INCORPORATING WHITEWATER BOATING IN:
THE NIMBUS FISH PASSAGE PROJECT

ALEX KOUTZOUKIS

2012 SENIOR PROJECT

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Abstract

This project focuses on a half mile stretch of the Lower American River directly below Nimbus Dam in Rancho Cordova, California. It explores the possibility of incorporating recreational whitewater features in a river restoration project. Currently, the United States Bureau of Reclamation is obligated to make improvements to the fish collecting system at the Nimbus Fish Hatchery. As part of Alternative 1 in the Nimbus Fish Passage Environmental Impact Report, it is possible to construct recreational whitewater features with the removal of an old, damaged weir that spans the river. This project aims to evaluate the structures that are used in whitewater park design and how they can be conducive to salmonid spawning habitat. The design of the site includes the surrounding landscape which will serve to provide interpretive and educational opportunities for learning about salmonid species and the importance of protecting the American River Watershed. This project demonstrates how fish passage, stream restoration, and recreational whitewater boating can coexist for multiple benefits.

Fig. 1: Author river-surfing in Munich, Germany

About the Author

I am fascinated with the interaction between humans and nature. Being an avid whitewater enthusiast, this project was a perfect platform to combine my interests in Landscape Architecture, Ecological Restoration, and Outdoor Recreation. I can be contacted at akoutzoukis@gmail.com.

Dedication

This project is dedicated to my family. Thank you for your constant support over the past 22 years!

Acknowledgements

I would like to thank the following individuals for their assistance and contribution to my project.

Laura Drath
Fish and Wildlife Interpreter, California Department of Fish and Game, Nimbus Fish Hatchery

John Gainey
Lutsko Associates Landscape Architecture

Eric Giddens
Kern River Valley Council

Eric Larsen
Associate Researcher, Program of Landscape Architecture, University of California Davis

Alison McNally
Geography Graduate Group, University of California Davis

Michael Picker
Sacramento Paddle and Oar

David Robinson, Robert Hilldale and staff
United States Bureau of Reclamation

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Introduction

In urban areas across the United States, rivers have been severely disturbed as a result of human activities. Often, vegetation is cleared and channels are straightened or even lined with concrete to move water faster. However, during the past 20 years in the United States, some cities have recognized the great recreational significance of this natural resource and implemented what is known as “whitewater parks” in an attempt to restore and revitalize them. A whitewater park can be defined as “one or more man made structures in a stream, which create hydraulic features used by whitewater enthusiasts” (McGrath 2003). In the United States, over 30 whitewater parks have been constructed, with nearly half being located in Colorado (McGrath 2003). Studies have shown that whitewater parks not only are a great boost to local economies, they also can be symbiotic with the creation of salmonid habitat and returning rivers to a more stable geologic form.

The Lower American River

The Lower American River has been extremely altered over the past 150 years. Settlers clear-cut riparian forests and converted them to agricultural fields. Hydraulic gold mining in upstream rivers deposited large amounts of sand, silt, and fine gravels on the bed of the Lower American River, resulting in inadequate spawning conditions for salmonid species. Encroaching development and the hardening of channel edges has resulted in a habitat with lower complexity and cover for fish and other species.


Fig. 2: Folsom Dam

Prior to the construction of Folsom and Nimbus Dams, 125 miles of habitat in the American River Watershed was used by anadromous salmonids, fish that spend most of their life at sea. However, the construction of Nimbus Dam in 1955 completely cut off this habitat.

Folsom and Nimbus Dams have drastically altered the sediment deposition in the Lower American River. The two dams have cut off the upstream sediment supply that would normally accumulate as gravel beds used by salmonids for spawning.

Historically, the temperature in the Lower American River was far too warm for fry survival. However, the fighting chance that salmon have for survival is the fact that the water released from Folsom Dam is a much lower temperature, allowing for suitable spawning conditions.

Still, due to the destruction of the riparian forest of the Lower American River, salmonids are still facing the threat of high water temperatures (NOAA 2009).

These issues have the opportunity to be addressed in restoration projects on the Lower American River, and the Nimbus Fish Hatchery is an excellent location to serve as an example.

Nimbus Fish Hatchery

The Nimbus Fish Hatchery is located a quarter mile downstream of the Nimbus Dam on the Lower American River. The Hatchery was constructed in 1955 as a mitigation for Chinook salmon (*Oncorhynchus tshawytscha*) and Central Valley steelhead trout (*Oncorhynchus mykiss*) loss of spawning habitat due to the construction of Nimbus Dam.

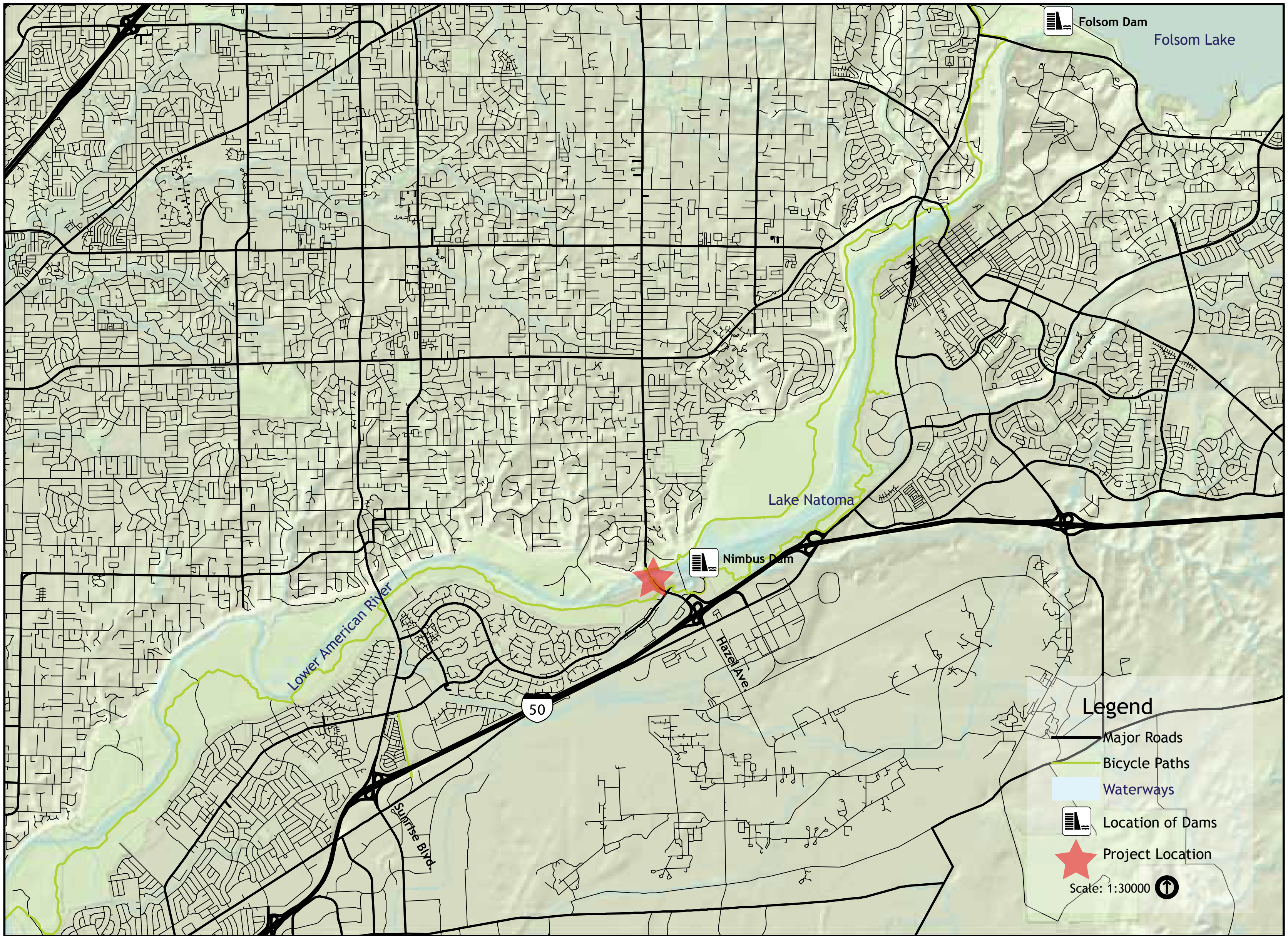


Fig. 3: Context Map

Central Valley Steelhead

Oncorhynchus mykiss

Status: Federally and California State listed as "Threatened"

Life History: The Steelhead in this project area are considered "Winter-run" and begin their migration in Fall. Unlike Chinook salmon, steelhead do not always die after spawning. They often return to the ocean and spawn in later years. (USBR, CDFG 2011). When the fry hatch, they move to other areas of the river for 1 to 3 years before becoming smolts and migrating to the ocean. Juvenile steelhead spend between one to four years in the ocean before migrating back to their spawning streams and repeating the process (USBR, CDFG 2011).

Diet: Juvenile Central Valley steelhead are opportunistic and will feed on almost anything available. Juvenile diet includes anything from aquatic and terrestrial insects to small fish, frogs, and even mice (Moyle, Israel, Purdy 2008).

Habitat Requirements: Central Valley steelhead require cold, clear, and well oxygenated water to successfully spawn. The optimal spawning temperature range is between 4-11 degrees Celsius, with embryo death starting at 13 degrees Celsius (Moyle, Israel, Purdy 2008). The gravel size that is preferred by steelhead for spawning tends to be 2"-3" in diameter and .5"-6" deep. Structures such as log and boulder weirs, deflectors, and clusters of rocks will also improve steelhead spawning habitat. During the first summer after spawning, steelhead tend to use shallow areas with cobble or boulder bottoms at pool tailouts, or riffles shallower than 24" deep. In winter, steelhead use large boulders in shallow riffles (CDFG 1998).

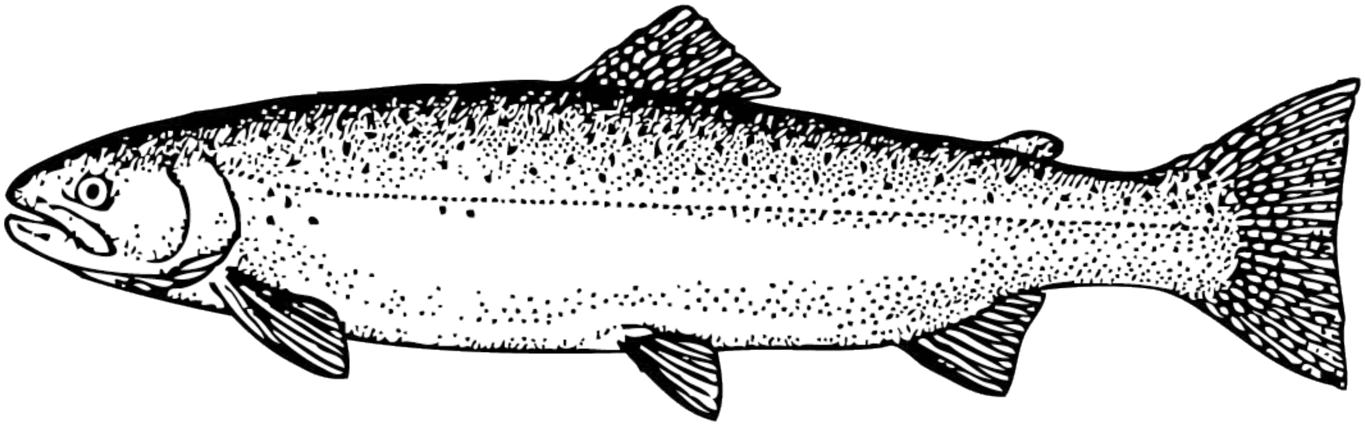


Fig. 4: Steelhead Illustration

Chinook Salmon
Oncorhynchus tshawytscha

Status: Candidate for Federal "Threatened" status, and a California "Species of Special Concern."

Life History: Fall run Chinook salmon are mainly seen between September and November (Moyle, Israel, Purdy 2008). Redds are dug in coarse gravel by female salmon who lay eggs and guard their redds for 4 to 25 days before dying (USBR, CDFG 2011). After fry hatch, they spend between 1 to 7 months in their spawning streams before moving downstream. They enter the San Francisco Bay as both fry and smolts (Moyle, Israel, Purdy 2008). Juvenile salmon spend between two to four years in the ocean before migrating back to their spawning streams and repeating the process (USBR, CDFG 2011).

Diet: Juvenile Chinook salmon are opportunistic and will typically forage on aquatic and terrestrial insects (Moyle, Israel, Purdy 2008).

Habitat Requirements: Generally, Chinook spawn in water with a depth between 1-3' however spawning can occur in water anywhere from 6" to 20' deep. Chinook use substrate that is .5"-10" deep with 1"-3" cobble. Other requirements include a water velocity of 1-3' per second with a gradient of .2%-1% (CDFG 1998). A combination of large gravel and small cobble provides sufficient opportunity for subsurface infiltration which is needed to provide oxygen for embryos. Therefore, the selection of redd sites depends on the permeability of gravel. Once hatched, fry tend to use stream edges and seek cover in vegetation against dark backgrounds. As they become larger, they are often predated by birds so they move into water deeper than 18". As they move downstream, they spend time in open waters at night and deep pools during the day (Moyle, Israel, Purdy 2008).

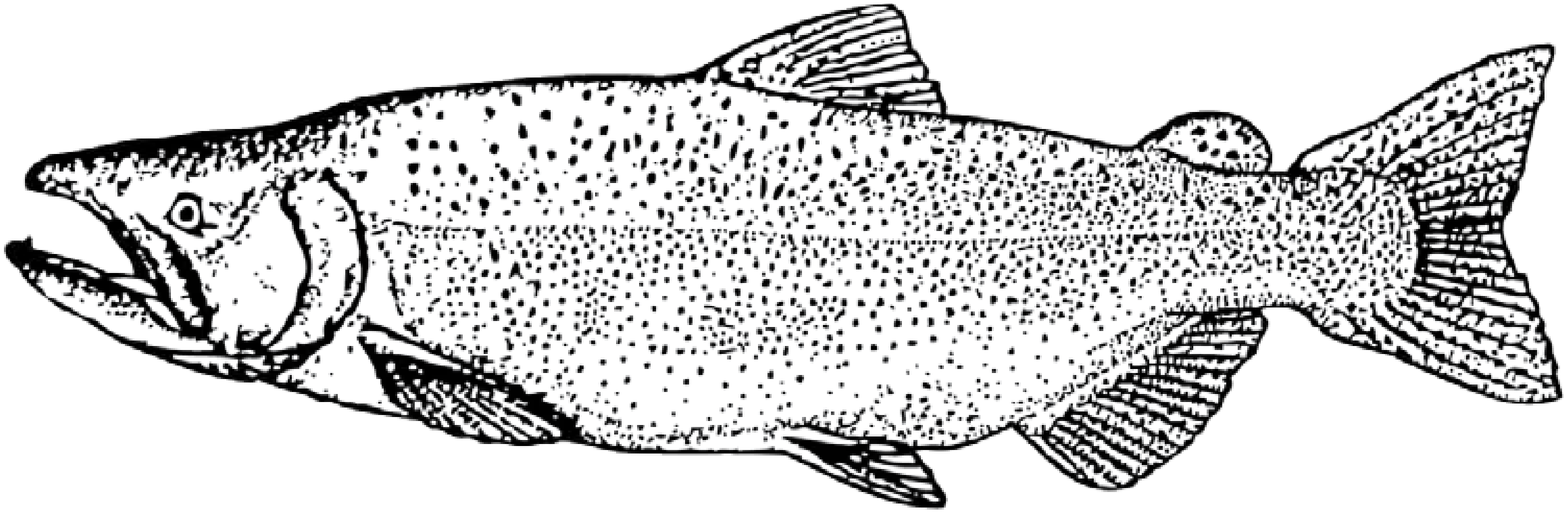


Fig. 5: Chinook salmon illustration

The Nimbus Fish Passage Project

Each Fall, Chinook and steelhead begin to appear at the Lower American River after a long journey from the ocean. When the water temperature is below 60 degrees (typically in November), California Department of Fish and Game employees install temporary screens in a weir that blocks salmon from continuing upstream. When the salmon reach the weir, they are directed up a fish ladder and into the hatchery where eggs are harvested and artificially fertilized. Although this system currently works, this is no replacement for natural reproduction as there are numerous problems associated with hatchery raised fish (NOAA 2011).

However, the weir has been damaged over the years, reducing the effectiveness of this system and posing a danger to staff that install the screens. The damaged weir also poses a significant threat to recreational users.

Fig. 6: Nimbus Fish Hatchery Weir

In order to continue to raise four million Chinook salmon smolts and 430,000 steelhead as obligated by the United States Fish and Wildlife Service and the California Department of Fish and Game; the United States Bureau of Reclamation has been authorized to make improvements to restore the functionality of this system. In August 2011, the United States Department of the Interior Bureau of Reclamation (USBR) and the California Department of Fish and Game (CDFG) released the Final Environmental Impact Report (EIR) for the Nimbus Hatchery Fish Passage Project (USBR, CDFG 2011).

EIR Alternative 1

Under Alternative 1, the weir would be removed and the fish passageway relocated upstream at Nimbus Shoals adjacent to Nimbus Dam. The channel would be restored and provide opportunity for salmon spawning. This alternative allows for the possibility of a recreational hydraulic feature.

EIR Alternative 2

Under Alternative 2, the weir would be replaced with an improved weir and new fish ladder. This alternative does not allow for the possibility of a recreational hydraulic feature and would have limited or benefit for salmon spawning.

EIR Alternative 3

Alternative 3 is to take no action and continue operations in current condition (USBR, CDFG 2011).

The preferred alternative appears to be Alternative 1, due to having a lower cost and potentially multiple benefits for habitat and recreation. The weir removal and restoration will enable the possibility of incorporating whitewater boating in the final design.

Project Goals

Using the EIR guidelines, this senior project will address the following goals through Landscape Architectural design:

1. Fish Collecting System Improvements

As part of Alternative 1, the weir will be removed and a more effective fish ladder will be relocated upstream.

2. In-Stream Spawning Habitat Enhancement

When the weir is removed, it will be necessary to restore the streambed and return the river to a more stable geologic form. This will create the potential for better spawning conditions.

3. Whitewater Boating Opportunities

As part of the stream channel restoration, it will be possible to incorporate features for whitewater boating in the design. Access points can be strategically located to allow users entry to the river.

4. Educational and Interpretive Opportunities

Where possible, educational displays and viewing opportunities will be included to promote awareness of the American River watershed and the potential impacts that humans have.

Design of Whitewater Parks

Whitewater Parks are typically designed as part of a larger stream restoration or urban revitalization project. These parks vary in appearance from highly urban to natural-looking, and everywhere in between.

Figure 7: Confluence Whitewater Park in Denver, Colorado

Although the majority of whitewater park design is done by engineers, according to Christine Clark a Landscape Architect at S2O Design and Engineering, "There is a surprisingly large role in whitewater park design for Landscape Architects as well as for architects and planners" (Clarke 2011). Currently there appear to be 3 main engineering firms that specialize in whitewater park design in the United States. S2O Design and Engineering is one of them. According to S2O, the whitewater park design process includes at least 7 steps.

Step 1: Interest

First, it is crucial that there is significant interest in getting a whitewater park constructed at a given site. Typically, a local whitewater paddling group or individual will work with government and stakeholders to create community interest (S2O 2012). At the Nimbus Fish Hatchery Project, a group known as the River City Oar and Paddle Foundation recognized the possibility of the creation of a recreational feature at the Nimbus Weir, and began to attend community meetings in order to gain community interest. In December, 2004, workshops were held to gain community input on the project. Attendees included groups from SAFCA (Sacramento Area Flood Control Agency), the Water Forum, the Sierra Club, Save the American Association, River Park Neighborhood Association, as well as fishing groups, local paddling groups and government agencies (Philip Williams & Associates 2005).

Step 2: Feasibility Report/Conceptual Design

Once there is significant interest in getting a whitewater park built, an engineering firm will be brought in to study the feasibility of implementation. If feasible, a conceptual design, cost estimate, and feasibility report will be produced in order to provide stakeholders with enough information to understand how the constructed whitewater park will look, function, and cost (S2O 2012). The River City Oar and Paddle Foundation hired a Sacramento engineering firm, Philip William & Associates, Ltd to prepare a feasibility study and conceptual design for a recreational hydraulic feature as part of the Nimbus Fish hatchery project. Inside the feasibility study is information such as existing geologic and hydraulic conditions, as well as three different conceptual design alternatives (Philip Williams & Associates 2005).

Step 3: Fundraising

After the feasibility study and conceptual design(s) have been completed, the interested parties have enough information to accurately inform the public about the proposed project. The next stage is to raise funds and inform the community about the changes proposed.

Step 4: Preliminary Design

Once it appears that the project has a high chance of being implemented, additional design work needs to be completed. At S2o Design and Engineering, a preliminary design is completed based on input from meetings with the public and/or stakeholders. A series of drawings and reports are produced (S2O 2012). Since no further design advancements have been made for the Nimbus Fish Hatchery Project, this senior project will start at this stage and build on the conceptual design produced by Peter Williams and Associates.

Step 5: Permitting Process

Although not within the scope of this senior project, the next stage of the whitewater park design process is to create and apply permits. According to the S2o website, S2o will "shepherd the design through the permitting process" (S2O 2012). It appears that the permitting process is difficult and the expertise of a firm that specializes in this kind of work would be very beneficial. Furthermore, there is only one completed whitewater park in California, whereas there are 13 in Colorado (American Whitewater 2012), possibly due to environmental regulations.

Step 6: Revisions

Once the permitting process is complete, S2o will update and make changes to the design based on what is required from the permitting process. Final construction and bidding documents will be produced for the construction of the park.

Step 7: Construction

The final stage is the overseeing of construction. It appears that most engineering firms encourage construction oversight by their staff. S2o states that "S2o works with the contractor to ensure that the project is built to our exacting standards" (S2O 2012)

Economic Impact

Numerous whitewater parks have demonstrated that these projects can have a great economic impact on nearby communities. The Reno Whitewater Park was constructed at a cost of approximately $1.5 million and it has been estimated that the annual economic benefit is between $2 million and $4 million. Another project in Breckenridge, Colorado was constructed at a cost of $500,000 and yields $1.5 million each year (REP 2011).

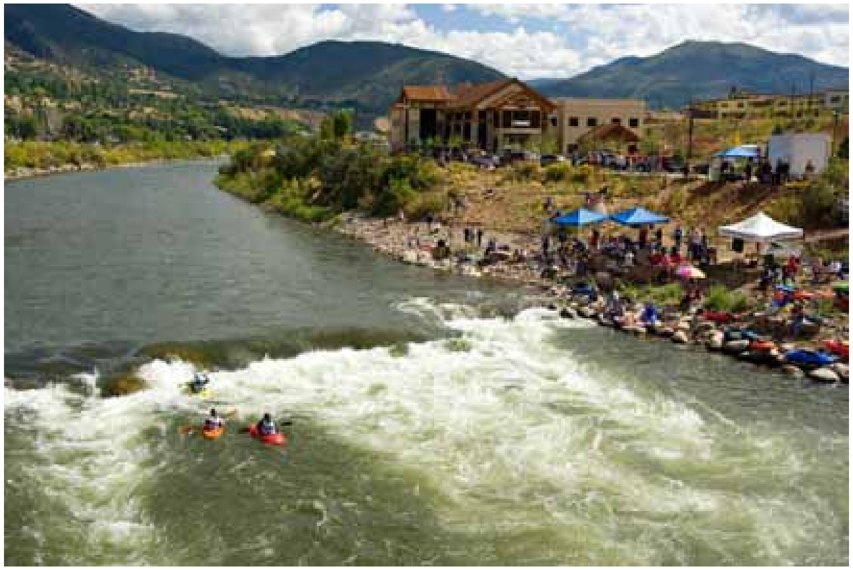


Fig. 8: Glenwood Whitewater Park in Glenwood Springs, Colorado

Geomorphology of Rivers

The design of whitewater parks is multi disciplinary and includes engineers, geomorphologists and hydrologists, yet it is important that a stream designer understand concepts from fluvial geomorphology so that they understand the implications that design decisions might have on the function of a stream.

Although a natural stream channel may appear to be stationary, it is in constant change. As one bank is eroded laterally, it is deposited on the opposite bank, maintaining a constant cross section on average. Although the stream will migrate laterally, the cross section stays stable. According to Leapold, “the stable form the channel will assume is one in which the shear stress at every point on the perimeter of the channel is approximately balanced by the resisting stress of the bed or bank” (Leapold 1994).

The shape of a stream channel can be attributed to flow, sediment in motion, and composition of materials. Materials such as vegetation, bedrock, and the properties of bed material all have an effect on channel shape. As threshold of erosion of these materials increase, channels become narrower. For example, a stream with a silty bed and bank will be narrower than a similar, sandy one. Rivers in the southern United States are relatively muddy and deep, while rivers in the semiarid Southwest are relatively sandy, wide, and shallow (Leapold 1994).

As a the tightness of a stream curve increases, so does the rate of erosion and deposition. As sediment is deposited at the convex bank of a river, a flat surface (floodplain) is formed. A floodplain is defined by Leapold as “a level area near a river channel, constructed by the river in the present climate and overflowed during moderate flow events.” The term “present climate” is used because in drier climates with less average flow, a floodplain can be abandoned leaving a terrace. Leapold observed that “channels in western states showed that streams in the semiarid areas changed from a state of erosion and instability during the first quarter of the twentieth century to a state of healing by vegetation in the midcentury” (Leapold 1994).

In general, a river channel alternates between deeps (pools) and shallows (bars) every 5 to 7 times the channel width. The same is true for straight channels. According to Leapold, “the similarity in spacing of the riffles in both straight and meandering channels suggests that the mechanism which creates the tendency for meandering is present even in the straight channel.” Leapold has found this pattern to be true in almost all channels with bed material larger than coarse sand. At a high flow, water is forced to rise over a bar, while at a low flow, some of the water sinks and flows through the bar. One of the reasons that salmonids lay eggs at the upstream side of a bar is so eggs do not get washed downstream. (Leapold 1994). In whitewater park design, a shallow could be considered a grade control structure that creates a hydraulic jump or riffle.

Rivers are almost never straight. Even in an apparently straight reach, the “thalweg” or deepest part of the channel tends to sinuously wander relative to channel width. According to Leapold, there is “in channels of all sizes a remarkable relationship among the wavelength, channel width, and radius of curvature.” The wavelength (distance between each pool and bar) is typically 11 times the channel width, and almost always between 10 and 14 widths. The radius of the channel bend is typically 1/5th of the wavelength (Leapold 1994).

Fig. 9: *Author at swiftwater rescue certification course*

Safety Considerations

Whitewater recreation is inherently dangerous. However, there are various ways to reduce safety hazards when designing a stream channel.

In March, 2012 I enrolled in a swiftwater river rescue certification course to better understand whitewater hazards and how physical features of a stream can be designed to be safer.

Safety Considerations

Strainers and Sieves

A strainer occurs when water flows through living or dead wood along the bank that a swimmer or boat cannot. Sieves are similar to strainers, but occur when water flows through rocks or boulders. Both strainers and sieves are life threatening and should be avoided (Colburn 2012). A stream that is subject to recreational use should be designed without strainer or sieve hazards.

Fig. 10: Example of strainer hazard

Underwater Hazards

A stream bottom can contain hazards such as strainers hidden just below the surface. One of the most dangerous stream bottom features are undercut rocks that can cause foot entrapment (Blum 2012). When rocks and boulders are installed in a river, it is important that they be set flush to the bottom to prevent foot entrapment.

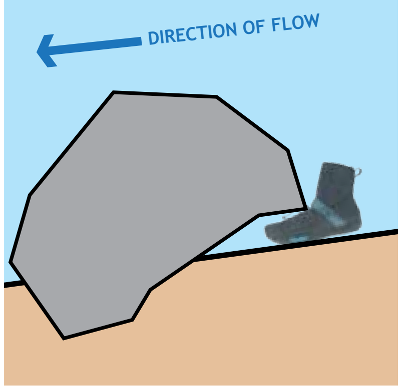


Fig. 11: Example of foot entrapment rock

Hydraulics

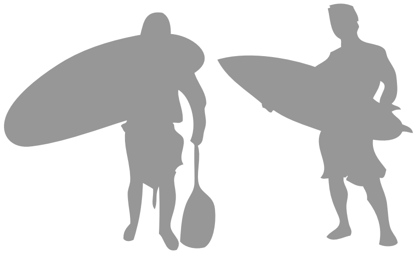
Hydraulics are waves or holes formed by underwater bathymetry and rock formations including man-made grade control structures. Hydraulics can be considered fun or life threatening depending on a variety of factors. Generally, the steeper a hydraulic, the more “hole-like” it becomes and the harder it is to escape. For example, a low head dam creates a very steep, uniform hydraulic that poses a severe hazard to swimmers. Hydraulics should be designed asymmetrically so that there is variability for boaters to move to either side if they become stuck in a hydraulic (Colburn 2012).

Fig. 12: Example of a low head dam hydraulic

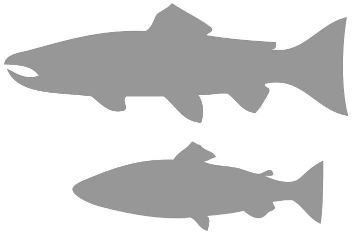
River Features

For most whitewater boaters, a day on the river consists of more than just traveling from point A to B. Boaters seek out particular features that provide opportunities to perform specific maneuvers.

Vertical Drops



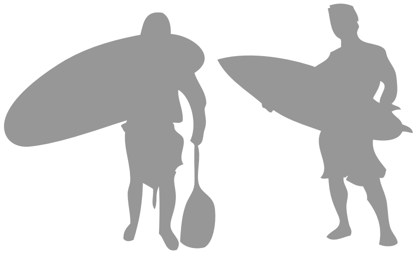
Experienced paddlers often look for vertical drops while paddling downriver. They are used for “boofing” which is thrusting off a rock and landing flat. Paddlers “boof” for fun or to launch over a potentially dangerous hydraulic (Colburn 2012).



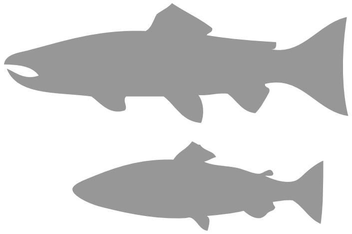
Vertical drops typically occur naturally in rivers and often create a hole at the bottom of the drop. Hydraulic jumps such as vertical drops contribute to the oxygenation of water that is vital to salmonid spawning (McGrath 2003).

Fig. 13: Kayak boof maneuver

Hydraulics; Waves and Holes



Holes are more retentive and provide opportunities for moves such as front loops. Waves typically are shaped like an ocean wave (Colburn 2012) and allow for more surfing oriented maneuvers.



Similar to vertical drops, waves and holes are formed by natural or artificial hydraulic jumps. These features also contribute to oxygenation of water for salmonid spawning and cover (McGrath 2003).

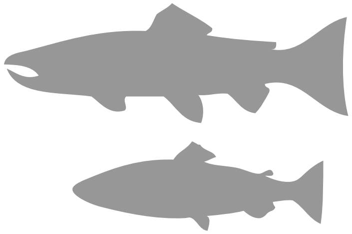
Fig. 14: Wave shaper model creating a hole feature

Fig. 15: Wave shaper model creating a wave feature

Fig. 16: River-surfers in Munich, Germany

Pools

Deep pools help with recovery and rescue room for boaters after rapids. Quiet water provides a place to rest for the next rapid (Colburn 2012).



Deep water helps keep temperatures cool for steelhead during Summer. Juvenile salmonids use deep pools for cover and heads of pools for feeding (Moyle, Israel, Purdy 2008).

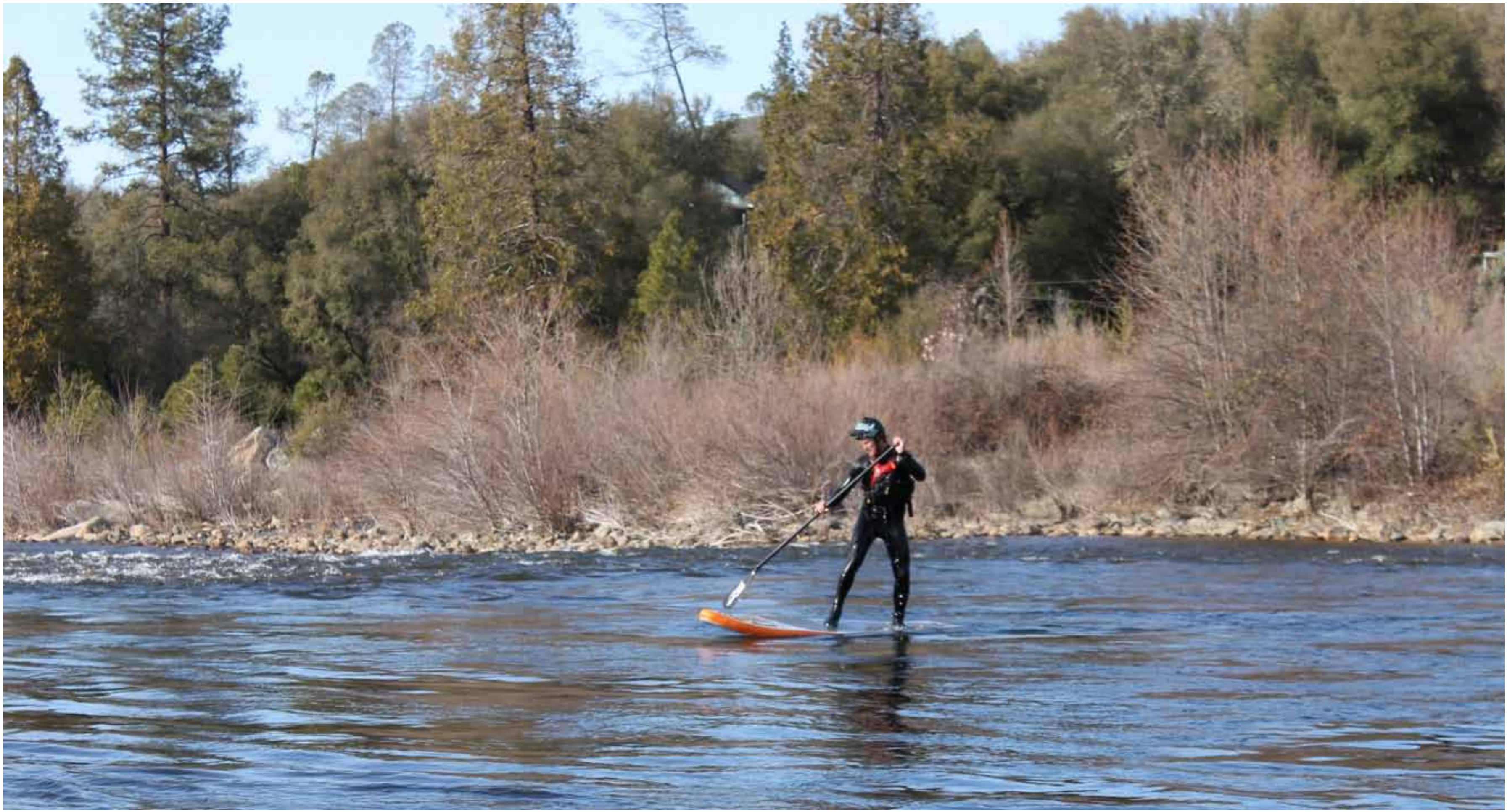
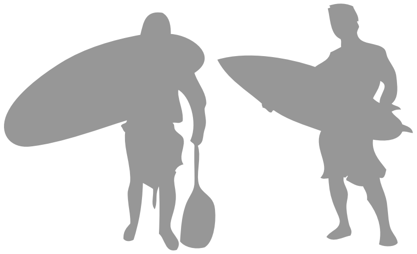
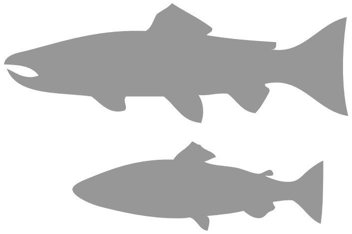


Fig. 17: Standup paddle boarder using a deep pool on the South Fork American River

Random Boulders and Eddies



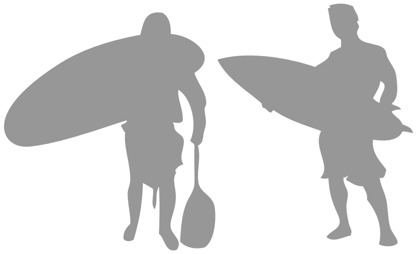
Random boulders can be used to “eddy-hop” through rapids and scout the rapid before moving downstream (Blum 2012).



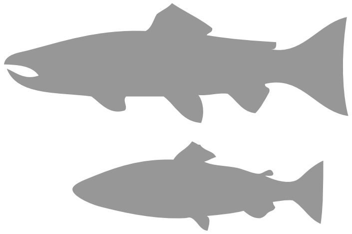
Eddies created by boulders are used by salmonids for resting in search of food and cover from predators. Boulders can help with scouring and deposition of spawning gravels (CDFG 1998).

Fig. 18: Riverboarder using boulders to eddy hop on the South Fork American River

Access Points



Access points can be used to help river users descend to the water. Some whitewater parks have included ADA water access ramps in their designs.



By having designated access points, negative impacts such as trampling of vegetation, erosion, and disturbance of sensitive habitat can be avoided.

Fig. 19: River access point at the Brenta River in Italy

Anatomy of a Hydraulic Jump

This small artificial grade control structure creates a hydraulic jump at a whitewater park in Italy containing many of the features that are seen in typical whitewater parks.

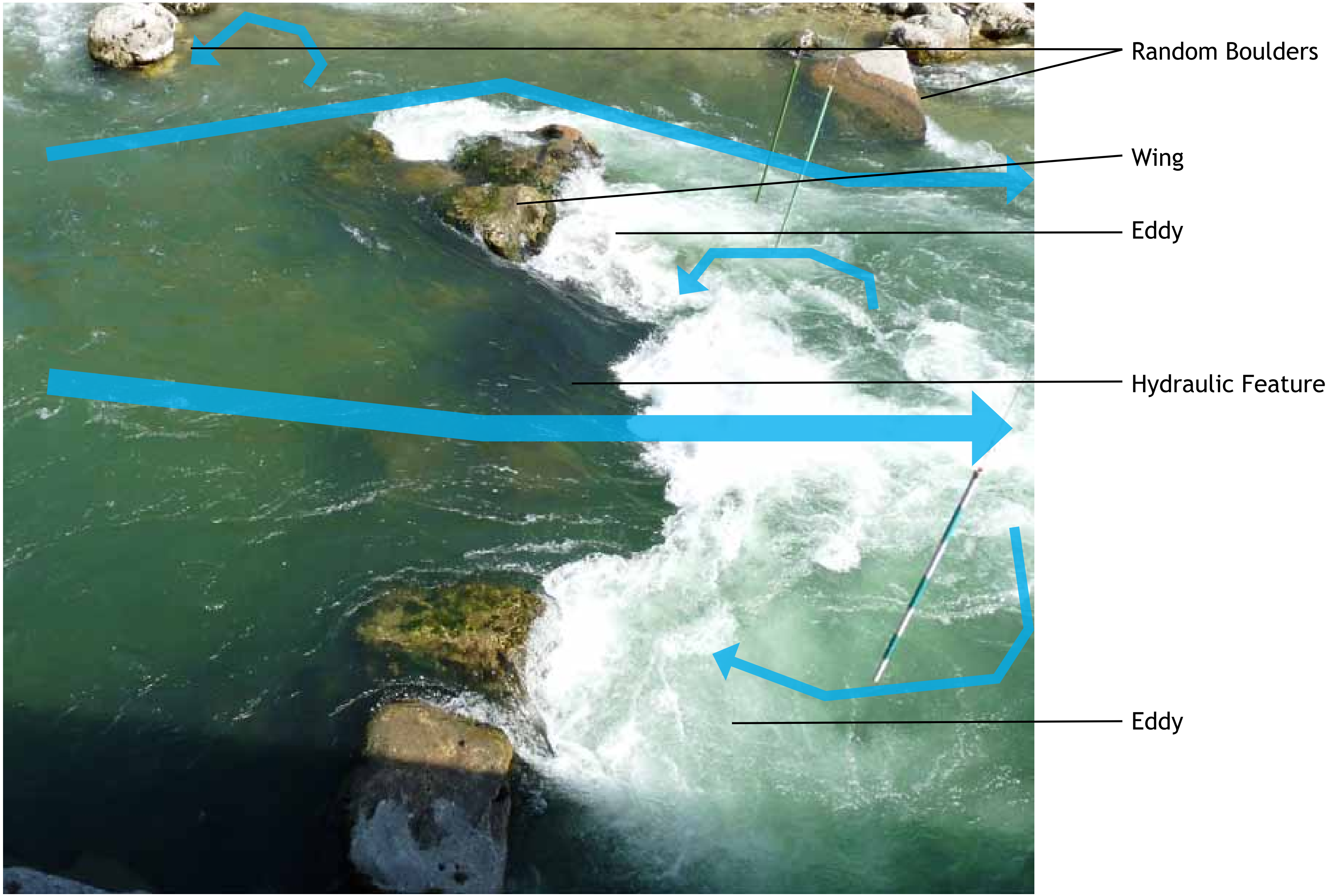


Fig. 20: A grade control structure in the Brenta River, Italy

Case Studies

Throughout 2011-2012, I visited various hydraulic features in the Sierra Nevada foothills that are frequented by whitewater boaters to analyze how the sites were being used. Locations of structures were noted, and currents and eddy locations were observed at various flows.

Barking Dog Rapid

River: South Fork American, California
Natural/Artificial: Natural with modifications by river users
Suitable Flow: 1,200-2,300 cfs
Characteristics: The hydraulic at Barking Dog Rapid has both a hole and wave section for a variety of maneuvers. Kayakers are seen performing freestyle maneuvers in the hole section, while the glassy wave is used more for surfing.

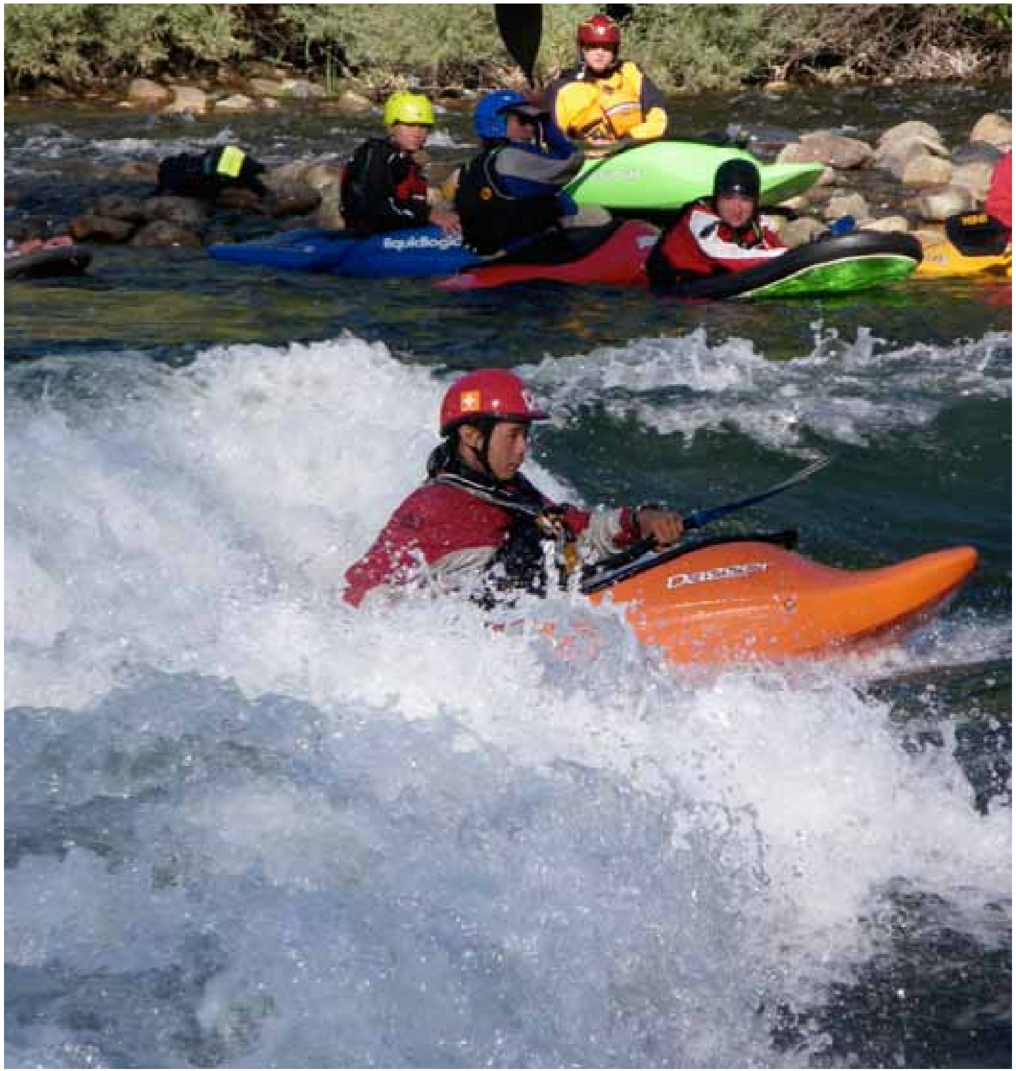


Fig. 21: Kayaker on Barking Dog

Fig. 22: Riverboarder on Barking Dog

Fig. 23: Riverboarding using eddy at Barking Dog

Barking Dog Rapid

Description: River users frequent this rapid for the purpose of boating in the hydraulic jump. Barking Dog occurs as the main river makes a right hand turn. A boulder structure causes the river to become narrower as it plunges into a deep pool forming the hydraulic feature.

Accessibility: There is no way to directly access Barking Dog rapid by public land. Users typically launch at Camp Lotus (private campground) and paddle approximately 500 feet downstream to use the feature. Others use the feature as part of a longer float downriver.

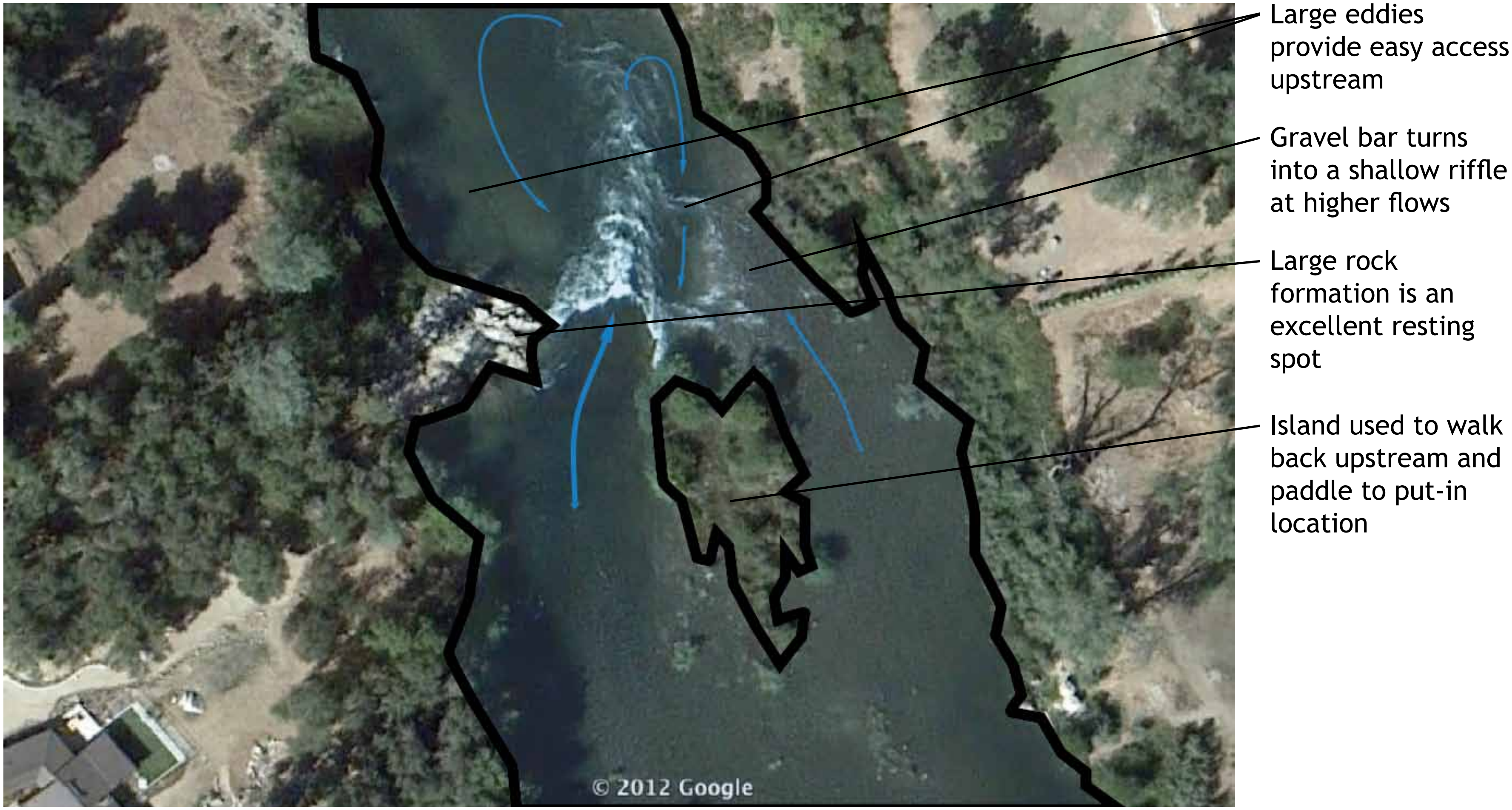


Fig. 24: Barking Dog Rapid

Reno Whitewater Park

River: Truckee River, NV
Natural/Artificial: Artificial
Suitable Flow: 300-3,000 (+) cfs
Characteristics: The whitewater park varies depending on flows. At lower summer flows, the hydraulics are typically more "hole-like", while at higher flows, they will become more "wave-like". A wide range of uses are seen at the park including rafting, kayaking, and inner tubing


Fig. 25: Reno slalom channel


Fig. 26: Reno main channel

Fig. 27: Kayaker looping on a feature in Reno

Reno Whitewater Park

Description: The Reno Whitewater Park was completed in 2003 and was designed by Recreation Engineering & Planning at an expense of $1.5 Million for channel improvements. The park consists of two channels with five grade control structures in the larger channel, and six in the smaller channel. The park revitalized a neglected stretch of river and is regarded as a great urban design success. The design features smooth flat top boulders for easy access and spectating.

Accessibility: The park is centrally located in Downtown Reno and is well integrated into the existing street grid layout with multiple entrances.

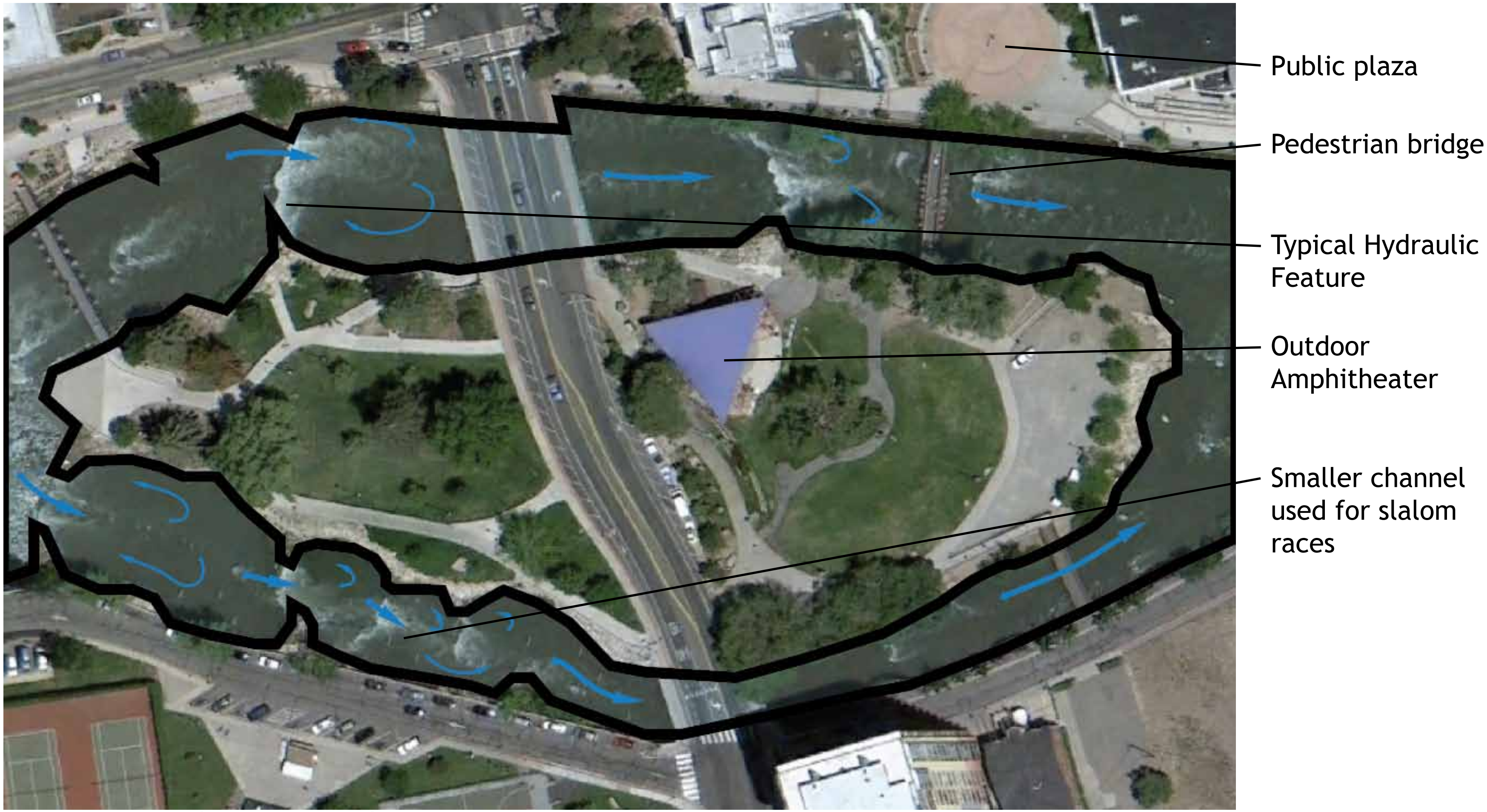


Fig. 28: Reno Whitewater Park

First Threat Rapid

River: South Fork American River, CA
Natural/Artificial: Natural
Suitable Flow: 1,200-4,000 cfs
Characteristics: First Threat is a very powerful wave that boaters spend time on as part of a longer trip downriver. Dr. Greg Pasternack, of UC Davis studied this hydraulic and found that it contained 58% air content, the highest recorded in his study of multiple hydraulic jumps in this river (Pasternack 1999). Aerated water can be beneficial to salmonid spawning.

Fig. 29: Kayaker on First Threat

Fig. 30: Freestyle surfing competition at First Threat

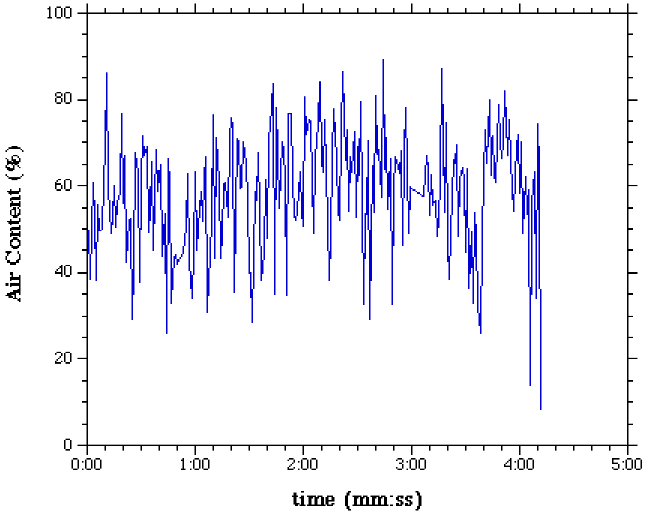


Fig. 31: Air content in First Threat

First Threat Rapid

Description: First Threat occurs as the river makes a right hand turn. A boulder structure at river left causes the river to become narrower as it plunges over a series of boulders that act as a grade control structure. Boaters can be seen using the feature year-around due to guaranteed weekend recreational releases on the South Fork American River.

Accessibility: There is no way to access First Threat rapid directly by public land. Users typically launch below Chili Bar Reservoir and paddle approximately 3 miles downstream to use the feature, paddling 2 more miles downstream to Henningson-Lotus Park where they take out.

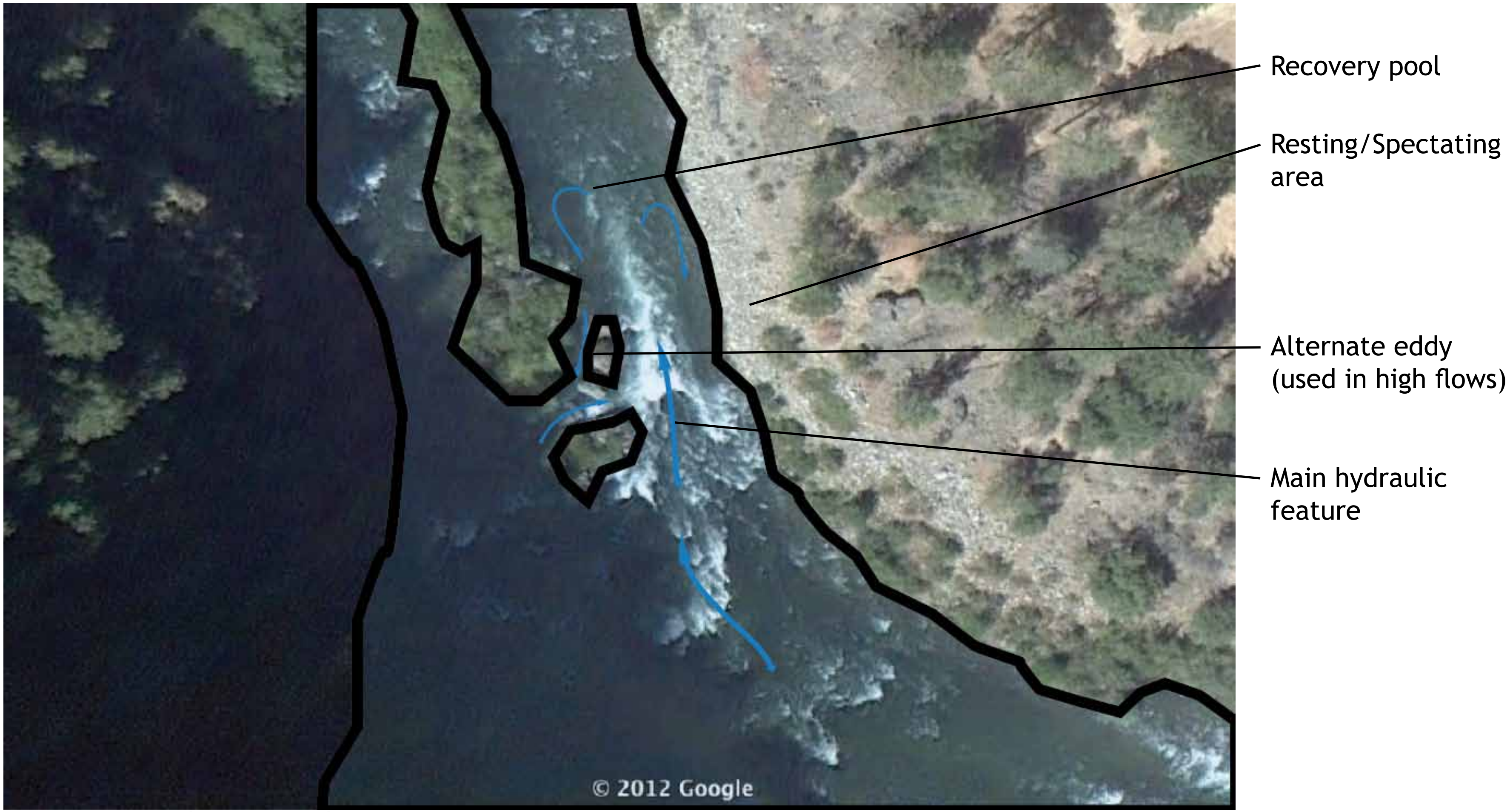


Fig. 32: First Threat Rapid

Site Inventory and Analysis

The Nimbus Fish Hatchery was visited multiple times over the course of six months in a variety of weather conditions to better understand the feel and functionality of the site.

River Bathymetry

Since topography is a critical component of this site, it was necessary to create a fairly accurate base map. This was accomplished by using GIS (Geographic Information Systems).

Step 1: Process Bathymetric Survey

A bathymetric survey performed in 2008 was obtained from the United States Bureau of Reclamation (USBR). The survey consisted of coordinates and depth measurements from a Trimble 5800 RTK-GPS and ADCP (Acoustic Doppler) running on a boat. Using ArcMap, the survey was processed and converted into a TIN elevation model.

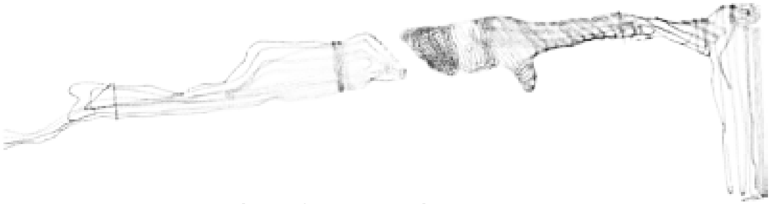


Fig. 33: GPS tracks of survey boat

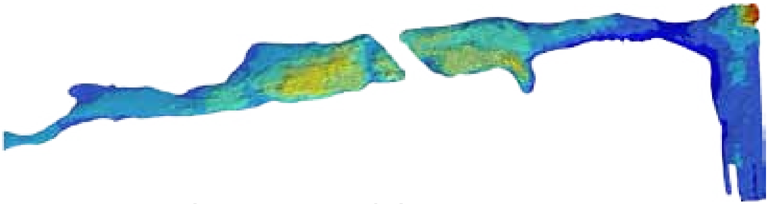


Fig. 34: TIN elevation model

Step 2: Merge Bathymetry with Sacramento County Elevation Data

The TIN model was merged with 2 ft. contours from Sacramento County to create a Digital Elevation Model (DEM) of the entire site which can easily produce analyses such as slope, aspect, and produce topographic contours.

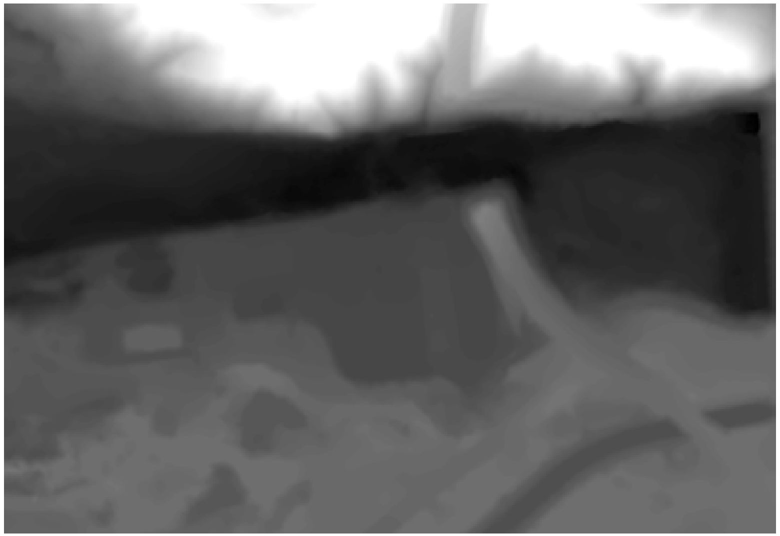


Fig. 35: TIN model merged with Sacramento DEM

Fig. 36: Final topographic map

Site Layout

The site is adjacent to the American River Fish Hatchery and the Sacramento State Aquatic Center. The Aquatic Center could potentially use the whitewater park in their programs. The existing fish ladder extends from the weir to the hatchery facility, while the proposed fish ladder will be extended to Nimbus Shoals creating a more gently sloped approach to the hatchery.

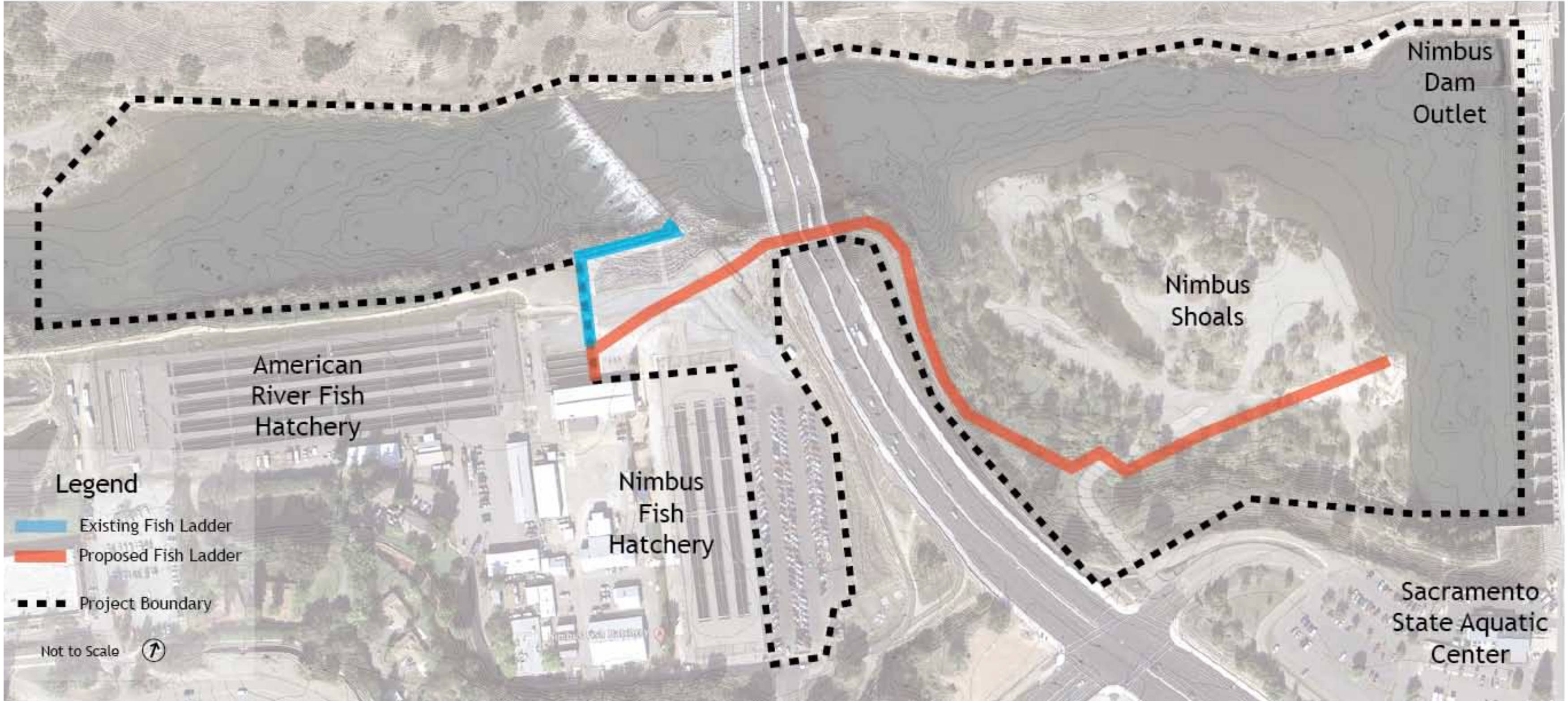


Fig. 37: Site Layout

Fig. 38: Location of fish ladder approach

Circulation

The site is located a half mile from Highway 50 off Hazel Avenue. The American River Bike trail passes through the site, providing alternative transportation options. Pedestrian access is extensive through the site however there needs to be more convenient access between the hatchery and Nimbus Shoals. The Fish Hatchery Parking lot is extremely large with potential for pavement removal and stormwater infiltration.

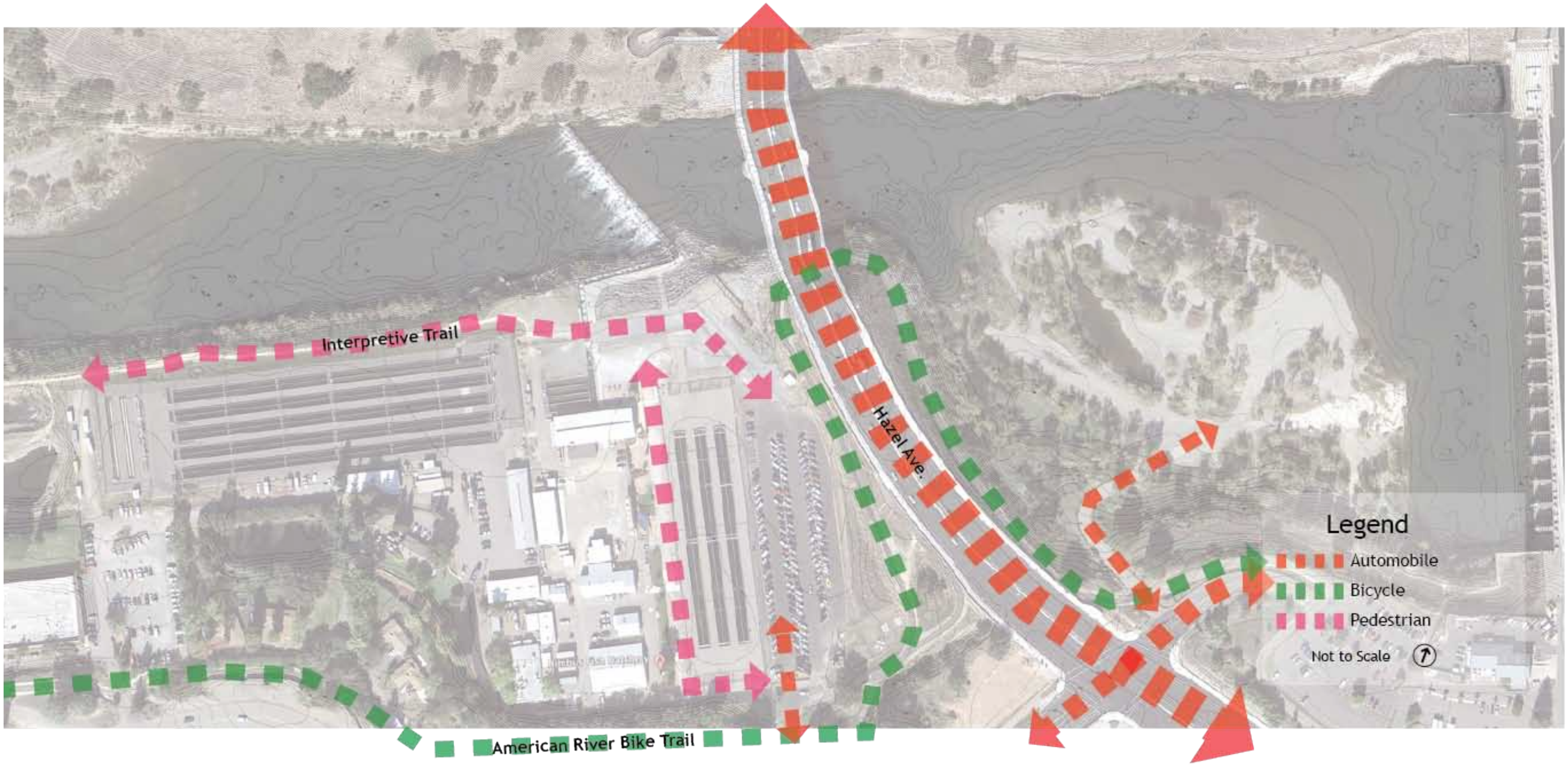


Fig. 39: Circulation

Weather

Weather at the site is typically suitable for whitewater recreation year around with appropriate equipment. Average river flows vary from 2,000 cfs during Fall to 5,000 cfs during peak runoff times. During spawning season when the whitewater park would be closed, flows are typically the lowest. Therefore, the park should be designed for flows between approximately 2,000 cfs and 5,000 cfs.

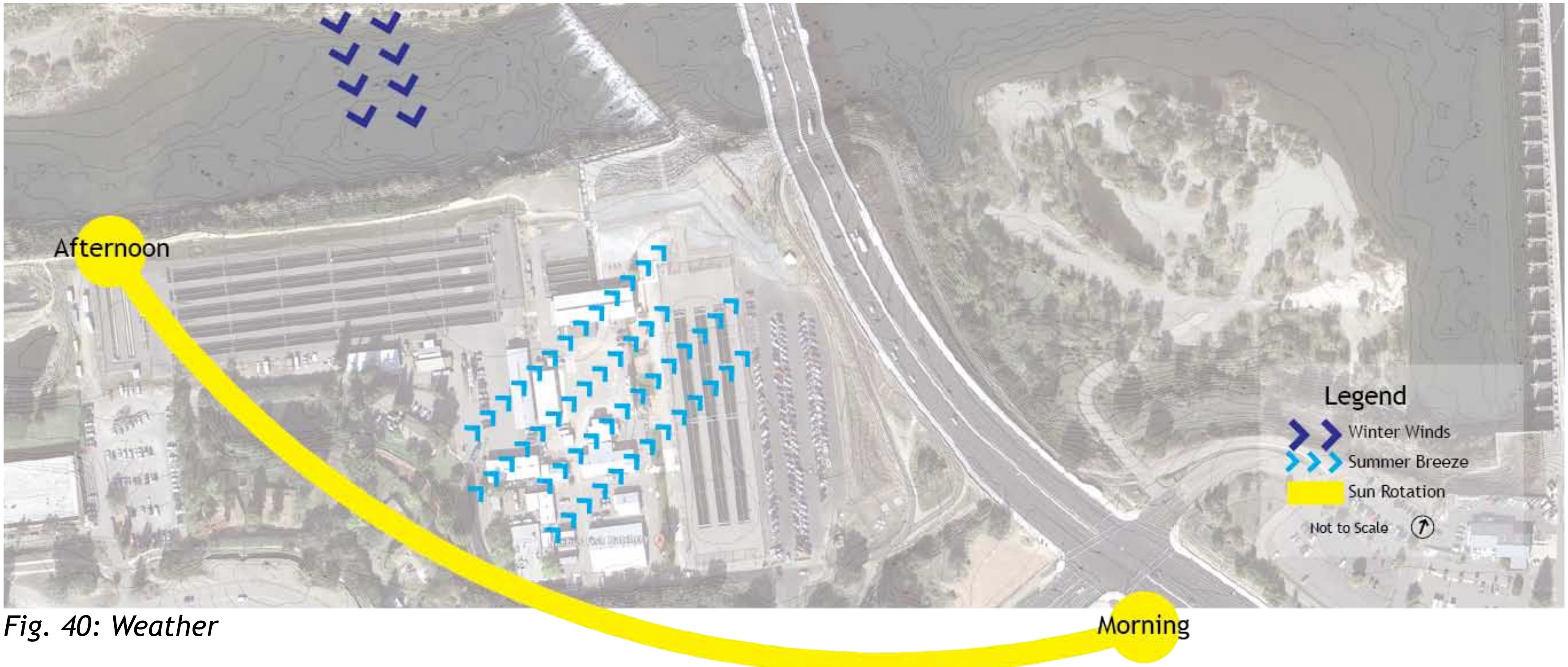


Fig. 40: Weather

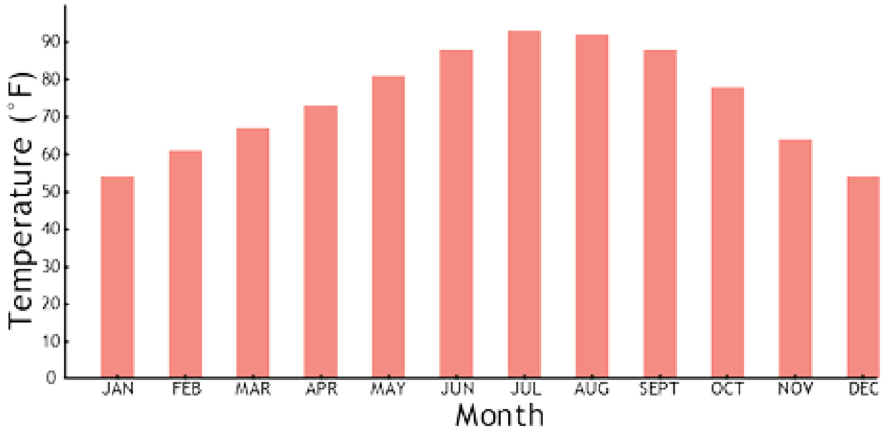


Fig. 41: Temperature in Rancho Cordova

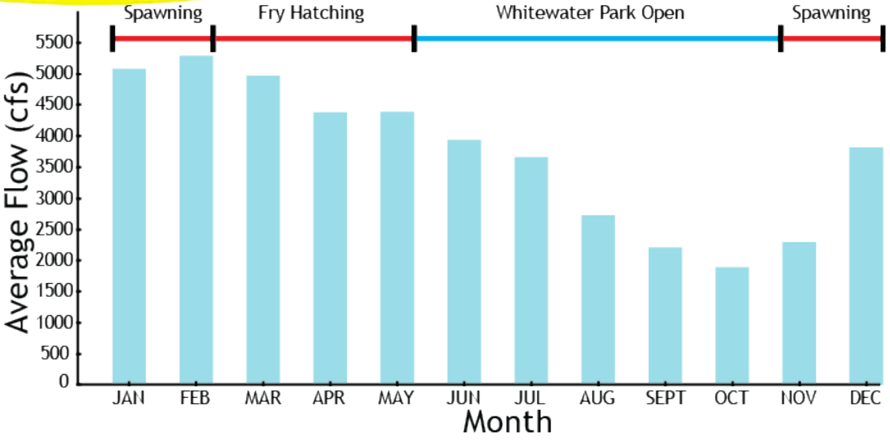


Fig. 42: Lower American River Flows

Geomorphology

The river has been extremely altered due to dams, mining, and encroaching development. The South bank consists mostly of rip-rap with some vegetation. It appears that releases from Nimbus Dam have severely eroded the North bank. The weir has been severely damaged and may be a hazard to swimmers and boaters. The weir creates a hydraulic jump of 4.5 feet. When the weir is removed, that jump could be distributed in multiple drops that are more friendly towards whitewater recreation.

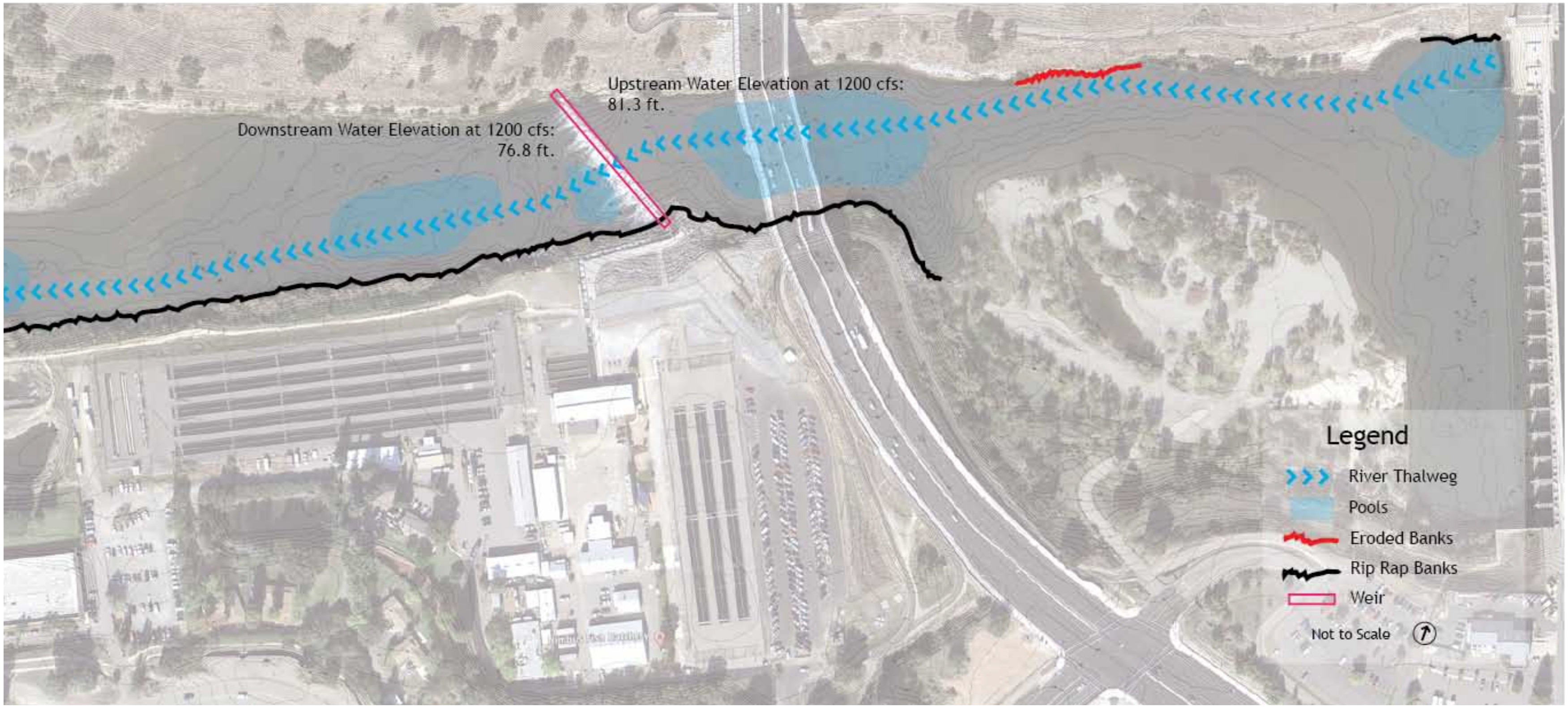


Fig. 43: Geomorphology

Fig. 44: Eroded banks

Design

This design is based on the site analysis and incorporates multiple interests including fish passage and restoration, whitewater boating, and education into a cohesive master plan.

Master Plan

❶ Fish Hatchery Visitor Center
❷ Proposed Fish Ladder
❸ Proposed Grade Control Structures 1-4
❹ Fish Viewing Plaza
❺ ADA Access Ramp
❻ Stormwater Parking Lot
❼ Turf Area
❽ ADA Accessible Restroom

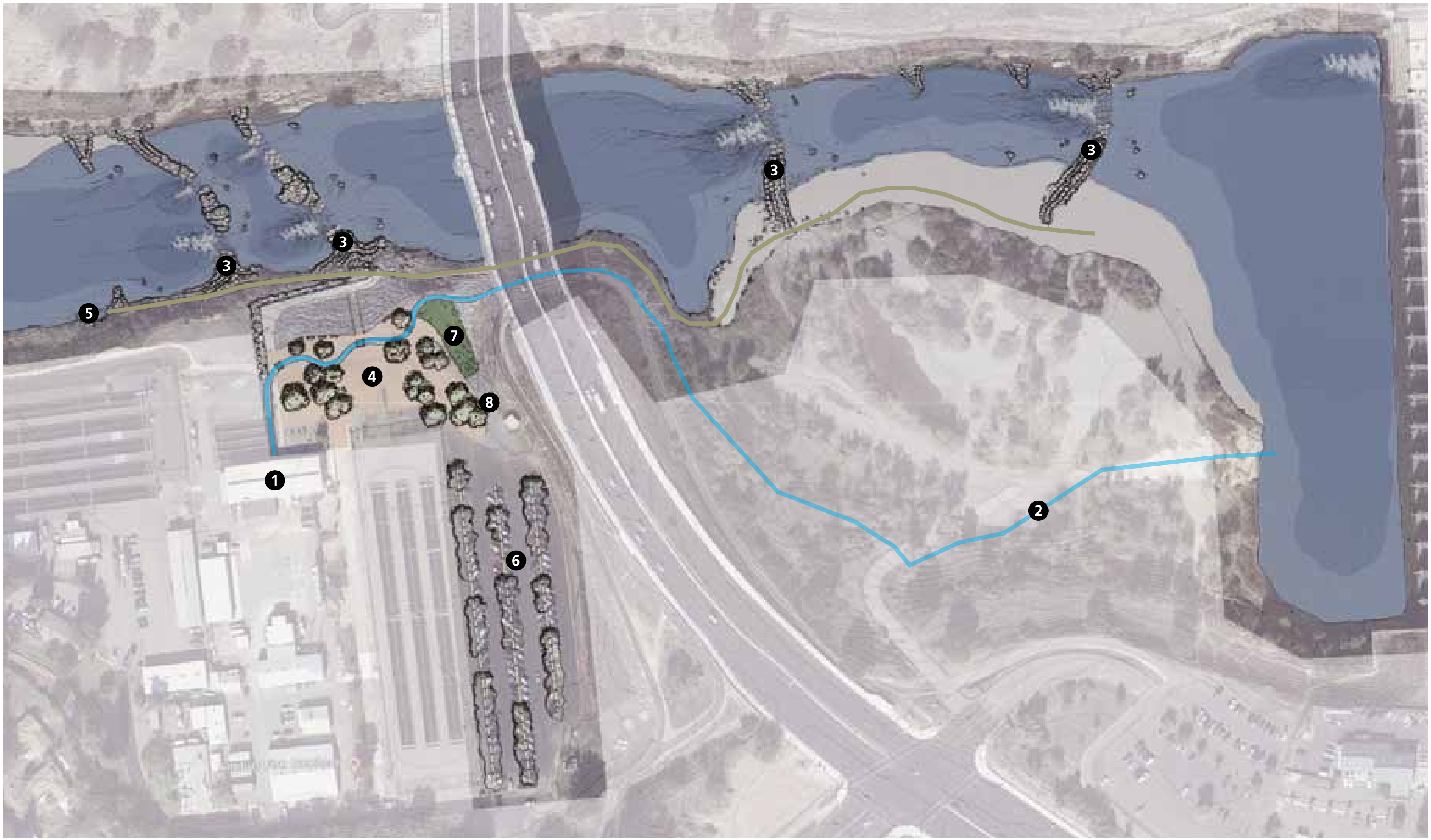


Fig. 45: Master Plan

Proposed River Profile

At approximately 1,200 cfs the upstream water elevation of the fish weir is 81.3 while the downstream elevation is 76.8. Four grade control structures are used to control the 4.5 foot elevation change. Structures #1 and #2 are designed for intermediate level boaters with an elevation change of 1 and .5 feet, respectively. Structures #3 and #4 are designed for intermediate and advanced level boaters with elevation changes of 1.5 feet. Each grade control structure will be engineered to produce a safe and high quality hydraulic for boating and surfing.

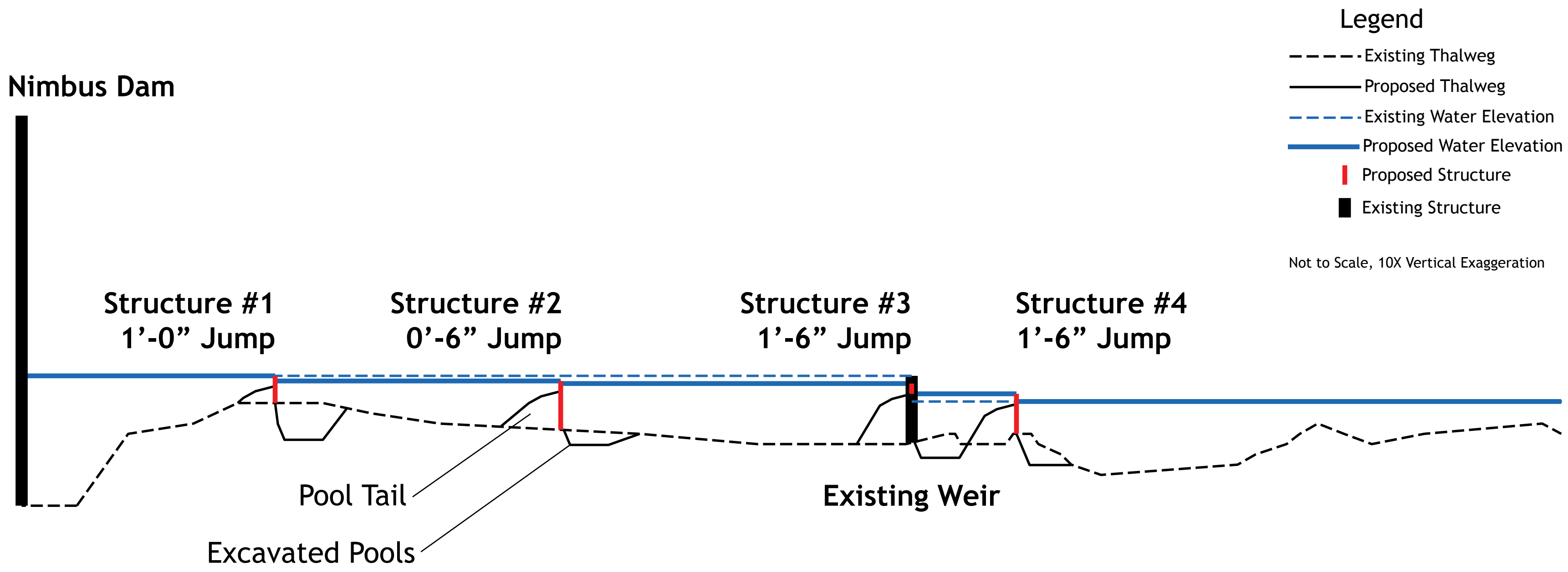


Fig. 46: Proposed River Profile

Typical Grade Control Structure

Terracing is used to help accommodate a range of flows. At higher flows during late spring when the whitewater park opens, the structures will produce a hydraulic that is more wave-shaped and favored by advanced kayakers and river-surfers. The 2nd terrace will become submerged at this flow. At the end of summer when the flow drops, the hydraulic will become more hole-shaped and be favored by kayakers, riverboarders, and bodyboarders. Only the lowest terrace will be submerged at this flow.

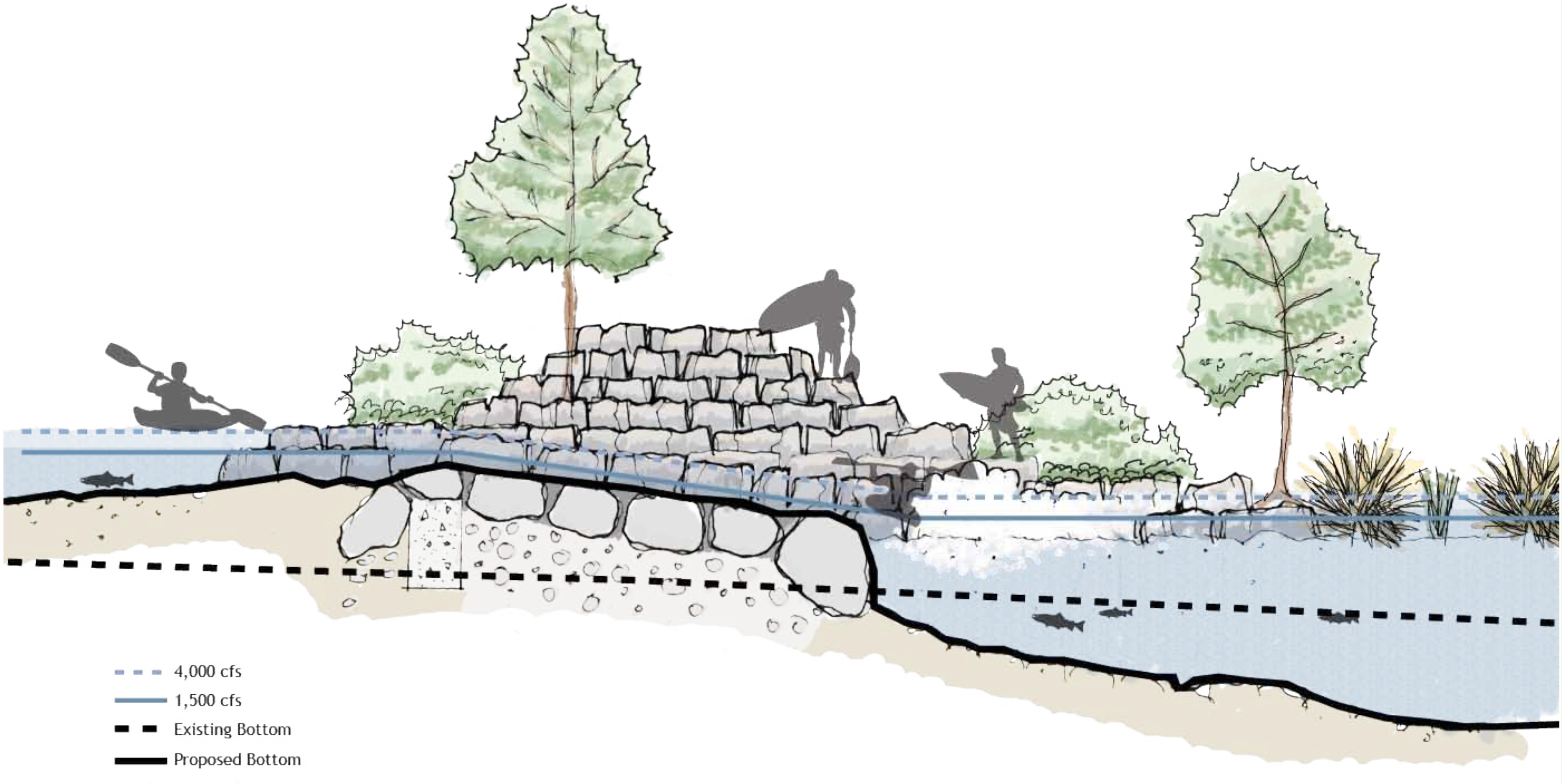
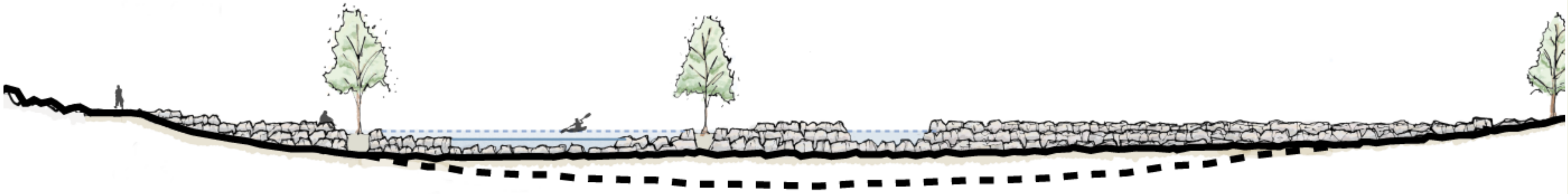


Fig. 47: Typical Grade Control Structure

Typical River Cross Sections

Since the river is so wide at the existing weir, structures #3 and #4 include side spillways that will be full of water at higher flows. These add to the diversity of the park for habitat benefits, as well as the possibility of a more challenging and interesting river run. Pools are excavated below each drop structure at the proposed thalweg of the river.

Typical Grade Control Structure



Typical Excavated Pool

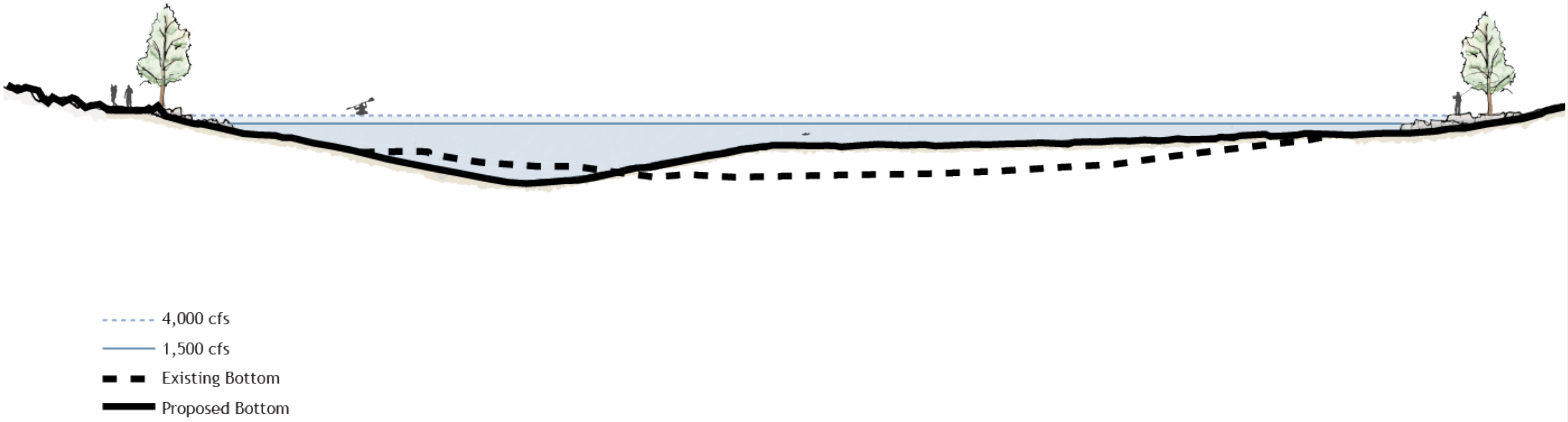


Fig. 48: Typical Cross Sections

Structure #1

This is the first feature of the whitewater park. With a 1'-0" jump, it is suitable for beginners. Random boulders provide plenty of opportunities for finding an eddy. The two deflector wings at the North side of the channel are used to discourage erosion of the bank. They also create eddies and encourage the accumulation of spawning gravels.

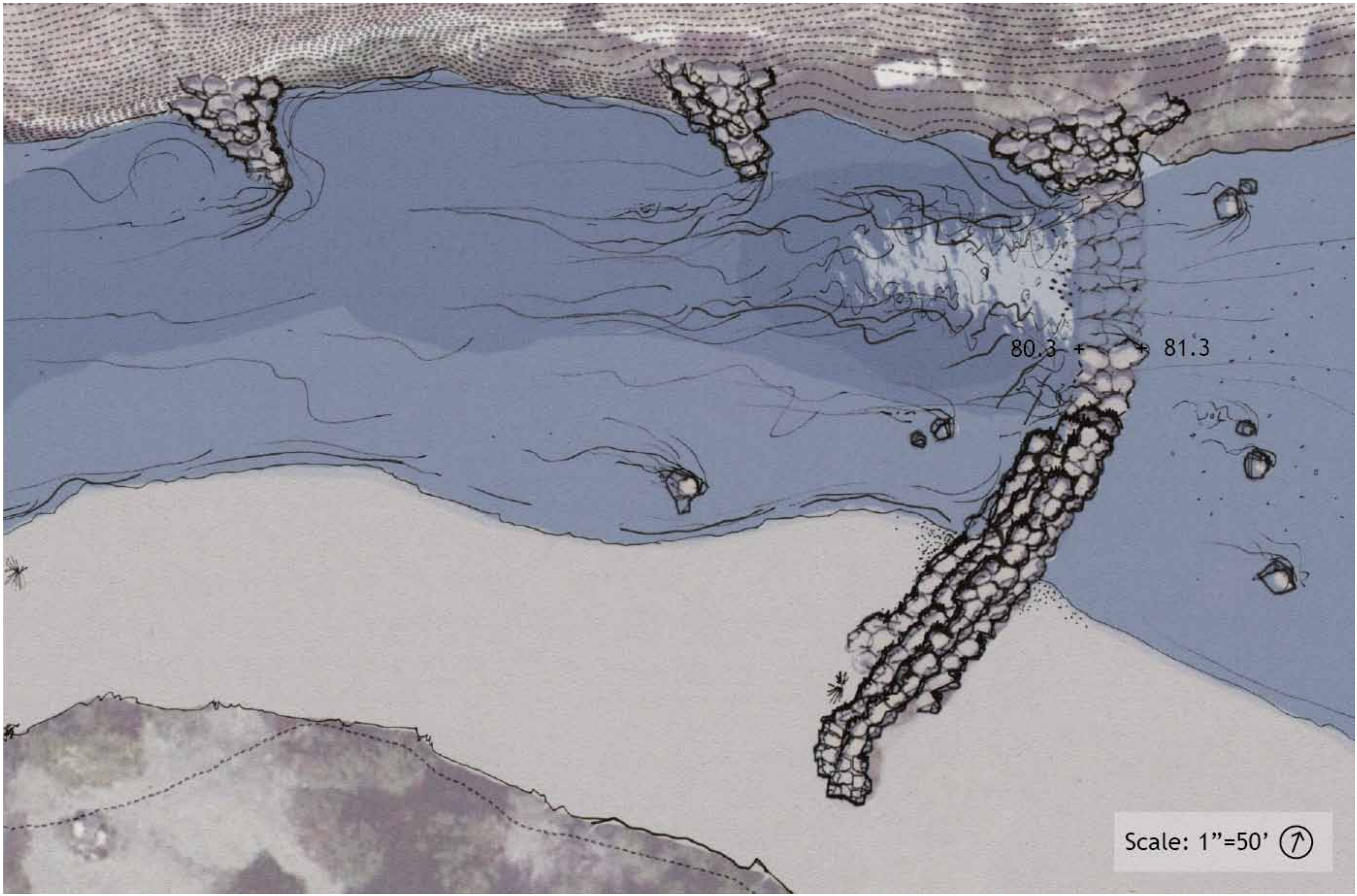


Fig. 49: Structure #1

Structure #2

This is the second feature of the whitewater park. With a jump of only 0’-6”, it will become submerged at high flows. Beginners can paddle to the large eddy and walk back to go down structure #1 and #2 again. Once they feel comfortable with these hydraulics, they may move on down the course to structure #3 and #4.

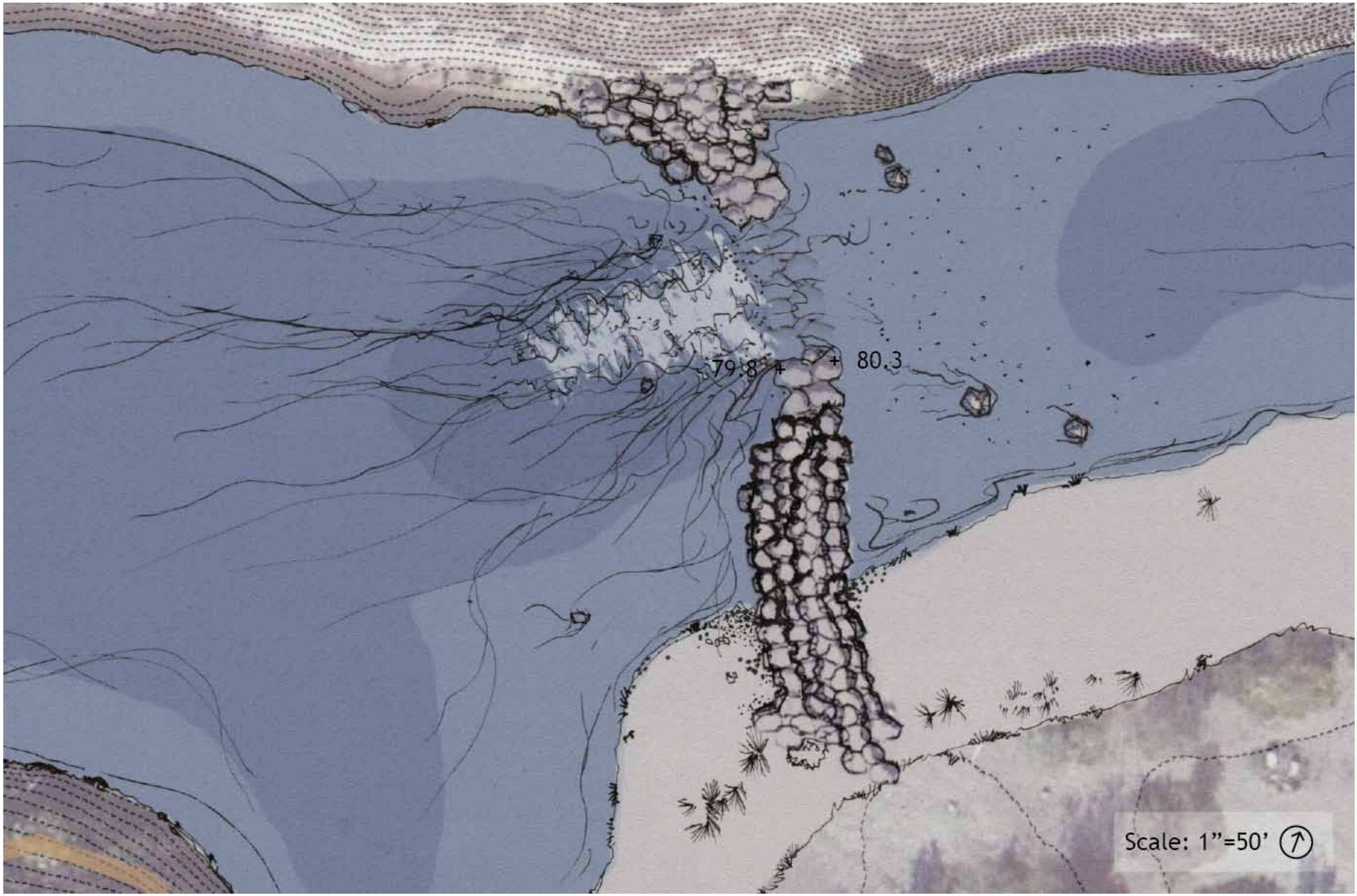


Fig. 50: Structure #2

Structures #3 and #4

These two structures are the main features of the whitewater park and are located adjacent to the fish hatchery viewing area. Intermediate to advanced boaters will tend to use these features. The side overflow channel will become submerged at higher flows and can be used as a bypass by boaters wanting to avoid the large features in the main channel.

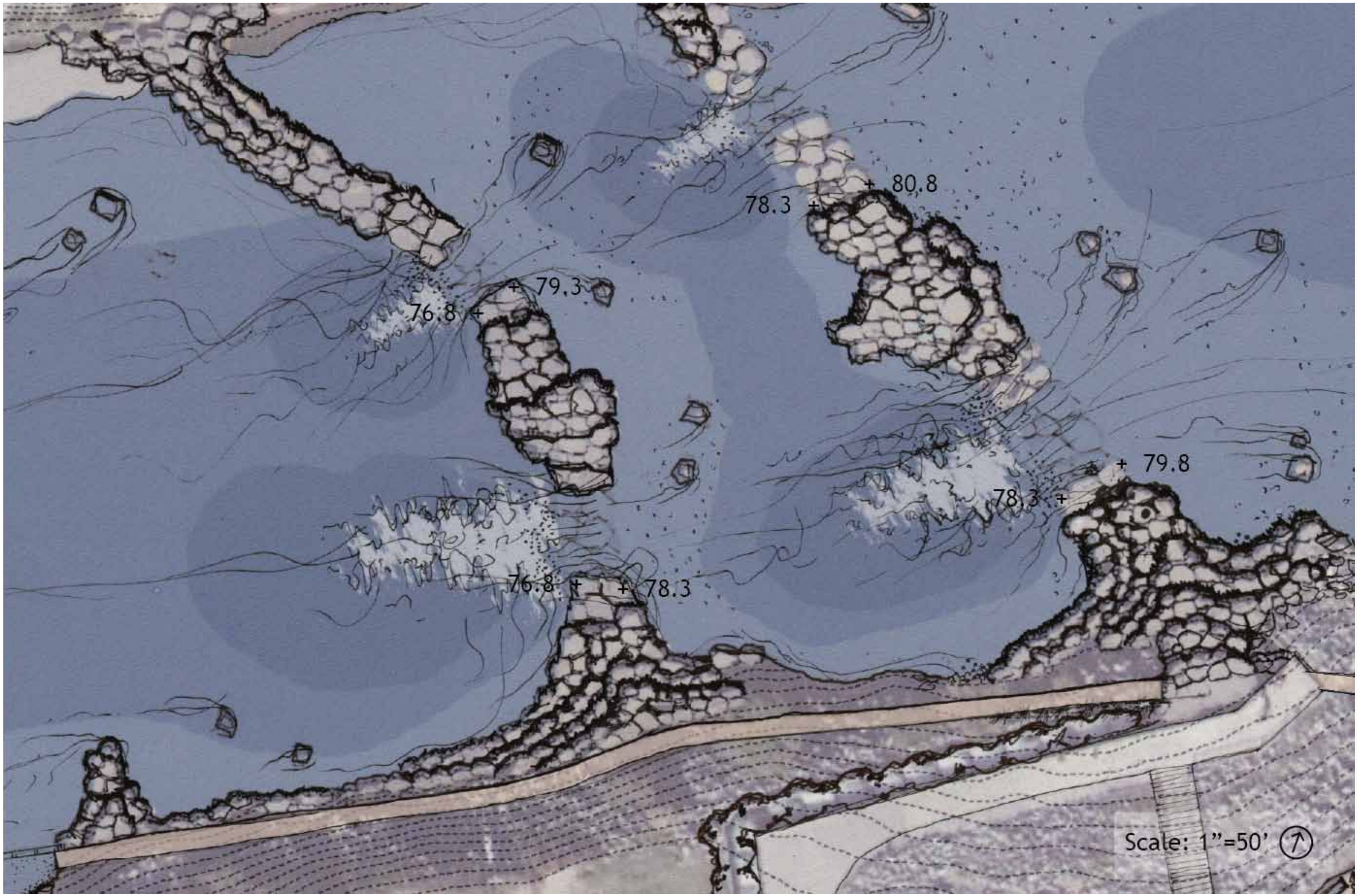


Fig. 51: Structure #3 and #4

Fish Hatchery Viewing Area and Lawn

As the ladder approaches the hatchery, it becomes a meandering flume where the public can view salmon traveling up to the facility. Materials used to construct the flume will be natural but not allow for spawning in the bed. Guests can observe salmon underwater through viewing windows and cross the flume on wood bridges. A turf area at the Northeast corner of the site is used by boaters to prepare equipment for entry into the water. A wash rack and cleaning station is located between the parking lot and turf area to be used as a precaution against spreading the New Zealand mudsnail as Laura Drath, CDFG suggested. Next to the cleaning station is a new restroom that will accommodate increased traffic to the site.

Fig. 52: Viewing area and lawn

Additional Features: Stormwater Parking Lot and ADA Ramp

The proposed parking lot incorporates stormwater infiltration by reducing the size of travel lanes and adding vegetated swales. The overhead canopy of trees shades the parking lot and helps reduce summer temperatures. Interpretive signage can educate the public on how stormwater infiltration helps protect the American River watershed and the salmon that use the river.

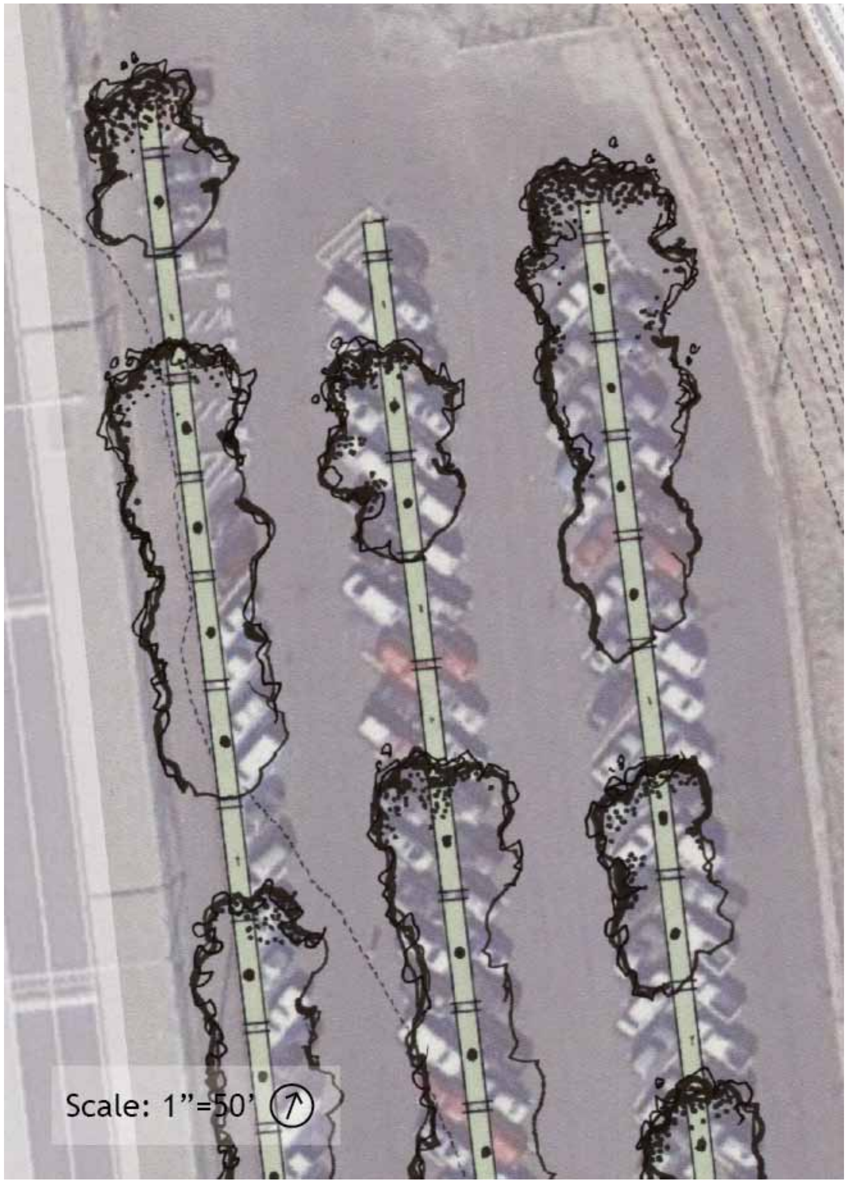


Fig. 53: Parking lot

Disabled users are able to enter the water at the gently sloping Nimbus Shoals to start the course. At the end of the course, this ADA ramp extends from the overlook to past structure #4 where users can easily exit the water.

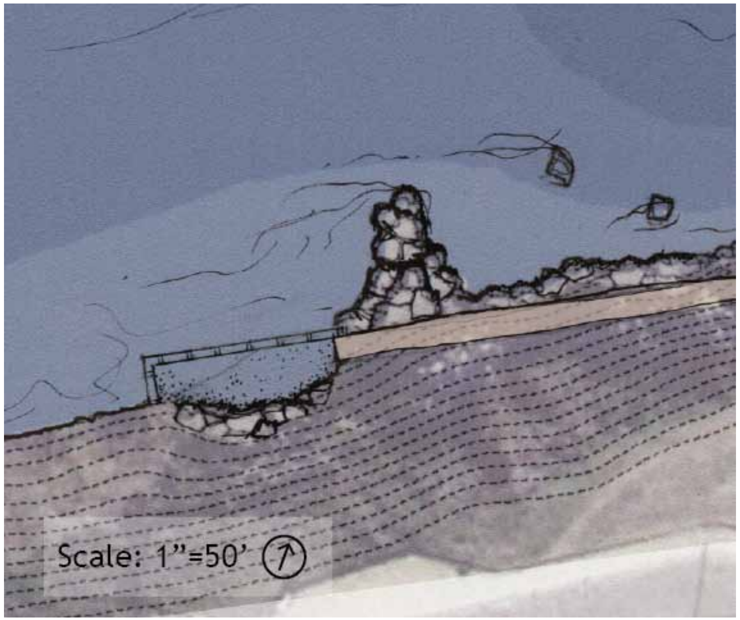


Fig. 54: ADA access ramp

Conclusion

With more awareness of whitewater parks, cities can better design stream modification projects that have multiple benefits. By integrating whitewater boating in restoration and revitalization projects when appropriate, multiple social, environmental, and economic benefits can be achieved.

Salmon habitat on many California streams has been destroyed or is threatened. Projects like this can potentially be implemented in areas where there is heavy use as a way to successfully manage both human and wildlife needs.

Thanks for reading my senior project!

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