and included in this project.

The only dam of the three that serves a modern purpose is the northernmost, the Piqua Water Works Dam. This dam has provided drinking water to the citizens of Piqua since its construction. The former Power Plant dam in Piqua serves no purpose as it stands today, and the gates which once altered water elevation in the backwater and downstream flow require periodic maintenance to function. This operation is required for flood control purposes, but the maintenance is cumbersome, expensive, and becoming more frequently necessary.

Troy’s low-head dam also once provided power, in this case to a nearby factory, but is more known for the watersports that thrived in Troy for several decades between 1950 and 1980. It was during this time that the city hosted water-skiing tournaments, festivals, and concerts at Treasure Island Park. However, use of the river for motor sports required periodic dredging and increased dam maintenance. E.A. Hobart, an early contributor to Troy’s boating community, donated the park which became Treasure Island to the city in order to secure onetime funds for river maintenance (dredging, bank clearing, etc.).

Over time, the river became too shallow for boating, most likely due to sediment deposition as a result of decreased water velocity behind the dam. Dredging became too expensive to maintain and was eventually discontinued, but Treasure Island, its lagoon, and the river access provided by the park space remains one of Troy’s most valuable recreational assets.

LEGEND

12 DIGIT HUC BOUNDARY

DAM LOCATIONS

GREAT MIAMI RIVER

A map of Miami County, Ohio, showing the Great Miami River and its tributaries. The river is highlighted in blue. Various 12-digit Hydrologic Unit Code (HUC) boundaries are shown in different colors: purple for Loramie Creek, orange for Rush Creek, pink for Spring Creek, and light blue for the main river. Towns labeled include Lockington, Piqua, Troy, Fletcher, Casstown, and Christian. Three dam locations are marked with red dots and labeled: Piqua Water Works Dam, Piqua Power Plant Dam, and Troy Low-Head Dam. Callouts point to specific river segments with HUC numbers: (05080001) for Great Miami River above Loramie Creek, Rush Creek at mouth, Great Miami River at Piqua, Great Miami River above Rush Creek, Great Miami River above Spring Creek, Great Miami River at Troy, and Great Miami River at Tipp Elizabeth Road. A legend in the bottom left corner defines the symbols for HUC boundaries, dam locations, and the river. A north arrow and 'NOT TO SCALE' text are in the bottom right.

MAP 4.6-1 | Dam Locations in Miami County, OH

NOT TO SCALE

50 | The Great Miami River

This report is a discussion of the proposed removal and/or modification of the three Miami River dams located in Troy and Piqua, Ohio. This report will look at general reasons for dam removal (ecology, economics, safety, failure, recreation).



FIGURE 4.6-2 | Piqua Water Company Dam

PIQUA WATER INTAKE DAM
This steel sheet-pile dam stands North of Piqua, and serves as a water source for the city. Initially, it also maintained water levels for the northern reaches of the Miami-Erie canal. You can still take a ride on the canal near the former Piqua Historical Area, now known as Johnston Farm and Indian Agency, just north of the dam.



FIGURE 4.6-3 | Piqua Power Plant Dam

PIQUA POWER PLANT DAM
This dam was installed with adjustable gates which could be opened and shut to control the water elevation of the backwater, a former attraction for boaters. The town once held an annual water skiing contest on the river, but sediment buildup behind the now dysfunctional dam has rendered that event impossible without significant investment in yearly dredging and dam maintenance.



FIGURE 4.6-4 | Troy low-head Dam

TROY LOW-HEAD DAM
Known to some as an eyesore and others as a peaceful observation point, Troy’s low-head dam sits in the middle of downtown. Now obsolete, the dam serves as an obstacle to small watercraft but a landmark for Great Miami Bike Trail users. The last major maintenance work conducted on the dam was completed in the early 2000s.



5. MIAMI COUNTY DAM REMOVAL EFFORTS

5.1 MIAMI COUNTY RIVER INVESTMENT

Contemporary dam removal efforts in Troy and Piqua are rooted in a multi-year history of exploration and public concern generated by numerous organizations and initiatives.

GREAT MIAMI RIVER CORRIDOR

The Great Miami River Corridor is an interconnected network of paved trails, connected communities, and river across 99 miles in Southwestern Ohio. It is Ohio's only National Water Trail, and the nation's largest interconnected paved trail network. The Great Miami Riverway website provides links to attractions, hotels, campgrounds, and local events along the trail and river in order to promote local businesses and cultural assets.

Trails, parks, and other attractions have been common along the Miami river since the mid-1900s. During this time the Miami Conservancy District periodically released maps and/or pamphlets showcasing recreation along the corridor, county by county. These included information regarding access points and dam portages, as well as warnings to canoers regarding the dangers of low-head dams. In 1976, Miami University's Institute of Environmental Services developed and published an in-depth proposal for parks, trails, and other improvements along the Great Miami River in Miami and Shelby counties. Some of those improvements were implemented and can be seen today, while others were quite ambitious; such as a multi-acre complex of recreational lakes in Piqua's old quarry, surrounding the former nuclear reactor.

During this early time, the cities of Troy and Dayton built paved multi-use paths through their river and downtown areas. Troy's section of the Great Miami River Trail is largely regarded as the first section to be completed. Due to its size, Dayton's trail, the River Corridor Bikeway, gained in popularity immensely and has since expanded to become the Great Miami River Trail. This trail extends south to Franklin, OH and northwards to Piqua, but will soon extend further in each direction thanks to the cooperative efforts of 19 communities and organizations in the Great Miami Riverway Coalition. All together, the riverway represents 99 miles of paved trails, river, and connected urban communities in southwest Ohio.

This coalition initially met together in 2008 with the first River Summit, and officially formed the coalition in 2017. The Tait Station dam removal in Dayton this year is a result of their efforts, as well as the success of the river trail and abundant availability of maps and information regarding attractions along the Great Miami River.

RIVERFRONT DEVELOPMENT STUDIES

Many cities along the Great Miami are seeking to reinvest and reinvigorate their waterfront areas. Troy and Piqua have both completed comprehensive studies in recent years to strategize a reinvestment in the economic development and job growth in their respective downtown areas. As a part of these studies, each town has decided that the riverfront should be of primary concern, both due to its public nature and proximity to downtown businesses. Residents desire pedestrian access and views of the river adjacent to the downtown core, making an additional riverside trail on the bank adjacent to the downtown area an enticing proposition. Both Troy and Piqua's downtown development studies can be found in the references section.

As part of this comprehensive riverfront development plan, Troy's Strategic Development Study recommended a dam removal feasibility study. By clearing the waterway of this dangerous obstacle, Troy could significantly enhance recreational opportunities along the riverfront and help reconnect the downtown with the Great Miami, currently separated by a floodwall. The idea of dam removal in southwestern Ohio has become more and more popular with successful projects in Dayton and on the Stillwater River over the last ten years.

5.1 MIAMI COUNTY RIVER INVESTMENT (cont.)

THE US FISH & WILDLIFE SERVICE

Due to significantly decreased water quality throughout the backwater of Miami County’s dams as it relates to aquatic health, the USFWS has taken a special interest in the removal of Troy and Piqua’s low-head dams. The American Recovery and Reinvestment Act provides a funding source to help benefit our natural aquatic resources, and can shoulder the primary financial burden for removing these dams. While these funds wouldn’t be able to be used for human amenities such as a trail, the removal of Troy’s low-head dam is an essential first step in making the south bank of the Miami more accessible to the downtown area.

HYDRAULIC MODELING

In order to maintain the intricate lock and levee system that protects Miami River Valley residents from a 500-year (0.2% annual chance) flood event, the MCD maintains detailed hydraulic models of the river and levee system. Any changes to the levees, river, or built environment within the river’s natural floodplain (bridges, pedestrian trails, parks, etc.) must be approved by the MCD. This approval certifies that whatever changes are proposed, they will not adversely affect the ability of the levee system to protect developed areas from flooding. Typically, a low-head dam of the size considered in this study will have a virtually nonexistent effect on the 500 year flood elevation.

If, however, any new structures or improvements are made as a part of the dam removal, this model must be updated to ensure that the cross-sectional area of the river at the 500-year flood elevation is not reduced by too much. The cross-sectional area describes the area water is able to flow through unrestricted in the case of a major flood. For example, at the location of the Piqua dam the cross-sectional area of the river at that flood elevation is about as narrow as it gets throughout the watershed, forming a “choke point”. This is one reason why the city is required by the MCD to maintain the functionality of the dam’s floodgates, and therefore have the ability to increase the available cross-sectional area, if necessary. This would prevent the floodwaters from getting blocked and “backing up” behind the dam in the case of a flood. If any work is to be conducted in this location, the result must be a reduction of the cross sectional area of the river as compared to the existing conditions.

MCD & THE GREAT MIAMI RIVERWAY COALITION

The Great Miami Riverway Coalition initially met at the first river summit, in 2008. Today, ten cities, three parks districts, and two county commissioner boards are members of the coalition, receiving support from various foundations, including the Troy Foundation. The purpose of the coalition is to understand community water resource concerns, promote economic development and attract more visitors to the 99 mile river corridor. The riverway produces and publishes a variety of maps and trip recommendations for bikers, paddlers, and other pedestrians as well as hosts events along the Great Miami in various communities. According to the coalition’s website, over \$500 million in riverfront investments have occurred throughout the last decade along the Miami River corridor, \$1 million of which has come directly from the coalition’s partners.

One of the coalition’s founding members, the Miami Conservancy District (MCD) primarily maintains the locks, levees, and flood-control dams constructed throughout the Great Miami Watershed in the wake of the 1913 “Great Flood”. In addition, the Conservancy seeks to protect and preserve the river’s natural scenic and recreational assets, as well as its pristine water quality through investment in these assets and in community events such as ‘clean sweep’ river cleanup. Over the years, most of the improvements made along the Miami, Stillwater, and Mad Rivers have been organized and/or carried out with the help of the Conservancy District.

The rationale identified for dam removal over the years includes the following:

- (1) Dams can negatively impact sediment regimes in the river. According to the Ohio EPA, the Great Miami River is impaired for sediment. The EPA has periodically assessed the habitat and water quality of the river for over 30 years and has documented the relationship between elevated sediment levels, lack of oxygen (specifically in the backwater of Miami County’s two low-head dams), and impairments to mussels and other aquatic organisms.
- (2) The WRRSP, advocates for recreational uses of streams and recognizes that the removal of dams will increase recreational opportunities for paddle sports and tubing and fishing.

(3) One of the greatest concerns that the WRRSP has regarding dams is the human safety factor. Low-head dams pose significant risks to recreational enthusiasts. Reports on dam risks have helped build greater awareness, but have concurrently reduced citizen confidence in canoeing and kayaking.

PIQUA RIVERFRONT DISTRICT DEVELOPMENT STRATEGY

In 2013, Piqua completed a development strategy for a small area of town next to the river, including Lock Nine Park. This plan stemmed from a brownfield development strategy addressing the same area, and resulted in some recommendations for potential improvements that would be beneficial to the entire downtown. According to the study, “The redevelopment of the downtown riverfront is the most significant and impactful project that will take place in Piqua for decades into the future”. The riverfront site is unique for a few reasons; it has a rich history of industrial and commercial use, it is almost entirely publicly controlled, and it is one of the few places in the city that is not visually “cut off” from the Great Miami River. With the completion of Lock Nine Park’s renovations in 2020, the City is making leaps towards reconnecting with the Great Miami River in its downtown.

TROY DOWNTOWN STRATEGIC DEVELOPMENT PLAN

Troy also recently completed a comprehensive study analysis of their downtown area, resulting in a plan to activate and revitalize the downtown corridor. The study identified four essential opportunities for improvement, all along the river. Troy desires a better connection with the river, which has been “walled off” from the downtown core by the levee system. Although essential for flood protection, the levee system has prevented building a riverside trail or providing access to the water from the West bank. Removal of Troy’s low-head dam is being considered, in part, because the project could allow for a new bankfull bench along this bank. Providing a green space and a new trail to give residents access to both sides of the river is a desire many in Troy share, but it is only possible with the lower water levels that would result from a dam removal.

Simultaneously, the preservation and activation of Treasure Island and its amenities is also an essential part of the redevelopment plan, requiring an innovative solution to maintain the “lagoon”. This is a distinct possibility even if the dam is removed, but will require an innovative solution.

5.2 PUBLIC INPUT

HISTORIC PRECEDENT

Since its inception, the WRRSP program in Ohio has removed at least one dam from around the state nearly every year. The success of many of these projects has helped to raise awareness of the dangers of low-head dams, and led people to reconsider the benefits and consequences of having a dam nearby. The last major maintenance project on Troy's low-head dam occurred in the late 1990s, and Piqua's steel gates have recently needed repairs every few years. They will both need significant maintenance within the next ten years to remain safe. This, combined with the hydraulic modeling concerns raised by the MCD when planning for major rain events has led each town to consider dam removal and/or modification.

HISTORIC CHALLENGES

One of the primary reasons residents have an initial tendency to dismiss dam removal as an option is the fact that removing the dams will permanently lower the backwater areas of each dam, traditionally used by townspeople for motorsports (water skiing, boating, etc.). The towns used to have water skiing competitions, and some residents still use the Miami for boating, although non-motorized boating activities (kayaking, canoeing) have grown significantly in popularity over recent years. Due to their important history in each city, the Miami's characteristics, especially those modified by the two dams, are recognizable and nostalgic to many of the city's residents. The people of each town also see the dams on a nearly yearly basis with the water "drawn down", and tend to have a negative opinion of that visual state of the river, even though it isn't necessarily indicative of future appearance, should the dams be removed.

DAM REMOVAL PUBLIC FORUMS

As a part of the Dam Removal Feasibility study, project partners hosted two public forums in the Cities of Troy and Piqua. Flatland Resources (FLR) led the first public meeting on March 20th, 2019. The meeting was hosted at the Miami County Highway Department with approximately 55 citizens from across Miami County and the State at large. The goal of the meeting was to glean as much information as possible from the residents; what they thought about low-head dams, what they used the river for, etc.



FIGURE 5.2-1 | First public Meeting for Feasibility Study

The meeting started with introductions from the U.S. Fish and Wildlife Service and Flatland Resources representatives. A survey was then passed around to all attendees, which asked eight questions regarding the Great Miami River and the low-head dams in Troy and Piqua. After everyone was given time to write out their responses, FLR then led the group in a Q&A session about those same questions on the survey.

Initial reactions to the study were positive, as many residents see the benefit of dam modification or removal. There were a few attendees who did not want to see the dams removed, mostly because of the historical and cultural importance the dams represent in each city. Nearly all attendees were fishermen/women, who questioned how the dam removal would affect the local fisheries. Both FLR and USFWS dove into these questions, offering examples of other dam removals where the fisheries quality increased significantly over time.

A breakdown of the answers given in the survey and during the group discussion can be found on the following pages. A common theme in the responses were the safety issues that low-head dams create for recreational users of the river. Section 2.4 of this study explains why low-head dams are so dangerous to canoers, kayakers, and others that attempt to traverse them.

PUBLIC INPUT

5.2 PUBLIC INPUT (cont.)

PRESENTATION

During the 2019 meetings, Phil Tevis of Flatland Resources delivered the introductory presentation. The presentation included information regarding: historical uses of dams in rivers, national dam removal trends, local dams in Miami County, and benefits of dam removal including economic, recreation, and safety. Two short videos where also shown. A summarized version of this introduction was given by David Heilman of Flatland Resources during the 2020, and final meetings for both Troy and Piqua.

The first video demonstrated how mussels use bass to transport young through the river ecosystem. The second video was an excerpt from the Indianapolis PBS Documentary *Over, Under, Gone: The Killer in Our Rivers*, which discussed the hydraulic jump and the dangers that recirculating currents pose to users, even the most seasoned rescue specialists. Tevis then facilitated the public question and answer session.

PANEL MEMBERS

The panel consisted of the following members:
Phil Tevis, Principal of Flatland Resources. Tevis is a stream restoration ecologist and natural channel design specialist (Rosgen Level 4).
David Heilman, Landscape Designer with Flatland Resources, natural channel design specialist (Rosgen Level 2).
Donnie Knight, Jr., USFWS Partners for Fish and Wildlife Program, private lands biologist.
Lori Stevenson, Ohio State coordinator for the USFWS Partners for Fish and Wildlife Program.
Donovan Henry, Biologist at US Fish and Wildlife Service and an administrator of the Ohio River Basin Fish Habitat Partnership.

QUESTION AND ANSWER SESSION

Comments and questions were taken after each presentation for approximately one half-hour to forty-five minutes. The question and answer portion of each public input meeting was recorded. The typical questions asked during the sessions were as follows:

- What are the sources of funding for the feasibility study and for future dam removal efforts?
- Will dam removal impact water levels, hydrology, and flooding?
- What type of biological impacts will occur if dams are removed?
- How will dam removal impact fishing opportunities?
- What local, state, and federal approvals are required?
- What is the potential timeline of the dam removal efforts?
- What types of contaminants were found in the dam’s sediment?

RESPONSE

Panel members adequately answered questions and provided attendees verbal responses based on the information contained in this feasibility study. Questions were rather comprehensive, with community members seeking to learn about the different options for removal/modification, the economic reasoning behind dam removal, the source of funding for removal, and general questions about the Great Miami River.

PUBLIC SUPPORT

There was some opposition to dam removal voiced during the question and answer sessions, especially during the first two meetings. A few people feel a very strong connection to the dams and the historical, cultural importance of each dam to its respective town. A small, local organization of boaters expressed their desire to retain the ability to use larger boats on the river, but are understanding of the ramifications of keeping the dams. Overall, the community in general seems to agree that because of current safety concerns and long-term maintenance requirements, removal and/or modification (rock riffle) is likely the best option for the community. Additionally, community members are excited for the potential improvements to the local trail network and waterfront accessibility that could be undertaken following the removal of the dams. Everyone in town recognizes the importance of the river and the economic benefits associated with a visually improved waterfront.

There were also concerns raised about the funding mechanism behind the dam removal program, and a general lack of understanding as to how the WRRSP program funds these projects. Donnie Knight was able to explain many of these intricacies, and alleviate concerns that the towns would be making a larger investment into removing the dams than they would be by maintaining them.

FINAL COMMENTS

The intent of the public input process was to provide the public with accurate information, answer questions, and discern general attitudes towards local dam removal. While the citizens and organizations that attended the public forums represent a small percentage of the entire community, we believe that it is fair to conclude that: (a) the public supports dam removal efforts in Miami County, (b) the public is grateful to the local private foundations that support dam removal efforts, (c) the public is grateful that state and federal funding has been secured for the dam removal effort, and (d) the public encourages efforts to pursue modification and/or removal of the three dams.

Members of the panel have reviewed this assessment of the public input process and attest to the description/narrative described in this summary. Miami Valley Today summarized both the initial and final community meetings, these articles are included in the references section.

FIG. 5.2-2 | Organizations attending First Public Meeting

Representatives from the following organizations attended the public forums. This listing is for reporting purposes only and does not represent formal support for the dam removal efforts:

- POWW - Protecting Our Water Ways
- ODOW - Ohio DNR (Department of Natural Resources)
 - Division of Wildlife
- SWCD - Soil and Water Conservation District (Upper Miami)
- OHIO EPA - State Environmental Protection Agency
- MCPD - Miami County Parks District
- CITY OF TROY
- CITY OF PIQUA
- NAPRA - National Association of Professional River Anglers
- UC - University of Cincinnati
- SMH Fly Fishing

- Local “Tackle Shack” Owner
- Landowners
- Citizens

PUBLIC MEETING #1

During the first public meeting, questionnaires were filled out by community members and collected by Flatland Resources. These were intended to gather information about the communities general sentiment towards the river, dams, and general local recreation. The responses included words or phrases community members associate with the river, dams, or their community, and these responses have been illustrated in the “word clouds” on this page. The questions and responses covered several topics; including the dams themselves (below), the Great Miami River (top middle), the role that the river plays in the community (middle bottom), dam removal (top right), and the role of the river in local recreation. The size of each word correlates to the popularity of each word in the responses for that particular subject.

Some of the words/phrases were slightly altered grammatically to more closely match the other responses, and to create a legible graphic (close synonyms were combined, plurals changed to singular form, etc.)



FIGURE 5.2-4 | Public responses: Describe the Miami River

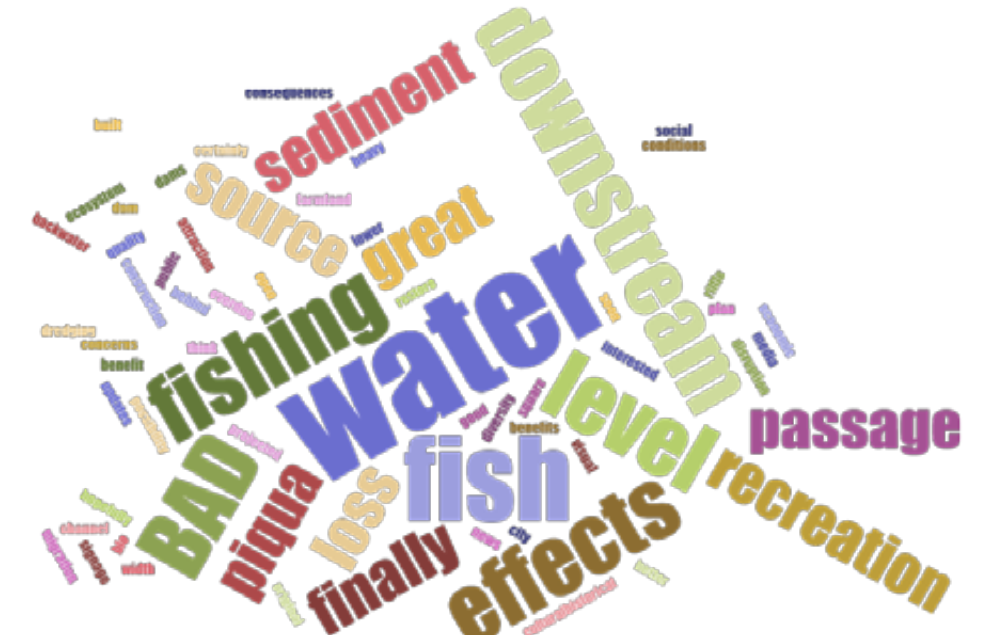


FIGURE 5.2-6 | Public responses: How do you feel about dam removal?



FIGURE 5.2-3 | Public responses: Describe low-head dams



FIGURE 5.2-5 | Public responses: Describe how the Great Miami River is vital to your community

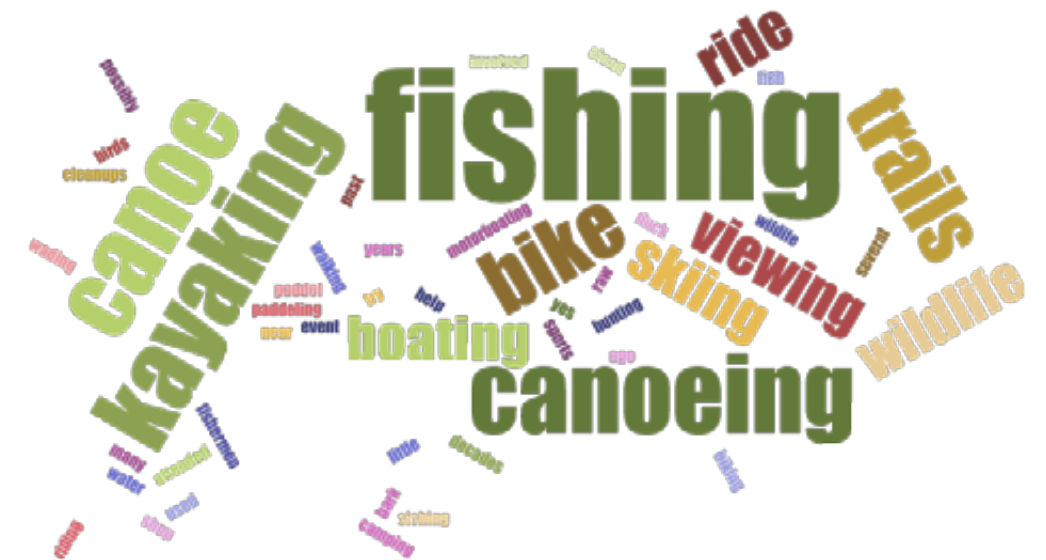


FIGURE 5.2-7 | Public responses: What activities do you associate with the Great Miami River?

5.3 DAM BACKWATER SEDIMENT STUDY

USFWS & WRRSP funding included analysis of the sediment behind the dams, completed by HydroTech Corporation.

Sediment as it relates to dam removal can be considered in three spheres. (1) Sediment in suspension (i.e. sediment generated upstream, mobilized and transported into and through the local stream reach). (2) Bank erosion sediment within the dam reaches (i.e. sediment that is deposited from the previous into the stream pools and back water areas of the dam reaches). (3) Bedload or depositional or dam back water sediment.

WATERSHED SEDIMENT

Upstream sediment has been extensively explored as a part of ongoing Ohio EPA and Miami Conservancy District studies. Troy and Piqua are in the Ohio Valley, in a region of the country that has been labeled by the USGS as a sediment rich pollution zone. The Upper Great Miami Watershed is a sediment rich system. While the majority of the Miami River is rated as Exceptional Warmwater Habitat (EWH) by the Ohio EPA, the impounded areas (dam backwaters) of each the Troy and Piqua dams do not meet this criteria. These impoundments are rated as Warmwater Habitat (WWH), as they only partially meet the requirements to be classified as WWH due to sediment loading and a lack of oxygenation as a result of lower water flows as compared to the free-flowing sections of the Great Miami.

VARIATION IN SEDIMENT TYPES

The three dams in Miami County all appear to have slightly different sediment presences in their backwater areas. The Troy Dam impoundment includes a sediment wedge consisting of mostly sand, with some silt and clay. The Piqua Water Works Dam’s sediment wedge is nearly completely sand, with some silt and a minimal amount of clay. The low-head dam located at Piqua’s former power plant has a backwater sediment wedge of sandy loam. This material contains more silt and slightly less sand than the other dam locations, but a similar amount of clay to the Troy dam. All of the samples taken contain significant portions of cobbles and boulders, larger deposits than were analyzed in laboratory testing. These materials were documented in a reachwide pebble count, the results of which can be found on pages 66-67.

SUMMARY

In each city the dams have been well maintained to preserve the functionality of either adjustable gates (Piqua Power Plant) or bypass pipes (Troy). Usually a yearly occurrence, the backwaters of these two dams have been periodically flushed over time, reducing the presence of heavy metals and other detrimental chemicals, minerals, and other impurities.

With the Clean Water Act (CWA) in the 1970s, factories across the nation fell under tight guidelines to maintain compliance with in order to prevent the discharge of pollutants into rivers. Prior to this legislation factories dumped heavy metals, pesticides, and harmful byproducts into rivers, like a drain. Using this local knowledge, the sediment that has dropped out and is stored behind the dams was sampled for heavy metals. No readings of concern based on the Ohio EPA standards for sample testing has been noted. The lack of high concentrations of constituents of concern is information that would allow for the release of the sediments stored in the dam back water basin areas.¹

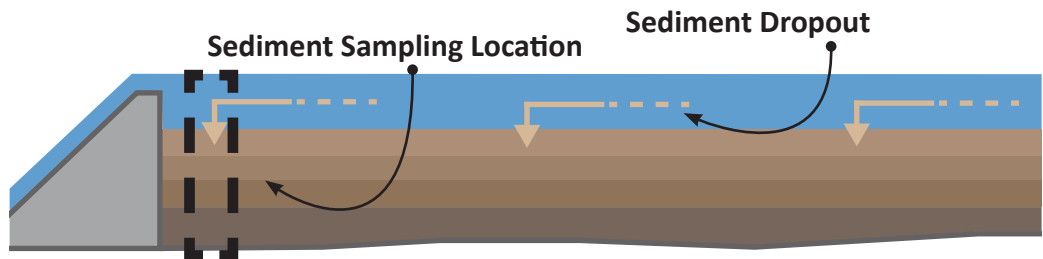


FIGURE 5.3-1 | Sampling Locations

SEDIMENT

¹ https://www.nrcs.usda.gov/wps/portal/nrcs/detail/il/home/?cid=nrcs141p2_031337
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/de/home/?cid=nrcs143_014201

5.3 DAM BACKWATER SEDIMENT STUDY

DAM REMOVAL SEDIMENT ANALYSIS

Aggregate soil sediment sampling was conducted in 2019 at the Troy, Piqua, and Piqua Water Intake Dams by HydroTech Corporation of Anderson, Indiana. This sampling event focused on determining if potential environmental contaminants may be present in river sediments on the up-gradient side of each of the aforementioned dams. Sampling and analysis were performed in a manner consistent with both the scope of work requirements of the Great Miami River Dam Removal Feasibility Study, and instructions from the Client.

CORE SAMPLES

HydroTech collected three (3) sediment samples from the up-gradient side of each dam (sediment sampling locations at Troy low-head dam, Piqua low-head dam, and Piqua water intake). Table 5.3-2 presents the sample identifications and sample depths for each dam. Three samples were taken at each dam from the top of sediment down to an elevation below the toe of the dams. The lower elevations are hoped to be at legacy sediment levels. In other words, samples were taken of all the sediment that has formed behind each dam since they were constructed. The samples at each dam were combined and one test was done for each dam. In almost all of the constituents analyzed, the testing was reported to be below the Probable Effect Concentration (PEC) but above the Threshold Effect Concentration (TEC).

SEDIMENT SAMPLE COLLECTION AND ANALYSIS

Sediment samples were obtained by hand driving a Hand Core Sediment Sampler, or equivalent sampling equipment, to at least one foot (ft) below the bottom of each dam. The samplers were equipped with a new plastic internal liner prior to collecting each sample to prevent potential cross contamination. During sampling, HydroTech personnel inspected each sediment sample in the field. Sediment sample intervals and soil classification characteristics are provided on the boring logs included in Appendix A.E. Sediment collected from each sample was composited in a stainless steel bowl. After composting, each sample was containerized in laboratory supplied sampling jars, labeled, and placed in a cooler with appropriate chain-of-custody documentation and ice, pending delivery to the selected laboratories. A portion of each sediment sample was shipped to Pace Analytical Laboratories, Inc. (Pace) facility in Indianapolis, Indiana for chemical analysis. The remaining portion of each sample was delivered to the A&L Great Lakes Laboratories, Inc. (A&L) facility located in Fort Wayne, Indiana for particle size analysis. Sediment samples were submitted for the following analyses described in Table 5.3-3.

ANALYTICAL RESULTS

The following is a summary of the analytical results for the sediment samples collected from each dam. Several values listed in the following tables have a “less than” sign (“<”), which means that levels were below the method detection limit. The full laboratory report for the sediment samples from each dam, including a copy of the completed chain-of-custody and laboratory quality assurance/quality control (QA/QC) documentation, is contained within Appendix B.

TABLE 5.3-2 | Sample Identification

DAM	IDENTIFICATION	INTERVAL
Troy Low-head Dam	263 - 1	8 - 9 feet
Troy Low-head Dam	263 - 2	8 - 9 feet
Troy Low-head Dam	263 - 3	8 - 9 feet
Piqua Low-head Dam	259 - 1	10 - 12 feet
Piqua Low-head Dam	259 - 2	10 - 12 feet
Piqua Low-head Dam	259 - 3	10 - 12 feet
Piqua - Unnamed	258 - 1	4 - 5 feet
Piqua - Unnamed	258 - 2	4 - 5 feet
Piqua - Unnamed	258 - 3	4 - 5 feet

TABLE 5.3-3 | Analytical methods

PARAMETER	ANALYTICAL METHOD
Total Organic Carbon	Walkley Black
Phosphorus	US EPA SW 846 Method 6010
Arsenic	US EPA SW 846 Method 6020
Cadmium	US EPA SW 846 Method 6020
Chromium (Total)	US EPA SW 846 Method 6020
Copper	US EPA SW 846 Method 6020
Lead	US EPA SW 846 Method 6020
Mercury	US EPA SW 846 Method 7471
Nickel	US EPA SW 846 Method 6020
Selenium	US EPA SW 846 Method 6020
Silver	US EPA SW 846 Method 6020
Zinc	US EPA SW 846 Method 6020
PAHs	US EPA SW 846 Method 8270SIM
SVOCs	US EPA SW 846 Method 8270
Pesticides	US EPA SW 846 Method 8081
PCBs	US EPA SW 846 Method 8082
Particle Size	ASTM D422-63

5.3 DAM BACKWATER SEDIMENT STUDY (cont'd)

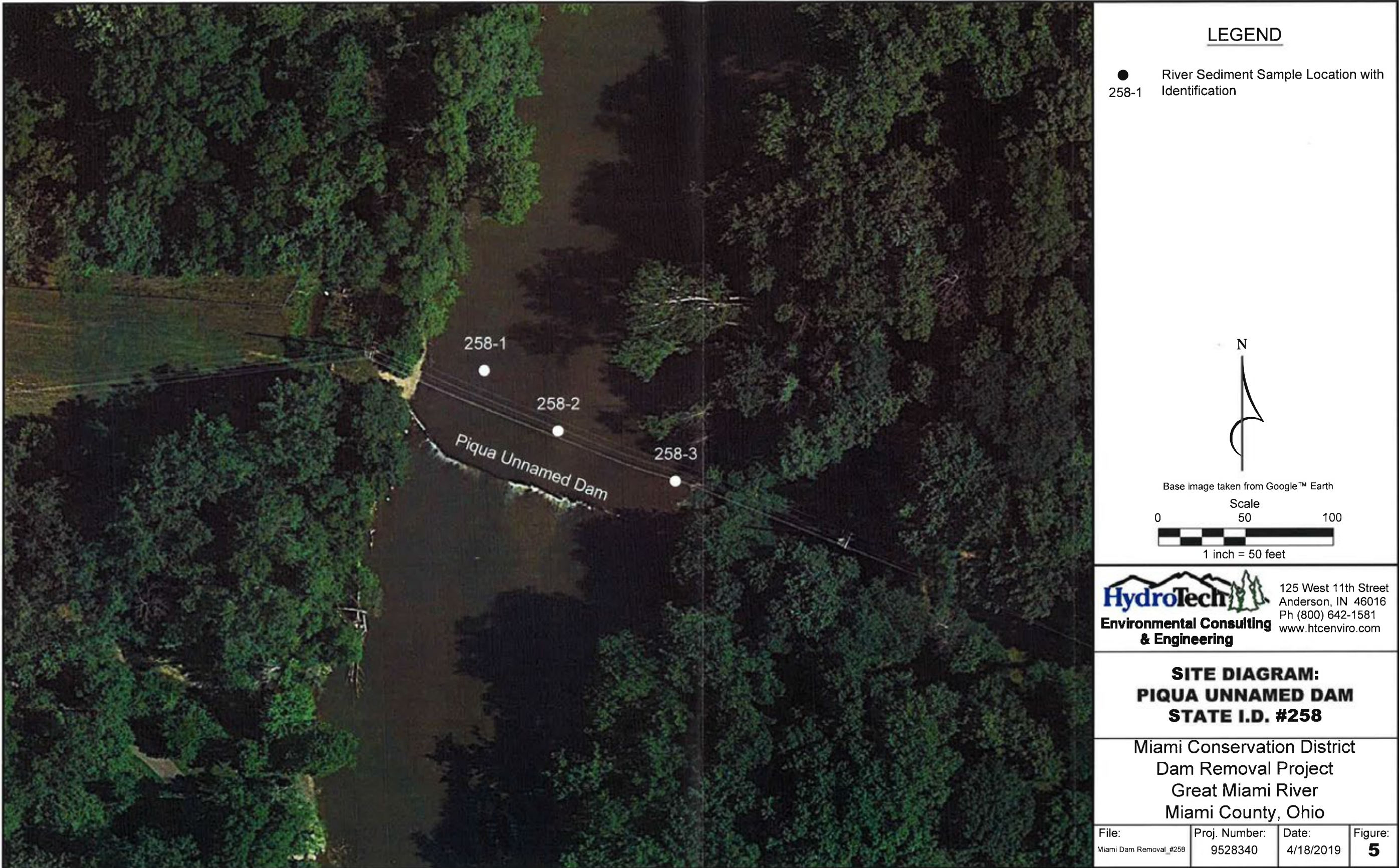


FIGURE 5.3-4 | Sampling Locations at Piqua Unnamed Dam (Piqua Water Works Dam)

5.3 DAM BACKWATER SEDIMENT STUDY (cont'd)

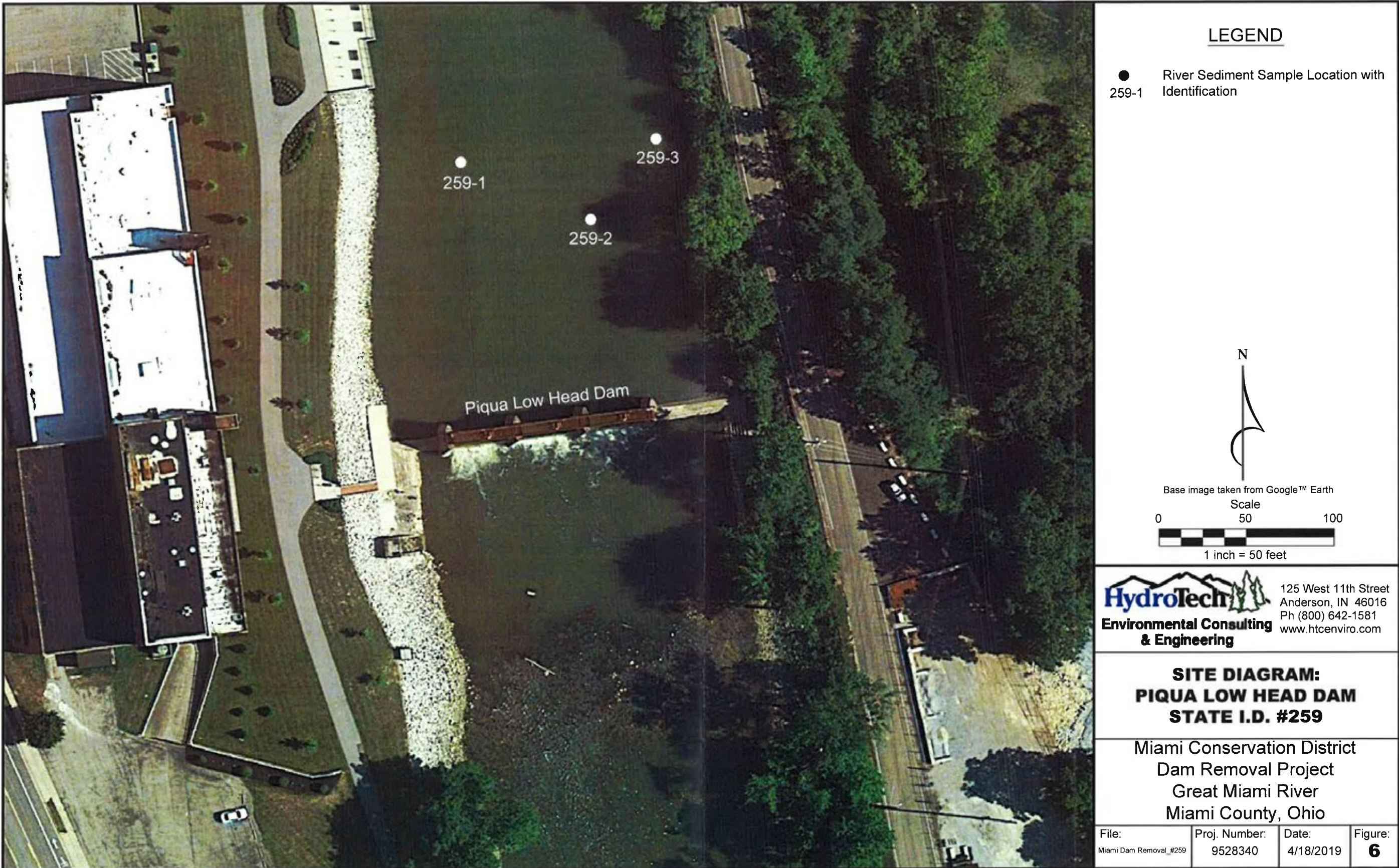


FIGURE 5.3-5 | Sampling Locations at Piqua Low-Head Dam (Piqua Power Plant Dam)

5.3 DAM BACKWATER SEDIMENT STUDY (cont'd)



FIGURE 5.3-6 | Sampling Locations at Troy Low-Head Dam
62 | Great Miami River Dam Removal Efforts

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5.3 DAM BACKWATER SEDIMENT STUDY (cont'd)

DISCUSSION

Analytical results from sediment sampling were compared to Ohio Environmental Protection Agency (EPA) standards provided in the Division of Surface Water *Surface Water Field Sampling Manual*, dated March 30, 2018. Additionally, analytical results for metals were compared to Sediment Reference Values (SRVs) provided in the Ohio EPA Department of Environmental Response and Revitalization (DERR) *Environmental Risk Assessment Guidance* dated July 2018. The SRVs used in this report represent a background level based on samples from non-contaminated sites across the state of Ohio, so any concentration found that is higher than the SRV listed for that contaminant represents an outlier. Of the samples taken, only one was found to have a concentration higher than the SRV, the heavy metal contaminant ‘Lead’ in sample 263-3, behind the Troy Low-Head Dam. This concentration fell below the Probable Effect Concentration (PEC) established regionally by the Ohio EPA.

Based on an analysis of the sampling results and relatively low concentrations of chemicals detected, adverse effects are not expected to occur to ecological receptors from exposure to the sediments. In addition, a conservative comparison of the sediment concentrations of chemicals detected to U.S. EPA Regional Screening Levels (RSLs) for residential soil does not indicate potential human health concerns.

--Vanessa Steigerwald Dick, Ph.D. ; Environmental Scientist, Ohio EPA

TABLE 5.3-7 | Sediment Sample Results compared to Ohio EPA SRVs; and US EPA ESVs, and RSVs.

Parameter	Troy Low-Head Dam mg/kg			Piqua Unnamed Dam mg/kg			Piqua Power Plant Dam mg/kg			Ohio EPA SRV mg/kg	TEC mg/kg	PEC mg/kg
	263-1	263-2	263-3	258-1	258-2	258-3	259-1	259-2	259-3			
Arsenic	2.9	2.9	5.6	3.4	4.0	4.7	5.6	4.6	7.0	18	9.8	33
Cadmium	0.29	0.24	0.43	0.24	0.11	0.12	0.24	0.33	0.43	0.9	0.99	4.98
Chromium	13.5	9.9	17.4	10.4	9.5	4.8	12.9	12.9	16.8	40	43.4	111
Copper	10.9	9.6	20.2	9.5	4.8	4.6	13.6	11.7	17.8	34	31.6	149
Lead	18.9	10.9	108	8.4	3.5	4.4	39.2	26.0	23.8	47	35.8	128
Nickel	12.2	10.4	13.6	12.3	9.2	7.3	15.1	14.7	19.1	42	22.7	48.6
Selenium	0.72	1.2	0.87	0.68	0.43	0.38	1.1	1.1	1.4	2.3	NE	NE
Silver	0.071	0.043	0.087	0.033	0.014	0.016	0.064	0.057	0.079	0.43	NE	NE
Zinc	41.4	40.4	83.5	35.4	14.8	16.5	54.8	62.1	74.7	160	121	459
Mercury	< 0.075	< 0.085	< 0.072	< 0.066	< 0.061	< 0.068	< 0.073	< 0.066	< 0.086	0.12	0.18	1.06
Anthracene	0.0084	0.009	0.129	< 0.0018	0.0623	0.0132	0.0242	0.013	0.0075	NE	0.0572	0.845
Benzo(a)anthracene	0.0365	0.032	0.553	< 0.0019	0.0967	0.0335	0.0725	0.0591	0.0261	NE	0.108	1.05
Benzo(a)pyrene	0.0387	0.0311	0.505	< 0.0022	0.0673	0.021	0.0628	0.0525	0.0236	NE	0.15	1.45
Chrysene	0.0539	0.0448	0.57	0.0022	0.0987	0.0357	0.0842	0.0714	0.0326	NE	0.166	1.29
Dibenz(a,h)anthracene	0.0142	0.01	0.156	< 0.0026	0.0197	0.006	0.017	0.0149	0.0068	NE	0.033	NE
Fluoranthene	0.0856	0.0771	0.868	0.0038	0.237	0.0786	0.151	0.121	0.0602	NE	0.423	2.23
Fluorene	0.0024	< 0.0020	0.0355	< 0.0016	0.0445	0.004	0.0081	0.0033	0.0033	NE	0.0774	0.536
Naphthalene	0.003	0.0034	0.0632	< 0.0012	0.0168	< 0.0012	0.0102	0.0048	0.0033	NE	0.176	0.561
Phenanthrene	0.0258	0.0276	0.277	0.0024	0.228	0.0521	0.0973	0.0462	0.0334	NE	0.204	1.17
Pyrene	0.0767	0.0652	0.749	0.0037	0.167	0.0645	0.137	0.104	0.0517	NE	0.195	1.52
Total PAH	0.000	0.415	5.526	0.012	1.290	0.378	0.869	0.659	0.334	NE	1.61	22.8
Total PCB	< 13.2	< 15	< 12.8	< 11.7	< 10.8	< 11	< 12.8	< 11.9	< 15.2	NE	59.8	676

TABLE 5.3-8 | Highest Concentration Per Site

Metals	TEC	PEC	Troy*	Water*	Piqua*
Arsenic	9.79	33	5.6	4.7	7.0
Cadmium	0.99	4.98	0.43	0.24	0.43
Chromium	43.4	111	17.4	10.4	16.8
Copper	31.6	149	20.2	9.5	17.8
Lead	35.8	128	108	8.4	39.2
Nickel	22.7	48.6	13.6	12.3	19.1
Selenium			1.2	0.68	1.4
Silver			0.087	0.033	0.079
Zinc	121	459	83.5	35.4	74.7
Mercury	0.18	1.06	< 0.085	< 0.068	< 0.086

TEC = Threshold Effect Concentrations - negative environmental effects are unlikely to occur below this concentration of contaminants

PEC = Probable Effect Concentrations - negative environmental effects are likely to be observed at concentration levels higher than this value

* = Highest Reported Concentration at each site

OHIO EPA SRV: Ohio EPA Department of Environmental Response and Revitalization (DERR) *Environmental Risk Assessment Guidance*. <https://www.epa.state.oh.us/portals/30/rules/RR-031.pdf>

OHIO EPA TEC: Swartz, R. C. 1999. Consensus sediment quality guidelines for polycyclic aromatic hydrocarbon mixtures. *Environmental Toxicology and Chemistry*. 18:780-787 <http://www.setacjournals.org/>

OHIO EPA PEC: MacDonald, D. D., C. G. Ingersoll, T. A. Berger. 2000. Development and Evaluation of Consensus-based sediment quality guidelines for freshwater ecosystems. *Arch. Environ. Contam. Toxicol.* 39:20-31 (<http://www.springerlink.com/content/89h1txc7f5a07ybc/>)

TABLE 5.3-9 | Troy Low-head Dam

Summary of Analytical Results			Sample Identification			
	Parameter	Method	Units	263-1	263-2	263-3
PCBs	Aroclor 1016	EPA 8082	mg/kg	< 4.3	< 4.8	< 4.1
	Aroclor 1221	EPA 8082	mg/kg	< 13.2	< 15	< 12.8
	Aroclor 1232	EPA 8082	mg/kg	< 9.2	< 10.4	< 8.9
	Aroclor 1242	EPA 8082	mg/kg	< 3.1	< 3.5	< 3
	Aroclor 1248	EPA 8082	mg/kg	< 3.2	< 3.7	< 3.1
	Aroclor 1254	EPA 8082	mg/kg	< 2.8	< 3.2	< 2.7
	Aroclor 1260	EPA 8082	mg/kg	< 4.5	< 5.1	< 4.4
	Total PCB	EPA 8082	mg/kg	< 13.2	< 15	< 12.8
Metals	Arsenic	EPA 6020	mg/kg	2.9	2.9	5.6
	Cadmium	EPA 6020	mg/kg	0.29	0.24	0.43
	Chromium	EPA 6020	mg/kg	13.5	9.9	17.4
	Copper	EPA 6020	mg/kg	10.9	9.6	20.2
	Lead	EPA 6020	mg/kg	18.9	10.9	108
	Nickel	EPA 6020	mg/kg	12.2	10.4	13.6
	Selenium	EPA 6020	mg/kg	0.72	1.2	0.87
	Silver	EPA 6020	mg/kg	0.071	0.043	0.087
	Zinc	EPA 6020	mg/kg	41.4	40.4	83.5
	Mercury	EPA 7471	mg/kg	< 0.075	< 0.085	< 0.072
	Total Organic Carbon	Walkley Black	mg/kg	16100	15700	42900
	Phosphorus	EPA 6010	mg/kg	369	441	474
Polycyclic Aromatic Hydrocarbons (PAHs)	Acenaphthene	EPA 8270	mg/kg	< 0.0018	< 0.0020	< 0.0261
	Acenaphthylene	EPA 8270	mg/kg	0.0073	0.0052	0.0787
	Anthracene	EPA 8270	mg/kg	0.0084	0.009	0.129
	Benzo(a)anthracene	EPA 8270	mg/kg	0.0365	0.032	0.553
	Benzo(a)pyrene	EPA 8270	mg/kg	0.0387	0.0311	0.505
	Benzo(b)fluoranthene	EPA 8270	mg/kg	0.0414	0.028	0.463
	Benzo(g,h,i)perylene	EPA 8270	mg/kg	0.0336	0.0233	0.273
	Benzo(k)fluoranthene	EPA 8270	mg/kg	0.0399	0.0364	0.435
	Chrysene	EPA 8270	mg/kg	0.0539	0.0448	0.57
	Dibenz(a,h)anthracene	EPA 8270	mg/kg	0.0142	0.01	0.156
	Fluoranthene	EPA 8270	mg/kg	0.0856	0.0771	0.868
	Fluorene	EPA 8270	mg/kg	0.0024	< 0.0020	0.0355
	Indeno(1,2,3-cd)pyrene	EPA 8270	mg/kg	0.0323	0.0222	0.296
	1-Methylnaphthalene	EPA 8270	mg/kg	< 0.0014	< 0.0016	0.0217
	2-Methylnaphthalene	EPA 8270	mg/kg	< 0.0015	< 0.0017	0.027
	Naphthalene	EPA 8270	mg/kg	0.003	0.0034	0.0632
	Phenanthrene	EPA 8270	mg/kg	0.0258	0.0276	0.277
	Pyrene	EPA 8270	mg/kg	0.0767	0.0652	0.749
	Total PAH	EPA 8270	mg/kg	0.000	0.415	5.526

TROY Low-head DAM

The metals arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc were reported by the laboratory at concentrations that exceeded the reporting limits on one or more occasion in the sediment samples collected from the Troy Low-head Dam (samples labeled 263:1, 263:2, and 263:3). Lead was reported at the threshold effect level (TEC), but below the probably effect level (PEC) in one of the samples. Mercury and the polychlorinated biphenyls (PCBs) were not reported above the laboratory reporting limits for these samples. Table 5.4-3, summarizes the results.

TABLE 5.3-10 | Piqua Unnamed Dam

Summary of Analytical Results			Sample Identification			
	Parameter	Method	Units	258-1	258-2	258-3
PCBs	Aroclor 1016	EPA 8082	mg/kg	< 3.8	< 3.5	< 3.5
	Aroclor 1221	EPA 8082	mg/kg	< 11.7	< 10.8	< 11
	Aroclor 1232	EPA 8082	mg/kg	< 8.1	< 7.5	< 7.6
	Aroclor 1242	EPA 8082	mg/kg	< 2.7	< 2.5	< 2.6
	Aroclor 1248	EPA 8082	mg/kg	< 2.9	< 2.6	< 2.7
	Aroclor 1254	EPA 8082	mg/kg	< 2.5	< 2.3	< 2.3
	Aroclor 1260	EPA 8082	mg/kg	< 4	< 3.7	< 3.8
	Total PCB	EPA 8082	mg/kg	< 11.7	< 10.8	< 11
Metals	Arsenic	EPA 6020	mg/kg	3.4	4.0	4.7
	Cadmium	EPA 6020	mg/kg	0.24	0.11	0.12
	Chromium	EPA 6020	mg/kg	10.4	9.5	4.8
	Copper	EPA 6020	mg/kg	9.5	4.8	4.6
	Lead	EPA 6020	mg/kg	8.4	3.5	4.4
	Nickel	EPA 6020	mg/kg	12.3	9.2	7.3
	Selenium	EPA 6020	mg/kg	0.68	0.43	0.38
	Silver	EPA 6020	mg/kg	0.033	0.014	0.016
	Zinc	EPA 6020	mg/kg	35.4	14.8	16.5
	Mercury	EPA 7471	mg/kg	< 0.066	< 0.061	< 0.068
	Total Organic Carbon	Walkley Black	mg/kg	12500	11100	6390
	Phosphorus	EPA 6010	mg/kg	386	270	247
Polycyclic Aromatic Hydrocarbons (PAHs)	Acenaphthene	EPA 8270	mg/kg	< 0.0016	0.016	< 0.0015
	Acenaphthylene	EPA 8270	mg/kg	< 0.0018	0.0243	0.0057
	Anthracene	EPA 8270	mg/kg	< 0.0018	0.0623	0.0132
	Benzo(a)anthracene	EPA 8270	mg/kg	< 0.0019	0.0967	0.0335
	Benzo(a)pyrene	EPA 8270	mg/kg	< 0.0022	0.0673	0.021
	Benzo(b)fluoranthene	EPA 8270	mg/kg	< 0.0025	0.0629	0.0171
	Benzo(g,h,i)perylene	EPA 8270	mg/kg	< 0.0027	0.0339	0.0113
	Benzo(k)fluoranthene	EPA 8270	mg/kg	< 0.0024	0.0632	0.0232
	Chrysene	EPA 8270	mg/kg	0.0022	0.0987	0.0357
	Dibenz(a,h)anthracene	EPA 8270	mg/kg	< 0.0026	0.0197	0.006
	Fluoranthene	EPA 8270	mg/kg	0.0038	0.237	0.0786
	Fluorene	EPA 8270	mg/kg	< 0.0016	0.0445	0.004
	Indeno(1,2,3-cd)pyrene	EPA 8270	mg/kg	< 0.0024	0.0379	0.0118
	1-Methylnaphthalene	EPA 8270	mg/kg	< 0.0013	0.0062	< 0.0012
	2-Methylnaphthalene	EPA 8270	mg/kg	< 0.0013	0.0076	< 0.0012
	Naphthalene	EPA 8270	mg/kg	< 0.0012	0.0168	< 0.0012
	Phenanthrene	EPA 8270	mg/kg	0.0024	0.228	0.0521
	Pyrene	EPA 8270	mg/kg	0.0037	0.167	0.0645
	Total PAH	EPA 8270	mg/kg	0.012	1.290	0.378

PIQUA UNNAMED DAM (WATER INTAKE)

The metals arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc were reported by the laboratory at concentrations that exceeded the reporting limits on one or more occasion in the sediment samples collected from the Piqua Unnamed Dam (samples labeled 258:1, 258:2, and 258:3). Mercury and the polychlorinated biphenyls (PCBs) were not reported above the laboratory reporting limits for these samples. Table 5.4-3, summarizes the results.

TABLE 5.3-11 | Piqua Low-head Dam

Summary of Analytical Results			Sample Identification			
	Parameter	Method	Units	259-1	259-2	259-3
PCBs	Aroclor 1016	EPA 8082	mg/kg	< 4.1	< 3.8	< 4.9
	Aroclor 1221	EPA 8082	mg/kg	< 12.8	< 11.9	< 15.2
	Aroclor 1232	EPA 8082	mg/kg	< 8.9	< 8.3	< 10.6
	Aroclor 1242	EPA 8082	mg/kg	< 3	< 2.8	< 3.5
	Aroclor 1248	EPA 8082	mg/kg	< 3.1	< 2.9	< 3.7
	Aroclor 1254	EPA 8082	mg/kg	< 2.7	< 2.5	< 3.2
	Aroclor 1260	EPA 8082	mg/kg	< 4.4	< 4.1	< 5.2
	Total PCB	EPA 8082	mg/kg	< 12.8	< 11.9	< 15.2
Metals	Arsenic	EPA 6020	mg/kg	5.6	4.6	7.0
	Cadmium	EPA 6020	mg/kg	0.24	0.33	0.43
	Chromium	EPA 6020	mg/kg	12.9	12.9	16.8
	Copper	EPA 6020	mg/kg	13.6	11.7	17.8
	Lead	EPA 6020	mg/kg	39.2	26.0	23.8
	Nickel	EPA 6020	mg/kg	15.1	14.7	19.1
	Selenium	EPA 6020	mg/kg	1.1	1.1	1.4
	Silver	EPA 6020	mg/kg	0.064	0.057	0.079
	Zinc	EPA 6020	mg/kg	54.8	62.1	74.7
	Mercury	EPA 7471	mg/kg	< 0.073	< 0.066	< 0.086
Total Organic Carbon		Walkley Black	mg/kg	14900	13300	13600
Phosphorus		EPA 6010	mg/kg	383	406	697
Polycyclic Aromatic Hydrocarbons (PAHs)	Acenaphthene	EPA 8270	mg/kg	0.0081	< 0.0016	0.003
	Acenaphthylene	EPA 8270	mg/kg	0.0052	0.0062	0.0039
	Anthracene	EPA 8270	mg/kg	0.0242	0.013	0.0075
	Benzo(a)anthracene	EPA 8270	mg/kg	0.0725	0.0591	0.0261
	Benzo(a)pyrene	EPA 8270	mg/kg	0.0628	0.0525	0.0236
	Benzo(b)fluoranthene	EPA 8270	mg/kg	0.0536	0.0461	0.0209
	Benzo(g,h,i)perylene	EPA 8270	mg/kg	0.0383	0.0316	0.0155
	Benzo(k)fluoranthene	EPA 8270	mg/kg	0.0536	0.0507	0.0239
	Chrysene	EPA 8270	mg/kg	0.0842	0.0714	0.0326
	Dibenz(a,h)anthracene	EPA 8270	mg/kg	0.017	0.0149	0.0068
	Fluoranthene	EPA 8270	mg/kg	0.151	0.121	0.0602
	Fluorene	EPA 8270	mg/kg	0.0081	0.0033	0.0033
	Indeno(1,2,3-cd)pyrene	EPA 8270	mg/kg	0.0361	0.0316	0.0151
	1-Methylnaphthalene	EPA 8270	mg/kg	0.0044	< 0.0013	0.0031
	2-Methylnaphthalene	EPA 8270	mg/kg	0.0054	0.0025	< 0.0017
	Naphthalene	EPA 8270	mg/kg	0.0102	0.0048	0.0033
	Phenanthrene	EPA 8270	mg/kg	0.0973	0.0462	0.0334
	Pyrene	EPA 8270	mg/kg	0.137	0.104	0.0517
	Total PAH	EPA 8270	mg/kg	0.869	0.659	0.334

PIQUA Low-head DAM (FORMER POWER PLANT)

The metals arsenic, cadmium, chromium, copper, lead, nickel, selenium, silver, and zinc were reported by the laboratory at concentrations that exceeded the reporting limits on one or more occasion in the sediment samples collected from the Piqua Unnamed Dam (samples labeled 259:1, 259:2, and 259:3). Mercury and the polychlorinated biphenyls (PCBs) were not reported above the laboratory reporting limits for these samples. Table 5.4-3, summarizes the results.

5.4 SEDIMENT RELEASE

DAM REMOVAL SEDIMENT RELEASE CALCULATIONS

The sediment calculations for the Troy and Piqua Dam removal study have been generated as follows and are intended to create feasibility level sediment quantities.

MAXIMUM DRY STORAGE

A quantity that assumes the total area of the backwater basin is completely filled with sediment and no recognition of water flow/volume. The quantity is a wedge calculation: back water pool length X average width X average depth. This would be the maximum storage capacity without water flow.

MAXIMUM WET STORAGE

A quantity that utilizes the maximum dry storage area less the channel bankfull cross sectional area as established by the regional curve drainage area. The calculation assumes a maximum head cut discharge volume created by the bankfull water volume. The calculation is backwater pool length X bankfull cross sectional area / 2. The maximum wet storage volume does not reflect the formation of pools and or bank slopes. This discharge volume assumes a maximum discharge when one-step removal of a dam is used with no bank stabilization or channel feature construction. For the purposes of this study, the backwater length has been adjusted to reflect what was discovered through the actual field survey of the dam backwater areas.

DESIGN DISCHARGE

A quantity that utilizes actual stream cross-sectional survey data. This calculation is based on establishing a preliminary design profile and stream cross sections based on the regional curve bankfull cross sectional areas. Limited bank grading is included in the cross-sections. The calculations are created using AutoCAD and excel cross sections.

ESTIMATED ONE-STEP REMOVAL SEDIMENT RELEASE

A quantity that divides the Design Discharge by three years. This estimate is assuming the one-step removal of a dam will result in the typical three to six year sediment wedge release time frame for the stored sediment to migrate through the system.

The one-step release estimate utilizes multiple existing cross-sections taken upstream and downstream of each dam. A post dam removal profile grade is established to create a control line of the riffle invert elevations. The upstream dam cross-sections then have regional curve cross-sectional areas super imposed at each section location. The bottom of the regional curve cross-section is placed at the control line profile grade of the back water area. An estimated post dam removal thalweg is established to tie the lowest point of the regional cross-section. The difference of the existing cross-sections is then subtracted from the regional curve cross-section then multiplied by length to establish an estimated one-step removal maximum release. The release is divided by a number of years to get an annual release quantity.

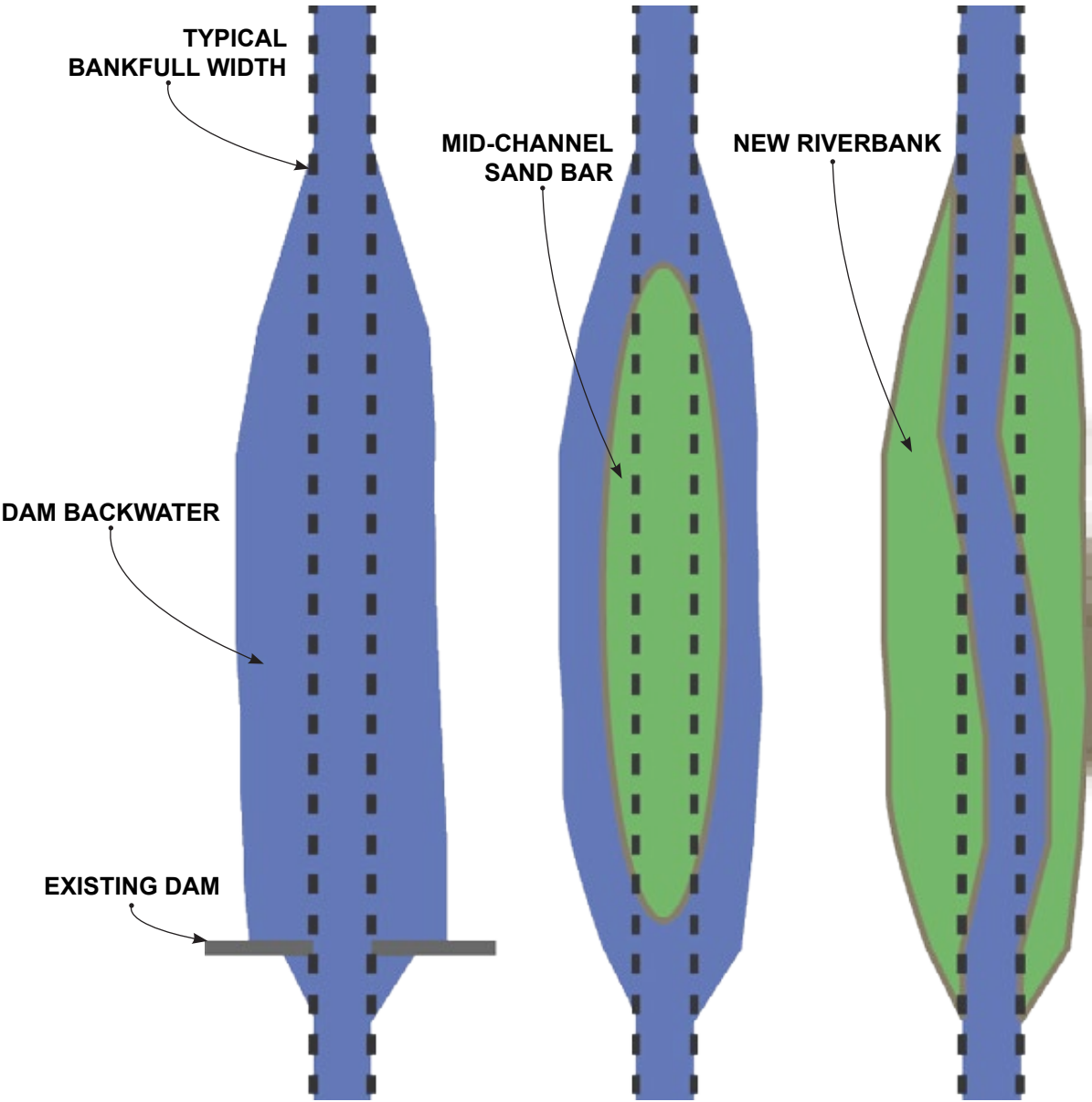


FIGURE 5.4-1 | Natural sediment movement following dam removal

Following dam removal, it is intended, and expected, that the channel will naturally return to the proper bankfull width for the stream in question (right diagram). However, in some cases high water events may remove sediment from near the riverbanks as opposed to the middle of the sediment wedge formed by the previous dam. In these cases, a sandbar will form in the middle which will eventually host stabilizing vegetation (middle diagram). In the meantime the water diverted to either side of this sandbar will increase near-bank stress on the former impounded section's riverbanks, causing erosion problems and future investment in bank restoration. In order to avoid this, some dam removals may require constructed riverbanks stabilization and/or dredging and design of a riffle-pool system to return the river to a more naturalized state. In Miami County, construction of an artificial levee toe along the existing floodwalls would serve this purpose.

EXISTING CONDITIONS

Under normal conditions a low-head, or any run-of-the-river, dam will accumulate sediment and other fine particles behind the dam continually throughout its lifespan. In the case of Troy and Piqua's dams, regular use of the piped spillways (Troy) and adjustable gates (Piqua) has allowed for partial dispersal of this sediment and a reduction in the overall sediment mass in the immediate vicinity of each dam. At the very least, this sediment has been released primarily in the center of the river channel, and will guide the future release of sediment, avoiding creating channel islands and scour along the edges of the river channel.

0 - 1 YEAR POST - REMOVAL

As with all dam removals, there will be a noticeable release of sediment immediately following dam removal. This initial release will immediately begin to change the makeup of the river channel, and improve the habitat available to freshwater mussels and other organisms. As illustrated in the pebble counts taken downstream of the Troy dam, the current channel consists of primarily larger materials. As sediment is moved downstream by periodic high water events, smaller particles will fill in the rocky riverbed, and create a more evenly distributed substrate.

1 - 3 YEARS POST - REMOVAL

Immediately following dam removal the backwater of each dam will likely appear extremely shallow, but over time the river will scour out it's desired path from the existing sediment wedge. With some rivers there is a risk that the river will scour out the edges of the former backwater, creating a center island and increasing bank erosion. However, due to the periodic flushing of each dam there is an existing low-point in the center of the channel throughout the backwater, which will serve as a "guide" for the erosion of each sediment wedge and create a more typical river channel.

>3 YEARS POST - REMOVAL

Following a few years of erosion throughout the sediment wedge of each dam, the river channel will begin to take its permanent shape. Sediment from this upstream region of each dam will continue to move further downstream with each high water event. The portions of the sediment wedge remaining along each bank will also begin to stabilize as the river's new bankfull bench. Vegetation will naturally begin to fill in these areas to stabilize the bench, but could be helped along with seeding and/or planting of native perennials.

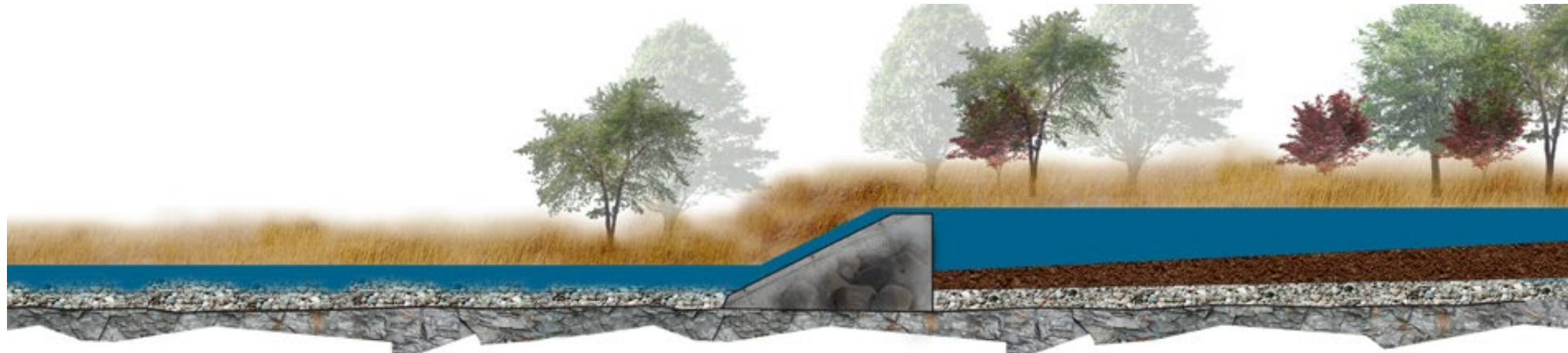


FIGURE 5.4-2 | Dam backwater sediment wedge prior to dam removal

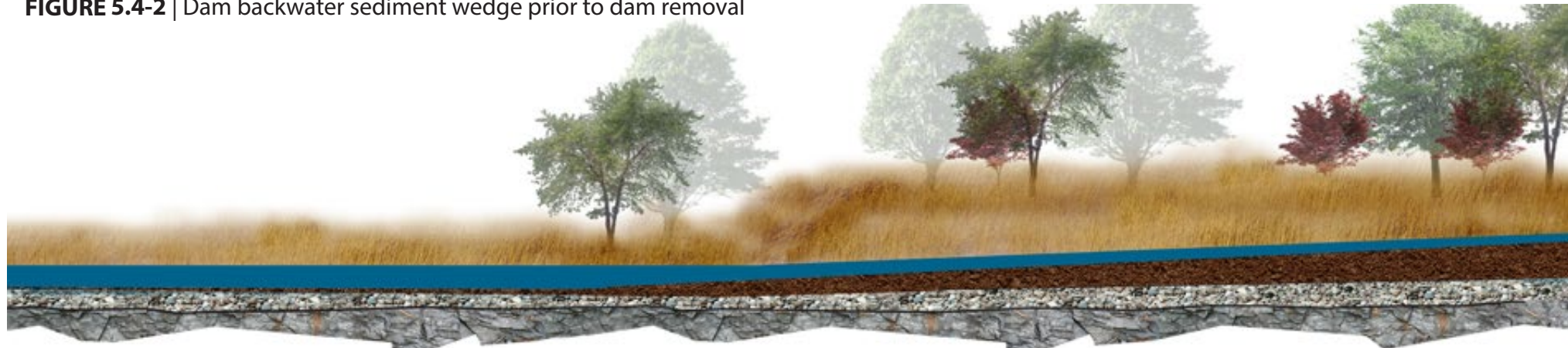


FIGURE 5.4-3 | Dam backwater sediment wedge less than one year following dam removal



FIGURE 5.4-4 | Dam backwater sediment wedge one to three years following dam removal



FIGURE 5.4-5 | Dam backwater sediment wedge more than three years after dam removal

5.5 WOLMAN PEBBLE COUNTS

WOLMAN PEBBLE COUNTS

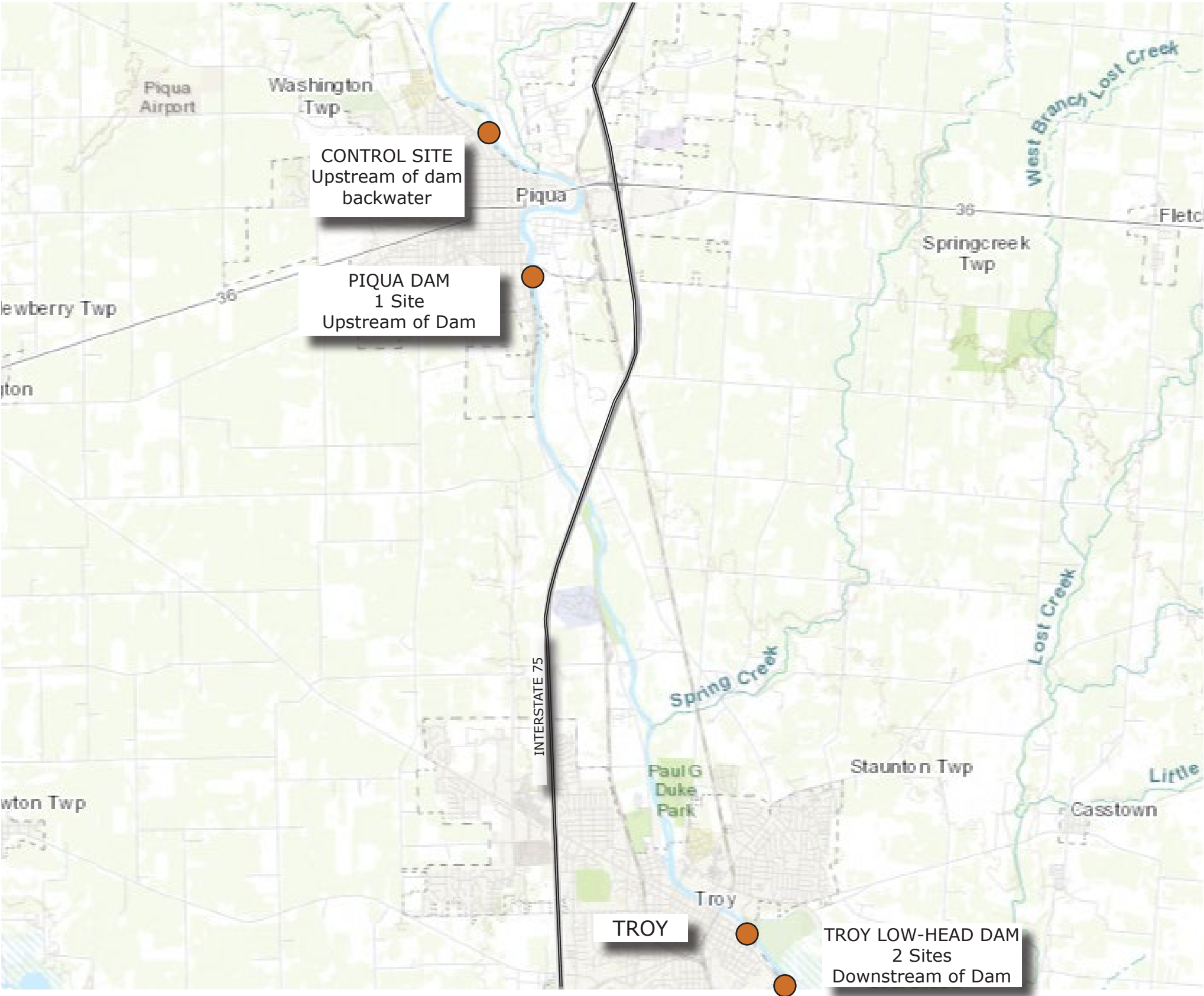
To help with the understanding of the study reach dam backwater sediment, Wolman representative pebble counts were taken upstream and downstream of each of the dams. Representative pebble counts are a stratified systematic sample method to proportionally sample all bed features present within the bankfull channel through a designated reach; this count is used to determine stream type. (Rosgen, River Stability Guide, 2008)

The pebble counts collected for each dam of this project have been compared to pebble counts collected upstream of Piqua, and downstream of Troy. These comparison locations were selected as they do not have a direct flow influence of the Miami County dams. The comparisons, or control locations, were sampled at riffle cross sections. The pebble counts were not taken as stream length representative sampling.

The upstream control, North of Piqua, is assumed to be a best representation pebble count location of a stream riffle upstream and not influenced by dams.

The Piqua Water Works Dam pebble counts show a very similar distribution in particle sizes upstream and downstream of the dam, as well as the control locations. This small dam does not create a backwater area that allows for deposition of finer sediment. The immediate reach of this dam functions more like a stream riffle, but water action over the dam creates a scour hole behind it. The planned constructed riffle, within this scour hole, will initially increase the downstream sizes of pebble counts at the onset of modification. A blending of finer particulates may not be seen in the immediate years of dam modification.

It is anticipated that there will be a more uniform distribution of stream particle sizes after the dams have been removed/altered. Particle distribution at the future riffle locations in dam backwater areas will most likely, over time, become very similar to the knee of distribution at the upstream control site after the dams are removed.



MAP 5.5-1 | Wolman Pebble Count Locations

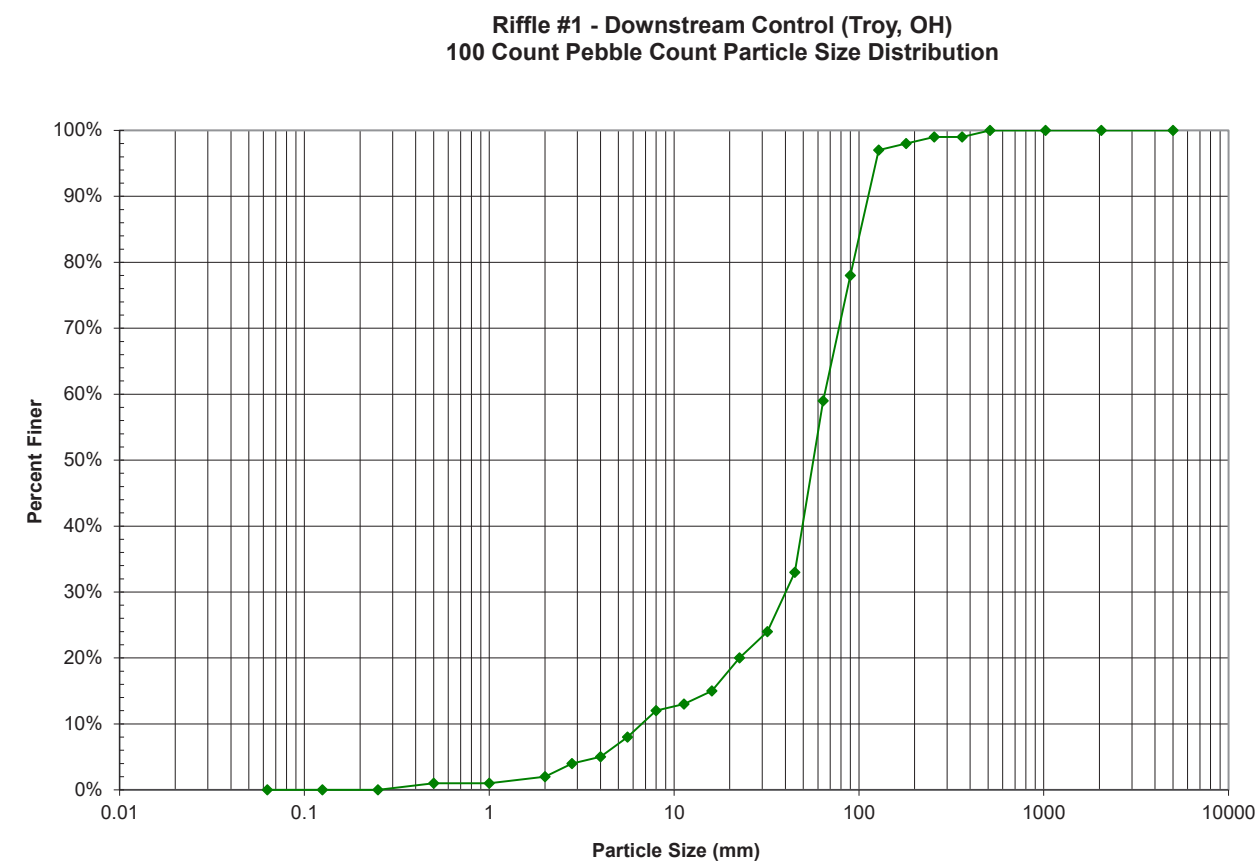


FIGURE 5.5-2 | Particle Size Distribution, Downstream control point

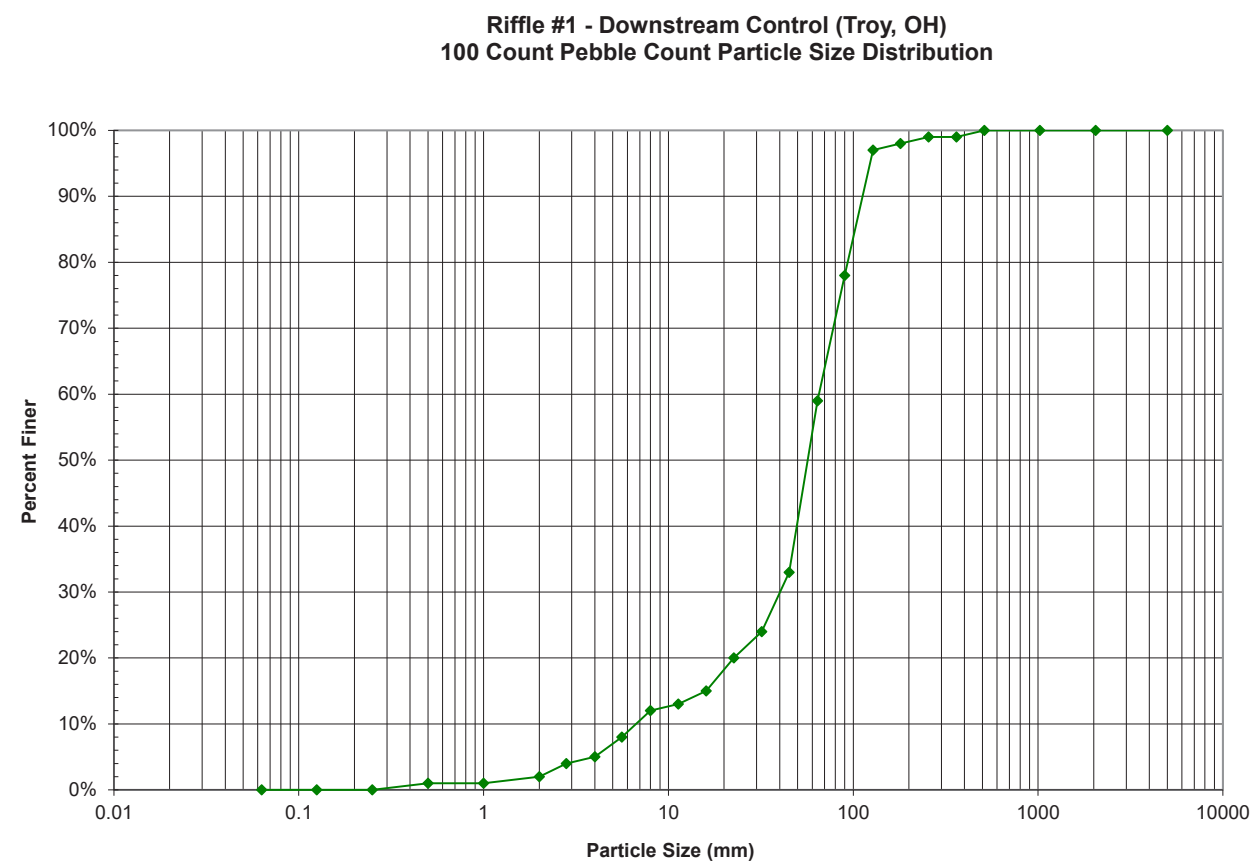


FIGURE 5.5-3 | Particle Size Distribution, Troy Low-Head Dam

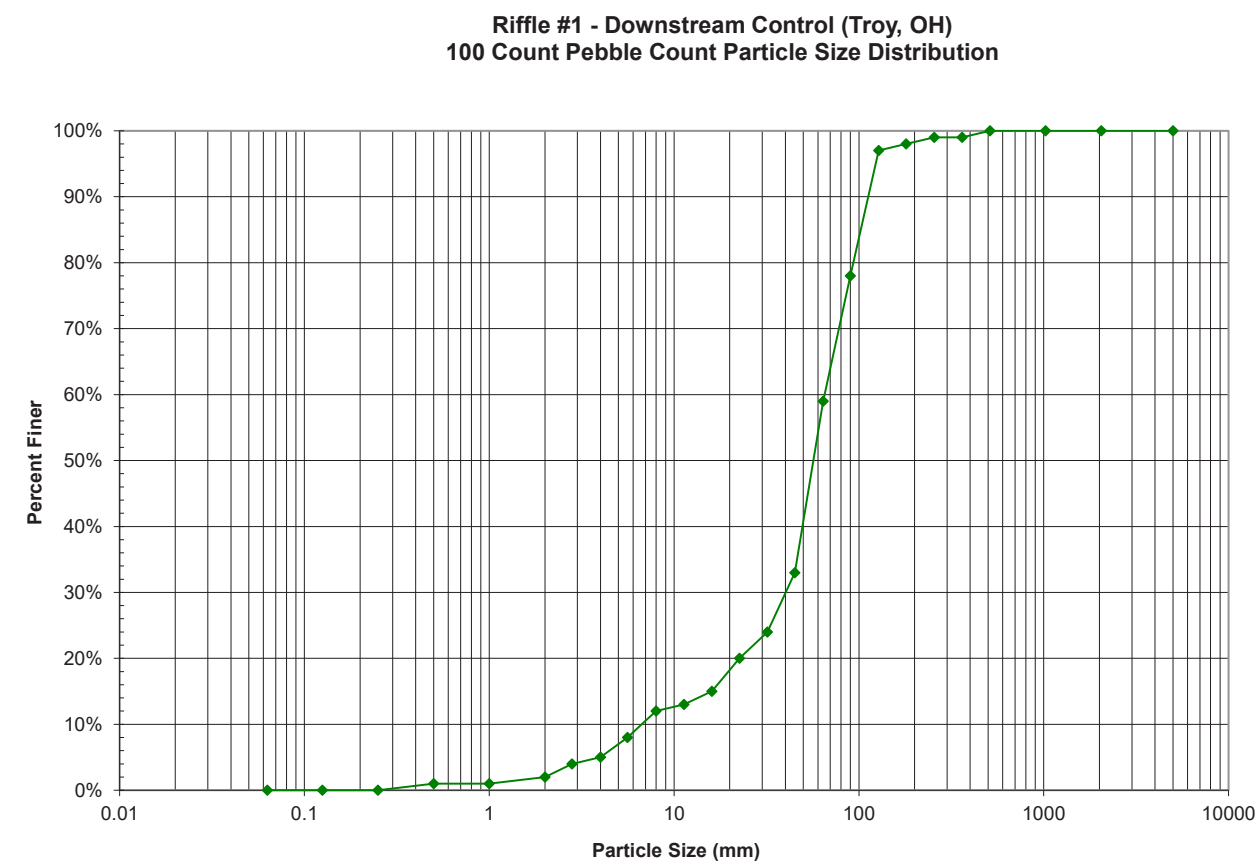


FIGURE 5.5-4 | Particle Size Distribution, Piqua Power Plant Dam

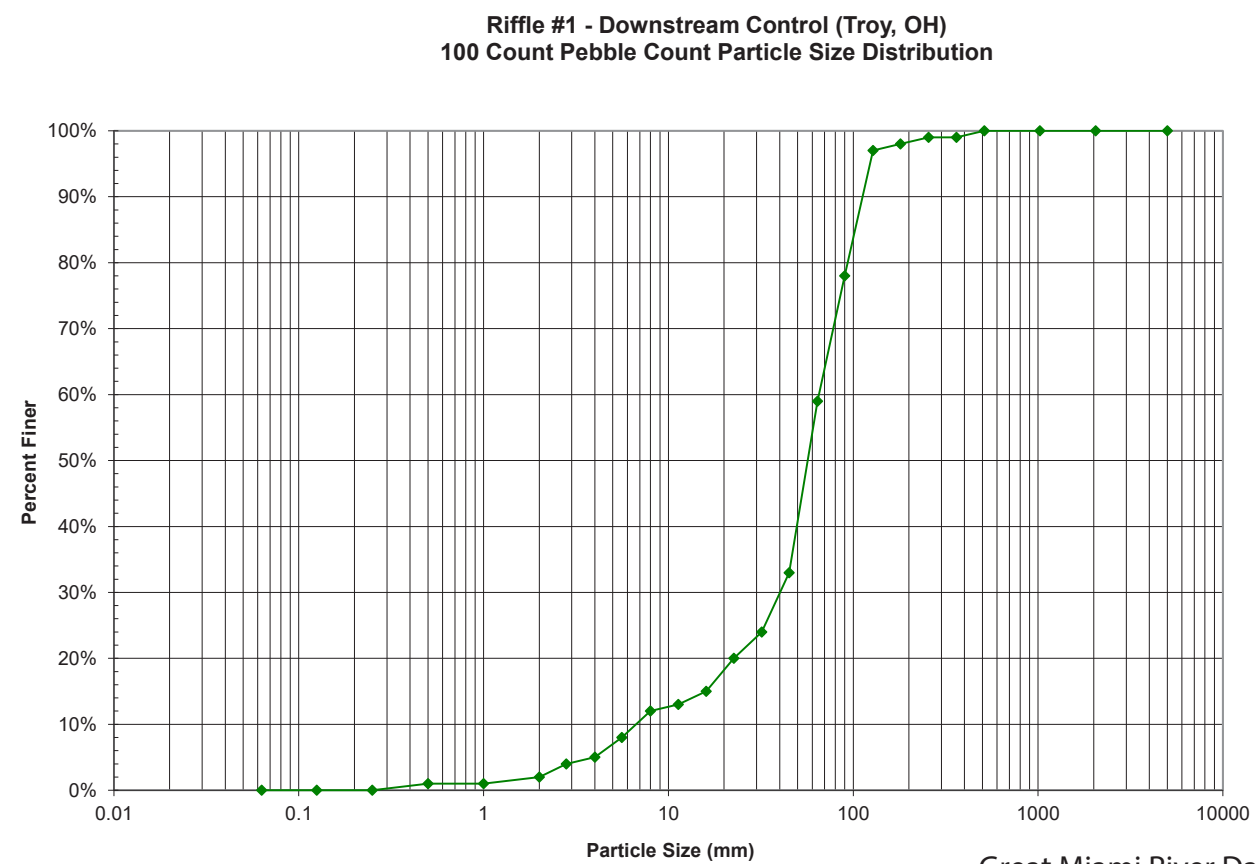


FIGURE 5.5-5 | Particle Size Distribution, Upstream control point



6. PIQUA WATER WORKS DAM

6.1 PIQUA WATER WORKS DAM HISTORY

Piqua has uniquely developed as a thriving industrial town, despite its small size and proximity to larger cities. Prominent former citizens such as the Johnston family and their public projects like the canal, water system, and nuclear reactor, have been essential in propelling Piqua and its development. The dam, as it exists today near Johnston's Farm and Indian Agency, is one of three backup water sources for Piqua's water system, a system that was created in conjunction with the canal about 150 years ago.

By 1829, the Miami-Erie Canal had extended to Dayton from Cincinnati and its arrival was met with fanfare immediately upon completion. This wave of approval spurred Col. Johnston and the other Piqua residents to action, resulting in the extension of the canal to the mouth of Loramie Creek on June 22, 1837. At this time, Piqua became the distribution point for Northwestern Ohio, with many residents "wagoning" goods from Piqua to their various points of business (First Century of Piqua, 1916). In 1844, the canal was successfully extended to Lake Erie, reducing Piqua to a stop along the canal as opposed to an end-point.

Although efforts to procure water supply for Piqua were first initiated in 1833, it was not until 1866 that the city agreed to fund a water works and hydraulic canal to provide the city with drinking water and fire prevention. The Hydraulic Company was formed in order to build the project, and an agreement was put in place with the State of Ohio to use water from the Miami-Erie canal. In 1872 the Hydraulic Company was facing financial difficulties amidst the construction of the canal, and the city bought the company and created a three-member board. The city completed the canal, retarding basins at Swift Run, Echo Lake, and Franz Pond, and paid for iron pipes, pumphouses, and fire hydrants to be installed in time for a grand opening on June 16, 1876.

Originally built by the state for the Miami-Erie Canal System, the dam pictured to the right was constructed entirely of local stone. The dam stretched from the West bank of the Miami 160 feet eastwards to a stone retaining wall. On the other side of that wall an earthen levee completed the dam's span across a more narrow portion of river, but those earthen levees were washed away during the Great Flood. One of the many structures essential to the Miami-Erie Canal that failed during the flood, the original dam was never replaced, allowing water to flow freely around the structure for a few years (right).



FIGURE 6.1-1 | Piqua Water Works Dam - May 1916

PIQUA WATER WORKS DAM

Bankfull Width (W_{bkf}): 197.4 FT*

Bankfull Mean Depth (d_{bkf}): 9.0 FT*

Bankfull Cross Sectional (A_{bkf}): 1,767 SFT*

*Based on regional curve data

**Based upon the approximate design discharge

Following the Great Flood, the canal was abandoned and the dam was re-built at a lower elevation as part of the water works. The Water Works Dam today is a short, low-head dam made with steel sheet pilings that maintains a consistent depth behind the dam for water intake. It cannot be removed, as a portion of the town's emergency water intake depends on the consistent backwater pool, but it could be modified to improve fish passage and boater safety.

Constructing a rock riffle would eliminate the hydraulic jump caused by the short height of the dam, reduce the need for canoes and kayaks to portage around the dam, remove a barrier to fish passage, and virtually eliminate future maintenance costs.

6.2 PIQUA WATER WORKS DAM AS-BUILTS

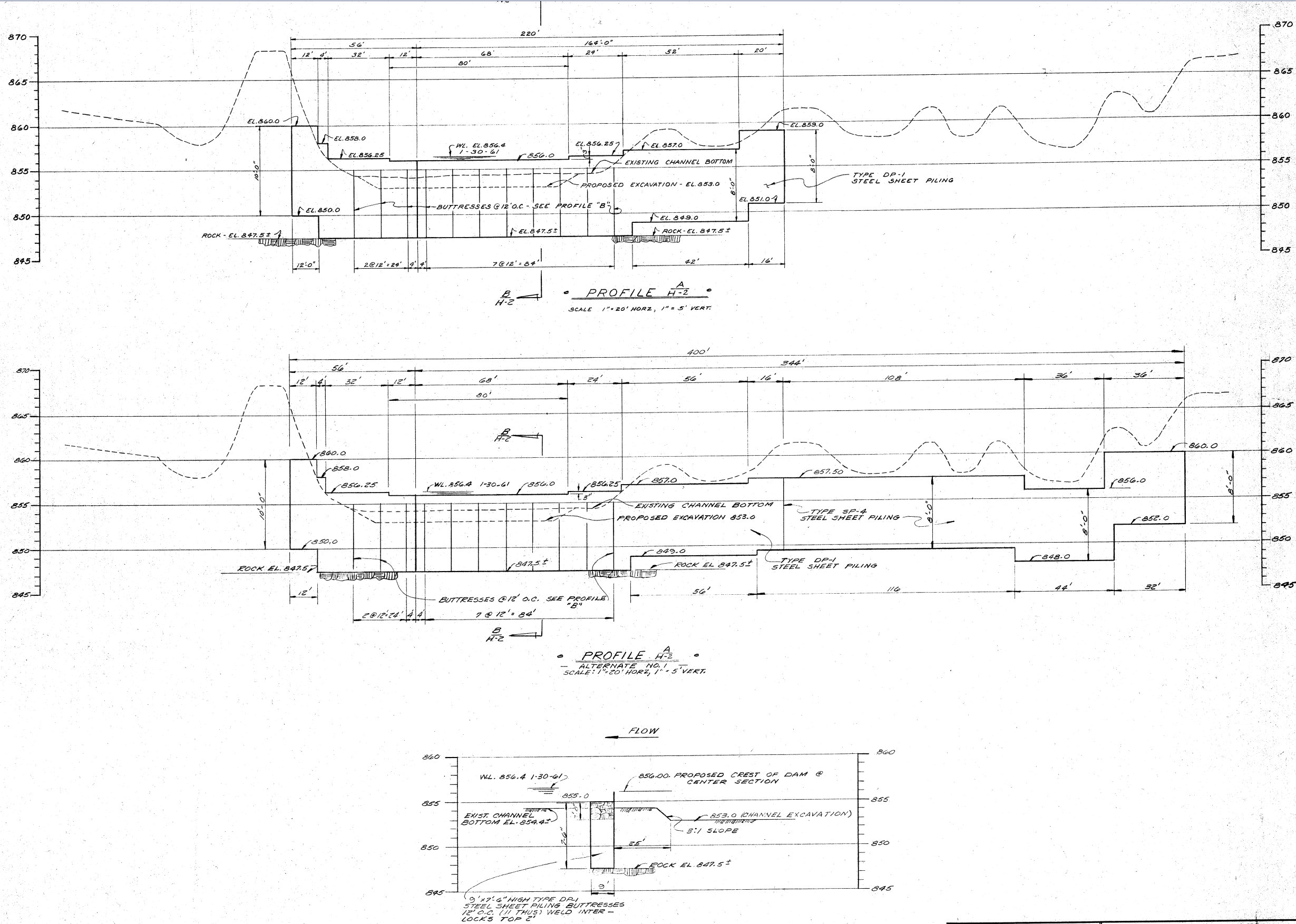


FIGURE 6.2-1 | As Built Drawings of the Piqua Water Works Dam

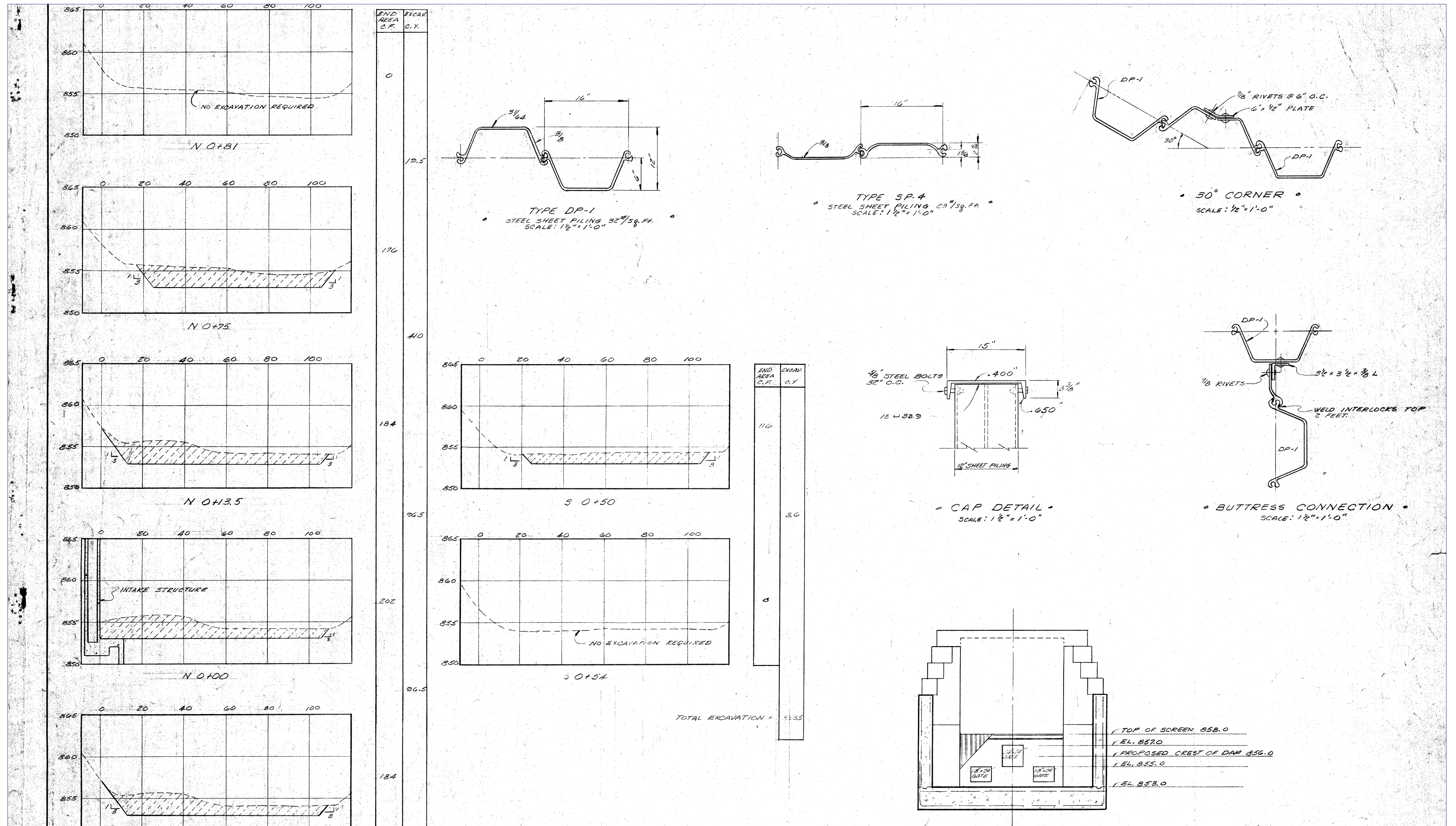


FIGURE 6.2-2 As Built of the Piqua Water Works Dam

6.3 PIQUA WATER WORKS DAM PROPOSED MODIFICATION

While Piqua’s water intake dam is very small and does not pose as much of a risk to humans as the other two dams in this study, it remains a significant barrier to fish passage and biotic diversity within the Great Miami River. It’s purpose is to maintain water elevation behind the dam for water intake purposes, and therefore cannot be removed. It is for this reason that this study recommends the modification of this structure by construction of a “rock riffle”. This constructed riffle will mimic a natural riverine feature, posing no threat to aquatic life and providing additional riffle habitat where none previously existed.

The structure is built by placing several tons of stone in the area just downstream of the dam, converting the dam’s immediate “drop-off” into a gently sloping riverbed. This riverbed will be made up of cobble and river rock, large enough to not be picked up by increased currents in heavy rainfall events. Not only will this structure be safe for water users to travel across via canoe, kayak, etc. but it will maintain the backwater elevation for water intake and provide additional habitat for aquatic species.

Fish use natural riffles as feeding grounds, searching for insects that gather on the water’s surface and on the exposed rock of the riffle during low-flow. Some species have their spawning grounds in riffles, and many invertebrates call these areas home. Riffles also help to oxygenate the water, an essential service for all aquatic species.



FIGURE 6.3-1 | Conceptual Rendering of the modified Piqua Water Works Dam

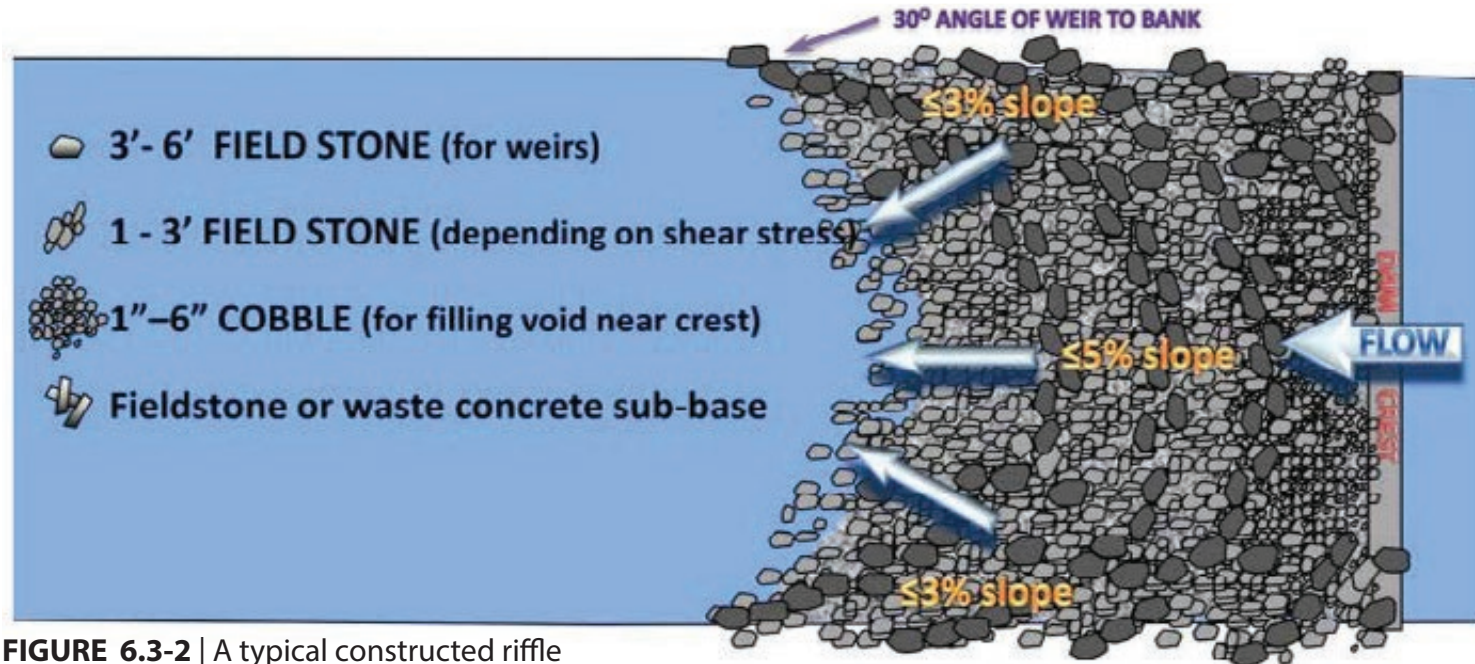


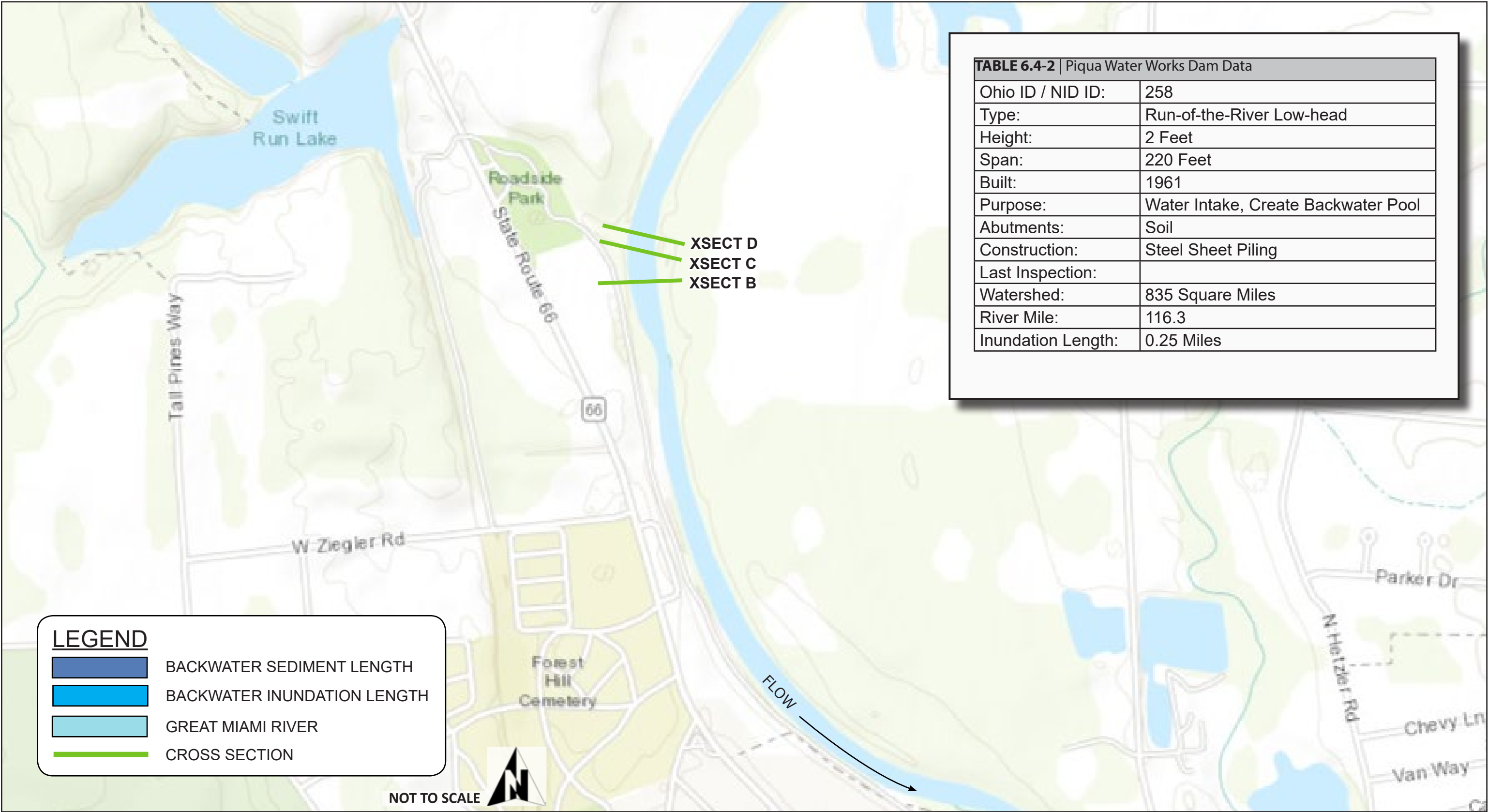
FIGURE 6.3-2 | A typical constructed riffle



FIGURE 6.3-3 | Existing Condition of the Piqua Water Works Dam and Backwater.

6.4 PIQUA WATER WORKS DAM CROSS SECTIONS

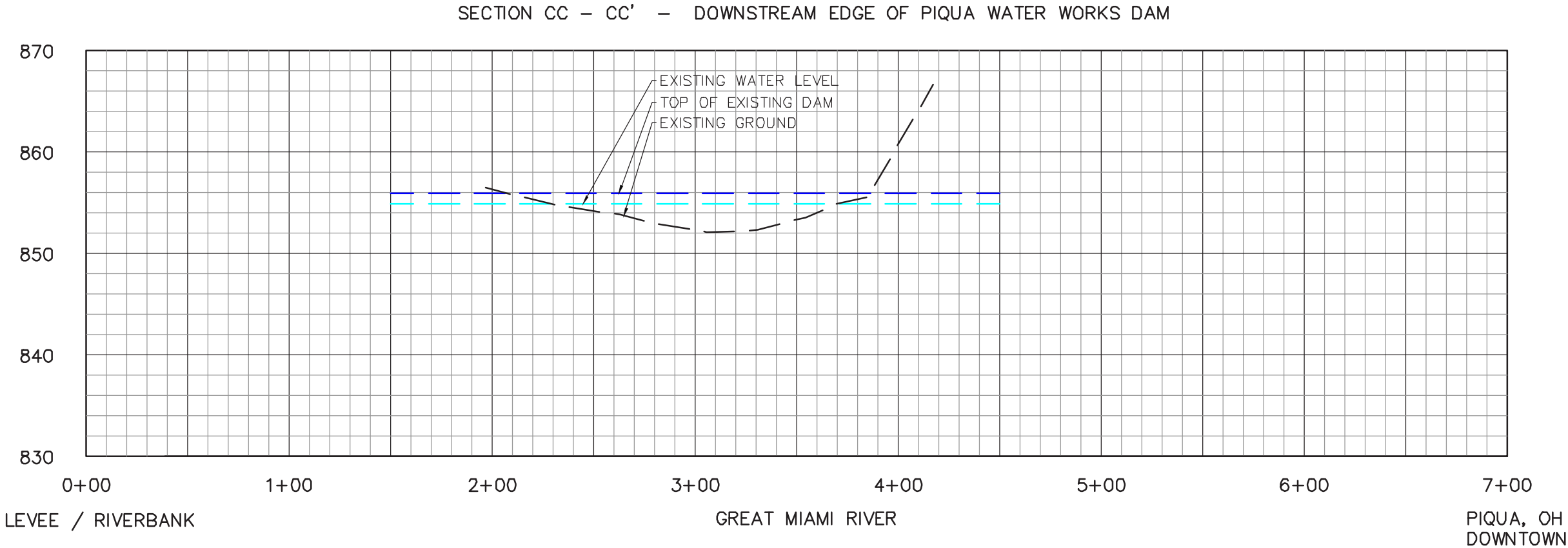
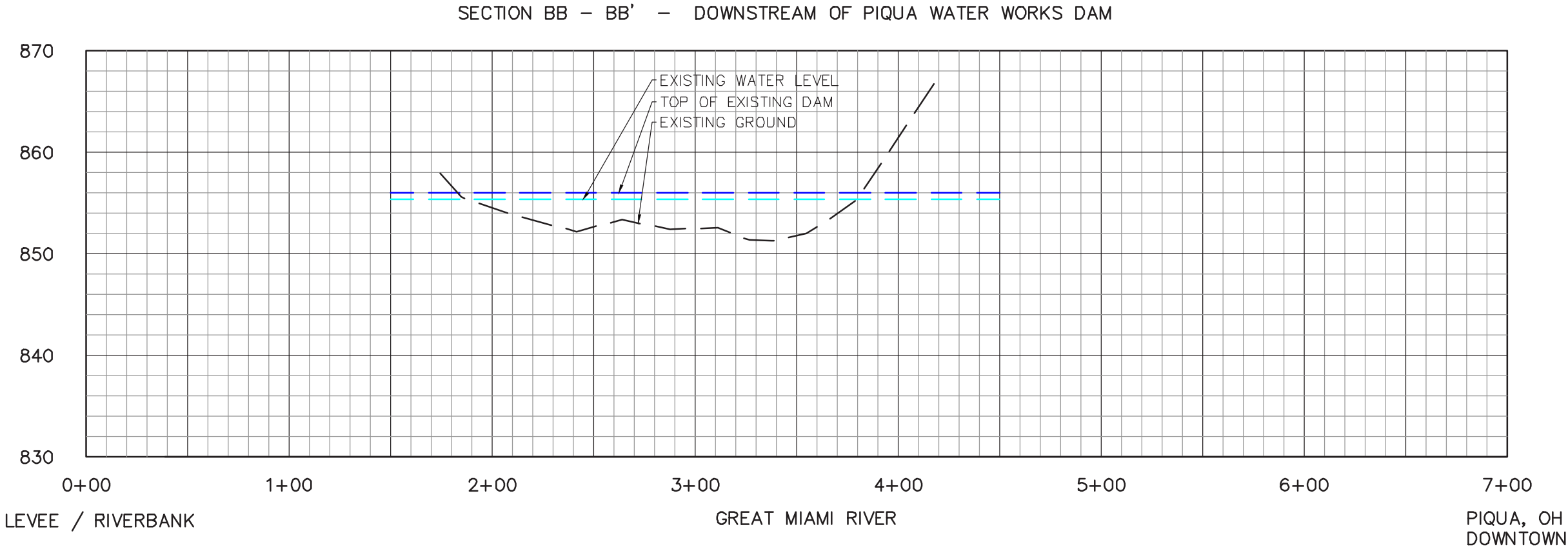
PRE AND POST MODIFICATION

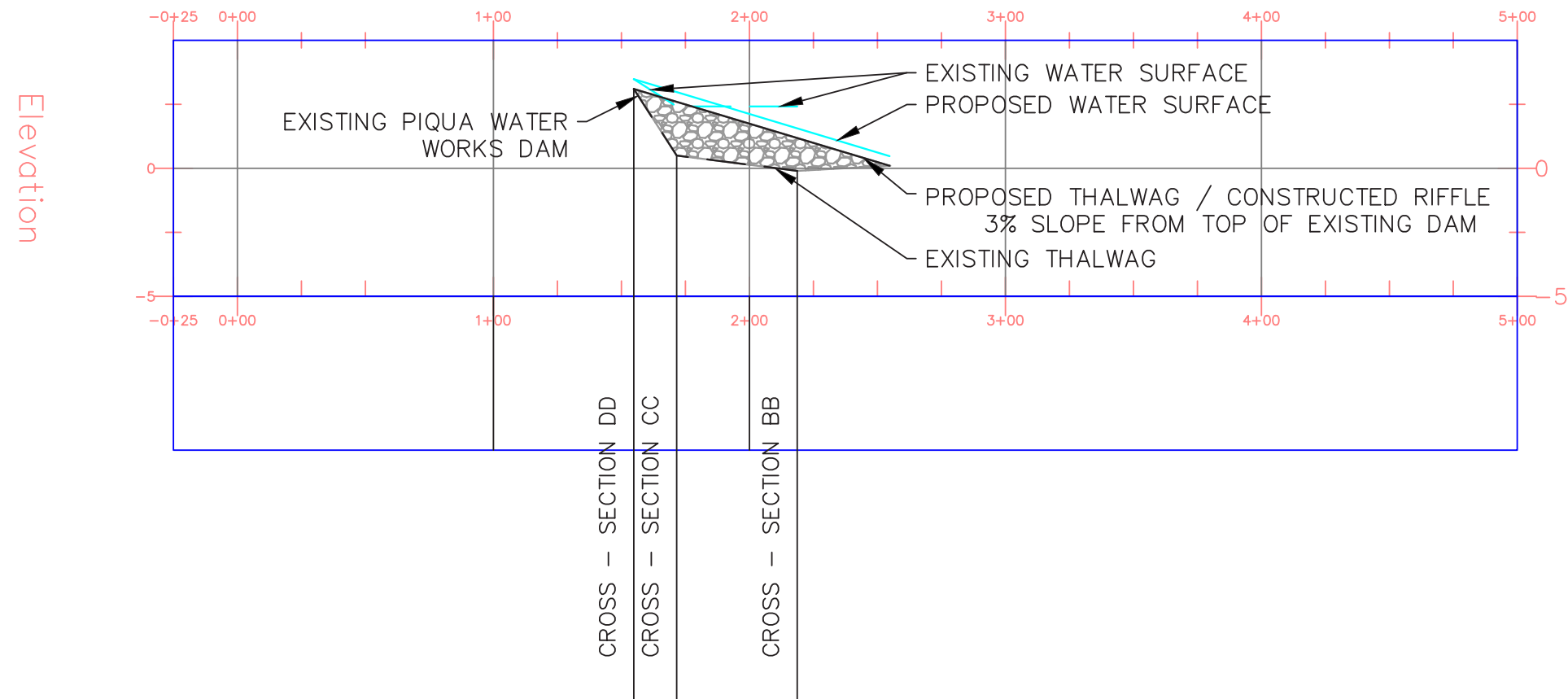
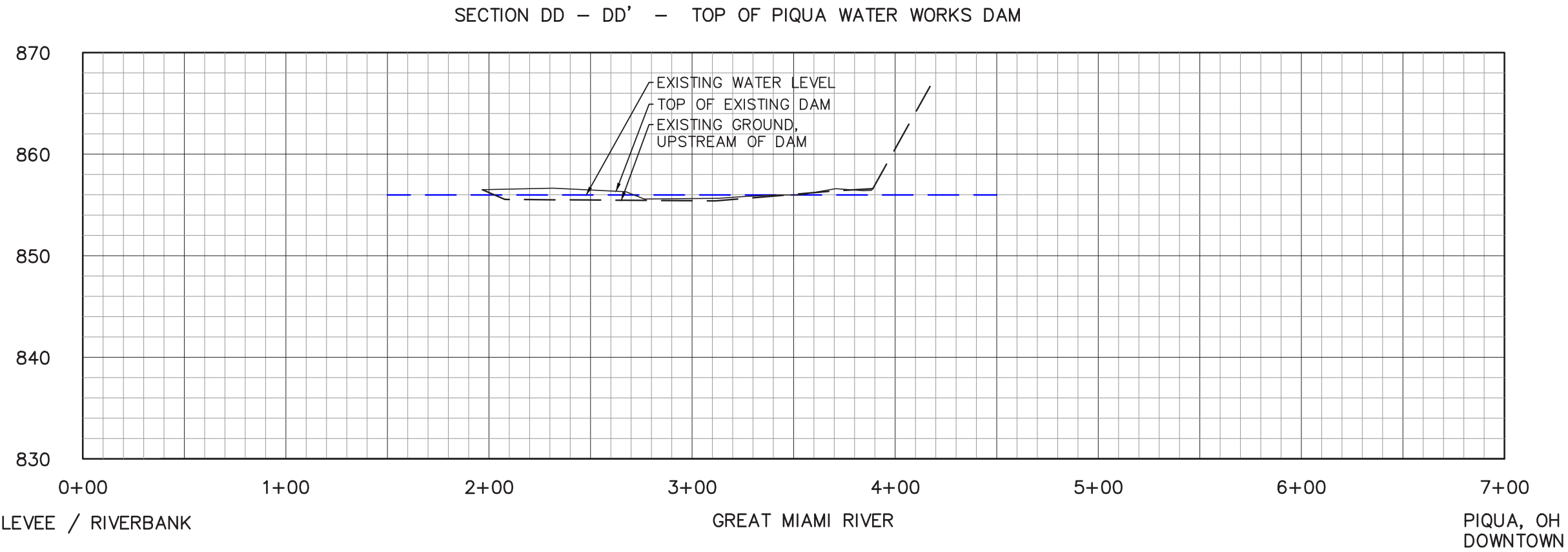


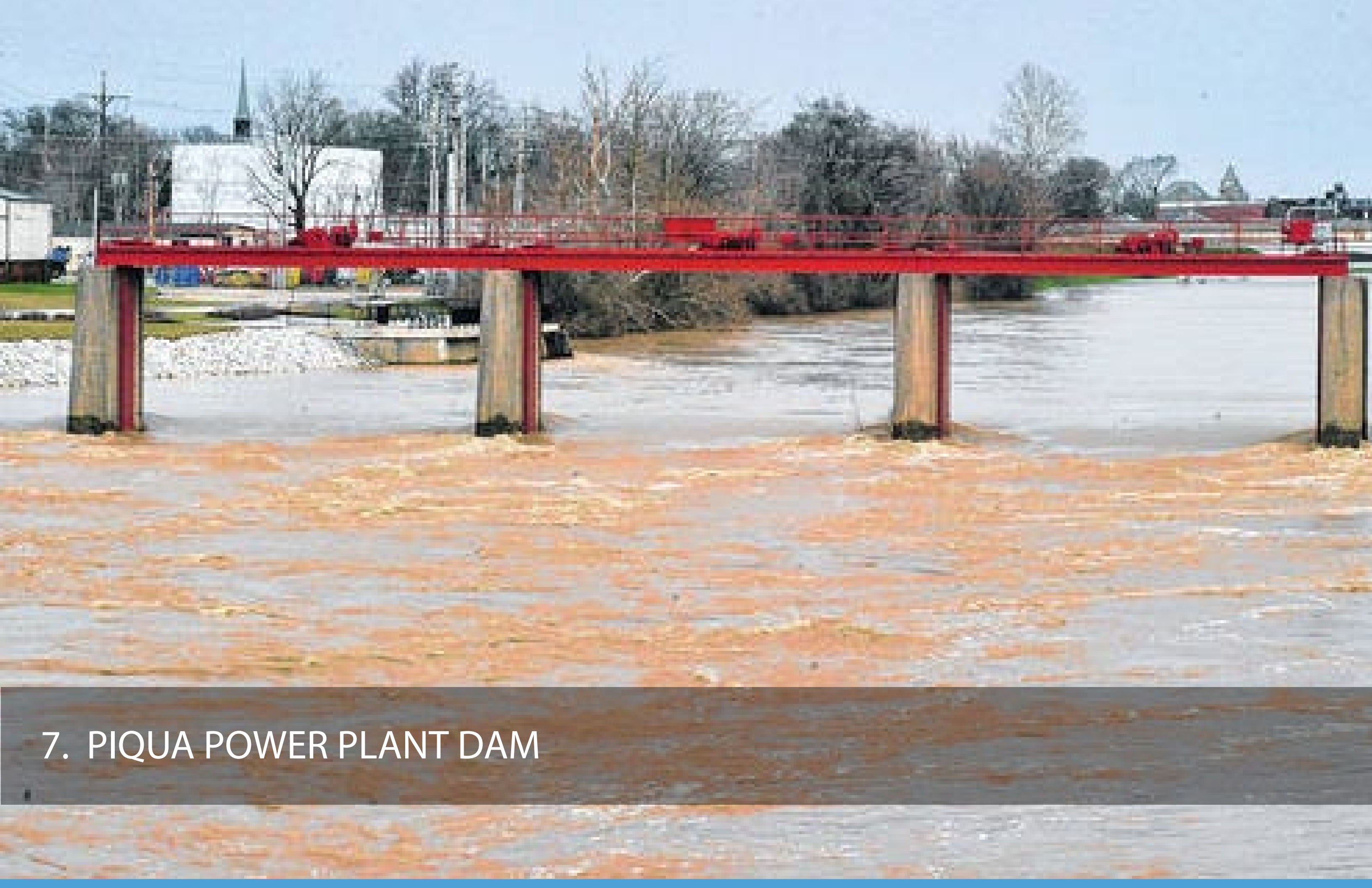
MAP 6.4-1 | Piqua Water Works Dam location, cross sections

6.4 PIQUA WATER WORKS DAM CROSS SECTIONS

PRE AND POST MODIFICATION







7. PIQUA POWER PLANT DAM

7.1 POWER PLANT DAM HISTORY

Piqua's adjustable gate dam was originally built as a wooden structure that required frequent repair and was completely washed out in the flood of 1913. A temporary rockfill dam located just upstream of the present-day dam replaced the wooden structure until the dam we see today was completed in 1937. The adjustable gates, powered by electric winches, control the Great Miami's water level behind the dam and downstream flow rate. These gates are mounted on top of a concrete base, effectively a smaller low-head dam itself. The last major repair work occurred in 2016, when the metal panels were replaced and the dam repainted (Figure 7.1-1).

Originally, the dam pooled water to serve as condenser cooling water for a thermal electricity generating system. Piqua's power plant was an independent entity created to supply the city with power using a number of turbines from its completion in 1933 until 1996. At this time the community completely switched to purchasing power from the open market, as it had been doing in lesser quantities to supplement its own power generation for years. The plant endured several expansions and renovations, in 1939, 1948, 1952, and 1961. For a brief period, from about 1963 to 1966 the City of Piqua received some of its power as part of a federal Atomic Energy Commission (AEC) project. A small organic moderated nuclear reactor was commissioned in 1956 to provide 12,500 megawatts of electricity. Problems with maintenance and the cooling system plagued the plant, resulting in it often operating at partial capacity and its discontinuation by the AEC in 1966.

Today the dam serves no specific purpose, but the MCD requires the the ability to adjust its gates be maintained for flood control purposes. These maintenance costs are the responsibility of the City of Piqua.

The dam's bright red structure, remarkable engineering capabilities, and the history of public events along the river has long made it a local landmark, but its current lack of purpose and need for expensive maintenance makes it a liability to the local taxpayer. A crane of the size necessary to make repairs to the dam's adjustable gates and associated cable systems costs hundreds of thousands of dollars to mobilize. This cost will become increasingly familiar to the local taxpayers as the dam ages and requires more frequent repairs, as most structures do.

Piqua's adjustable gate dam is a modern marvel, with many complexities and multiple components that will take time and caution to remove safely. Access to the extremely channelized river in this location will be difficult for construction crews and the dam will need to be removed in sections, the overhead structure first and then the concrete base. However, we are confident that the dam's removal will benefit the average citizen of Piqua through its cost savings, elimination of a safety hazard, and beautification.

Following dam removal, the water level will drop and the river will find a new equilibrium. Riffles and other submerged features will reveal themselves, providing high quality habitat and a more interactive waterfront for fisherman, boaters, and trail users.



FIGURE 7.1-1 | A large crane makes repairs to the dam's adjustable gates.

PIQUA POWER PLANT DAM

Bankfull Width (W_{bkf}): 200.4 FT*

Bankfull Mean Depth (d_{bkf}): 9.1 FT*

Bankfull Cross Sectional (A_{bkf}): 1,814 SFT*

Backwater Reach Length: 12,500 LFT

Backwater Sediment Length: 9,000 LFT

Estimated Max Dry Sediment Volume: 306,666 CYS

Estimated Max Wet Sediment Volume: 302,383 CYS

Estimated Design Discharge Sediment Volume: 419,479 CYS

Annual Sediment Release: 120,000 - 160,000** CYS yearly

*Based on regional curve data

**Based upon the approximate design discharge

7.2 PIQUA POWER PLANT DAM REMOVAL



FIGURE 7.2-1 | Existing Conditions of the Piqua Dam Backwater



FIGURE 7.2-2 | Rendering of Proposed Changes to the Piqua Dam Backwater

7.2 PIQUA POWER PLANT DAM REMOVAL

The back water area of the Piqua Power Plant Dam is approximately 1.4 miles long (Map 7.5-1).

Following dam removal, it is expected that the width of the Great Miami as it flows through Piqua would be reduced to 190' - 200', as opposed to the current ~240' width of the dam's backwater. This change would more closely align the river's features with that of the non-impounded sections immediately North and South of the city, which exemplify characteristics more closely associated with this type/size of river according to regional curve data. The expected change in river width throughout the backwater is illustrated in Figure 7.2-2, as compared to the original width shown in Figure 7.2-1. Additionally, areas of bedrock that are currently submerged would likely be exposed by the drop in water level associated with dam removal. This bedrock would form natural riffles and other features not seen in this stretch of river in some time, creating high quality aquatic habitat and interesting water features for recreational users.

In some areas where near bank shear stress is high, particularly the riprap armored outside meander bend near Lock Nine Park (Figure 7.4-5), in-stream structures may be utilized to dissipate water velocities and prevent future erosion. See page 84 (Figure 7.4-4) for examples of these structures. These features, like the naturally exposed riffles that will present themselves as the dam's backwater is reduced by removal, could also be utilized by both humans and aquatic life in ways not possible in the existing impounded pool. In the immediate vicinity of the former dam, the channelized nature of the river as it exists today means less of a reduction in overall width will be observed, however water velocities will likely increase. The use of in-stream structures in this area could help provide additional stabilization, much like the existing bedrock further upstream (See Figure 7.2-3).

By eliminating the dam and implementing some in-stream improvements a few immediate goals will be realized: 1) future long-term maintenance costs of repairing the dam's structure and adjustable gates will be eliminated, 2) features and recreational opportunities not previously available will become available for all, and 3) fish passage and aquatic habitat will be significantly improved, improving the fishing available in town.



FIGURE 7.2-3 | Conceptual Rendering of the former Piqua Power Plant Dam



FIGURE 7.2-4 | Existing Condition of the Piqua Power Plant Dam.

7.3 POWER PLANT DAM AS-BUILTS

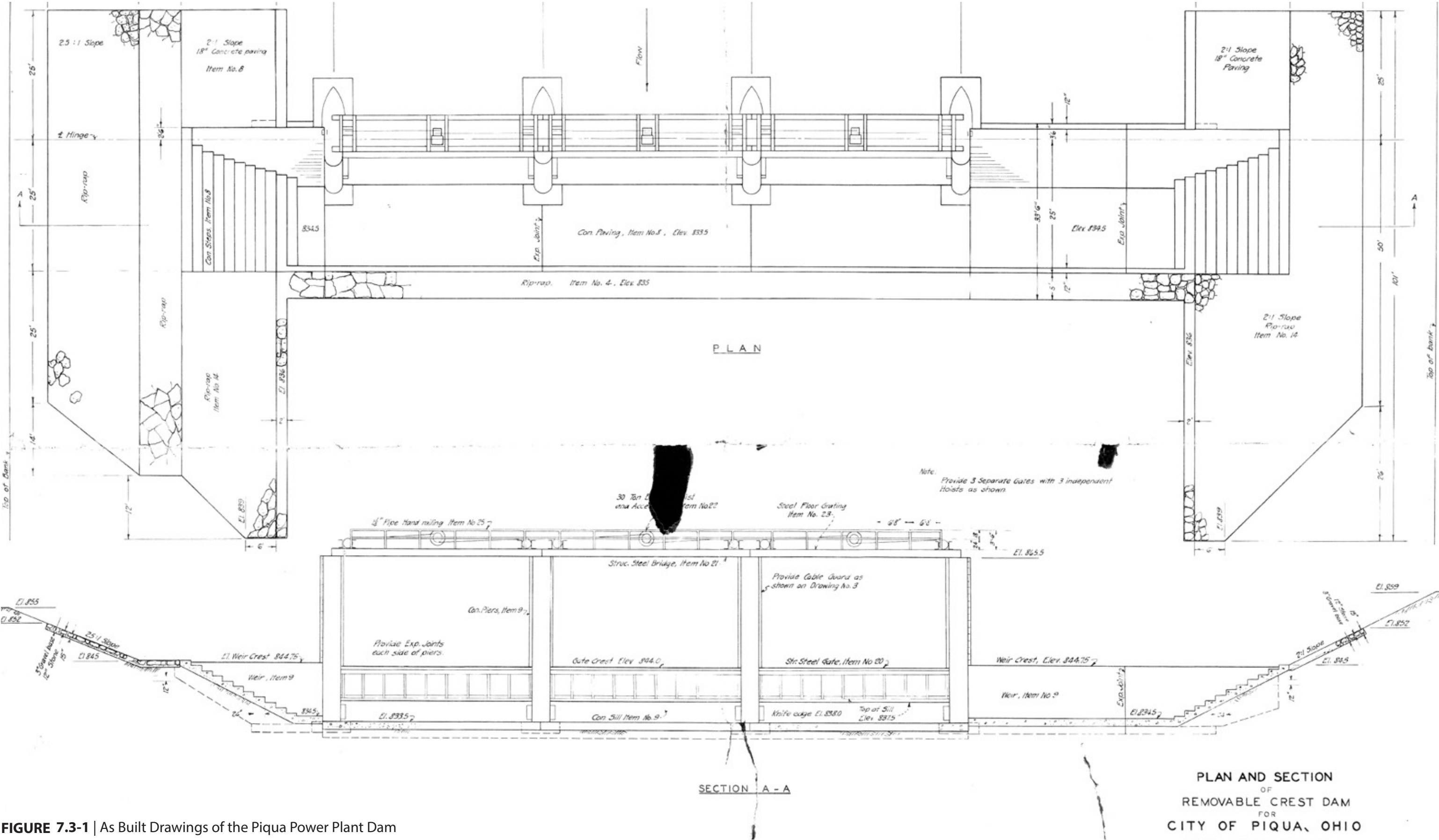


FIGURE 7.3-1 | As Built Drawings of the Piqua Power Plant Dam
82 | Piqua Power Plant Dam

7.3 POWER PLANT DAM AS-BUILTS (cont.)

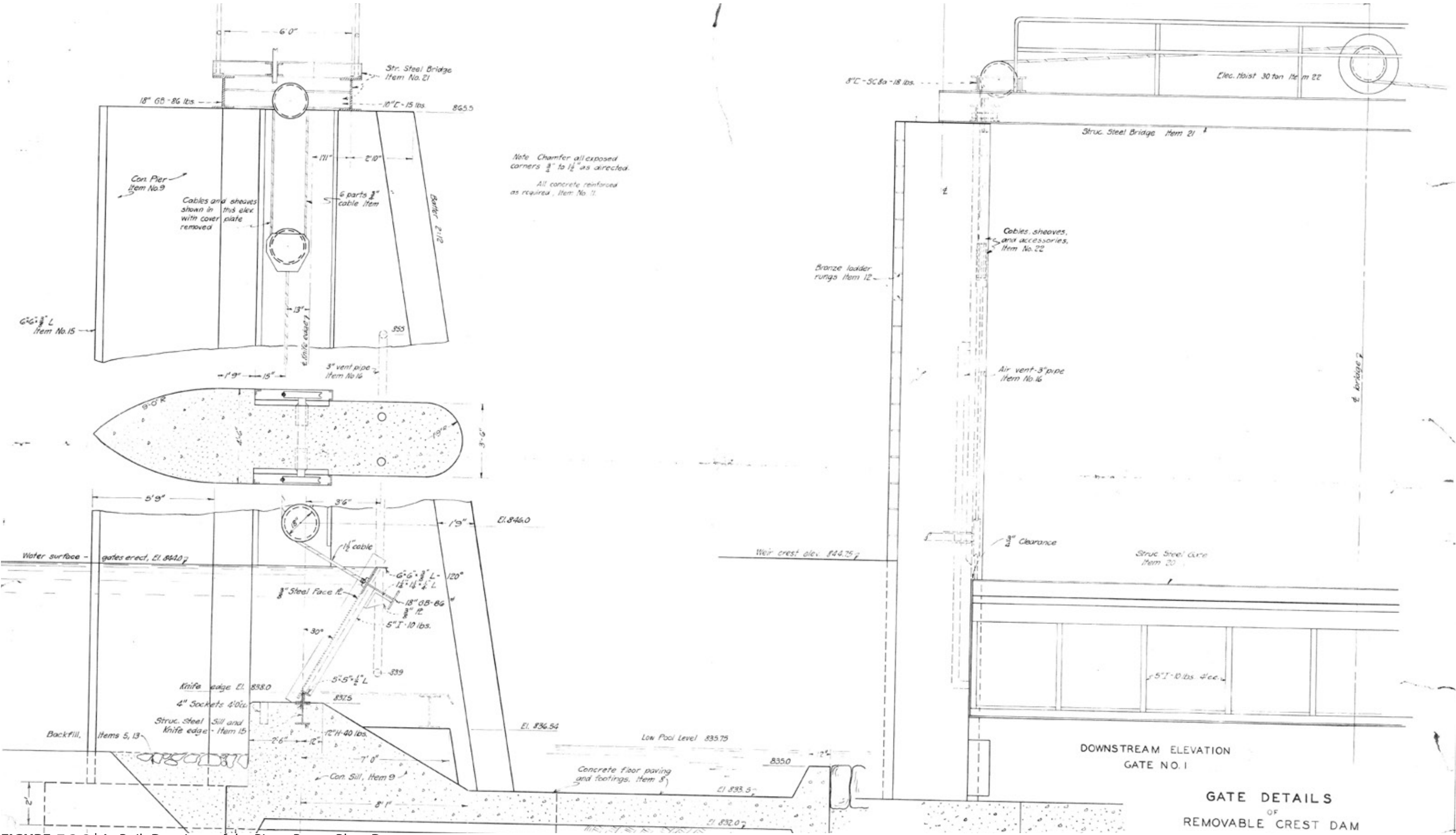


FIGURE 7.3-2 | As Built Drawings of the Piqua Power Plant Dam

7.4 IN-STREAM STRUCTURES



FIGURE 7.4-1 | J-Hook

ROCK STRUCTURES (J-HOOK, W-WIER, CROSS VANE)

Rock structures, such as j-hooks, w-wiers, and cross vanes redirect flows away from stream banks, thereby preventing erosion (Fig. 7.4-1). These can be constructed of entirely rock or a combination of rock and logs along with on-site alluvium or imported stone, and filter fabric. The placement of these structures is similar to the placement of rock vanes in that they are typically placed at the 1/2 to 2/3 point along a meander bend. They are installed to not only protect stream banks from erosion, but also to help aid in grade control and create more bedform diversity. Channel flows that are redirected from stream banks typically create scour pools immediately downstream of the structure. As a result, deep pools typically form, creating habitats for both fish and macro invertebrates.



FIGURE 7.4-3 | Rootwads

ROOTWADS

Rootwads are stream bank stabilization structures typically placed on outside meander bends. The rootwad is positioned on the lower one-third to one-half of bank to ensure the wood is submerged in order to prevent wood rot (Fig. 7.4-3). Locating the rootwad within the stream also helps dissipate the energy of the water as it flows into the bank. Typically, soil lifts and live cuttings are installed on top of the rootwad to create a stable bank system while also ensuring the rootwads do not float downstream during a high water, high energy event. Of all the natural channel design structures, rootwads by far offer the best habitat for fish, mussels, and other species.



FIGURE 7.4-2 | Vegetated geolift

VEGETATED GEOLIFTS

A vegetated geolift is a stream bank stabilization structure built of soil, coconut fiber matting, live brush cuttings, and either a stone or rootwad footer. These structures are typically placed in highly eroded areas where a new bank needs to be built or in areas of high erosion potential. The purpose of this structure is to create a hardened, live stream bank. The live cuttings create shade to reduce in-stream water temperatures. A stone or rootwad footer is installed to create a solid platform for subsequent soil lifts. Coir fabric matting is rolled out and soil is placed on top of the matting in approximately 6"-12" lifts. The matting is wrapped back over the soil and keyed into the adjacent bank. Live cuttings of either willows or dogwoods (other species can be used) are placed in a row with the bottom ends making contact with the adjacent bank and the bud ends sticking out towards the water to help create the live bank. This process is repeated several times until the desired height is reached (typically bankfull stage). Installed live cuttings establish a robust root system through the vegetated geolift which helps to maintain stream bank integrity. Figure 7.4-2 represents a vegetated geolift (on October 29, 2013 by Flatland Resources).

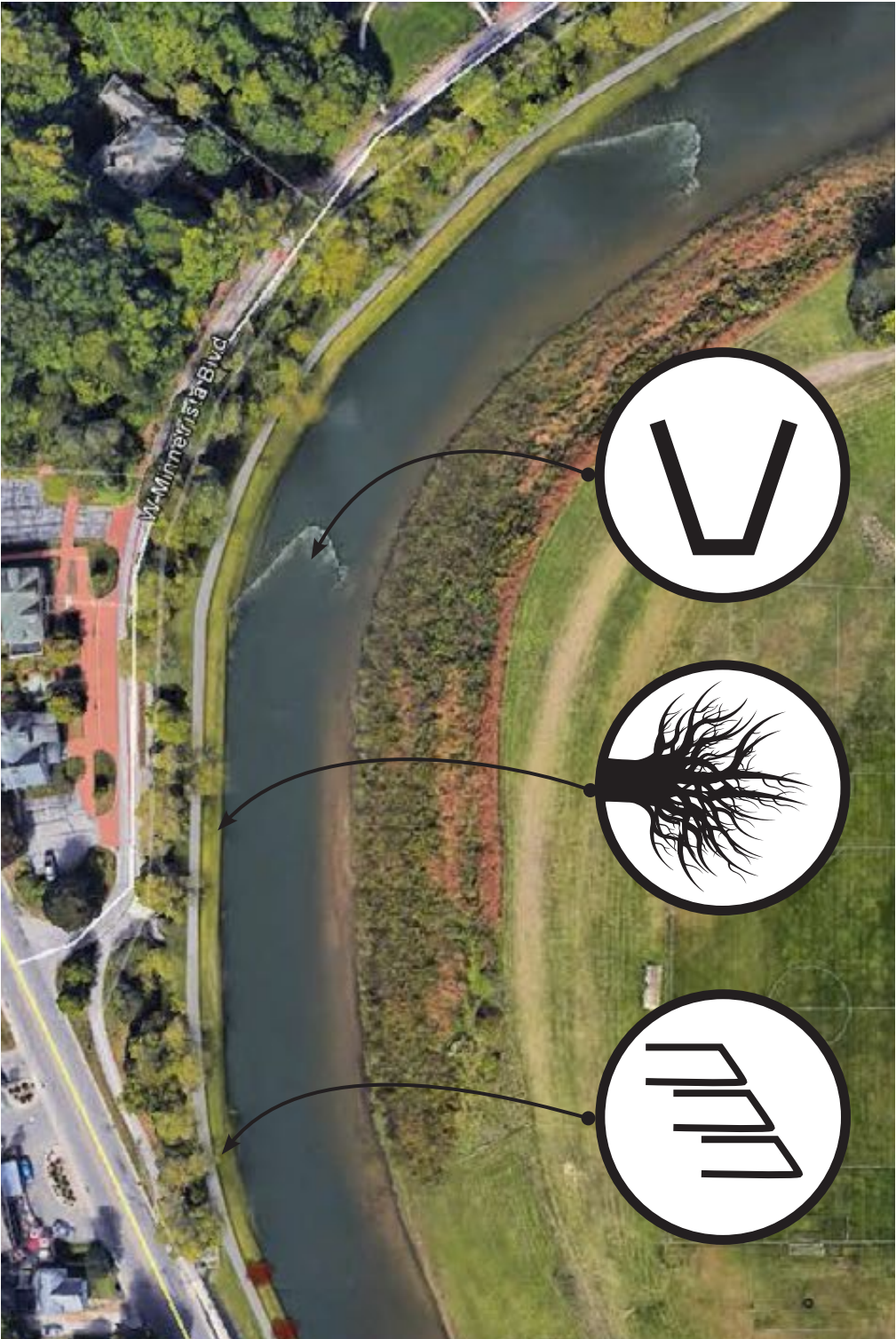


FIGURE 7.4-4 | Conceptual Plan View of an outside meander bend



FIGURE 7.4-5 | Conceptual rendering of proposed in-stream improvements along the outside meander bend where Lock Nine Park is located.

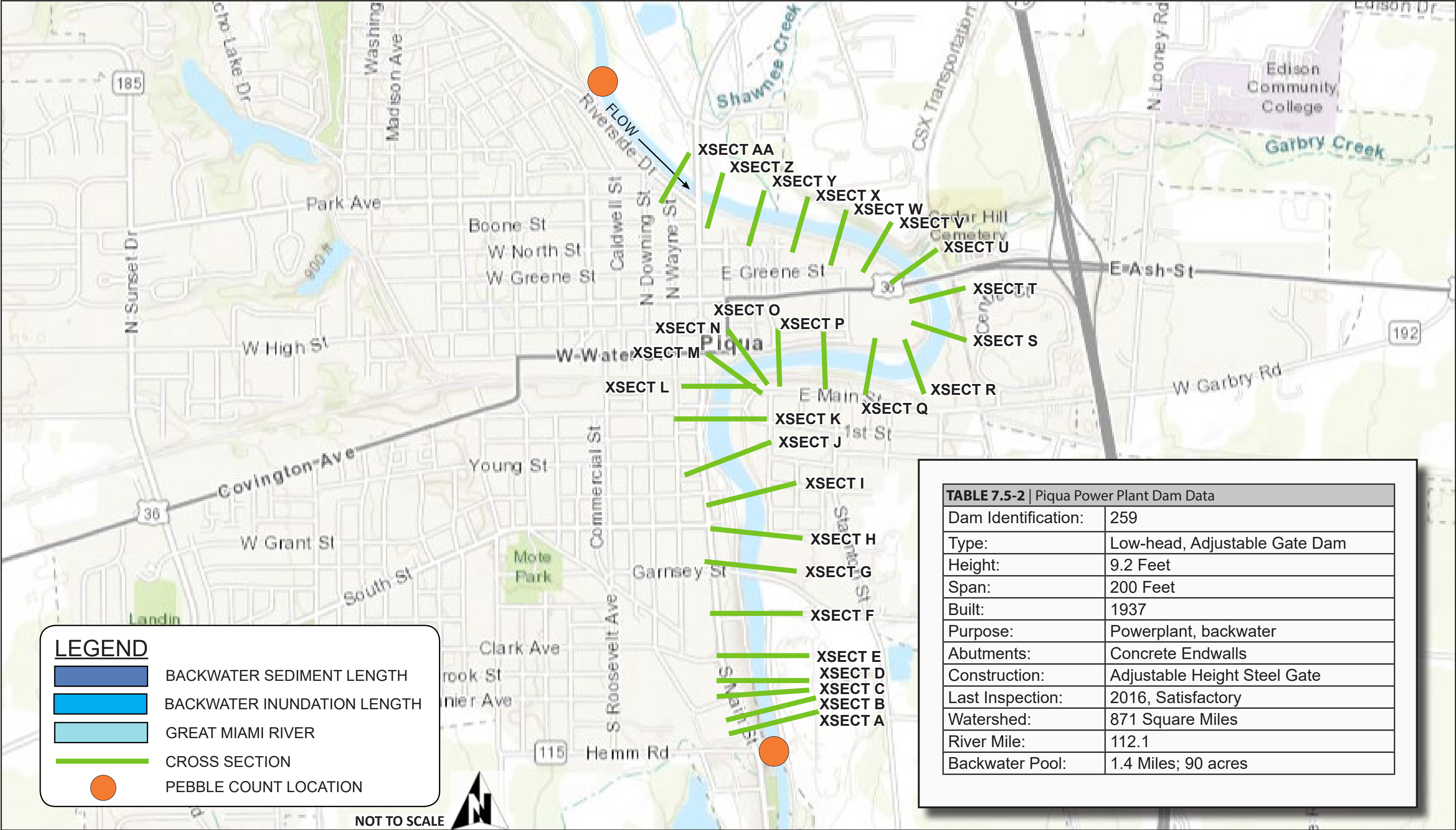
IN-STREAM IMPROVEMENTS NEAR LOCK NINE PARK

Lock Nine Park in Piqua sits atop the levee slope, located on an outside meander bend in the river. This natural bend in the river is typically a location of extreme erosion due to high near-bank stress on the outer bend, resulting in part from extremely high water velocities. Bare soil, or lightly vegetated soil, will likely wear away over time without reinforcement with rootwads, vegetated geolifts (Figures 7.4-3, 7.4-2) and/or a method of diminishing the extreme water velocities along these outside meander bends, especially during high water events.

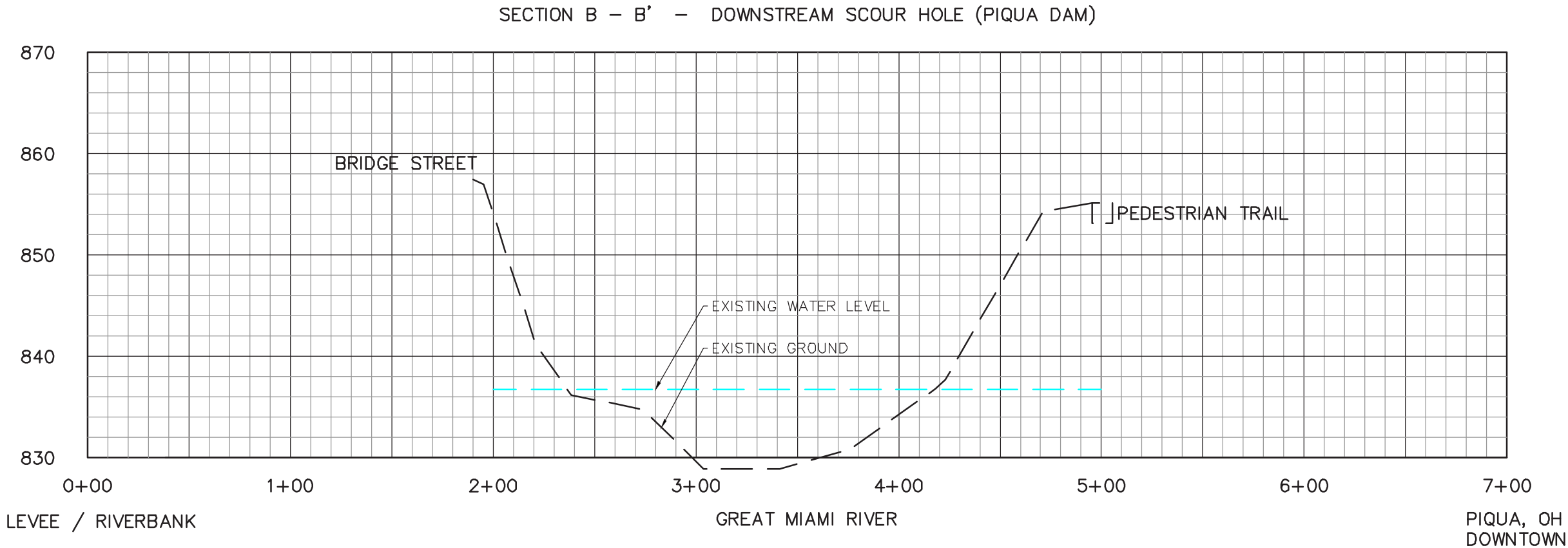
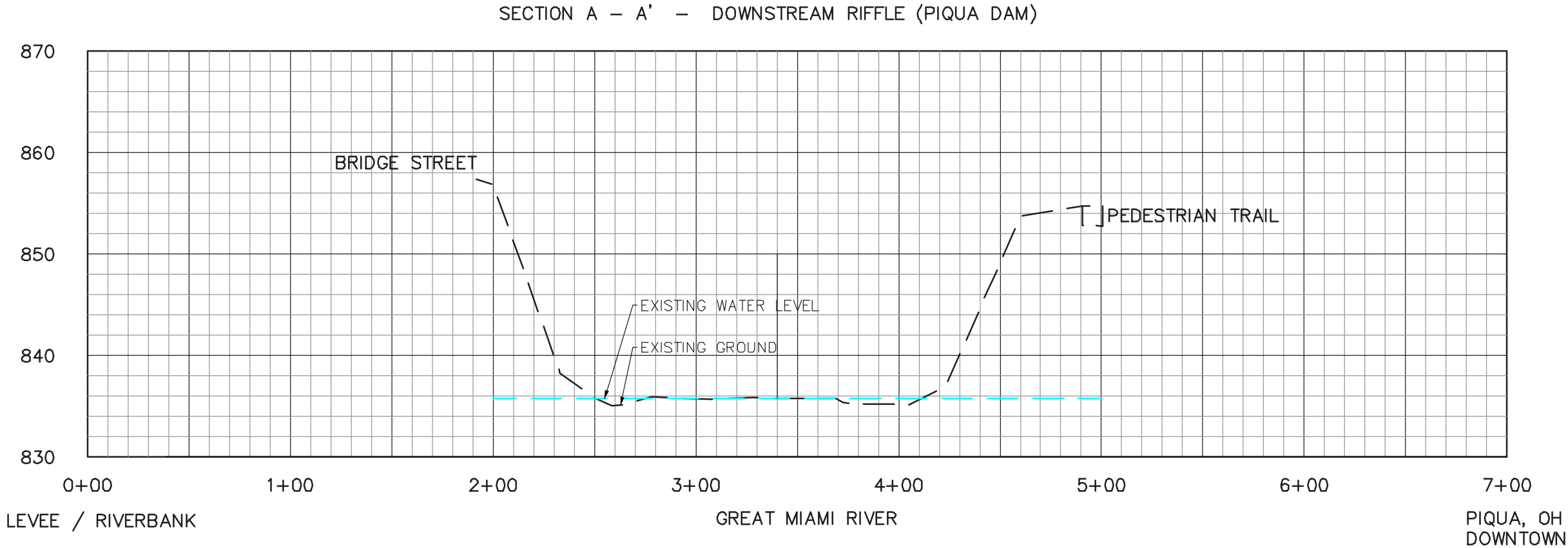
In-stream rock structures (Figure 7.4-1) can serve to dissipate these increased water velocities, and could be a useful feature in this location for several reasons. Dissipating water velocities at this outside meander bend will reduce shear stress on the toe of the levee, and thus prolong the life of the levee toe and any improvements made there.

Additionally, rock structures used to dissipate water velocities will create additional wildlife habitat, new fishing spots, and exciting water features for kayakers and canoers to enjoy.

7.5 POWER PLANT DAM CROSS-SECTIONS



MAP 7.5-1 | Piqua Power Plant Dam Backwater
86 | Piqua Power Plant Dam

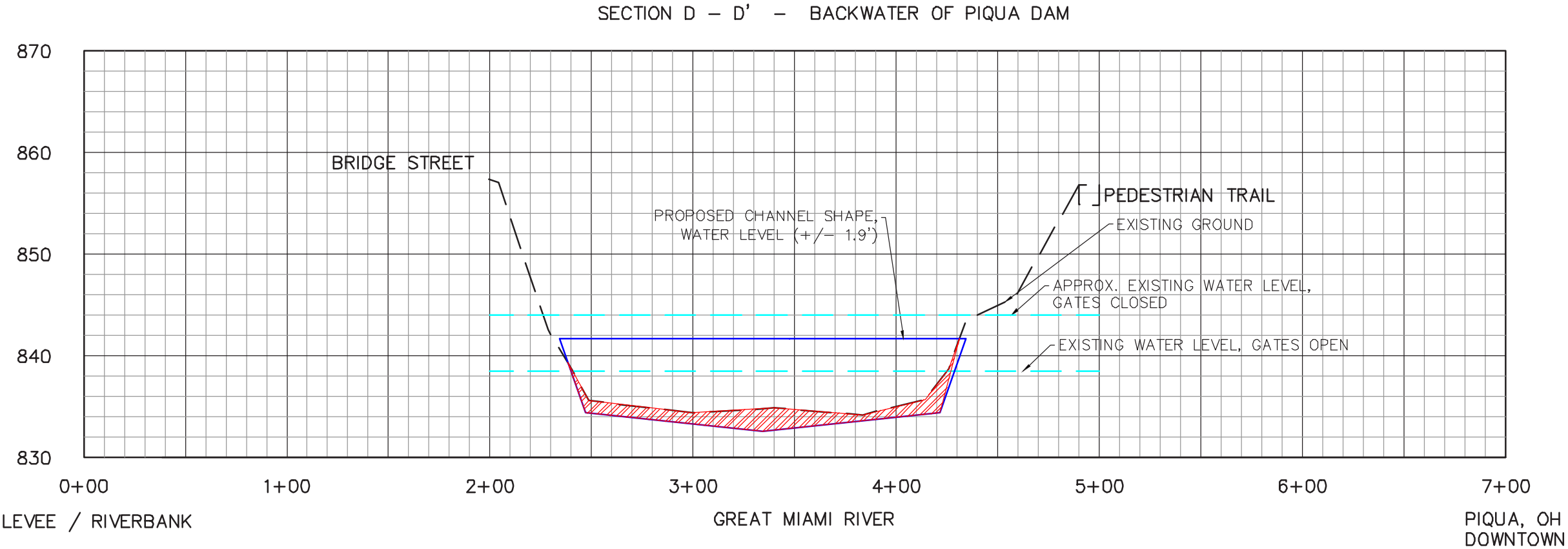
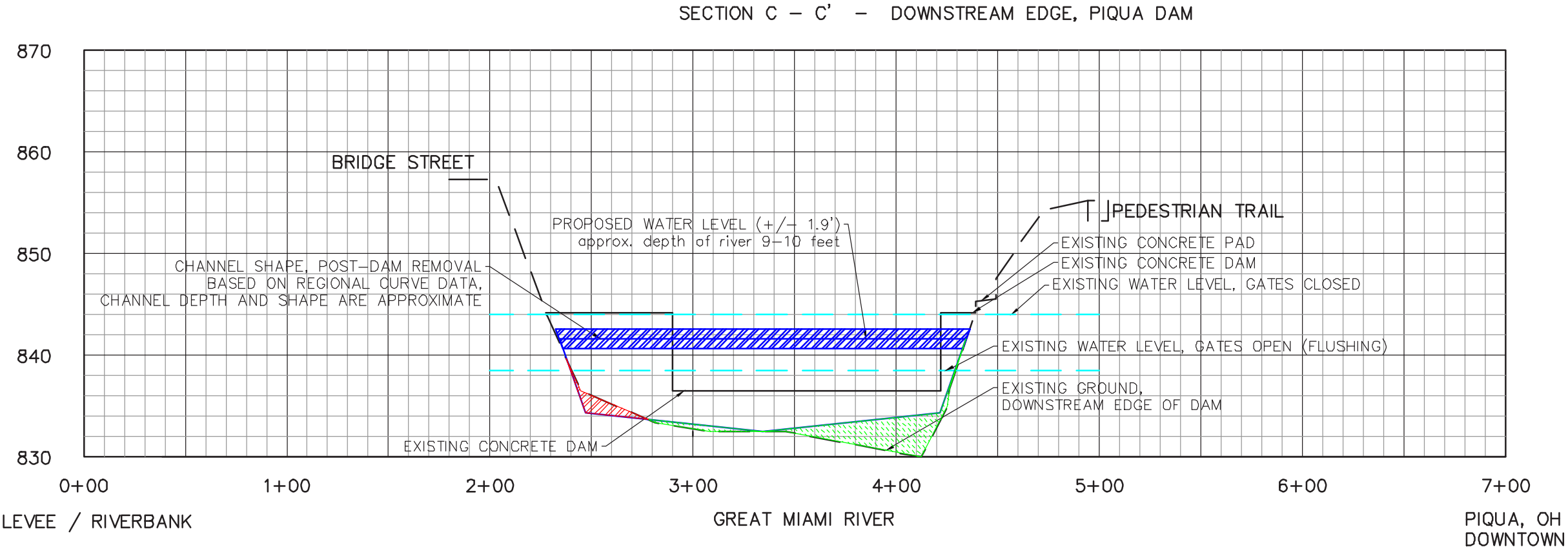


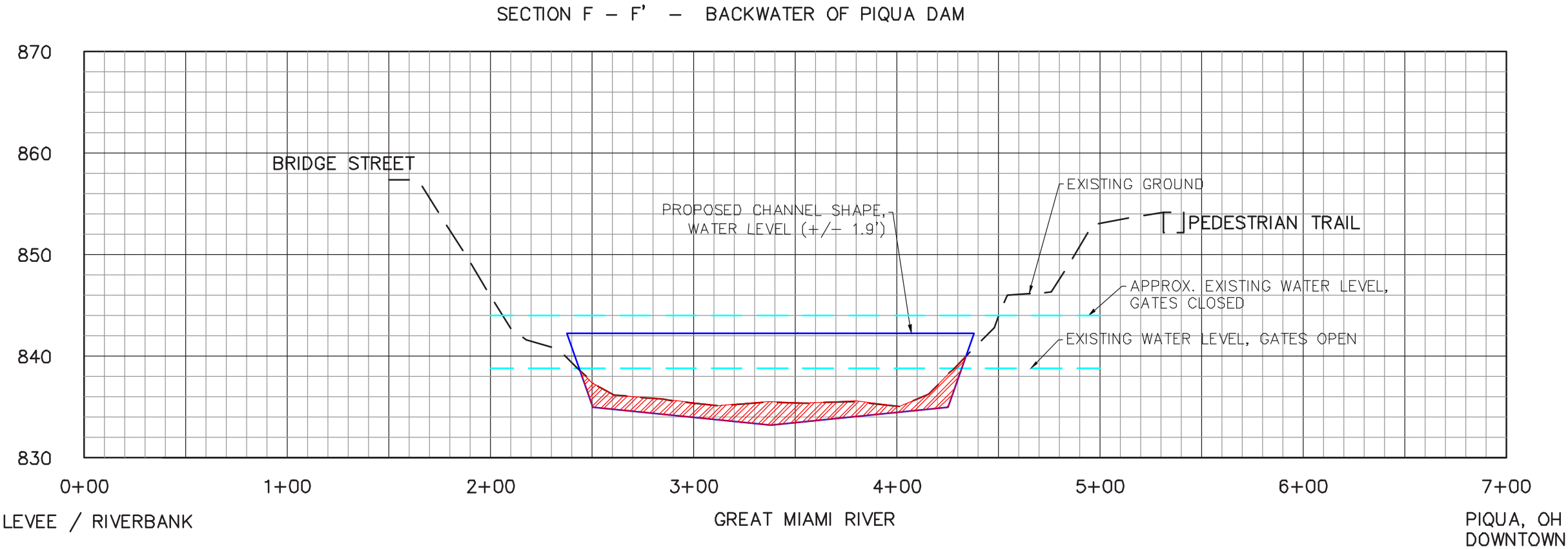
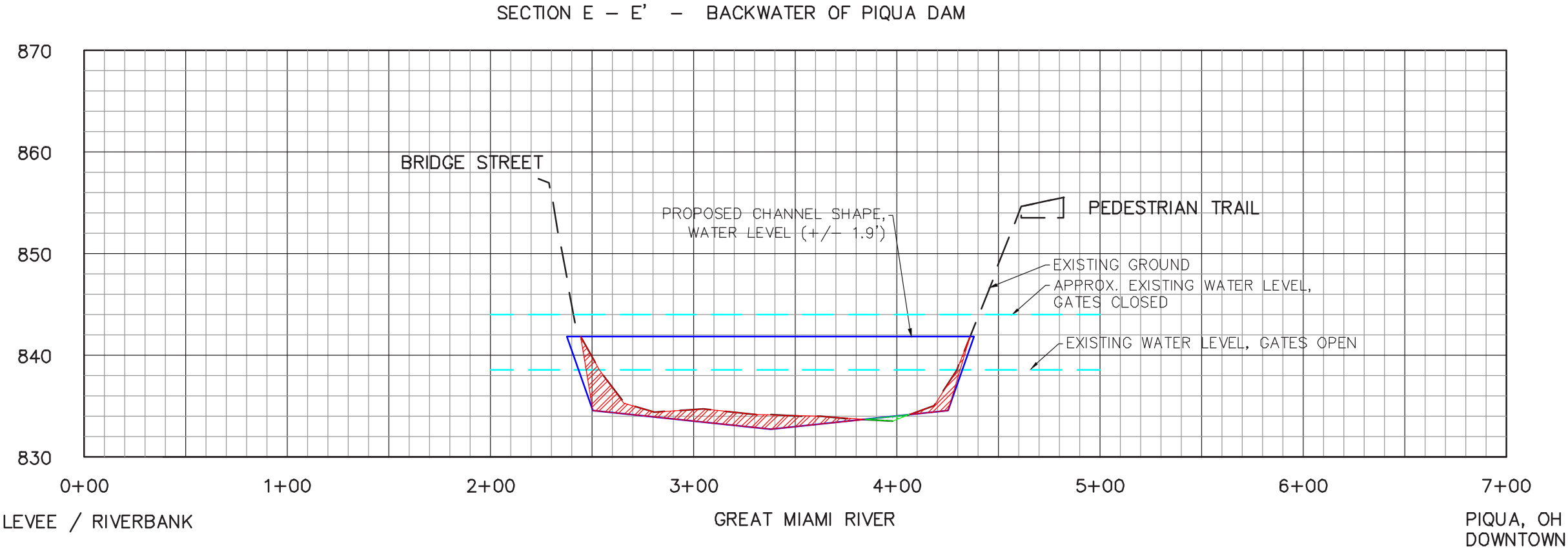
7.5

PIQUA POWER PLANT DAM CROSS SECTIONS

PRE AND POST DAM REMOVAL

Great Miami River Dam Removal Feasibility Study





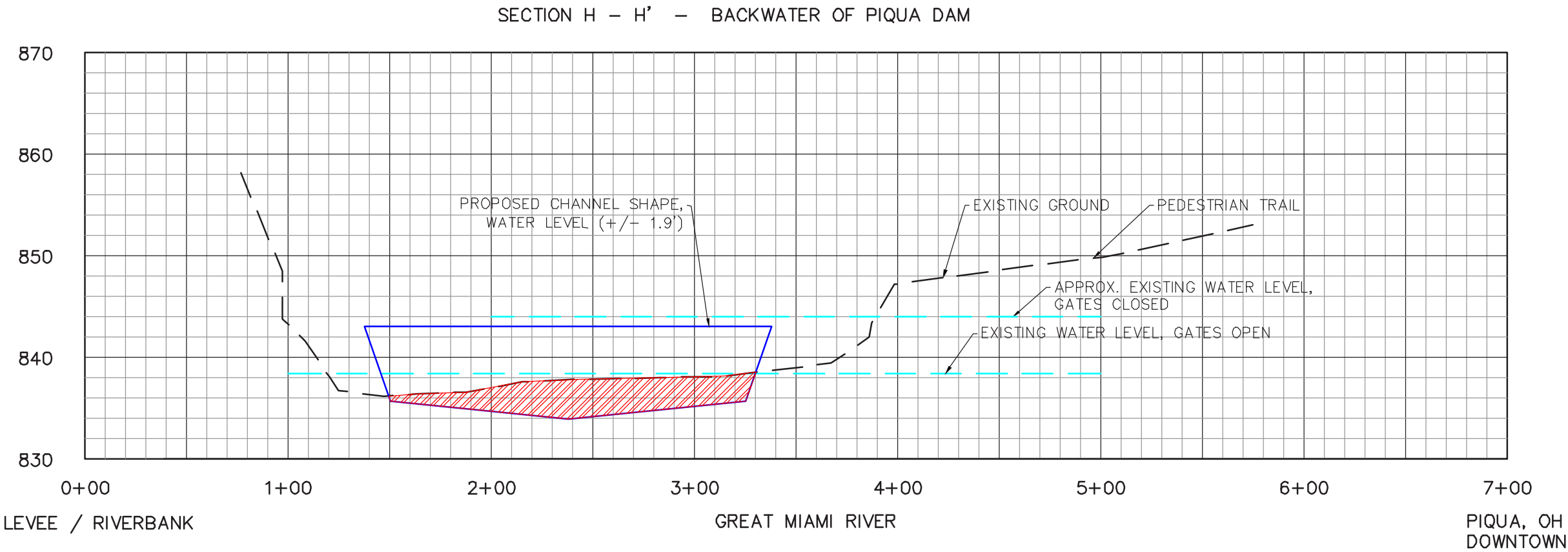
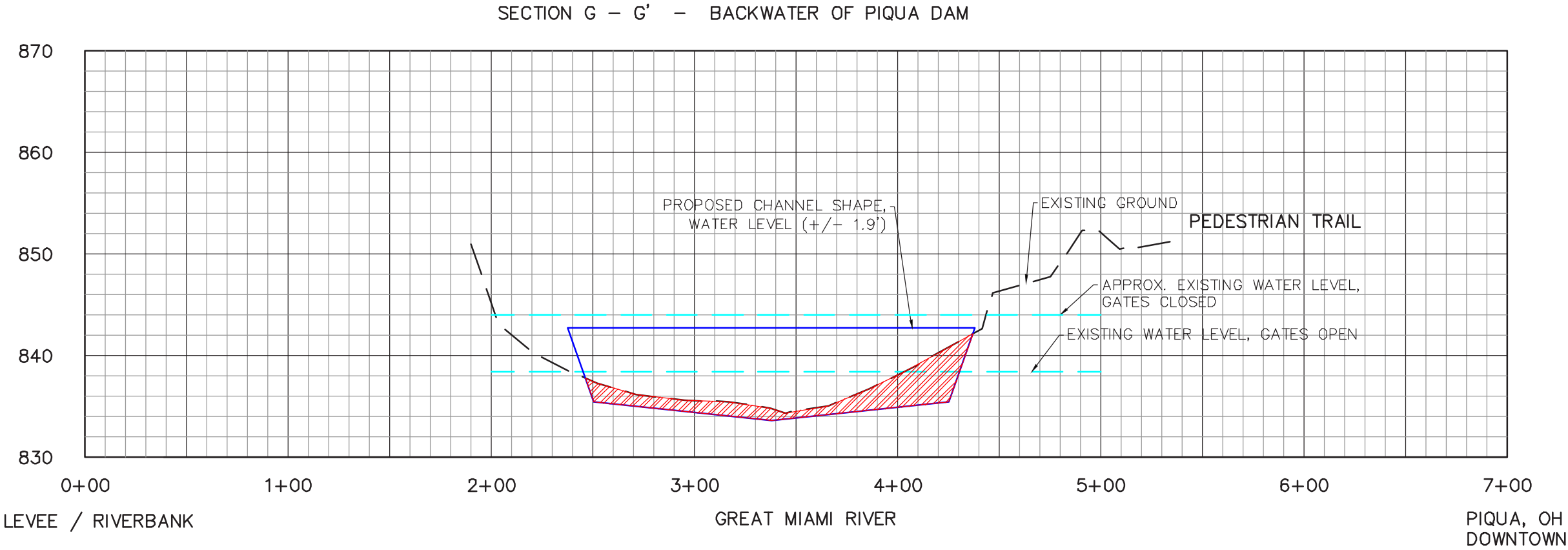
APPROXIMATE CHANNEL SHAPE BASED ON REGIONAL CURVE DATA. RIVER DEPTH WILL VARY

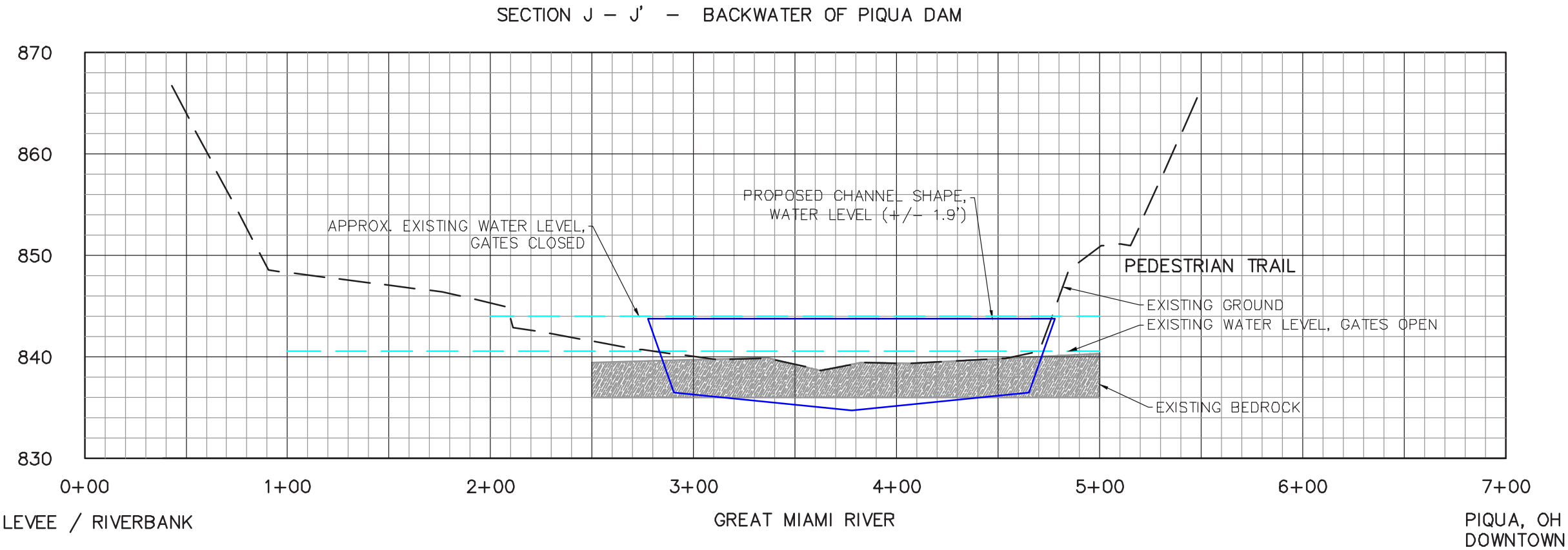
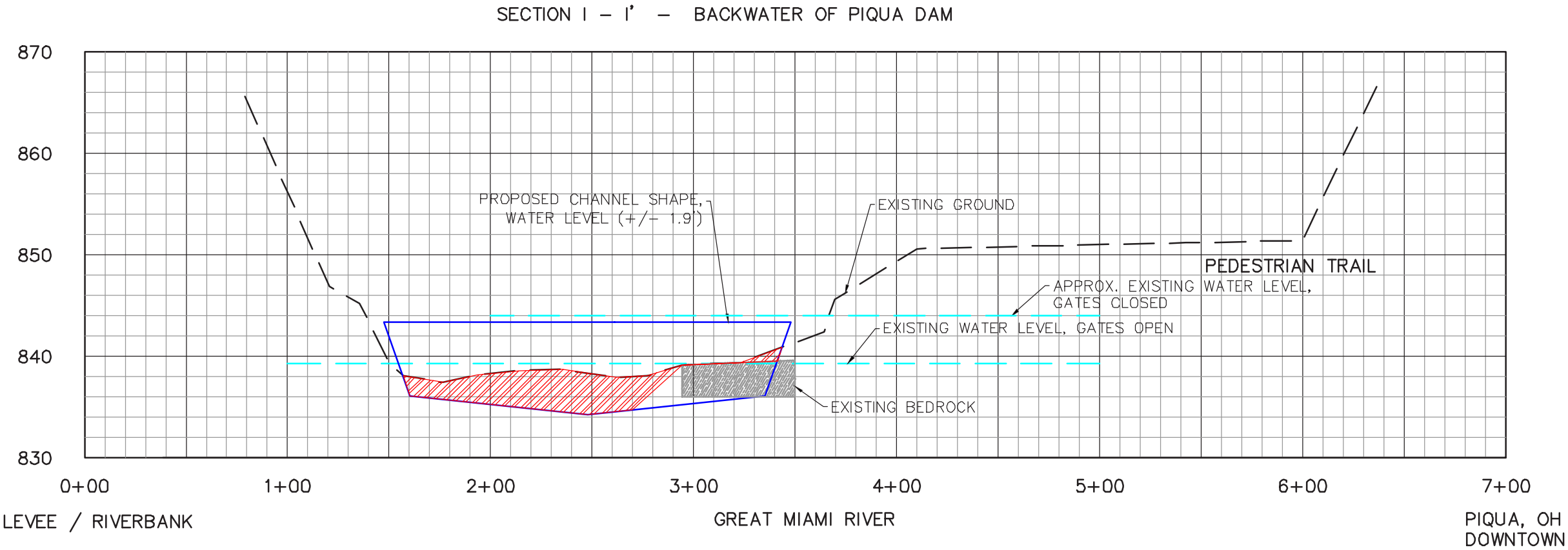
7.5

PIQUA POWER PLANT DAM CROSS SECTIONS

PRE AND POST DAM REMOVAL

Great Miami River Dam Removal Feasibility Study





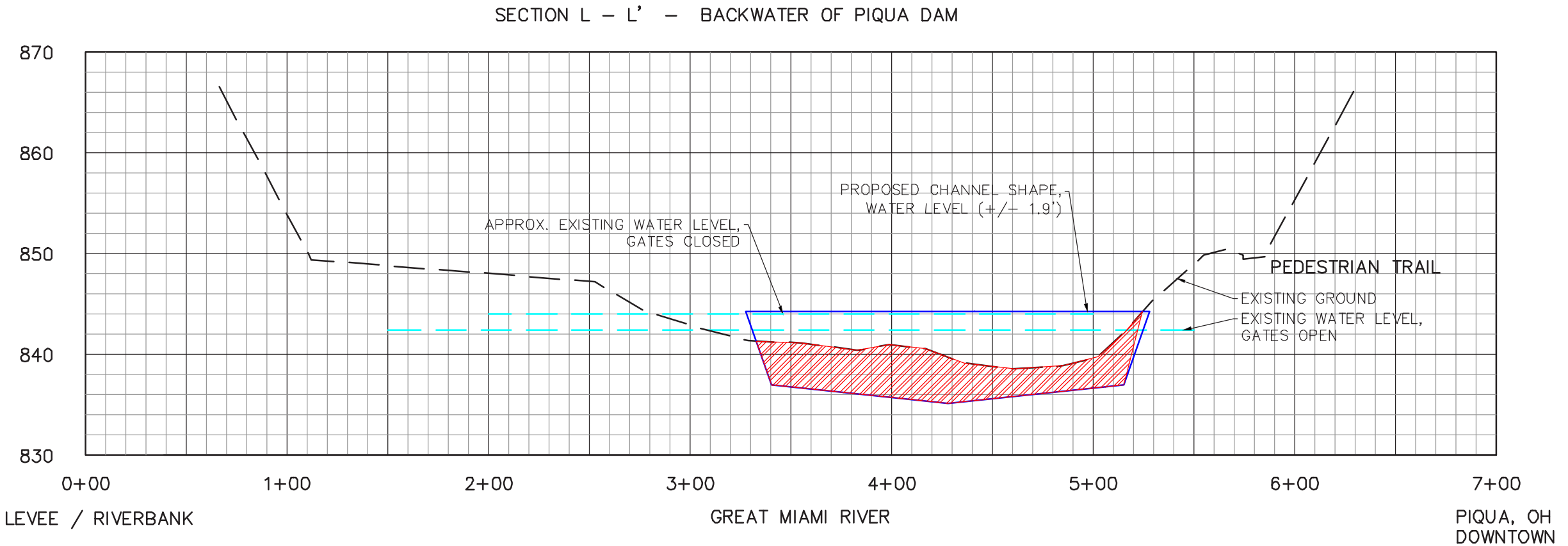
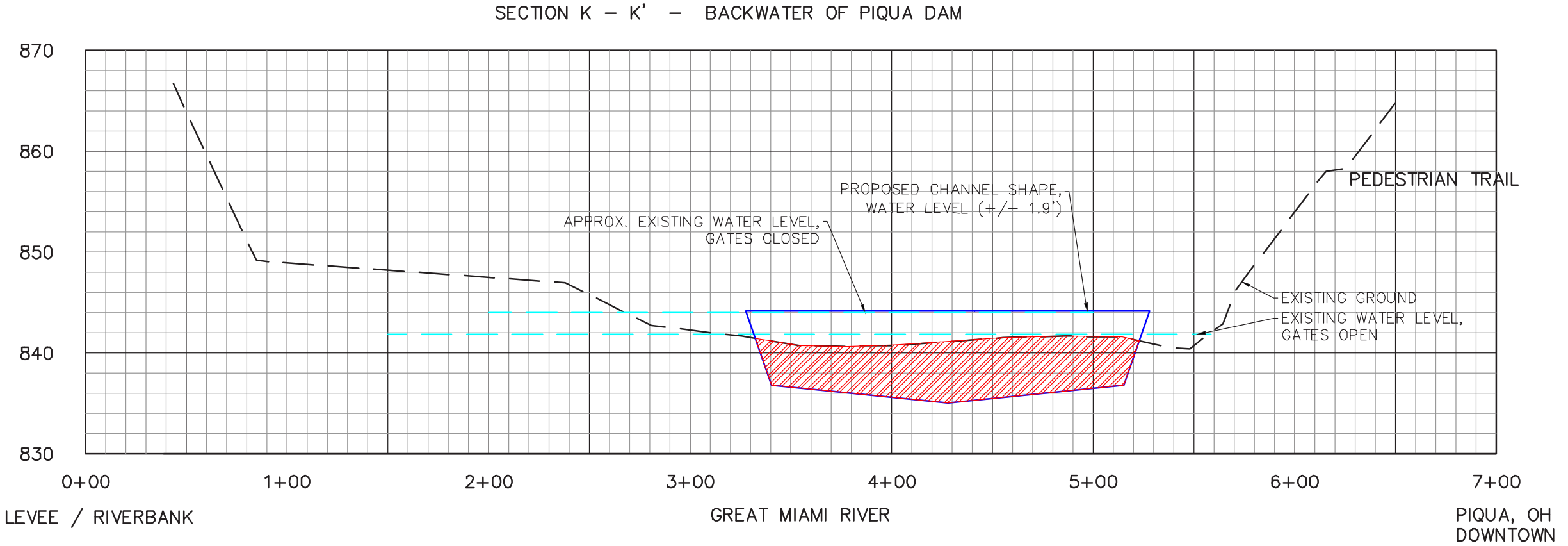
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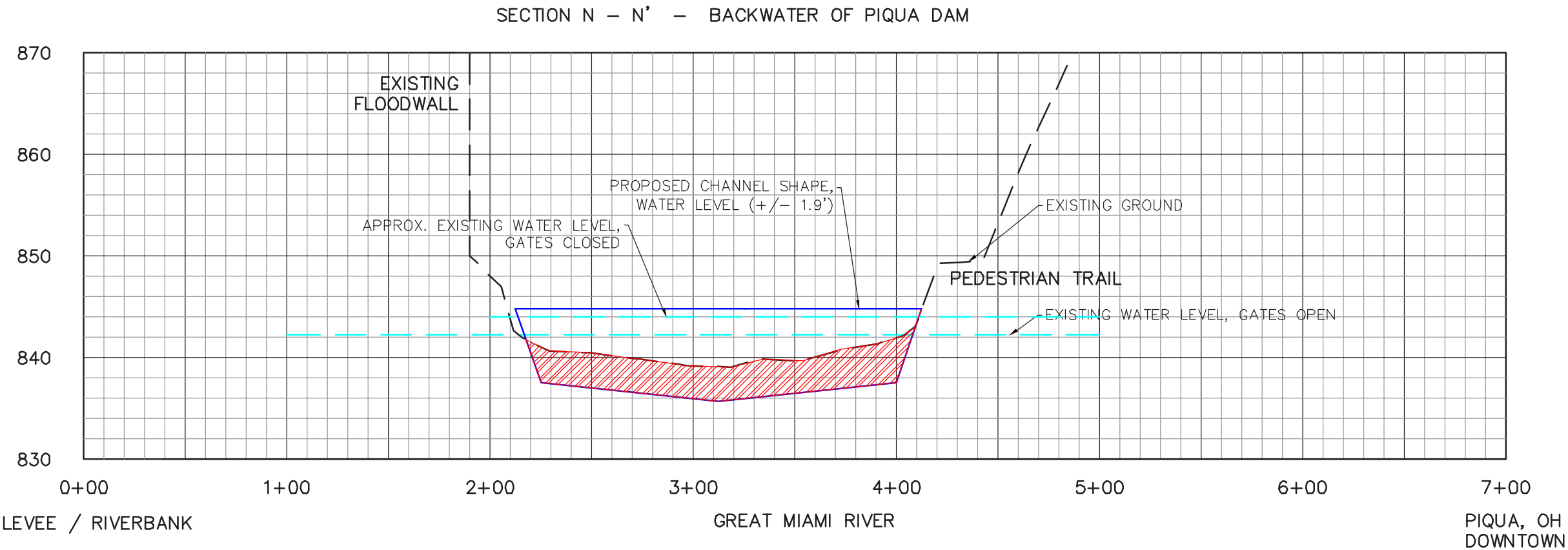
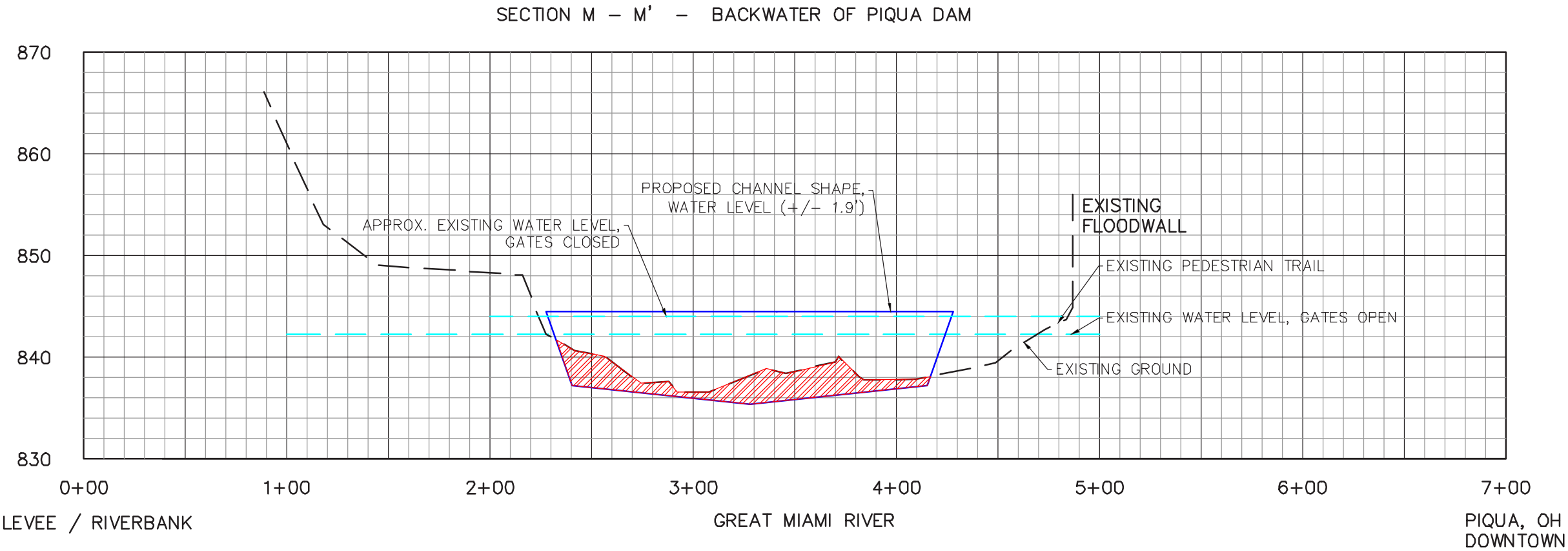
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PIQUA POWER PLANT DAM CROSS SECTIONS

PRE AND POST DAM REMOVAL

Great Miami River Dam Removal Feasibility Study





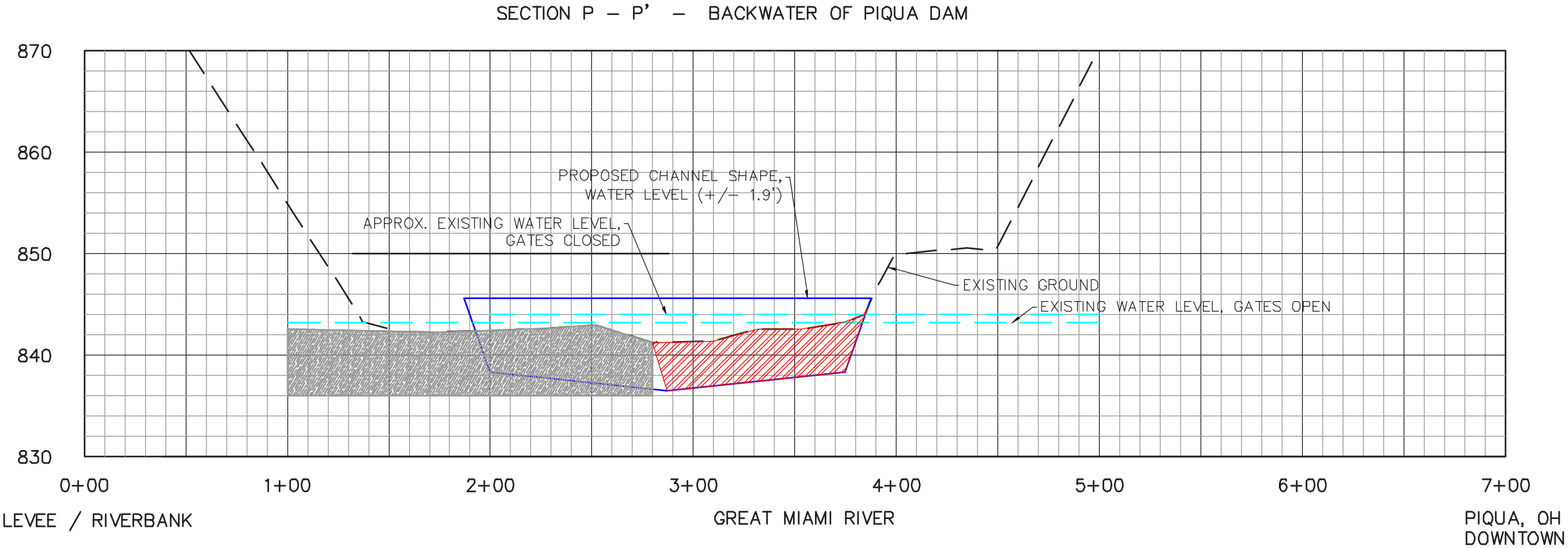
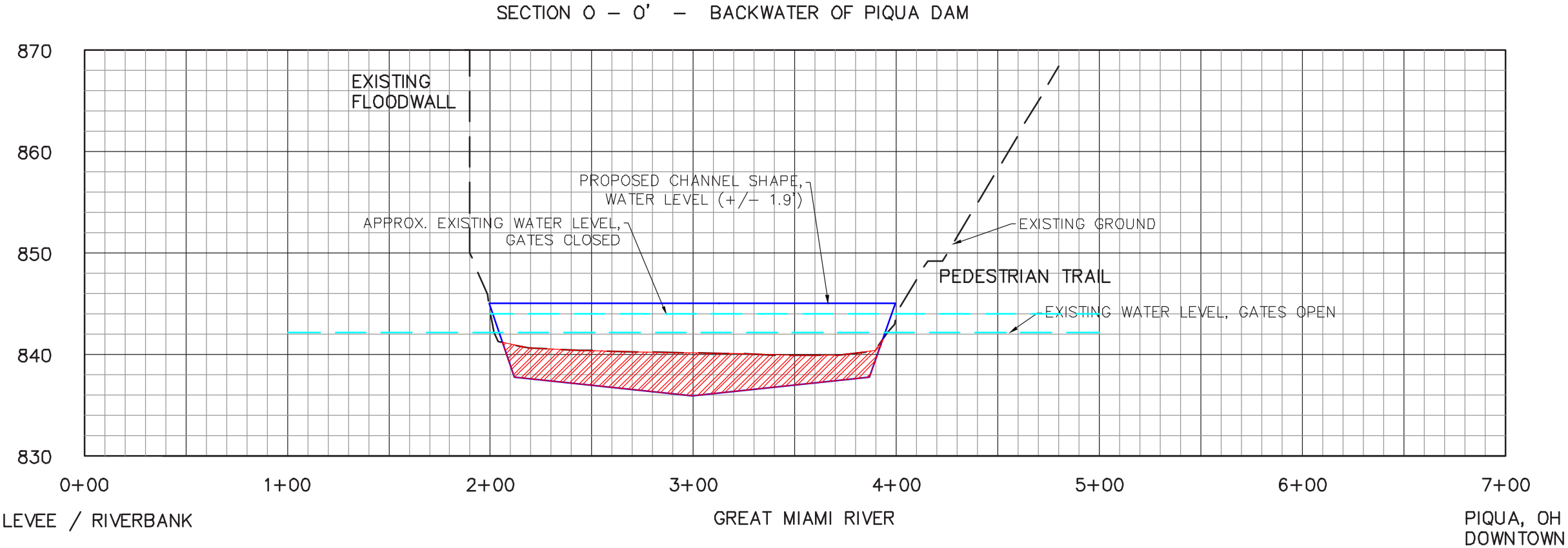
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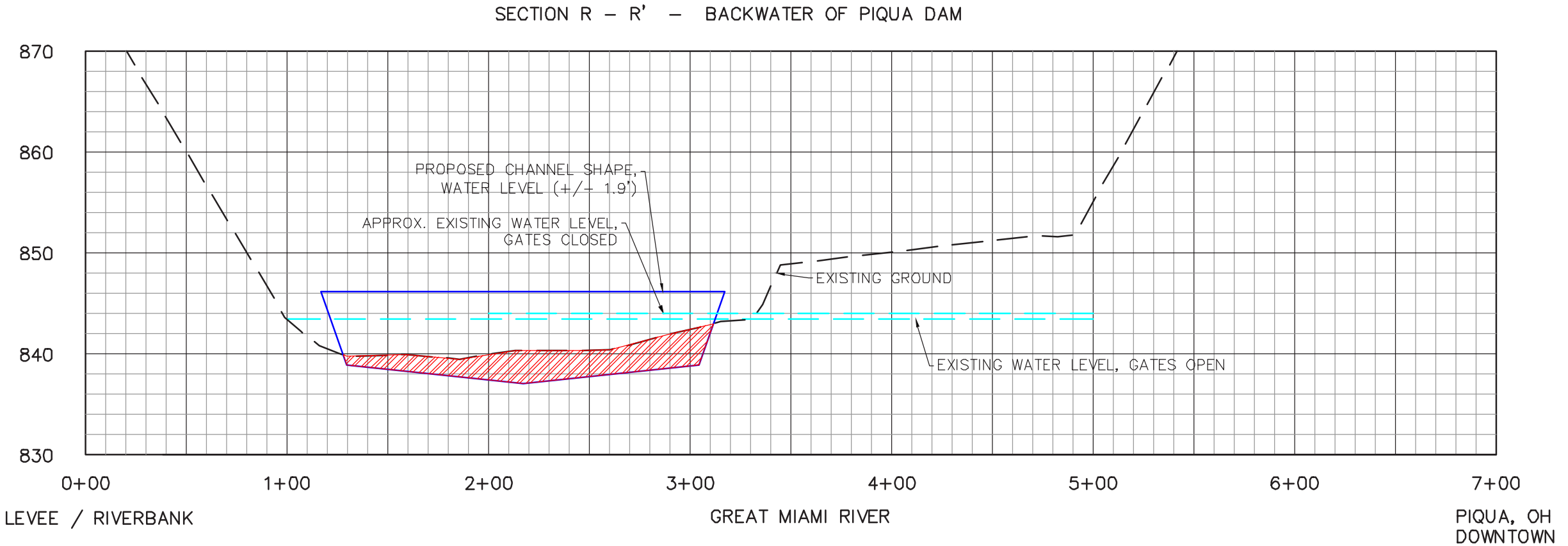
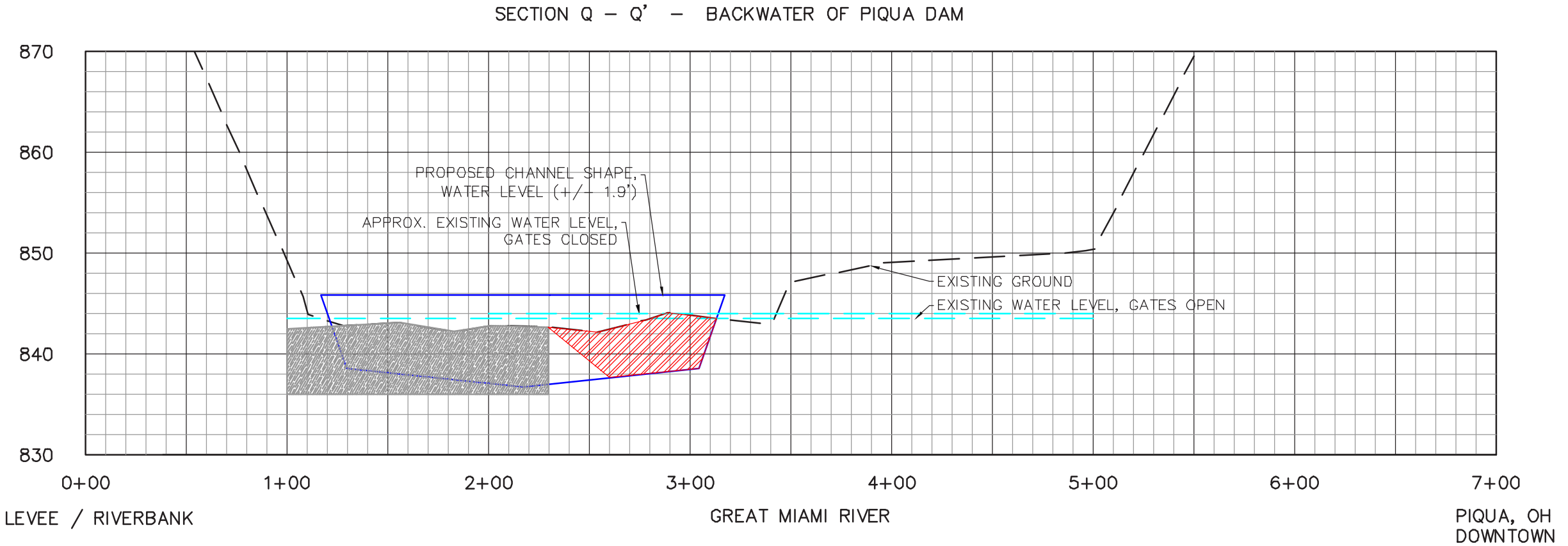
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PIQUA POWER PLANT DAM CROSS SECTIONS

PRE AND POST DAM REMOVAL

Great Miami River Dam Removal Feasibility Study





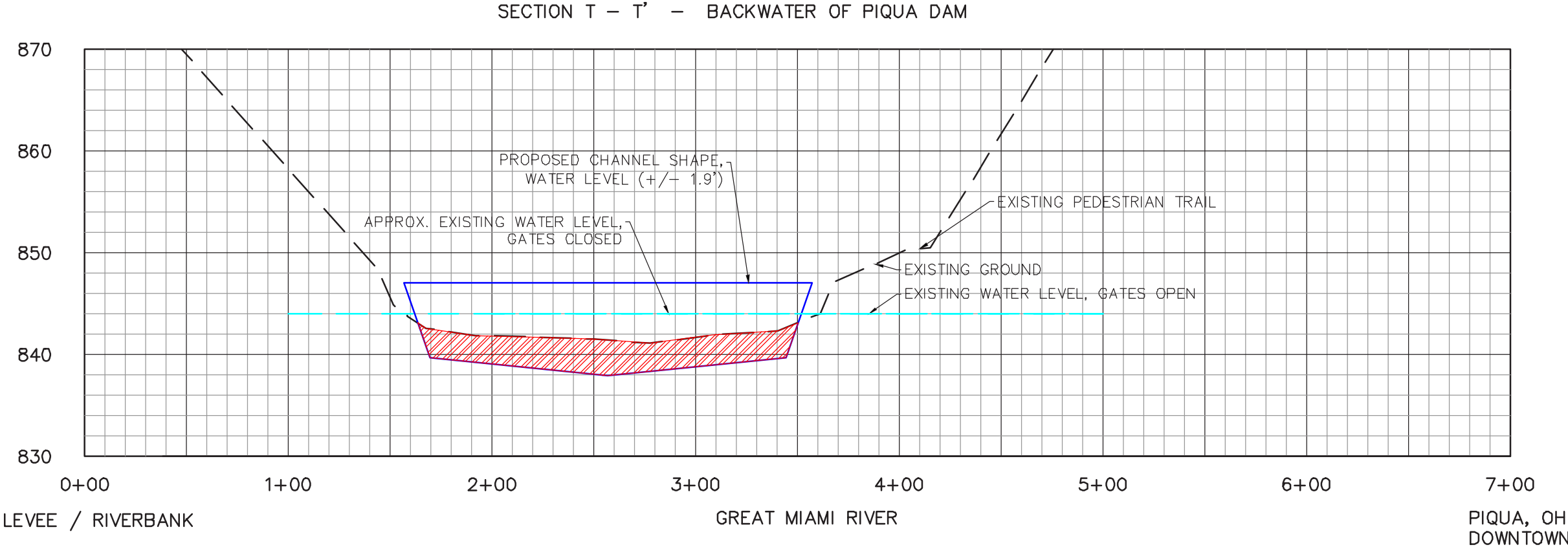
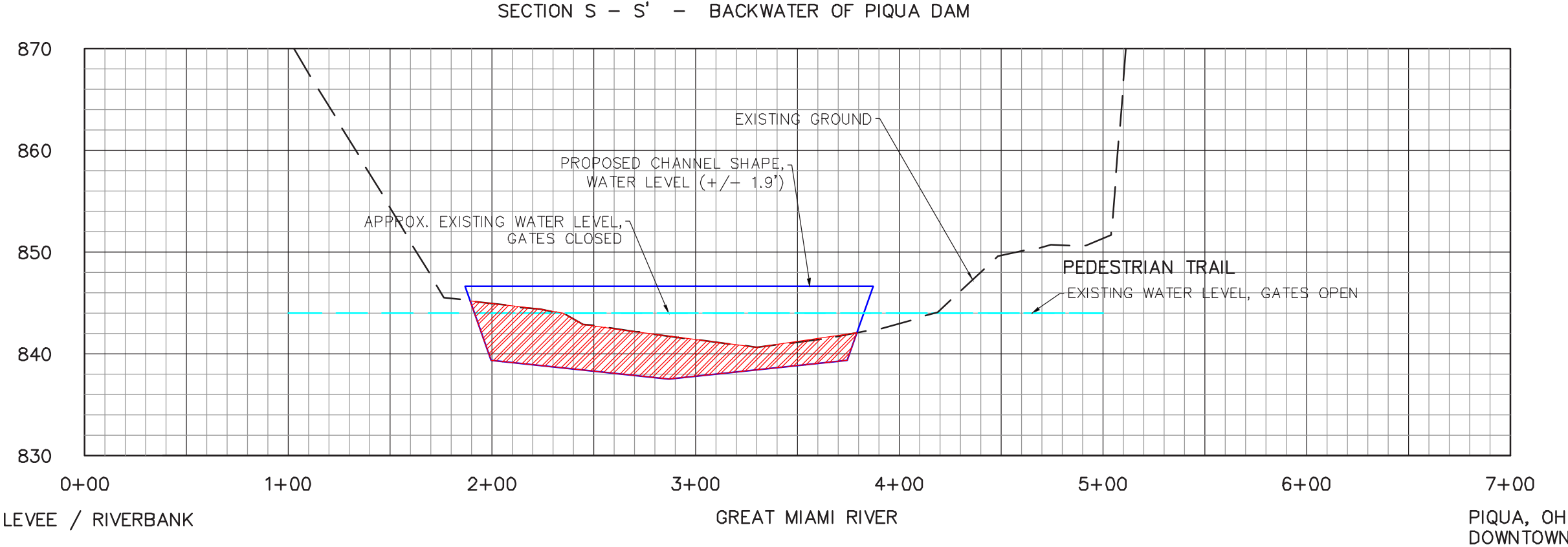
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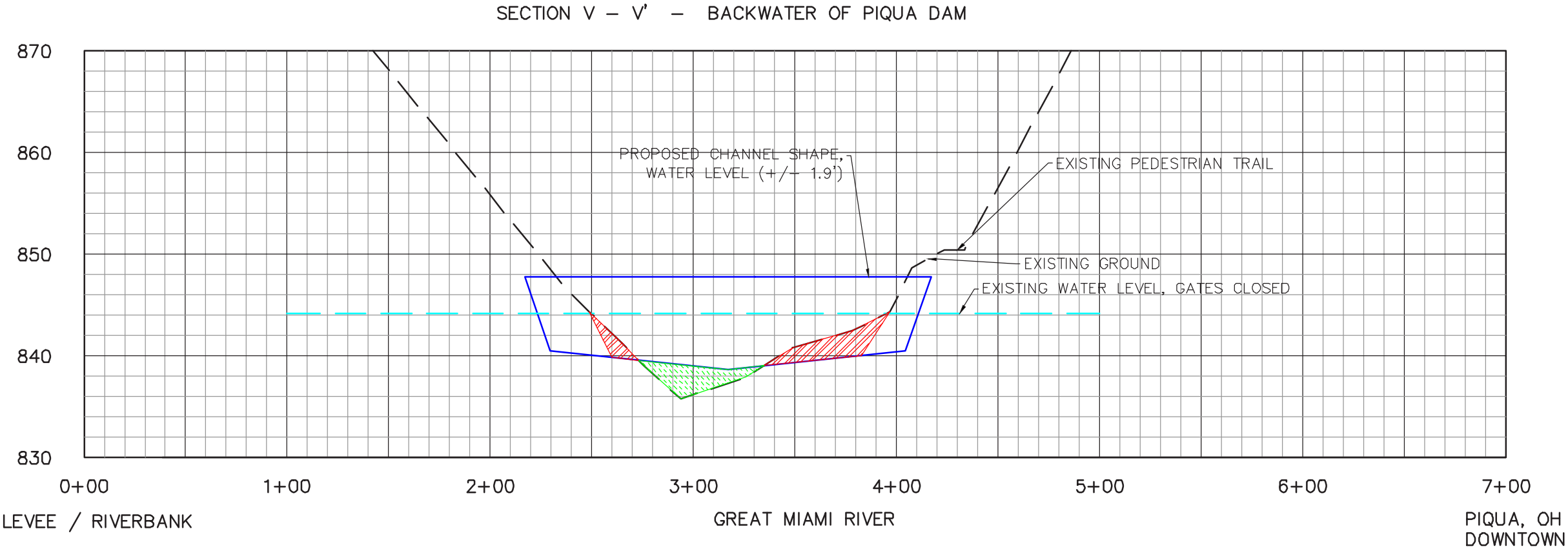
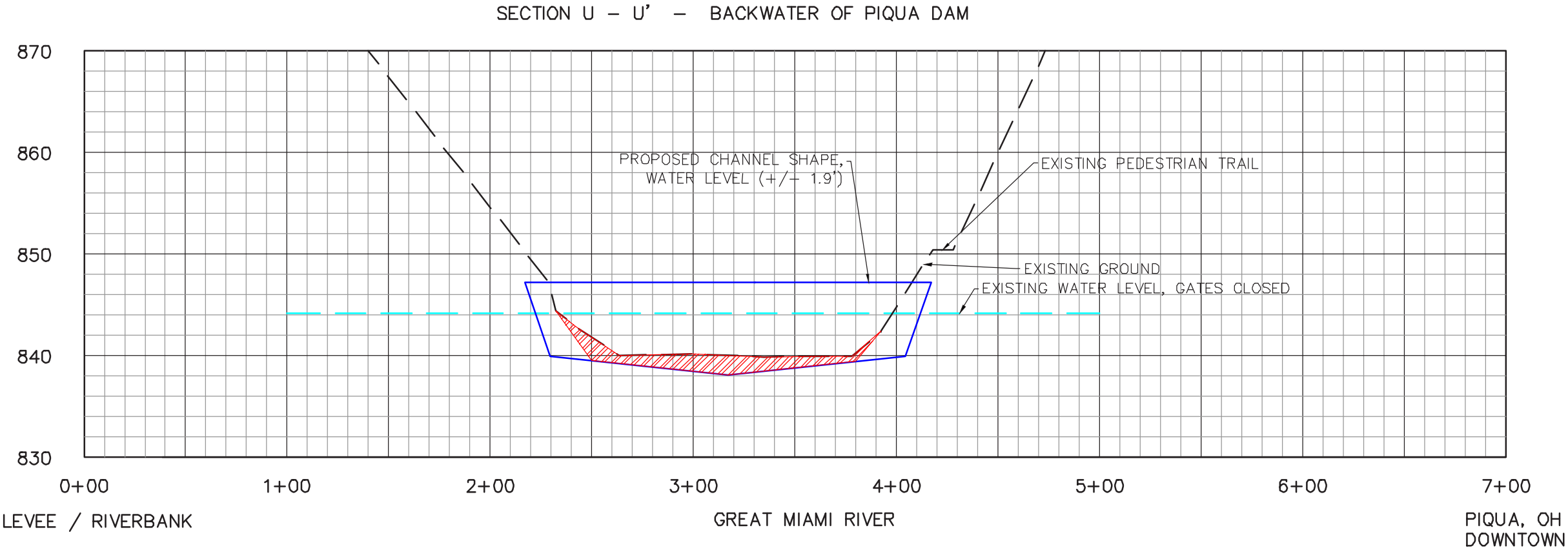
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PIQUA POWER PLANT DAM CROSS SECTIONS

PRE AND POST DAM REMOVAL

Great Miami River Dam Removal Feasibility Study





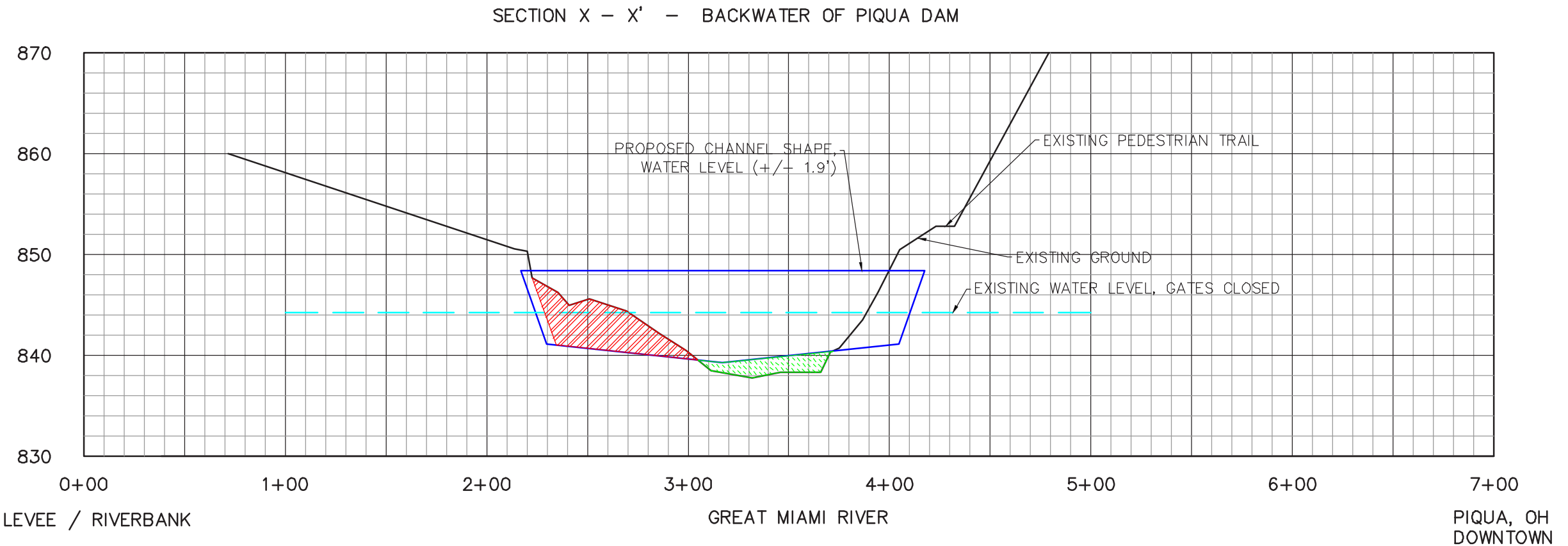
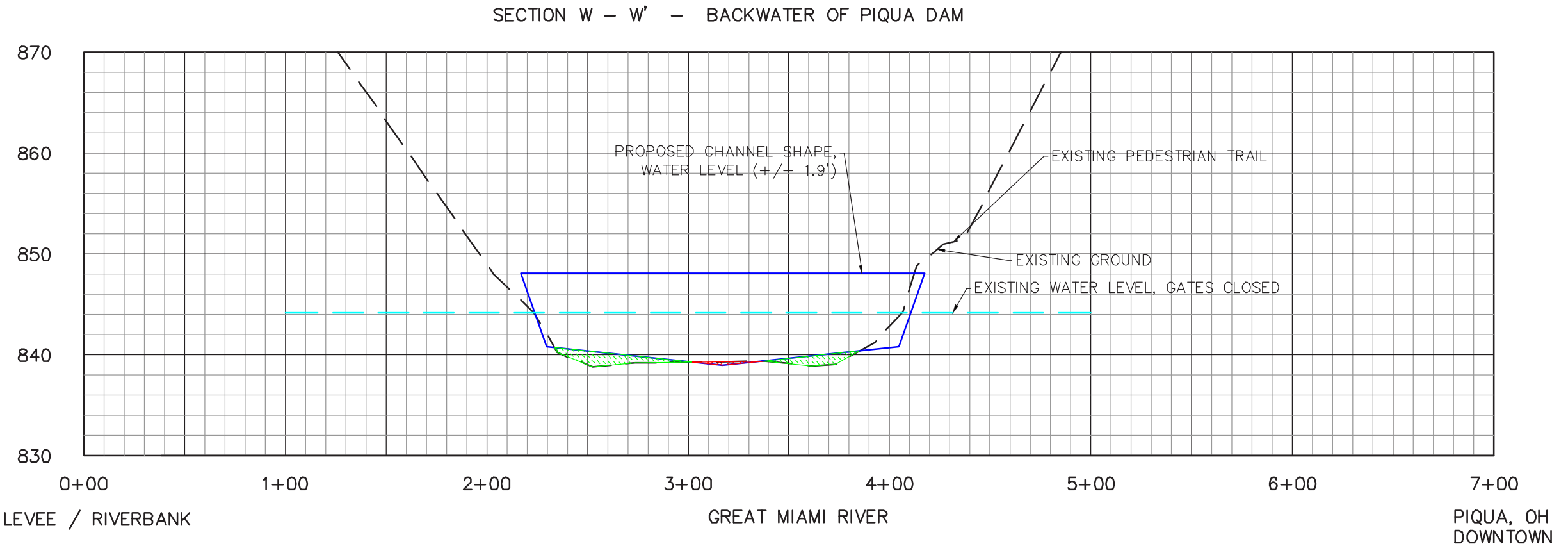
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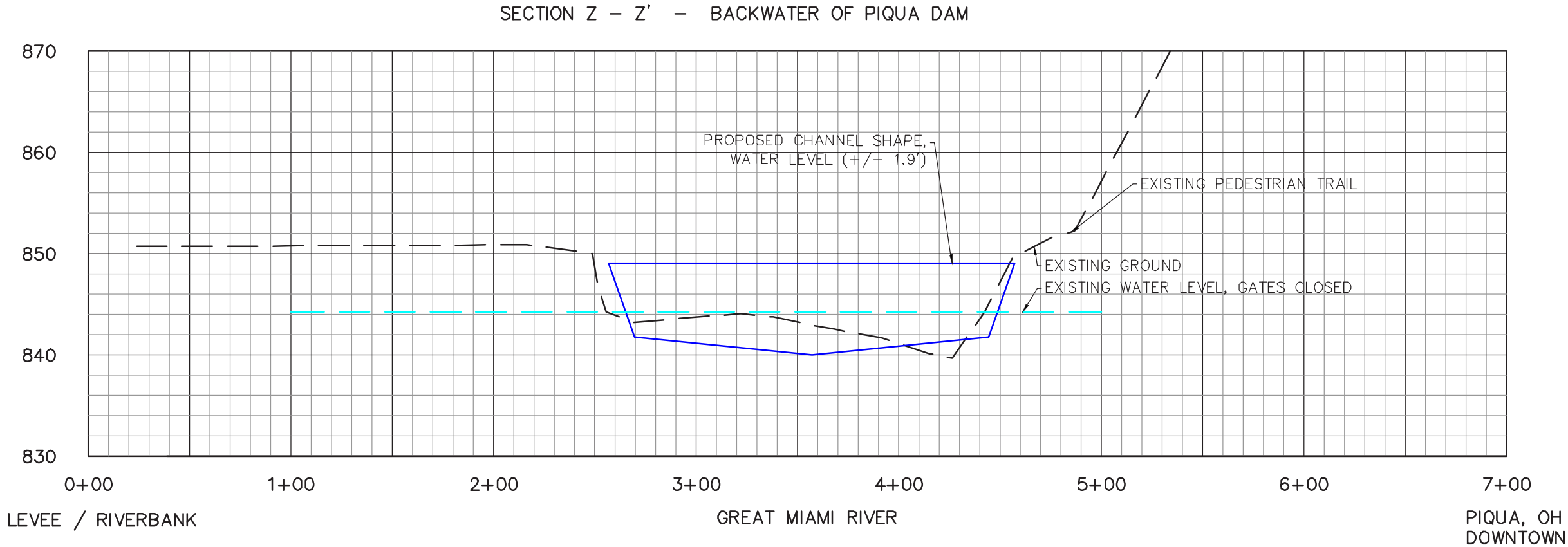
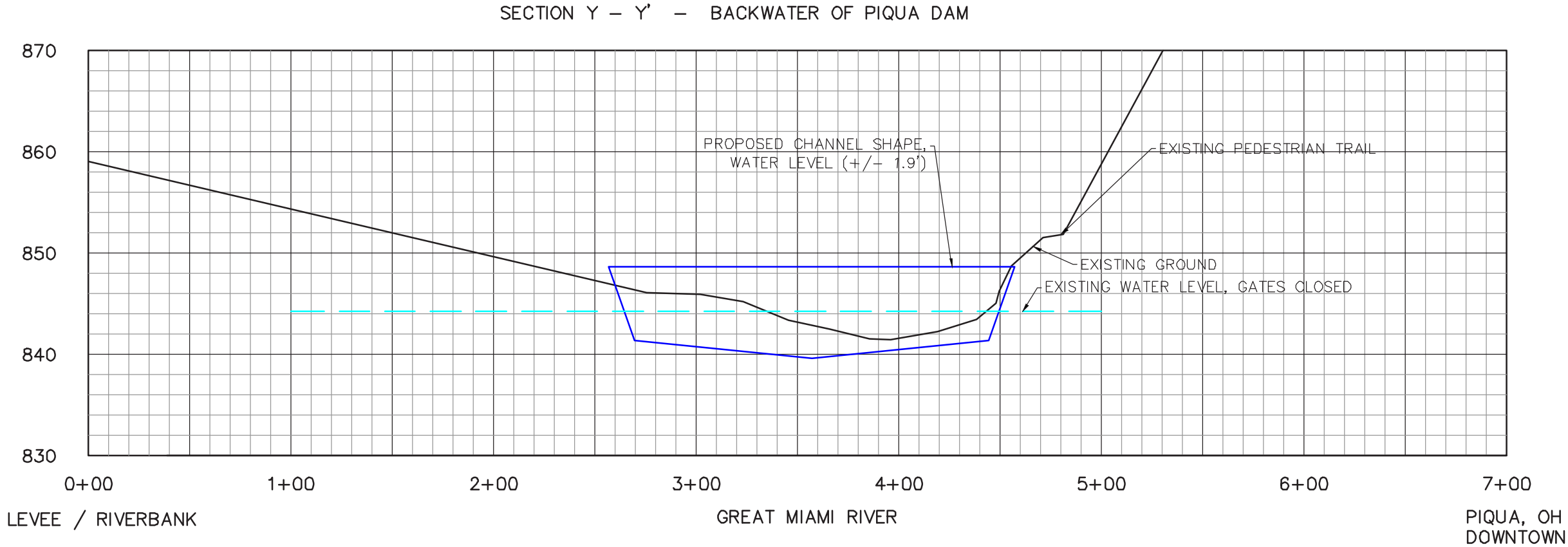
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PIQUA POWER PLANT DAM CROSS SECTIONS

PRE AND POST DAM REMOVAL

Great Miami River Dam Removal Feasibility Study





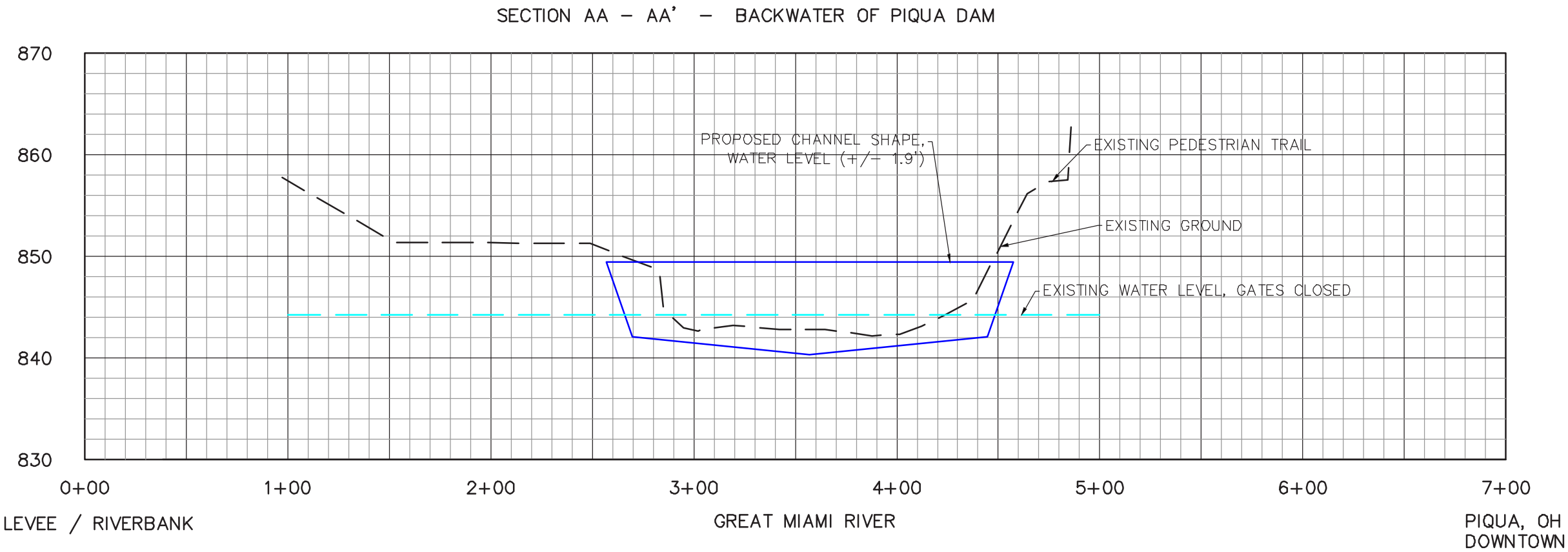
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PIQUA POWER PLANT DAM CROSS SECTIONS

PRE AND POST DAM REMOVAL

Great Miami River Dam Removal Feasibility Study

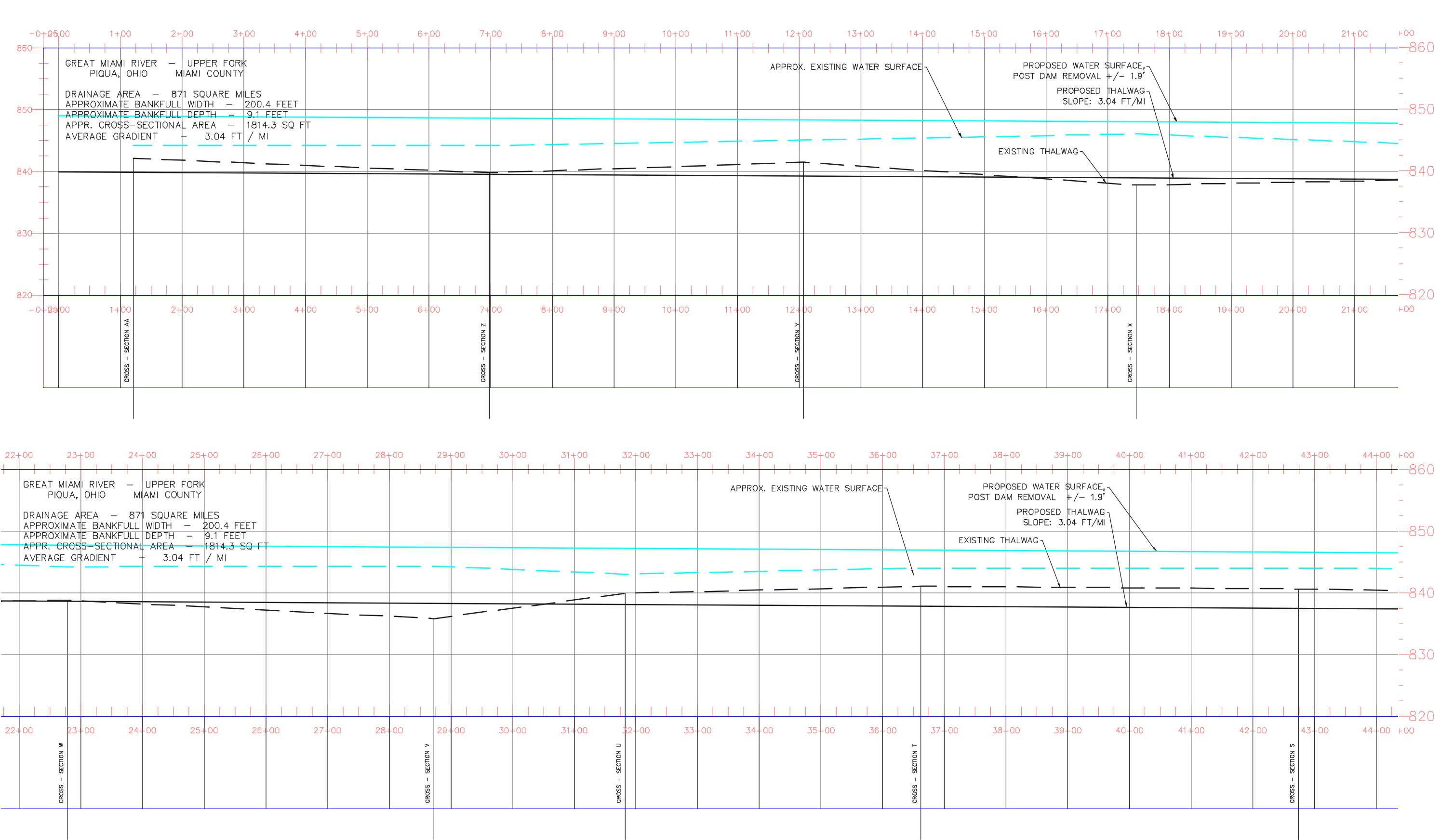


7.6

PIQUA POWER PLANT DAM PROFILE

PRE AND POST DAM REMOVAL

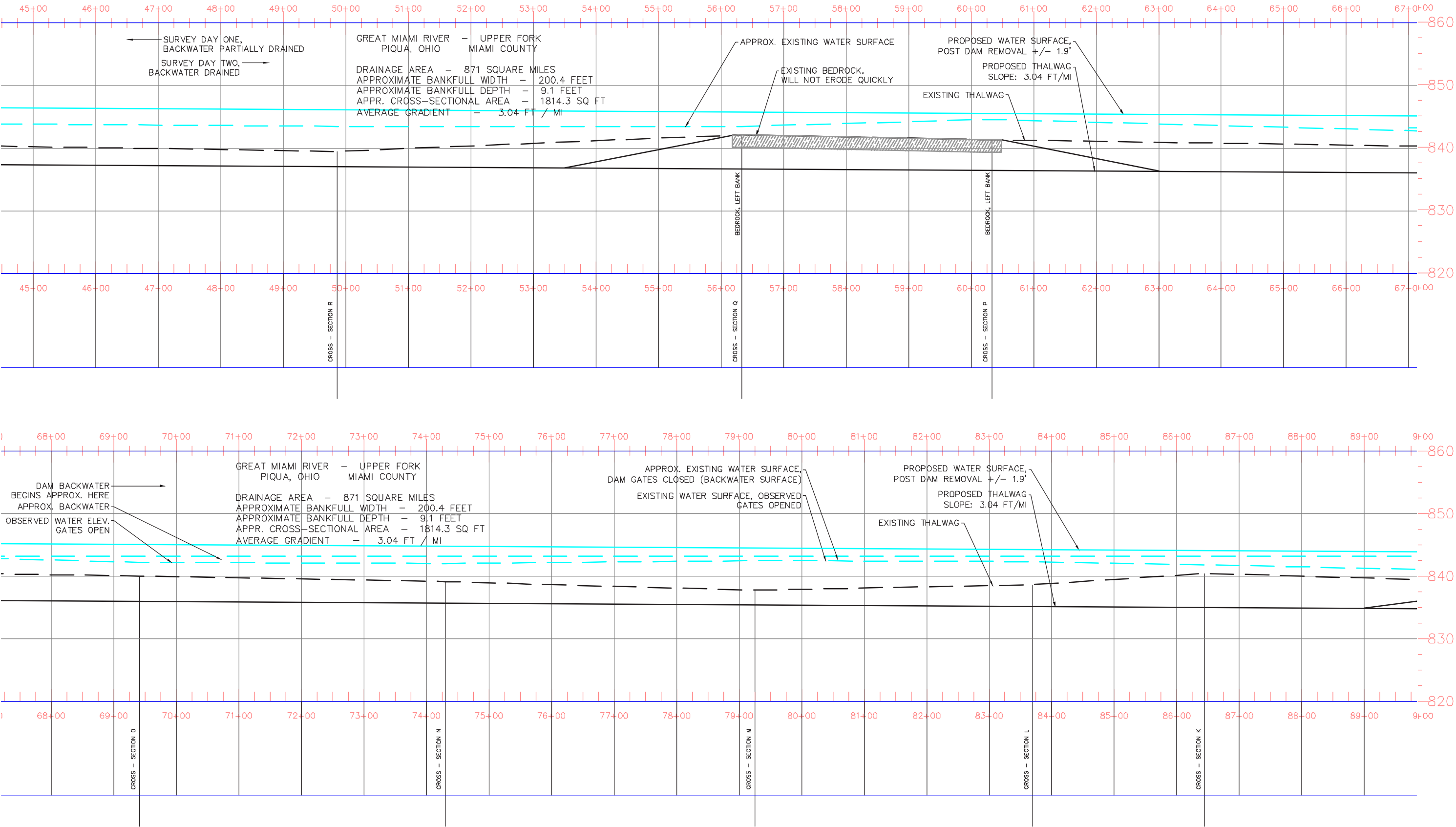
Miami County Soil & Water Conservation District

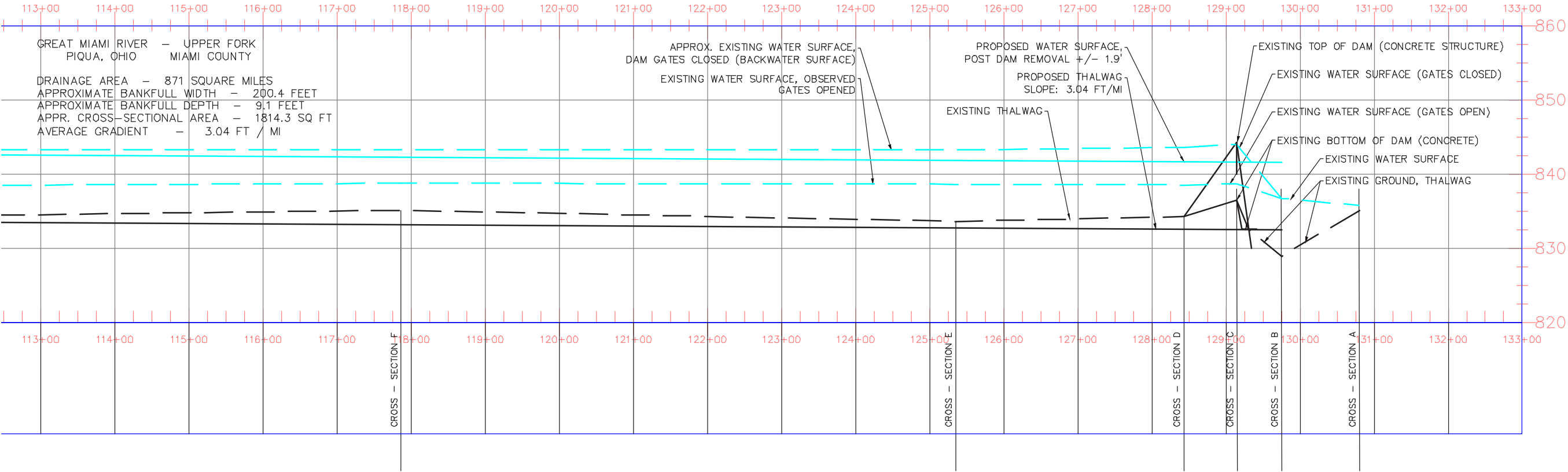
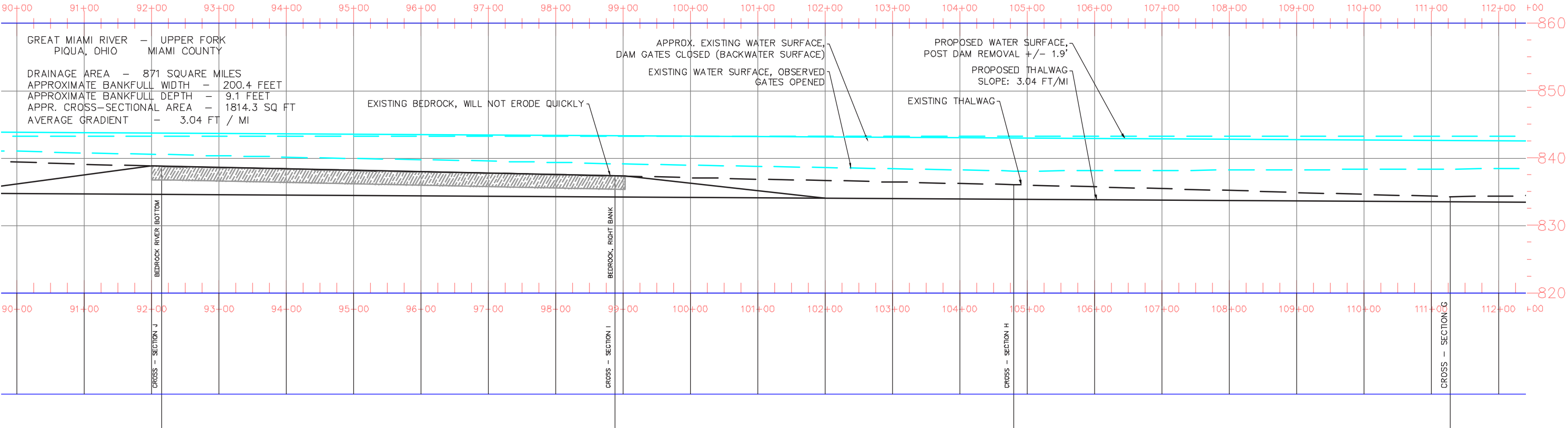


APPROXIMATE CHANNEL SHAPE BASED ON REGIONAL CURVE DATA. RIVER DEPTH WILL VARY

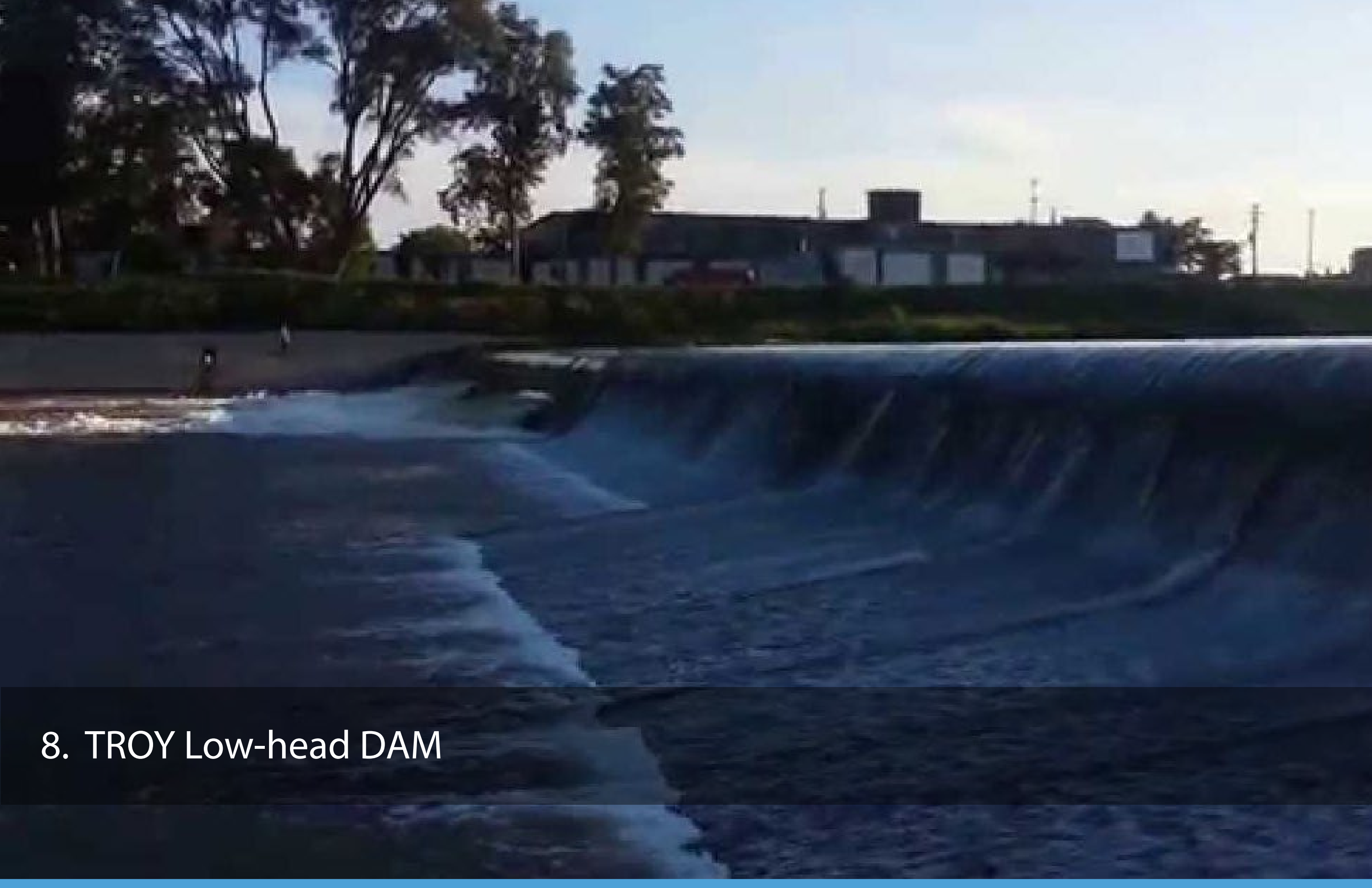
7.6 PIQUA POWER PLANT DAM PROFILE

PRE AND POST DAM REMOVAL





APPROXIMATE CHANNEL SHAPE BASED ON REGIONAL CURVE DATA. RIVER DEPTH WILL VARY



8. TROY Low-head DAM

8.1 TROY LOW-HEAD DAM HISTORY

Troy's low-head dam, as we know it today, was designed in 1998 by Burgess & Niple, Ltd. out of Columbus, OH. The initial concrete structure dates back to 1923, when it was constructed of concrete, rebar, and oak pilings, some of which are likely intact today. The dam has always stretched entirely across the river's floodway in the middle of town, but only allows water through a 138' gap during normal flows. The old dam had stop log buttresses, concrete and rebar "teeth" placed along this middle section to dissipate water energy as it came over the dam. However, these "teeth" often had to be repaired as logs and other debris rammed into them and were replaced in the 1998 work with "hydraulic roller breakers", the two side-by-side humps you see today.

Long ago, Troy's low-head dam once provided power to a nearby power plant, but is more known for the watersports that thrived in Troy for several decades between 1950 and 1980. Many residents who lived along the river built docks and had speedboats, and a boat launch was put in at Treasure Island. Treasure Island was initially a private company, started by Hobart Brothers, Inc., in response to local interest in watersports on the river. They formed a company who cleared the banks and dredged the river through town, and created Treasure Island as a haven for their employees and their families.

By 1960, the river needed to be dredged again in order for the watersports to continue. In order to obtain over a quarter of a million dollars of state and federal funding for river enhancement, E. A. Hobart donated Treasure Island to the city, who in turn was able to dredge nearly 2 miles of river (from the dam to Lytle Road) for watercraft use.

It was during this time that festivals and concerts were hosted at Treasure Island Park, which was quickly becoming known throughout the region as a water sports destination. Unfortunately, due to the nature of low-head dams, sediment continued to build up in the Miami and the water again became too shallow for boating. We now understand more fully the effects of dredging rivers, and how unsustainable a practice it is for purely recreational purposes.

Currently, the dam serves no purpose within town, and while thankfully no incidents have occurred in Troy, the dam remains a drowning hazard to watercraft users and fisherman who popularize this stretch of river. Removal of the dam would eliminate this safety hazard and promote a more beneficial aquatic habitat, in turn improving the already plentiful fishing opportunities in town.

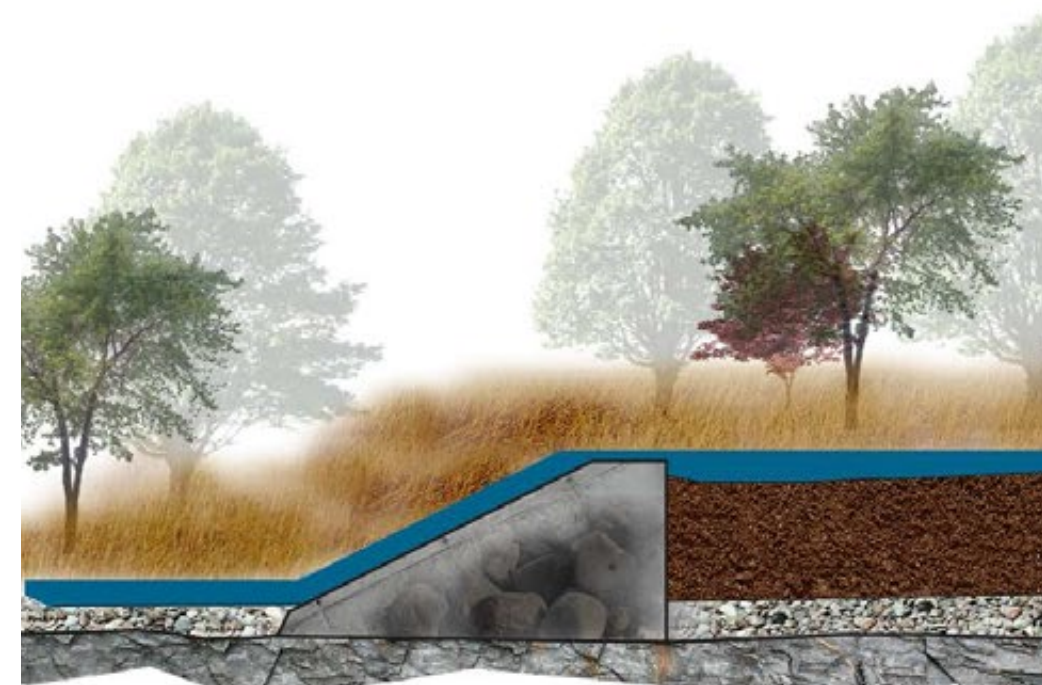


FIGURE 8.1-1 | Diagram of Sediment Dropout Behind Troy Low-Head Dam

TROY LOW-HEAD DAM

Bankfull Width (W_{bkf}): 204.8 FT

Bankfull Mean Depth (d_{bkf}): 9.3 FT

Bankfull Cross Sectional (A_{bkf}): 1,884 SFT

Backwater Reach Length: 5,280 LFT

Backwater Sediment Length: 5,280 LFT

Estimated Max Dry Sediment Volume: 202,204.4 CYS

Estimated Max Wet Sediment Volume: 184,213.3 CYS

Estimated Design Discharge Sediment Volume: 81,009.1 CYS

Annual Sediment Release: 23,000-31,000 CYS (~15% of above)**

*Based on regional curve data

**Based upon the approximate design discharge

8.2 TROY LOW-HEAD DAM REMOVAL

The entire length of concrete levee along Water Street, built to protect Troy from flooding in extreme high water events, included the installation of concrete paving slopes that start just downstream of the dam and slope down into the river.

A concern could be raised about protecting the toe of these concrete-armored slopes. Review of the Miami Conservancy District’s as-built plans show that the seepage cut-off sill was installed below the excavated channel depth of the river. In some locations, sheet piles were installed with the cut-off sills being poured onto the piles. The two design details appear to accommodate two field conditions, one to install cut-offs in bedrock while the other is to install cut-offs on subgrade river soils (see Appendix)

This concrete wall is located on the right bank and intended to protect Water Street from scour. The excavation and wall construction included construction of an earthen toe at the base of the wall. Today, because the wall is located in the outside river meander bend at a location of a pool, the earthen levee wall toe is gone. The missing toe could have an effect on the integrity of the retaining wall that protects Water Street and the rest of downtown Troy.

Removal of Troy’s low-head dam would allow for the reconstruction of the missing toe at the base of this retaining wall, and this reconstructed toe could be built wide enough to accommodate a pedestrian trail (See Figure 8.2-3). According to Troy’s Downtown Development study, a trail or other accomodation to better unite the downtown core with the Great Miami River is desired for economic purposes. Removing the low-head dam just downstream of this location would reduce the width of the backwater by approximately 40’-60’, therefore creating an opportunity for this new levee toe and accompanying trail (See Figure 8.2-1).

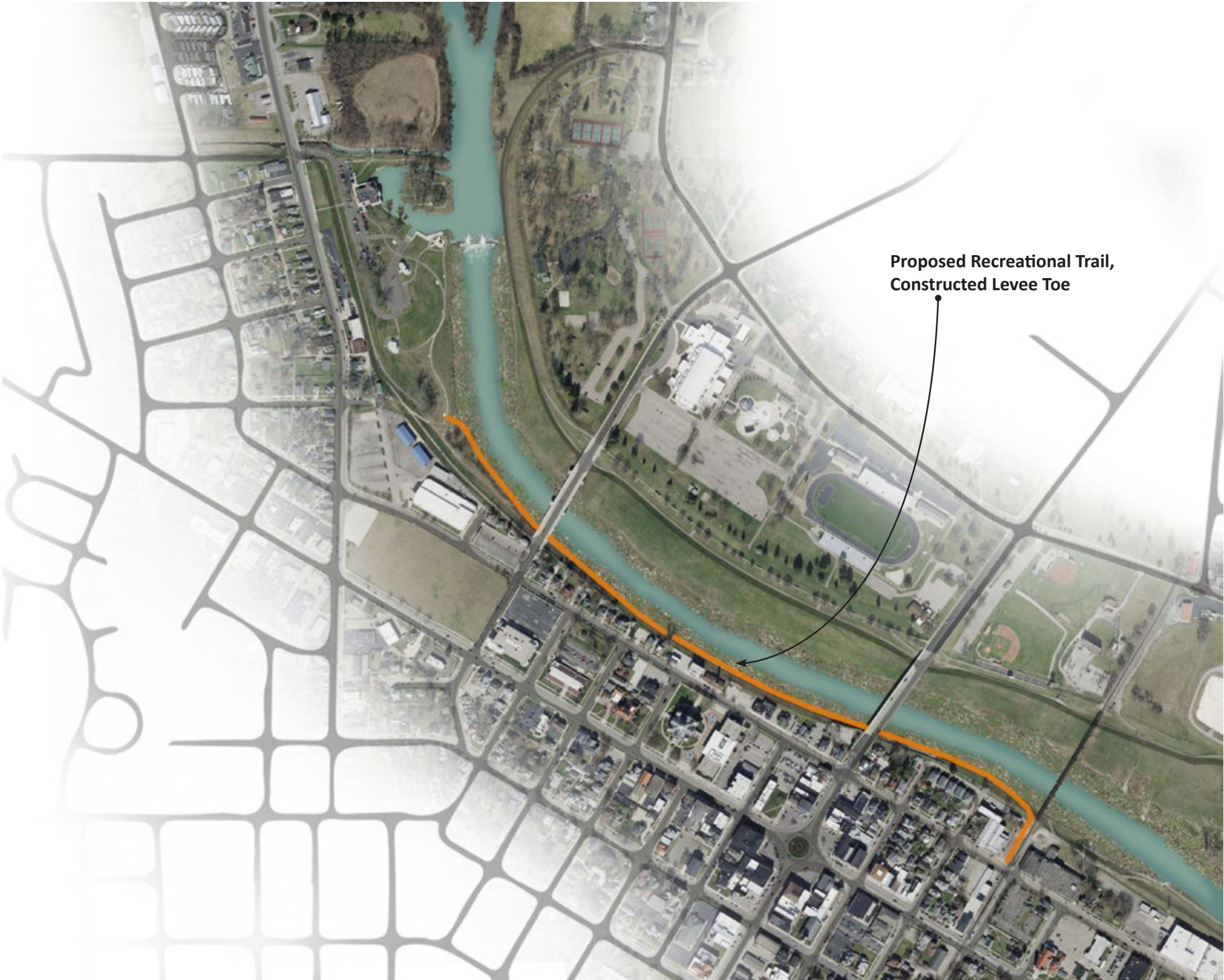


FIGURE 8.2-1 | Proposed Condition of the Troy Low-Head Dam Backwater

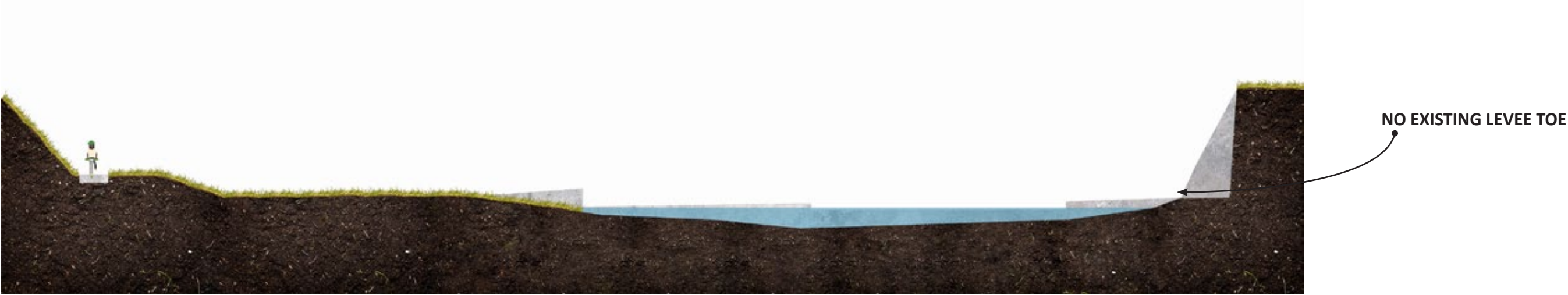


FIGURE 8.2-2 | Existing Conditions at the Troy Low-Head Dam



FIGURE 8.2-3 | Potential Future Condition of Troy Dam site

8.3 TROY LOW-HEAD DAM AS BUILT DRAWINGS

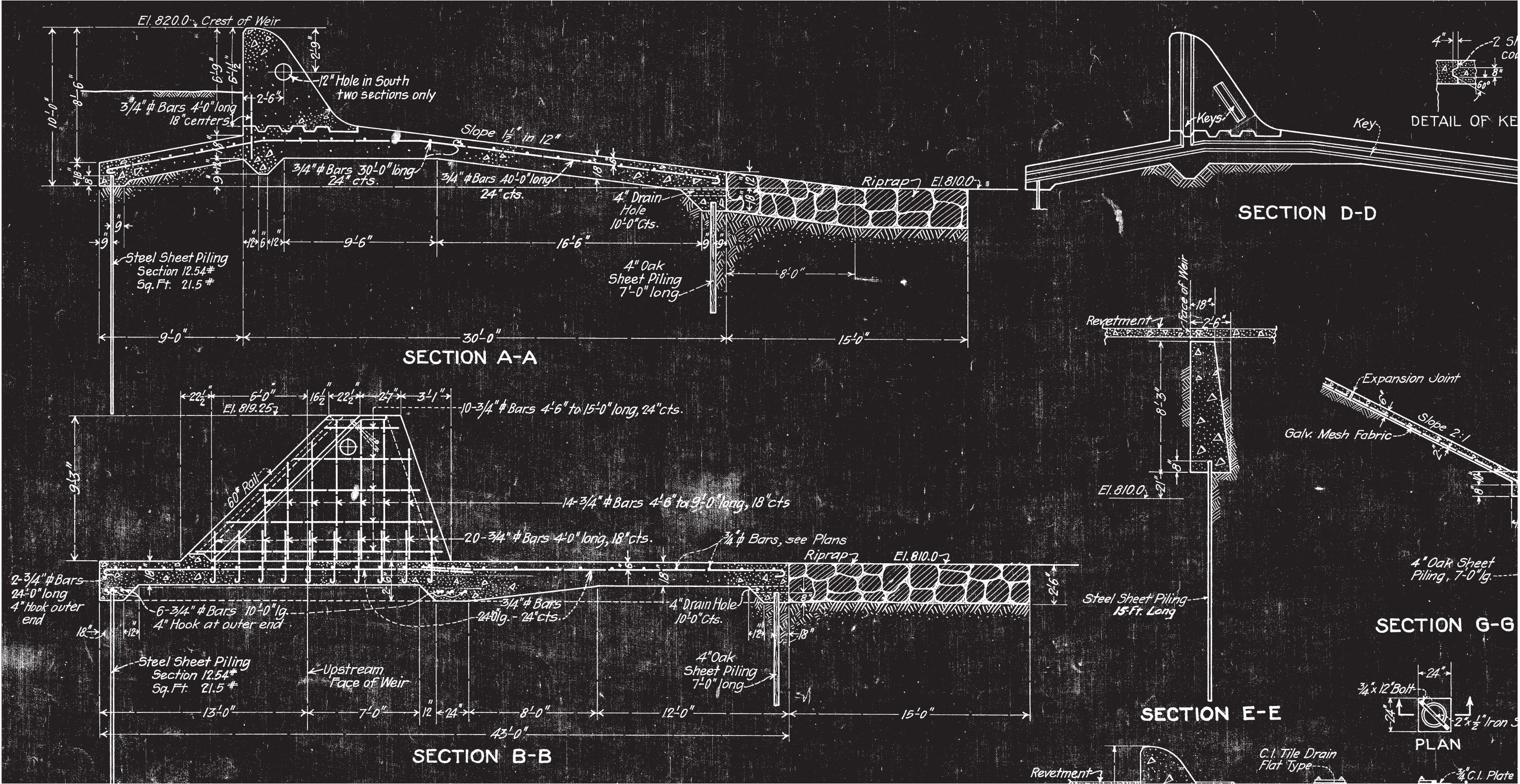


FIGURE 8.3-1 | As Built Drawings of the Troy Low-Head Dam

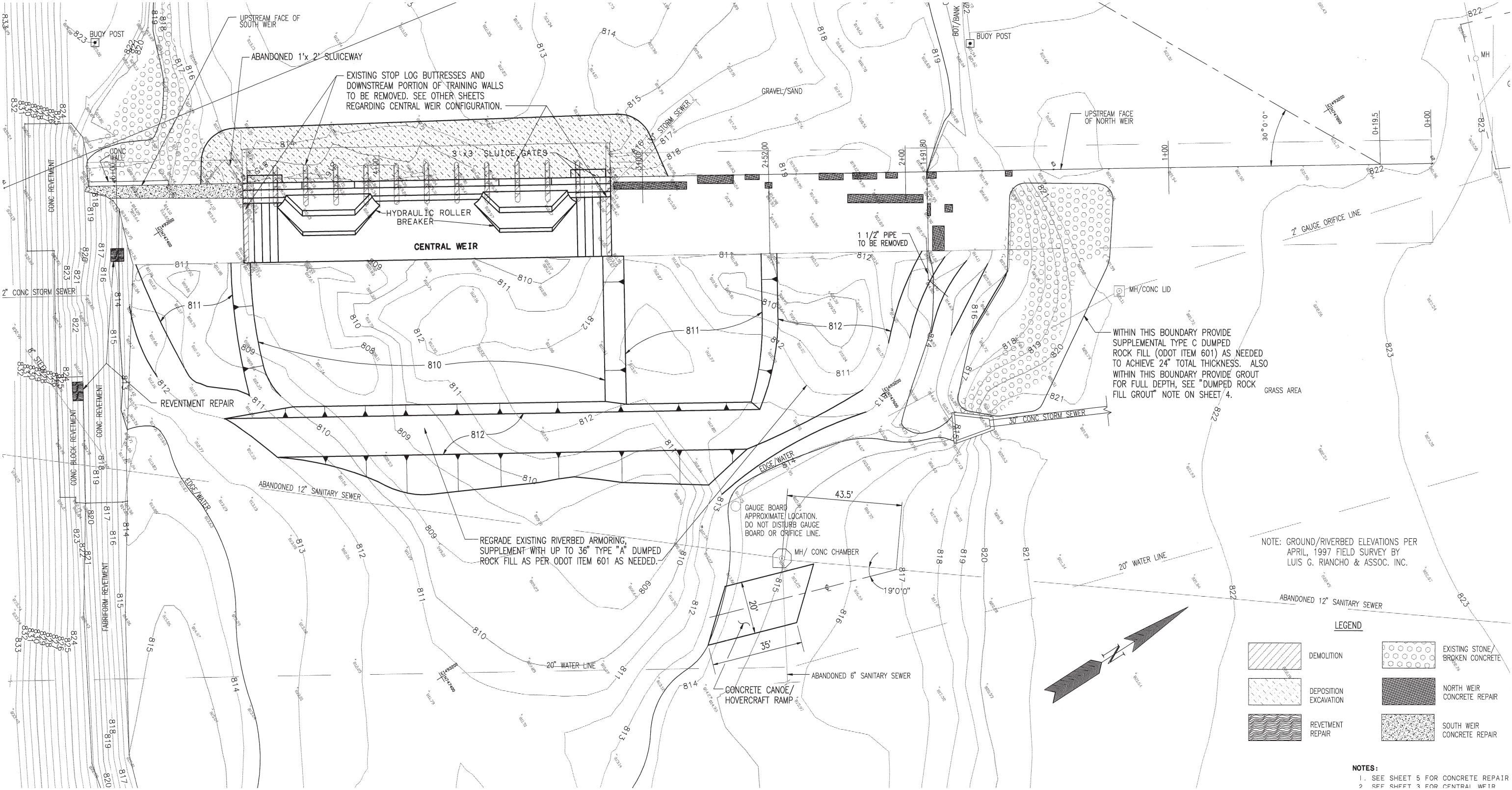


FIGURE 8.3-2 | As Built Drawings of the Troy Low-Head Dam

8.4 TROY LOW-HEAD DAM REMOVAL & TREASURE ISLAND

TREASURE ISLAND IN-STREAM IMPROVEMENTS

At Treasure Island, it is desired that the current typical water elevation be maintained so as to not “empty” the lagoon and maintain the functionality of it’s fountain and small boat launch. In order to maintain this, a few different options are available to the city, each with unique challenges. The favored strategy proposed by the city would be to create a “grade-control” structure within the Great Miami River itself that could also serve as a water feature to kayakers. This structure could become a new focal point for the town’s watercraft users and provide a scour hole for fisherman.

If built improperly, a structure to maintain water elevation in this area following removal of Troy’s low-head dam could effectively just replace the dam slightly further upstream, in terms of fish passage capability and recreational safety. A w-weir is recommended to achieve the consistent water levels desired by the city while maintaining improved fish passage. However, it is important to understand what makes structures such as cross vanes and “w-weirs” more beneficial to fish than a low-head dam.



FIGURE 8.4-1 | A cross-sectional view of proposed w-weir at treasure island.



FIGURE 8.4-2 | A aerial view of proposed w-weir at treasure island.

8.5 TROY LOW-HEAD DAM REMOVAL & CITY PRODUCTION WELLS

GREAT MIAMI BURIED VALLEY AQUIFER

The Great Miami Valley Aquifer is one of the largest and cleanest natural aquifers found in the United States, and is a reliable source of clean drinking water for millions of people in southwest Ohio and across the Miami Valley. The City of Dayton, the Butler County Miller-Coors brewery (the largest MillerCoors brewery in North America), and the Cargill Agriculture Sidney Grain and Dayton Corn Mills all use the aquifer as their primary water source. The saturated sand and gravel deposits found underground in the Miami watershed store trillions of gallons of freshwater in the glacially carved spaces between “canyonlike” bedrock walls. The aquifer is designated a “Sole Source Aquifer”, and is therefore protected by the US EPA.

The aquifer can be anywhere from 30 to 300 feet deep, and from less than a mile to more than 3 miles wide. The river traverses the length of the aquifer, and exchanges water with the aquifer, purifying the water for both in the process. The aquifer itself is split into two levels, an upper and a lower aquifer, separated by silt and clay deposits within the sand and gravel substrate. Exchange between the river and upper aquifer is relatively continuous throughout the year, but especially during high flow conditions (usually November - April). Exchange between the upper and lower aquifers (through the middle silt and clay layer) occurs throughout the year, but at a lesser rate.

TROY PRODUCTION WELLS

The City of Troy has its own municipal drinking water system that relies on two wellfields (WF) located on the East side of the Great Miami River, one upstream of the low-head dam (West WF) and one downstream (East WF). These production wells draw water from the lower aquifer throughout the year, but their productivity is constantly changing and dependent on many factors; including river stage (water level of the Great Miami), permeability of riverbed sediment, and other factors that affect the exchange of water between the Great Miami River and its aquifer.

Surface water exchanged between the upper aquifer and the Great Miami River varies throughout the river's length in areas that can be characterized as recharging and discharging ‘zones’. Recharging zones are typically where water would enter the upper aquifer through the river's sediment bed, while discharging zones are areas where water is typically transferred from aquifer

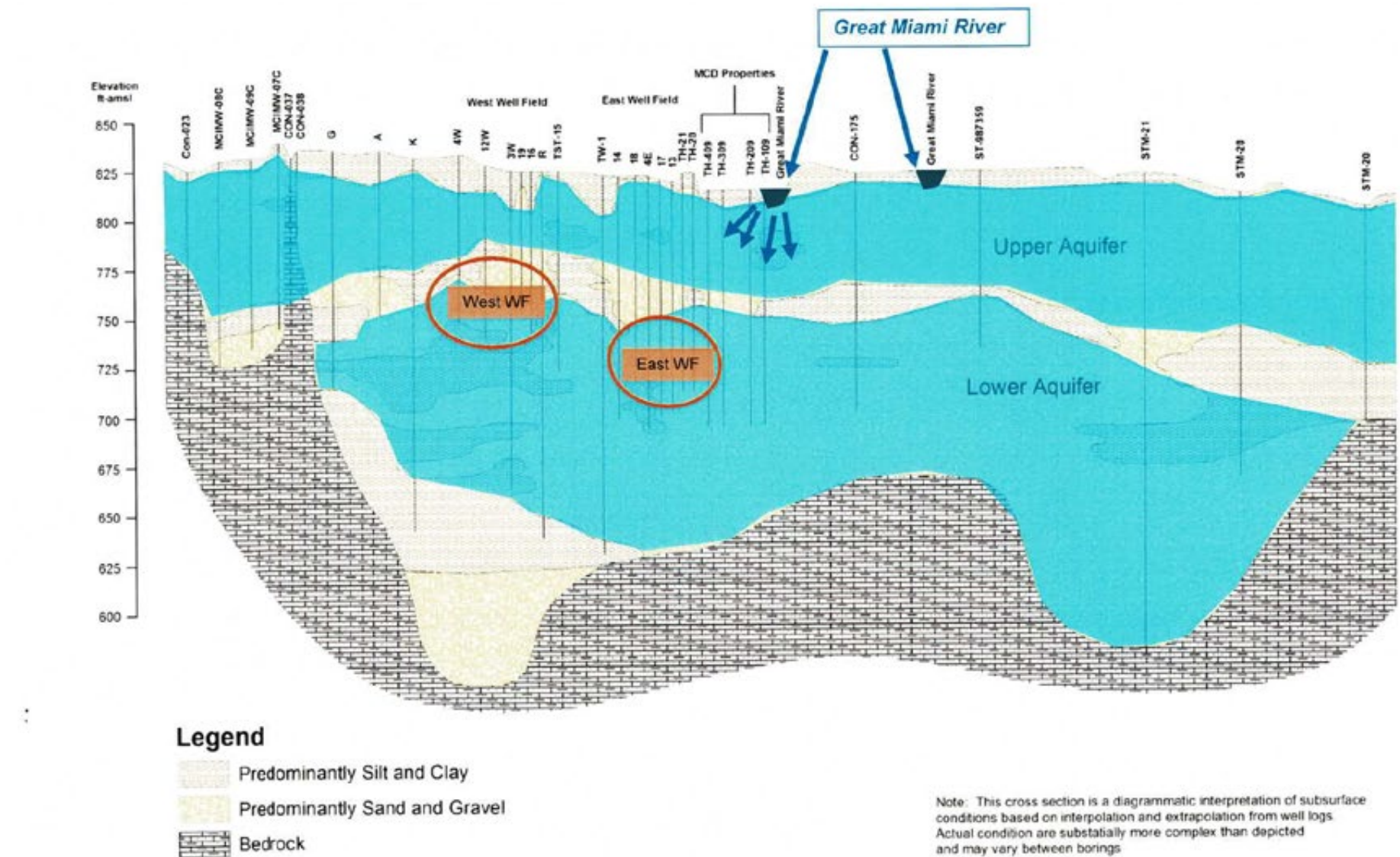


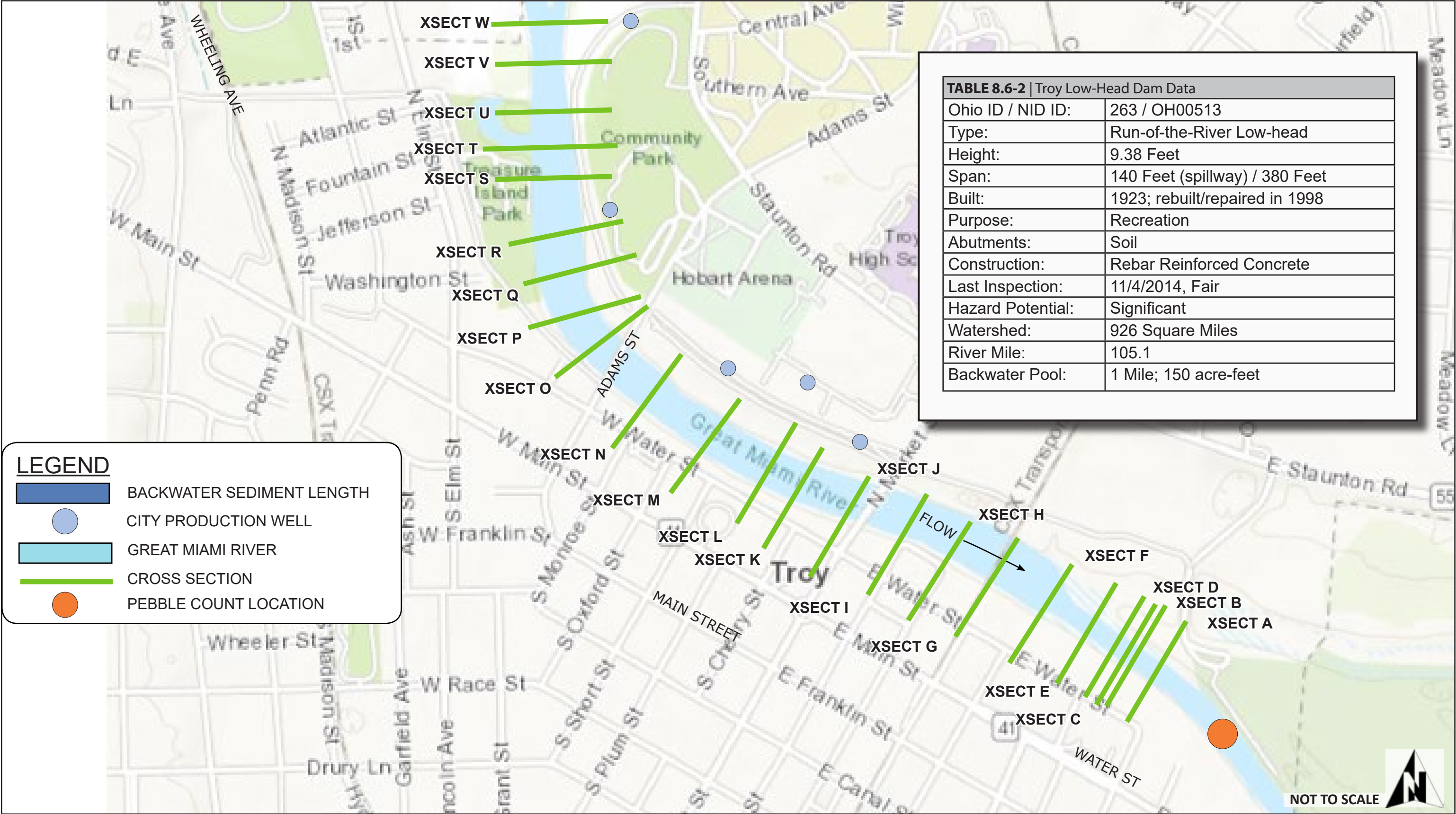
FIGURE 8.5-1 | A cross-sectional view of the Great Miami Buried Valley Aquifer in Troy (Provided by Arcadis design and consultancy).

to river. Recharging zones are typically deeper, slower moving pools of water such as the backwater of Troy's low-head dam. Discharging zones occur where the water is shallow and faster moving, also known as a “riffle”. In Troy, one of these discharging zones occurs just downstream of the dam, between the Miami Shores Golf Course and the dam itself.

Because of this dynamic, we know that if Troy's low-head dam is removed this pattern of recharging and discharging will be altered. The former dam's backwater will, either through natural process or intentional modification, form a new pool and riffle structure. Instead of being one long recharging zone, the former dam backwater will have several different recharging and discharging zones.

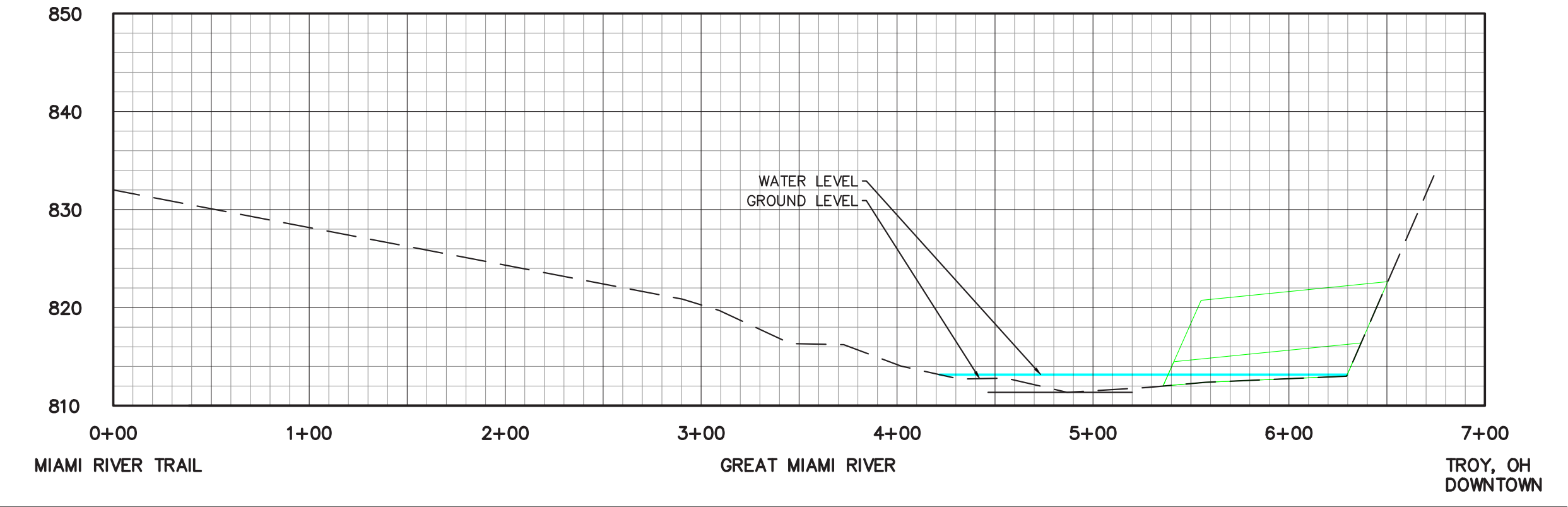
Utilizing cross-sectional data collected in a field survey by Flatland Resources, Arcadis Design & Consultancy, a company specializing in these types of wells, has determined that the removal of Troy's low-head dam will not have any adverse effects on the quality of drinking water produced by Troy's wells.

8.6 TROY LOW-HEAD DAM CROSS SECTIONS

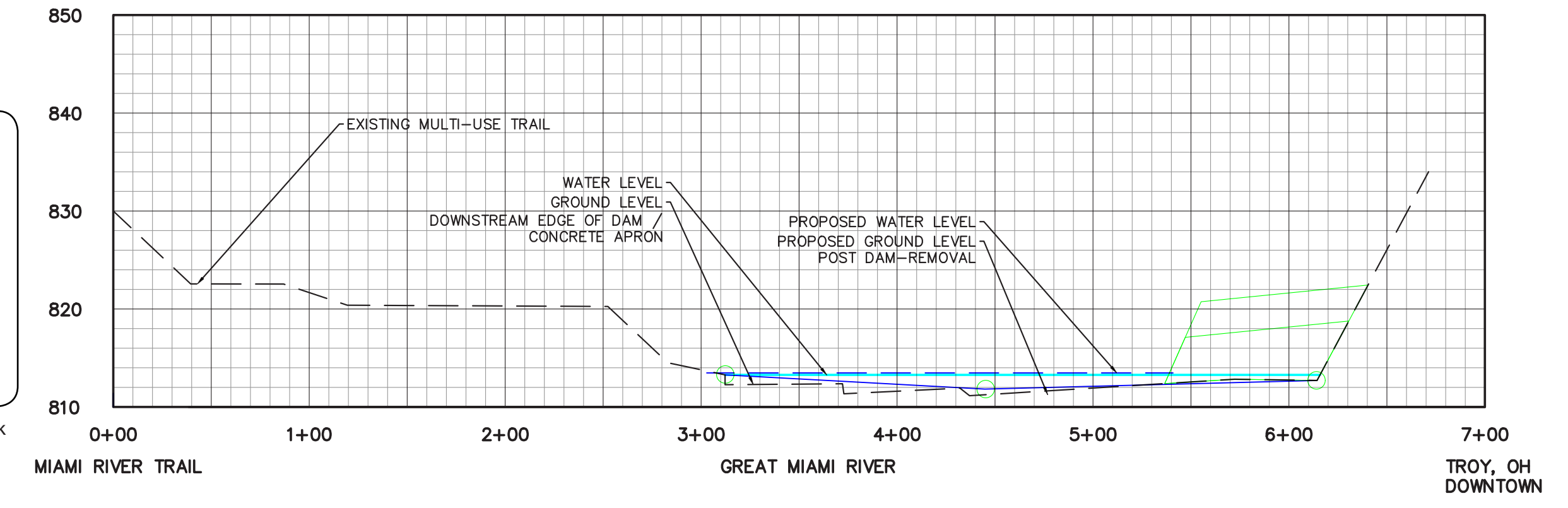


MAP 8.6-1 | Troy Low-Head Dam

SECTION A – A’ – DOWNSTREAM OF TROY DAM



SECTION B – B’ – DOWNSTREAM EDGE OF TROY DAM



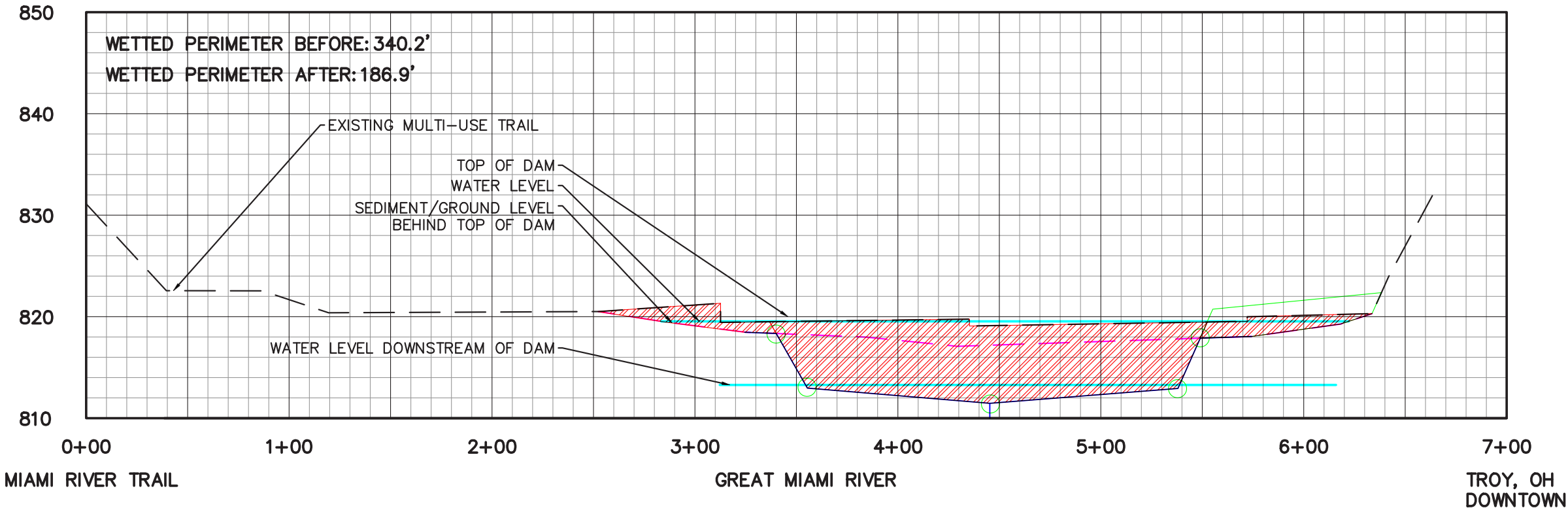
LEGEND

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- FILL
- EXISTING BANKFUL
- PROPOSED BANKFUL
- APPRX. 100 YEAR FLOOD ELEVATION

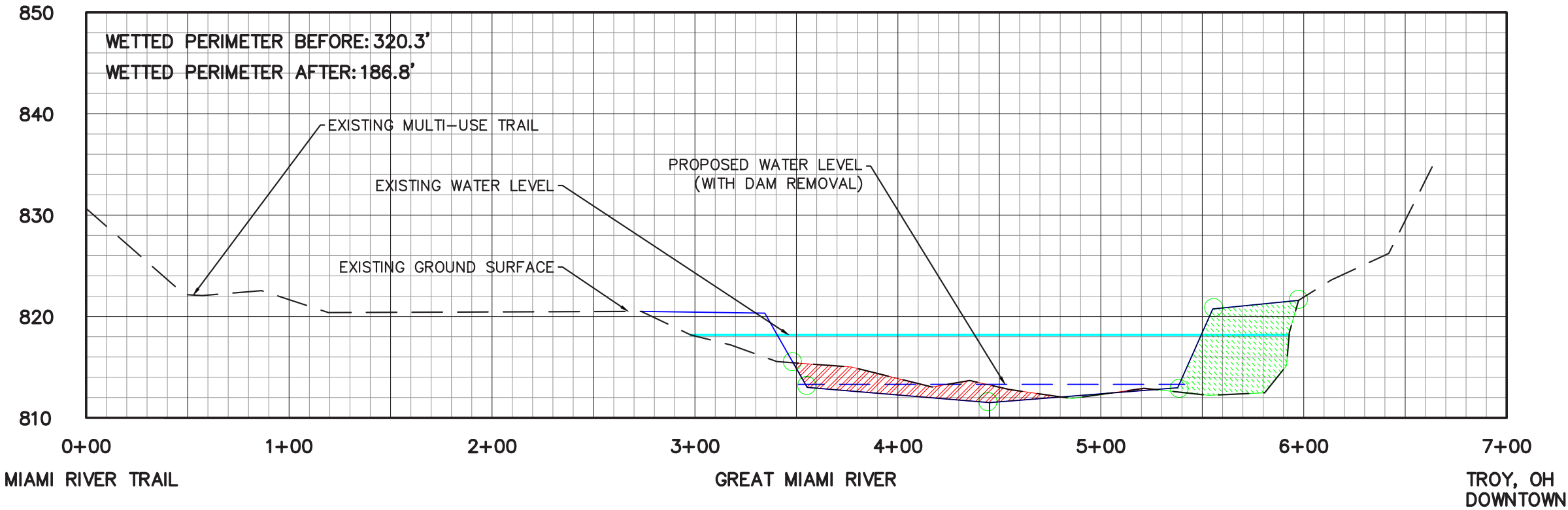
* CUT / FILL shown to illustrate necessary work for building pedestrian trail / levee toe along right bank (adjacent to downtown Troy)

8.6 TROY LOW-HEAD DAM CROSS SECTIONS (cont.)

SECTION C – C’ – TROY DAM



SECTION D – D’ – BACKWATER OF TROY DAM



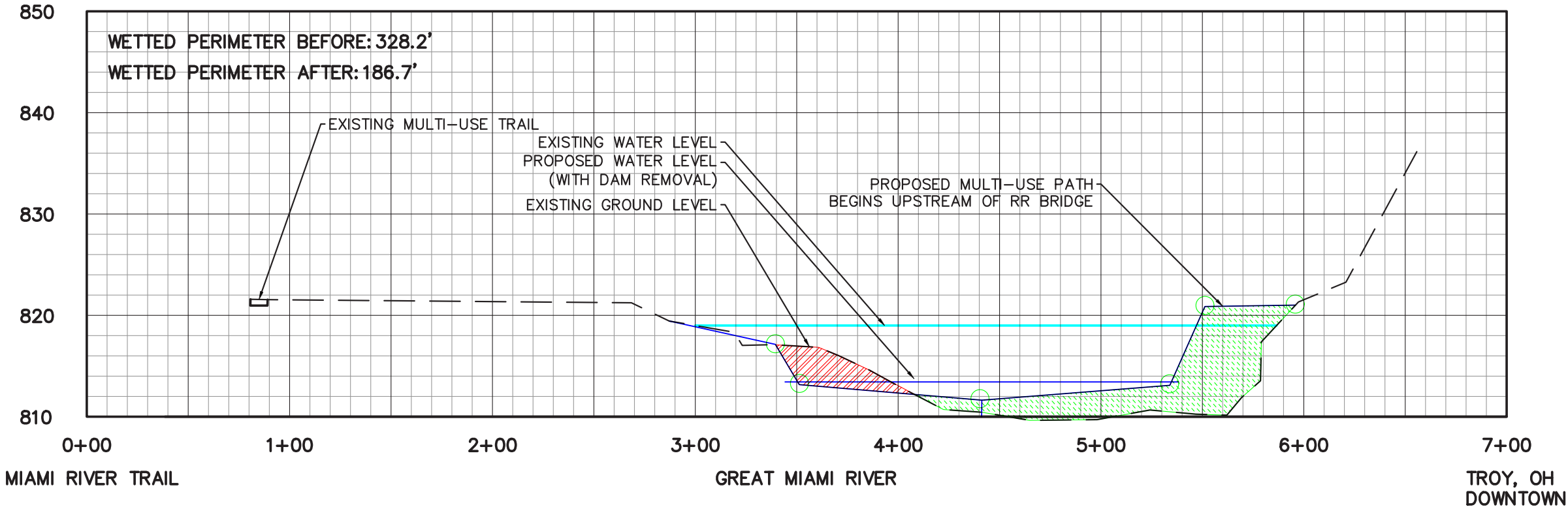
LEGEND

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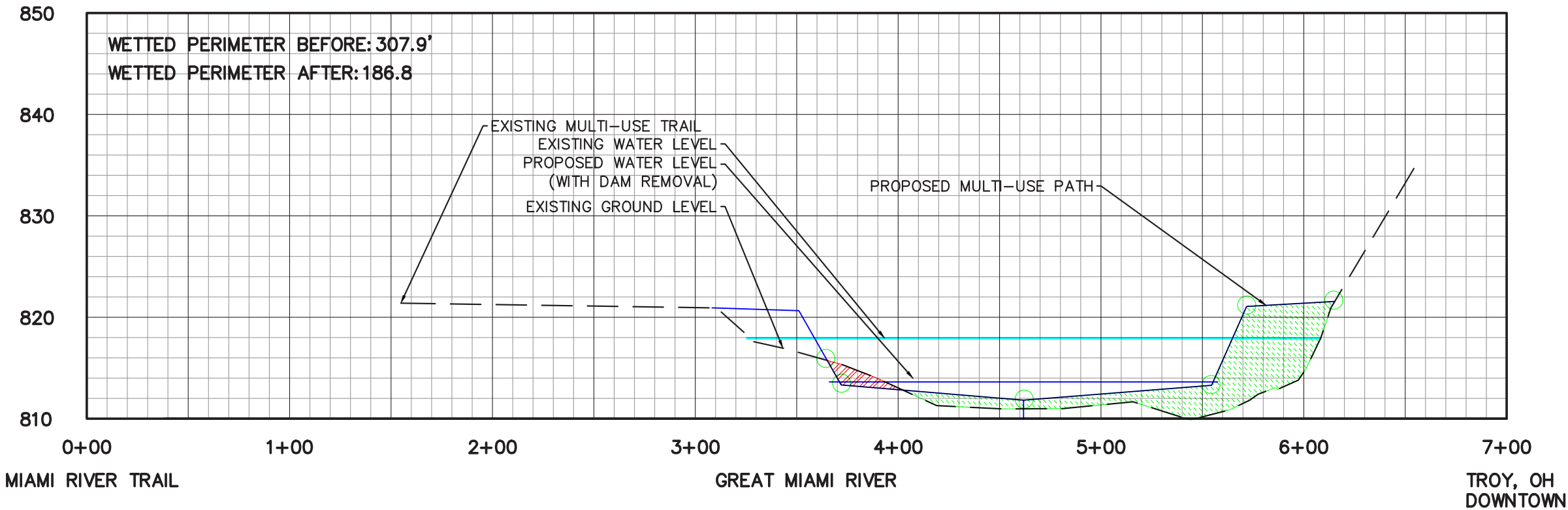
* CUT / FILL shown to illustrate necessary work for building pedestrian trail / levee toe along right bank (adjacent to downtown Troy)

APPROXIMATE CHANNEL SHAPE BASED ON REGIONAL CURVE DATA. RIVER DEPTH WILL VARY

SECTION E – E’ – BACKWATER OF TROY DAM



SECTION F – F’ – BACKWATER OF TROY DAM



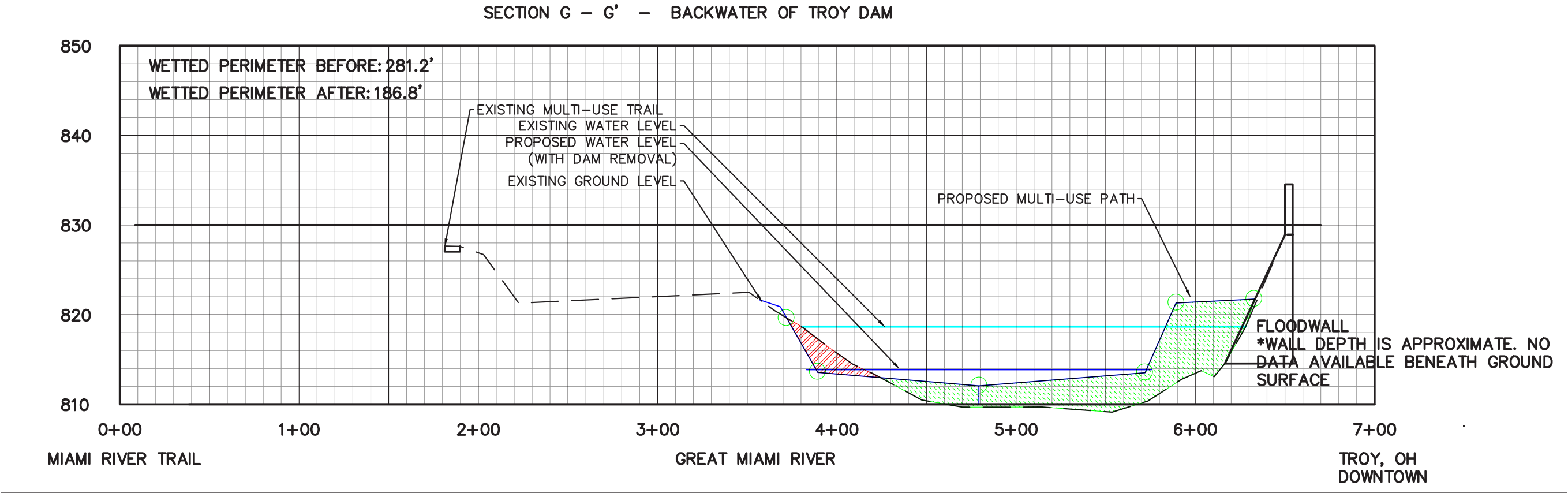
LEGEND

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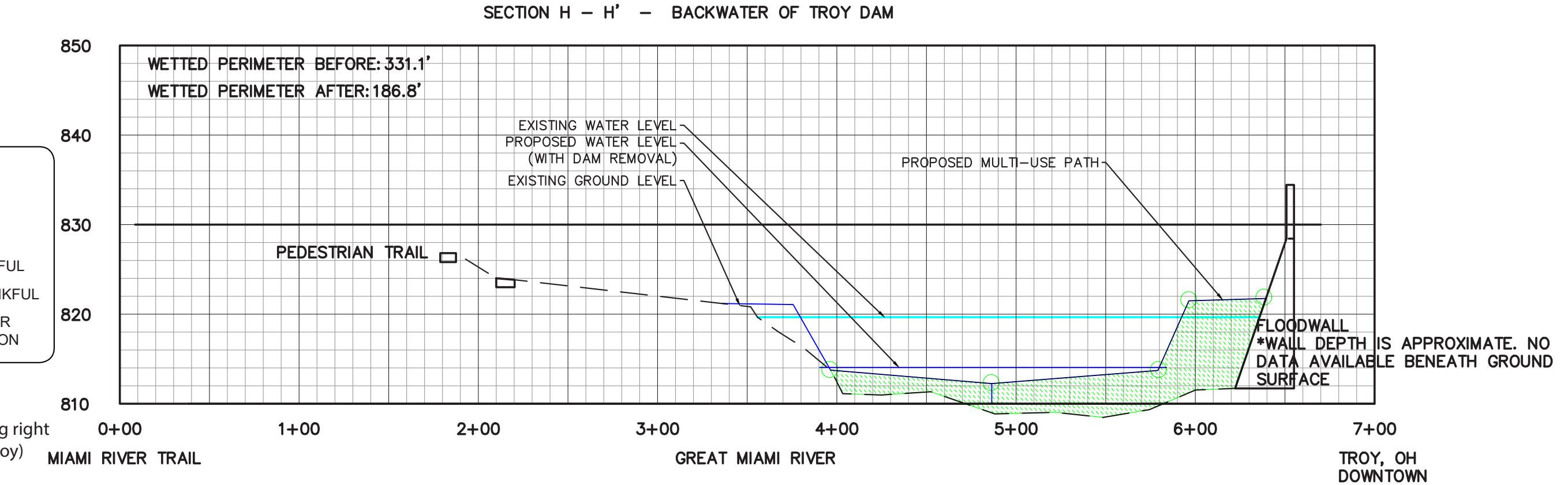
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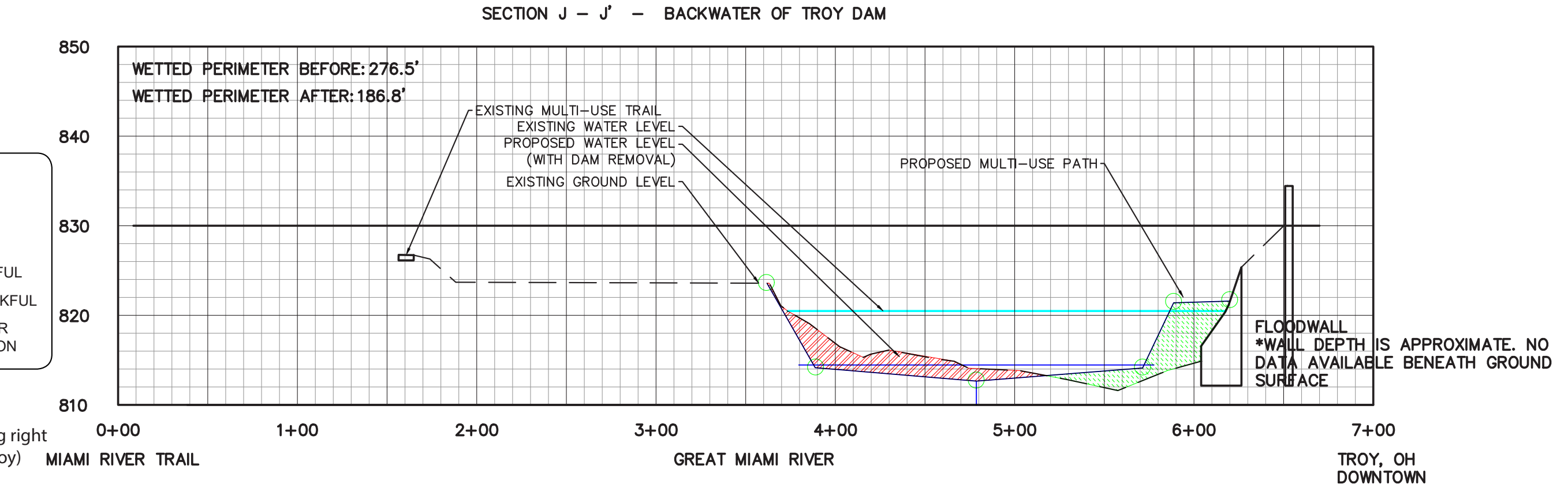
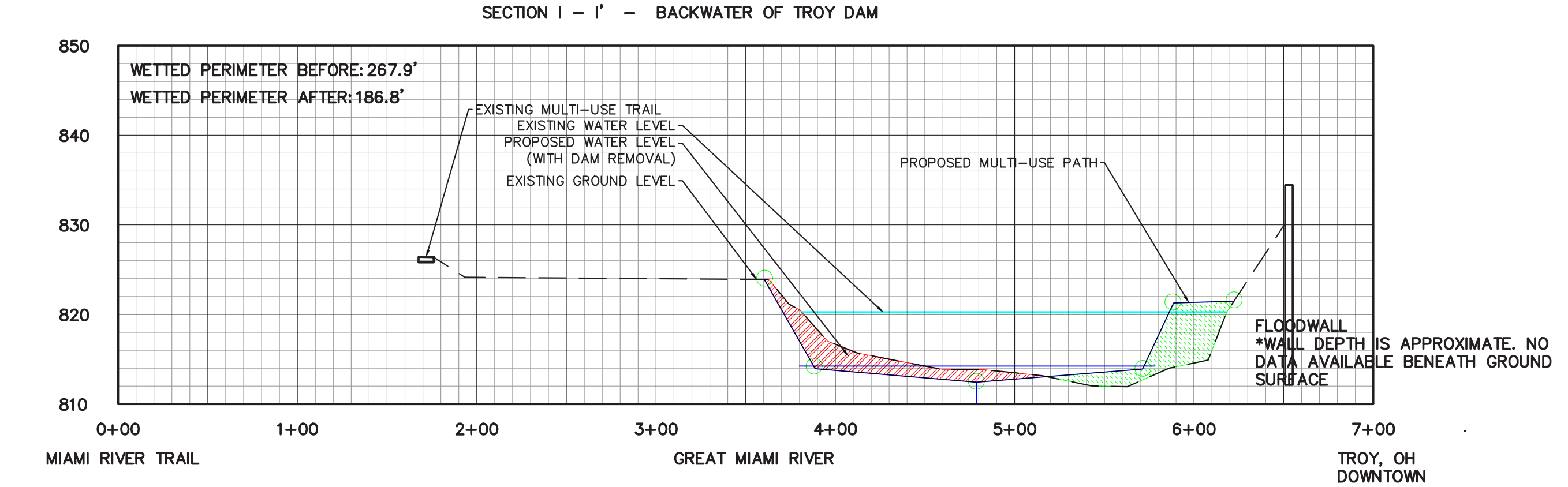


LEGEND

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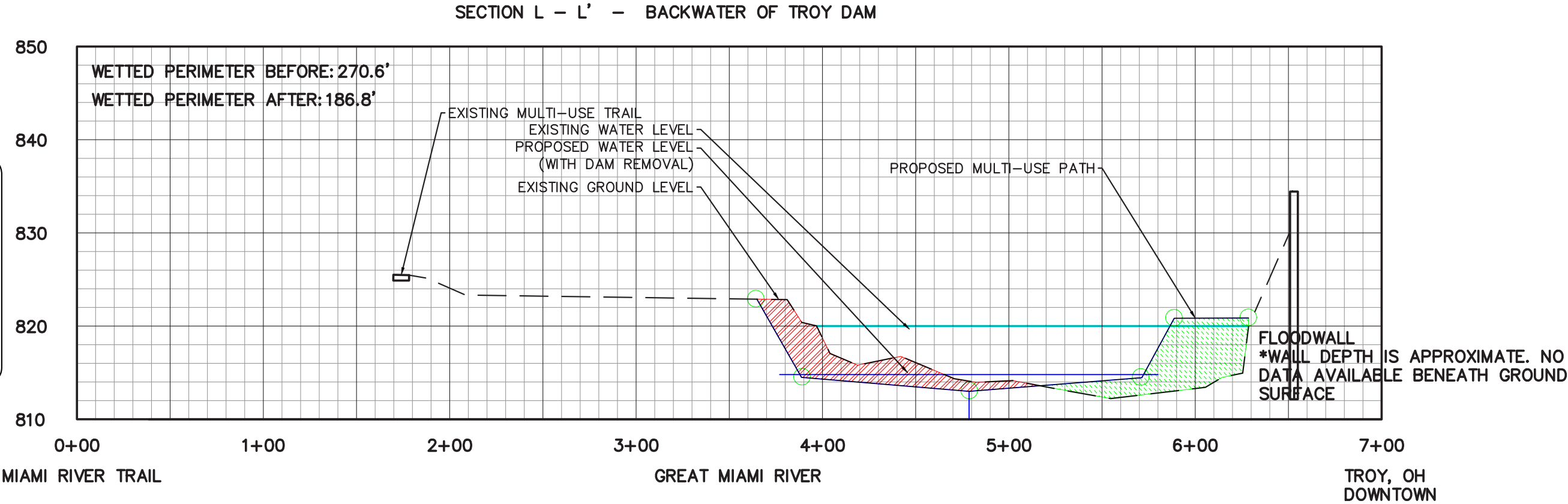
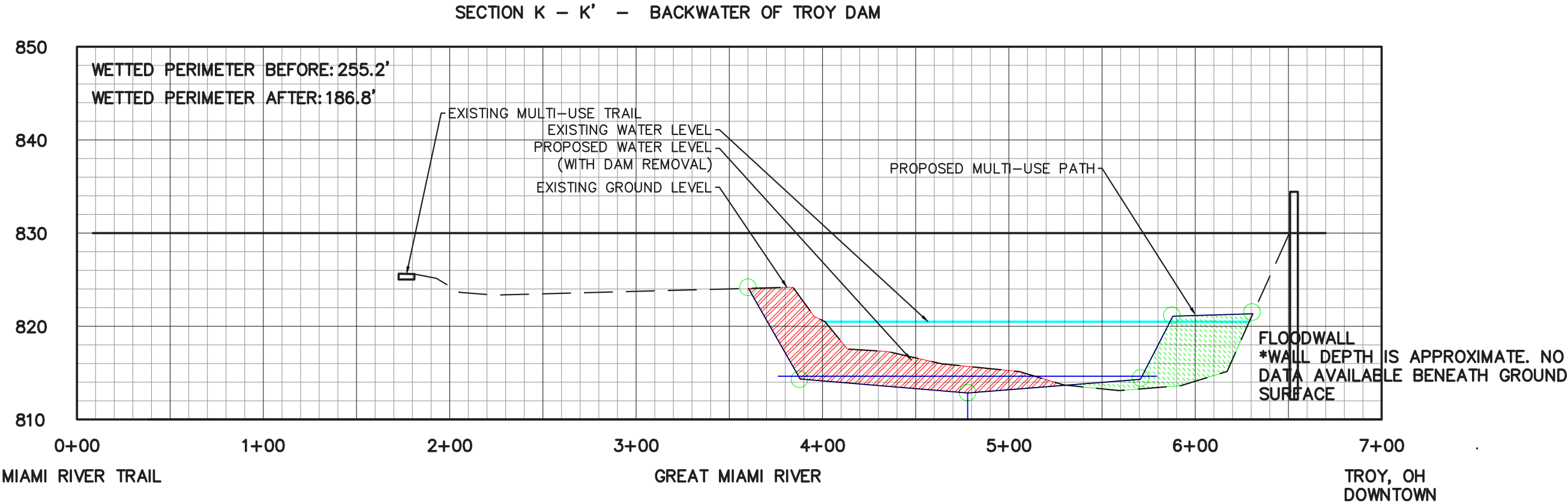
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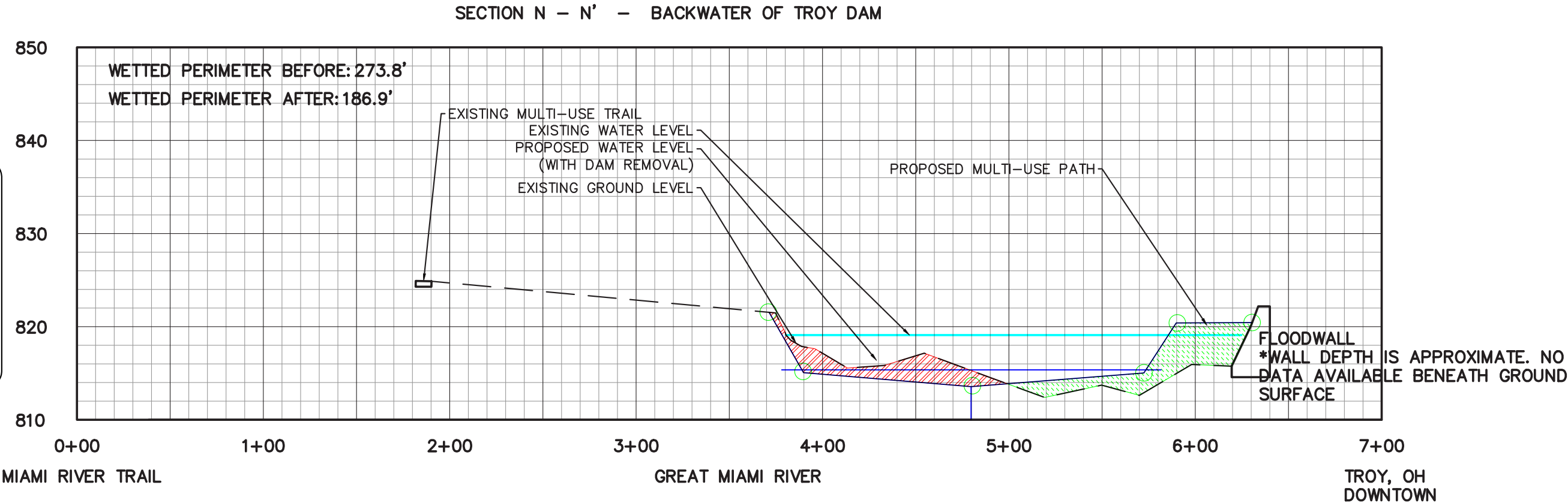
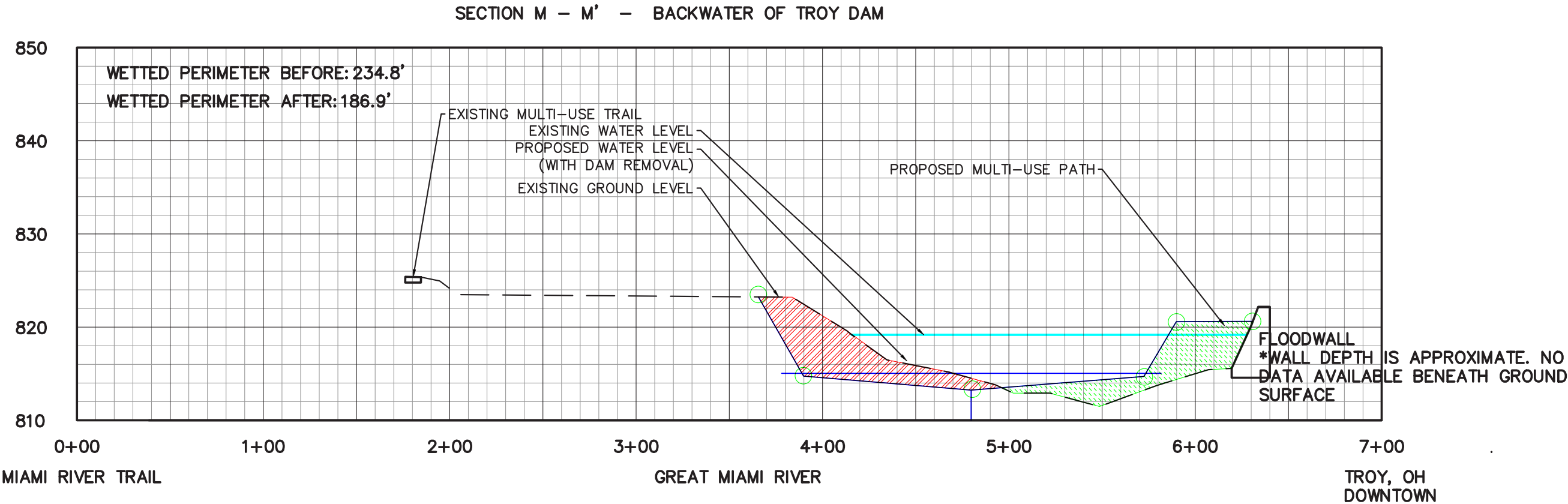
8.6 TROY LOW-HEAD DAM CROSS SECTIONS (cont.)



LEGEND

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- APPRX. 100 YEAR FLOOD ELEVATION

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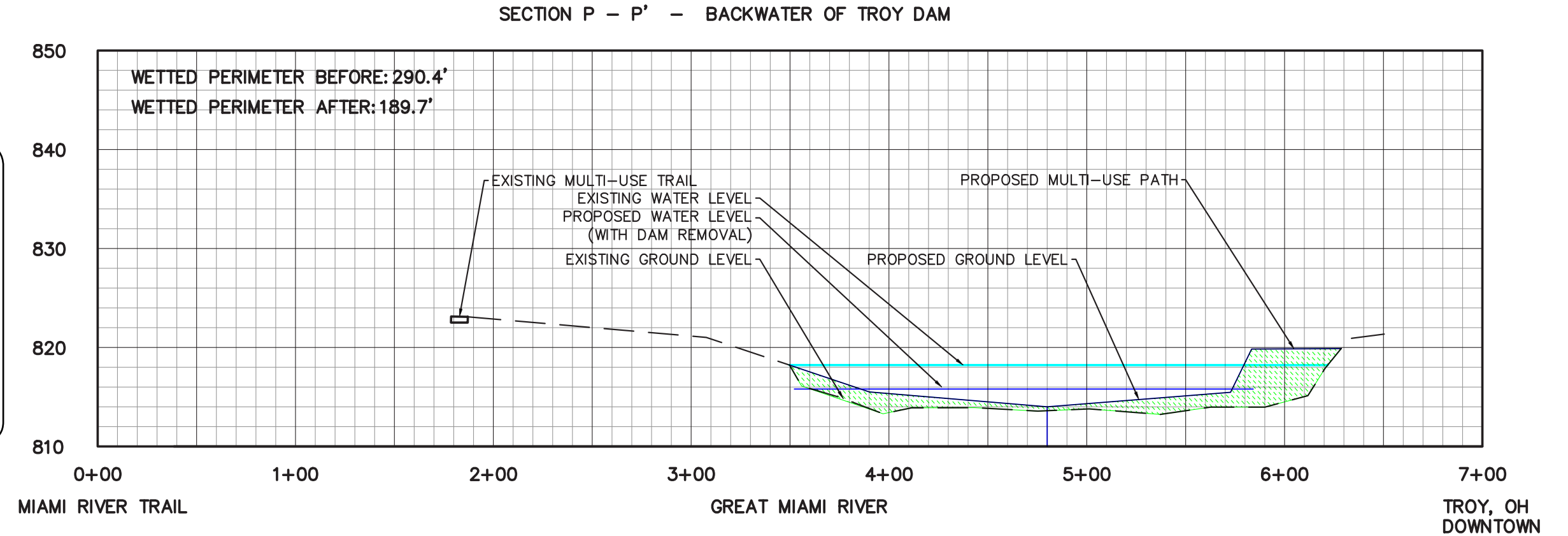
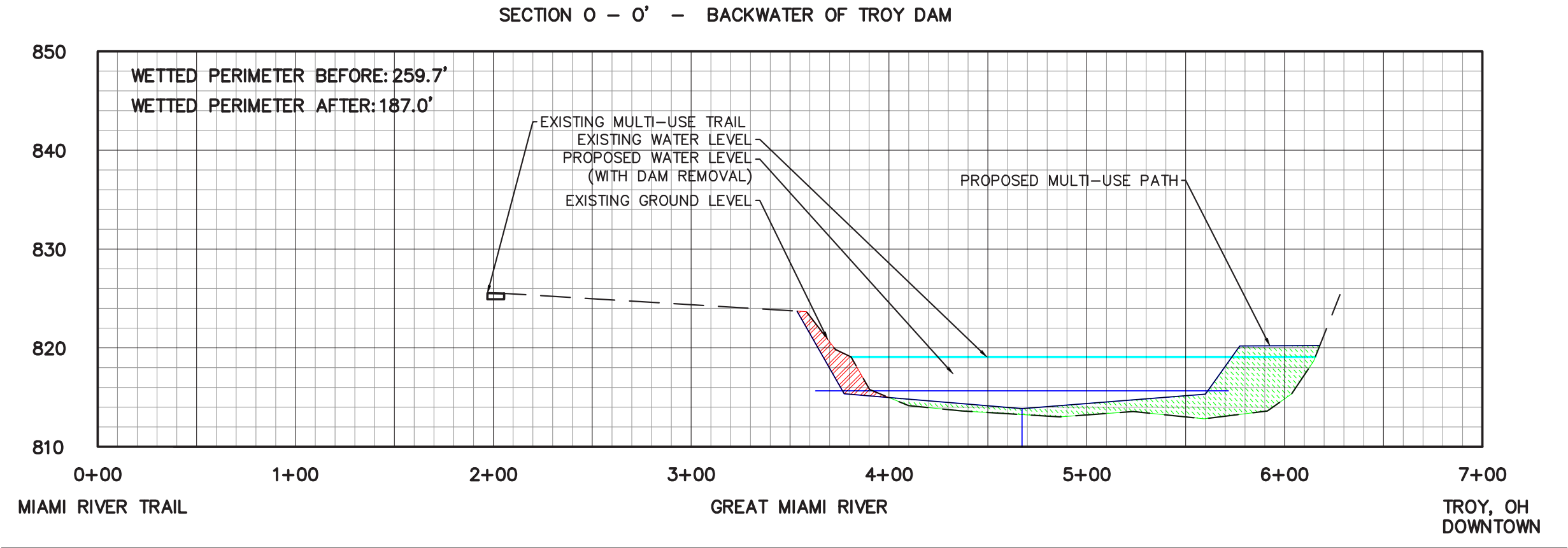
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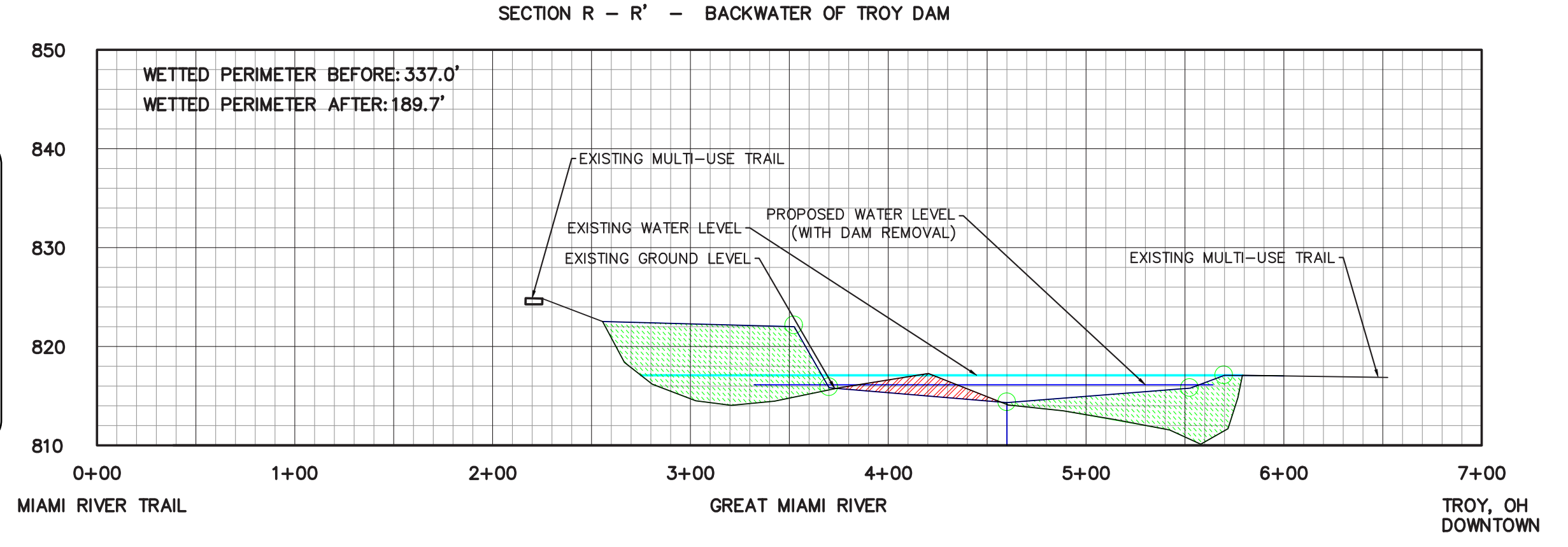
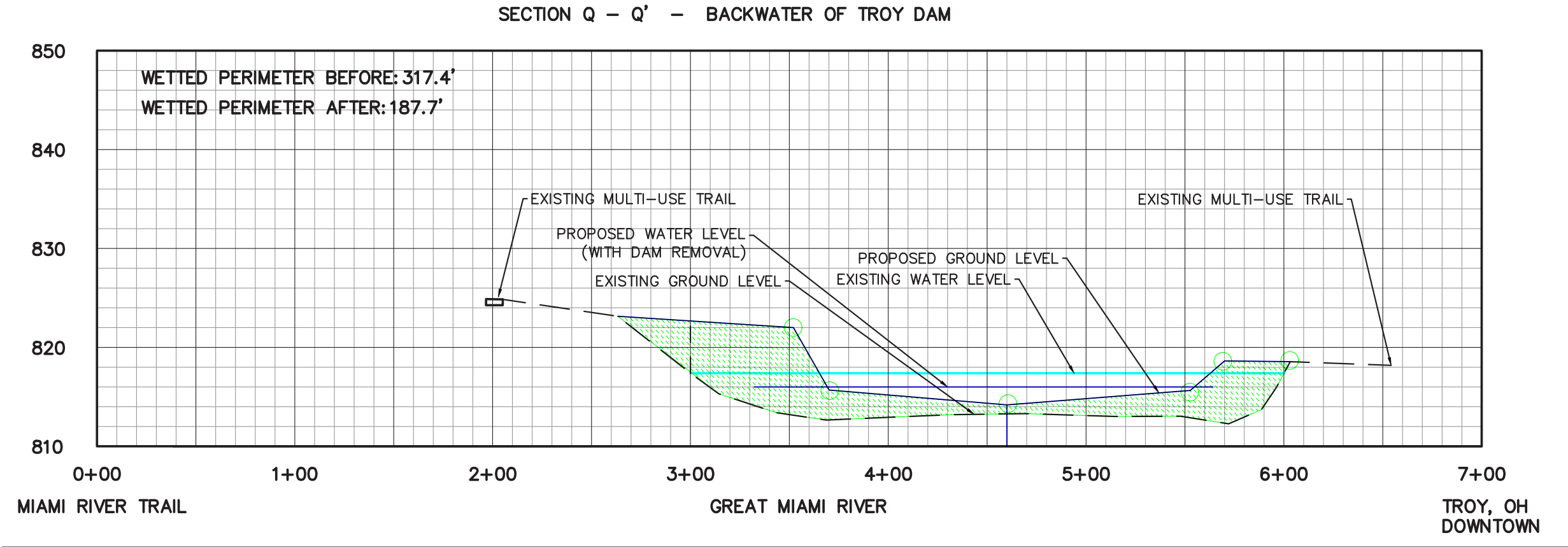
8.6 TROY LOW-HEAD DAM CROSS SECTIONS (cont.)



LEGEND

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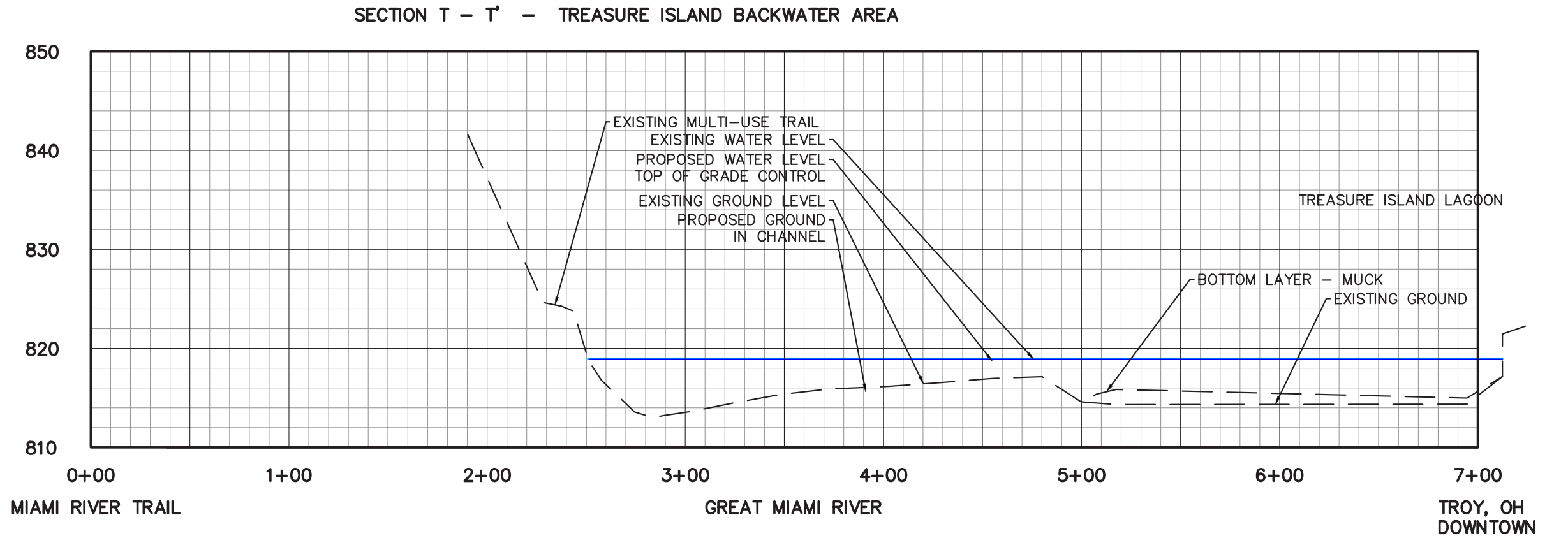
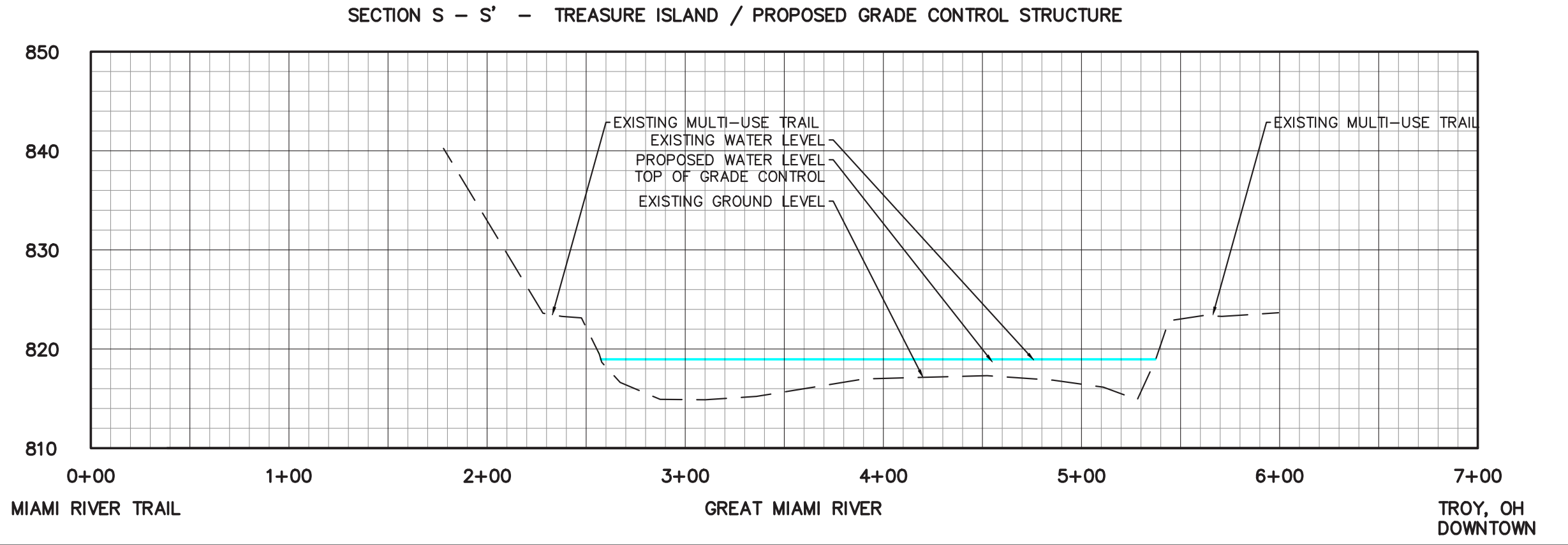
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8.6 TROY LOW-HEAD DAM CROSS SECTIONS (cont.)

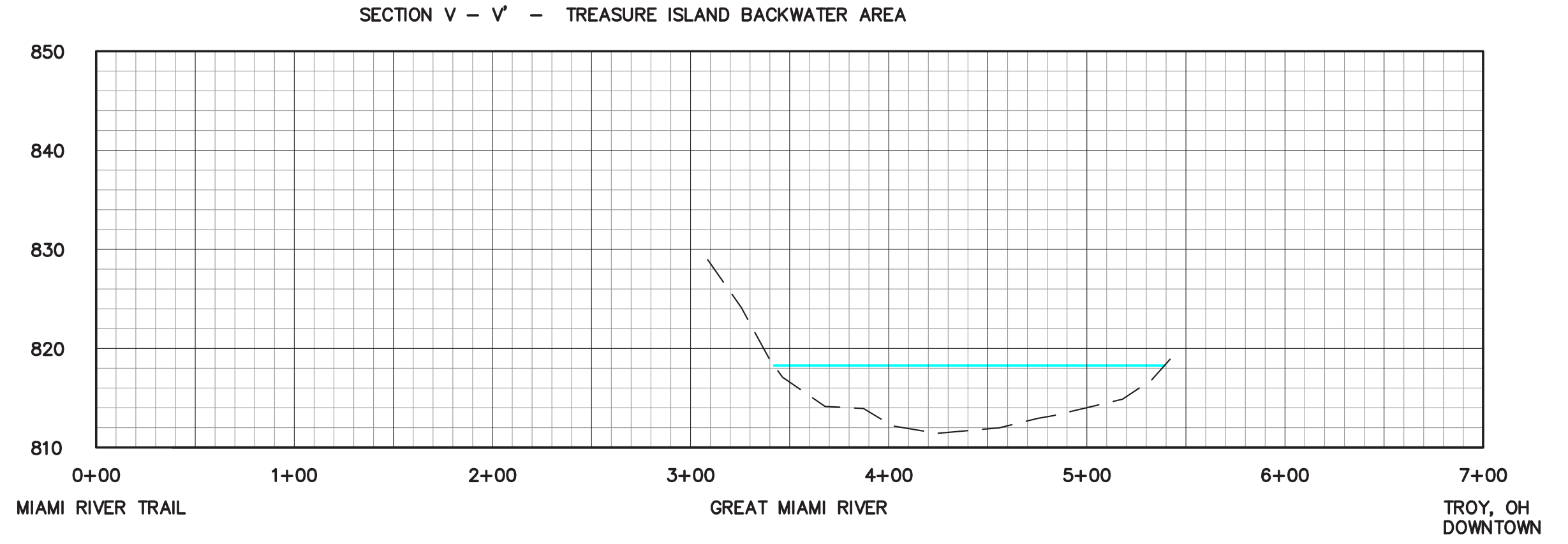
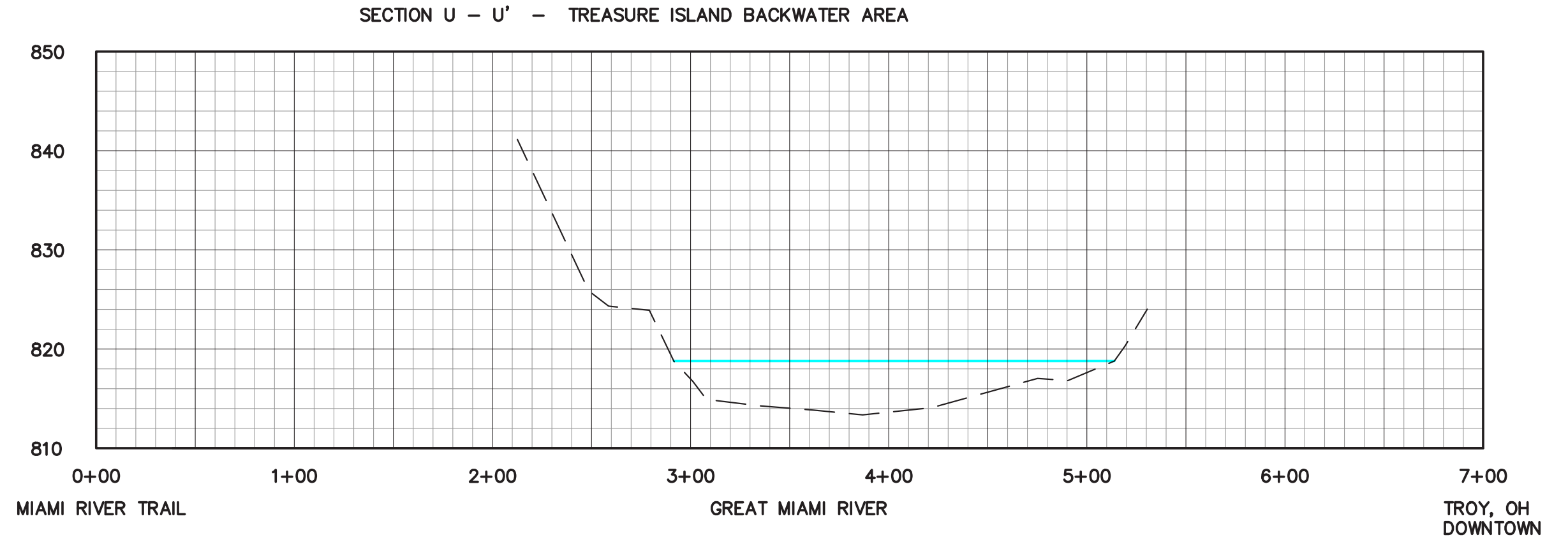


LEGEND

- CUT
- FILL
- EXISTING BANKFUL
- PROPOSED BANKFUL
- APPRX. 100 YEAR FLOOD ELEVATION

* CUT / FILL shown to illustrate necessary work for building pedestrian trail / levee toe along right bank (adjacent to downtown Troy)

APPROXIMATE CHANNEL SHAPE BASED ON REGIONAL CURVE DATA. RIVER DEPTH WILL VARY



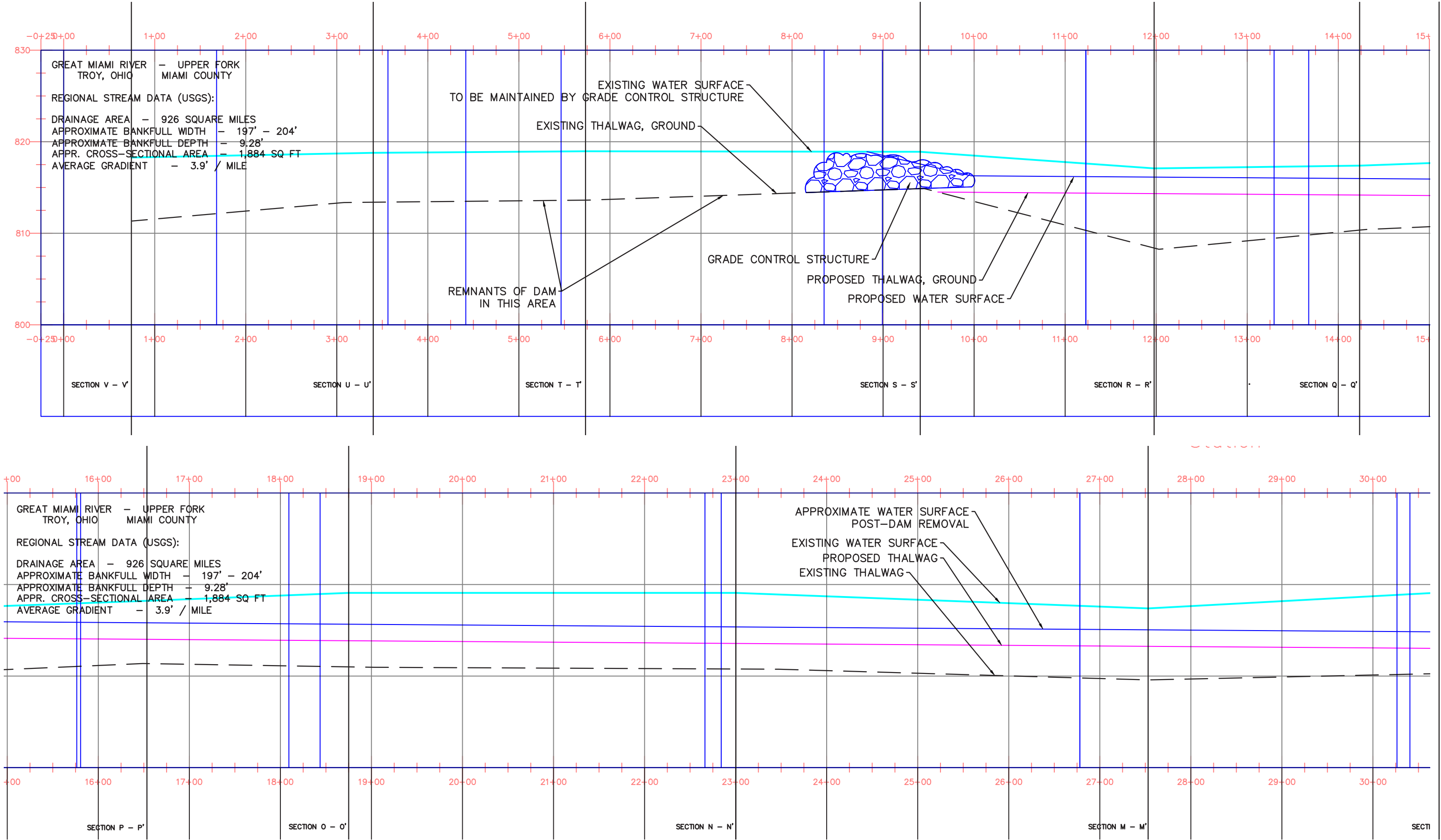
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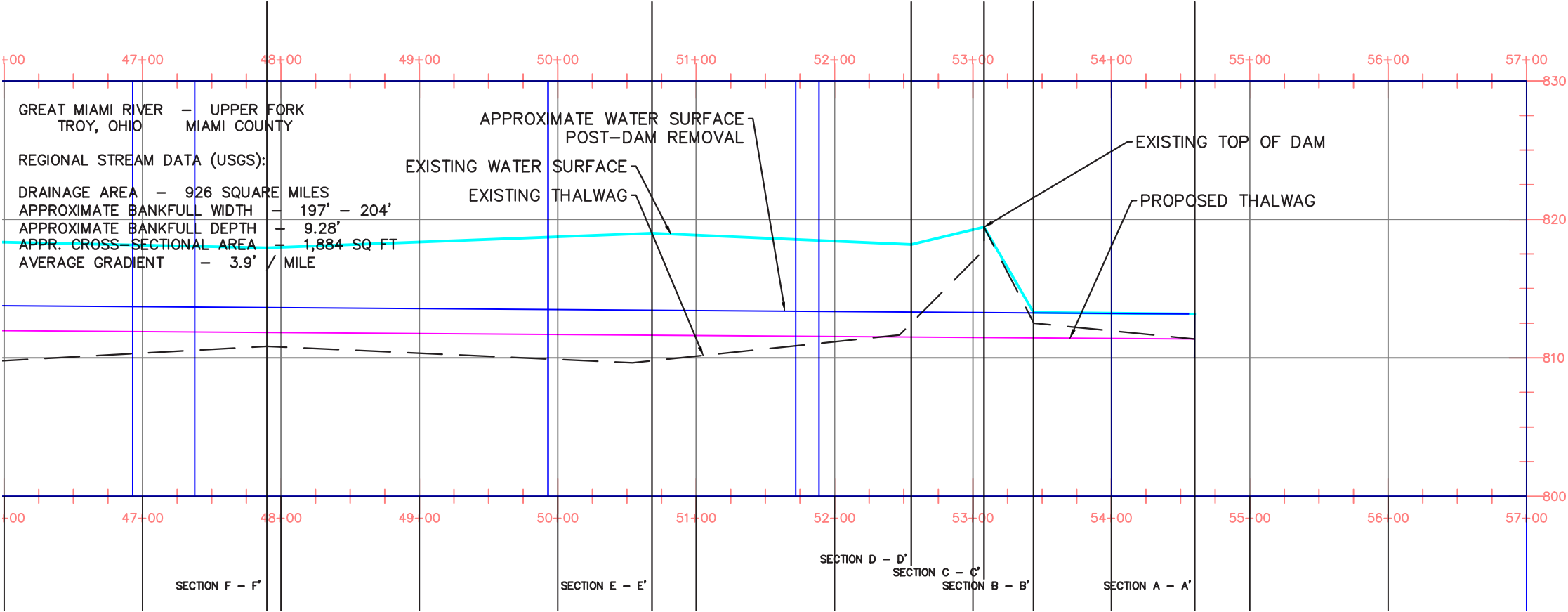
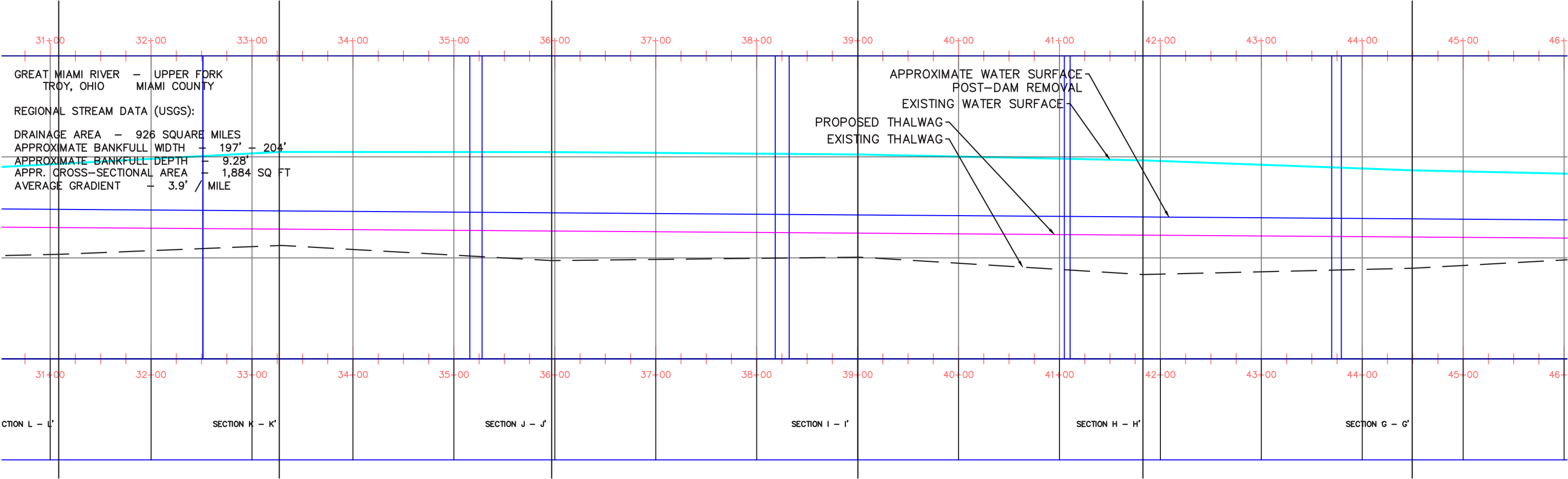
- CUT
- FILL
- EXISTING BANKFUL
- PROPOSED BANKFUL
- APPRX. 100 YEAR FLOOD ELEVATION

* CUT / FILL shown to illustrate necessary work for building pedestrian trail / levee toe along right bank (adjacent to downtown Troy)

APPROXIMATE CHANNEL SHAPE BASED ON REGIONAL CURVE DATA. RIVER DEPTH WILL VARY

8.7 TROY LOW-HEAD DAM PROFILE





APPROXIMATE CHANNEL SHAPE BASED ON REGIONAL CURVE DATA. RIVER DEPTH WILL VARY

9.1 MEASURES OF SUCCESS

In summary, three dams are being proposed for modification or removal because of the negative impacts that defunct dams have on the quality of life of the communities of Troy and Piqua. Despite local historical and nostalgic value, the structures examined as a part of this study have reached the end of their useful lifespans. Future maintenance needs will outweigh the value of the structures, and therefore this report has presented the following justifications for removal:

1. The report has provided a history of dam installation in Miami County, along with discussion regarding the three dams relevant to this study. There is ample qualitative evidence to suggest that the burden of maintenance of these dams no longer justifies the functional purpose for which they are used today.
2. This report outlines reasons for dam removal and how removal outcomes relate to ecology, safety, recreation, economics, and geomorphology. There is a greater burden for justifying why these defunct dams should stay, as compared to the net benefit for the Troy and Piqua communities once they are removed.
3. There are national and state dam removal efforts underway and countless precedents for dam removal efforts.
4. There is historic and contemporary support for local dam removal initiatives.
5. Contemporary dam removal studies (sediment and hydraulic analysis) indicate no major red-flags cautioning against dam removal.
6. Realistic strategies have been developed for each of the dams proposed for removal or modification.

MEASURES OF SUCCESS:

The “measure” of success for this report is simply the direct physical removal of the dams (or modification) in ways that are ecologically prudent and mindful of restoring stream segments to their natural geomorphology. The removal efforts will have obvious ramifications to human safety, and will set the stage for greater recreational usage and indirect economic benefits for the communities. These outcomes can be synergistically accomplished by simply following the dam removal guidance as described in the individual dam removal sections.

SHORT-TERM GOALS

Short-term goals are described in the adjacent page along with cost-estimates. The total estimated project cost for short-term goals is approximately \$1,405,643.76.

LONG-TERM GOALS

Long-term goals include large-scale improvements which could provide significant long-term savings by promoting river stability.

MEASURING THE IMPACT OF THE INDIVIDUAL RATIONALE:

Each of the reasons for dam removal can also be measured based on their level of success as it relates to removal justification:

ECOLOGICAL

Science shows that dams cause considerable disruption and are detrimental to the ecology of the river. The Ohio EPA is already monitoring the Great Miami River. The USFWS intends to analyze future chemical, physical, and biological data to determine if the dam removal project has had positive impacts to the ecology of the Great Miami River.

SAFETY

Low-head dams have the ability to produce dangerous recirculating currents, hydraulic jumps, and other hazardous conditions. The removal of the dams will also remove this risk.

RECREATION

Recreation along the river includes passive contemplation and active recreation, such as fishing, paddle sports, tubing and exploring the river’s edge. Removal of the dams will open up more of the river to paddlesports, and provide a new experience for users of the Great Miami Recreational Trail. Additionally, removal of the dams will provide an opportunity for a second multi-use trail, significantly increasing each community’s access to the Great Miami River.

ECONOMIC

Many cities are removing dams for the economic boosts that come with increasing land value. In Troy and Piqua, the opportunity for a new bankfull bench and multi-use trail adjacent to their downtown areas will provide additional benefit to economic activity and property values. Direct economic returns on investment is a challenge to document. It is anticipated the increase in recreational opportunities, and general quality of life improvements resulting from safety, will have economic benefit. Additionally, a positive impact on fish species will benefit fisherman, and local tackle shops. There are currently no plans to create a formal economic impact study in the future.

GEOMORPHOLOGICAL

Dams disrupt the critical pool to riffle to pool rhythm that naturally occurs in rivers, and in turn affects the exchange of water between the Great Miami River and the buried valley aquifer. Removal of these dams will affect this exchange.

9.2 SHORT-TERM GOALS: COST ESTIMATES

Goal 1: Modify the Piqua Water Intake Dam

The modification of this dam will be to install a boulder rock arch rapid or a constructed riffle. The riffle will eliminate the hydraulic jump through reduced shear stress and will provide start stop locations behind the boulders in the constructed riffle for fish passage. The modification will restore fish passage to this section of the Miami river, and eliminate a human safety hazard.

*assumes all permits will be packaged together;
includes hydraulic modeling costs

Goal 2: Remove Piqua Power Plant Dam

The proposed removal method of the Piqua dam is twofold. First, the overhead structure and adjustable gates will need to be removed and disposed of. Second, the concrete base of the dam will need to be removed to the existing riverbed elevation. All rebar and other reinforcing material will be removed from the concrete base. The concrete landings and stairs on the river’s west bank will remain.

*assumes all permits will be packaged together;
includes hydraulic modeling costs

Goal 3: Remove Troy Low-Head Dam

The removal of the Troy dam will take place in one step, as all concrete and rebar will be reduced to rubble and removed from the floodplain via excavator, jackhammer, etc. The dam will be removed entirely, except for the portion which is currently entirely buried, and the concrete reinforcement (sea wall) along the southern bank.

Additionally, an in-stream structure will be constructed at Treasure Island to maintain water levels in the lagoon. This structure will also be a recreational asset for kayakers.

*assumes all permits will be packaged together;
includes hydraulic modeling costs

TABLE 9.2-1 | Piqua Water Works Dam - Modification

Item	Unit	Quantity	Unit Cost	Total	Notes
Design / Engineering	LS	1	\$16,800.00	\$16,800.00	12% of construction costs
Permitting*	LS	1	\$6,000.00	\$6,000.00	
Mobilization	LS	1	\$9,800.00	\$9,800.00	7% of construction costs
Construction Entrance	LS	1	\$15,000.00	\$15,000.00	
Boulder Placement	TONS	850	\$140.00	\$119,000.00	
Construction Oversight	LS	1	\$19,600.00	\$19,600.00	14% of construction costs
			Subtotal:	\$186,200.00	
			Contingency:	\$46,550.00	+ / - 25%
			Grand Total:	\$232,750.00	

TABLE 9.2-2 | Piqua Power Plant Dam - Removal

Objective	Unit	Quantity	Unit Cost	Total	Notes
Design / Engineering	LS	1	\$47,970.00	\$47,970.00	12% of construction costs
Permitting*	LS	1	\$6,000.00	\$6,000.00	
Mobilization	LS	1	\$27,982.50	\$27,982.50	7% of construction costs
Construction Entrance	LS	1	\$40,000.00	\$40,000.00	rip rap access to channel
Concrete Portion of Dam	LF	225	\$350.00	\$78,750.00	
Gates, Structure Demo	LS	1	\$275,000.00	\$275,000.00	
Construction Oversight	LS	1	\$55,965.00	\$55,965.00	14% of construction costs
			Subtotal:	\$531,667.50	
			Contingency:	\$132,916.88	+ / - 25%
			Grand Total:	\$664,584.38	

TABLE 10.2-3 | Troy Low-Head Dam - Removal

Item	Unit	Quantity	Unit Cost	Total	Notes
Design / Engineering	LS	1	\$36,690.00	\$24,175.00	12% of construction costs
Permitting*	LS	1	\$6,000.00	\$6,000.00	
Mobilization	LS	1	\$21,402.50	\$21,402.50	7% of construction costs
Construction Entrance	LS	1	\$15,000.00	\$15,000.00	
In-Stream Structures	LS	1	\$204,750.00	\$204,750.00	W Weir / Vane Arm @ Treasure Island
Dam Removal	LS	1	\$80,000.00	\$80,000.00	
Construction Oversight	LS	1	\$42,805.00	\$42,805.00	14% of construction costs
			Subtotal:	\$406,647.50	
			Contingency:	\$101,661.88	+ / - 25%
			Grand Total:	\$508,309.38	

9.3 LONG-TERM GOALS: COST-ESTIMATES

Goal 4: Troy Oxbow Reconnection

The USFWS has recommended reconnection of Troy’s abandoned oxbow (surrounding Miami Shores Golf Course), a project which could obtain funding through other USFWS programs. By reconnecting this abandoned oxbow the river would gain significant floodwater capacity and add prime habitat for aquatic species. Additionally, by increasing flow to this stretch of former river the standing water currently “stuck” in the oxbow would be eliminated, reducing mosquito habitat.

*assumes all permits will be packaged together; includes hydraulic modeling costs
**work limited to the road, box culvert. downstream and/or in-channel work may be required but is not included in this price
***cost does NOT represent hydraulic modeling to determine optimal culvert sizing. total cost could increase based on the need for additional modeling information.

Goal 5: Troy Levee Toe & Multi-Use Trail

As part of Troy’s downtown development plan, the city has expressed a desire to build a recreational trail along the West bank of the Great Miami, extending from the dam’s current location to Treasure Island. This will only be possible with the construction of a levee toe at the base of the existing floodwall, which this trail will be built on top of.

*assumes all permits will be packaged together; includes hydraulic modeling costs
**estimate based on cut shown in cross sections, potential for additional material NOT included in this estimate to be harvested from existing bank. See diagram below.

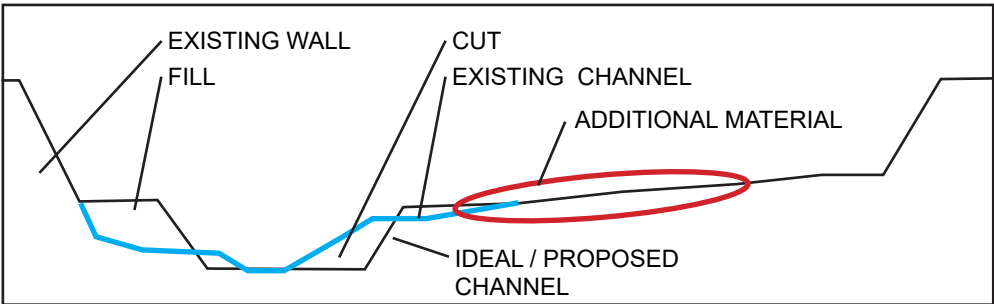


TABLE 9.2-4 | Troy Oxbow Reconnection

Item	Unit	Quantity	Unit Cost	Total	Notes
Design / Engineering***	LS	1	\$124,749.96	\$124,749.96	12% of construction costs
Permitting*	LS	1	\$15,000.00	\$15,000.00	
Mobilization	LS	1	\$72,770.81	\$72,770.81	7% of construction costs
Staging Area	LS	1	\$15,000.00	\$15,000.00	
Common Ex.	CYS	5272	\$20.00	\$115,440.00	
Box Culvert	LF	444	\$1,700.00	\$754,800.00	4 box culverts, 34’ wide
Borrow	CYS	2666	\$30.00	\$80,000.00	
#53 Stone Base	TONS	144	\$30.00	\$4,333.00	
HMA Intermediate 3”	TONS	146	\$120.00	\$17,520.00	
HMA Surface 1.5”	TONS	73	\$130.00	\$9,490.00	
Class 1 Stone**	TONS	350	\$80.00	\$28,000.00	
Construction Oversight	LS	1	\$145,541.62	\$145,541.62	14% of construction costs
			Subtotal:	\$1,382,645.39	
			Contingency:	\$345,661.35	+ / - 25%
			Grand Total:	\$1,728,306.74	

TABLE 9.2-5 | Troy Levee Toe and Multi-Use Trail

Item	Unit	Quantity	Unit Cost	Total	Notes
Design / Engineering	LS	1	\$221,036.04	\$221,036.04	12% of construction costs
Permitting*	LS	1	\$25,000.00	\$25,000.00	
Mobilization	LS	1	\$128,937.69	\$128,937.69	7% of construction costs
Construction Entrance	EA	4	\$60,000.00	\$60,000.00	
Utility / RR Coordination	LS	1	\$25,000.00	\$25,000.00	Relocation & Permissions from RR
Imported / Add'l Borrow	CYS	27,020	\$30.00	\$810,600.00	add approx 1,900 CYS for ext. trail
Borrow / Bankfull Bench**	CYS	31,420	\$15.00	\$471,300.00	assumes dredged material used
Paving Multi-Use Trail					10’ W x 3970’ L
Common Ex.	CYS	1111	\$15.00	\$16,665.00	Excavation for trail base
Linear Grading	SYS	5333	\$7.00	\$37,331.00	Rough grading - trail sub-base
Compacted #53 Stone	TON	1333	\$42.00	\$55,986.00	888.8 CYS (* 1.4 tons/SYD)
HMA Intermediate 3”	TON	840	\$110.00	\$92,400.00	Base, binder (asphalt)
HMA Surface 1.5”	TON	420	\$140.00	\$58,800.00	Surface layer (asphalt)
Finish Grading	SYS	17,777	\$2.00	\$35,554.00	
Seeding	SYS	17,777	\$3.00	\$53,331.00	fescue mix (turf)
Bank Stabilization	LS	1	\$100,000.00	\$100,000.00	Erosion Control (new bench)
Construction Oversight	LS	1	\$257,875.38	\$257,875.38	14% of construction costs
			Subtotal:	\$2,449,816.11	
			Contingency:	\$612,454.03	+ / - 25%
			Grand Total:	\$3,062,270.14	

9.4 FUNDING SOURCES

UNITED STATES FISH AND WILDLIFE SERVICE

Fish and Wildlife Management Assistance works to provide technical and financial assistance to conduct fish and wildlife management activities that align with the conservation, restoration, and management goals of the Fish and Wildlife Conservation Offices. Restoration work could consist of habitat construction, habitat restoration, or removal of barriers to passage. Representatives from the USFWS Private Lands Program, Partners for Fish and Wildlife Program, and the National Fish Passage program are involved with this project.

Carterville - Marion Fishery Resources Office
9053 Route 148
Marion, IL 62959
(618) 997-9185

MIAMI SOIL & WATER CONSERVATION DISTRICT

The Miami County, Ohio SWCD is a legal subdivison of the Ohio Department of Agriculture, Division of Soil and Water Conservation, supervised by an unpaid five member board of supervisors, who serve 3 year elected terms. Their mission is to provide quality conservation assistance to the people of Miami County and enhance the local quality of life. They strive to be responsible leaders in promoting innovative stewardship of natural resources through the development of conservation partnerships.

Kristin Lewber
Miami SWCD
1330 N CR 25A; Ste C
Troy, Ohio 45373
(937) 335-7645

RECOVERY ACT FUNDS – HABITAT ENHANCEMENT, RESTORATION, AND IMPROVEMENT

Recovery Act Funds for Habitat Enhancement, Restoration, and improvement provides assistance to projects that improve the habitat or any related activity necessary to accomplish these goals. Funds may be used for habitat assessments, protection, and restoration of public and private land. Providing fish passage and stocking of fish from National/State Hatcheries and advising on wildlife management techniques may be management tools considered.

Fish and Wildlife Regional Office
5600 American Boulevard West
Bloomington, Minnesota 55437-1458
(612)713-5475

WATER RESOURCE RESTORATION SPONSOR PROGRAM

The goal of the WRRSP is to counter the loss of ecological function and biological diversity that jeopardize the health of Ohio’s water resources. To achieve this goal, the WRRSP provides funding for projects that specifically target the protection and restoration of high-quality streams and wetlands. This project qualifies as it will result in the restoration of aquatic resources achieving warmwater habitat aquatic life use.

The USFWS, on the behalf of Troy and Piqua, have submitted a 4 million dollar WRRSP grant request to fund the removal of each city’s low-head dams, modification of the third (Piqua Water Intake Dam), and reconnection of the Troy Oxbow.

Water Resource Restoration Sponsor Program
Ohio EPA - DEFA, OFA
Lazarus Government Center
50 W. Town Street, Suite 700
Columbus, Ohio 43216-1049
(614) 644-2798

10.1 APPENDICES

Copies of appendices listed below are not included in this report, but are available upon request. Please contact tfreudenthal@flatlandresources.com for information.

- A** Biological Assessment of the Great Miami River, Piqua
- B** MCD Floodwall As-Built drawings
- C** Piqua Water Works Dam, As-Built Drawings
- D** Piqua Power Plant Dam, As-Built Drawings
- E** Troy Low-Head Dam, As-Built Drawings
- F** Hydrotech Corporation Sediment Analysis
- G** Troy Downtown Development Study
- H** Piqua Riverfront District Development Study

11. RESOURCES

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