FINAL DESIGN REPORT

Provo River Delta Restoration Project

September 2019

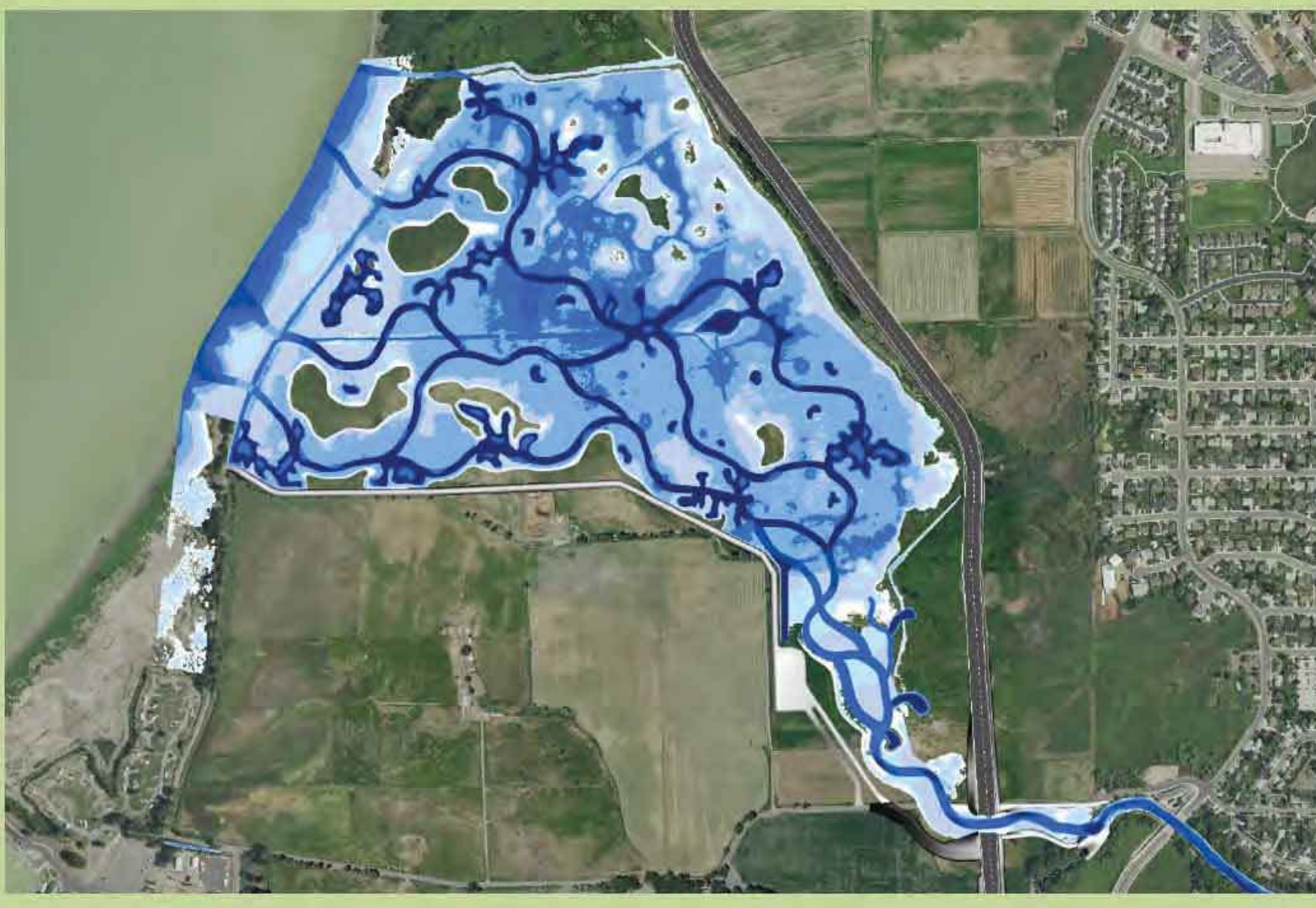

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Table of Contents

List of Figures

List of Figures (continued)

List of Figures (continued)

Appendices

1 Introduction

The Utah Reclamation Mitigation and Conservation Commission (Commission) is responsible for mitigating the impacts to fish and wildlife that resulted from construction of the Central Utah Project and other federal US Bureau of Reclamation (USBOR) projects in Utah. As part of its mitigation activities, the Commission participates in the June Sucker Recovery Implementation Program (JSRIP). The Provo River Delta Restoration Project (PRDRP) has been developed over the past decade through efforts by the JSRIP and its member entities to investigate and determine the actions needed to recover the June sucker (*Chasmistes liorus*), a federally listed endangered fish species that occurs naturally only in Utah Lake. The PRDRP is a directly necessary step to achieve two of the four conditions identified in the June Sucker Recovery Plan (USFWS, 1999) as being required for "downlisting" the June sucker from endangered status to threatened status under the federal Endangered Species Act. Those two requirements are: (1) habitat in the Provo River and Utah Lake has been enhanced and/or established to provide for the continued existence of all life stages, and (2) an increasing self-sustaining spawning run of wild June sucker resulting in significant recruitment over ten years has been re-established in the Provo River.

The Provo River is specifically identified in the June Sucker Recovery Plan because June sucker spawning has been documented there for decades. Historically, June sucker most likely spawned in several of the tributaries to Utah Lake, but changes to those environments associated with flow depletions, diversion structures, and channelization have greatly reduced suitable spawning habitat in tributaries other than the Provo River. Even in its current, altered condition, the section of the lower Provo River designated as critical habitat provides the greatest, though still limited, habitat suitable for June sucker spawning in the Utah Lake system. However, very limited rearing or "nursery" habitat is available. Monitoring efforts have not documented the successful recruitment of wild June sucker from Provo River, and research has shown that larval fish generally do not survive longer than 20 days after hatching. It is believed that the larval fish die because of a lack of suitable nursery or rearing habitat and they are, therefore, unable to recruit into the adult population. The PRDRP is proposed as an essential action needed to recover the June sucker.

It is important to recognize that the Endangered Species Act's (United States Government, 1988) purpose is to protect and recover imperiled species **and the ecosystems upon which they depend** (emphasis added). The PRDRP will restore a functional ecosystem in the lower Provo River and its interface with Utah Lake that will provide habitat conditions needed for spawning, hatching, larval transport, survival, rearing, and recruitment of young June suckers so they can grow, become reproducing adults, and be self-sustaining as a population.

A Final Environmental Impact Statement (FEIS) for the PRDRP was issued in April 2015 (Commission et al., 2015). Records of Decision (RODs) were signed by both the Department of the Interior and the Commission on May 26, 2015. Each agency selected to implement the Proposed Action, identified as Alternative B in the FEIS.

This report presents final PRDRP designs based on the Alternative B concepts.

2 Purpose of this Document

This document presents a channel realignment design for the most downstream section of the Provo River and a delta area design for the river/lake interface between the Provo River and Utah Lake (project area). Figure 1 (figures are included at the end of this document) shows the general location of the PRDRP within the state of Utah and Figure 2 shows an aerial image of the project area and the major features of the PRDRP.

This document presents final designs for the proposed relocation of the Provo River Channel and the creation of a new Provo River Delta and its interface with Utah Lake. Table 1 lists the major features of the proposed PRDRP and identifies the group that is responsible for the design of those features. This final design document focuses on the first three rows of Table 1, but it includes limited information on the other major components for completeness.

Table 1. Major Components of the PRDRP, with Responsible Party and Designer.

FEATURE NAME	RESPONSIBLE PARTY [a]	DESIGNER
New Provo River Channel, Delta Channels, and Delta Ponds	Commission	Allred Restoration, Inc.
Skipper Bay Dike Removal and Delta Outflow Channels	Commission	Allred Restoration, Inc.
Existing Provo River Channel	Commission	Allred Restoration, Inc.
Recreation Features (Delta and Existing Provo River Channel)	Commission	Various
Delta Diversion Berm	Commission	USBOR
Small Downstream Dam	Commission	USBOR
New Berm with Trail	Commission	USBOR
North River Berm	Commission	USBOR
Water Diversion	Commission	USBOR
Lakeview Parkway, Bridge/Trail Underpass, and Boat Harbor Drive Relocation	Provo City	AECOM
620 North Roadway	Provo City	AECOM

[a] Commission = Utah Reclamation Mitigation and Conservation Commission, USBOR = US Bureau of Reclamation, CUWCD = Central Utah Water Conservancy District

The design of and planning for the new Provo River channel and Delta areas are being completed using a partial design/build approach that has been incorporated on several successful projects in the past. This design approach requires a level of detail that will ensure that PRDRP implementation will be successful, but it also allows adjustments to be made during the construction process to take advantage of conditions encountered on the site. Using this method, the up-front design costs are reduced, and some decisions are made in the field based on specific site conditions.

Due to the complexity of implementing the PRDRP and the large number of associated components, as well as projects underway by others that are being completed on a similar timing track, this document cannot include detail on many peripheral features, particularly those being designed by others. However, those features are discussed in this document to give the reader understanding of the major proposed features and who is responsible for their design. Details of those designs will be provided by the respective designers.

3 Background

3.1 Hydrology of the Provo River

3.1.1 High Flows

The hydrologic regime of the Provo River was a key consideration in developing PRDRP designs. Streamflow variability within the Provo River is largely driven by snowmelt runoff, which varies seasonally throughout the year. Streamflow is usually highest during the months of May and June, when the high-elevation snowpack is melting rapidly.

The high-flow hydrology of the lower Provo River was evaluated using the Hydraulic Engineering Center's Statistical Software Package (HEC-SSP) and presented in the Provo River LAMP Study Hydrology Report (AECOM 2016). The HEC-SSP was used to perform a log-Pearson type III (LPIII) peak flow frequency analysis based on the procedures of Bulletin 17B (IACWD, 1982) for the Provo River gage record from 1996 to 2015, the period following closure and filling of Jordanelle Reservoir. Peak discharges and associated recurrence intervals for the Provo River are shown in Table 2.

Table 2. Provo River peak flow magnitudes for various flood recurrence intervals (based on data at USGS gage #10163000).

FLOOD RECURRENCE	PEAK DISCHARGE (cubic feet per second [cfs])
2-year	825
10-year	1,475
100-year	2,325
500-year	2,935

These high-flow events have been used for design purposes, as have a range of additional discharges including lower flows.

3.1.2 Low Flows

In a typical water year, flows are lowest during the period from July through September, when diversion for irrigation is at its highest levels and base flows are low. Discharges of 0 cubic feet per second (cfs) have occurred in the past between April and October, but they have not between November and March when diversion is limited.

Low flows on the lower Provo River have been the focus of considerable concern, and the flow study titled Lower Provo River Ecosystem Flow Recommendations Report (Stamp et al. 2008) identifies target flows and makes recommendations for future management. In that report, a form of dimensionless flow analysis was used to set the following summer baseflow targets:

- dry year – 57 cfs,
- moderate year – 86 cfs, and
- wet year – 113 cfs.

The Utah Lake Drainage Basin Water Delivery System (ULS) has been completed, and it will augment future streamflow during critically low periods. The ULS will help to augment existing streamflow in most months and years to help meet baseflow targets. The RODs for the PRDRP FEIS formally adopted these seasonal flow targets. The FEIS also includes a commitment to deliver up to an additional 4,500 acre-feet of conserved water to the lower Provo River via the Utah Lake Drainage Basin Water Delivery System. At this time, the volume of water that has been secured for instream flow purposes is sufficient to ensure a minimum summer baseflow of 50 cfs can be delivered to the lower Provo River. Efforts to acquire additional water to fully meet the seasonal targets remain ongoing.

Future management of the PRDRP will include dividing the instream flow of the river such that most of the river flows will be diverted into the new river channel and delta area. A minimum of 10 cfs and maximum of 50 cfs of instream flow will be delivered to the existing river channel to help maintain aesthetics, water quality, and recreational values. For the purposes of designing the new river channel and delta area, it was assumed that the lowest summer baseflow that would be delivered to the new delta would be 40 cfs (i.e., 50 cfs instream flow minus 10 cfs delivered to existing channel).

3.2 Hydrology of Utah Lake

The seasonal and annual hydrologic patterns of Utah Lake were a key consideration in developing PRDRP designs. Utah Lake is a shallow, freshwater lake located in Utah County, with a storage capacity of approximately 870,000 acre-feet. The hydrology of Utah Lake is driven by annual precipitation and snowmelt cycles, but it has been greatly altered from natural patterns by human intervention: specifically, by the construction of two large dams on Provo River, Jordanelle and Deer Creek, by numerous smaller diversions, by importation of water from the Weber and Duchesne River basins, and by construction of outlet gates and a pumping plant at Utah Lake’s outlet to Jordan River.

Utah Lake elevations are somewhat controlled by releases from the dam and pumping station at Utah Lake’s outlet to the Jordan River. Management of Utah Lake water levels is governed by a court ruling (Utah Lake Landowners Association et al. versus Kennecott Corporation, et al.) that specifies how the lake will be operated to provide water for the most senior rights held in storage at Utah Lake and specified that the maximum legal elevation in Utah Lake shall be 4,489.045 feet (1929 National Geodetic Vertical Datum). This is commonly called the “compromise” elevation. The Utah Lake Interim Water Distribution Plan (Utah State Engineer 1992) applied that ruling and other water rights information to define how Utah Lake water rights would be administered.

Note: Elevations referenced in this document apply the 1929 NGVD vertical datum that has been used historically for Utah Lake.

Although compromise is the highest level that the lake is intended to reach, in practice the lake level has gone and may yet go much higher, particularly during periods when snowpack is high for several consecutive years. The current estimate of the 100-year lake level is 4494.58 feet (FEMA 1988; FEMA 2014).

Utah Lake water levels fluctuate seasonally and year-to-year, depending on climatic conditions and water storage and release operations. Typically, lake levels are highest in the spring and lowest in the fall, and they fluctuate, on average, approximately 3 feet per year Figure 3.

As part of planning and analyses for the ULS project, baseline monthly Utah Lake water levels were simulated using current/planned water operations and water year 1950–1999 hydrologic conditions (CUWCD, 2007). These results are shown in Figure 4. The data summarized in Table 3 were produced using these simulation results. Figure 5 illustrates the lake level duration relation and adds seasonal variability for the runoff period and the entire growing season. Lake levels are higher in May and June when spring runoff is highest. When the longer growing season is plotted, average lake levels are lower but similar to the overall duration relation.

Table 3. Summary of predicted Utah Lake water levels for various seasons of interest. Data are based on current/planned water operations simulated for water years 1950–1999.

MEASUREMENT	UTAH LAKE WATER LEVEL (FEET, NGVD29 DATUM)		
	Entire Year	Growing Season (April-October)	Spring Runoff (May and June)
Minimum	4,481.25	4,481.25	4,483.00
Maximum	4,492.55	4,492.55	4,492.55
Average	4,487.57	4,487.53	4,488.35
50th Percentile	4,487.95	4,487.80	4,488.55
20th Percentile	4,489.00	4,489.00	4,489.55
80th Percentile	4,486.10	4,485.94	4,487.21

Measured lake elevation data, collected between 1/1/2003 and 3/3/2019, were analyzed and compared to simulated data to determine how closely recent lake management and operations matched projections. The results generally show that measured data were lower than predicted lake levels from the simulation. For example, Table 4 compares simulated and measured data for the months of May and June (Spring runoff period). Note that measured lake levels were consistently lower than simulated levels and that the differences are generally more pronounced at high exceedance percentages (low lake elevations). Although the measured lake elevations span a shorter time period than the simulation and are not directly applicable, these differences are pertinent.

Table 4. Comparison between measured and simulated Utah Lake water levels for the months of May and June (Spring runoff period). Measured data are from 1/1/2003 to 3/3/2019.

	Exceedance Percentage				
	90%	75%	50%	25%	10%
Measured Lake Elevation (ft)	4484.7	4485.8	4487.7	4489.0	4489.6
Simulated Lake Elevation (ft)	4486.0	4487.4	4488.6	4489.3	4490.1
Difference (ft)	-1.3	-1.6	-0.9	-0.3	-0.5

Lake level data were extremely important for the development of the delta design because water levels in Utah Lake will affect water depths in the delta, as well as habitat suitability and availability within the delta during various periods of the June sucker's life cycle. The delta design presented in this report limits water level fluctuations within the delta by allowing the delta water levels to be higher than the lake if the lake drops below 4,487 ft. Details of this design feature are presented later in this report.

3.3 Wetland Delineation and Mapping Efforts

The distribution of wetlands within the project area is an important factor for overall project design of the PRDRP, for a variety of reasons. Peat wetlands are present in the project area and avoiding them was deemed to be an important design consideration. Fill areas were also designed specifically to avoid placing fill in wetlands. Wetland mapping within the project boundaries has been an ongoing process for many years, and those efforts are summarized below.

BIO-WEST and others have delineated the project area wetlands over the course of many years, starting in August 2010 and continuing through 2016. Numerous site visits and delineations were required due to changes in the project area, lack of landowner access permissions, changes requested by the U.S. Army Corps of Engineers (USACE), and the complex and dynamic nature of the project area hydrology.

BIO-WEST has coordinated directly with the USACE since the beginning of the delineation process. Mapping efforts and revisions continued through 2012, and a delineation report was submitted to the USACE in April 2013. The USACE issued two written preliminary jurisdictional approval letters that covered different portions of the project area, and those delineations were used for preparation of the EIS.

In 2016 the project team determined that updating the existing, verified delineation report would be in the best interest of the PRDRP. Significant time had passed since the original delineation work was done, and the team wanted to ensure that the most current and accurate delineation possible was used for final project design and approval. BIO-WEST and Wetland Resources, Inc. worked together to update the delineation report and gathered significant supplemental data in November 2016. The report was submitted to the USACE in December 2016. The USACE issued a written preliminary jurisdictional approval letter on March 21, 2017. A map of jurisdictional wetlands is shown in Figure 6.

Wetlands within the project area were re-visited in spring 2019 to assess whether wetland conditions had changed substantially since earlier mapping efforts. The

2019 assessment found that approximately 8 acres of the project area are trending toward a drier condition than was found during the 2016 assessment and would now be considered uplands rather than jurisdictional wetlands. However, the distribution of wetlands shown previously in Figure 6 is sufficiently accurate for design purposes.

3.4 The June Sucker

Shallow submersed aquatic and wetland vegetation types, interspersed with open water, provide an important function for June sucker rearing habitat as they produce cover and structure for young fish to hide in and avoid predation. They also provide an important food source. Providing escape cover for June sucker fry and juvenile fish through creating the physical framework needed for establishment and perpetuation of submerged and emergent native wetland plants is a primary goal of the proposed design.

Radant et al. (1987) developed habitat suitability index (HSI) curves for preferred water depth and velocity for June sucker spawning. These curves indicate that June sucker spawn in areas with an average depth of 1.67 feet and an average velocity of 1.2 feet per second. Preferred substrate was described as ranging in size from 100 to 200 millimeters. However, June sucker spawning has occurred over larger substrates in Red Butte Reservoir and over smaller gravel and cobble sized substrate in the Provo River. The presence of low-velocity pools that provide resting habitat adjacent to spawning areas may also be important for spawning success.

The common factor seems to be use of a gravel/cobble substrate as the spawning bed. It is possible that spawning will occur independent of water velocity, as long as the water temperature is within the optimum range of 12−17 °C (Keleher et al., 1998) and a suitable substrate for spawning is present.

3.5 Lakeview Parkway

The Lakeview Parkway is a new road that is being constructed by Provo City. It passes through the project area and essentially defines the eastern boundary of the delta reach (see Figure 2 for location and alignment). The PRDRP design team has been meeting with Provo City and its engineering team on a regular basis to ensure that river and roadway designs are compatible.

3.6 High-Pressure Gas Pipeline

A high-pressure gas pipeline crosses the project area at the approximate location shown in Figure 7. The elevation and location of the pipeline were field verified in July 2018 and determined to be too near the surface to accommodate construction of planned delta features. The Commission and the PRDRP design team have been coordinating with Dominion Energy to arrange for the pipeline to be relocated to a depth that will allow for safe construction of the PRDRP. Currently, Dominion engineering personnel are nearing completion of designs for the pipeline relocation, and they intend to complete the relocation effort during the fall of 2019.

3.7 Other Threatened or Endangered Species - Ute Ladies'-Tresses

Surveys have identified Ute Ladies'-Tresses (ULT) plants that are known to occur in the project area. The layout of the river and delta features presented in this final design attempts to minimize direct impacts to known ULT locations to the extent possible.

3.8 Bird Strike/Wildlife Hazard

The proximity of the PRDRP to the Provo Airport has prompted considerable discussion, data collection, and planning. Project managers have agreed to take steps to identify and implement compatible wildlife hazard-reduction measures to reduce the likelihood of bird strikes for planes using the nearby Provo Airport.

Designers interacted with several individuals and organizations with the goal of identifying the appropriate steps necessary to better understand existing and anticipated wildlife hazards around Provo Airport and implement compatible measures in the project design. Discussions have included representatives from the following groups: the Commission and other joint lead agencies, the design team, the Federal Aviation Administration, USDA Animal and Plant Health Inspection Service - Wildlife Services, Provo City, Provo Airport, Utah County, USFWS, USBOR, June Sucker Recovery Implementation Program Technical Committee members, wildlife biologists including a certified airport wildlife biologist, and many others. The following concepts were discussed and are incorporated into the proposed design.

- The delta ponds are designed with an irregular shape with lots of edge habitat and small pockets of deep open water, broken up with shallow vegetated islands and irregularly shaped shorelines.
- The proposed design attempts to avoid creating long takeoff and landing areas for birds by varying water depths to create pockets of deep water. Waterfowl and other water birds are attracted to large areas of open water for take-off and landing. The open water portions of the delta would be less

of an attractant to certain types/species of birds if the ponds were designed to avoid long takeoff and landing areas (<150 feet).

- The proposed design creates many locations within the delta where water is deep enough to discourage feeding by white pelicans (*Pelecanus erythrorhynchos*). Research on the local population of American white pelicans using the Great Salt Lake and Utah Lake shows that they eat primarily within the first meter of the water surface (Frank Howe, Utah Division of Wildlife Resources/Utah State University, personal communication), and they primarily eat carp (Cyprinidae).
- The revegetation plan includes measures to aggressively seed and plant bare shorelines with desirable emergent wetland vegetation to minimize the amount and length of bare shorelines which are an attractant for wading birds and nesting waterfowl. Aggressively revegetating created shorelines with native species will also minimize phragmites and other noxious weed invasions

4 General Design Approach – An Ecosystem Philosophy

According to statute (301(g)(4) of CUPCA) the Commission is directed to plan and implement projects that "…restore, maintain or enhance the biological productivity and diversity of natural ecosystems within the State {Utah}…". The ESA also emphasizes recovery of ecosystems upon which T&E species depend.

As the designers of many large restoration and enhancement projects, our team has developed an ecosystem-based approach to design. This approach emphasizes an understanding of the diverse array of physical and biological processes that combine to create and maintain aquatic systems. These physical processes include upland, floodplain, riparian, and aquatic interactions, as well as channel hydraulics, sediment transport, and the redistribution of energy and nutrients.

Humans are a part of the ecosystem, and the important role they play must also be understood and directly incorporated in the planning process. The ability of these restored/enhanced ecosystems to function in perpetuity is an important goal for the PRDRP.

The foundational framework outlined below has been applied by our team and proven on many successful projects. This is a useful framework for all riverine and aquatic restoration planning; however, each new project has a unique set of goals and constraints that must be understood and evaluated, and then skillfully incorporated into the final plans. This framework was primarily developed for river restoration projects but is also directly applicable to river deltas that occur at the river/lake interface.

4.1 The Overarching Framework for Planning the PRDRP

There are many important factors that need to be considered when planning a river restoration or aquatic enhancement project, particularly when planning on a large scale. The following sections illustrate the major factor framework that has guided the design of the PRDRP. They include a general discussion of the major design concepts and a brief explanation of why they are important.

Riverine and aquatic restoration planning efforts should include several factors as a basic framework for evaluating the system and its current and future conditions. These factors include:

- legal protection,
- space,
- “natural” hydrology,
- continuity,
- connectivity,
- complexity, and
- dynamics.

The factors included in this framework have been carefully assessed and evaluated from an ecological perspective, and then interwoven with the need for the PRDRP which includes creating and enhancing June sucker rearing and nursery habitat while improving recreational use in the area. Each factor is explained in the sections that follow.

4.1.1 Legal Protection

Legal protection of both the property and the water is a critical factor that should be considered for all restoration projects and is of particular importance for the PRDRP. The project lands will be protected into the future so that designed improvements will continue to provide benefits in perpetuity.

4.1.2 Space

Given the dynamic nature of river delta areas, space for long term movement and adjustment is critically important. Most riverine and aquatic habitats need space to allow proper function, and sufficient space is of paramount importance for proper functioning of the PRDRP in the future. The proposed project area offers the space that is essential to provide important refuge areas for many species.

The Provo River also requires space for migration and overbank flooding in the short section upstream of the delta. Although space for overbank flooding is somewhat limited in the upstream-most section of the PRDRP design, some space for flooding is included, and the available area increases as the river flows toward the delta.

4.1.3 Natural Hydrology

Streamflow variability, both seasonal and from year to year, can take many forms, and it is critical that restoration planners understand that variability and how it drives physical processes and supports the life histories of various aquatic and terrestrial organisms living in the river and delta area. Many organisms have adapted over time to use a particular part of the streamflow variability and if that variability is lost, the organisms will have a difficult time perpetuating themselves in the ecosystem.

The flow regime of the Provo River has been greatly altered by human activities, but current management tries to mimic natural streamflow patterns to support the native species that live in and around the river.

4.1.4 Continuity

The term “continuity” refers to the longitudinal “continuum” of river channels and other connected features within a riverine ecosystem. River managers have been working to restore connectivity on the Provo River to allow June sucker to swim upstream and spawn, by removing barriers to fish passage. If the PRDRP is successful in restoring rearing habitat that is of sufficient quality to increase fish numbers, upstream continuity improvements will become even more important, because those fish will need access to increased spawning areas.

4.1.5 Connectivity

The term “connectivity,” when used to describe rivers, refers to the lateral connection of a channel to its floodplain. Many important riverine ecosystem processes are driven by overbank flooding, including nutrient cycling, overbank deposition of suspended sediment, deposition of seeds onto disturbed surfaces, etc., and these processes can be extremely important to the ecosystem. Connectivity is essentially nonexistent in the existing Provo River channel, except at extremely high discharges, but the newly-designed river will be better connected to its floodplain.

The proposed delta is a transitional zone between a river system and a lake system, and it provides an extremely high level of connectivity that is common in delta zones but missing in the current configuration. The delta zone is unique area in its own right because of the extensive connectivity it offers.

4.1.6 Complexity

Complexity of aquatic and terrestrial habitats is normally quite high in natural or pristine riverine and aquatic ecosystems, largely because of the variability in streamflow and other natural processes that occur. However, when human impacts start to affect an ecosystem, habitat complexity often diminishes rapidly. The proposed delta design emphasizes habitat complexity as a primary goal.

4.1.7 Dynamics

In riverine and aquatic ecosystems, “dynamics” refers to the ability of the river to move around on its floodplain and/or transport, erode, and deposit sediment along its course. This process is particularly important in river deltas, which are often very active areas of deposition. In a delta setting, dynamics are often associated with high flow events combined with large sediment inputs. These conditions promote channel braiding that creates and maintains a diversity of habitats.

4.2 Summary of the Planning Framework

The framework described above provides a basis for aquatic restoration and enhancement planning and design. In many settings, some of these factors cannot be returned to predisturbance conditions; however, each factor has been considered and addressed to determine to what extent it could be included in the proposed PRDRP design, given the opportunities and constraints of the site. As each design item was planned, the framework provided guidance and direction for assessment of options and selection of components that work together to meet these larger framework goals.

5 Major Design Features

5.1 Overall Description

The PRDRP will create a new section of the Provo River that flows north of the current river alignment though a complex river delta and into Utah Lake. River deltas occur all around the world, and although each is unique in character, most share a common general form that includes four functional zones, as illustrated in Figure 8. The proposed PRDRP design mimics these zones in many ways. The proposed plan includes four major design zones: (1) the Lake Zone, (2) the Delta Zone, (3) the River Zone, and (4) the Existing Provo River Channel, as shown in Figure 9.

Major design zones 1–3 include the new Provo River Channel and Delta area and are the primary focus of PRDRP. Zone 4 includes plans for proposed modifications to the existing river channel, which will be retained and continue to receive a small amount of streamflow. Each of these design zones are described in further detail in following sections.

Figure 2 (previous) shows the major design components of the proposed new delta. The new river channel and delta area will be constructed in an area near the Provo River' s existing mouth, which was formerly a part of Utah Lake but was separated from the lake by construction of Skipper Bay Dike. This dike was constructed and subsequently modified and “improved” over an extended time period, but it has effectively been separating the proposed delta area from the lake for decades. In 2011, Utah Lake reached an elevation of 4491.5 feet, and Skipper Bay Dike was partially overtopped by wave action. However, only during extended wet periods, when lake levels exceeded 4,492 feet above sea level (asl), has Skipper Bay Dike been completely overtopped, allowing water from the lake to flow directly into the proposed delta area.

The design described in this report proposes partial removal and lowering of the Skipper Bay Dike and the surrounding area, thus reconnecting the proposed delta to the lake whenever Utah Lake is 4,487 feet asl or higher.

The design also proposes to realign roughly 1.8 miles of the Provo River and route it through the proposed delta area, incorporating a distributary channel pattern that is common for river deltas around the earth. The proposed delta diversion berm will divert the majority of the lower Provo River’s flow north of its current channel into the new river channel and delta area and then over the lowered portion of Skipper Bay Dike and into Utah Lake. When lake levels drop below 4,487 feet asl, the delta area will remain wet because the lowered dike will create a backwater that keeps the delta channels and ponds full and surrounding areas wetted.

Many deeper excavations are also proposed that will provide deep-water habitat areas that will remain open after emergent vegetation becomes established in shallower areas.

PRDRP design features that are being designed by others are also discussed briefly in the later sections of this report.

A comprehensive revegetation plan (Appendix A) is being developed concurrently with the delta and channel designs. The goal of the PRDRP revegetation plan is to restore native aquatic, wetland, and riparian vegetation communities at the river/lake interface, necessary for restoring the functioning ecosystem needed for June sucker recovery. The revegetation plan includes compatible wildlife hazard-reduction measures, best management practices, ULT conservation measures, and recommendations to map, monitor, and control the spread of invasive and noxious weeds.

5.2 New Provo River Channel and Delta Area

5.2.1 Skipper Bay Dike Lowering – Lake Zone

As discussed in the Overall Description section, Skipper Bay Dike (see Figure 2) plays an extremely important role in the overall design for the delta. Much of Skipper Bay Dike and the surrounding area will be lowered (Figure 10), and the Provo River will be rerouted to create the new delta.

In its current configuration, the dike prevents Utah Lake water from entering the proposed delta area except when the lake level exceeds roughly 4,492 feet asl, which is an unusually high level for Utah Lake (Figure 11). The proposed design will lower the dike and surrounding area to reestablish a direct connection between the proposed delta and Utah Lake whenever lake levels rise above 4,487 feet asl (Figure 12). In the proposed design, Skipper Bay Dike and surrounding delta/lake interface area will be lowered to an elevation of roughly 4,488 feet asl, with an undulating surface to match local grades at the margins. Outflow channels will be lowered to 4,487 ft asl and will slope toward the lake.

The lowered dike will provide very different functions depending on whether lake levels are higher or lower than 4,487 feet asl. During periods when lake levels are at 4,487 feet asl or higher, the delta and the lake will be connected directly, as the delta area essentially becomes part of the lake (see Figure 12). However, during periods when lake levels are lower than 4,487 feet asl, the lowered dike will create a backwater (Figure 13) that will maintain water depths and support a wide array of diverse habitats within the delta. A substantial proportion of the ground east of the outlet channels in the new delta area is lower than the outlet channels, so a backwater will form that will maintain inundated habitat within the delta area even during extended periods of reduced runoff, when lake levels can be very low. The lowered dike will keep river water ponded in, but flowing through, the delta area when lake levels drop below 4,487 feet asl, so long as the Provo River is flowing into the delta.

Figure 13 also shows that the range of water levels within the delta is quite small compared with Utah Lake. During normal years, water levels in the delta will remain between 4,487 and 4,489 feet asl (roughly compromise elevation). This narrow range of water levels will promote establishment and maintenance of desirable vegetation within the delta (see Appendix A for further details on revegetation plans).

The west side of Skipper Bay Dike currently has a scattering of large rocks that likely have provided limited erosion protection from the wave action that occurs due to the long fetch of Utah Lake, although dike erosion has been a problem in the past when lake levels are high. In areas where the dike will be lowered, the existing large rocks will be salvaged and combined with imported rock (primarily 6” to 12” riprap) to create a hardened sill at the finished bottom elevation of 4,487 feet asl for the outlet channels and roughly 4,488 feet asl for the remainder of the lowered dike between the channels (Figures 14 and 15). The rock will prevent downcutting of the outlet channels, allow access for management activities that will be needed along the delta/lake interface, and it will also provide protection from wind, wave, and ice erosion. In addition, particularly vulnerable exposed lakebed sediments in lowered areas will be capped with a veneer of cobble-sized rock (3” plus rounded, if available - see Figure 15). A cross section through the lowered Skipper Bay Dike area illustrating future expected vegetation conditions is shown in Figure 16.

The lowered dike area will have four outlet channels (see Figure 10) that cut through it at an elevation of 4,487 feet asl. These channels will be roughly 40 to 50 feet wide (Figure 17) and will slope gradually toward the lake to allow fish to pass from the lake to the delta even during periods when lake levels are low. Outflow channels will be lined with 6” to 12” rock and will have substantially larger rock incorporated into the matrix to increase local roughness and reduce flow velocity to promote fish passage. The largest boulders will rise high above the bed and into the flow and will be organized into arching cross-channel features to further lower local flow velocities. A photographic representation of a typical outflow channel is shown in Figure 18 to help visualize these features.

A control weir will likely be installed in each outflow channel to allow managers to limit fish passage when lake levels are lower than 4,488 feet asl. Although the particulars of the weir design are still being discussed, Figure 19 illustrates one possible approach whereby pickets are installed across the channel to prevent fish passage.

When the lake is lower than the four outlet channels through Skipper Bay Dike, the highly erodible lakebed sediments on the west side of the lowered dike will be scoured and channels will form as water leaves the delta area and flows westward into the lake. This process is common in western United States reservoirs that have highly variable water surface elevations. When water levels recede, rivers cut channels into the lakebed sediments and a system of channels results. These channels are often filled in when lake levels rise, but they reform again during low-water periods. The area west of Skipper Bay Dike is expected to experience similar cycles of erosion and infilling, but the dike itself will be hardened to retain water levels within the delta at designed elevations.

The flow characteristics (depth, velocity etc.) of the outflow channels are assessed later in this report in Section 7 (Evaluating Design Performance).

5.2.2 New Provo River Channel - Delta Zone

The new Provo River “Delta Zone” extends from Skipper Bay Dike upstream to the margin of the backwater it creates (see Figure 9 previous). The proposed delta reach design is shown in Figure 20. The design creates a Delta Zone with varied water depths and a highly complex habitat distribution pattern (Figure 21).

The delta marsh complex habitat type is extremely important for the life history of June sucker, and it is almost nonexistent in the current, highly manipulated channel configuration of the lower Provo River. Because June sucker fry cannot swim well, the need for water that flows into heavy vegetative cover is extremely important. The proposed Delta Zone design is targeted at providing a wide array of aquatic, wetland, and riparian vegetation zones that are hydrologically well connected (Figure 22), in addition to areas of dense cover that can be used by these fish to avoid predation, grow, and eventually recruit to the spawning population.

The proposed design divides the streamflow into multiple-channel threads as soon as it enters the delta area, which (1) reduces flow velocity, (2) promotes flow interactions with shallow-water vegetated areas that provide cover, (3) increases water temperatures, and (4) creates a more gradual temperature transition as cold river water mixes with warmer water in the delta. It also provides a mosaic of deep-water and shallow-water areas that will support the full range of native vegetation that occurs in deltas in the Intermountain West, from dense emergent vegetation to submerged aquatics, thus providing diverse habitat for fry and juvenile June suckers, and their food resources, allowing them to escape predation by fish and access open water for feeding.

Throughout most of the delta area, the channels will be excavated to depths between 3 and 6 feet lower than the surrounding topography. It is important to note that these channels are simply deeper areas within the backwater created by the lowered Skipper Bay Dike, and that they are not channels in a more classic riverine sense. The bed will tend to be quite smooth, with gradual variation in depth. Intensive bank treatments will not be needed because stresses there are low. Channel banks will not be dry areas, but rather will simply be shallower water areas that sustain a dense emergent marsh vegetation community, primarily composed of bulrush (Figure 23).

The channels will provide locations where water is deep enough to limit vegetation growth, thus allowing flow velocities to be higher than in surrounding areas of dense vegetation. These channels will serve to concentrate flow in a few locations, which will help maintain those channels as open water over time. The channels will also provide pathways for fish to move within the delta. In addition, the channels will be important for boating access for both recreation and management purposes.

5.2.3 Delta Ponds and Depressions – Delta Reach

In addition to the channels, the design also includes many delta ponds and depressions that will provide a mosaic of unvegetated deep water, vegetated shallow water, and fringe wetland habitats, all of which are important for young June suckers (see Figure 20).

The average width of the irregularly shaped delta ponds is over 100 feet, with average lengths of several hundred feet. Within the delta ponds, distances of deep open water will be less than 150 feet at most locations, to reduce creation of landing and take-off zones for large birds. Larger ponds will be divided into smaller sections by using shallow areas with emergent marsh vegetation and rooted aquatics (Figure 24) to make the ponds less attractive for waterfowl, shorebirds, pelicans, and cormorants. These design features are included to help reduce the likelihood of airplane bird strikes.

The delta ponds have been designed to have large amounts of edge habitat, or areas where deeper waters (7 to 8 feet) are adjacent to shallower areas with aquatic and emergent vegetation that can provide cover for juvenile fish. Deeper areas become more important as lake levels drop, because they provide a substantial amount of area that will remain wetted when some areas within the delta are drying. Figure 25 was shows a typical cross section through a delta pond.

Delta depressions are smaller in size than the ponds and they are primarily designed to become disconnected from flowing water during periods when lake levels and streamflow are low. Most depressions will have a limited area where low water depth exceeds 6 feet (Figure 26) but will primarily provide shallower rooted aquatic and emergent marsh conditions.

5.3 New Provo River Channel - River Reach

5.3.1 Description and Constraints

The River Reach of the PRDRP begins at the delta diversion berm and extends downstream for roughly 2,700 feet (Figure 27). The channel is designed to carry Provo River water from the existing Provo River channel to the new Provo River Delta and to provide June sucker spawning habitat.

The upstream part of the River Zone will be surrounded by infrastructure elements including existing and future roadways and bridges, irrigation ditches, trails, stormwater drains and an associated pumping station (owned by Provo City), proposed sewer lines (Provo City), and a variety of other anthropogenic features. These features place serious constraints on the range of possibilities for the river design and must be accommodated. They largely dictate what the river can be and limit the possibility of designing this section to allow many natural processes that would be desirable and possible in a less-developed setting. In particular, any form of natural channel migration in this reach is unacceptable.

The upstream-most channel section of the PRDRP, from the delta diversion berm downstream to the proposed Lakeview Parkway Bridge, will largely be confined between berms and cannot be allowed to migrate. Banks in that area will primarily be protected with large rock (6 to 24-inch diameter) to prevent lateral migration, but the visible portion of the rock will be placed with an irregular form and hidden by surrounding willow plantings and root wads to create a more natural-looking channel. Uniform riprap banks will be avoided. Figure 28 shows a typical riffle cross section in the area between the diversion berm and the Lakeview Parkway bridge, with revegetation treatments.

Large (18 to 36-inch diameter) angular rock riprap will be used to create the sill below the delta diversion berm at an elevation of 4492.2 feet asl. Large rock will also be used near the Lakeview Parkway Bridge (designed by AECOM).

A longitudinal profile of the channel with modeled water surface elevations for three river discharges is shown in Figure 29 along with an aerial image with location and stationing for the profiles. Pool depths vary with streamflow but are typically between 2+ and 5 feet for a range of flows between 40 and 825 cfs. Pool depths are over 2 feet even during periods of extreme low streamflow and lake level. Pool depths can be increased substantially without affecting water surface elevations, so constructed pools may be excavated in some areas to greater depths if conditions warrant the change, but under no circumstances will pool depths be less than those illustrated. As the river approaches the Delta Zone, backwater effects begin to appear, as illustrated in Figure 29.

A kayaking play area may be incorporated into the new river channel immediately downstream of the delta diversion berm, but that feature is only in the discussion phase and is not detailed in this report.

West of the proposed Lakeview Parkway Bridge, the river turns to the north and flows through a section that has very little slope along the floodplain. In this area the floodplain will need to be lowered by 1 to 2 feet to allow overbank flooding to occur on a relatively frequent basis (see Figure 27). This lowering will not be uniform and will provide a hydrologically well-connected surface that will promote floodplain revegetation using mostly riparian species.

After the Lakeview Parkway bridge, the river gradually becomes less laterally constrained and will be free to migrate within the project boundaries and to flood the project area without negative consequences. High flows from runoff will remain confined within the project area because of the local topography. Lands south of the berm with trail are still susceptible to lake-caused flooding when lake elevation are extremely high.

Hydraulics in the most downstream portion of the River Reach will be affected by backwaters caused by fluctuations in water levels of Utah Lake whenever the lake is above 4,487 feet asl (1929 NGVD). When lake levels are below 4,487 feet asl, the River Zone will no longer be influenced by the lake, but it will continue to be affected by the backwater created by the lowered Skipper Bay Dike. Figure 30 illustrates the section of Provo River channel that will be most affected by typical lake level fluctuations, although backwater effects influence flows farther upstream as well.

The River Reach will provide potential spawning habitat for adult June sucker and will be finished with that goal in mind. Cobble and gravel substrates will be sized to meet June sucker spawning needs, and roughness elements will be included that will enhance spawning success. The channel will include alternating gravel bars with associated riffles at crossover points and pools on the outside of the bends. The constructed channel will also provide resting areas adjacent to targeted spawning areas, because those resting areas have been identified by the June Sucker technical team as an important habitat element. Resting areas will be created by using a structural element such as rocks or tree roots to create protected pockets of low velocity habitat.

The channel bed throughout the River Zone will be lined with gravel and cobbles to limit downcutting. The bed will be composed of a 9 inch thick matrix of larger bed material (preferably rounded 3-inch plus) that is essentially immobile during typical runoff events, covered by a 3 inch thick layer of finer gravel material (rounded 1.5-inch minus) that will be mobilized frequently to allow cleaning and flushing for spawning of June sucker. Some of the bed material could be harvested from the existing channel downstream of the delta diversion berm, but most will need to be trucked to the site from elsewhere.

River channel banks in the section downstream of the Lakeview Parkway Bridge, where the river turns to the north, will be constructed using a series of coir fabric-wrapped soil lifts with coir blocks at the channel margin for added erosion protection (see Figure 30). This treatment will begin at about Boat Harbor Drive, which will be removed, and will continue downstream to where backwater effects occur at low lake levels (see profile plot in Figure 29).

These fabric-covered soil lifts will overlap the 3-inch plus cobble described in the previous paragraph. Figures 31 and 32 show typical cross section views in a single channel section and a divided flow section of the new river channel, respectively, with bank treatments, plantings and approximate water levels for the 2-yr runoff event. Willow cuttings will be used extensively between successive soil lifts and can also be pushed directly into the lifts in large numbers to promote rapid revegetation of the newly constructed banks. Appendix B includes additional details for installation of the soil lifts and manufacturer recommendations.

Existing soils in the River Zone are mostly loamy with some sand and peat soils interspersed (see Appendix A for complete soil testing information). The loamy lakebed sediments are not cohesive enough to provide stable banks when the new channel is excavated through that area and streamflow is introduced, thus the need for soil lifts. While some channel movement is expected and even desirable, excessive erosion after construction would be problematic, so revegetation success in this section will be of utmost importance.

5.3.2 Channel Size and Form

The proposed meander geometry of the riverine section is based on natural meander geometries. Research has shown that river meander and channel geometry tend to scale with channel width in natural channels (Williams 1986). This means that the shape of meanders is consistent from small streams to large rivers, when channel width is included as a scaling factor. This fact is extremely important and useful for designers. Relationships have been identified that show how meander descriptors like radius of curvature, belt width, and wavelength are related to channel width. Similarly, descriptors like channel depth and channel area are also related to width in natural channels. These relationships are useful for guiding overall designs, and they were used in conjunction with flow modeling, sediment mobility and other approaches to determine the basic size and shape of the proposed channel alignment.

The basic meander geometry of the River Reach is described in Table 4. Bankfull widths from 50 and 70 feet were used to provide an appropriate range of channel descriptors to guide layout of the new channel alignment. This width range was selected based on relationships of width versus discharge (Figure 33) as explained by Andrews (1984), and because it compares favorably with the dimensions of the existing channel. A discharge equal to the 2-year flow event (825 cfs) was used for the Andrews relation; however, widths slightly larger than the range from Andrews were included for consideration, given that the new channel will be almost devoid of vegetation when first constructed.

As designed, the bankfull width of the channel varies through the River Reach, but it generally stays within the 50 to 60-foot range, and meander proportions match the parameters in Table 4. Figures 31 and 32 (previous) show examples of channel sections in the unconfined section downstream of the Lakeview Parkway bridge.

Table 4. River channel and meander descriptors computed from two bankfull channel widths that encompass the range of widths proposed for the River Reach design. (Relations used for computations are from Williams [1986].)

SYMBOL	DESCRIPTOR	MEAN	+SD	-SD
W	Width	**70**		
Rc	Radius of Curvature	175	271.0	113.6
D	Depth	2.57	4.9	1.4
Bw	Meander Belt Width	501	872	291
C Area	Channel Area	162	319.6	82.7
WaveL	Meander Wavelength	792	958	657

SYMBOL	DESCRIPTOR	MEAN	+SD	-SD
W	Width	**50**		
Rc	Radius of Curvature	120	185.9	78.0
D	Depth	2.00	3.8	1.1
Bw	Meander Belt Width	344	598	199
C Area	Channel Area	91	179.6	46.5
WaveL	Meander Wavelength	543	657	451

The designed channel begins to divide in the downstream section where flow energy levels begin to be reduced by backwater effects from lowered Skipper Bay dike and/or Utah Lake. Due to fluctuations in the water surface elevation of Utah Lake, the location of the backwater effect moves longitudinally, upstream when lake levels are high, and downstream when lake levels are low (see Figure 30 previous).

Appendix C includes tables with important descriptive parameters for the river channel, delta and outflow channels, as well as important spot elevations, bed material sizes and other relevant information.

5.3.3 Channel Capacity

The new Provo River channel within the River Reach has been designed with a bankfull capacity that is roughly equal to the 2-year recurrence interval peak flow of 825 cfs, although some overbank flooding occurs at lower discharges. This choice was made for a variety of reasons, which were primarily tied to a desire for relatively frequent overbank flooding onto the new floodplain in the area downstream of the Lakeview Parkway Bridge.

When the Provo river streamflow level approaches the 2-year event, water begins to leave the channel and inundate the floodplain in the area downstream of the Lakeview Parkway bridge and further downstream where the existing ground surface will be lowered to provide improved connection between the channel and the floodplain (see Figure 27). As streamflow continues to increase, a greater proportion of the flow will spill onto the floodplain. River stage rises quite rapidly with increasing discharge when flows are contained within the channel, but after flows overtop the channel banks and spill onto the floodplain stage changes are less pronounced. Seasonally inundated streambanks and floodplains within the River Reach will be revegetated with native riparian and wet meadow species important for both June sucker and ULT.

5.4 River Ponds – River Reach

A series of three River Ponds are included in the design (see Figure 27). These ponds are located upstream of the normal delta backwater area and will be topographically connected to the river at essentially all discharge because the inlets are at low elevation, but they will not have streamflow through them unless the river is nearing a 2-year peak discharge. Topographic lows between the ponds and the river will provide a hydraulic connection during most flows, but streamflow will enter the ponds and will not continue because the ponds will have no outlet. In larger peak events, streamflow will exit the ponds by flowing over the surrounding floodplain. River pond depths will be variable, mostly between 3 and 7 feet below the 2-year peak. These River Ponds are intended to provide off-channel June sucker nursery habitat that is different in character from areas farther downstream within the delta. Ponds like these were included previously in the restoration of the Hobble Creek Delta, and they have been found to hold surviving juvenile June sucker.

5.5 Existing Provo River Channel

5.5.1 Existing Conditions and Proposed Design

When water is routed into the delta, the existing Provo River Channel will remain an important community resource for recreation and other uses. The Provo River Parkway Trail that parallels the existing channel is a high-use area and extremely popular with citizens of the community. During public meetings the consensus was to keep recreational opportunities within and along the existing Provo River channel as they currently exist, adding only aesthetic enhancements and improvements to water quality. As such, the proposed designs for this area attempt to retain the current uses and provide additional ways for the public to enjoy the area while also providing ecological benefits.

The proposed design includes construction of a small downstream dam (see Figure 2 for location and section 6.4 for more information) that will be constructed near the existing Center Street Bridge. This will allow water levels in the existing channel to be managed at relatively constant levels for fishery and recreation purposes. Specific design elements within the existing channel will need to be coordinated between the river designers and the recreation designers; however, the basic goals and physical design are presented below.

As seen in Figure 34, most of the existing Provo River channel is very deep, having been dredged many times over the years. This deep area extends from near the current Provo River mouth upstream to the fish weir (see Figure 2). The backwater that will be created by the small downstream dam will continue upstream past the fish weir to the proposed Lakeview Parkway Bridge.

5.5.2 Proposed Design Features

The design for the existing Provo River channel will include (1) a shallow flowing channel section from the delta diversion berm downstream to the Lakeview Parkway Bridge, and (2) a deeper and extremely slow flowing flatwater area that continues downstream to the small dam (see Figure 34).

Plans for the existing channel are being coordinated with Provo City, who is designing the Delta Gateway Park, located adjacent to the delta diversion berm at the upstream-most margin of the PRDRP (see Figure 2). Landscape architects from Blu Line Designs have created an overall vision for the park and a portion of the existing river channel in that area, which is illustrated in Figure 35.

Upstream of the future Lakeview Parkway Bridge over the existing channel, a roughly 1,000-foot section of shallow flowing channel will be constructed that is designed to allow small watercraft to pass from the Provo River into the deeper ponded section of the existing channel that begins just downstream of the future Lakeview Parkway. A plan view of the proposed design for the shallow flowing channel is shown in Figure 36, along with the locations of five channel constrictions (narrow areas) that are intended to create backwaters and increase flow depth to make floating the section easier. A minor boundary issue that is being addressed by the URMCC is also shown.

The existing Provo River channel is approximately 70 feet wide between the levees in the section between the river diversion berm and the Lakeview Parkway crossing. Some gravel and cobble bed material in this reach may be extracted for use on the bed of the new Provo River channel, so the existing bed configuration will necessarily be altered. The remaining material will be reconfigured and supplemented with excavated material from the delta to provide a roughly 12 to 18-foot wide channel with a series of runs, shallow pools and flow constrictions that will increase depth and allow boaters to pass through to the downstream ponded section. Figure 37 shows a typical method for treatment of the existing channel, which will be filled in with excavated material and narrowed to create this section of shallow flowing channel.

Figure 36 (previous) showed the proposed location of constrictions within the flowing reach of the existing Provo River channel, along with other features around the Delta Gateway Park. Based on the expected flow of 10 cfs that will normally be delivered into the existing Provo River channel, the planned constrictions are needed to allow the flow depth to remain deep enough for boaters to pass with relative ease.

The proposed constrictions in the shallow flowing channel will be hardened using large flat rocks that are either salvaged from the existing Provo River channel or trucked to the site. The narrow constrictions will be roughly 15 to 20 feet long and will have a stepped cross-section shape with an inset thalweg roughly 7 feet wide (average), and a wider throat of 15–20 feet to allow for occasional periods of higher flow. Figure 38 shows a typical cross section through a constriction, and Figure 39 shows an artist’s rendering of one of these narrow areas after vegetation has fully matured.

The small channel has roughly 3 feet of fall between the outflow of the diversion berm and the backwater from the small dam. Based on simple 1D modeling, flow depth in the constrictions is expected to be roughly 6 inches. The designed elevations of both water and channel bed at the diversion outflow and at the five designed constrictions illustrated in Figure 36 (previous) is shown in Table 5.

Table 5. Designed water surface and bed elevations for constriction in the small channel.

Location	Bed Elevation ft	Water Surface Elevation ft
BOR Sill	4491.5	4492
Constriction 1	4491	4491.5
Constriction 2	4490.5	4491
Constriction 3	4490	4490.5
Constriction4	4489.5	4490
Constriction 5	4489	4489.5
Backwater from small dam	DEEPER	Approx. 4489

Runs and pools will be excavated between the constrictions to provide water depths between 1.0 and 3.5 feet. Figure 40 shows a typical cross section in the channel area between constrictions and Figure 41 shows an artist's rendering after vegetation has fully matured. Given the limited slope in the channel section, flow velocities will likely be quite low, between 0.2 and 1.0 foot per second depending on the cross-sectional area of the channel.

In the Delta Gateway Park area, a shallow play place for children has been recommended by partners and could be included within the small flowing channel reach. Such a place would be easy to include by simply widening a short reach and sculpting the bed to create a shallow-water area that would provide children with a place to splash and play. Figure 42 shows an artist's rendering of a play place within the existing Provo River channel. The play place could easily be constructed but the safety of children could be an issue and managers would need to carefully consider what steps to take to make the area safe for kids.

Downstream of the Lakeview Parkway crossing, the existing Provo River channel will be ponded by the small downstream dam to create a long, deep section, called the "flatwater section,". Figure 43 shows a typical cross section within the lower reach. Although this area will have streamflow, the velocity will be near zero and it will have the general character of a curving, linear lake.

5.5.3 Aeration System - Water Quality Issues

Recent water quality monitoring in the lower Provo River has indicated that current conditions are poor for aquatic life during the summer due to low concentrations of dissolved oxygen (DO). Standards for DO are currently not being met during extended periods of the hot summer months, when DO concentrations have been recorded below the published lethal limits for most fish species. Current conditions indicate an impairment of designated beneficial uses such as recreation, aesthetics, cold water fisheries, and warm water fisheries.

An aeration system is proposed for the flatwater section of the existing Provo River channel to increase oxygen levels to help meet State water quality standards. Preliminary details of the aeration system are described in the FEIS.

6 Other Design Elements

6.1 New Berm with Trail

The berm along the south margin of the delta is being designed by the USBOR engineering group, which is based in the Provo, Utah, office. This berm, dubbed the “New Berm with Trail,” will be located as shown previously in Figure 2. On the west end, the top of the berm will be at an elevation of 4,495 feet asl, which is slightly higher than the designated 100-year lake level of 4,494.58 feet asl (FEMA 1988). As the berm approaches Boat Harbor Drive, the top will increase in elevation to at least 4,498 feet asl.

The berm will be lined with rock on the delta side to protect it from streamflow stress and wave-action erosion. It will have a trail located on top and an equestrian trail on the south sideslope. Figure 44 shows an illustration of the general form of the new berm with trail and some structural details. In areas where fill material will likely be placed along the berm, the trail may be routed farther north, off the berm and onto some of the proposed fill areas (see Figure 2 for fill locations near berm). Recreation designs are not complete at this time, so the final routing of the trail is yet to be determined.

6.2 Boat Harbor Drive and the North River Berm

The intersection of Boat Harbor Drive and the proposed Lakeview Parkway is perhaps the most complex location for the PRDRP design because many features intersect there, including: (1) the new Provo River channel, (2) the Lakeview Parkway and bridge, (3) Boat Harbor Drive, (4) the new berm, and (5) the trail system (see Figure 2). To ensure compatibility of all designs in that area, the river design has been coordinated with the road and bridge design work being completed by Provo City’s consultant, AECOM.

AECOM was provided with the location and hydraulics of the new Provo River channel by the PRDRP design team, and they completed other aspects of the design in the intersection area with input from the Commission and others. Their designs were provided to the Commission, USBOR, Allred Restoration, and others, both for review and to allow for fitting of other connections to their designs. Soil loading for the bridge is already underway.

Boat Harbor Drive will be realigned in the area near the intersection as it approaches Lakeview Parkway from the west, and it will terminate at the parkway. The remaining section of Boat Harbor Drive located east of Lakeview Parkway will be abandoned as a through road and will be built higher to act as a berm to discourage water flow to the north (see “North River Berm” - Figure 2). Provo City has also proposed a sewer line that will be incorporated along the north side of this berm. The top of the berm will act as a maintenance access for the sewer and may also be used as a trail. The USBOR designed the North River Berm in cooperation with Provo City.

6.3 Project Area Recreation

Recreation is an important component of the PRDRP, and several items have been included in the proposed design to promote public use and enjoyment of the area. Conceptual designs were presented in a Recreation Concept Report prepared by HDR (2016). Figures 45 and 46 show draft concepts and planning for recreational features in the new Provo River delta and the existing Provo River channel, respectively. Final decisions for recreation feature designs and locations will be determined by the Commission in conjunction with Provo City, Utah County, Utah Lake State Park, Utah Division of Wildlife Resources, JSRIP, and other stakeholders.

6.4 Small Downstream Dam

The USBOR is designing a small downstream dam that will be located approximately 350 feet downstream of the Center Street Bridge in the existing Provo River channel (Figure 47). This structure will serve two purposes: (1) it will act to create a backwater within the existing Provo River channel that will provide an area with stable water levels that is intended to enhance aesthetics and water-related recreation, and (2) it will prevent fish residing in Utah Lake from swimming upstream into the existing Provo River channel except during rare occasions when Utah Lake is well above compromise elevation.

The small downstream dam will be constructed of earthen material and will have outlet works that release inflows to the lake. It will be operated to maintain relatively stable water levels or roughly 4,489 feet asl in the flatwater portion of the channel, rather than being subject to the large fluctuations in water levels that occurred in the past as Utah Lake levels rose and fell and the Provo River streamflow varied from season to season.

6.5 Delta Diversion Berm and Water Diversion

A berm is needed to direct streamflow into the new Provo River channel that flows toward the delta (Figure 48). This berm was designed by the USBOR engineering group in cooperation with Allred Restoration, CUWCD, and the Commission.

The delta diversion berm design goals include building up an area within the confines of the existing channel that will: (1) redirect flow into the new Provo River Delta, (2) be protected from overtopping and erosion, (3) accommodate the delivery system pipeline that will carry flow from the water diversion intake to the existing Provo River channel, (4) allow portage of small portable non-motorized watercraft, and (5) allow the trail system to cross over the top.

When the new Provo River channel is in place and water is flowing into the delta, a water diversion will be needed to deliver 10 to 50 cfs of water into the flowing and flatwater sections of the existing Provo River channel. Design of this diversion is being coordinated by the USBOR engineering group in cooperation with Allred Restoration, CUWCD, and the Commission. The design for this structure includes an intake structure and outlet works that are housed within the delta diversion berm, with pipes that will carry water through the berm to the outflow location. Figure 48 shows the approximate location of the water diversion intake and outflow and how they will be situated within the delta diversion berm.

7 Evaluating Design Performance

7.1 HEC-RAS Modeling – 1-D and 2-D

HEC-RAS modeling has been used at nearly every stage of the proposed design process for a wide array of purposes including: (1) to determine channel size and channel capacity, (2) to assist in flow routing, (3) to explore various runoff scenarios, (4) to explore lake/river interactions at various lake levels and various river discharges, (5) to compute sediment mobility, and (6) to determine likely zones of sediment deposition.

HEC-RAS 5.0 was used to construct both 1-D and 2-D flow models of the Riverine and Delta Reaches of the PRDRP, as well as the river's interface with Utah Lake and the modification of Skipper Bay Dike. Initially, 1-D models were constructed and used for channel alignment and sizing to promote overbank flooding in frequent recurrence interval events. These 1-D models were built using topography from a 2011 LiDAR dataset that was collected by the Commission. The LiDAR surface was sliced along cross-sectional lines and then input to RAS. These data were then modified to represent the new river channel, and various discharges were simulated to determine channel performance under a wide range of flow scenarios. Nearly all the detailed initial channel design was completed using 1-D models, because running 2-D models is time consuming and doesn't lend itself well to design and testing of minor changes in geometry.

After building and testing the 1-D models, they were used, in conjunction with available LiDAR data, to create a terrain surface model of the channel and delta area that includes the major design components. Figure 49 shows the terrain surface used for model simulations completed to date. Approximately thirty separate 1-D models were combined with the LiDAR to create the current working terrain surface.

The terrain surface shown in Figure 49 provides the basis for 2-D flow modeling of various lake-level and river-discharge combination (scenarios). Many scenarios have been modeled to explore the performance of the river and delta and to examine the distribution of available habitat that occurs under a range of likely conditions. Results from a few of these model runs are presented in the following sections.

Note: The project boundary has been changing in recent weeks and those changes are not reflected in the modeling results presented in this report. One boundary change resulted in a slight shift in the alignment of the berm and trail over a short distance. All boundary changes that have occurred were minor adjustments in a hydraulic sense, and none have the potential of changing model results in a meaningful way. A new terrain model will be constructed when all boundary issues are resolved, and it will be used to guide construction efforts.

7.2 Results

7.2.1 Depths - Dry Spring - Typical Conditions

The model run for typical conditions during a dry spring evaluated a scenario with a Provo River discharge of 500 cfs, and a Utah Lake level of 4,486 feet asl. This scenario represents springtime conditions in the delta during a dry year when runoff is lower than normal and Utah Lake water levels are low.

Figure 50A shows a plot of water depth within the river and delta and shows the extent of ponded water. Notice that streamflow in the Provo River is not high enough to spill onto the floodplain in the River Zone. Water depth within the delta is varied and diverse, as flows from the river disperse into flooded areas that will offer excellent cover for fry and juvenile June suckers.

7.2.2 Depths - Wet Spring - Typical Conditions

The model scenario for typical conditions during a wet spring evaluates a Provo River discharge of 1,475 cfs (10-year event), and a Utah Lake level of 4,489 feet asl (roughly compromise elevation). This scenario represents springtime conditions in the delta during a high-snowpack year when water levels in both the Provo River and Utah Lake are high.

Figure 50B shows a plot of typical water depths within the river and delta, as well as the extent of ponded water, during a high-runoff year and a wet spring. Notice that water levels in the new channel are high enough to cause substantial overbank flow within the River Reach.

7.2.3 Depths - Summer - Typical Conditions

The model run for typical conditions during the summer evaluates a Provo River discharge of 40 cfs, and a Utah Lake level of 4,485 feet asl. This scenario represents summertime conditions in the delta during a dry year when streamflow in the Provo River is very low due to irrigation diversions and Utah Lake levels are well below the elevation of the modified Skipper Bay Dike, so June sucker habitat within the delta is at its minimum for both depth and areal extent.

Figure 50C shows a plot of water depth within the river and delta during a typical summer period, as well as the extent of ponded water. This scenario represents nearly the worst-case scenario for habitat availability within the delta, with low flow and low lake levels, but the lowered Skipper Bay Dike maintains water levels in the delta. Despite the low-water conditions, habitat within the delta remains varied and diverse, with a distribution of shallow water that will support emergent vegetation and deeper areas for submerged aquatic vegetation and open water.

7.2.4 Depths - Extreme Wet Spring - 100-year Peak River Level

The scenario for extreme wet spring conditions evaluates (1) a Provo River discharge of 2,325 cfs (100-year event), and (2) a Utah Lake level of 4,489 feet asl (roughly compromise level). This combination represents springtime runoff conditions in the delta during an extremely high-snowpack year.

Figure 51 shows a plot of water depths and the extent of ponded water within the river and delta for the scenario that includes the Provo River at 100-year peak discharge and Utah Lake at compromise level. Within the project area, no flooding of adjacent land occurs.

The design features of the PRDRP will provide a level of flood protection equal to or greater than the current level. In fact, water levels upstream of the project, during the 100-year flood event, will be slightly lower than under existing conditions. Figure 52 shows the Provo River in the area near the delta diversion berm where the proposed channel diverts from the existing channel. It includes cross sections from the current FEMA model (not yet finalized) for the existing Provo River. Modeled water surface elevations are shown at five cross sections for both the FEMA existing conditions model and the PRDRP model, for the 100-yr event (2,325 cfs). Note that water surface elevations are lower following completion of the project than they are for existing conditions.

The proposed design maintains the current level of flood protection, but it will not address any existing flood problems upstream of the project area. The new berm with trail that defines the southern boundary of the Delta and River Zones, will not overtop under any modeled flow scenario up to and including the 100-year peak event.

Notes on RAS model comparison: In order to ensure comparable results between RAS models, the exact topography from a section the Provo River channel was exported from the FEMA model and added to the PRDRP model DEM to create a combined terrain file. That file was used to model the 100-year event scenario only and was not used for any other scenario. Thanks go out to Tom Wright (AECOM) for providing us with critical FEMA model data before they were widely available.

7.2.5 Velocities in the Delta Zone

Within the Delta Zone velocities are low everywhere under most circumstances but are locally highest in the excavated channels where flow is expected to be concentrated because depths are greater, and vegetation is less dense. Flow velocity in these channels ranges from near zero when streamflow is extremely low, to roughly 1 foot per second when streamflow is at 2,325 cfs (100-yr event). Velocities will be very low throughout non-channel areas of the delta during most of the year, with typical values of 0.01 to 0.03 feet per second.

7.2.6 Depths in the River Zone

Hydraulic conditions for typical streamflows are similar in the upstream confined river section and farther downstream, where it is less confined. Flow depths in the River Zone vary with discharge and position along the channel. Average pool depths are mostly between 2 and 5 feet over a common range of flows from 40 to 825 cfs (see Figure 29), and deeper still at higher discharges. Average riffle depth is only roughly 6 inches when flows are extremely low but increases to 3 feet when streamflow is at 825 cfs. Although the modeled channel bed is relatively planar, the constructed channel will be filled with subtle variations in roughness and depth that produce micro-habitat changes on a small scale, thus avoiding uniform shallow areas at low flow.

7.2.7 Depths in the Outflow Channels

Flow depth in outflow channels varies with discharge and lake level. Several combinations of river discharge and lake level were modeled using the 2D capabilities in HEC-RAS, and typical depths in the outflow channels were:

- Skipper Bay dike invert depths of 0.2 to 0.3 feet during low flow and low lake level (40 cfs with lake level of 4,485 feet asl),
- Skipper Bay dike invert depths of 0.4 to 0.5 feet during medium flow and low lake level (125 cfs with lake level 4,486 feet asl)
- Skipper Bay dike invert depths of 0.9 to 1.1 feet during “dry spring” runoff with low lake level (500 cfs with lake level 4,486 feet asl)

7.2.8 Flow Velocity in the Outflow Channels

Flow velocities in outflow channels varies with lake level, discharge and position in the channel. This variation is best presented in graphic fashion to allow for comparison between various scenarios. Note that calculated velocities in a 2D model are vertically averaged and therefore don’t capture the expected vertical velocity distribution, where velocities near the stream bed are lower than average and those nearer the surface are higher than average. This vertical distribution of velocity is important to a fish swimming upstream against the current, because it allows them to hug the stream bed and stay in the zone where velocities are lowest.

The ability for a fish to swim upstream against a current is limited by the burst speed the fish can attain for short periods of time. In Utah, burst speeds for benthic species, including June sucker, range from 3.5 feet per second for small fish to 4.5 feet per second for large fish (Aedo, Belk and Hotchkiss, 2009). These burst speeds are general rules only, and the individual ability of each fish will vary.

Figure 53 A-C provides maps of vertically averaged flow velocities for three different scenarios that have been color coded to assist the reader with interpretation of the results. Green and yellow areas are easily passable for any mature June sucker attempting to enter the delta, orange areas are nearing the burst speed for small fish, and red is at or above the burst speed for a small June sucker. Notice that the only area of real concern is the invert of the lowered Skipper Bay dike, which has vertically averaged velocities that are passable everywhere even when streamflow is at 825 cfs and lake levels are low.

7.2.9 Flow Velocity in Potential Spawning Areas

Although creation of habitat that will allow June sucker larvae and juveniles to survive is the primary goal of this project, spawning of June sucker in the River Zone is an important goal as well. Several aspects of the design are intended to promote spawning within the channel and to allow passage of fish to upstream spawning areas. As discussed previously in the outflow channel section, flow velocities are important, especially as compared to burst speed of migrating fish. Figure 54 A-C shows three color-coded maps of flow velocities, both in the River Zone and in a short section of channel upstream of the project area. Portions of the channel have vertically averaged velocities that approach burst speeds for June sucker, but channel margins and other areas provide lower velocities for passage. Also, near bed velocities are substantially lower than averages and June sucker can hug the bottom to aid in upstream migration.

7.3 Habitat Distribution Based on 2D Modeling Results

Model results have demonstrated that water levels in the delta reach are not particularly sensitive to changes in Provo River discharge once river flows exceed 200 cfs. This lack of pronounced change in water level with discharge is the result of the wide opening between the delta area and Utah Lake proper that will be created when Skipper Bay Dike is lowered. When river discharge increases, the available area for flow to leave the delta reach increases rapidly. The result is that lake level is a far better predictor of habitat availability within the Delta Zone than is river discharge.

Total aquatic habitat availability within the delta area increases with increasing lake levels. Figure 55 shows a map of inundated area for two scenarios with identical discharges but different lake levels: (1) river flows of 125 cfs with lake level of 4,486 feet asl (delta water level controlled mostly by Skipper Bay dike outlet channel invert), and (2) Provo River streamflow of 125 cfs with a lake level of 4,489 feet asl (roughly compromise level). The area of inundation increases with lake level, especially in flatter areas, but both lake levels provide a considerable amount of flooded habitat.

The distribution of elevation and variation in depth within the delta will provide for a wide range of wetland plant communities from riparian to emergent to submerged aquatic, mixed with some open water areas. Table 6 provides acreage estimates for each vegetation type based on elevation. Additional detail and maps of vegetation types are included in Appendix A.

Table 6. Acreages of various vegetation types within the delta area.

Vegetation Type (based on elevation)	Approx. Acreage
Riparian	30
Emergent	153
Submerged Aquatic	20
Open water	42

7.4 Bedload Sediment

7.4.1 Streambed Sediment Mobilization Analyses

In 1995 and 1996 BIO-WEST developed "flushing flow" recommendations for the lower Provo River (Olsen et al., 1996) to determine the magnitude and duration of peak flows that would effectively clean spawning gravels in early spring in preparation for the June sucker spawn. Streamflow and sediment interactions were also assessed further in a subsequent study (Olsen et al., 2003). The 1996 study assessed bed material transport at two sites, one of which was located near the current sites of the Lakeshore Drive Bridge, immediately upstream of the project area. These data are extremely useful for the delta design process because they provide some understanding of the likely sediment sizes that will be delivered to the PRDRP from upstream.

At the site near the Lakeshore Drive Bridge, measured median particle size (D_{50}) in the Provo River was 54 millimeters (mm), and the D_{16} and D_{84} particles were 15 mm and 100 mm, respectively. Their analyses (Olsen et al., 1996, 2003) of the flow required to mobilize the bed material near Lakeshore Drive indicated that the river needed to be extremely high, roughly 2,000 cfs, to mobilize the D_{50} particles. This indicates that the river in that area is essentially acting as a threshold channel, which is a channel that transports finer material delivered to it from upstream but rarely reworks the larger material in the bed.

Bed material mobilization is important in rivers and streams because it cleans and scours the gravel and cobbles and improves spawning habitat and success. Therefore, the designs for the River Reach of the new Provo River channel were evaluated to assess the mobility of different sediment particle sizes. The results were compared with the size distribution of material expected to enter the reach from upstream.

It is possible to calculate the depth of flow required to initiate motion of a given-size particle when the channel slope is known. The method used for calculation of the flow depth needed to move particles on the bed is from Shields (1936) and is as follows:

$$Tau^* = \frac{\rho_w \, gDS}{g(\rho_s - \rho_w)D_p} = \frac{\rho_w \, gDS}{g\rho_w(2.65-1)D_p} = \frac{DS}{1.65 \cdot D_p} \qquad \text{(Equation 1)}$$

where,

- Tau* = the dimensionless shear stress developed by Shields (values of Tau* near 0.06 are considered very mobile on the bed, values near 0.03 are considered to be beginning to move, and values of 0.02 are essentially immobile)
- g = the acceleration of gravity
- ρ_w = the density of water
- ρ_s = the density of sediment particles
- D_p = the particle diameter
- D = the flow depth (hydraulic radius is often used)
- S = the local slope

Equation 1 is dimensionless, so the solution for depth has the same units as those used for the particle diameter (D_p). It can be solved using modeled depth and slope data to determine the size of material that will be mobilized by a given flood event, assuming that initiation of motion occurs when Tau* is roughly equal to 0.03 (a reasonable assumption). It can also be rearranged to solve for the depth required to move a given size particle or used with model outputs of shear stress to assess particle mobility.

Designed channel slopes in the River Reach were selected to produce shear stresses that will transport the smaller bed material well into the project area and avoid excessive deposition near project area margins. The proposed Provo River channel in the River Reach is designed with an average slope of 0.002 feet/feet.

Bed material sizes expected to enter the new River Reach are primarily gravel particles in the range of 2 to 32 mm. For the following mobilization assessment, the geometric mean particle size of the two largest fractions expected to be in motion (16mm and 32mm) was used, which resulted in a D_p of 22.6mm for use in the Shield's equation. Figure 56 A-C includes color-coded maps of shear stress with model results from three different discharges; 500 cfs, 700 cfs and 825 cfs. All three scenarios used a lake level of 4,486 feet asl. The plot shows immobile areas as green, barely mobile areas as white, mobile areas as yellow, highly mobile areas as orange and extremely mobile areas as red. The proposed channel in the River Reach is easily capable of mobilizing the sediment sizes that are likely to be delivered to it, in addition to those smaller sizes that will be added during construction (1.5-inch minus) even with discharges as low as 500 cfs. When lake levels are high, such as compromise elevation of approximately 4489 feet asl, the distribution of shear stress is nearly identical to those shown in Figure 56.

In summary, the river will be able to transport the sizes of sediments that are likely to be delivered to it, because the reach immediately upstream of the site only transports smaller material and doesn't mobilize the larger material in the bed on a frequent basis. Note the areas of low shear stress in the Provo river channel upstream of the Lakeshore Drive bridge.

Deltas are typically areas of sediment deposition and accumulation, as moving streamflow transitions to still lake conditions. Deposition is most likely to occur in the PRDRP near the transition between the River Zone and the Delta Zone, where velocities and shear stresses drop abruptly.

8 Construction Issues

8.1 Construction Team

Allred Restoration will be working closely with experienced crews from the USBOR during the construction of this reach. The key members of this design and construction team have been working together for 20 years and have a track record of implementing successful projects using the partial design/build approach.

8.2 Fill Material

The excavation work that is needed for the proposed design will generate large volumes of excess fill, perhaps as much as 400,000 cubic yards. Figure 57 shows a map of cut and fill for the project area, with fill areas in red and cut areas in blue: increasing color intensity signifies greater change in elevation.

Much of the fill (red) in Figure 57 is structural fill for berms and other engineered features, and those areas will not accept much fill from excavation of delta channels and ponds because it is mostly silt, sand and peat. Some of the fill generated by excavation will be used to create topographic variations, such as riparian mounds and other features within the project, but most of the fill will be excess and must be trucked offsite. There are limited areas within the delta where fill can be placed without impacting existing wetlands. Figure 2 shows locations that have been identified where fill material will be placed and contoured to create additional habitat diversity and offer options for trail routing, etc. Volume estimates suggest that these locations would hold no more than 100,000 cubic yards of spoil material; thus, additional areas and/or off-site disposal options are needed.

Provo City has reviewed the soil testing data that has been collected within the project area and has agreed to accept up to 2 million cubic yards of excess fill material for a planned sports park, located relatively close to the PRDRP project area. However, the spoil will need to be loaded onto trucks and delivered to the sports park area. Relocation of the excess fill represents a substantial cost for the project but cannot be avoided, given the current project boundary, if project goals for aquatic habitat creation are to be met.

BOR crews will be busy excavating project features, so loading the excess fill and trucking it to the site will likely fall to a contractor. BOR has agreed to make those arrangements.

The proposed sequence of events to allow trucking of fill material offsite includes:

- grubbing organic soils, lining with geotextile fabric, and backfilling the footprint of the south berm (Figure 58) with compacted structural fill to create a haul road that includes four temporary turnaround locations large enough for side-dump trucks (in tandem) to turn without backing up,
- creation and marking of designated temporary storage areas along the temporary haul road where excess fill will be placed (Figure 58),
- excavation and hauling of material to designated storage areas until those sites begin to fill,
- notification to contractor of need for trucking to commence,
- rapid removal of excess fill via large trucks.

This sequence of events will avoid constant traffic on the haul road by concentrating the trucking offsite to short time windows. The contractor will need to possess sufficient resources, when called upon, to rapidly mobilize and remove the stockpiled fill.

8.3 Water Management

Construction activities in the delta will require a plan to handle excess water that will accumulate within the excavated features. Agricultural management in the area currently includes operation of pumps that are located near Utah Lake State Park. These pumps remove accumulated water by pumping it into Utah Lake.

Water flows to that location (Figure 59) via a series of existing drains and ditches. The existing pumps require repairs and are not currently functional, and their location, which is south of the project boundary, does not provide a useful way to efficiently remove excess water from project features. Instead, BOR crews will need to install new temporary pumps along Skipper Bay Dike that can be used to pump water over the dike and into Utah Lake. One possible location for temporary pumping is shown in Figure 59, but other sites may be required. The existing dike includes a popular trail and efforts will be made to limit inconvenience for people traveling on the trail.

Each year following construction, revegetation efforts will commence, and establishing bulrush and other desirable plants will be difficult if water levels are too low in completed areas. Thus, project managers will need to weigh the need for deep water in excavated areas against the need to work with heavy equipment in dry conditions. Completed areas will be separated from future work zones using soil plugs or other flow limiting features, and pumping will be needed for construction in adjacent sites.

Two wells are present within the project area, and those wells may prove useful for providing water to revegetation sites during construction. The wells may be relocated after construction is completed, but those plans are not set.

8.4 Geotechnical Analyses

Based on soil testing within the project area (see Appendix A for soils maps) most of the excavated material will be silt or sand, with some peat soils. The BOR is still awaiting their geotechnical analyses for the berm, small dam and other areas, so no conclusive results are available for those locations.

The ability to directly use large equipment for the excavation work that is needed to implement the proposed design is uncertain, given the likelihood of deep mud within the project area. Large haul trucks may not be operable in many areas without considerable preparatory work, so plans are underway to procure tracked haul trucks for use in muddy locations. Temporary access roads and other features may be required to allow large equipment access to the site, but the conditions within the delta are highly unpredictable and will likely change with recent weather, lake levels. etc. The design team will need to work closely with USBOR management and other operators to determine the proper course of action for PRDRP implementation.

9 Proposed Construction Schedule

Land acquisition is now complete and major construction is set to begin in March of 2020. Figure 59 (previous) shows (1) the temporary berm haul road that will be constructed first to allow major excavation activities to commence, and (2) the target area for excavation in 2020. The proposed 2020 construction includes many features and will be challenging to complete in one year. The likelihood of completing these features in a single year will increase if the winter and spring are relatively dry, and if lake levels are lower than average.

When the last major parcel of land for the project was acquired, the landowner requested the right to graze cattle on a portion of the land for one year. This access was granted, and the location of the proposed pasture is shown in Figure 59 (previous).

The following schedule is provided as the best estimate of major project milestones (Figure 60). The proposed schedule has been revised from earlier versions and currently includes 3 years for construction activities in the delta and a fourth year to complete features in the existing Provo River channel.

10 Summary and Conclusions

The PRDRP has been designed with a focus on providing June sucker rearing habitat, which has been eliminated almost completely from the Provo River/Utah Lake interface under existing conditions. The proposed design creates a myriad of riparian and aquatic habitats that will persist at all Utah Lake levels and provide cover for vulnerable June sucker fry and juveniles while allowing adult fish to enter the channel and swim upstream to spawn.

The delta environment that will be created offers a diverse and productive ecosystem with a wealth of habitats to meet the needs of the June sucker Other organisms that evolved under similar conditions may also benefit.

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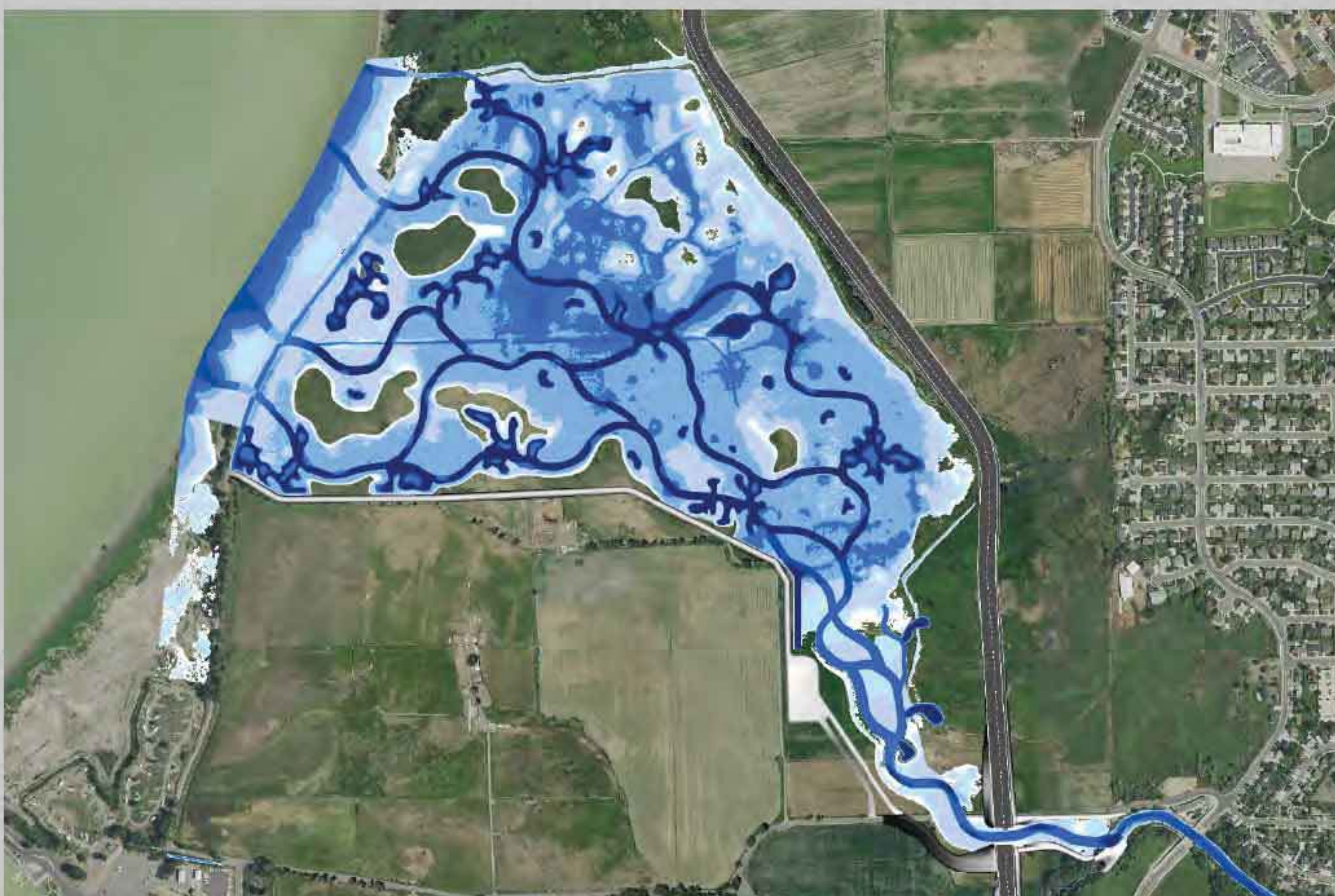
FIGURES TO ACCOMPANY DESIGN REPORT TEXT

Provo River Delta Restoration Project
Sept 2019



Prepared for: Utah Reclamation Mitigation and Conservation Commission

Prepared by: Allred Restoration and BIO-

BIO-WEST

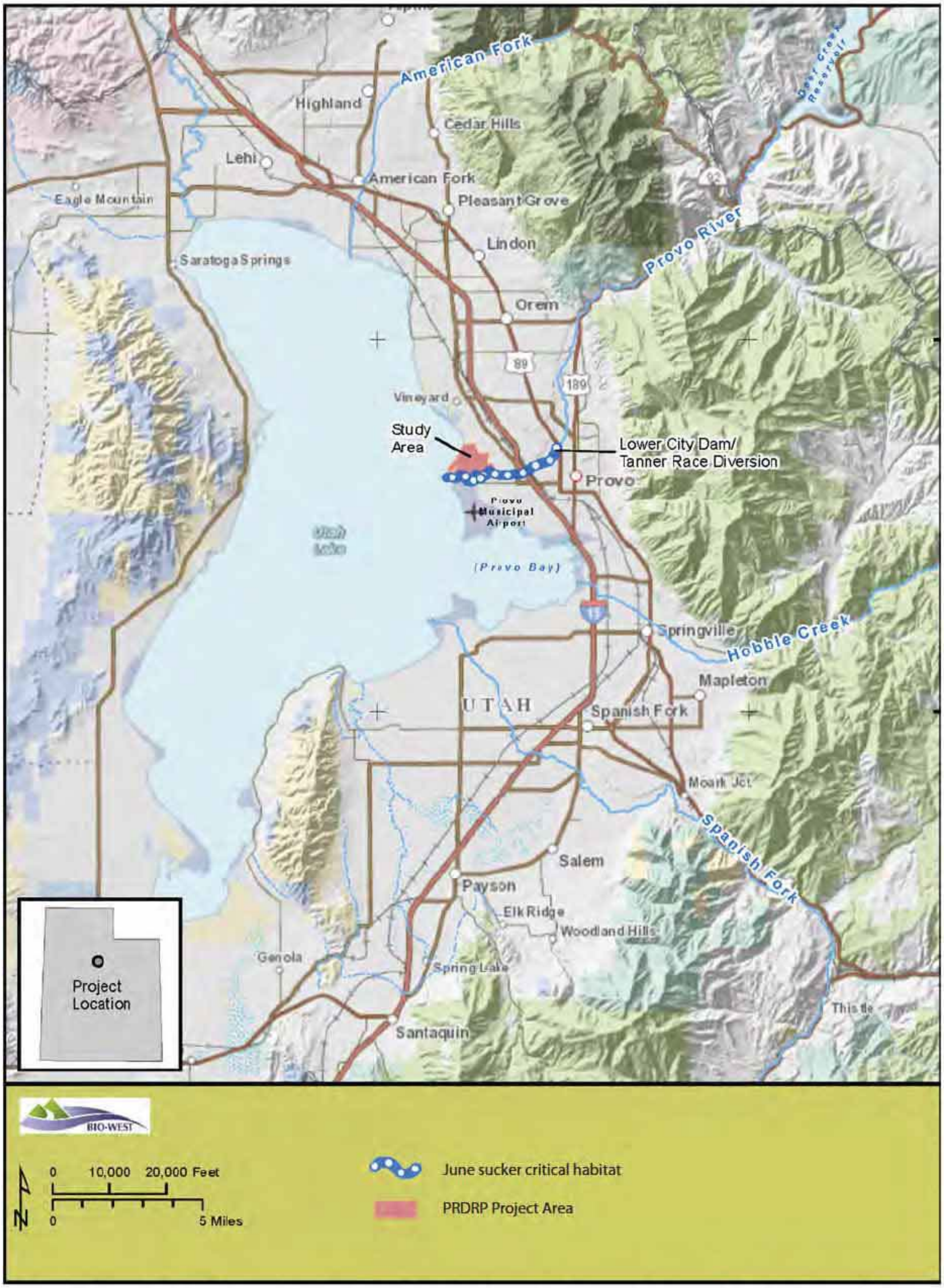


Figure 1. Provo Delta Restoration Project (PRDRP) vicinity map, showing the location of June sucker critical habitat.

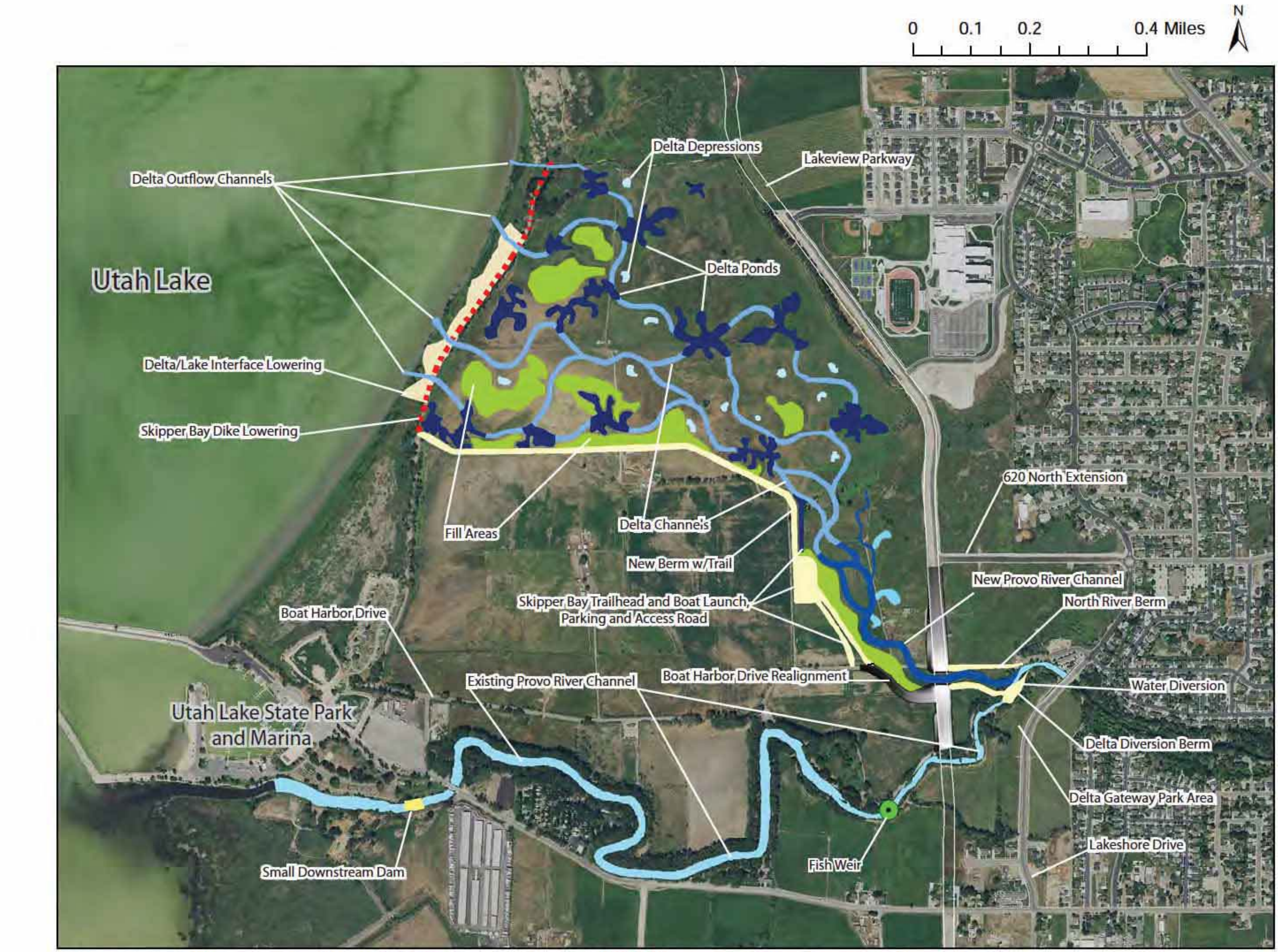


Figure 2. Aerial image of the Provo Delta Restoration Project (PRDRP) area, showing the general location of many important components of the project.

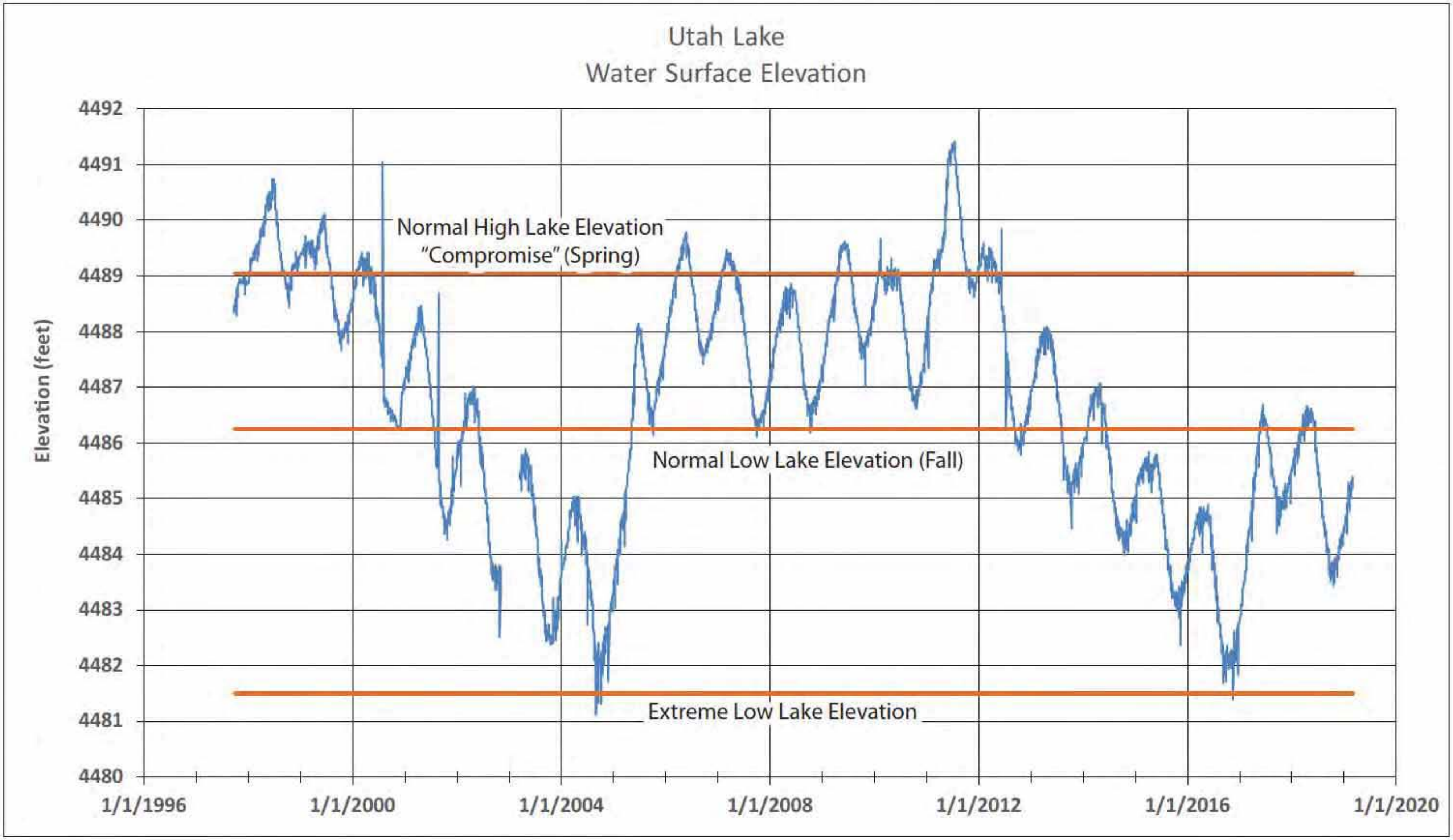


Figure 3. Plot of measured lake levels from 1997 to 2019.

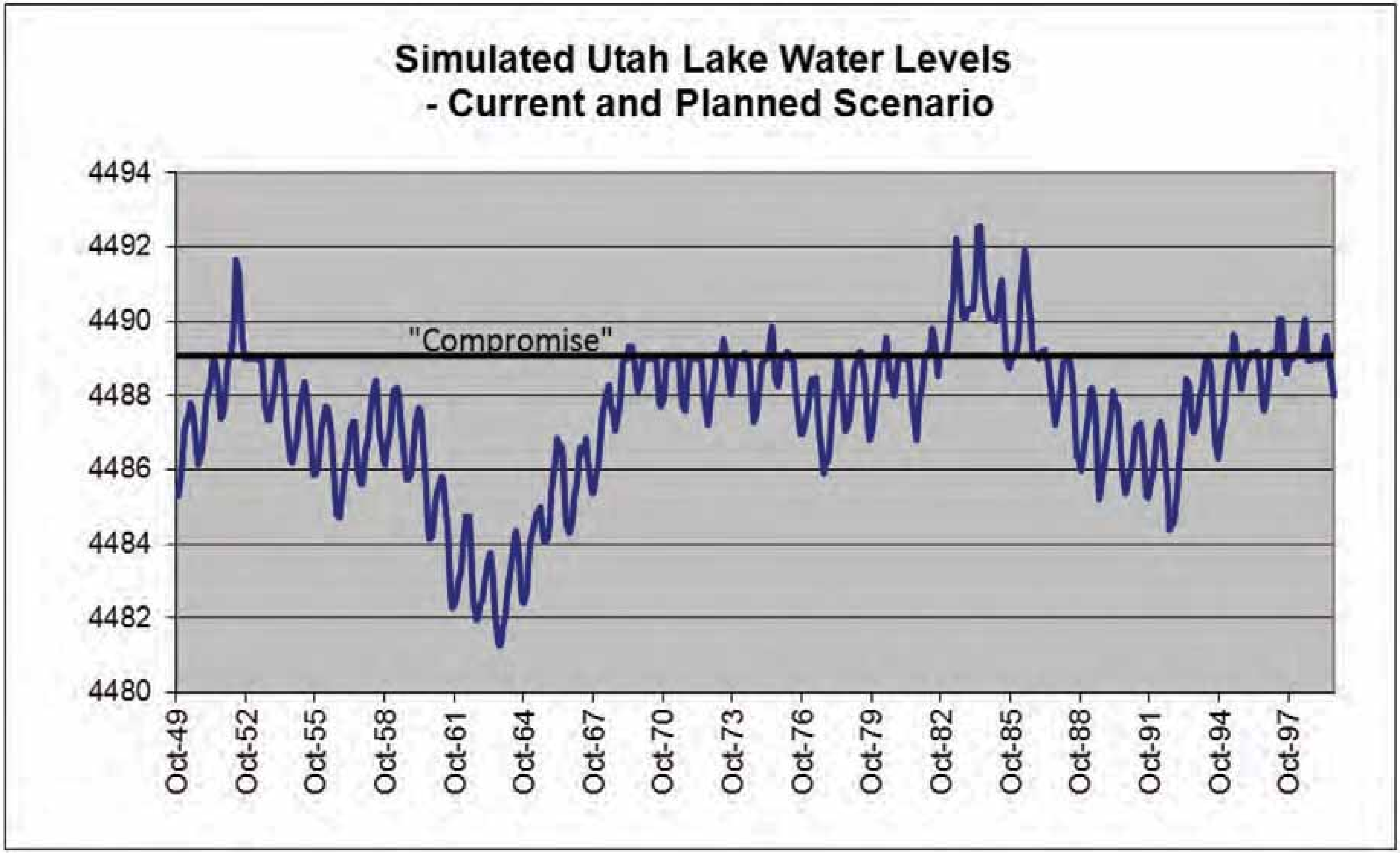


Figure 4. Plot of simulated lake levels based on 50 years of data, as described in the Utah Lake Drainage Basin Water Delivery System Environmental Impact Statement.

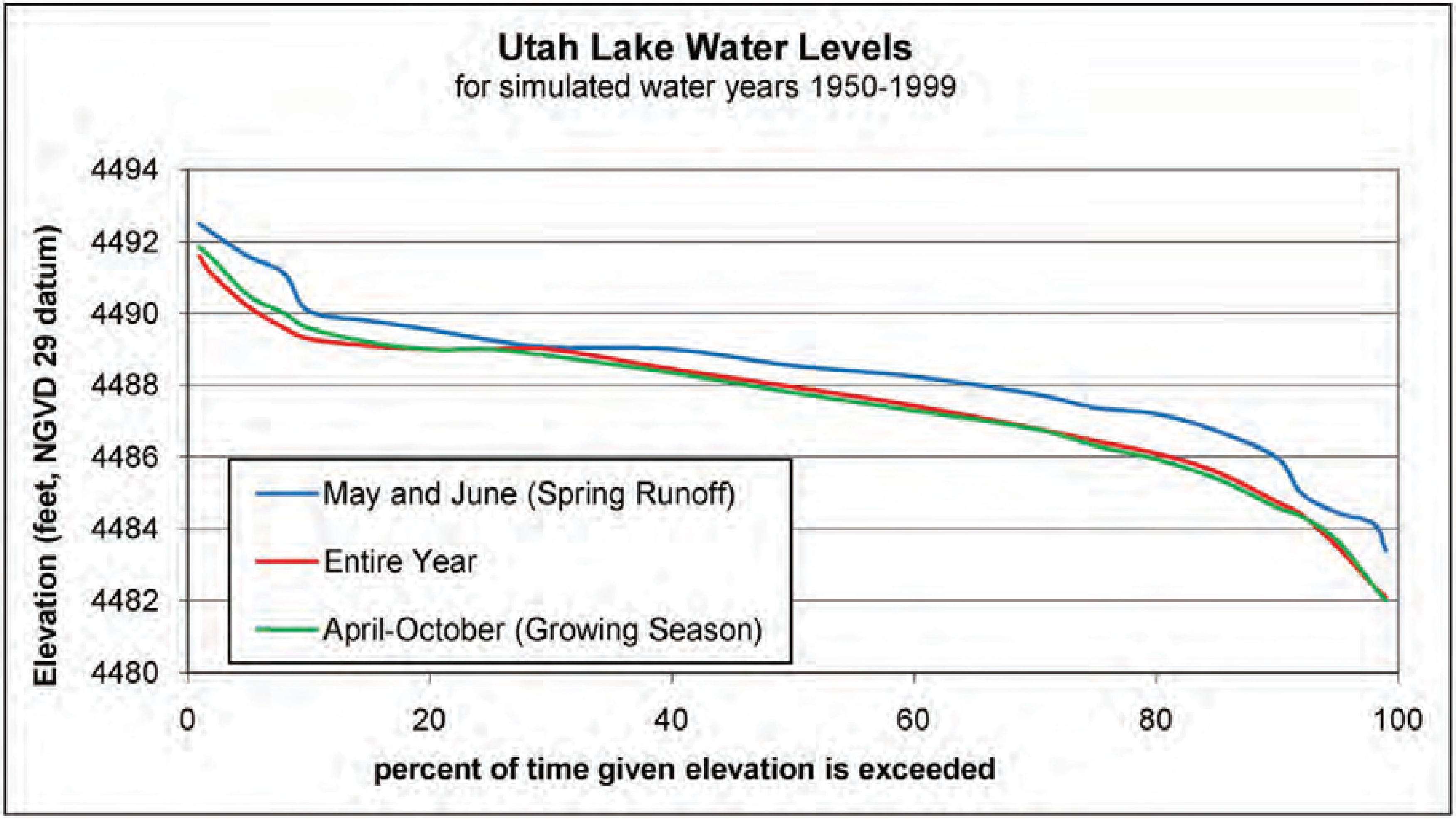


Figure 5. Plot of simulated lake level duration based on 50 years of data, showing seasonal variability.

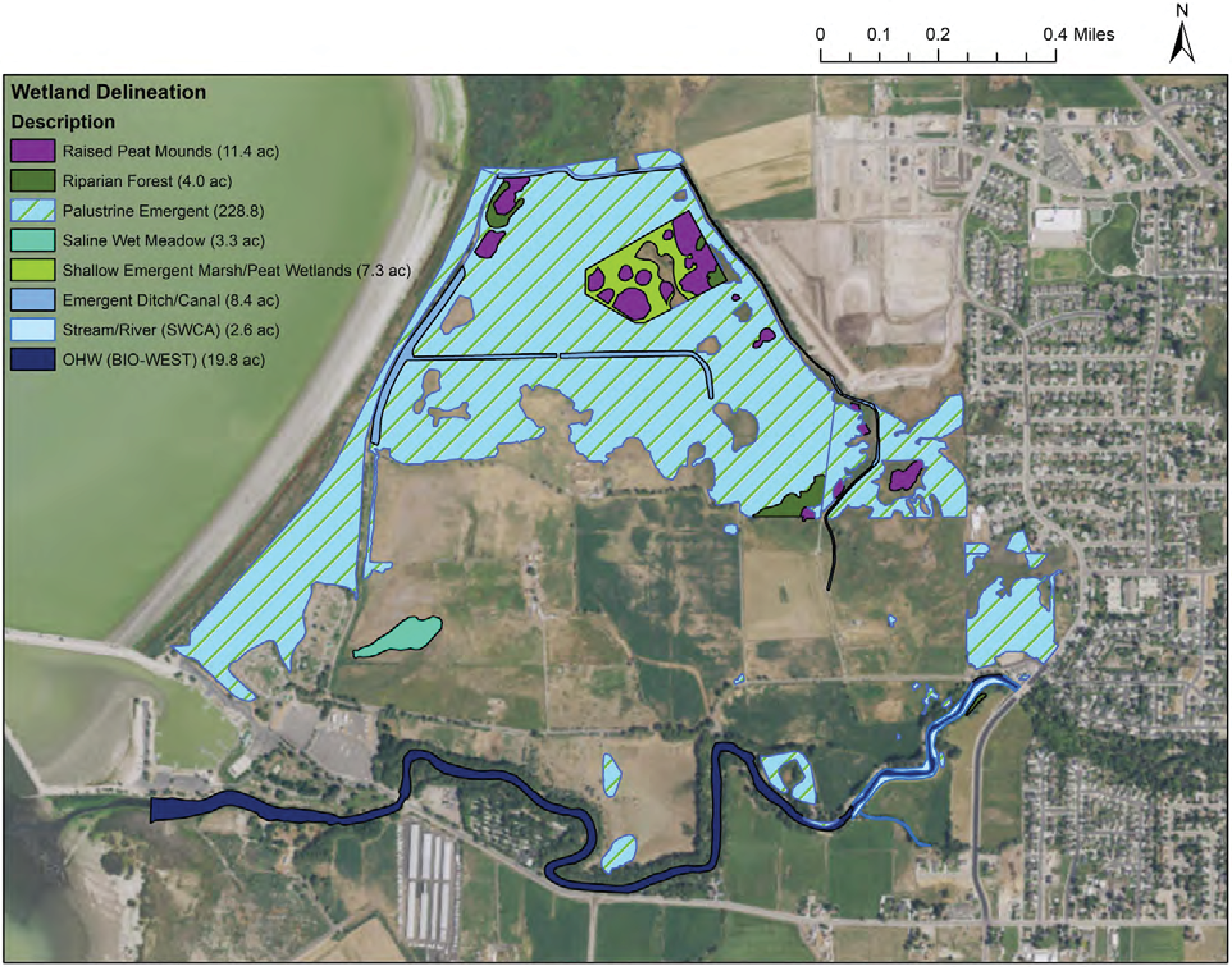


Figure 6. Wetland map of the project area, based on 2016 update of delineations completed in 2011 and 2012.

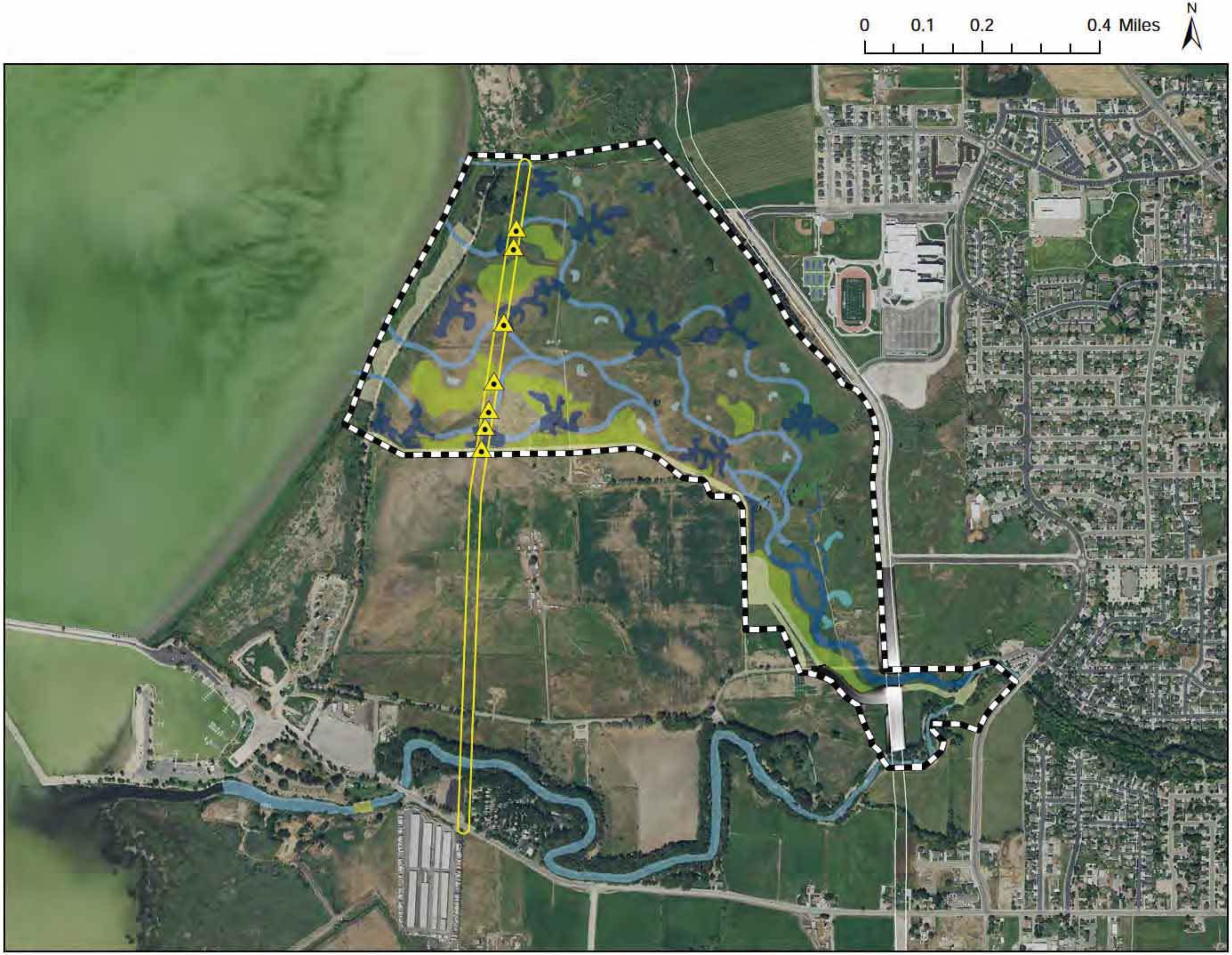


Figure 7. Map showing the location where a natural gas pipeline was surveyed in the field (triangles) and a rough location where the new pipeline will be placed (yellow outline). The new pipeline will be buried deep enough to avoid any safety issues for construction.

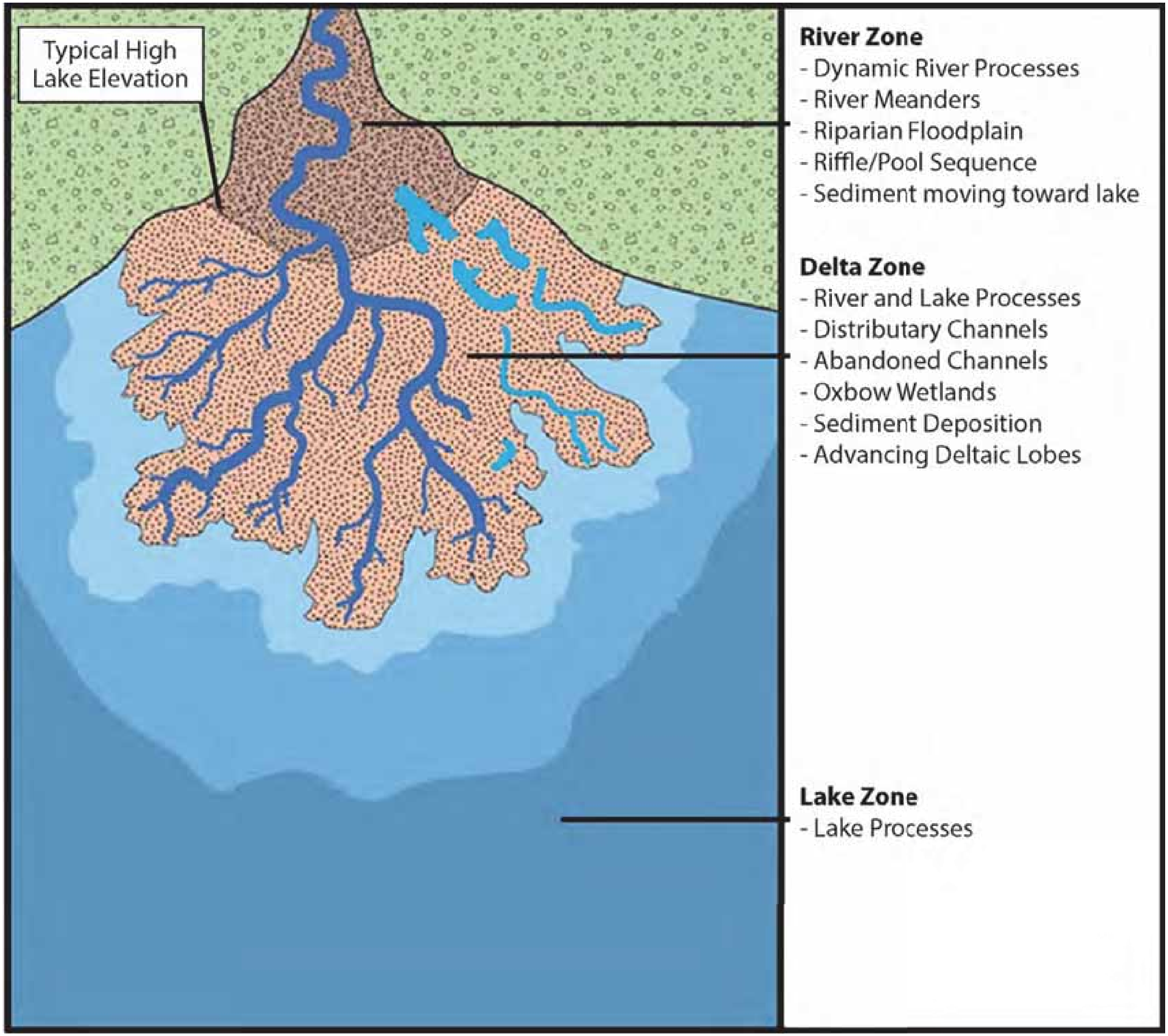


Figure 8. River delta zone map that describes characteristic zones found in river deltas worldwide.

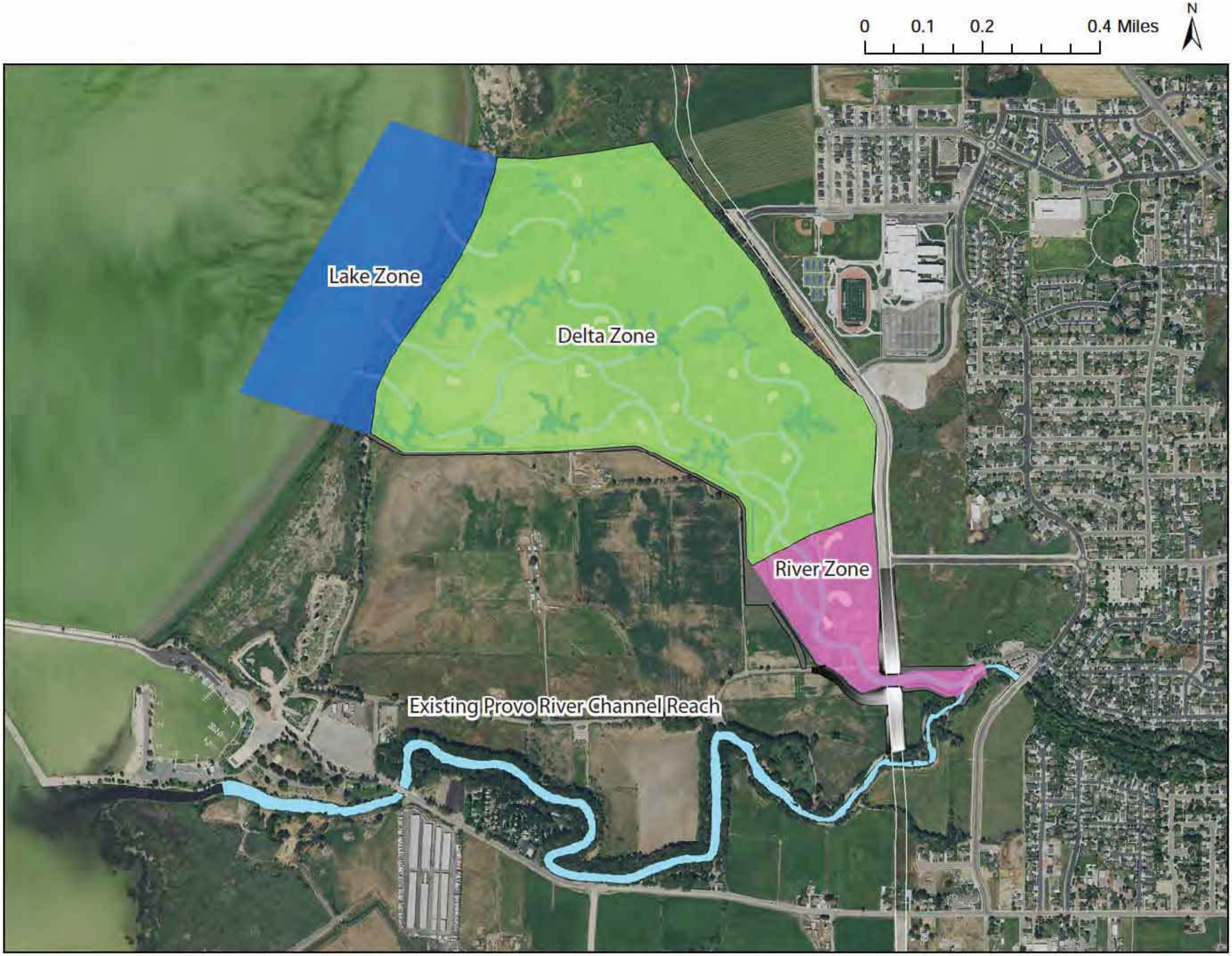


Figure 9. Map of project area showing the major design zones included in this report.

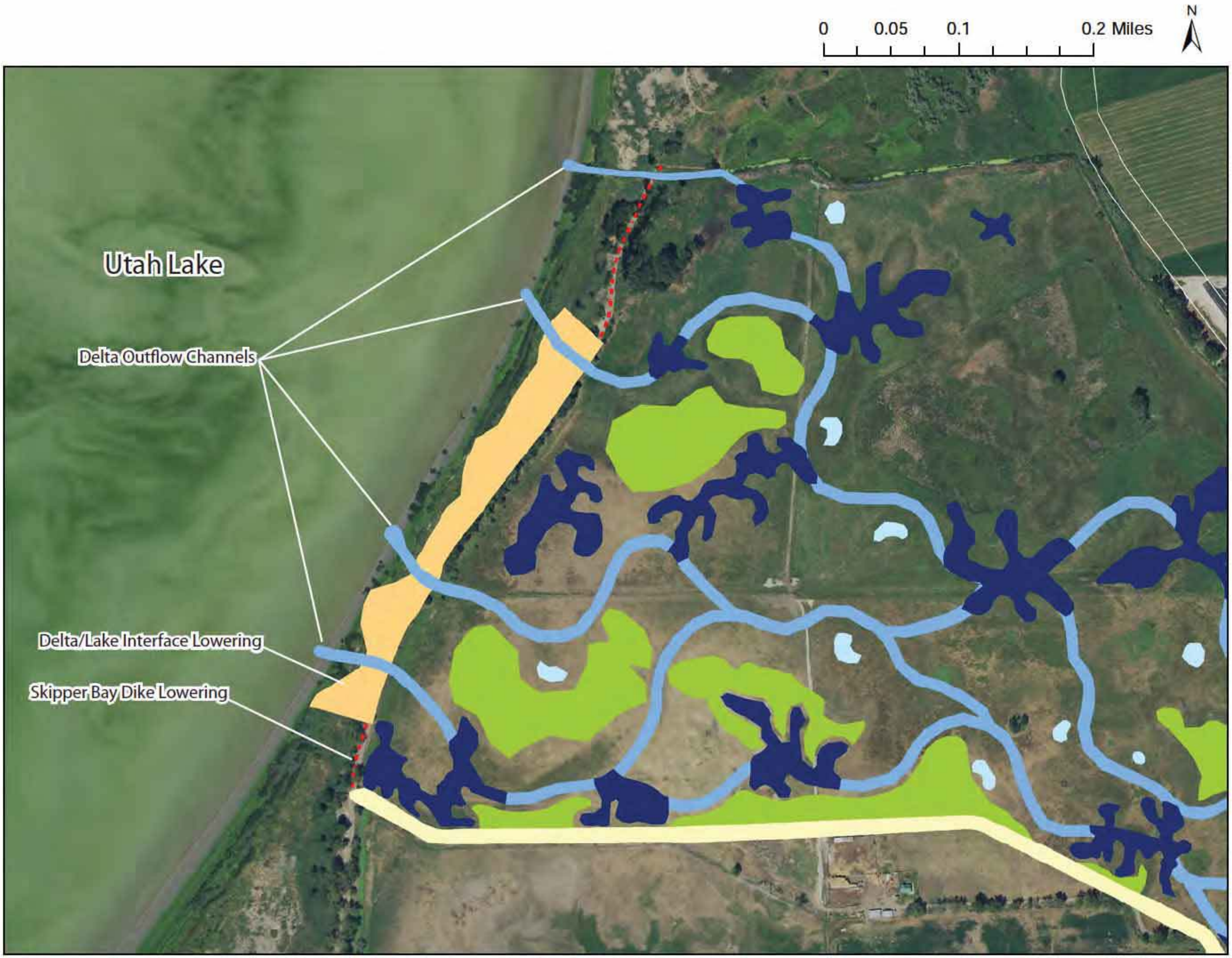


Figure 10. Map showing (1) the delta outflow channels, (2) the delta/lake interface area that will be lowered to an elevation of approx. 4488 feet asl and (3) linear areas where the asphalt trail will be removed and Skipper Bay Dike lowered to match local topography.

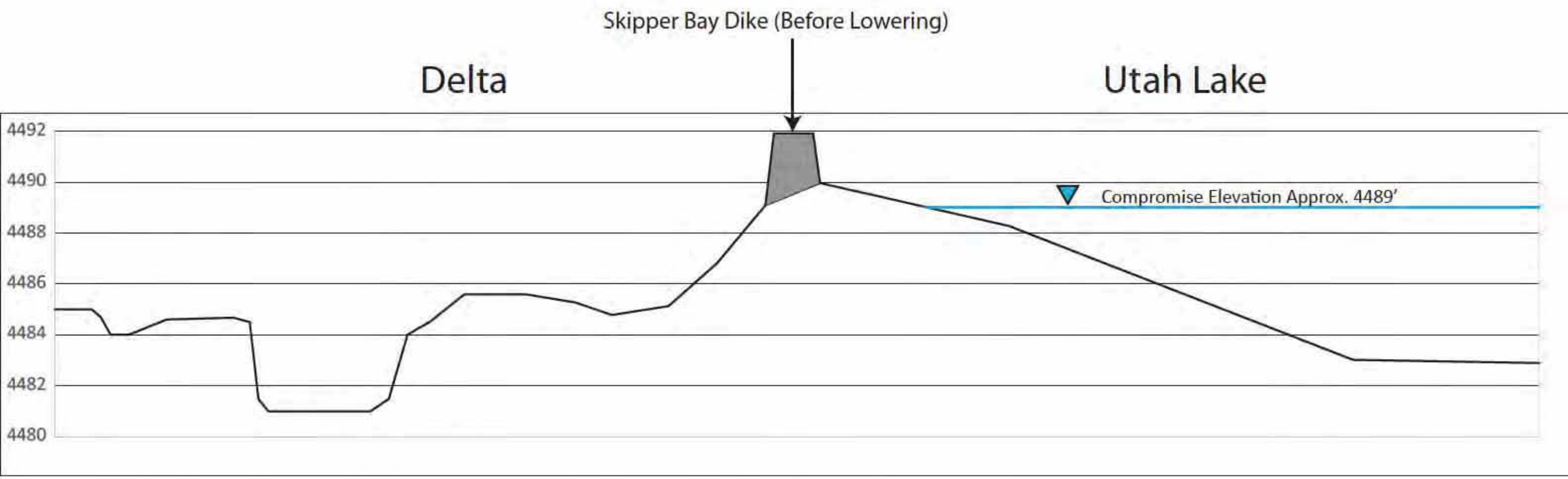


Figure 11. Existing condition and function of Skipper Bay Dike.

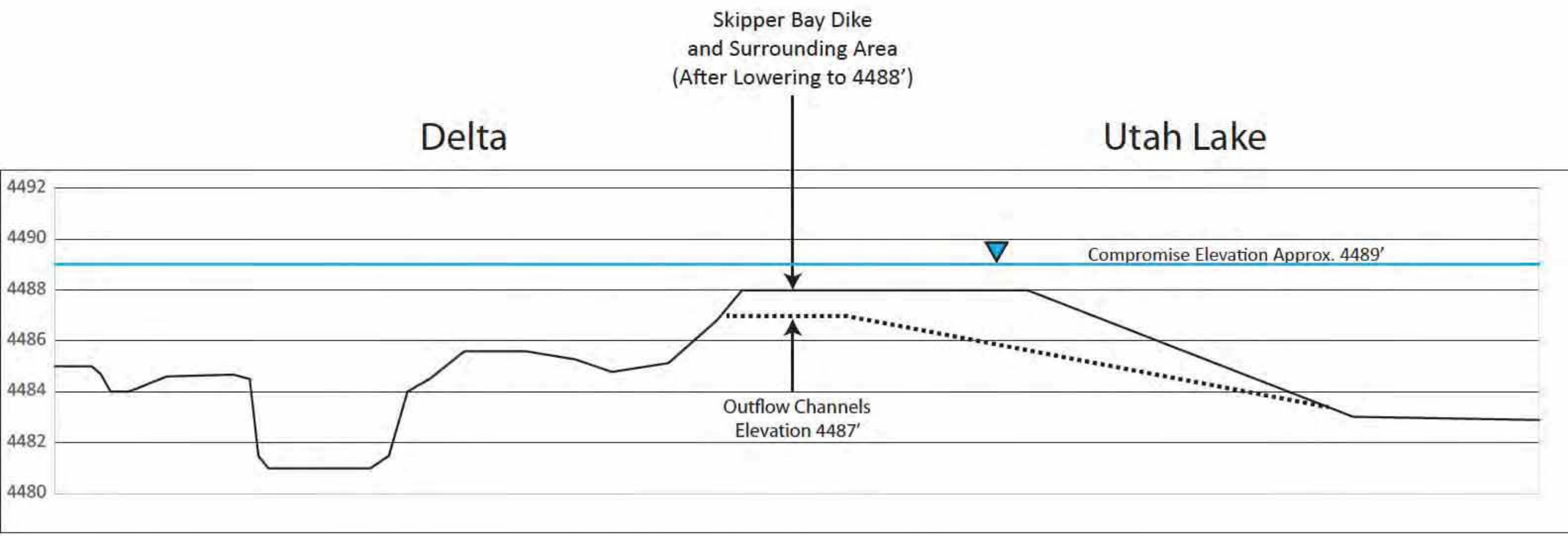


Figure 12. Proposed condition and function of Skipper Bay Dike area after lowering.

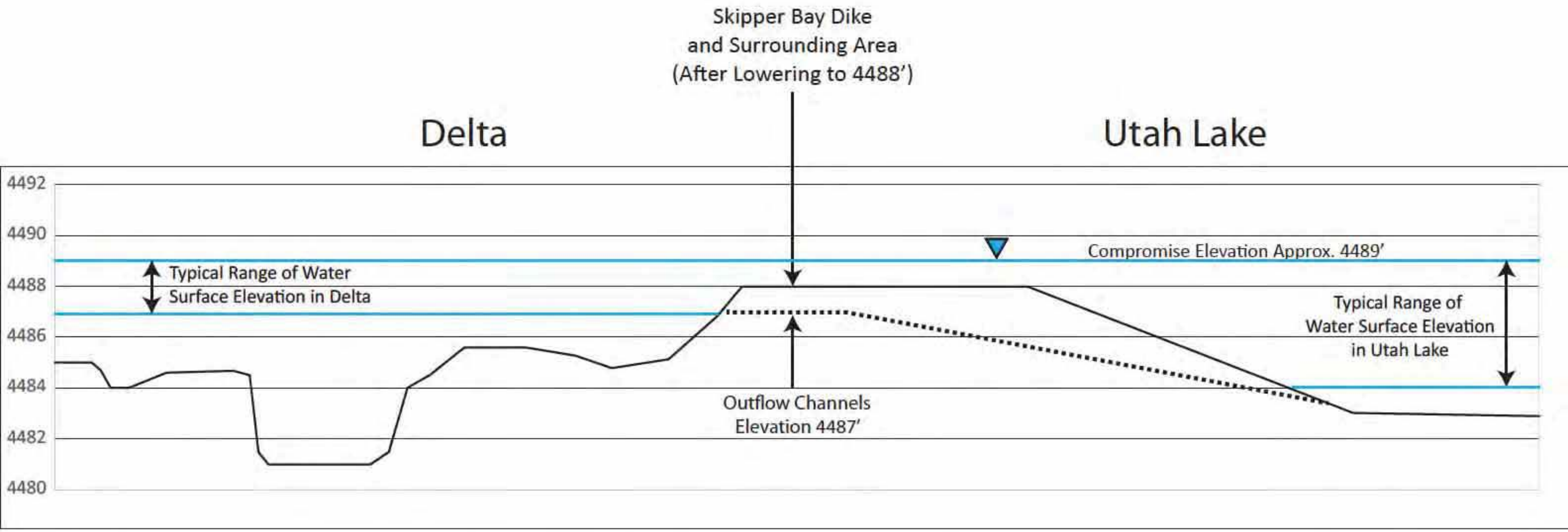


Figure 13. Proposed function of Skipper Bay Dike after lowering. When Utah Lake water levels are low, Skipper Bay Dike creates a backwater in the delta that will maintain a diverse array of habitat and prevent the delta area from dewatering.

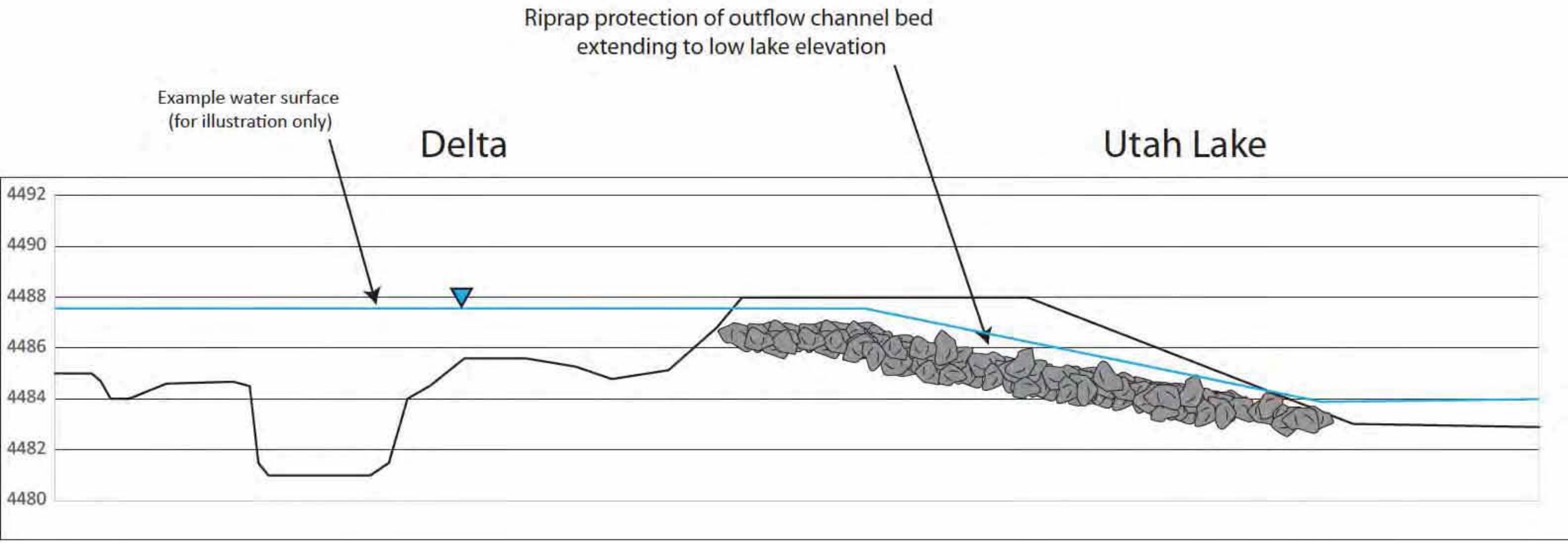


Figure 14. Rock protection of Skipper Bay Dike outlet channels to prevent downcutting during periods of low lake elevation and to allow fish passage for a wide range of streamflow conditions.

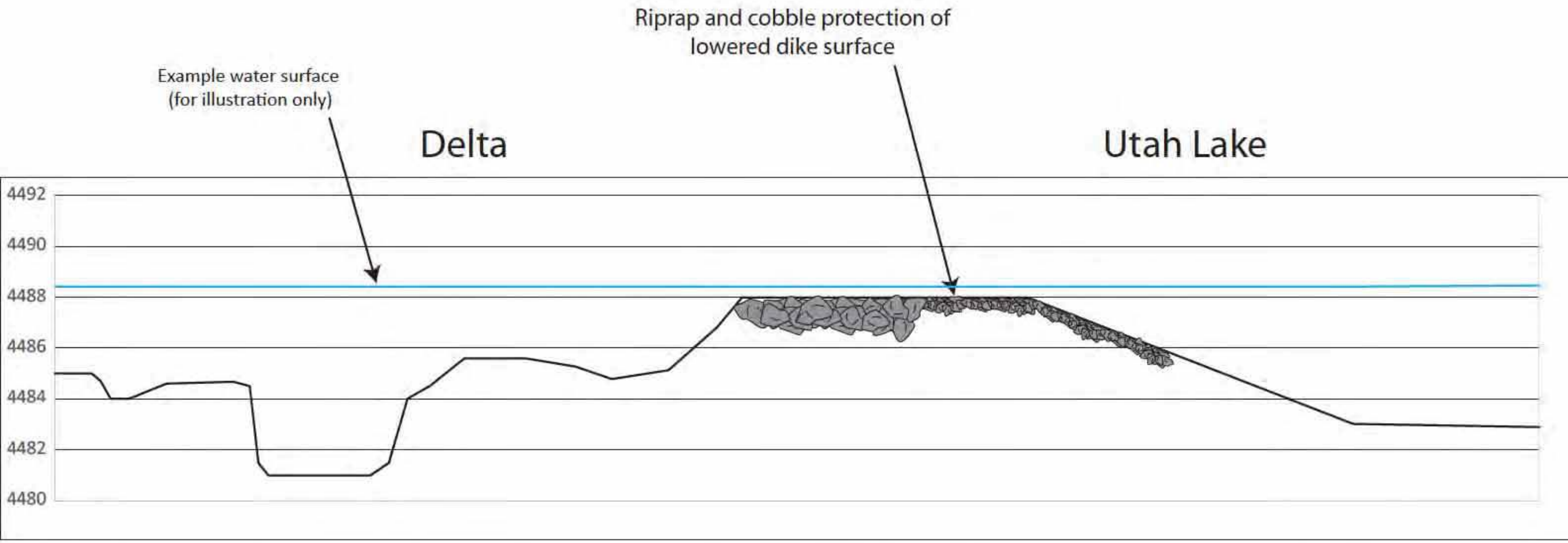


Figure 15. Rock and cobble protection of Skipper Bay Dike surface after lowering to prevent downcutting and to allow vehicle access for management activities.

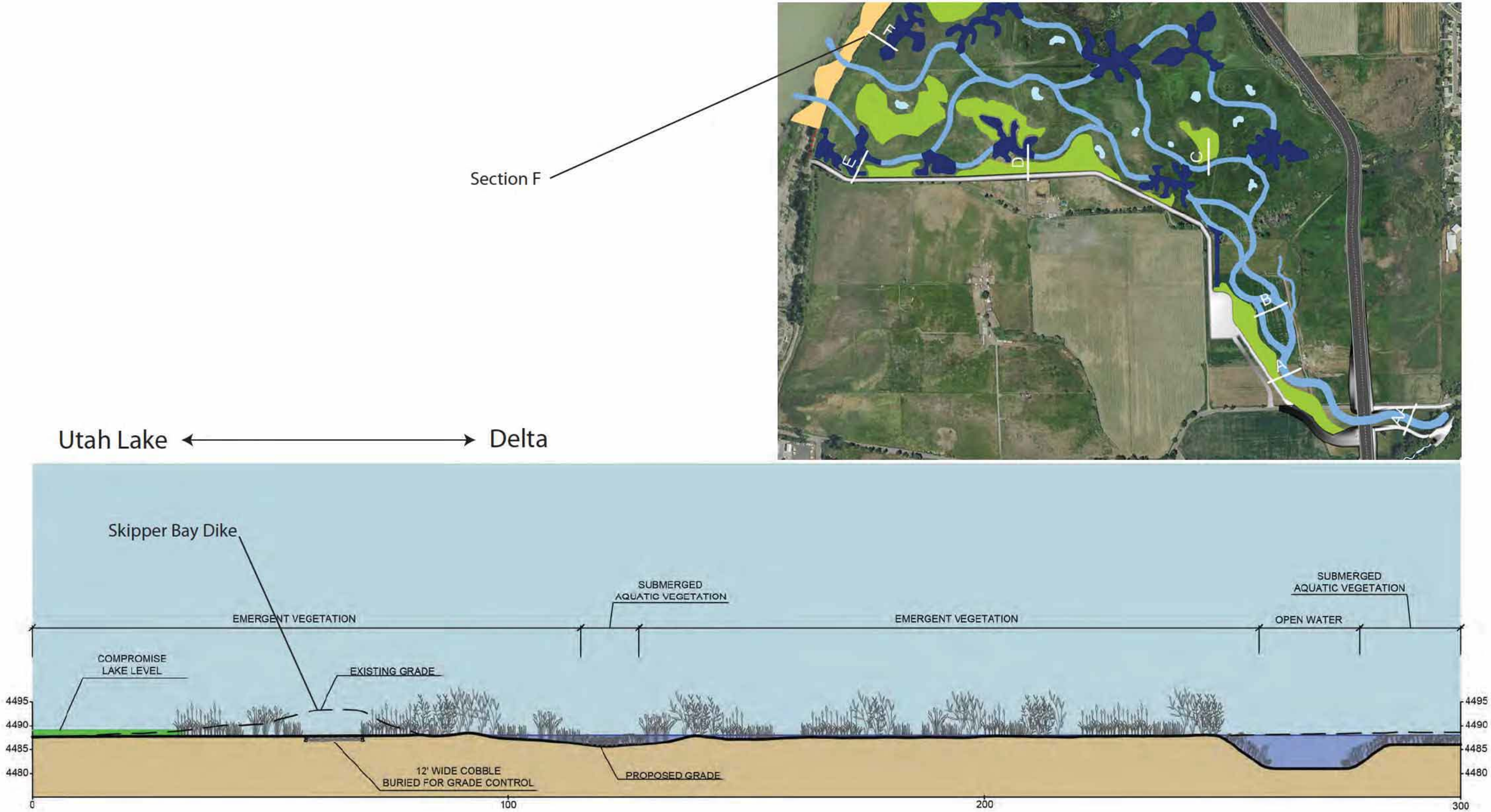


Figure 16. Typical cross-section view of the Skipper Bay dike removal area after construction, with revegetation zones shown. The illustration is from Appendix A where it is designated as "Cross Section F". Appendix A contains additional details on revegetation.

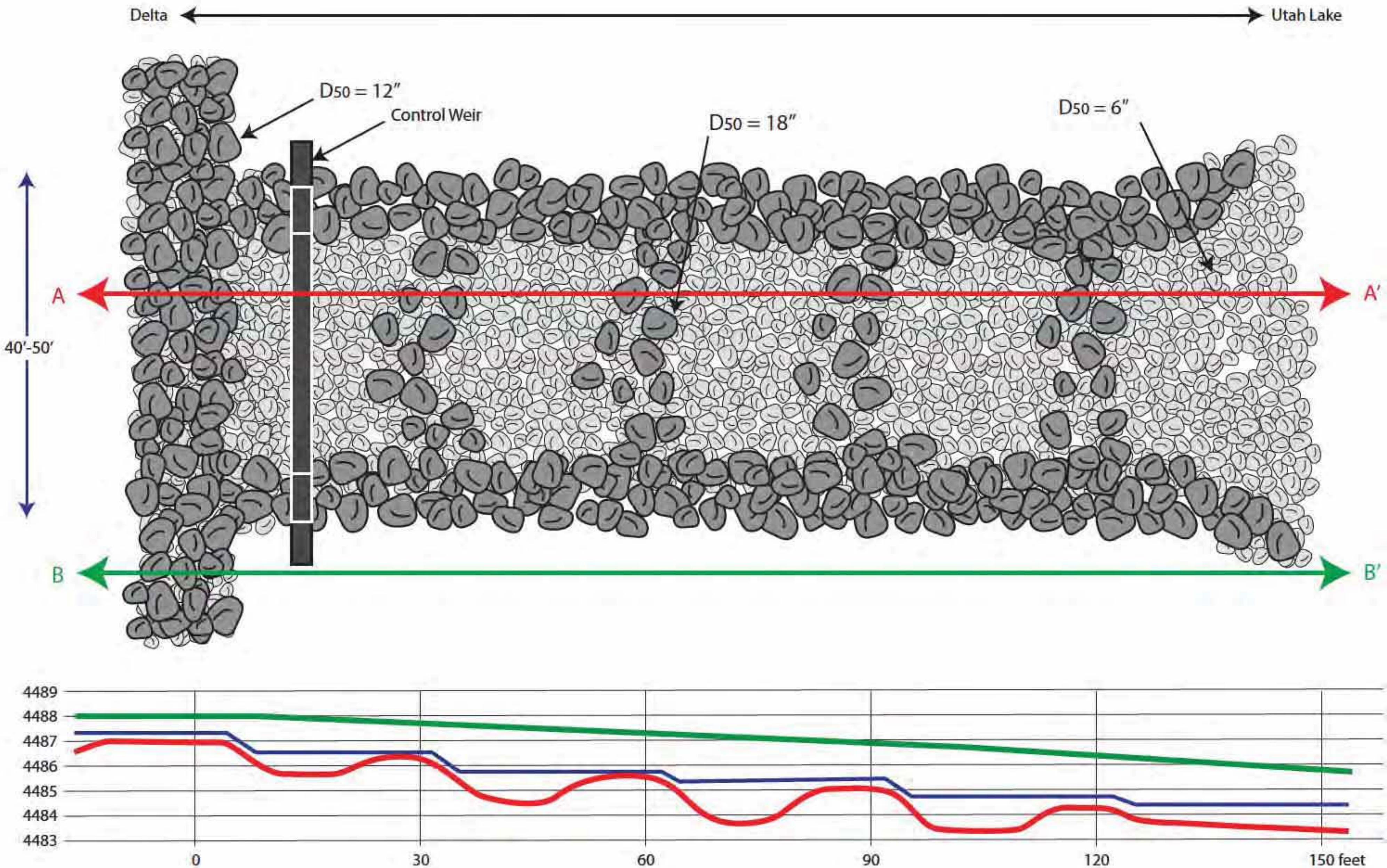


Figure 17. Sketch of a typical outlet channel with bed (red), bank (green) and water surface (blue) profiles.

Figure 18. Artist's rendering of a typical outflow channel, looking upstream toward the delta. The loosely-organized arching rock structures will help to slow velocities and promote fish passage when lake levels are lower than the lowered dike.

Figure 19. Artists rendering of a typical outflow channel with a picket fish-passage barrier installed. This configuration, or something similar could be used to limit movement of invasive predatory fish like pike or musky.

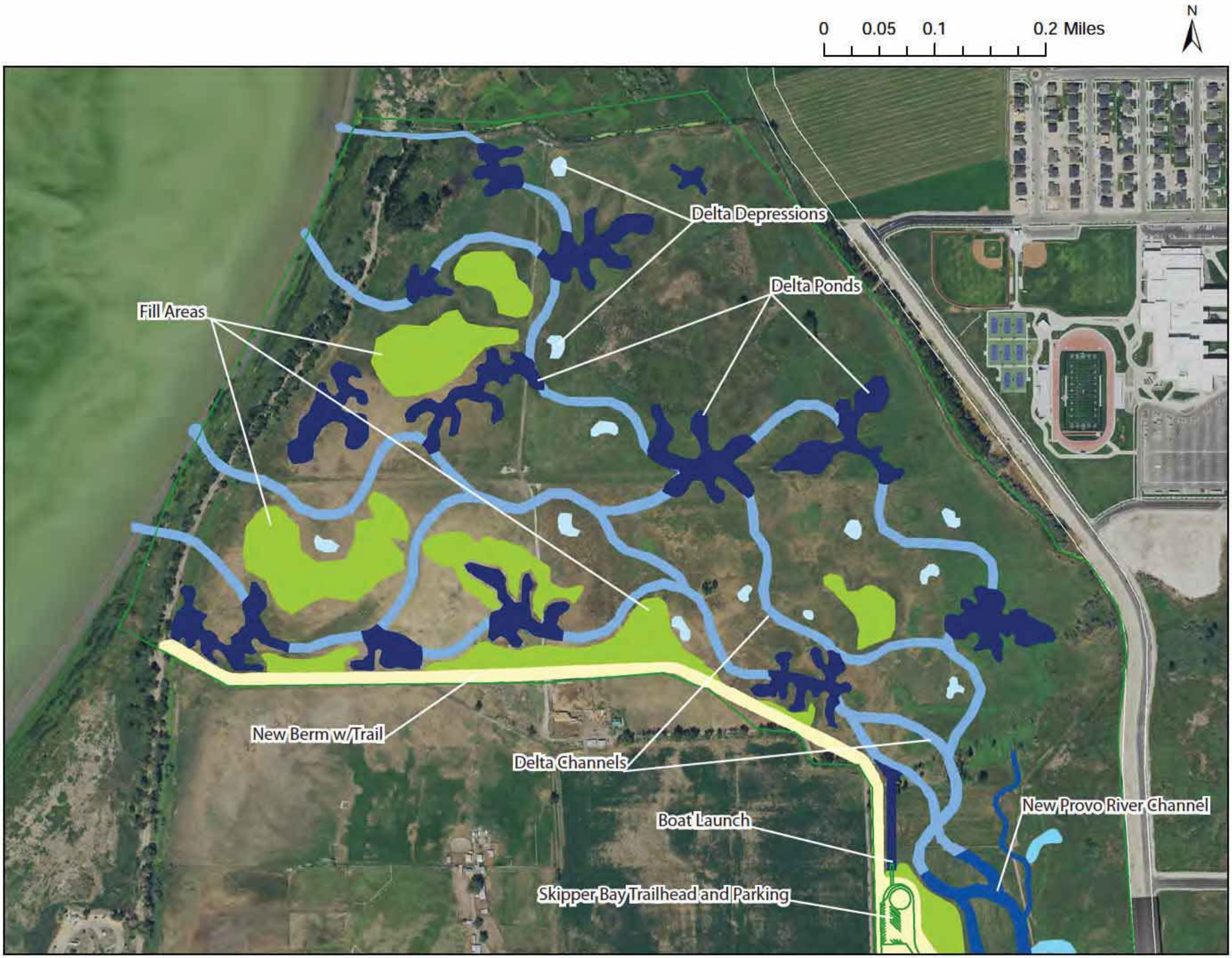


Figure 20. Map of project features in the "Delta Zone".

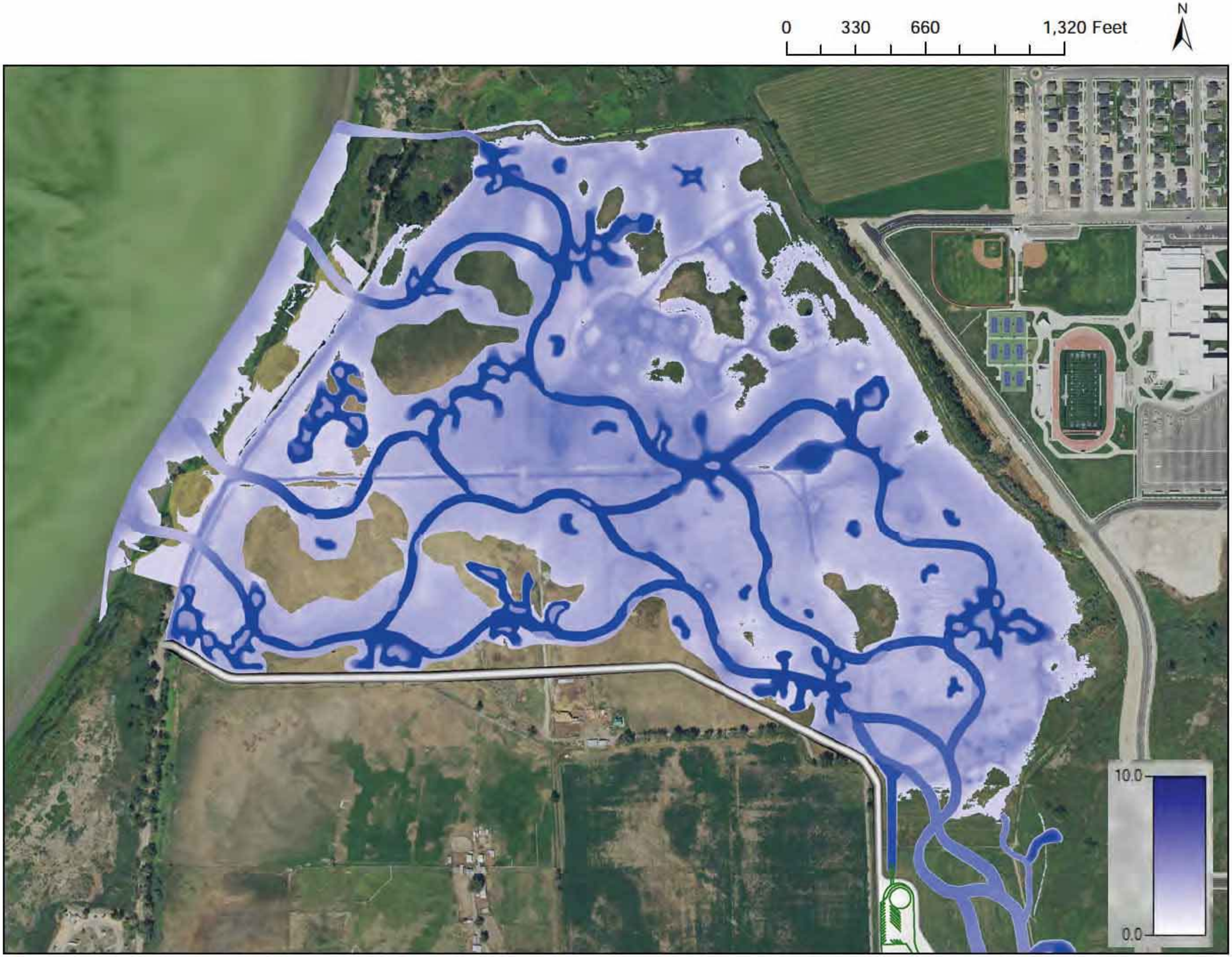


Figure 21. Map of typical variation and complexity in water depth within the "Delta Zone", based on the proposed design. The maximim depth in the delta is somewhat dependant on river discharge and lake level, but is typically between 7 and 10 feet.

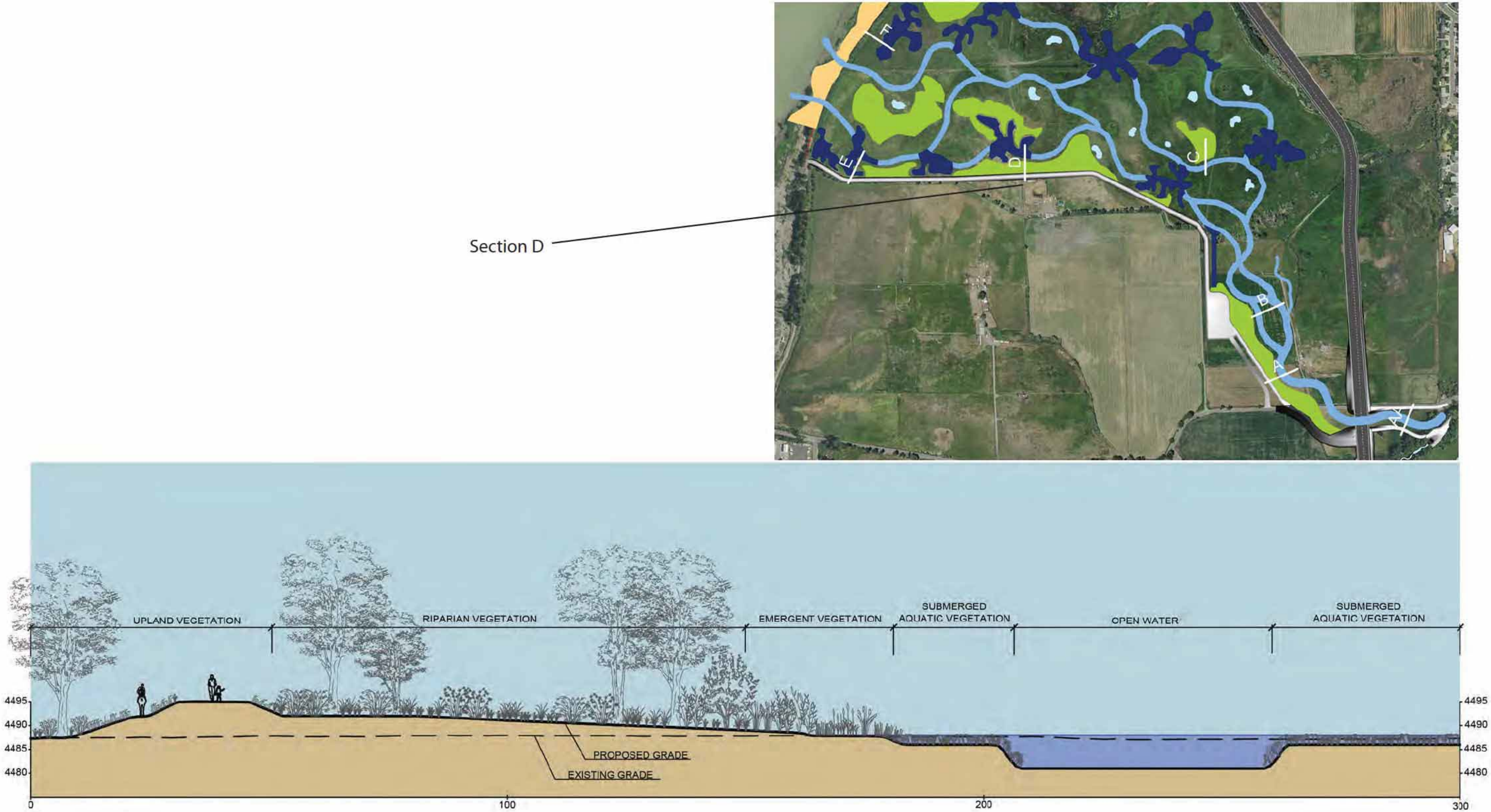


Figure 22. Illustration of typical habitat complexity within the delta zone, showing vegetation community change with water depth. This illustration is from Appendix A where it is designated as "Cross Section D". Appendix A contains additional details on revegetation.

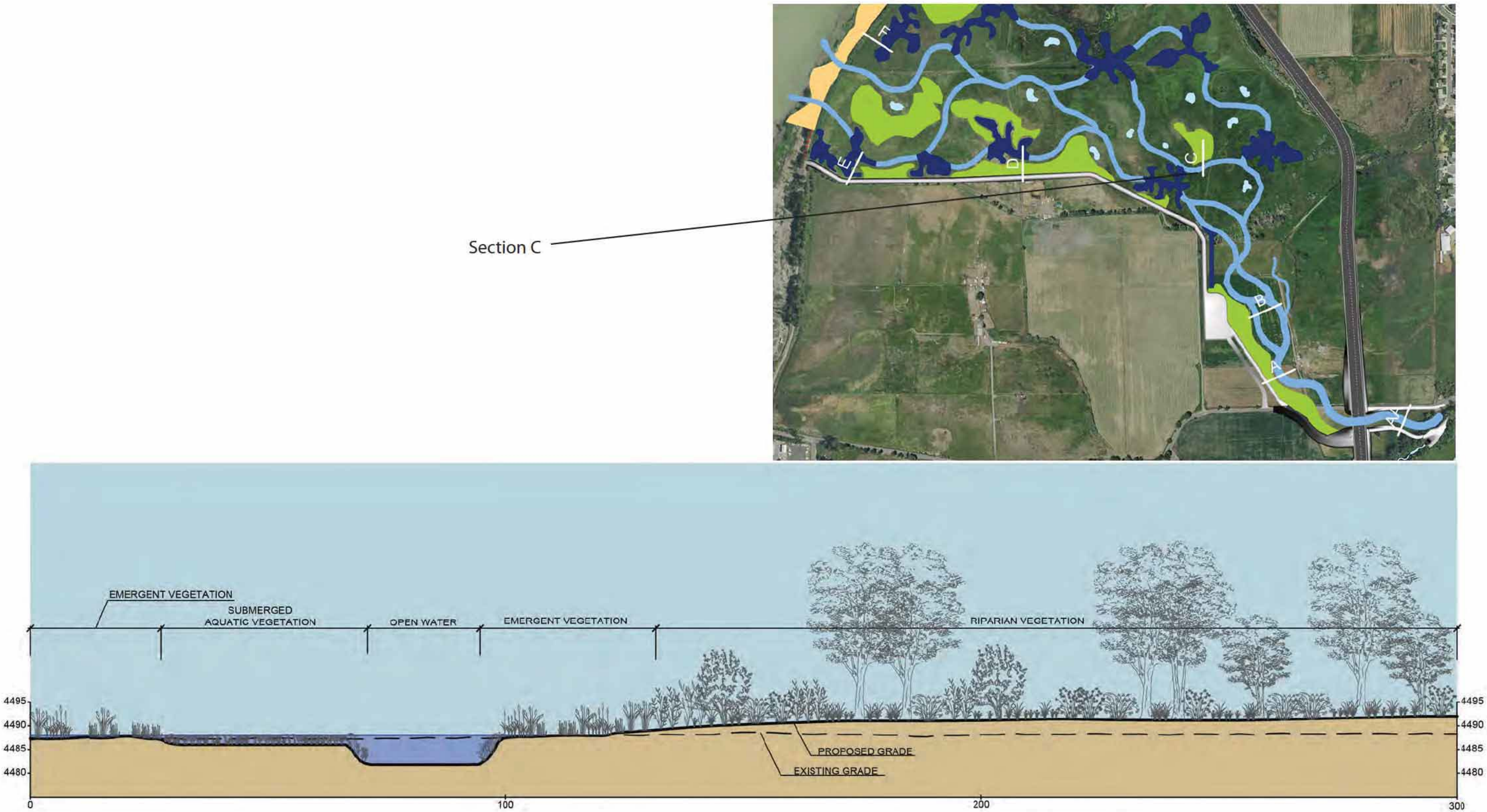


Figure 23. Illustration of typical habitat complexity around a delta channel and riparian area. The riparian area is created by adding fill to provide localized zones with higher elevations that will allow riparian vegetation to survive. Note that the margins of the channel are inundated. This illustration is from Appendix A where it is designated as "Cross Section C". Appendix A contains additional details on revegetation.

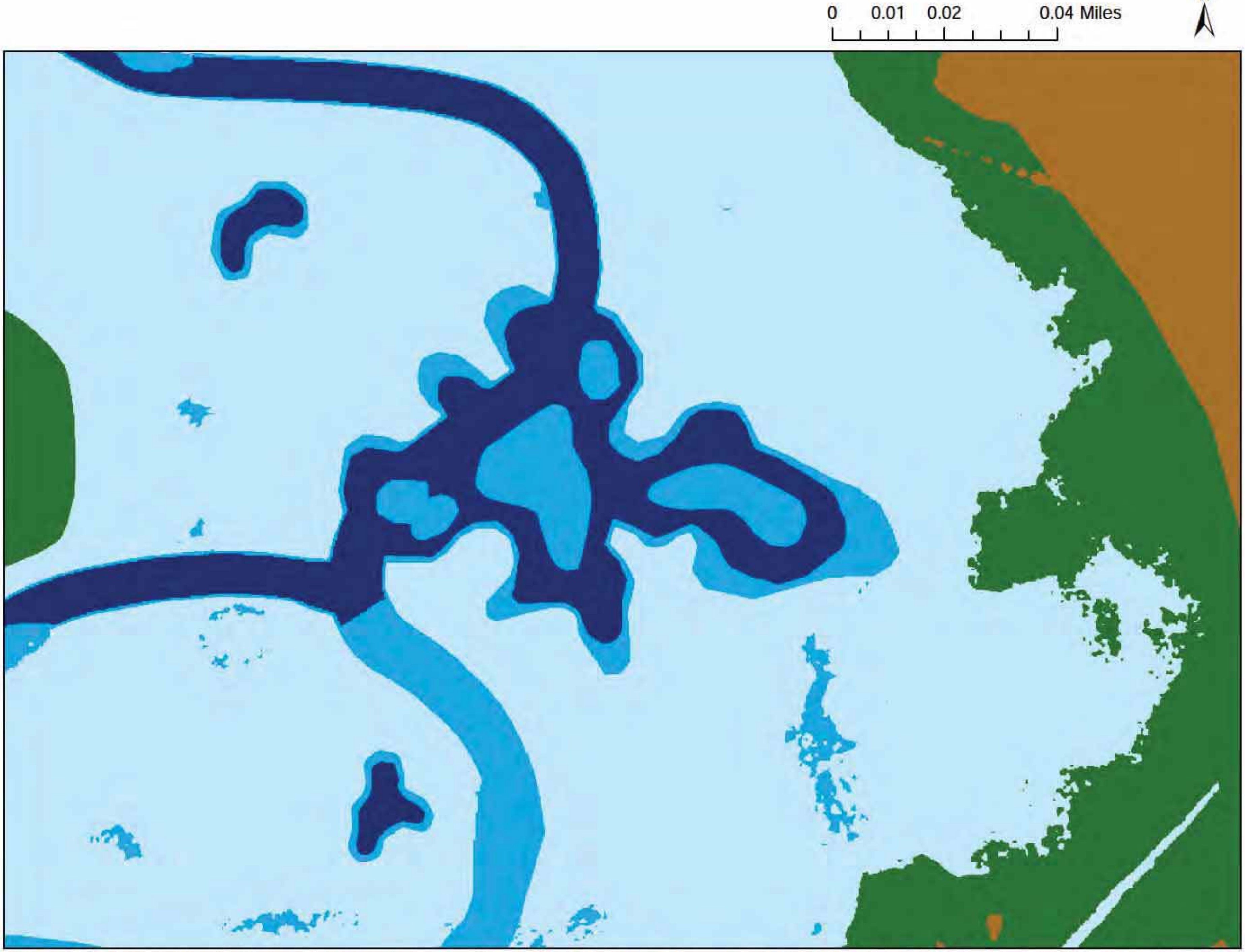


Figure 24. Illustration of proposed vegetation zones in a typical delta pond: open water (dk blue), submerged aquatic (med blue), emergent (lt blue), riparian (green) and upland (brown).

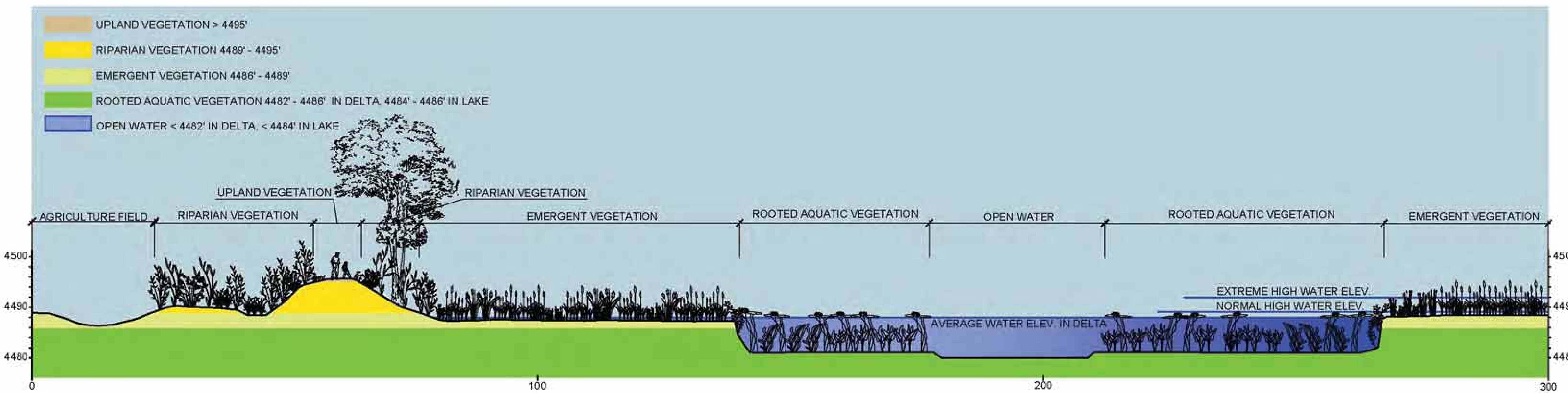


Figure 25. Illustration of a typical habitat complexity and vegetation bands within a delta pond, showing vegetation community change with water depth. Some delta ponds will have shallow areas with emergent vegetation, and others will have a mix of aquatic vegetation and open water, as illustrated above.

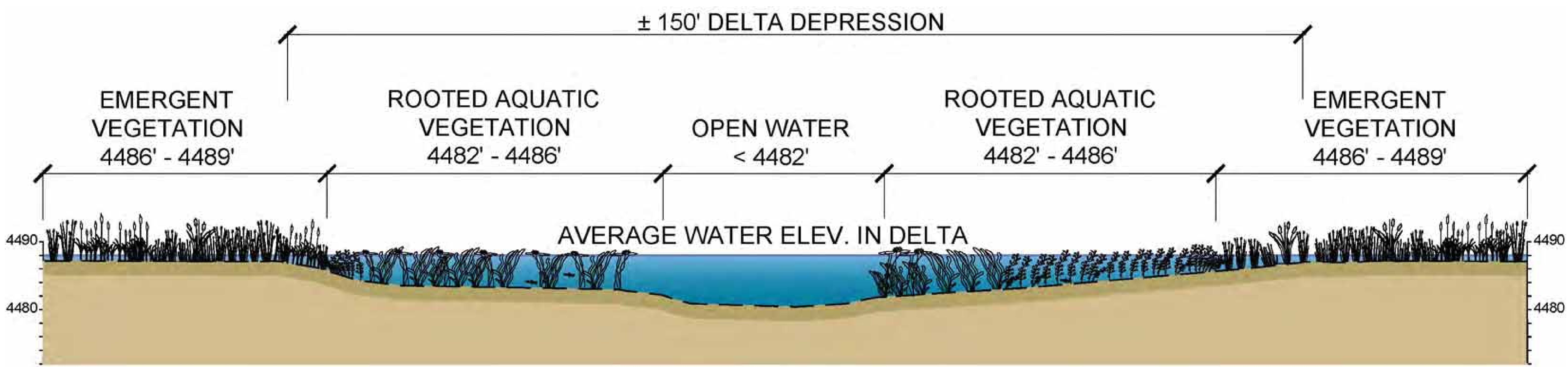


Figure 26. Illustration of typical habitat complexity and vegetation bands within a delta depression, showing vegetation community change with water depth. Delta depressions will have some deep water areas to provide refuge for June sucker that remain in them during periods of low water.

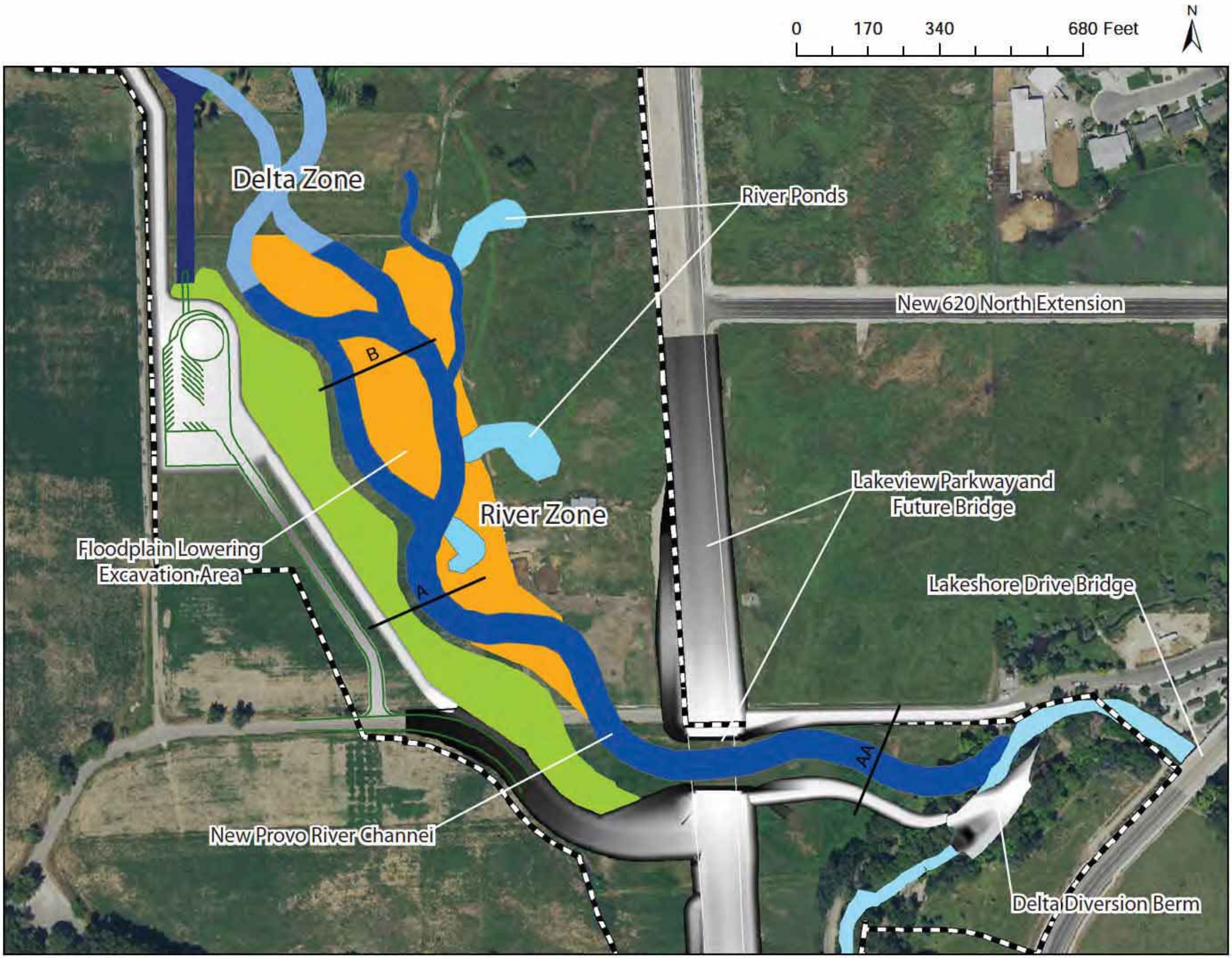


Figure 27. Map of designed features in the River Zone, which begins at the delta diversion berm and continues downstream for approximately 2,700 feet to the Delta Zone. The location of three river cross-section lines is shown in black.

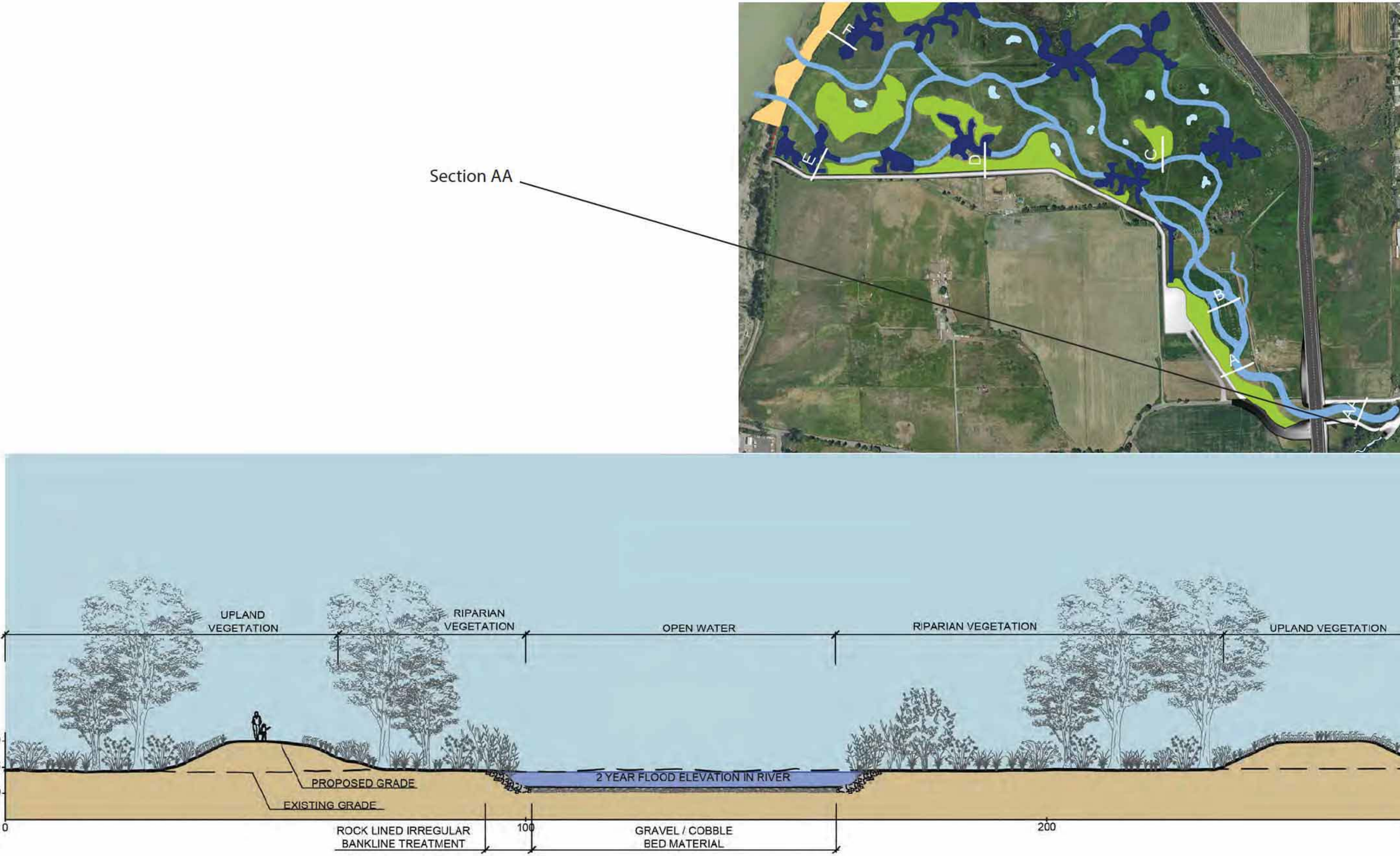


Figure 28. Typical cross-section view of the section of river channel between the delta diversion berm and the Lakeview Parkway bridge, with revegetation zones shown. This illustration is from Appendix A where it is designated as "Cross Section AA". Appendix A contains additional details on revegetation.

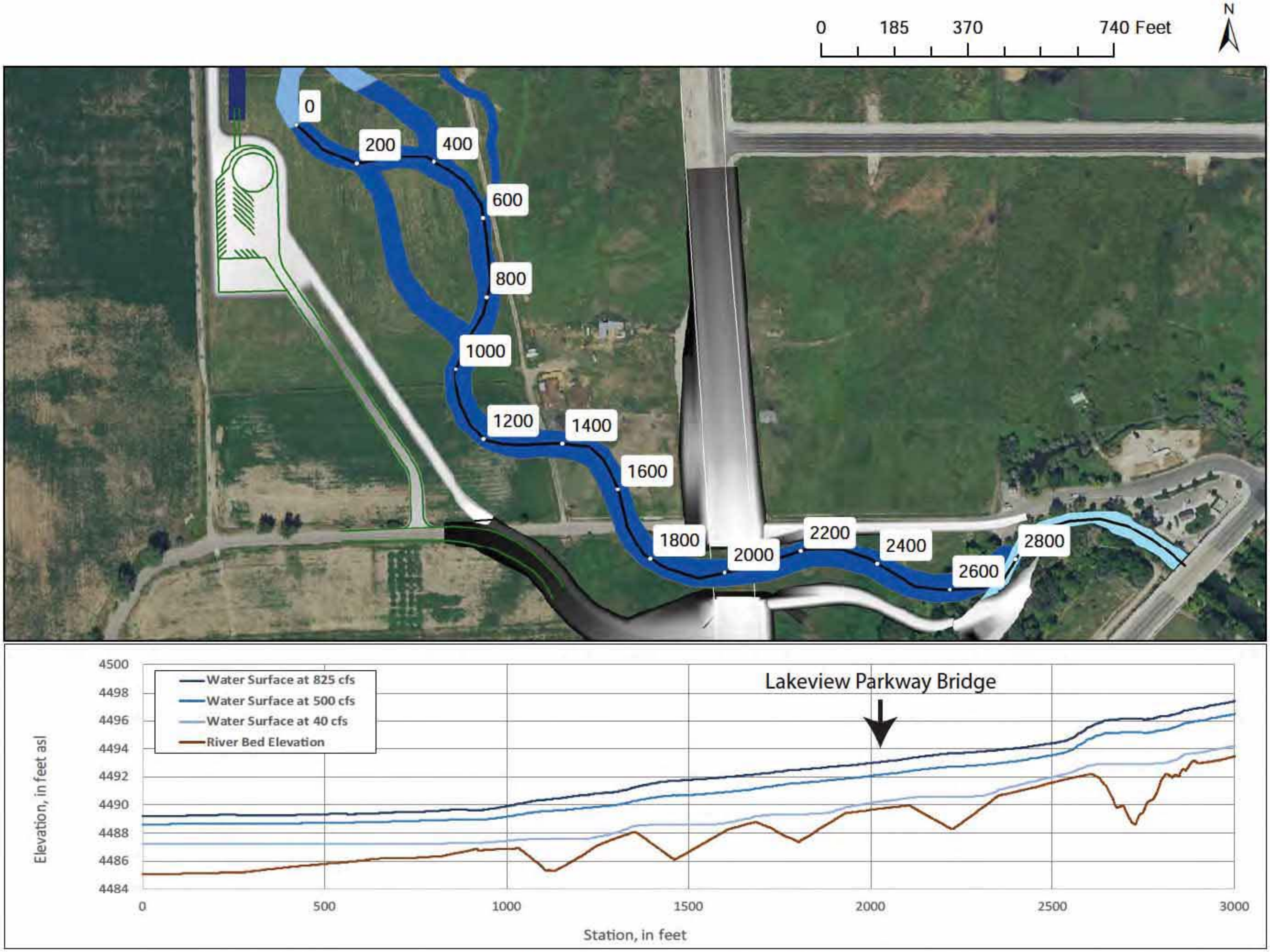


Figure 29. Plot of river bed elevation with three modeled water surface profiles in the River Zone, with stationing map. All three profiles have lake levels set at 4,486 feet asl. Note that the lowest 1,000 feet are backwater affected and the bed profile is not controlling the water surface elevation. Stationing is in feet upstream of the Delta Zone.

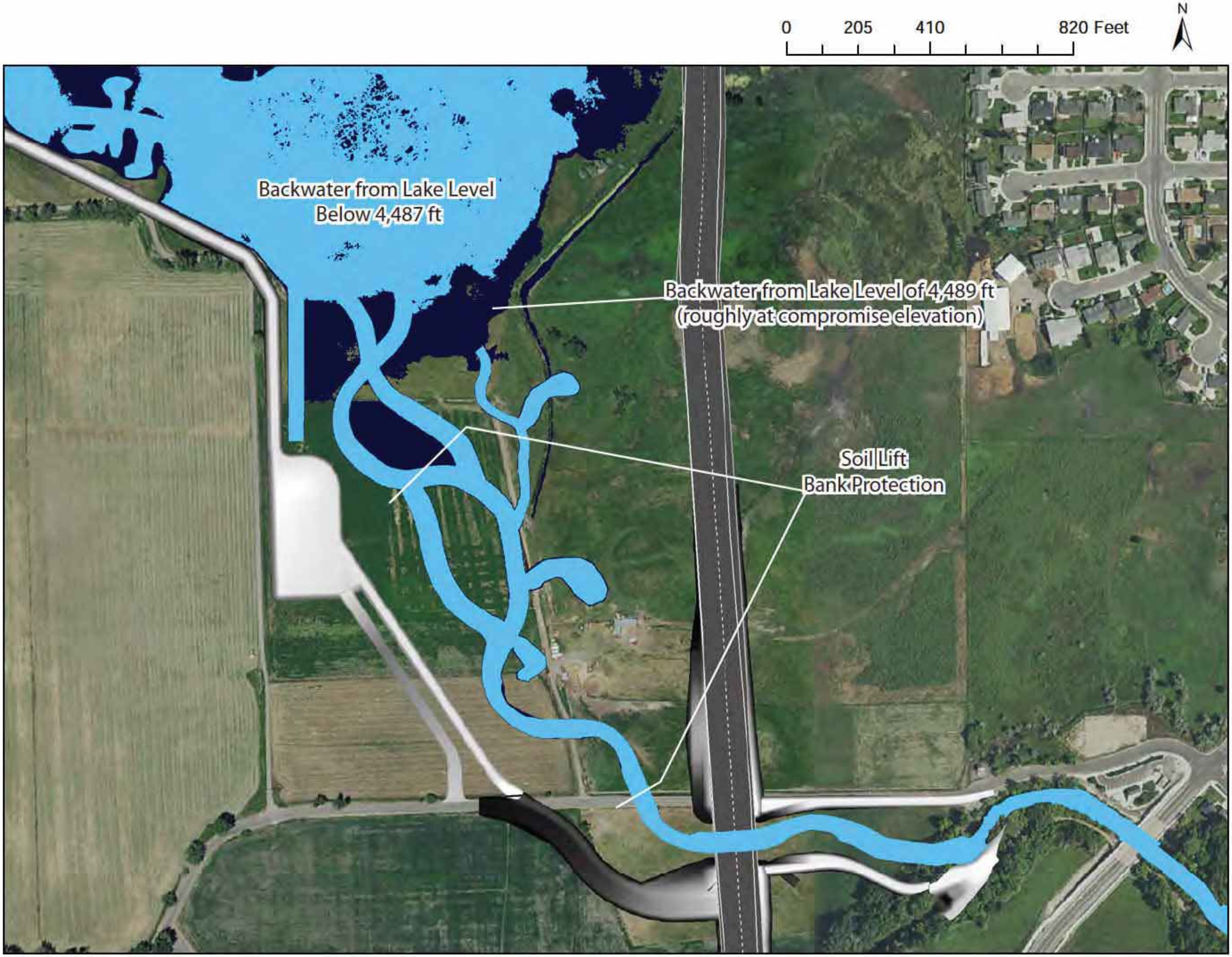
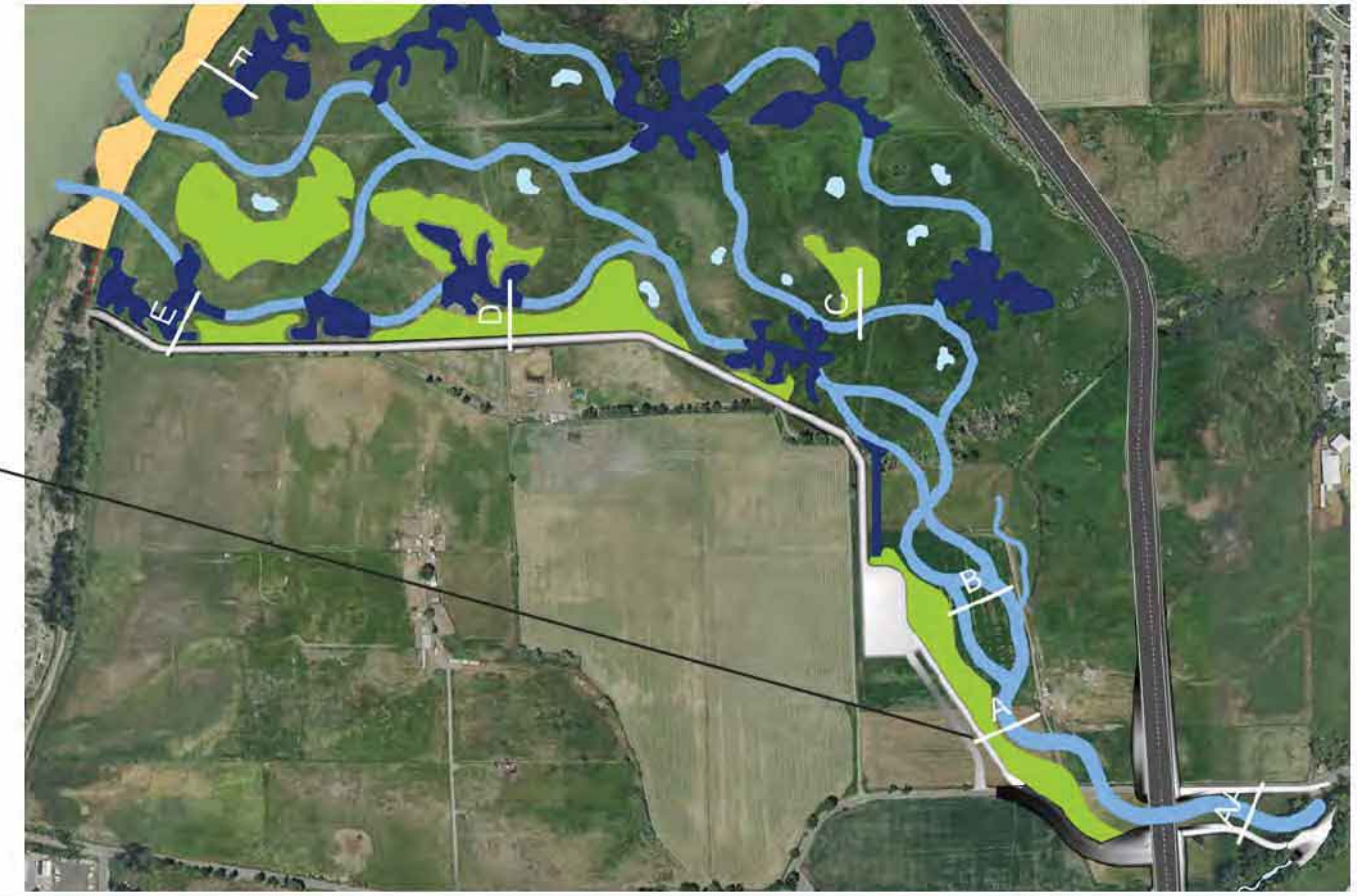


Figure 30. Map of the new Provo River transition from River Zone to Delta Zone. This common range of water level fluctuations in the delta affects channel capacity and hydraulics. A section of channel that requires soil lift bank protection is also illustrated.

Section A



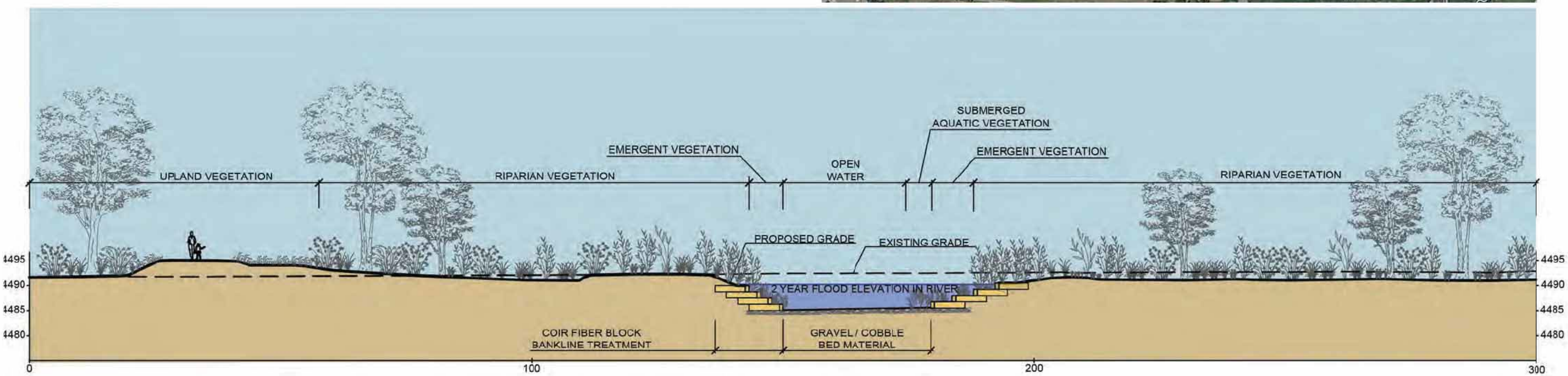


Figure 31. Typical cross-section view of a single threaded section of river channel downstream of the Lakeview Parkway bridge, with coir fabric lifts on channel banks and revegetation zones shown. Additional detail on the coir fabric lifts is included in Appendix B. This illustration is from Appendix A where it is designated as "Cross Section A". Appendix A contains additional details on revegetation.

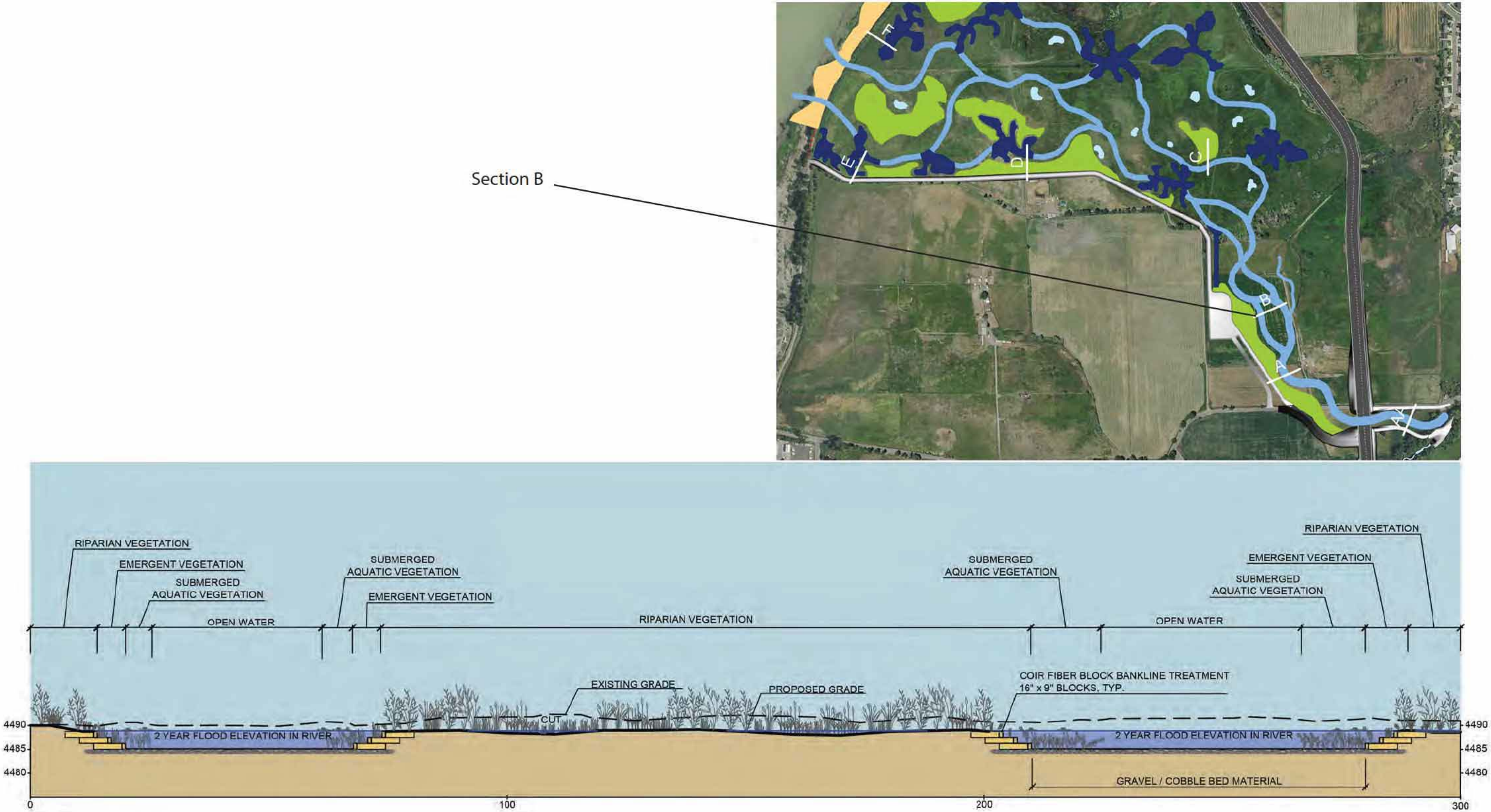


Figure 32. Typical cross-section view of a dual threaded section of river channel downstream of the Lakeview Parkway bridge, with coir fabric lifts on channel banks and revegetation zones shown. Additional detail on the coir fabric lifts is included in Appendix B. This illustration is from Appendix A where it is designated as "Cross Section B". Appendix A contains additional details on revegetation.

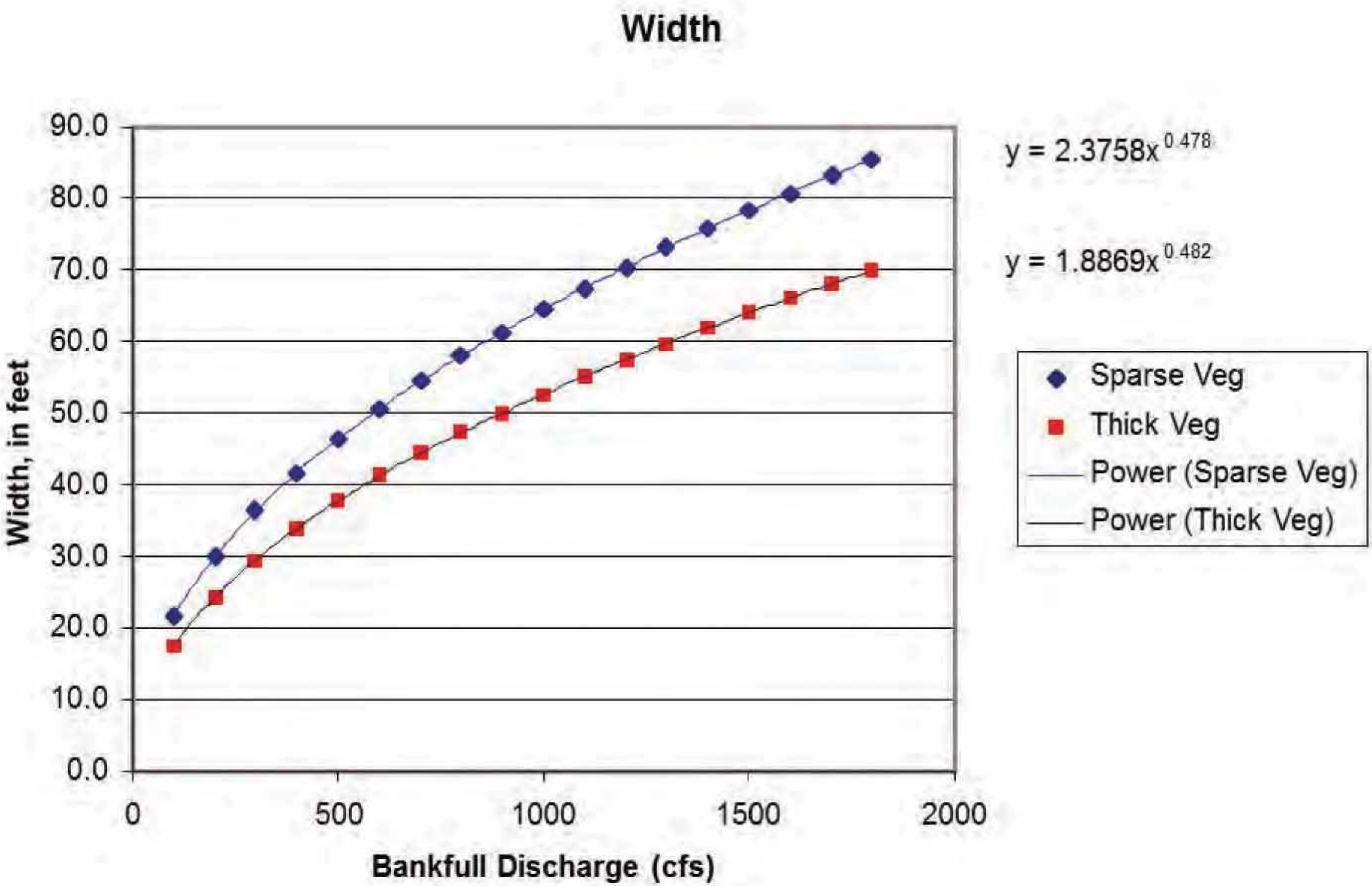


Figure 33. Plot of bankfull discharge versus channel width for gravel-bedded rivers in the Rocky Mountains, with separate relations for thick vegetation and sparse vegetation. Relationships from Andrews, 1984.

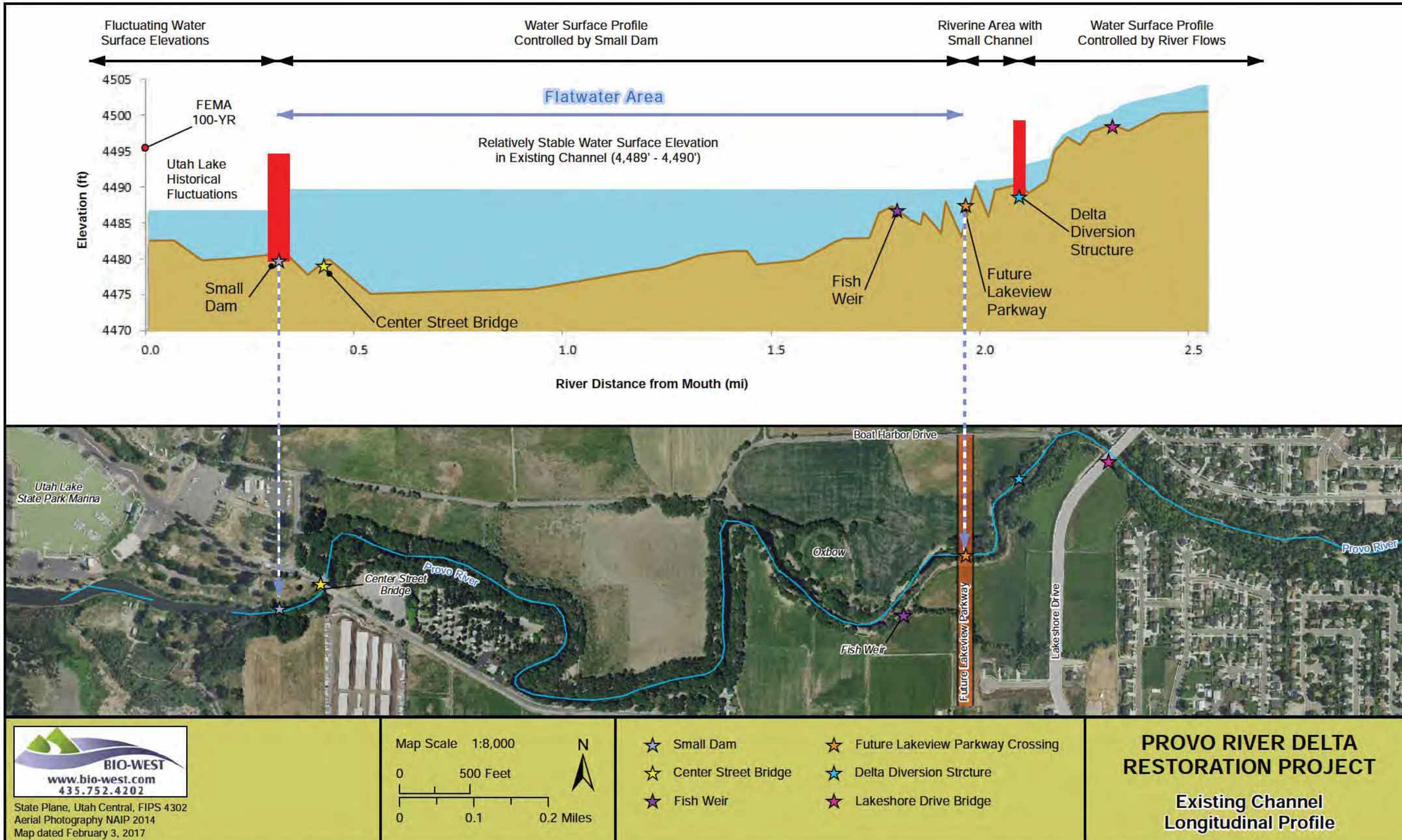


Figure 34. Map and longitudinal profile of the existing Provo River channel showing the small downstream dam location, and how it will affect water levels in the existing channel following construction of the new Provo River Delta.

Figure 35. Conceptual plan for the Delta Gateway Park showing features for the park and a section of the existing Provo River channel.

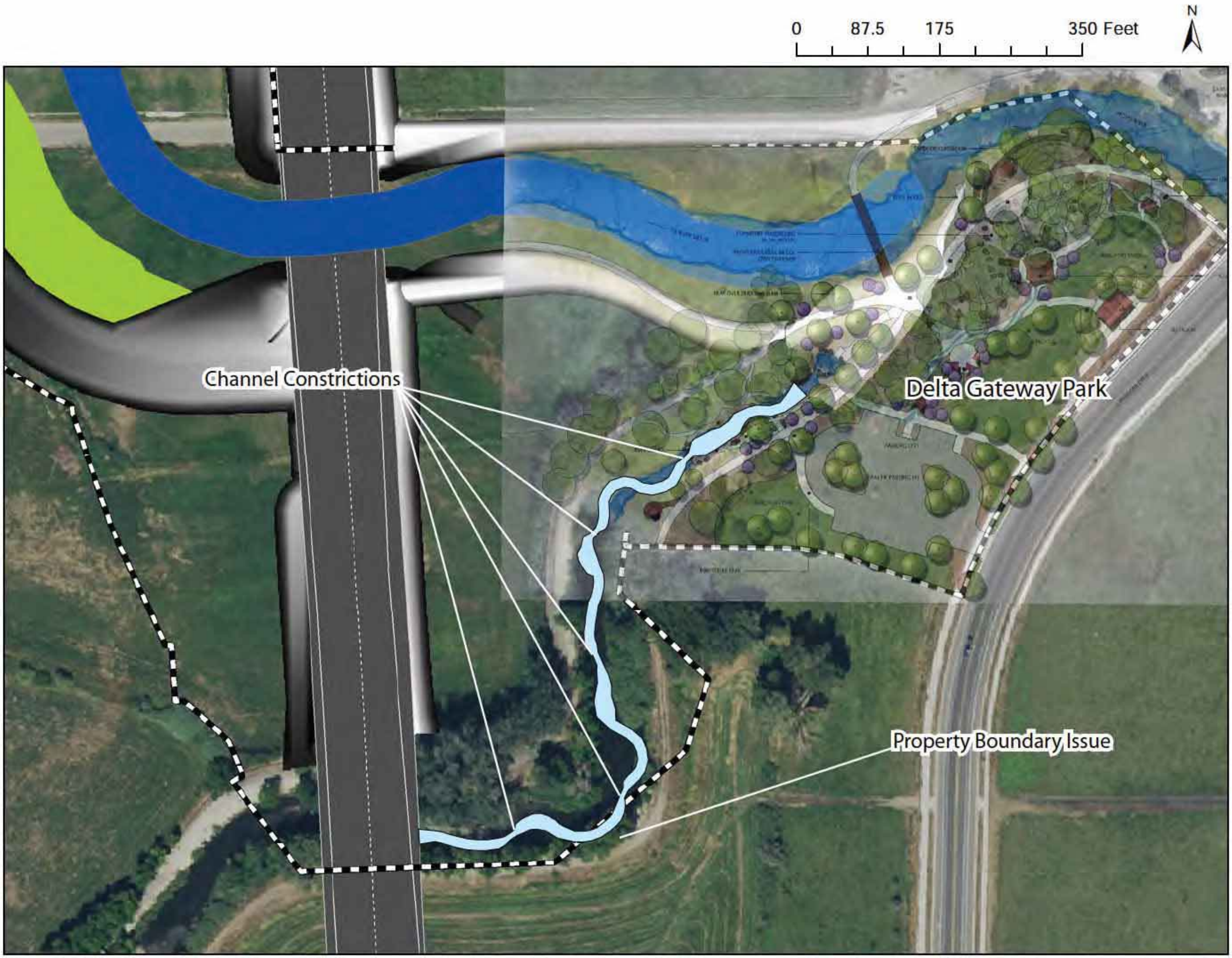


Figure 36. Design plan for the small flowing channel in and downstream of the proposed Delta Gateway Park, showing the location of five channel constrictions (narrow areas). The existing channel will be reconfigured with added fill to create the small flowing channel.

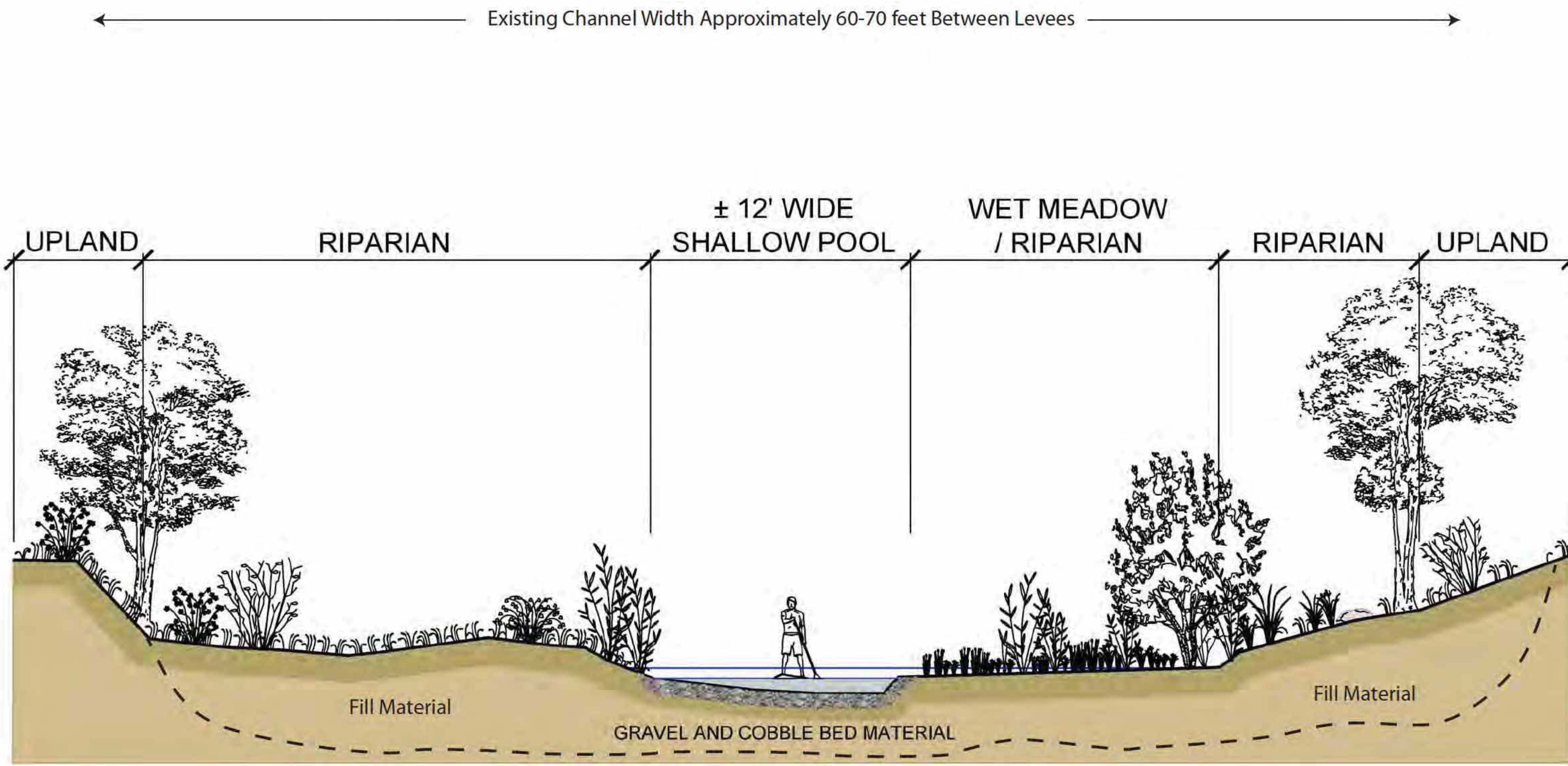


Figure 37. Typical cross-section view of the shallow flowing channel that will be constructed between the levees on the existing Provo River channel.

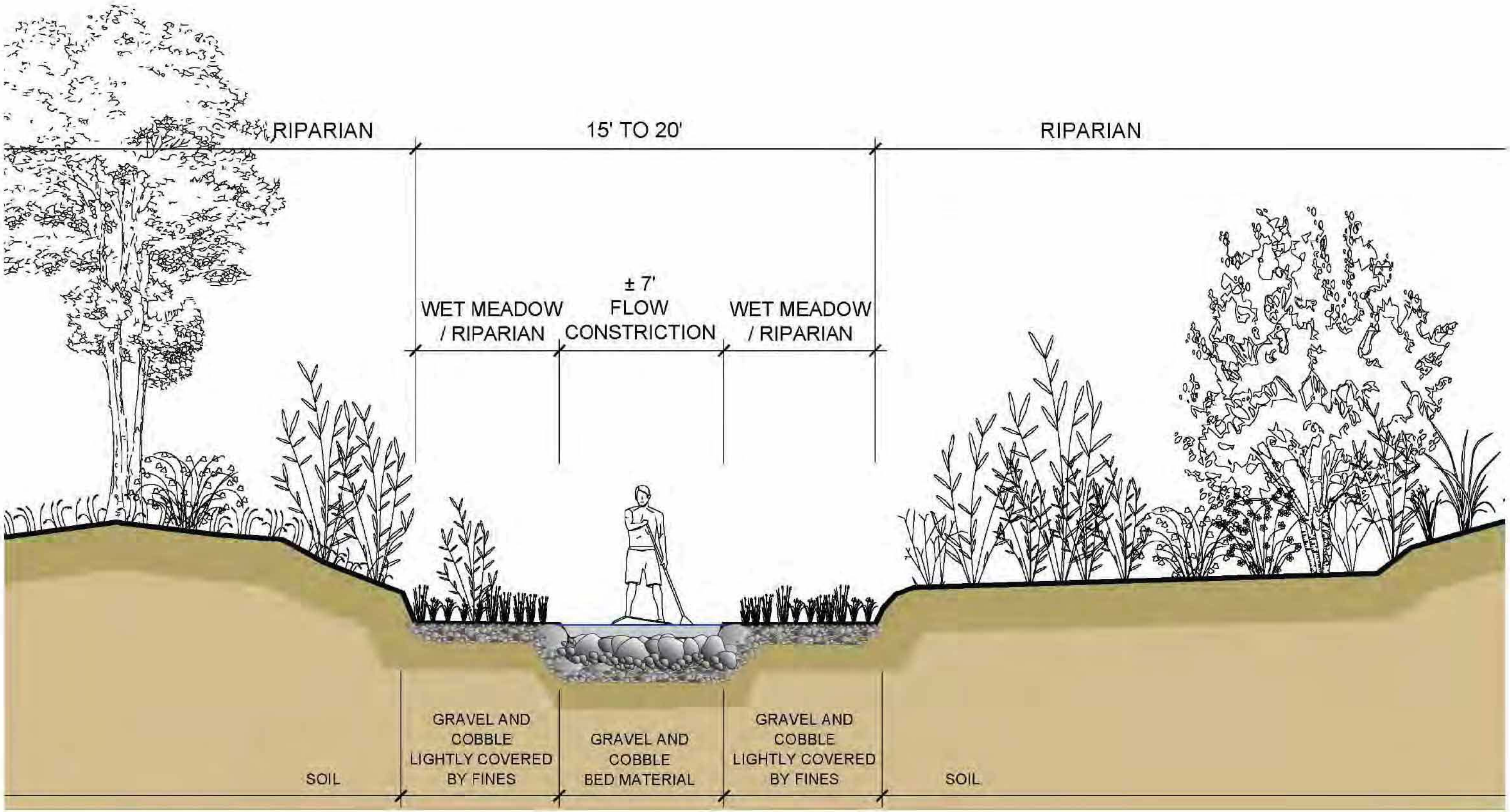


Figure 38. Typical cross-section view of the shallow flowing channel at a flow constriction.

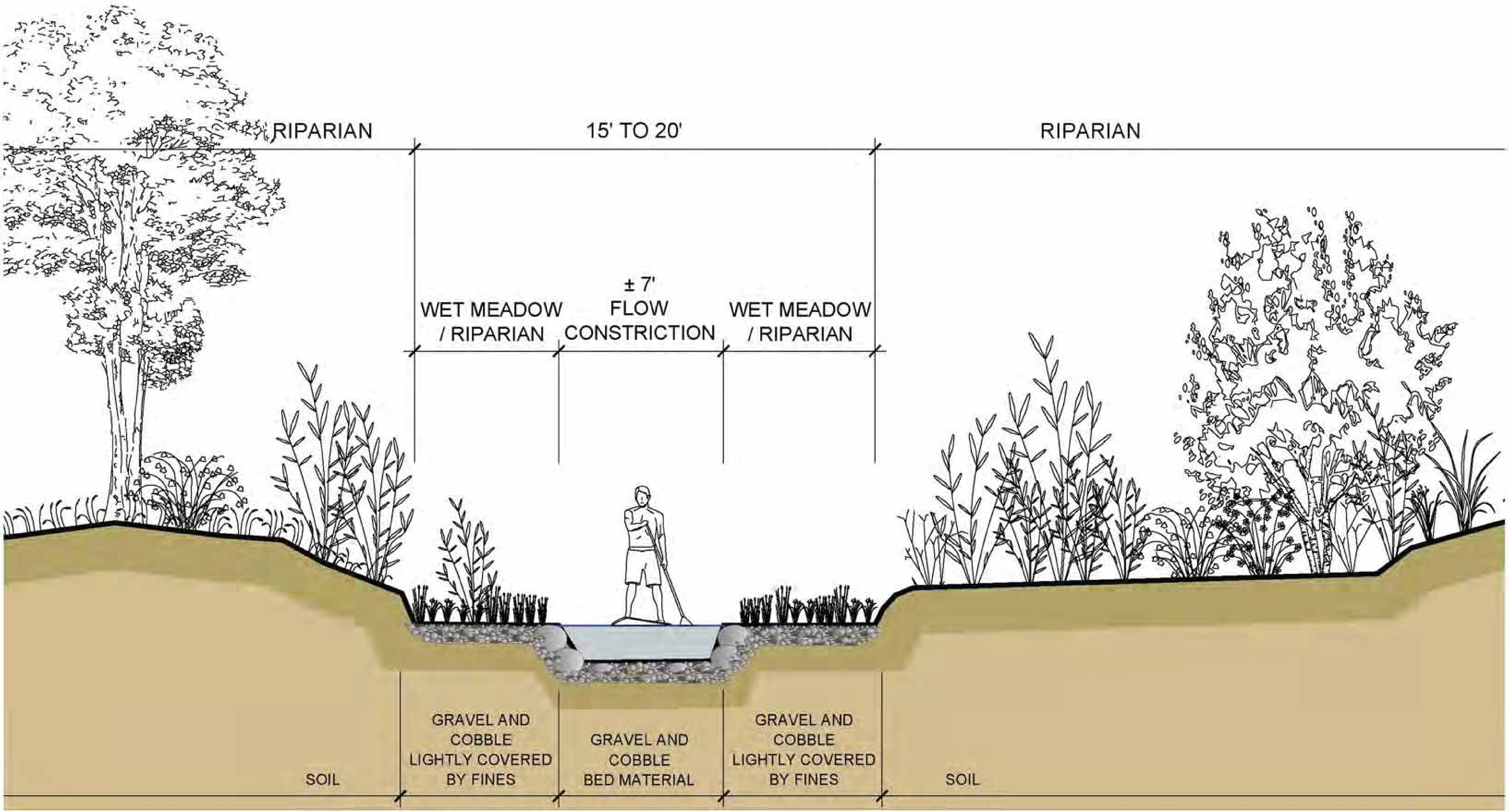


Figure 38. Typical cross-section view of the shallow flowing channel at a flow constriction.

Figure 39. Artist's rendering of a typical section of the small flowing channel at a constriction point

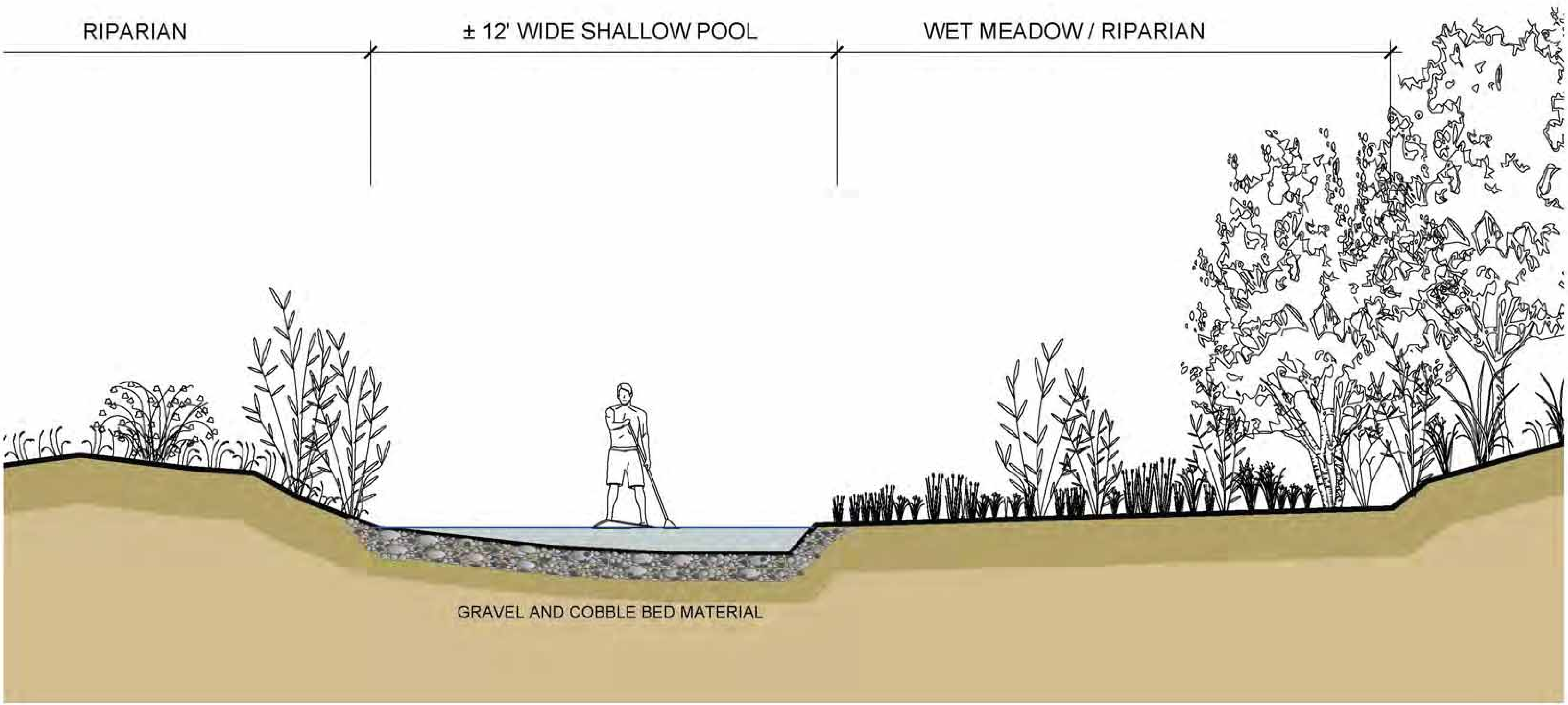


Figure 40. Typical cross-section view of the shallow flowing channel between constrictions.

Figure 41. Artist's rendering of a typical section of the small flowing channel between constrictions.

Figure 42. Artist's rendering of a play place where children could wade and play in shallow water,

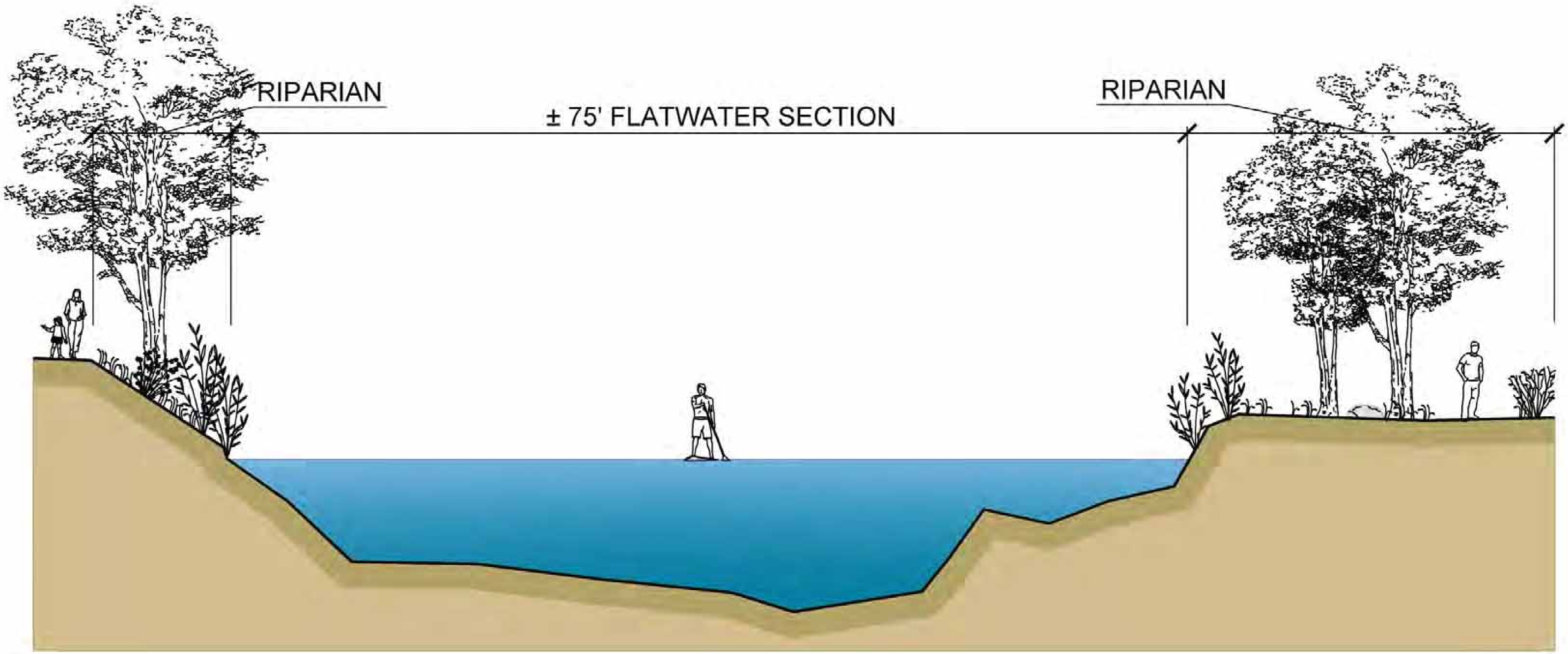


Figure 43. Typical cross-section view of the flatwater section of the Existing Provo River channel.

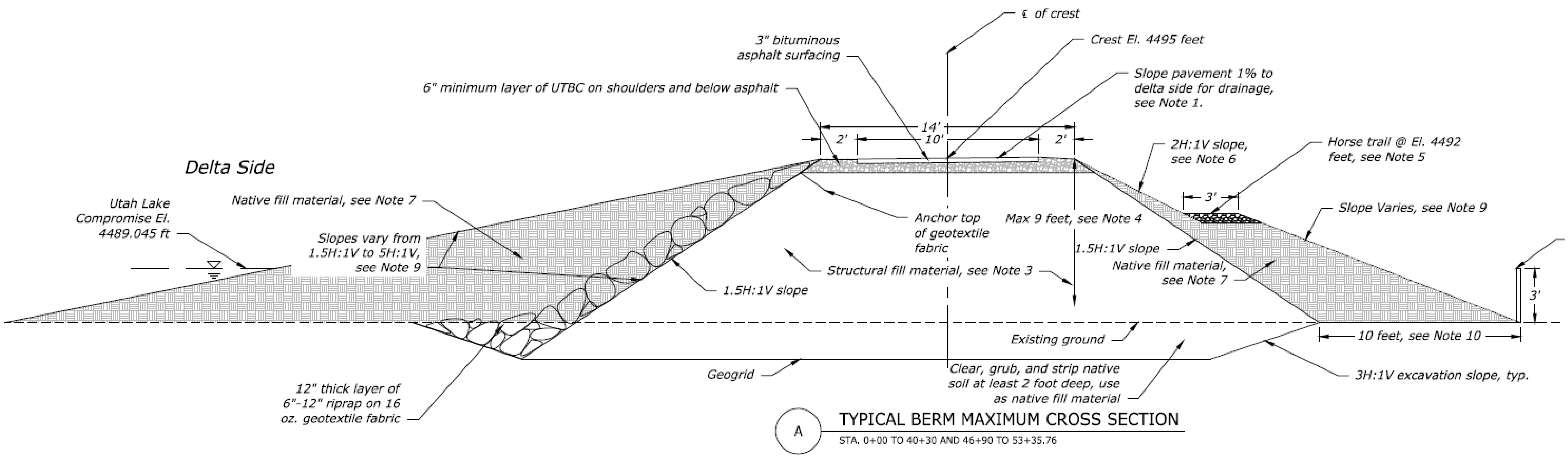


Figure 44. Typical cross-section view of the new berm with trail, including structural details. (Drawing from BOR 60% plan set).

Figure 45. Draft map of proposed recreational features for the new Provo River delta area. This map is for general reference only because many features have changed since it was created.

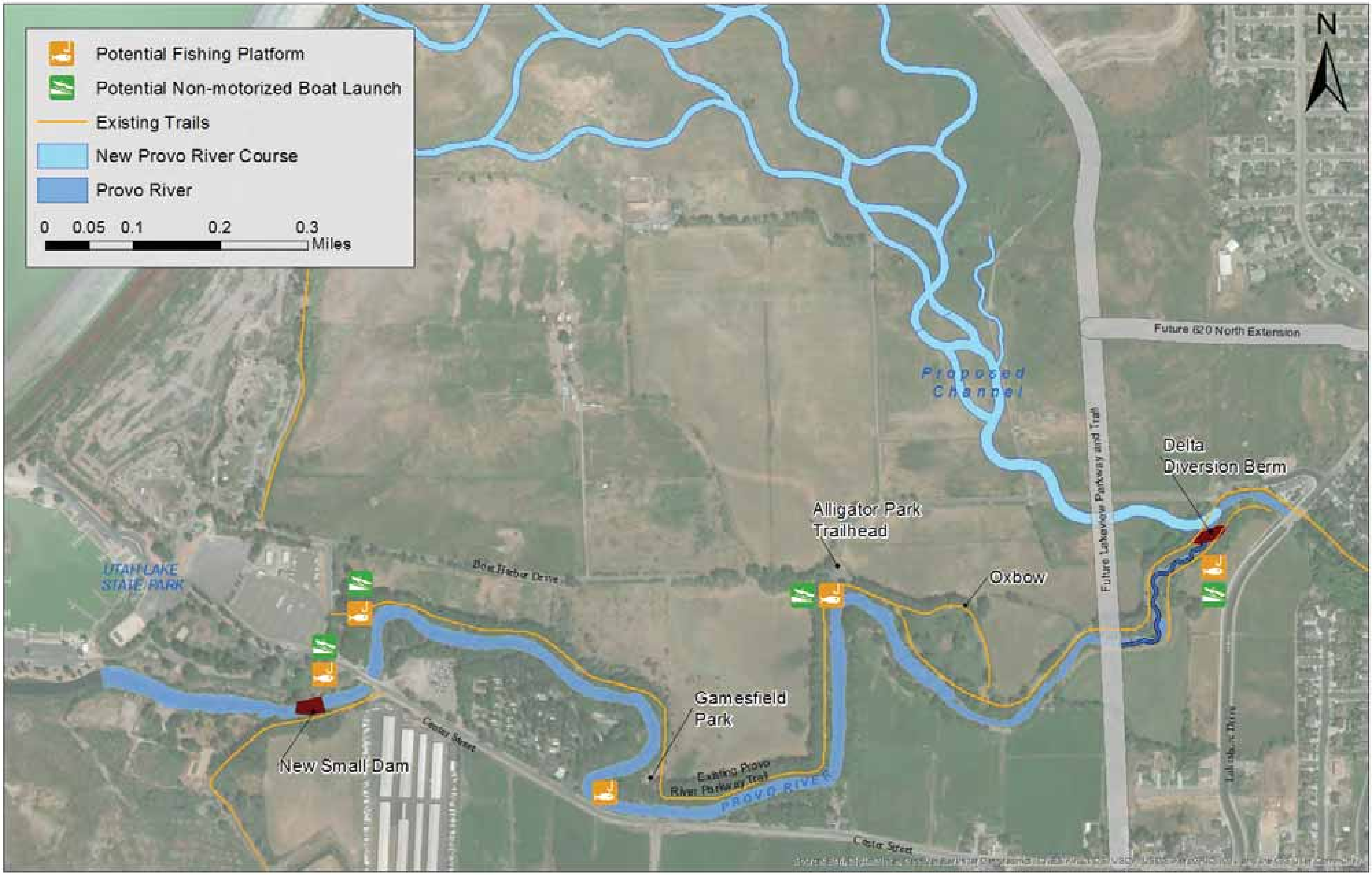


Figure 46. Draft map of recreational features along the existing Provo River channel.

Figure 47. Aerial image showing the location and approximate layout of the small downstream dam that will control water levels in the existing Provo River channel following completion of the delta construction.

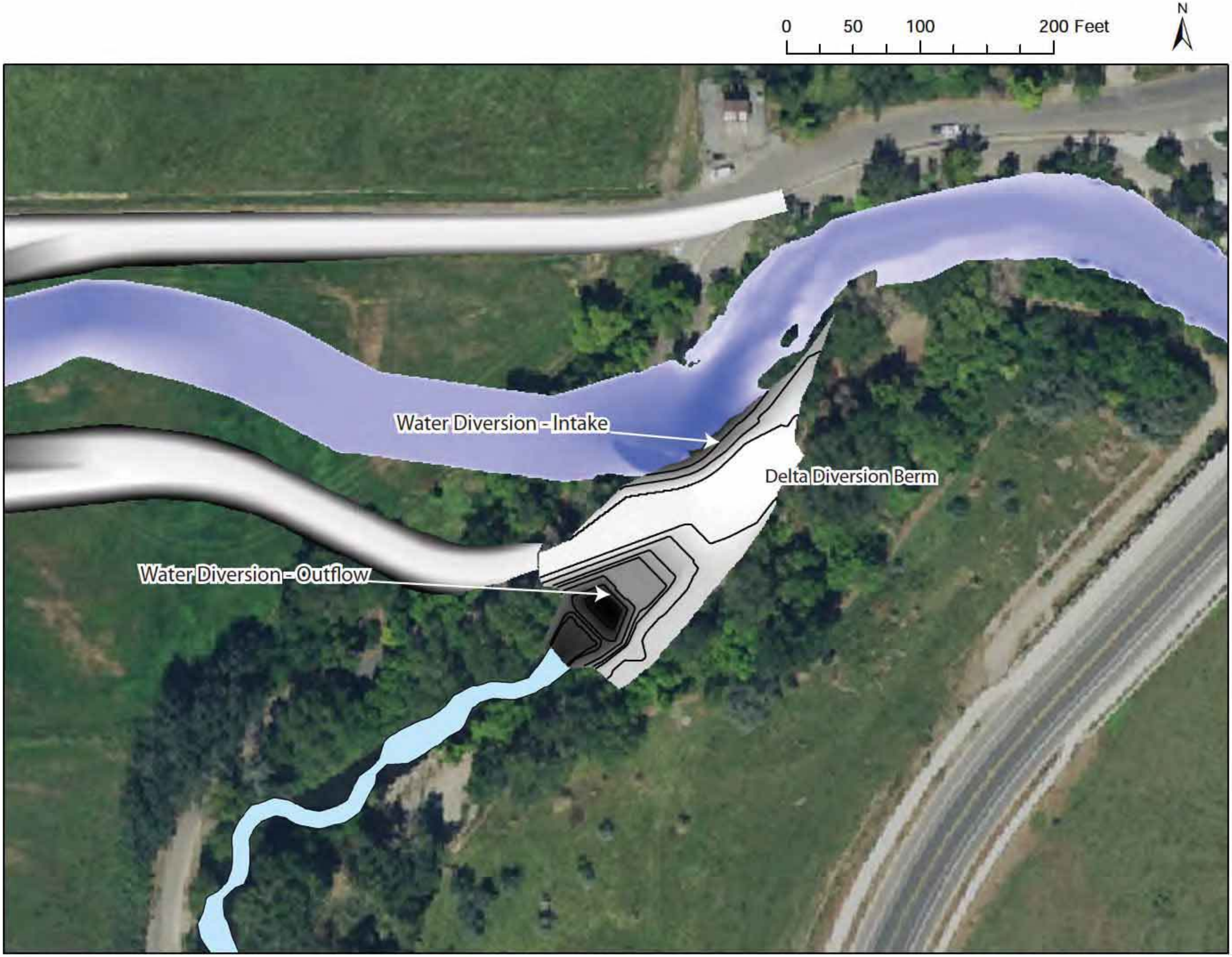


Figure 48. Map showing the location and approximate layout of the delta diversion berm, along with the water diversion intake and outflow locations.

Figure 49. Terrain model of design features used for the current round of two-dimensional HEC-RAS modeling.

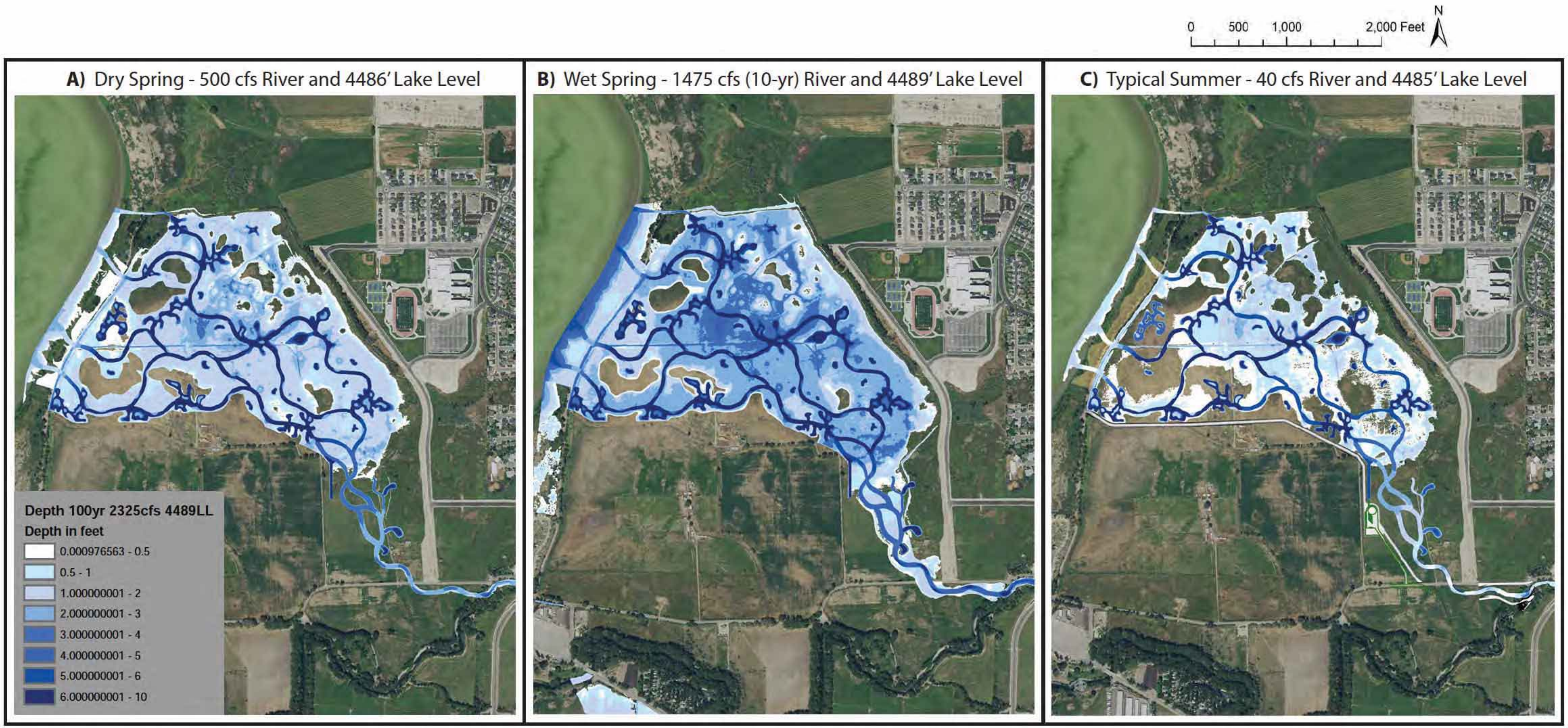


Figure 50 A-C. Maps showing modeled inundation area and water depth for three scenarios; A) Dry Spring with Provo River flowing at 500 cfs and Utah Lake level at 4,486 feet asl, B) Wet Spring with Provo River flowing at 1,475 cfs (10-yr peak) and Utah Lake level at 4,489 feet asl, and C) Typical Summer with Provo River flowing at 40 cfs and Utah Lake level at 4,485 feet asl.

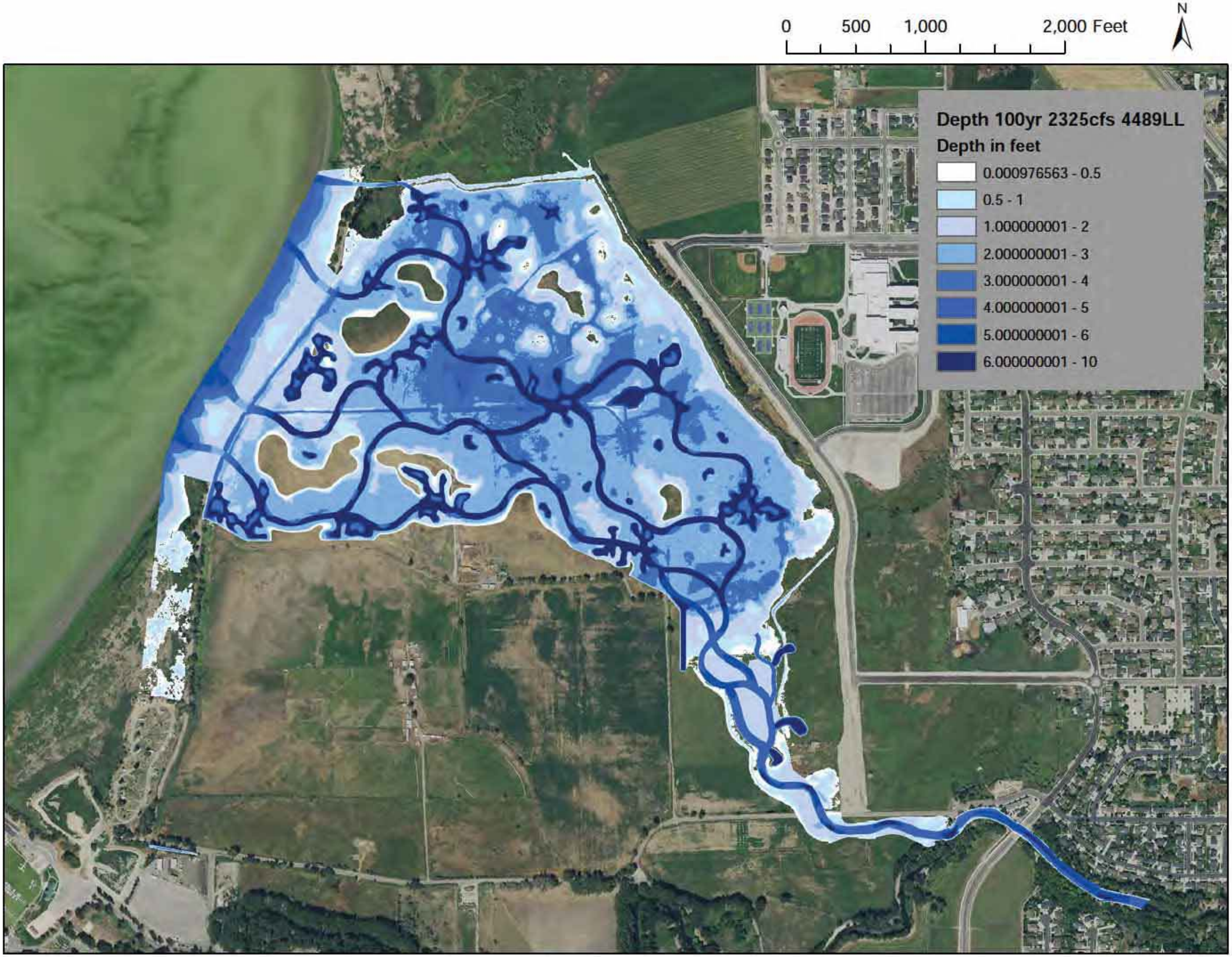
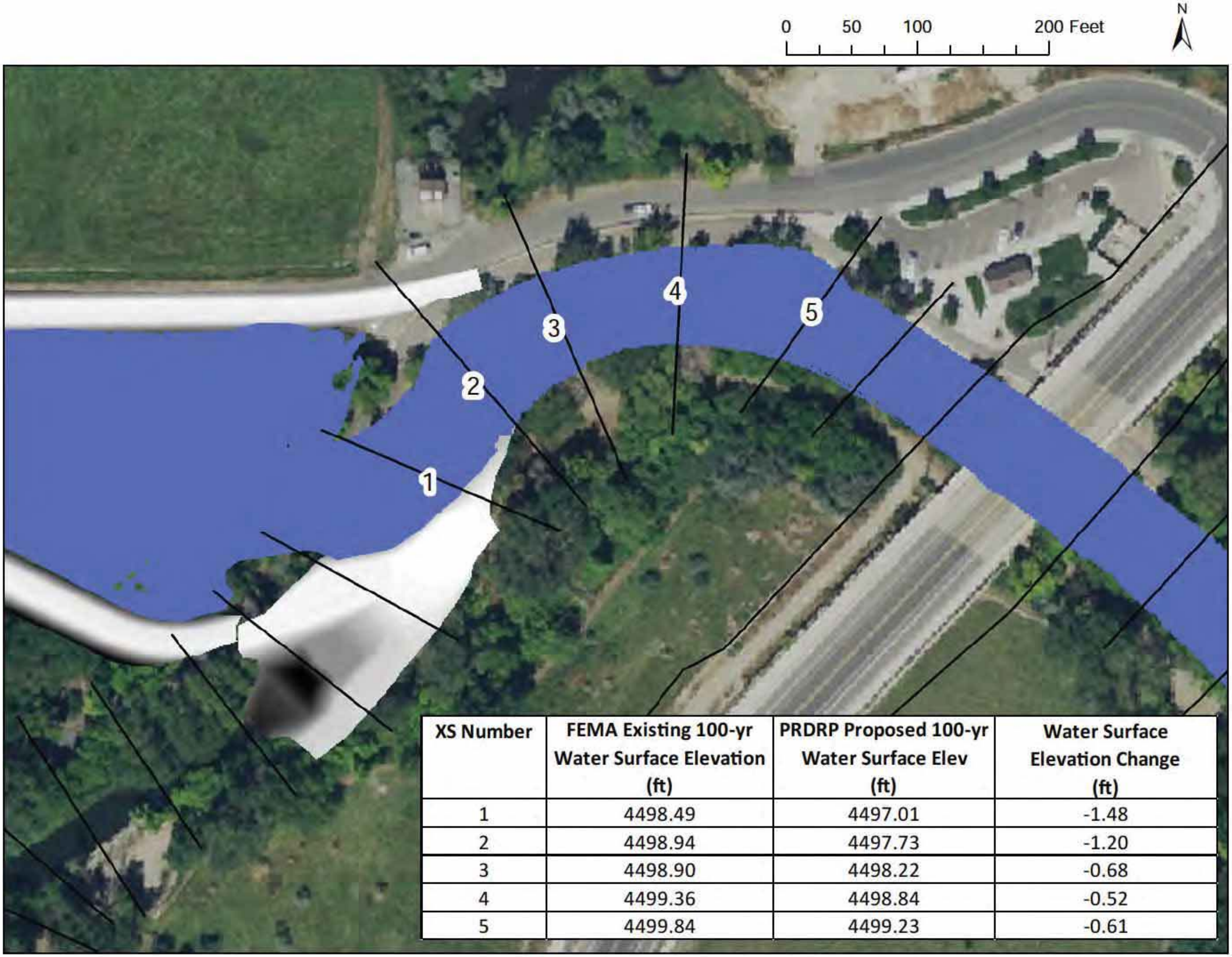


Figure 51. HEC-RAS modeling results for water depth during an extreme event, with the Provo River flowing at 2,325 cubic feet per second (100-yr event) and Utah Lake at an elevation of 4489 feet asl.



XS Number	FEMA Existing 100-yr Water Surface Elevation (ft)	PRDRP Proposed 100-yr Water Surface Elev (ft)	Water Surface Elevation Change (ft)
1	4498.49	4497.01	-1.48
2	4498.94	4497.73	-1.20
3	4498.90	4498.22	-0.68
4	4499.36	4498.84	-0.52
5	4499.84	4499.23	-0.61

Figure 52. Comparison of water surface elevations from the FEMA existing conditions model and the PRDRP project model, at five cross sections, for a 100-year event of 2,325 cubic feet per second. Note that post project water surface elevations are lower than existing.

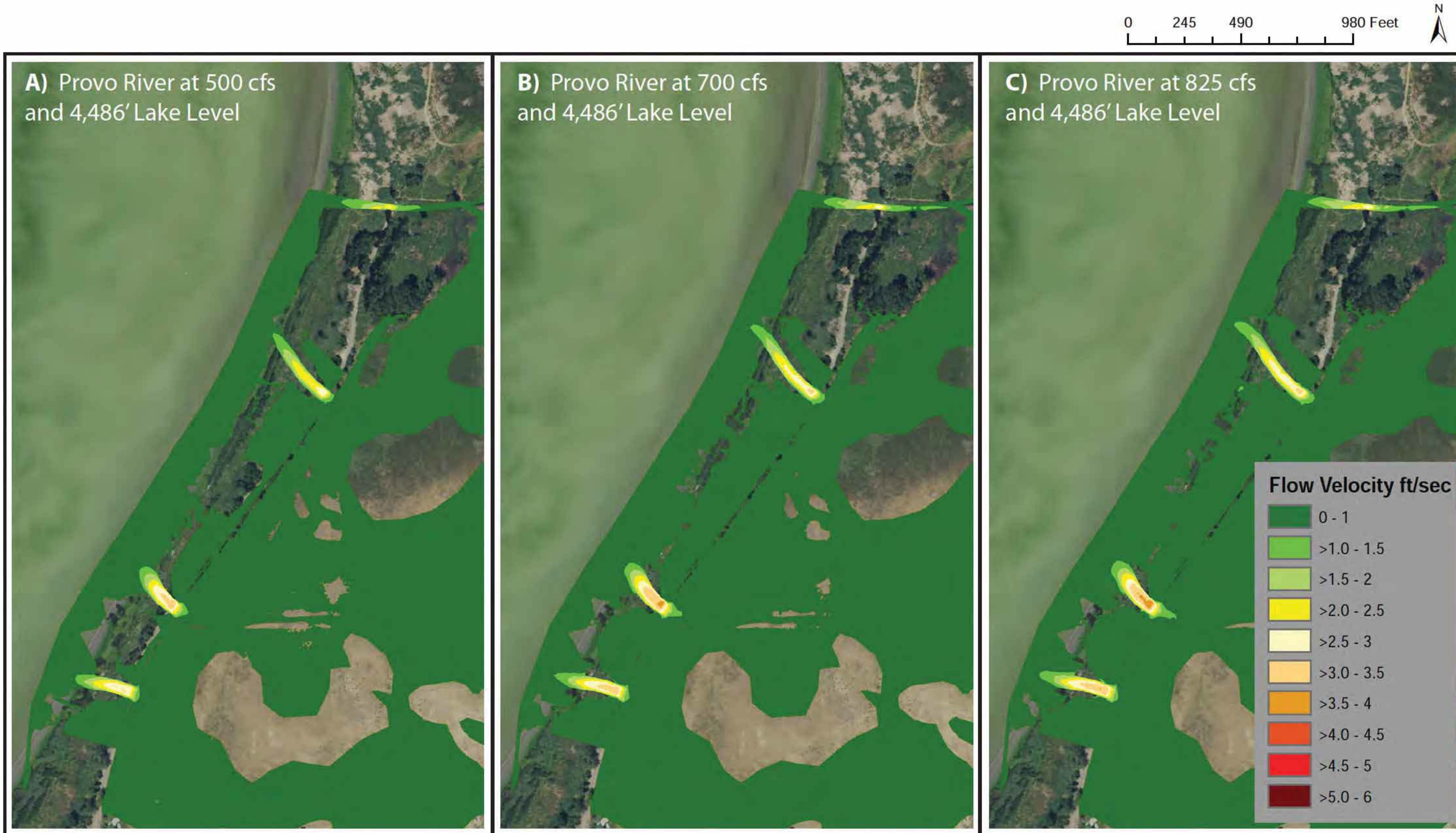


Figure 53 A-C. Maps of vertically-averaged velocities for three low lake (4,486') scenarios; A) Provo River inflow at 500 cfs, B) Provo River inflow at 700 cfs, and C) Provo River inflow at 825 cfs. Velocities are color-coded for June sucker burst speeds of 3.5 feet per second for small fish and 4.5 feet per second for large fish. Note that even under these worst-case scenarios of high discharge and low lake level, the outflow channels are passable . When lake levels are higher, velocities in the outflow channels are even lower than those illustrated here.

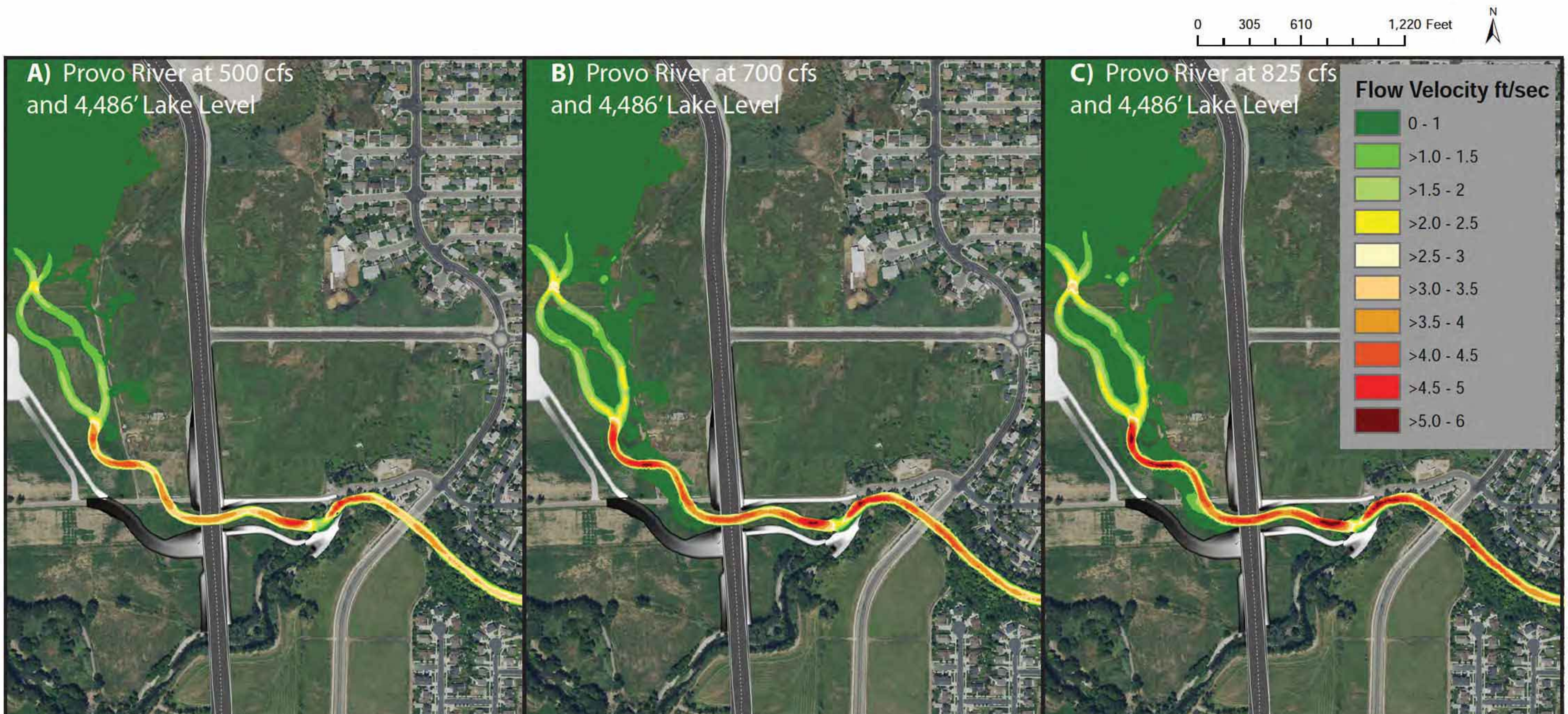


Figure 54 A-C. Maps of vertically-averaged velocities in the river zone for three low lake (4,486′) scenarios; A) Provo River flow at 500 cfs, B) Provo River flow at 700 cfs, and C) Provo River flow at 825 cfs. Velocities are color-coded for June sucker burst speeds of 3.5 feet per second for small fish and 4.5 feet per second for large fish. Note that even under these worst-case scenarios of high discharge and low lake level, the channels are passable in most areas and always passable along the margins. When lake levels are higher, velocities in the outflow channels are even lower than those illustrated here.

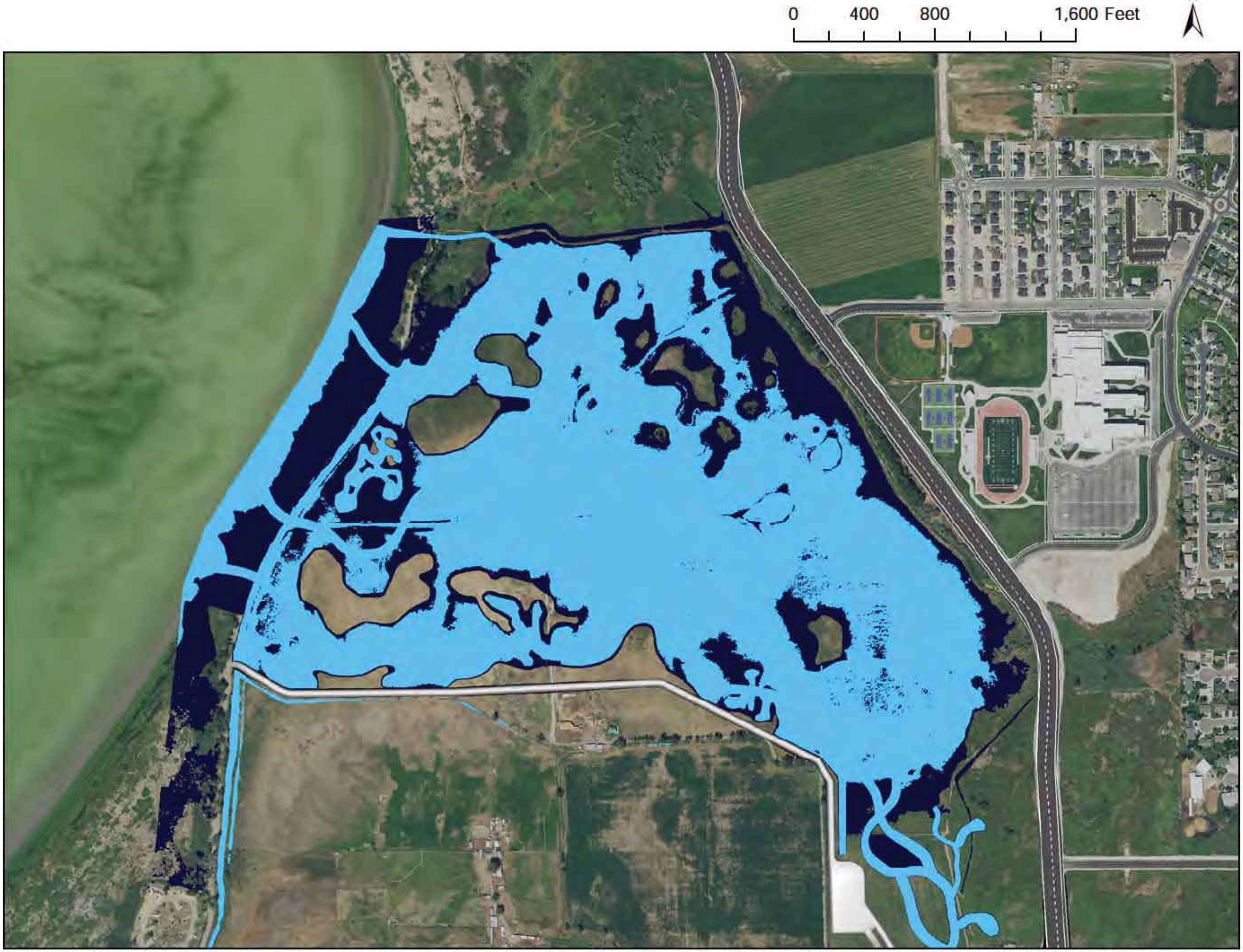


Figure 55. Map showing the area of inundation for a common streamflow of 125 cfs, at two different lake levels. Light blue is for lake level of 4,486′ (below outlet channel inverts) and dark blue is for 4,489′ (roughly compromise).

Figure 56 A-C. Maps of bed shear stress in the river zone for three low lake (4,486 feet asl) scenarios; A) Provo River flow at 500 cfs, B) Provo River flow at 700 cfs, and C) Provo River flow at 825 cfs. Shear stresses are color-coded for a particle size of 22.6mm (0.9 inches) with immobile areas as green, barely mobile areas as white, mobile areas as yellow, highly mobile areas as orange and extremely mobile areas as red.

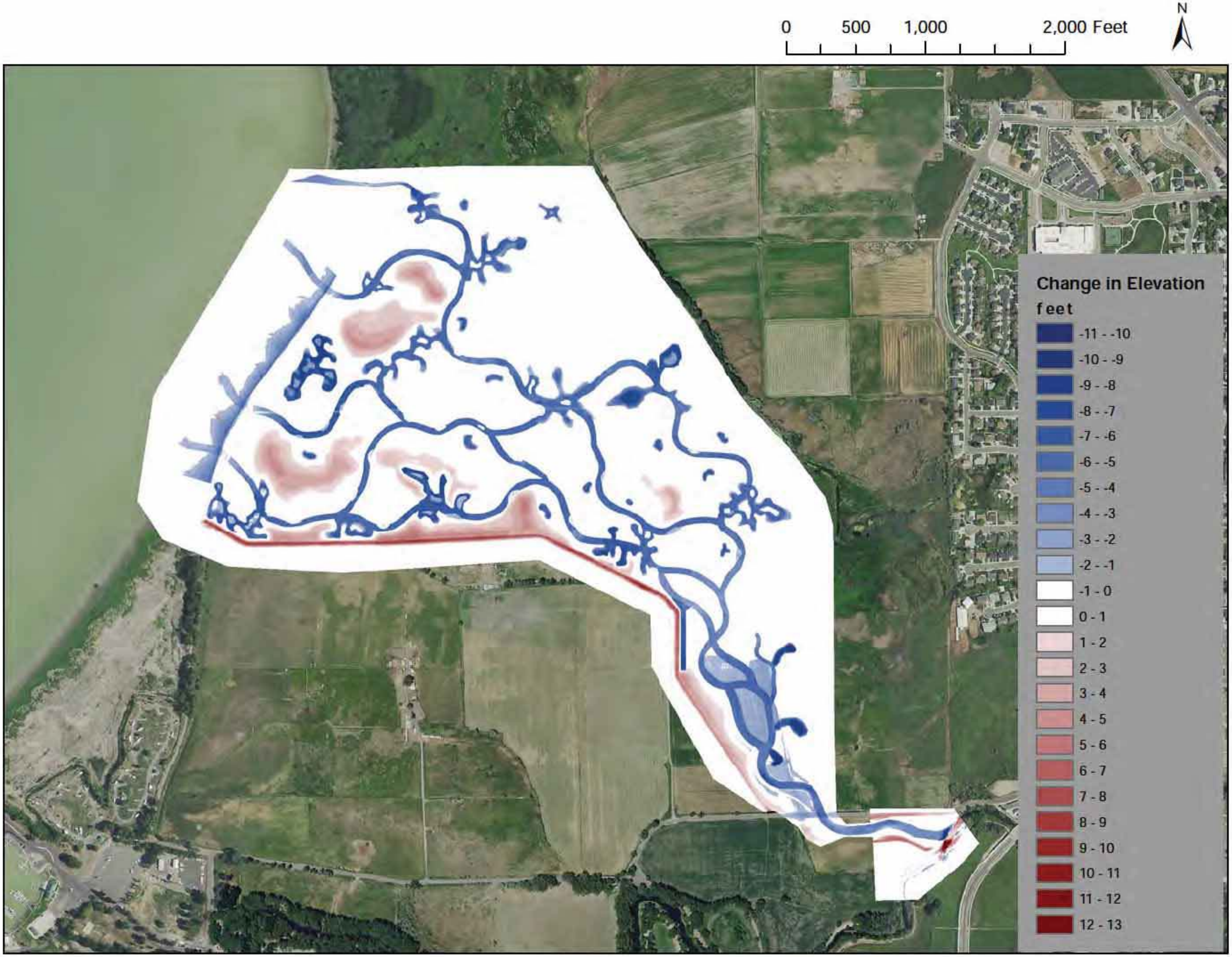


Figure 57. Map showing change in elevation from existing to proposed conditions. Cut areas are blue and fill areas are red.

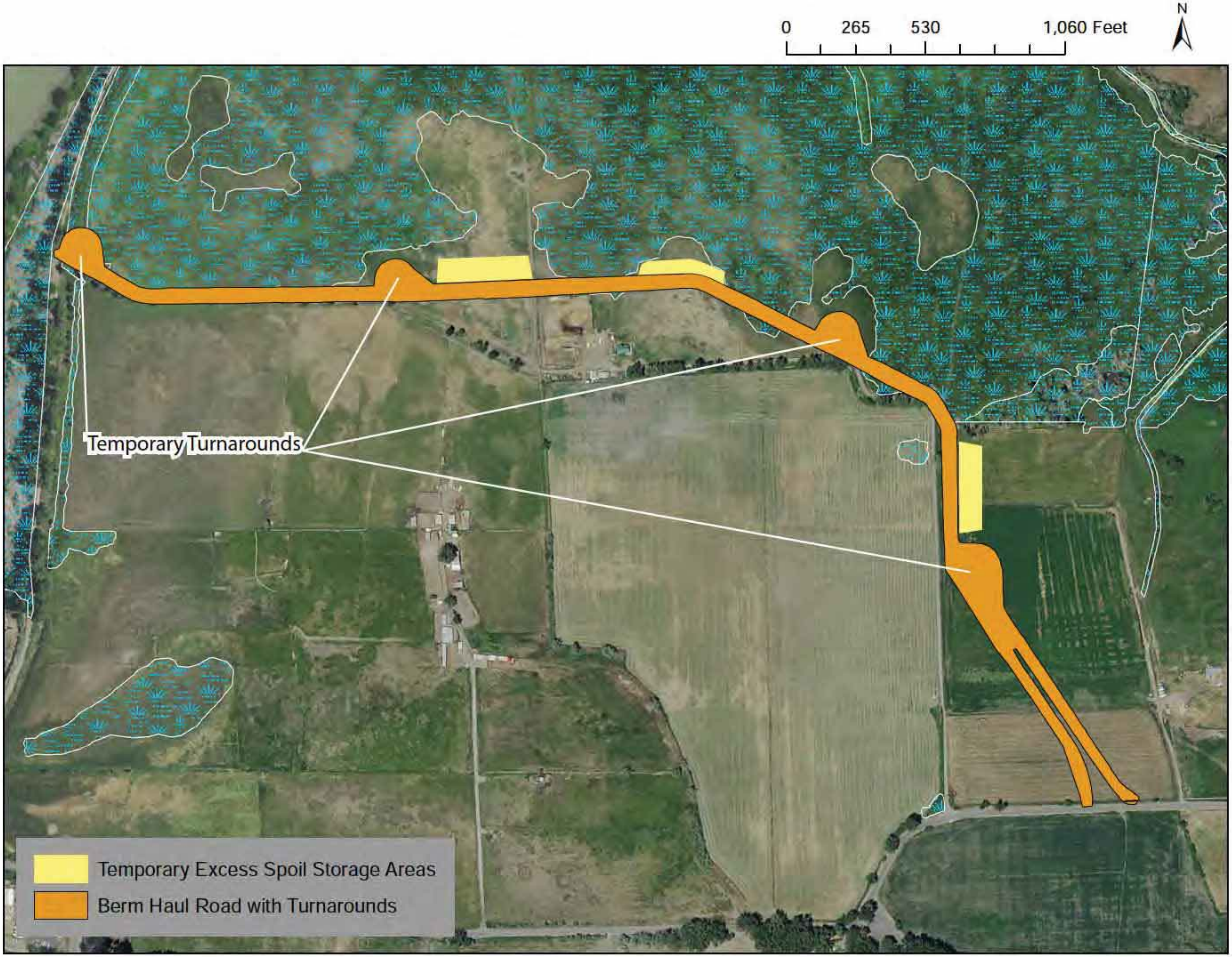


Figure 58. Map showing the berm footprint where a haul road with four temporary turnaround areas will be constructed. Excess spoil will be delivered to designated temporary spoil sites and then loaded onto trucks for relocation offsite. Wetland areas are in blue/white.

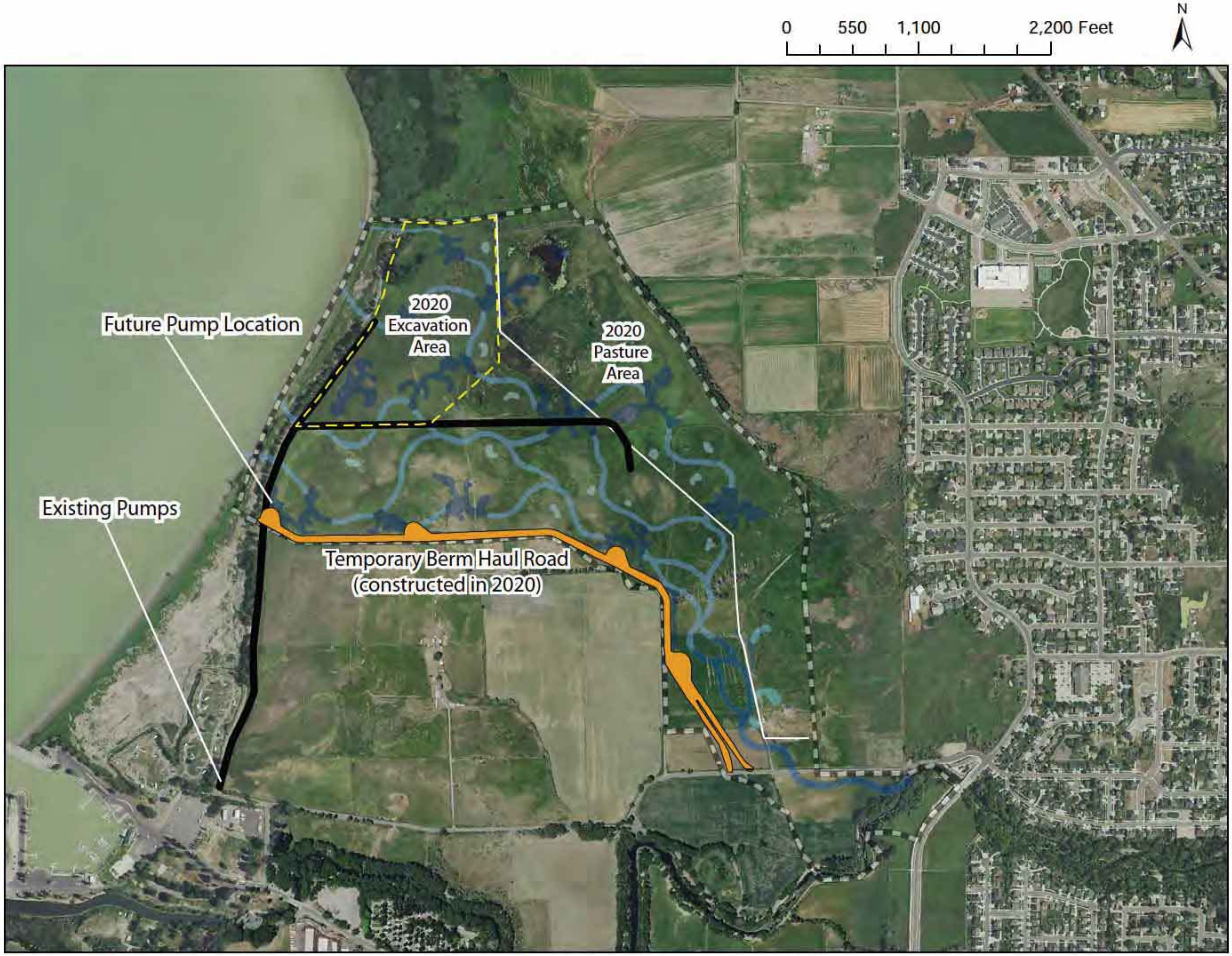


Figure 59. Map showing existing major drainage ditches (black) that route water to the existing pumps. A new pumping location will be established in the general area indicated. The estimated area of 2020 excavation is outlined in yellow, as is the location of a future temporary fence (white line) that will create a pasture to the east where the former owner will be allowed to graze cattle in 2020.

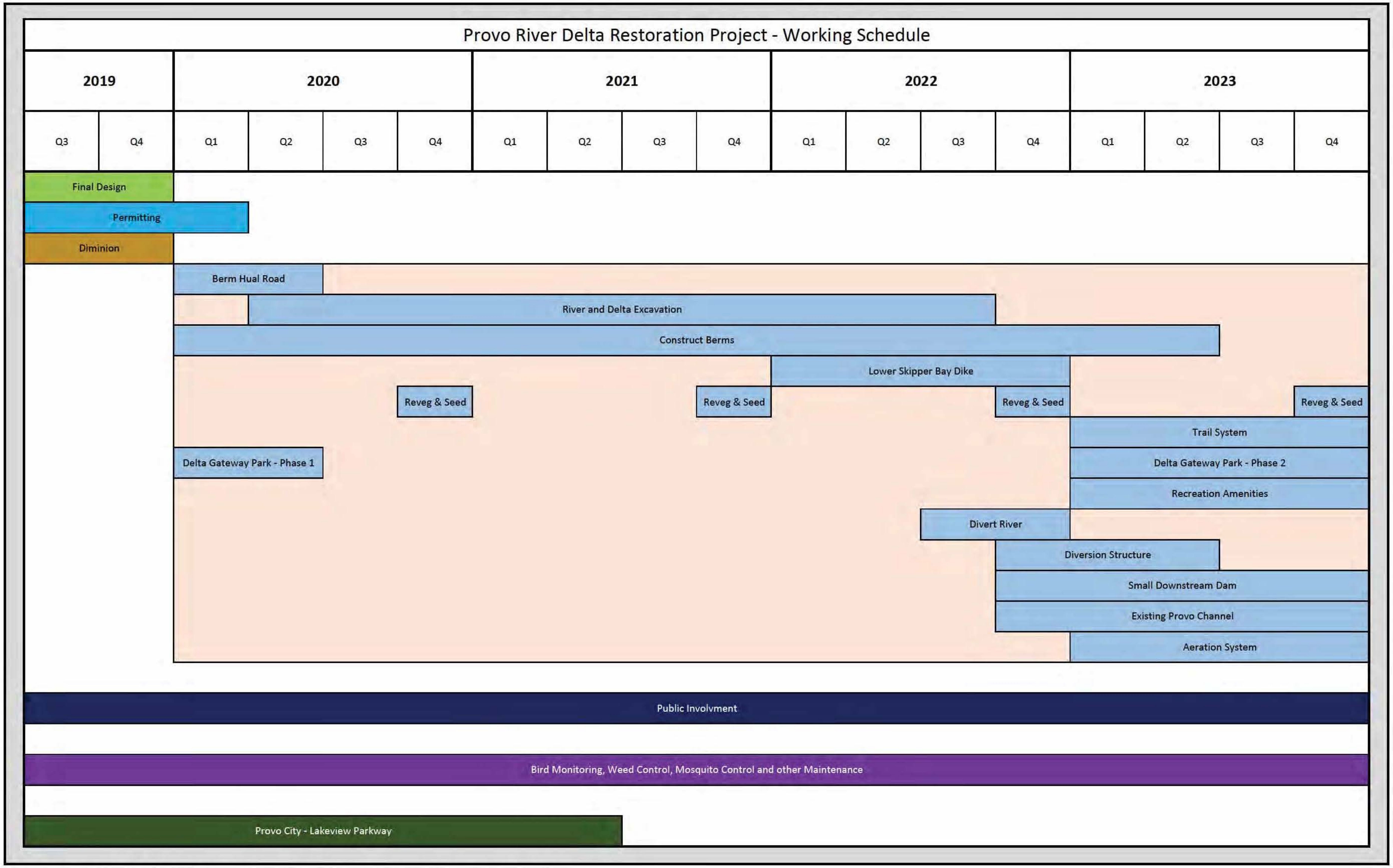


Figure 60. Schedule of major components of PRDRP construction and associated projects.