

WORKING DRAFT
CONCEPT DESIGN REPORT
BROWN BRIDGE DAM REMOVAL
BOARDMAN RIVER
GRAND TRAVERSE COUNTY, MICHIGAN



Prepared for:

BOARDMAN RIVER DAMS IMPLEMENTATION TEAM
Traverse City, Michigan

Prepared by:
Inter-Fluve, Inc.

In association with:
AMEC Environment & Infrastructure

Traverse City, Michigan

August 17, 2011

WORKING DRAFT
CONCEPT DESIGN REPORT
BROWN BRIDGE DAM REMOVAL
BOARDMAN RIVER
GRAND TRAVERSE COUNTY, MICHIGAN

Prepared for:

BOARDMAN RIVER DAMS IMPLEMENTATION TEAM

Traverse City, Michigan

Prepared by:
Inter-Fluve, Inc.

In association with:
AMEC Environment & Infrastructure
Traverse City, Michigan

AMEC Project Number: 33101100009

August 17, 2011

ACKNOWLEDGEMENT

This report was prepared under grants received by The Grand Traverse Band of Ottawa and Chippewa Indians from the Bureau of Indian Affairs, Circle-of-Flight Program, as Administered through the Great Lakes Restoration Initiative and the United States Fish and Wildlife, Tribal Wildlife Grants Program, as well as funding received by the City of Traverse City from the Great Lakes Fishery Trust in support of the removal of the Brown Bridge Dam and restoration of the Boardman River.

TABLE OF CONTENTS

<u>Section</u>	<u>Page</u>
1.0 INTRODUCTION	1-1
2.0 CHARACTERIZATION OF THE PROJECT AREA	2-1
2.1 HYDROLOGY OF THE BOARDMAN RIVER	2-2
2.2 FIELD OBSERVATIONS	2-4
2.2.1 Upstream of Brown Bridge Pond	2-4
2.2.2 Downstream of Brown Bridge Pond.....	2-7
2.2.3 Brown Bridge Pond	2-11
3.0 DAM REMOVAL AND DEWATERING	3-1
3.1 APPROACH TO DAM REMOVAL AND DEWATERING (COMMON TO ALL RESTORATION APPROACHES)	3-1
3.1.1 Dewatering.....	3-1
3.1.2 Dam Removal	3-2
3.2 COSTS AND ASSUMPTIONS.....	3-2
4.0 CONCEPT DESIGNS FOR RESTORATION AT BROWN BRIDGE.....	4-1
4.1 OVERVIEW	4-1
4.2 RESTORATION CONCEPT ELEMENTS.....	4-1
4.2.1 Channel Restoration.....	4-1
4.2.2 Riparian Zones Error! Bookmark not defined.	
4.2.3 Floodplain and Wetlands	4-2
4.2.4 Upland Habitats	4-3
4.2.5 Invasive Species Management.....	4-3
4.3 FINAL RESTORATION CONCEPT ALTERNATIVES	4-3
4.3.1 One Hundred Percent Active Restoration.....	4-3
4.3.2 Component Approach.....	4-4
4.3.3 Estimated Costs	4-5
4.3.4 Summary – One Hundred Percent Active Approach.....	4-6
4.4 ONE HUNDRED PERCENT PASSIVE APPROACH.....	4-6
4.4.1 Component Approach.....	4-7
4.4.2 Estimated Costs	4-8
4.4.3 Summary – One Hundred Percent Passive Approach	4-8
4.5 FIFTY/FIFTY (50/50) ACTIVE AND PASSIVE RESTORATION.....	4-8
4.5.1 Component Approach.....	4-9
4.5.2 Estimated Costs	4-10
4.5.3 Summary.....	4-11
5.0 SUMMARY AND RECOMMENDATIONS.....	5-1
5.1 RECOMMENDED APPROACH	5-1
5.2 COST JUSTIFICATION	5-2
5.3 SUMMARY OF COSTS	5-2
5.4 RECOMMENDED IMPLEMENTATION	5-2
6.0 REFERENCES	6-1

LIST OF TABLES

Table 1	Estimated Recurrence Interval for the Boardman River near Brown Bridge Dam.....	2-2
Table 2	Summary of Restoration Elements under Each Concept Alternative	4-1
Table 3	Component Approach for the 100 Percent Active Restoration Alternative	4-4
Table 4	Concept Level - Engineer's Opinion of Probable Construction Costs for 100 Percent Active Restoration.....	4-5
Table 5	One Hundred Percent Active Approach Summary	4-6
Table 6	Characteristics of the 100 Percent Passive Restoration Alternative.....	4-7
Table 7	Concept Level - Engineer's Opinion of Probable Construction Costs – 100 Percent Passive Restoration	4-8
Table 8	One Hundred Percent Passive Approach Summary	4-8
Table 9	Component Approach for 50/50 Active/Passive Restoration Approach.....	4-9
Table 10	Concept Level - Engineer's Opinion of Probable Construction Costs	4-10
Table 11	Summary of Features of the 50/50 Active/Passive Restoration Alternatives.....	4-11
Table 12	Summary of Costs for the Conceptual Restoration Alternatives	5-2
Table 13	Implementation Scenario for 50/50 Approach	5-3

LIST OF APPENDICES

A	Concept Drawings
---	------------------

LIST OF FIGURES

Figure 1.	Shaded Relief, United States Geologic Survey (USGS) Topographic Map of Nearly the Entire Boardman River Watershed.....	2-1
Figure 2.	Average Daily Flow Exceedance above Brown Bridge Road	2-3
Figure 3.	Longitudinal Profile of the Boardman River.....	2-3
Figure 4.	Signs of Channel Migration on the Upper Boardman River	2-5
Figure 5.	Sand Deposits along the Channel Margin of the Boardman River from the Spring Flood.....	2-5
Figure 6.	Typical Long Riffle/Run Section along the Boardman River	2-6
Figure 7.	New Bankfull Surface Developed in Response to the 3-foot Drawdown in 2008, about 2 miles above Brown Bridge Dam	2-7
Figure 8.	Sand Load Entering the Boardman River from East Creek	2-8
Figure 9.	Rapids Section Just Upstream of Boardman Pond.....	2-9
Figure 10.	Former Boardman Pond and Resulting Channel Cut through Material Deposited Upstream of the Dam	2-10
Figure 11.	Beer Can (Circa 1978-80) noted in the Bank of the Former Boardman Pond	2-11
Figure 12.	Schematic of Delta Formation.....	2-12
Figure 13.	Helicopter View (2002) of the Brown Bridge Delta, before 2008 Drawdown	2-12
Figure 14.	Conceptualized View of Sediment Deposition above Brown Bridge Dam	2-13
Figure 15.	Aerial View (2005), "Lighter" Vegetation Color Indicating Influence on the Boardman River, Well Above the Impoundment.....	2-13
Figure 16.	Brown Bridge Delta ca. 2009.....	2-14
Figure 17.	Stumps Exposed following the 3-Foot Drawdown in 2008 along the Century Creek Inlet.....	2-14
Figure 18.	Bed Material Composition in the Lower Two-Thirds of the Brown Bridge Pond...	2-15
Figure 19.	Sediment Depths in the Wedge above Brown Bridge Pond.....	2-16
Figure 20.	View of Boardman Pond Illustrating Mobile and Immobile Portions of a Delta Deposit	2-17
Figure 21.	Plot of Channel Bottom Width Versus Sediment Volume.....	2-17

1.0 INTRODUCTION

This report presents a final conceptual plan for the restoration for the Boardman River within the Brown Bridge impoundment following the removal of the Brown Bridge Dam located near Traverse City, Michigan. Design for the removal and restoration of the Brown Bridge impoundment has progressed along a pragmatic path and is supported by data collection and field observation. Based on the observations to date, three concepts have been developed for review by the project stakeholders and all interested parties. Concepts were developed along a gradient from active to passive restoration of the former impoundment. Active restoration involves the construction of a restored channel within a short time period following removal. All attendant features are constructed in place for the development of a functioning river channel, with short-term vegetation management supporting long-term succession goals. In contrast, passive restoration includes limited, if any, active restoration within the channel, and typically limited management of the resulting colonizing vegetation. The passive approach allows the river itself to act as the mechanism to re-establish a river channel and its attendant floodplain. A number of options lie between these two extremes that borrow elements of both active and passive restoration. It is important to note that the outcome of dam removal is similar regardless of the restoration approach pursued – a return to the functions and features of a river channel. The difference among these approaches is the time and cost in arriving at this common endpoint.

Specific levels of cost and features inherent in the restoration approaches along the gradient between active and passive are presented as well. This information provides a foundation for understanding and informed discussion of the benefits and drawbacks of various approaches; resulting ultimately in the decision to move forward into final design with a preferred approach for restoration.

2.0 CHARACTERIZATION OF THE PROJECT AREA

The Boardman River begins in Kalkaska County as a series of small creeks and drainages that eventually form two distinct North and South channels. These join at the “Forks” to form the mainstem Boardman River channel near the county line. The river flows approximately 12 miles to the west, then continues north another 8 miles to flow into the west arm of Grand Traverse Bay. The river is relatively undeveloped from the Forks downstream to River Road at which location the riparian land use begins to be dominated by small cottages and low to moderate density residential development. Below the Sabin Dam the river begins to flow through the urban center of Traverse City. A number of private and road bridges intersect the channel, though none appear to have an adverse affect on the transport of either water or sediment along the river corridor from above Brown Bridge Dam to the Sabin Dam.



Figure 1. Shaded Relief, United States Geologic Survey (USGS) Topographic Map of Nearly the Entire Boardman River Watershed

The dams on the Boardman River have been recognized as having a detrimental effect on the ecosystem. Specific ecosystem impacts associated with the Boardman Dams are associated with habitat fragmentation, habitat degradation, thermal disruptions, and induced species disruptions [U.S. Army Corps of Engineers (USACE), 2006]. A brief discussion of each of these issues is provided below.

- **Habitat Fragmentation.** The existing dams on the Boardman River have the effect of dividing the mainstem of the Boardman River into four discontinuous segments. These segments result in isolation of resident populations of aquatic species (notably fishes) which makes them vulnerable to gene pool isolation and effects of environmental degradation (pollution, habitat degradation, and wetland filling). Coldwater fish species

that have demonstrated differences in abundance between upstream and downstream segments at Brown Bridge Dam have included brown trout, brook trout, and slimy sculpin.

- **Habitat Degradation.** Normal riverine processes consist of the downstream transport of woody debris, vegetation (and their propagules) and sediment. The dams on the Boardman River have the effect of interrupting these transport mechanisms resulting in the degradation of coldwater fisheries, aquatic invertebrates, and plant communities associated with riparian zones and floodplain wetlands. Additionally, interruption of riverine sediment transport processes results in stream bed and fisheries habitat degradation.
- **Thermal Disruptions.** Each of the existing Boardman dams is configured to draw water from the top of the water column prior to its discharge to downstream areas. This configuration disrupts the natural thermal regime of this largely groundwater supported stream by releasing surface water warmed through solar radiation absorbed by the relatively dark surface of the pond to downstream waters. For example, at Brown Bridge Pond in 2002, water released downstream averaged six degrees Fahrenheit (°F) warmer than water in the upstream channel during summer months.
- **Induced Species Disruptions.** The unnaturally warm temperatures discharged downstream of each dam has also had the effect of disrupting aquatic species distributions and abundances. Specifically, there is evidence to support that the tailwater fishery composition and abundances has shifted from what would normally be observed in an un-interrupted lotic system (brown trout, brook trout, slimy sculpin) to species that are more characteristic of transitional lotic/lentic or exclusively lentic coolwater habitats (northern pike, walleye, sunfishes, rock bass, largemouth bass, bullhead catfish, etc.).

The purpose of the restoration initiative associated with the removal of Brown Bridge Dam is to address these ecosystem needs and restore a functional riverine ecosystem at Brown Bridge Pond.

2.1 HYDROLOGY OF THE BOARDMAN RIVER

The Boardman River groundwater and surface water hydrology is very stable, owing largely to the high permeability of watershed soils, composed of glacial sands and gravel. The 500-year flood is only about twice the discharge of a 2-year event (Table 1), resulting in a stage increase of about 2 feet (average) based on the HEC-RAS hydraulic model. Steady base flow of cold water provides ideal conditions for the well developed trout fishery sustained along the length of the river. Springs entering from the adjacent valley walls parallel to the river channel also contribute to the base flow of 75 cubic feet per second (cfs) near the Brown Bridge area (Figure 2).

Return Period (years)	Estimated Discharge (cfs)
1	151
1.5	263
2	294
10	408
50	497
100	532
500	612

Four dams are located on the main stem of the Boardman River. The Union Street Dam is located near the outlet into Grand Traverse Bay. The Sabin and Boardman Dams, both former hydropower dams, are located approximately one mile upstream of Boardman Lake, a natural lake in the lower part of the river. These two dams occupy a noted steep section of the river (Figure 3). Well upstream of Sabin and Boardman Dams is the largest dam, Brown Bridge Dam, also a former hydro facility and the focus of removal and the Concept Designs presented in this report.

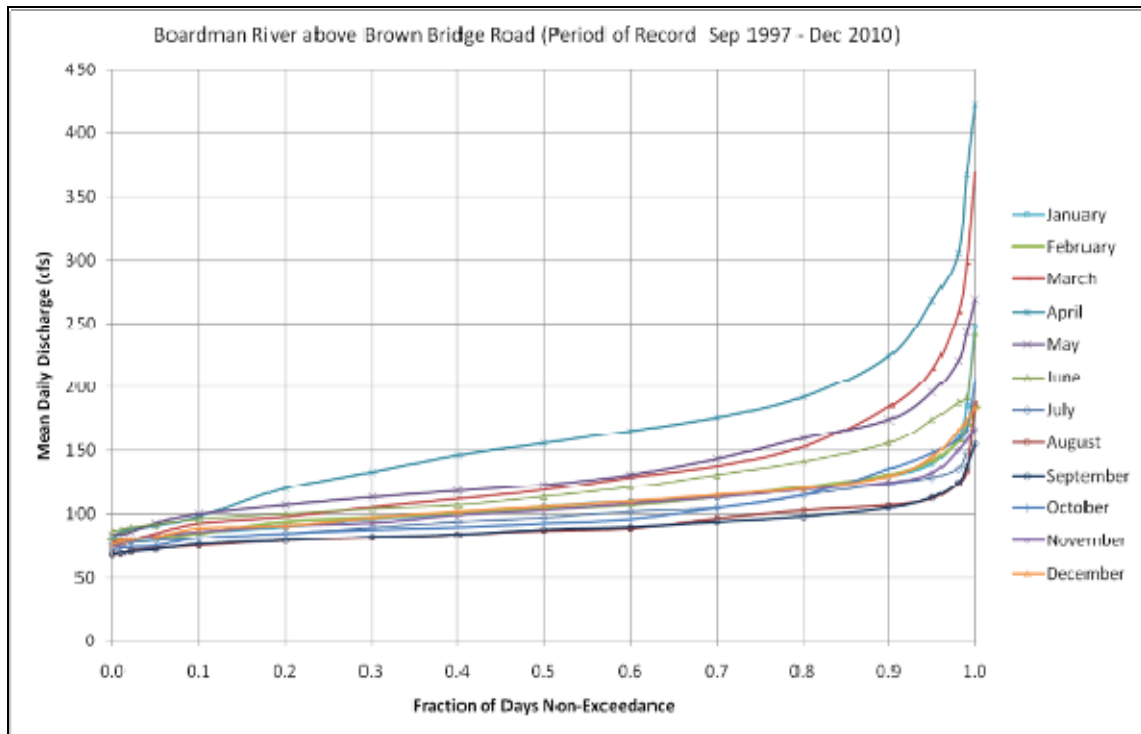


Figure 2. Average Daily Flow Exceedance above Brown Bridge Road

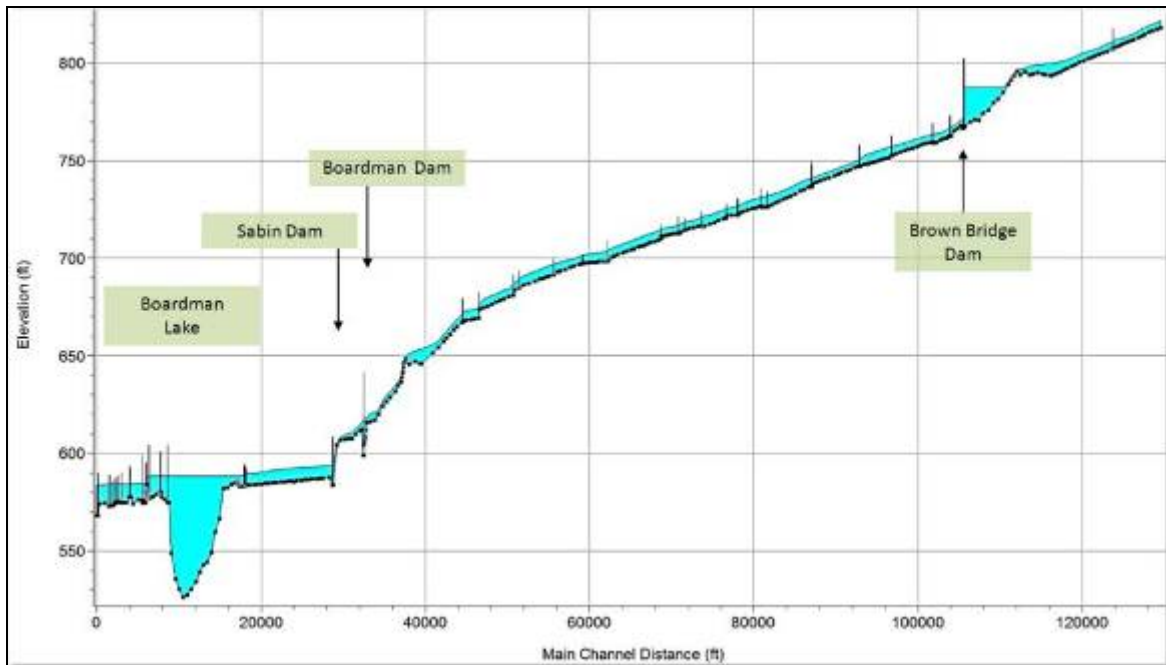


Figure 3. Longitudinal Profile of the Boardman River

2.2 FIELD OBSERVATIONS

Site reconnaissance included one day investigating the river above the Brown Bridge impoundment, a second day investigating the river below the Brown Bridge impoundment, and a third day investigating the river within the Brown Bridge impoundment itself. The intent was to gather a more thorough understanding of the river and its dynamics to inform concepts for dam removal and associated restoration of the river through the Brown Bridge impoundment. In addition, the trip offered an opportunity to mine the considerable institutional knowledge accrued by many of the local project team members. Channel cross-section and profile were measured in key segments to verify previous data collected in earlier studies. Observations were made regarding sediment continuity, channel slope, depositional bar formation, anthropogenic changes, pool and riffle forms and floodplain/valley morphology. Post drawdown characteristics were observed in the Boardman and Brown Bridge impoundments.

2.2.1 Upstream of Brown Bridge Pond

Site reconnaissance was performed in areas above the “Forks” by vehicle, whereas canoes were used to recon the river from the Forks to the public access at Brown Bridge Dam. The area upstream of the Forks consists of the north and south branches of the Boardman River. There is a sand sediment load in these upstream reaches, working its way downstream. This is reinforced by the delta deposit above Brown Bridge Dam that has accumulated since dam construction in 1921. There are few apparent sources for this sand, indicating that it may be a relic from historic and more contemporary impacts or is perhaps part of the natural delivery of sediment from the upper watershed and scour of channel banks. Regardless, considerable effort has been placed on reducing these sediment loads and has likely been successful, though observable changes in the sediment load of the river may be decades away as the river continues to transport a legacy of sand already present in the channel. In other parts of the upper Midwest, many now forested streams have shown a pattern of late 19th and early 20th century logging followed by reduced timber harvest and public acquisition of tax delinquent land. In these watersheds, sediment loads increased in the early 20th century, and have tapered off as hydrologic conditions drift back toward the pre-settlement condition (Fitzpatrick et al., 2006). Many of these streams are still transporting legacy sediment, and in some, like the Boardman River, dams have trapped that legacy sediment in place. Sand makes up much of the soil in the Boardman River valley, and thus sand is a natural part of the river geomorphology. It must be remembered that some sand transport is natural in this river system. This measured rate of transport (relative to systems with more intense flood hydrology) is due in part to the hydrologic stability of the river and reduced capacity to flush material downstream during flood events.

The section from the Forks down to Brown Bridge Pond is a dynamically stable river reach, with observable indicators of the rates of change present, but not readily apparent. The channel width is consistent between 50 feet and 60 feet along the entire length. Large trees occupy *both* sides of the bank in many places and are growing at or near the edge of the water, indicating that rates of horizontal channel migration have been minimal over recent decades (Figure 4). The line of woody vegetation is at or very near the top of bank, a further indicator that floods, when they reach this elevation, are short lived. Where horizontal channel migration does occur, it appears to proceed at a slow rate consistent with what might be considered natural rates of channel migration. Transport of the sand load of the channel is evident but gravel and larger portions of the bed appear to move infrequently. Based on patterns of erosion and deposition observed, the primary active sediment load is composed of sand. Numerous locations with sand deposits from a recent spring (2010) flood were noted (Figure 5). However, no evidence of overbank deposition or flood debris above the top of the channel banks was noted.



Figure 4. Signs of Channel Migration on the Upper Boardman River

(Note: The bend in the channel is slowly migrating to the left in the photograph, noted by the leaning trees on the left bank and the growing point bar on the right, but the rate of change is slow.)



Figure 5. Sand Deposits along the Channel Margin of the Boardman River from the Spring Flood

The river has well developed bedforms, with sequences of pools and riffles, particularly in the more sinuous sections. Pools are confined to the outside of meander bends, unless trees or other obstructions cause a local scour pool to develop. Less sinuous sections characterize areas where the channel slope increases slightly. These sections are best described as long riffles or runs, where the water moves swiftly over a plane bed with minimal vertical heterogeneity (Figure 6).

Geomorphically derived habitat features, such as riffles, bars and pools are present throughout the reach and are more prominent in areas of high sinuosity. Vertical heterogeneity and depositional microhabitat are limited due to the lack of large woody debris in the channel. Historically the Boardman River would have had a high density of fallen old growth trees and log jams. This condition is not achievable today given the young age of the surrounding riparian forest, and the heavy recreational use of the river, but improvements could be made by adding log jams and trees in configurations that create scour holes without obstructing the channel for paddlers. Large woody debris input is a function of tree age (and thus size) and channel migration. The Boardman River riparian area has a significant population of cedar, pine and other species varying in age from 30 years to 75 years. These trees will eventually input large wood into the river. However, due to the slow rate of channel migration and bank stabilization, significant large wood input will largely come from blowdown or falling limbs within 100 feet of the river. To bridge the time between present levels of wood input and future projected levels, active installation of log jams should be considered. The addition of large wood to the existing disturbance regime and bedform development would add substantially to the habitat quality of this reach.



Figure 6. Typical Long Riffle/Run Section along the Boardman River
(Note the surveyor in the background for scale.)

The influence of the dam becomes apparent well above Brown Bridge Pond. A low inset surface below what appeared to be the old top of bank elevation became more prominent in the downstream direction (Figure 7). This surface developed in response to the 3-foot drawdown that occurred in 2008. The point where legacy deposit exposure is first observed indicates the upstream extent of the dam's influence on the Boardman River. The composition of the channel bed includes a large component of sand just above Grasshopper Creek that becomes more prevalent in a downstream direction until eventually the coarse component (gravels and cobbles) disappear and sand covers the entire visible bed. The channel widens slightly downstream and channel depth in cross section becomes more homogenous. The riparian area is dominated by alder and other shrub species. Finally, the river opens up into the larger sand delta area and eventually the pond itself.



Figure 7. New Bankfull Surface Developed in Response to the 3-foot Drawdown in 2008, about 2 miles above Brown Bridge Dam

(Note the riparian vegetation composed of shrubs.)

2.2.2 Downstream of Brown Bridge Pond

The river was floated from Brown Bridge Dam to Boardman Dam. The sediment transport regime of the river in this stretch was evaluated qualitatively by comparing erosion and depositional features noted on the previous day above Brown Bridge Pond, to conditions below. Immediately below the Brown Bridge Dam, the river includes little fine or sandy material, much different than observed in reaches above the dam on the previous day. East Creek, the first major tributary below Brown Bridge Dam, enters about 0.8 mile below the dam. This creek appears to provide a significant sediment load to the river (Figure 8). Below East Creek, sand depositional features were noted once again in the margins of the channel and along the inside point bars, though not at the frequency above Brown Bridge Dam. Another 0.4 mile below East Creek, Swainston's Creek enters a second major tributary that also contributes sand load to the Boardman River. Below these two creeks, the sand load of the Boardman River appeared to be similar with what was observed on the previous day, upstream of the dam. Few signs of channel bank erosion were noted in the reach,

which should be common if the river, having a fairly resistant bed, were eroding into the channel banks to overcome a sediment deficit from Brown Bridge Dam. In summary, the qualitative information indicates that the sediment deficit below the Brown Bridge Dam exists for only a short distance before tributary inputs return the sediment load to what might be considered a more normal range.



Figure 8. Sand Load Entering the Boardman River from East Creek

The Boardman River channel below Brown Bridge Dam has a cross-sectional geometry and general geomorphology consistent with what was observed on the previous day above the dam. Channel widths, bank depths, habitat, and riparian vegetation were also consistent with those observed above Brown Bridge dam. Some noted differences are apparent, however. The channel encounters the valley wall with more frequency in this section, creating an additional sediment load from tributaries bisecting the valley wall that flow down to the river. These channels were frequent in this lower section and appeared to have varying flow and sediment loads. These channels likely replenish the Boardman River with a considerable amount of cool groundwater.

The second major difference is the notable increase in channel gradient just above the Boardman (Keystone) Pond formed by the Boardman Dam. This change in slope is marked by an increase in water velocity and turbulence and the presence of large boulders and cobbles in the channel (Figure 9). The “rapids” section located just above the former extent of the Boardman Pond, likely continued historically all the way through the Sabin impoundment before encountering a much lower slope below the Sabin Dam down to Boardman Lake, as observed in the long profile of the river from the HEC-RAS model (see Figure 3 above).



Figure 9. Rapids Section Just Upstream of Boardman Pond

The section through the former Boardman Pond provides a unique analog to what might develop in the Brown Bridge impoundment during dam removal. Similar to Brown Bridge Pond, the Boardman Pond included a substantial delta feature at the upstream end of the impoundment. The water level was drawn down over 20 feet at the dam, inducing a headcut and channel formation through the delta deposits. Bank heights through this section were in excess of 10 feet and the bank angle appeared to be consistent with the stable angle of repose of sand (30 to 35 degrees), which composed nearly all of the bank material (Figure 10). The river through this section does not have a floodplain which concentrates high water in the channel, thereby increasing erosive energy directly in proportion to an increase in river flood stage. For natural systems with intact floodplains there is a direct relationship between stage and stream power. When such streams reach bankfull condition, water is released onto the floodplain such that the increase in stream power is tempered with successive increases in stage. This floodplain is observed in all other locations on the river, outside of the influence of the dams.



Figure 10. Former Boardman Pond and Resulting Channel Cut through Material Deposited Upstream of the Dam

An aluminum can was observed in the left bank of the former Boardman Pond that provided important information about the formation of the sediment wedge (delta) (Figure 11). The can was identified by a local historian as a Stroh's beer container produced from 1978 through 1980. The can was embedded in the bank 3 feet below the former reservoir surface. Below the can, the sediment is dominated by sand approximately 10 feet deep. Above the can, the 3 feet of organic material was deposited in distinct layers, probably after 1980. It is likely that the large amount of sand in the lower elevations was the result of both natural sand transport as well as the failure of the Keystone Dam in 1961, well upstream of this location. The organic layers developed above the can were interpreted as the result of detritus brought into the pond during significant flood events as well as natural generation of organic material from growth and dieback of vegetation.



Figure 11. Beer Can (Circa 1978-80) noted in the Bank of the Former Boardman Pond

2.2.3 Brown Bridge Pond

The Brown Bridge Dam was built in 1921 using sluiced material from a nearby borrow pit. The extensive trees within the footprint of the impoundment were cut and used for scaffolding to guide the sluice chute carrying the earthen fill for the current embankment. The sediment transport of the Boardman River has thus been impeded since 1921, a period of nearly 90 years. The sediment load of the Boardman River, being largely composed of sand, deposited in the form of a delta at the upstream end of the impoundment. Over the years, as the delta grew it migrated downstream (prograded) with each successive flood that delivered additional sand to the impoundment. The extent of such migration is often marked by a steep front, usually set at the angle of repose of the material, in this case sand. Transport of sediment beyond this steep face, termed the “foreset” (Figure 12) is typically minimal unless the material resides in suspension in the water column. The delta at Brown Bridge Pond has evolved in exactly this manner over 90 years (Figures 13 and 16). Aerial photographs indicate a distinct color difference in vegetation well above the impoundment where it is likely the delta has deposited material and influenced local channel morphology within this reach, above what most would consider the extent of influence on the Boardman River from Brown Bridge Dam (Figures 14 and 15).

Stumps are evident throughout the impoundment following the drawdown in 2008 (Figure 17). Field assessment with side scan sonar indicated stumps visible within the depths of the impoundment as well, an indication of reduced sediment deposition in the lower impoundment.

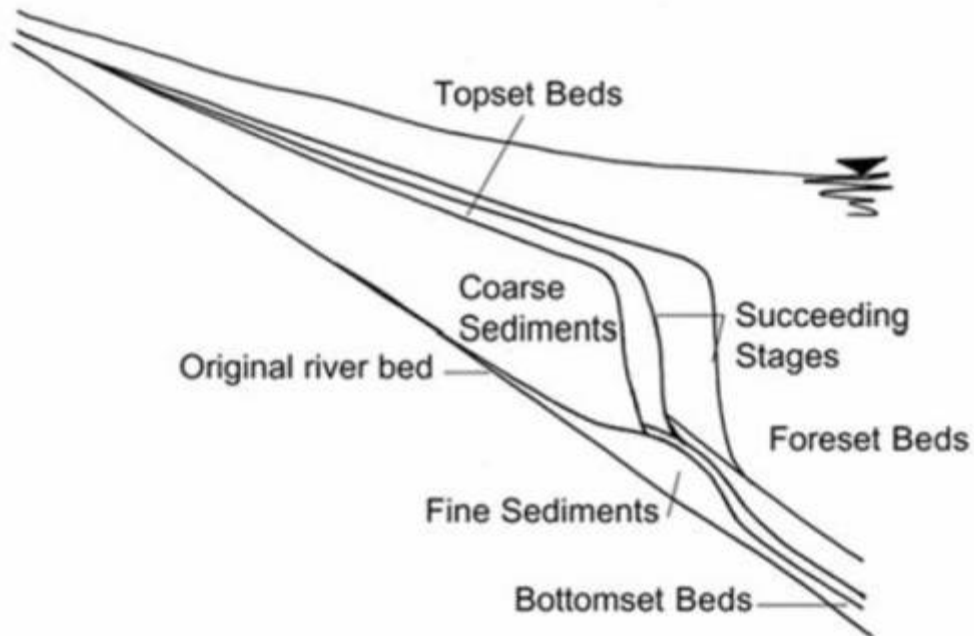


Figure 12. Schematic of Delta Formation
(Source: Cantelli et al. 2004)



Figure 13. Helicopter View (2002) of the Brown Bridge Delta, before 2008 Drawdown
(Photograph by: R. Christensen)

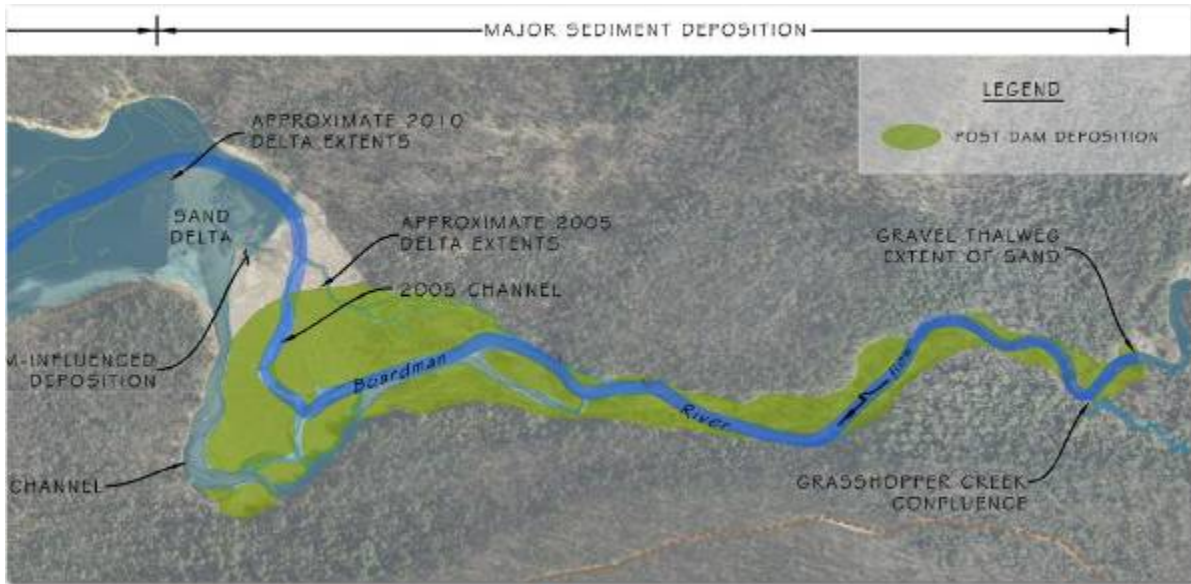


Figure 14. Conceptualized View of Sediment Deposition above Brown Bridge Dam



Figure 15. Aerial View (2005), "Lighter" Vegetation Color Indicating Influence on the Boardman River, Well Above the Impoundment



Figure 16. Brown Bridge Delta ca. 2009
(Photograph by R. Christensen)



Figure 17. Stumps Exposed following the 3-Foot Drawdown in 2008 along the Century Creek Inlet
(Photograph by: R Christensen)

The assumption that minor deposition exists below the leading edge of the delta has been based upon probing evidence gathered from a boat on the impoundment. A fiberglass rod 25 feet in length was used to probe the bed of the reservoir along cross-sections noting what material was encountered in the bottom of the impoundment. The pre-dam bed was composed of gravel and cobble. Therefore, an intact river channel below the delta would be reflected by the presence of such materials at or very near the surface within the old channel cross-section. The previously collected bathymetric data indicated the location of a relic channel that persists within the impoundment. Results of the field survey demonstrated that rock or gravel were present in areas where the bathymetry indicated the historic channel exists, lending evidence that minor sediment deposition has occurred in approximately the lower two thirds of the impoundment (Figure 18).



Figure 18. Bed Material Composition in the Lower Two-Thirds of the Brown Bridge Pond
(Note: Red line indicates the approximate location of the pre-dam river channel based on bathymetric data.)

The delta in the upper impoundment was surveyed with a graduated rod to determine the depth of deposited sand. The rod was pushed through the deposited material to a “refusal depth” assumed to be the pre-dam surface and the depth was recorded. The overall shape of the deposit resembles a wedge, with the steep, deep portion at the downstream end, then tapering upstream to a point (see Drawing 2 in Appendix A). The maximum depth encountered was just over 11 feet, consistent with the survey data plotted in the HEC-RAS model. When plotted, these sediment depths revealed the former channel location, shown in Figure 19. Of note, the previous channel location does not appear to have followed the existing bend to the south, occupied currently by the river following the 3-foot drawdown in 2008.



Figure 19. Sediment Depths in the Wedge above Brown Bridge Pond

The volume of delta material is important to sediment management approaches. There are two volumes of material, that which is included in the main channel and that which is included in the floodplain. Sediment in the main channel is readily and quickly eroded downstream through the process of headcut migration induced by dam removal. Sediment in the floodplain is less mobile, as the process of channel widening of the floodplain can only be accomplished by either large flood events or the horizontal migration of the channel, neither of which occur at rates or magnitudes on the Boardman River which would classify floodplain sediment as “highly mobile” under normal circumstances. Figure 20 illustrates an example of this downstream at Boardman Pond, where the channel cut through delta deposits, leaving the high banks with a large volume of deposited material well above the active water surface.

The volume of mobile material present within the “wedge” of the delta was estimated based on an assumed channel width of 55 feet and stable side slopes equal to the angle of repose for sand (an average of 32 degrees or 1.4H:1V). The beginning and end of the wedge is noted by the yellow line in Figure 19, and the area of each point with a depth along this line was estimated and averaged with the next upstream section. The total estimated volume is 84,800 cubic yards of material. This estimate translates into a blanket of sand 1 foot deep along a river channel 55 feet wide for 7.9 miles. The total length of the sediment wedge was estimated at 6,970 feet, along the endpoints described in Figure 19. Figures 21 and 22 below provide data for channel and floodplain dimensions expected to develop through the delta area.



Figure 20. View of Boardman Pond Illustrating Mobile and Immobile Portions of a Delta Deposit

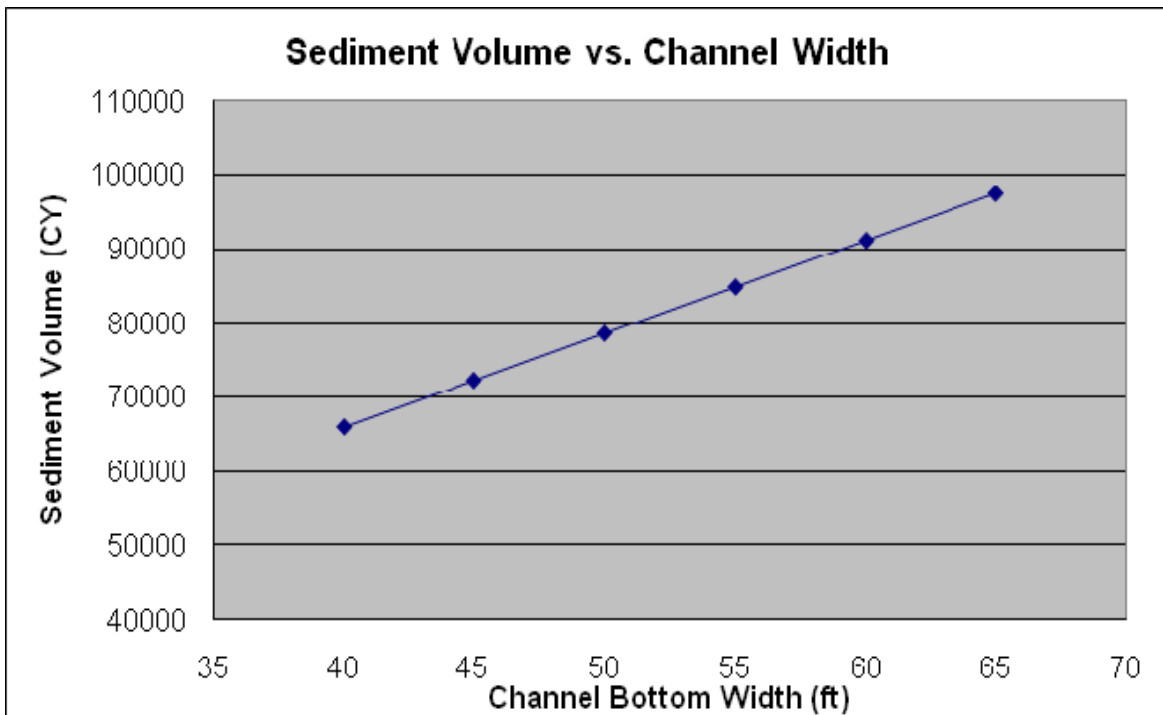


Figure 21. Plot of Channel Bottom Width Versus Sediment Volume
(Note: Average bottom width of the Boardman River is 55 feet.)

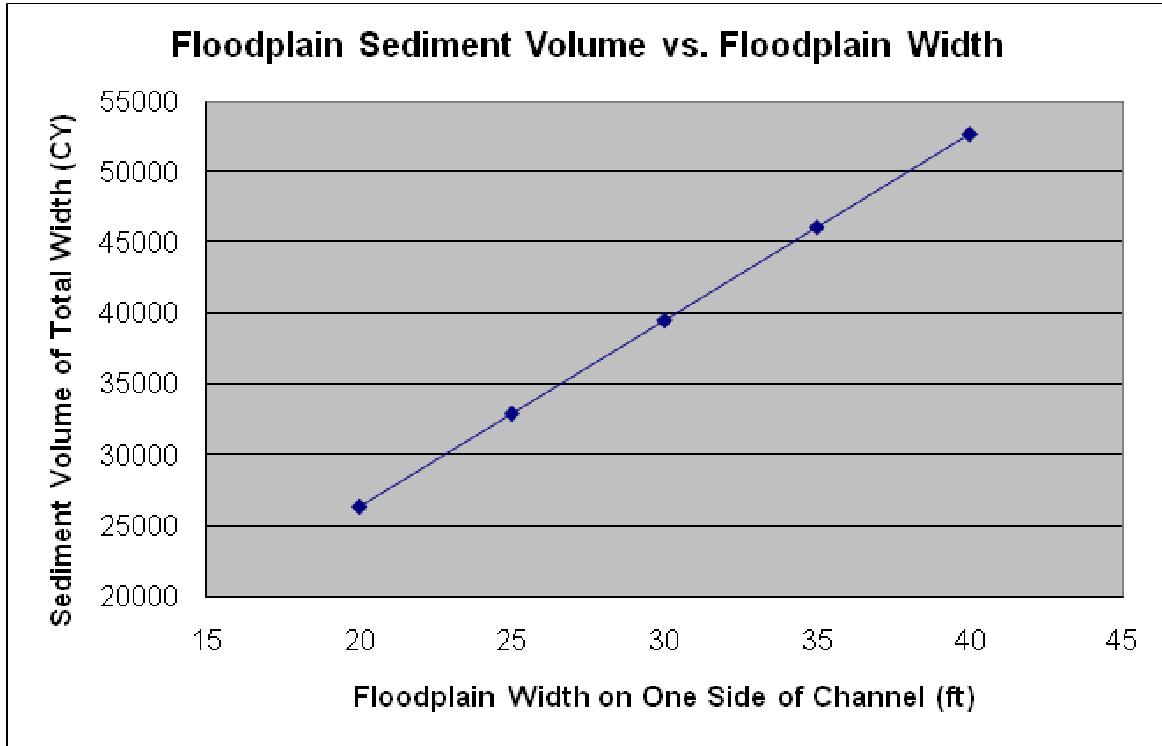


Figure 22. Plot of Channel Floodplain Width Versus Sediment Volume

(Note: X axis represents the width on one side of the channel, but the volume is calculated for both sides. Floodplain widths vary on the Boardman River.)

The data gathered indicate that the Brown Bridge impoundment exists as two distinct areas with respect to management actions associated with restoration. The Upper impoundment beginning at approximately the downstream end of the delta includes a distance of over a mile upstream where sediment has been deposited in the channel and will be mobilized under a dam removal scenario. The Lower impoundment, below the leading edge of the delta, likely includes some sediment, though it appears to be minimal. The intact channel illustrated in the bathymetry and confirmed by probing, represents an area that if managed correctly, will return quickly to a riverine form following dam removal. The largest risk to successful restoration is the mobilization of the stored delta sediment in response to drawdown and removal. Once this risk is mitigated, the implementation of other restorative efforts can be implemented under a relatively stable river condition.

A final area within the impoundment was noted as an area of concern. The North slope of the impoundment appears to include areas that may include a combination of steepness and sand substrate that will not vegetate quickly if exposed. The upstream slope of the dam embankment may also feature this combination of steep slope and poor soil conditions. At this stage of analysis, we have assumed the addition of soil amendments to these areas, much as was done in the Boardman impoundment, to spur the growth of stabilizing vegetation.

3.0 DAM REMOVAL AND DEWATERING

The removal of the dam structure and associated dewatering, common to all restoration scenarios, is described in this section.

3.1 APPROACH TO DAM REMOVAL AND DEWATERING (COMMON TO ALL RESTORATION APPROACHES)

Removal of the dam will include two components, including dewatering/drawdown of the headpond and partial demolition of the dam. Design of drawdown methods and the dam demolition by AMEC has not commenced to date; accordingly the actual method for each of these components has not been established. However, Prein & Newhof evaluated options for drawdown of the headpond in a study summarized in the document entitled *Boardman River Feasibility Study, Boardman Dams Breach Drawdown Study*, dated January 2009 (Prein & Newhof, 2009). In addition, Environmental Consulting & Technology, Inc. (ECT) evaluated dam removal alternatives in the document entitled *Boardman River Feasibility Study, Detailed Analysis of Alternative Report*, dated January 2009 (ECT, 2009). These consultants evaluated the costs for drawdown and dam removal. AMEC has reviewed the methods and costs summarized in these reports to aid in establishing estimated costs for each component of work.

3.1.1 Dewatering

Prein & Newhof evaluated four alternatives for drawdown, including explosives, by-pass pumping, embankment breaching, and installation of a temporary drawdown structure. Explosives and embankment breaching were eliminated as alternatives due the lack of control of water flow during the dam breach and given that each would be irreversible. By-pass pumping and temporary drawdown structure were evaluated in greater detail.

By-pass pumping would include pumping water over or around the dam until the headpond and tailwater are equalized, at which point the dam would be breached to allow final flow to occur while the dam is partially removed. This alternative was deemed by Prein & Newhof to be more expensive than a temporary drawdown structure (total cost ranging from \$1,143,300 to \$1,486,290). It was estimated that between 300 and 400 cfs must be pumped to maintain the existing flow and empty the impoundment. It is believed that this alternative would require constant maintenance and 24-hours per day, 7-days per week to ensure that limited to no flow set-backs occur. Further, this type of system may incur set-backs should large storm events occur.

A temporary drawdown structure was also evaluated by Prein & Newhof. This structure would consist of a sheeted, braced, excavation with stop log gates through the embankment on either side of the powerhouse. In brief, Prein & Newhof estimated this structure to be 90 feet long and 18 feet wide and oriented upstream/downstream. Sheets and H-piles would be extended up to 60 feet and 100 feet below the embankment surface, respectively. The structure would allow contained excavation to occur on the highest portion of the embankment, with open excavations near the toe and heel of the embankment. Subsequent to excavation of soil, a stop log gate would be used to adjust the flow to dewater the headpond in a controlled rate. Prein & Newhof estimated that the cost for this structure would range between \$735,640 and \$956,332, or approximately \$400,000 to \$500,000 less than by-pass pumping.

AMEC agrees that the temporary drawdown structure would be best suited for this application, as it is less expensive and would provide better control of flow, especially during storm events. AMEC

reviewed Prein & Newhof's recommendation regarding the proposed drawdown structure and estimated costs. The structure size and details appear reasonable for this application, and the unit rates applied are consistent with AMEC's estimated unit rates. The assumptions applied for estimating costs are generally consistent with those made by Prein & Newhof. AMEC's estimates indicate a total cost for this structure of approximately \$870,000, or midway between the range of costs estimated by Prein & Newhof. Accordingly, AMEC has applied the costs that were developed by Prein & Newhof (Prein & Newhof, 2009).

3.1.2 Dam Removal

ECT evaluated several alternatives for dam removal. At this point, the project will apply Alternative 79, which consists of repair of Union Street Dam, with partial or complete removal of Sabin, Boardman, and Brown Bridge Dams. Partial removal of Brown Bridge Dam is currently being considered. As part of its analysis report, ECT provided a costs range of \$1,000,000 to \$1,500,000, excluding management of sediment, stream banks, and impoundment restoration, although details of the construction costs are not provided in ECT's report.

As part of the concept design, a cost estimate for partial removal of the dam was developed. While the actual dam removal design has not been initiated as of the date of this Concept Design document, it is anticipated that the removal will consist of demolition of the powerhouse, spillway and log chute, with partial removal of the embankments adjacent to the powerhouse. Excavation of embankment soils would include the area of the temporary drawdown structure. This removal assumes improvement of construction access road(s) on the right embankment, complete removal of the concrete structure to tailwater level, stabilization of the embankment cut faces, and stabilization of the new channel bed. It has been assumed that the demolition would be complete within 12 weeks after drawdown of the headpond. Estimates for demolition and construction are \$1,200,000, or approximately midway between the cost estimate range developed by ECT (\$1,000,000 to \$1,500,000). We have, accordingly, applied the costs that were developed by ECT in their 2009 report.

3.2 COSTS AND ASSUMPTIONS

Costs are presented within each option that appear detailed, but are still planning level estimates, based on approximate quantities and a pre-design assessment level. These are intended to provide comparisons among approaches, indicating which may be more or less expensive than the other, and also to begin forming a planning level estimate of actual implementation costs. Under each scenario, assumptions were utilized to calculate costs. In many instances these assumptions are apparent within the noted quantities, but other assumptions include the following:

- Mobilization costs assume equipment mobilized to the site as well temporary controls for erosion, traffic, access, etc. These were assumed as a scaled percentage of the total construction cost.
- Channel length for restoration in the Lower impoundment is assumed to be 6,700 feet.
- Channel length for restoration in the Upper impoundment is assumed to be 5,500 feet.
- Area calculations are based on the channel lengths above.
- Dig and pitch approaches to channel bed restoration assume 250 feet per day can be built and the excavator can operate in the gravel bed of the river.
- Large woody debris (LWD) is assumed to be applied at a rate of 50 logs/500 feet, whole trees are assumed to be used.
- The unit costs for bank treatments assume the use of less intense approaches for most areas (grading and fabric) with sparing use of more expensive approaches (fabric encapsulated lifts).

- No rock is assumed to be imported for any restoration work.
- Daily oversight of channel and floodplain restoration by a member of the design team is assumed.
- Construction oversight is assumed as a percentage of the total construction cost, scaled to the construction budget. Percentages used are noted in the details of each estimate below.
- Unit costs for excavation assume material will be wasted on-site and the sediments are considered inert (e.g., no special handling due to chemical characteristics) and require no special handling.
- Water management during construction is assumed to favor exclusion from active flow of the work area and not active pump around to create dry work conditions.
- North Slope Stabilization – Three areas with a total of approximately 15 acres have been delineated along the north slope as areas of high risk for erosion and instability. These areas are long steep slopes composed of sandy soils. Soils here will be amended with compost which will be blown onto the slopes prior to seeding. Amended slopes will then be hydro-seeded with a native slope stabilization seed mix and slurry mulch. In order to reduce cost, it is assumed that the City of Traverse City will provide municipal compost for the project.
- A general native floodplain seed mix will be sown using traditional broadcast methods where seeding is applied in the restoration scenarios below.
- Live stakes along high risk bank locations will be used within 5 feet of the water's edge. Cuttings will be planted on 5-foot centers or approximately 1,742 stakes per acre.
- Woody floodplain plantings with appropriate native trees and shrubs will be 3-gallon plant material and will be planted on 20-foot centers or 108 plants per acre where used in the scenarios below.
- The Draft Invasive Species Management Plan details approaches to managing invasive species. For the purposes of cost estimating, this task is assumed to be performed by others, and not part of the re-vegetation costs.
- Cost assumptions for dam removal and dewatering are detailed in the ECT (2009) and Prein & Newhof (2009) reports. Costs assume up to \$50,000 for asbestos abatement.
- A 25 percent contingency is applied to all construction costs. Construction management costs are assumed to at 10 percent of the construction costs. A cost range is provided based on the 25 percent contingency (e.g., construction costs plus 10 percent (low end) and construction cost plus 25 percent contingency plus 10 percent on construction cost (high end) as presented in the cost tables presented in Section 4.3.below.

4.0 CONCEPT DESIGNS FOR RESTORATION AT BROWN BRIDGE

4.1 OVERVIEW

Regardless of the approach considered, the long term (centuries into the future) outcome of the removal of the Brown Bridge Dam will be a Boardman River restored back to a pre-dam condition. The achievement of this end goal can proceed along a restoration gradient of Active and Passive approaches each with their particular challenges and advantages. The information described in Table 2 to define a 100 percent Active, 100 percent Passive, and a 50 percent Active/50 percent Passive (50/50 Approach) restoration concept alternatives. Percentages indicated are simply for communication and do not reflect measured quantities. Consistent with the assessment above, the discussion is presented with information specific to the restoration of the Upper and Lower Brown Bridge impoundment.

Table 2. Summary of Restoration Elements Under Each Concept Alternative

Restoration Element	Project Alternative		
	100% Active	50/50 Plan Approach	100% Passive
Channel Restoration	12,200 LF Enhancements	12,200 LF Enhancements	12,200 LF Natural Development
Floodplain and Wetland Potential	79 Acres	74 Acres	74 to 79 Acres Unknown Development Upper Impoundment
Upland Habitat	106 Acres	111 Acres	111 Acres Unknown Development Upper Impoundment

4.2 RESTORATION CONCEPT ELEMENTS

Elements of the potential restored bottomland at Brown Bridge Pond include a number of elements that are common to each alternative under consideration. These elements are described in general below and include the following:

- River channel
- Floodplain Wetlands
- Upland

While it is recognized that other components of the restored bottomlands at each location will likely incorporate recreational elements including features such as pedestrian access, crossing and entry; these elements are not within the scope of this document and will be developed separately in a Recreational Concept Plan. Table 2 presents a summary of the restoration elements under each concept alternative described in Section 4.3.

4.2.1 Channel Restoration

At Brown Bridge it is estimated that the restored river channel common to all concept plan alternatives would be approximately 12,200 linear feet (LF). The channel and associated floodplain area in the Lower impoundment is assumed to remain intact, with minor if any sediment deposition. The Upper impoundment channel, characterized by the sand delta, will require the re-establishment of a channel and eventually a floodplain under either passive means that transport the

sand downstream through the process of headcut migration or through the active excavation of impounded sediment and exclusion of this material from downstream transport.

Restoration of in channel habitat will focus on the addition of large woody debris (LWD) throughout both the Upper and Lower impoundments as well as the reconstruction of bedforms (pools, riffles, runs) particularly in the Upper impoundment, where these features have been buried by deposited sediment. The Lower impoundment channel is assumed to be intact, including the pre-dam bedforms, which require only the restoration of natural river processes to return to a functioning condition. The restoration of these elements will provide the necessary roughness elements to induce local scour, create bed heterogeneity and thus complex habitat for both aquatic and terrestrial riverine species.

Channel banks will either be stabilized with a suite of bioengineering techniques, or allowed to self stabilize following exposure of the former floodplain and seedbank. Given the hydrologic stability of the Boardman, a number of options with respect to bank treatments are available.

4.2.2 Floodplain and Wetlands

Wetlands are expected to form within the restored pond areas by natural processes and by active restoration methods. Particularly in the Lower impoundment, this habitat type remains largely intact and will require management to develop fully. In the Upper impoundment the deposited sediment will have to be removed to reconnect the floodplain area with the necessary hydrology for the restoration of wetlands.



It is expected that riparian zones and wetlands within the restored areas would consist of a mosaic of wetland community types including shallow and deep marsh, scrub shrub, wet meadow, and future forested wetlands. The conceptual plans presented identify a general zone in which wetlands may be expected to form based on known terrain and hydrological relationship with the restored river channel. Opportunities for development of wetland communities beyond pre-dam extents will depend on active formation through excavation following drawdown. This is particularly true for off-channel deep marsh and scrub shrub habitats that may require some excavation to support their establishment in both the Upper and Lower impoundments. These features will contribute to greater habitat diversity within the restoration area; including niche habitats for amphibians, breeding birds, macroinvertebrates, and wetland plant species.

Plant establishment may entail natural recruitment of plants represented in the “seed bank” contained in the sediments of each pond, coupled with the use of other plant establishment techniques. Such measures may include seeding, live-staking, containerized seedlings and potted trees and shrubs. Extensive use of these measures would enhance rapid community restoration and facilitate the establishment of optimum combinations of native floristic communities.

Plant material considerations would include a diversity of size categories to provide extensive root establishment and commercial availability. The planting palette contains a mix of native trees, shrubs and herbs indigenous to Northern Michigan’s floodplains, wetlands and upland buffers, along with seed mixes of native grass and forb species. Consideration of plant species for introduction into the restored bottomlands at each location should also include those species that

have been documented as having Tribal uses as demonstrated through studies to develop Traditional Ecological Knowledge (TEK).

4.2.3 Upland Habitats

The upland buffer area will consist of conifers and deciduous trees with sporadic areas dominated by herbaceous vegetation and shrubs. Mid-canopy and overstory trees will be selected to provide long-term stability and increased buffering capacity of the system. These plant species will provide: root mass for soil and bank stabilization, mast production and cover for wildlife. Native riparian buffers, which include floodplain forest and upland forest, will aid in non-point source pollution filtration from agricultural drainage. Existing trees will be left intact within the project area wherever possible. Upland habitat development at Brown Bridge Pond consists of up to 111 acres. Upland communities surrounding each pond will in time become vegetated by trees and shrubs, including red and silver maple, cedar, balsam, willow, alder, black ash, elm and dogwood. In order to expedite this process, active restoration measures in these areas can include the installation of plant materials by seeding or by installing potted plants to establish particular tree masses.

4.2.4 Invasive Species Management

Dam removal will create opportunities for invasive species to become established. In particular, dam removal will create large expanses of previously inundated and un-vegetated soils that may be colonized by invasive plant species which may out-compete desirable native plant species. Furthermore, the change in aquatic habitat type from reservoir to free-flowing river may also provide opportunities for aquatic invasive species to become established or spread. Care must therefore be given to monitoring and management of recently exposed lands to minimize the potential for widespread establishment of invasive species. The *Invasive Species Management Plan for the Boardman River, Brown Bridge Pond to Union Street Dam* (MACTEC, 2011) provides information regarding the management of invasive species within the Boardman River bottomlands. In particular, this plan prioritizes species to be controlled and provides the methods and procedures for control of invasive species during dam removal and subsequent river/floodplain restoration.

4.3 FINAL RESTORATION CONCEPT ALTERNATIVES

Final restoration concepts for Brown Bridge Pond were developed to accomplish the stated goals for ecosystem restoration. Concept plan alternatives include the 100 percent Active, 100 percent Passive, and 50/50 Plan. Restoration elements as described in the preceding section are integrated into each alternative, but are variously applied and implemented. Each of these alternatives are discussed below and further illustrated in Appendix A.

4.3.1 One Hundred Percent Active Restoration

The active restoration of the Brown Bridge impoundment involves the active construction of the physical attributes of the pre-dam river corridor. This focuses largely on the use of earth moving equipment to remove accumulated sediment in the Upper impoundment as well as active planting, seeding, and management of the associated vegetation community in both the Upper and Lower impoundment. Bank treatments would be constructed to provide immediate bank stabilization and must be done in the absence of active flow, thus dewatering and flow exclusion is included as significant expense under this scenario. The floodplain excavation is set at 40 feet to either side of the top of bank of the 55-foot wide channel. This width will not remove all sediment deposited

since the 1921 construction of the dam, but the total width of the floodplain at 80 feet is in line with the range estimated in areas above and below the dam using the hydraulic model. To remove all deposited material is likely cost prohibitive, and in an effort to propose realistic options for implementation, was not considered. Re-vegetation efforts are concentrated within a 40-foot corridor of the channel, but all exposed areas on the entire site will be seeded. Active wetland development includes shallow excavation and planting of approximately 30 acres of wetlands in the Lower impoundment. In addition, special attention will be given to areas along the North shore of the Lower impoundment, expected to be difficult to stabilize naturally.

4.3.2 Component Approach

Table 3 presents a summary of the 100 percent active restoration alternative.

Table 3. Component Approach for the 100 Percent Active Restoration Alternative

Upper Impoundment	
Excavation/Sediment Management	The Upper impoundment includes the delta which will be excavated to expose a main channel (First priority in phased construction) with a bottom width of about 55 feet and an associated floodplain 40 feet to either side of the top of bank (Second priority in phased construction). The excavation of the main channel feature will remove the majority (qualitative estimate of 80 percent) of sediment from active transport during dam removal. The floodplain excavation at 40 feet to either side (80 feet total) will not completely re-expose the pre-dam surface but will expose a large majority of the floodplain.
In-Channel Habitat	In channel habitat will be enhanced with LWD habitat, at a rate of approximately 50 trees/500 feet. Bedforms such as pools, riffles, and runs will be actively created with existing material through a process called “dig and pitch” where the volume of material excavated for a pool is placed downstream to create a riffle feature. This technique has been used successfully and allows the river to quickly organize material in a short period of time.
Channel Banks	Channel banks in the Upper impoundment will be stabilized using a variety of methods including fabric lifts, typical on outside bends, and grading and surface fabric treatment in other areas. In addition, LWD and live stakes will be used to reinforce particularly vulnerable areas. This effort requires isolation of the work area and limited dewatering to complete in order to maintain active river flow during construction, a significant cost.
Riparian Zone Wetlands/Uplands	A corridor will be actively seeded and planted adjacent along a corridor 40 feet to either side of the top of bank, consistent with the excavated floodplain
Lower Impoundment	
Excavation/Sediment Management	There is assumed to be little sediment below the delta in the Lower impoundment. This area will not require excavation or intense sediment management efforts.
In-Channel Habitat	In channel habitat will be enhanced with LWD habitat, at a rate of approximately 50 trees/500 feet. Bedforms such as pools, riffles, and runs will be enhanced through a “dig and pitch” approach where the volume of pool material is excavated and used to create riffles. The need for this dig and pitch may be re-assessed once the channel bed is re-exposed.
Channel Banks	Channel banks in the Lower impoundment will be stabilized using a variety of methods including fabric lifts, typical on outside bends, and grading and surface fabric treatment in other areas. In addition, LWD and live stakes will be used to reinforce particularly vulnerable areas. This effort requires isolation of the work area and limited dewatering to complete in order to maintain active river flow during construction, a significant cost.

Riparian Zone Wetlands/Uplands	An actively seeded and planted corridor within the flood prone width of the channel most susceptible to an influx of invasive seed from upstream. Under the 100% Active approach, this area will be 40 feet to either side of the top of bank of the channel in the Lower impoundment. The balance of exposed areas following removal, largely in the Lower impoundment and lower delta area will be actively seeded in an effort to reduce invasive species presence. Approximately 30 acres of wetlands will be actively developed through shallow excavation and planting. In addition, the sand slopes exposed along areas of the North shore of the impoundment will be amended with organic material and seeded to promote rapid ground cover.
-----------------------------------	--

4.3.3 Estimated Costs

Costs reflect the approach outlined above with respect to various components of active restoration. Costs in Table 4 are given for the 100 percent active passive restoration approach and are based on the assumptions common among all components outlined above.

Table 4. Concept Level - Engineer's Opinion of Probable Construction Costs for 100 Percent Active Restoration

Description	Unit	Quantity	Unit Price	Subtotal
Mobilization and Controls	LS	1	\$349,453	\$349,453
Dam Demolition				
Dam Demolition and Disposal	LS	1	\$1,200,000	\$1,200,000
Construct Temporary Dewatering Control	LS	1	\$870,000	\$870,000
Sediment Controls (sediment trap or maintenance)	LS	1	\$30,000	\$30,000
Channel and Floodplain Restoration				
Lower Impoundment				
Construction Water Management	1,000 LF	6.7	\$10,000	\$67,000
Enhance In Channel Habitat (LWD only)	LF	6,700	\$50	\$335,000
Bank Treatment (each side)	LF	13,400	\$35	\$469,000
Wetland Excavation (allotment)	CY	25,000	\$8	\$200,000
Upper Impoundment				
Construction Water Management	1,000 LF	5.5	\$10,000	\$55,000
Excavate Delta Sand from Main Channel	CY	85,000	\$8	\$680,000
Excavate Delta Sand for Floodplain (40 feet each side)	CY	53,000	\$8	\$424,000
Enhance in Channel Habitat (pools/riffles/LWD)	LF	5,500	\$75	\$412,500
Bank Treatment (each side)	LF	11,000	\$35	\$385,000
Re-Vegetation				
Lower Impoundment				
Steep Slope Soil Amendments	Acre	14.7	\$7,000	\$102,900
Steep Slope Hydro-Seeding with Slurry Mulch	Acre	14.7	\$2,500	\$36,750
Seed (Floodplain Mix) All Newly Exposed Sediments	Acre	150	\$2,000	\$300,000
Stream Bank Stabilization - Live Stakes	Acre	2	\$10,000	\$20,000
Riparian Zone Planting - Trees and Shrubs	Acre	12.3	\$3,780	\$46,494
Wetland Zone Planting - Trees and Shrubs (allotment)	Acre	30	\$3,780	\$113,400

Table 4. Concept Level - Engineer's Opinion of Probable Construction Costs for 100 Percent Active Restoration (cont.)

Upper Impoundment				
Seed (Floodplain Mix) Newly Excavated Floodplain	Acre	9.5	\$2,000	\$19,000
Temporary Seed/Mulch on Spoiled Delta Sediment	LS	1	\$10,000	\$10,000
Stream Bank Stabilization - Live Stakes	Acre	1	\$10,000	\$10,000
Riparian Zone Planting - Trees and Shrubs	Acre	10.1	\$3,780	\$38,178
Subtotal				\$6,173,675
Contingency (25%)				\$1,543,419
Construction Oversight (10% of Subtotal)				\$617,368
Total				\$8,334,462

4.3.4 Summary – One Hundred Percent Active Approach

The 100 percent Active restoration approach is provided in Table 5 and is based on the assumptions common among all components outlined above.

Table 5. One Hundred Percent Active Approach Summary

Estimated Total Cost	Advantages	Disadvantages
\$6.8M - \$8.3M	<ul style="list-style-type: none"> • Eliminates impacts to natural river process from the Brown Bridge Dam. • Provides the most components possible of a restored channel, riparian zone and wetland system within the shortest time. • Reduces sediment transport out of the impoundment to the highest degree possible. 	<ul style="list-style-type: none"> • Significant capital expense.

4.4 ONE HUNDRED PERCENT PASSIVE APPROACH

The passive restoration of the Brown Bridge Pond involves only the removal of the dam with no work in either the Upper or Lower impoundments. In reality, if this approach is pursued, some level of sediment management (sediment traps) and perhaps vegetation management (herbiciding invasive species) might be employed at a relatively low cost. Techniques beyond these however begin to enter the 50/50 Plan, presented below, and move away from a Passive approach. The resulting landscape will look very similar to the partially drawdown Boardman impoundment. Sediment from the channel portion of the delta will be mobilized downstream. The high banks similar to that seen at Boardman Pond will be exposed and likely remain un-vegetated on their face, composed largely of sand. However, once the initial flush of sediment is moved out to form the channel, these banks will contribute relatively small amounts of sand overtime to the overall sediment load of the Boardman River. Vegetation will re-establish throughout the Lower impoundment from the existing seed bank exposed with drawdown. In the Upper impoundment, the seed bank will remain buried under the delta deposits and re-vegetation will occur from seed dispersed by the river or wildlife. No active wetland development will be performed for this alternative.

4.4.1 Component Approach

Table 6 presents a summary of the characteristics associated with the 100 percent passive restoration approach.

Table 6. Characteristics of the 100 Percent Passive Restoration Alternative

Upper Impoundment	
Excavation/Sediment Management	No mechanical removal of sediment will occur. Delta material will be allowed to naturally migrate downstream as the pre-dam channel is exposed. This process will likely take a few years to fully complete for the channel portion of the cross section, though is flood dependent and will progress faster in hydrologically wet periods than dry. The floodplain and associated wetland portions of the cross section will be slow (centuries), to develop and heavily dependent on flood magnitude and frequency.
In-Channel Habitat	In channel habitat in the form of pools, runs and riffles will likely develop within a few flood cycles (several years). Large wood inputs will require centuries for suitable conditions for initiation of growth, then maturity, and eventually death or channel capture of riparian trees to occur. Some trees will likely be transported into the reach from upstream sources.
Channel Banks	Banks will remain subject to the cycle of erosion and widening until a stable channel cross-section is developed. Banks will be slow to vegetate in the sandy deposits of the delta, similar to Boardman Pond conditions.
Riparian Zone/Wetlands/Uplands	Within the delta area, vegetation will be slow to recover as sand with little organic material coupled with a drop in the elevation of the wetted zone will make conditions difficult, similar to Boardman Pond. The native seed bank will remain largely covered by the delta deposition and re-vegetation will occur from seed stock washed or blown in from the surrounding area which is likely to include a significant portion of invasive species.
Lower Impoundment	
Excavation/Sediment Management	The existing cross-section is intact. As sand from the delta upstream is transported through the lower impoundment, the channel bed will be composed of a sizeable percentage of sand. Annual floods will continue to move sand through the section until eventually the coarse bed is re-established and the upstream source of sand from the delta is diminished.
In-Channel Habitat	In-channel habitat will develop after the initial volume of sand in the delta is passed through the system. The exposed native material should mobilize or perhaps even exists in the form of pools, runs, and riffles that existed before the dam was constructed. Large wood inputs will require growth, then maturity, and eventually death or channel capture of riparian trees to occur. Some trees will likely be transported into the reach from upstream sources. This process will likely occur at a faster rate than in the Upper impoundment as the pre-dam floodplain should provide suitable substrate and organic content for the establishment of vegetation immediately.
Channel Banks	Banks will be vulnerable but should re-vegetate quickly (within a single growing season) given the pre-dam substrate and possibly seed bank remain intact. Given the power of the stream, erosion will likely be relatively minor and within acceptable levels.
Riparian Zone/Wetlands/Uplands	The native seed bank is likely present in the Lower impoundment, though invasive species will have a competitive advantage in the newly available substrate for re-colonization. Some management of invasive species even under a passage approach can limit their composition in the Lower impoundment.

4.4.2 Estimated Costs

Costs reflect the approach outlined above with respect to various components of passive restoration. Costs in Table 7 are given for the 100 percent passive restoration approach and are based on the assumptions common among all components outlined above.

Table 7. Concept Level - Engineer's Opinion of Probable Construction Costs – 100 Percent Passive Restoration

Description	Unit	Quantity	Unit Price	Subtotal
Mobilization and Controls				
Mobilization and Controls	LS	1	\$100,000	\$100,000
Dam Demolition				
Dam Demolition and Disposal	LS	1	\$1,200,000	\$1,200,000
Construct Temporary Dewatering Control	LS	1	\$870,000	\$870,000
Sediment Controls (sediment trap or maintenance)	LS	1	\$30,000	\$30,000
Subtotal				\$2,200,000
Contingency (25%)				\$550,000
Construction Oversight (10% of Subtotal)				\$220,000
Total				\$2,970,000

4.4.3 Summary – One Hundred Percent Passive Approach

The 100 percent passive restoration approach is provided in Table 8 and is based on the assumptions common among all components outlined above.

Table 8. One Hundred Percent Passive Approach Summary

Estimated Cost	Advantages	Disadvantages
\$2.4M – 3.0M	<ul style="list-style-type: none"> • Lowest capital expense. • Eliminates impacts to natural river process. 	<ul style="list-style-type: none"> • Rate of river process recovery is slow. • Significant impact to downstream riverine function and ecology with sediment deposition. • Public use and aesthetics beyond the channel will be slow to develop. reduced until long-term natural recovery is complete.

4.5 FIFTY/FIFTY (50/50) ACTIVE AND PASSIVE RESTORATION

The 50/50 approach to restoration of the Brown Bridge impoundment is a balanced approach intended to reduce the shortcomings of both performance and restoration time under a fully passive option while reducing the costs involved in accomplishing the fully active approach. As a blended approach, the scale or level of effort of each major task can be adjusted in a manner that fits the various constraints of the project. Construction phasing can be accomplished in this approach once the sediment within the Upper impoundment channel cross section is removed from active transport. The major cost reduction differences in this approach are the removal of ubiquitous bank stabilization throughout both the Upper and Lower impoundments, the reduction of floodplain width from 40 feet to 20 feet in the Upper impoundment, and the removal of complete reseeding of

all exposed surfaces in the impoundment. Active wetland development includes shallow excavation and planting of approximately 15 acres of wetlands in the Lower impoundment.

4.5.1 Component Approach

Table 9 presents the characteristics of the 50/50 active/passive restoration approach.

Table 9. Component Approach for 50/50 Active/Passive Restoration Approach

Upper Impoundment	
Excavation/Sediment Management	The Upper impoundment includes the delta which will be excavated to expose a main channel (First priority in phased construction) with a bottom width of about 55 feet and an associated floodplain 20 feet to either side of the top of bank (Second priority in phased construction). The excavation of the main channel feature will remove the majority (qualitative estimate of 80 percent) of sediment from active transport during dam removal. The balance of material (20 percent) will be allowed to move downstream.
In-channel Habitat	In channel habitat will be enhanced with LWD habitat, at a rate of approximately 50 trees per 500 feet. Bedforms such as pools, riffles, and runs are likely presented but muted due to deposition in the Upper impoundment but should develop quickly during subsequent flood events.
Channel Banks	Channel banks in the upper impoundment will be allowed to stabilize through the development of vegetation. Placement of LWD as well as re-vegetation will reinforce susceptible meander bends but the native seed bank is expected to re-occupy these banks once the pre-dam floodplain surface is re-exposed, providing stabilization. The relatively muted flood regime of the Boardman River will further reduce the risk to considerable bank erosion during the vulnerable period prior to vegetation establishment.
Riparian Zone/Wetlands/Uplands	A corridor will be actively seeded and planted within the flood prone width of the channel most susceptible to an influx of invasive seed from upstream. Under the 50/50 Approach, this corridor will be 20 feet to either side of the top of bank, consistent with the excavated floodplain. The balance of exposed areas following removal will be managed for the establishment of native species which may be a challenge in the dryer areas of the delta deposits.
Lower Impoundment	
Excavation/Sediment Management	There is assumed to be little sediment below the delta in the Lower impoundment. This area will not require excavation or intense sediment management efforts.
In-Channel Habitat	In channel habitat will be enhanced with LWD habitat, at a rate of approximately 50 trees/500 feet. Bedforms such as pools, riffles, and runs are assumed to persist in the Lower impoundment from pre-dam conditions.
Channel Banks	Channel banks in the Lower impoundment will be allowed to stabilize through the development of vegetation. Placement of LWD as well as re-vegetation will reinforce susceptible meander bends but the native seed bank is expected to re-occupy these banks and provide stabilization. The high ground water to surface water ratio of the Boardman and expected relic root systems of cedar and other pre-dam vegetation will further reduce the risk to considerable bank erosion during the vulnerable period prior to vegetation establishment.
Riparian Zone/Wetlands/Uplands	Two areas are featured. First an actively seeded and planted corridor within the flood prone width of the channel most susceptible to an influx of invasive seed from upstream. Under the 50/50 Approach, this corridor will be 20 feet to either side of the top of bank in the Lower impoundment. The balance of exposed areas following removal will be managed for the establishment of native species, grown from an assumed pre-dam seed bank. In addition, the sand slopes exposed along the North shore of the impoundment will be amended with organic material and seeded to promote rapid ground cover.

4.5.2 Estimated Costs

Table 10 presents the costs of the various components of the 50/50 active/passive restoration alternative.

Table 10. Concept Level – Engineer's Opinion of Probable Construction Costs – 50/50 Active/Passive Restoration Alternative

Description	Unit	Quantity	Unit Price	Subtotal
Mobilization and Controls	LS	1	\$239,268	\$239,268
Dam Demolition				
Dam Demolition and Disposal	LS	1	\$1,200,000	\$1,200,000
Construct Temporary Dewatering Control	LS	1	\$870,000	\$870,000
Sediment Controls (Sediment Trap or Maintenance)	LS	1	\$30,000	\$30,000
Channel and Floodplain Restoration				
Lower Impoundment				
Enhance in Channel Habitat (LWD Only)	LF	6,700	\$50	\$335,000
Wetland Excavation (allotment)	CY	12,500	\$8	\$100,000
Upper Impoundment				
Excavate Delta Sand from Main Channel	CY	85,000	\$8	\$680,000
Excavate Delta Sand for Floodplain (20 feet each side)	CY	26,500	\$8	\$212,000
Enhance in Channel Habitat (LWD Only)	LF	5,200	\$50	\$260,000
Re-Vegetation				
Lower Impoundment				
Steep Slope Soil Amendments	Acre	14.7	\$7,000	\$102,900
Steep Slope Hydro-Seeding with Slurry Mulch	Acre	14.7	\$2,500	\$36,750
Seed (Floodplain Mix) Newly Exposed Floodplain	Acre	6.2	\$2,000	\$12,400
Stream Bank Stabilization - Live Stakes	Acre	2	\$10,000	\$20,000
Riparian Zone Planting - Trees and Shrubs	Acre	6.2	\$3,780	\$23,436
Wetland Zone Planting - Trees and Shrubs (allotment)	Acre	15	\$3,780	\$56,700
Upper Impoundment				
Seed (Floodplain Mix) Newly Excavated Floodplain	Acre	5	\$2,000	\$10,000
Temporary Seed/Mulch on Spoiled Delta Sediment	LS	1	\$10,000	\$10,000
Stream Bank Stabilization - Live Stakes	Acre	1	\$10,000	\$10,000
Riparian Zone Planting - Trees And Shrubs	Acre	5	\$3,780	\$18,900
Subtotal				\$4,227,354
Contingency (25%)				\$1,056,839
Construction Oversight (10% of Subtotal)				\$422,735
Total				\$5,706,928

4.5.3 Summary

Table 11 presents the summary of the 50/50 active/passive restoration approach.

Table 11. Summary of Features of the 50/50 Active/Passive Restoration Alternatives

Estimated Cost	Advantages	Disadvantages
\$4.6M – \$5.7M	<ul style="list-style-type: none">• Eliminates impacts to natural river process from the Brown Bridge Dam.• Provides most of the components of a restored channel system.• Controls sediment transport out of the delta.• Provides the best balance of risk, performance, and cost of all options.	<ul style="list-style-type: none">• Maintains some level of risk to the project with unstable banks (short-term).• May require management of public perception during immediate years following removal.• Does not fully restore floodplain surface in the Upper impoundment.

5.0 SUMMARY AND RECOMMENDATIONS

Dam removal is often an exercise in compromise of competing project objectives and resources. Consideration must be given to both the short term and long term planning horizons as well as the achievement of goals in the realm of landscape function, construction cost, and public perception. The constraints on this project in particular fall into the categories listed below.

- Cost of removal and subsequent restoration of the Brown Bridge impoundment.
- Need to reduce or eliminate all downstream impacts from the project.
- Need to restore within some acceptable time frame, a functioning river and bottomland ecosystem in the former impoundment and delta area, consistent to the extent possible with the overall plan for the Brown Bridge Quiet Area (BBQA).
- Expectations for users of BBQA, the Boardman River as a whole, and downstream landowners.

The approaches outlined above address each of these categories in a different manner. The approach that appears to best strike a compromise among the total cost and project success is the 50/50 active/passive restoration alternatives.

5.1 RECOMMENDED APPROACH

The 50/50 active/passive restoration alternative approach is intended to strike a balance among the constraints listed above. By removing sediment from the delta area, the risk of negative impacts to the river below the dam is greatly reduced. Further, the relatively intact channel and floodplain between the delta and the dam is preserved. The full width of the floodplain will not be restored in the Upper section, but providing a 20-foot bench to either side of the channel does allow some mitigation of flood power and more importantly restoration of floodplain wetland. If funds are procured at a later date, additional excavation may be accomplished to widen this feature to a pre-dam condition. The 50/50 alternative does not include large scale bank stabilization, which does create a source for sediment and potential risk for mainly aesthetic concerns, but provides a significant cost savings for construction. In the Lower impoundment, the intact channel should maintain some level of resistance to erosion from the pre-dam tree root systems that existed. In addition, the assumed organic composition of the floodplain along with the pre-dam seed bank should provide robust vegetation growth within a short time following dewatering of the surface. In the Upper section a similar situation should develop as the deposited material is removed, exposing the old floodplain surface. The risk to this approach comes from a significant flood event, occurring before any vegetation has had the opportunity to colonize the banks. Such an event would have a greater impact on the Upper impoundment, where the floodplain will be narrower, whereas the floodplain in the Lower impoundment will allow the flood to spread out. Under such a scenario, the erosion is likely to remain concentrated to the outside of meander bends or other areas where channel flow is focused directly on the bank.

From a functional perspective, the channel itself will recover as the pre-dam substrate is exposed and becomes organized into the habitat elements of pools, riffles, and runs in the Lower impoundment. The Upper impoundment may require several flood events to establish a stable bed heterogeneity. By adding LWD to the channel in both the Upper and Lower sections of the former impoundment, this critical habitat element will be restored which will aid significantly in-channel macroinvertebrates, fish, and even riparian species such as turtles and piscivorous birds. The floodplain in the Lower impoundment will require some vegetation management, but habitats that existed prior to 1921 should redevelop in similar fashion. The floodplain in the Upper

impoundment will likely redevelop within the excavated section, but areas that are topographically higher will likely revert to a new condition; a mixture of upland, transition, and wetland habitats, based on variation in slope, substrate composition, and hydrology.

5.2 COST JUSTIFICATION

Costs were developed with the contingencies outlined above and illustrate the range of costs typical of dam removal projects. The 50/50 Approach, though not the least expensive, provides the advantages of both Active and Passive restoration of the river corridor within acceptable levels of risk and assurances of project success. The low range does not include the 25 percent contingency that when applied provides the high range estimate.

5.3 SUMMARY OF COSTS

A summary of costs are illustrated below in Table 12.

Table 12. Summary of Costs for the Conceptual Restoration Alternatives

Cost Element	Conceptual Restoration Alternative					
	100 Percent Active		50/50 Approach		100 Percent Passive	
	Low Range	High Range	Low Range	High Range	Low Range	High Range
Mobilization and Controls	\$349,453	\$436,816	\$239,268	\$299,085	\$100,000	\$125,000
Dam Demolition	\$2,100,000	\$2,625,000	\$2,100,000	\$2,625,000	\$2,100,000	\$2,625,000
Channel and Floodplain Restoration	\$3,027,500	\$3,784,375	\$1,587,000	\$1,983,750	\$0	\$0
Re-Vegetation	\$696,722	\$870,903	\$301,086	\$376,358	\$0	\$0
Construction Oversight (10%)	\$617,368	\$617,368	\$422,735	\$422,735	\$220,000	\$220,000
Subtotal	\$6,791,043	\$8,334,462	\$4,650,089	\$5,706,928	\$2,420,000	\$2,970,000

5.4 RECOMMENDED IMPLEMENTATION

Large, grant based projects such as the Boardman effort are often phased in an effort to deal with the realities of funding limits and cycles. This strategy can be employed at Brown Bridge. The single factor representing the greatest risk to the success of restoration in the impoundment and reduction of the potentially negative impact to the river below the dam is the transport of sediment out of the delta deposit in the Upper impoundment. From a phasing perspective, this provides a convenient break. Once the majority of sediment expected to erode to form the new, post-removal channel is removed from active transport, the risk to downstream reaches is diminished considerably. Note this is only the sediment within the channel and does not account for the floodplain, which is likely to be transported downstream under only significant flood events and even then at only a fraction of the volume of material in the channel. All other restorative activities, including re-vegetation, channel habitat enhancements, and additional floodplain excavation in the Upper impoundment can occur within reasonable timeframes (years) following the removal of sand from the active channel area in the Upper impoundment. Challenges are inherent with delays in project implementation, particularly with respect to management of invasive species, but the impact of this delay on the project is likely manifest as a minor (compared to total project budget)

increase in cost. Table 12 presents a scenario for implementation that might be considered. Note the combined process of floodplain excavation and re-vegetation in the Upper impoundment can occur multiple times until a floodplain width with the desirable habitat and vegetation community is achieved.

Table 13. Implementation Scenario for 50/50 Approach

Action	Description	Year
Dewatering and Dam Removal	Includes construction of temporary dewatering control, demolition of the powerhouse, and removal and stabilization of dam embankment.	1
Excavation of Upper Impoundment Channel	Remove only the channel sediment from the Upper impoundment; coincide with preliminary drawdown to achieve maximum access to exposed sediment.	1
Control of Invasive Species	Implement elements of Invasive Species Management Plan until active seeding can occur.	1
North Shore Stabilization	Amend soil and plant North Shore areas	1-2
In-Channel Habitat Enhancement	Can be done in Lower impoundment as soon as year 2. Complete after initial floodplain excavation occurs in the Upper impoundment.	2-4
Floodplain Excavation	Excavate a minimum of 20 feet floodplain in the Upper impoundment. Available funds may allow more floodplain excavation and wetland development in the future.	2-4
Re-vegetation	Seed areas where new vegetation is dominated by undesirable species. Augment adjacent channel areas with shrubs and native trees	2-4

6.0 REFERENCES

Cantelli et al. 2004

Environmental Consulting & Technology, Inc. (ECT). 1009. Boardman River Feasibility Study, Detailed Analysis of Alternative Report.

Fitzpatrick et al., 2006

MACTEC Engineering and Consulting, Inc. 2011. Invasive Species Management Plan for the Boardman River (Brown Bridge Pond to Union Street Dam).

Prein & Newhof. 2009. Boardman River Feasibility Study, Boardman Dams Breach Drawdown Study.

U.S. Army Corps of Engineers (USACE). 2006

APPENDIX A

Concept Drawings

Brown Bridge Dam Removal Concept Submittal



Boardman River

TABLE OF CONTENTS

1	COVER
2	EXISTING CONDITIONS
3	LOWER IMPOUNDMENT ALTERNATIVES
4	UPPER IMPOUNDMENT ALTERNATIVES
5	UPPER IMPOUNDMENT TYPICALS

Prepared by:

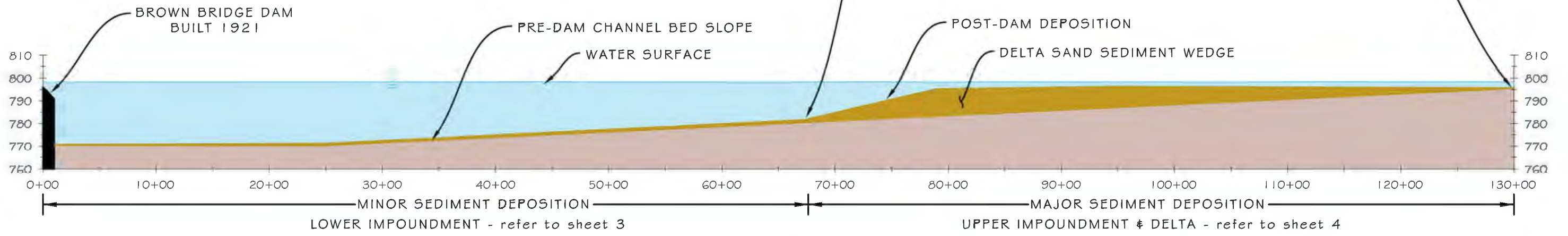
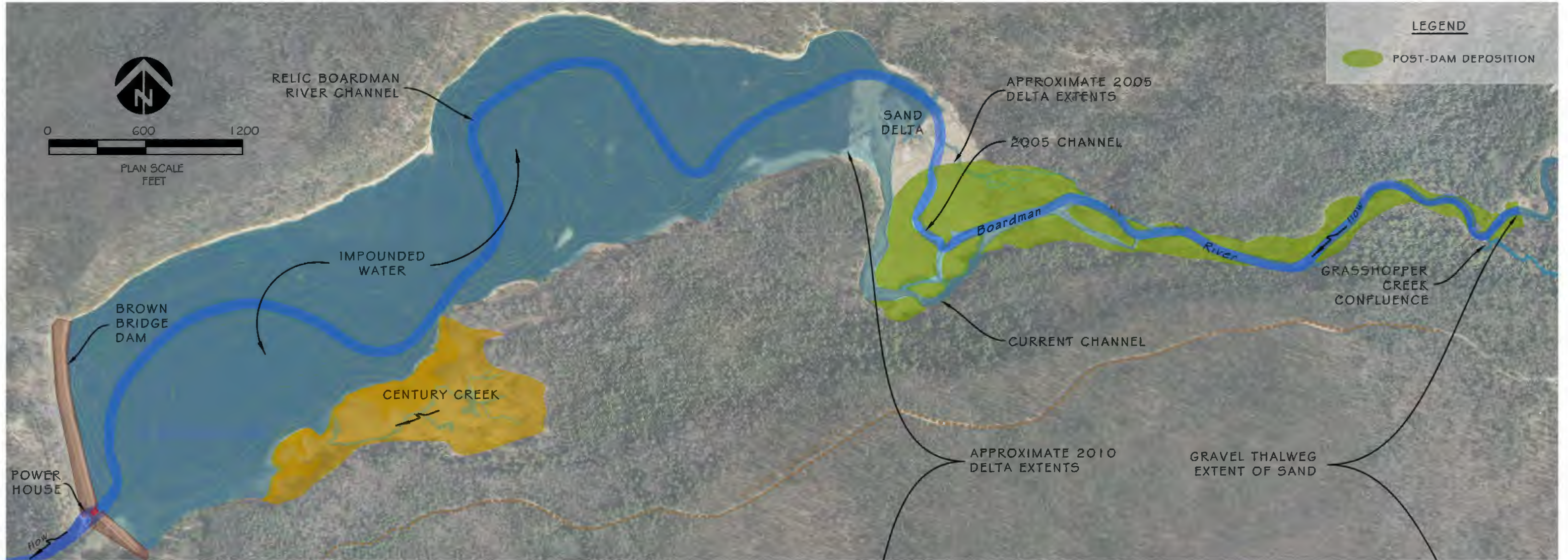


In association with:



MINOR SEDIMENT DEPOSITION
LOWER IMPOUNDMENT - refer to sheet 3

MAJOR SEDIMENT DEPOSITION
UPPER IMPOUNDMENT & DELTA - refer to sheet 4



CONCEPTUAL PROFILE
not to scale

100% Active Approach

Vegetation

- 40-foot wide actively seeded and planted corridor
- Management of invasive plants throughout
- Soil amendment as needed on steep sandy slopes
- Seed all exposed impoundment areas
- Native grasses, shrubs and trees

In-channel Habitat

- Large wood installation (50 trees per 500 ft) in the form of small jams and placed key pieces
- Construct bedforms such as pools, riffles, and runs

Channel Banks

- Active stabilization using a variety of methods including grading, fabric placement, LWD

Excavation / Sediment Management

- Assumed to be minimal sediment below the delta in the Lower impoundment. No excavation required.
- Excavate wetland features

50/50 Approach - Active and Passive Blend

Vegetation

- 20-foot wide actively seeded and planted corridor
- Management of invasive plants throughout
- Native grasses, shrubs and trees
- Soil amendment as needed on steep sandy slopes

In-channel Habitat

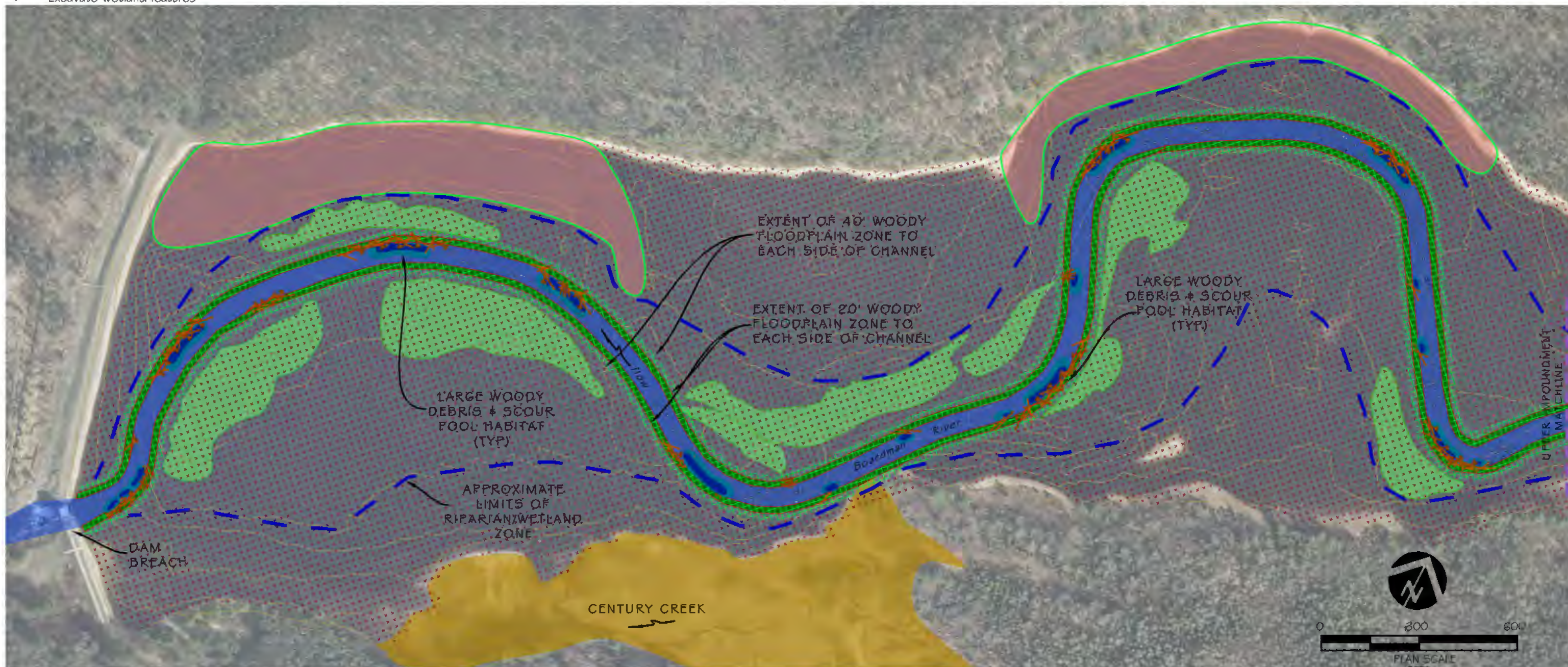
- Large wood installation (50 trees per 500 ft) in the form of small jams and placed key pieces
- Bedforms such as pools, riffles, and runs are assumed to persist in the Lower impoundment from pre-dam conditions.

Channel Banks

- No bank treatment

Excavation / Sediment Management

- Assumed to be minimal sediment below the delta in the Lower impoundment. No excavation required



100% Active Approach:

- Century Creek Passive Revegetation Area
- Stabilize North Slope - Amend Soil & Hydroseed
- Broadcast Native Floodplain Seed Mix over Newly Exposed Impoundment Area
- Plant Woody Floodplain Zone 40' to Each Side of Channel
- Floodplain Wetland

LEGEND

50/50 Approach Active / Passive Blend:

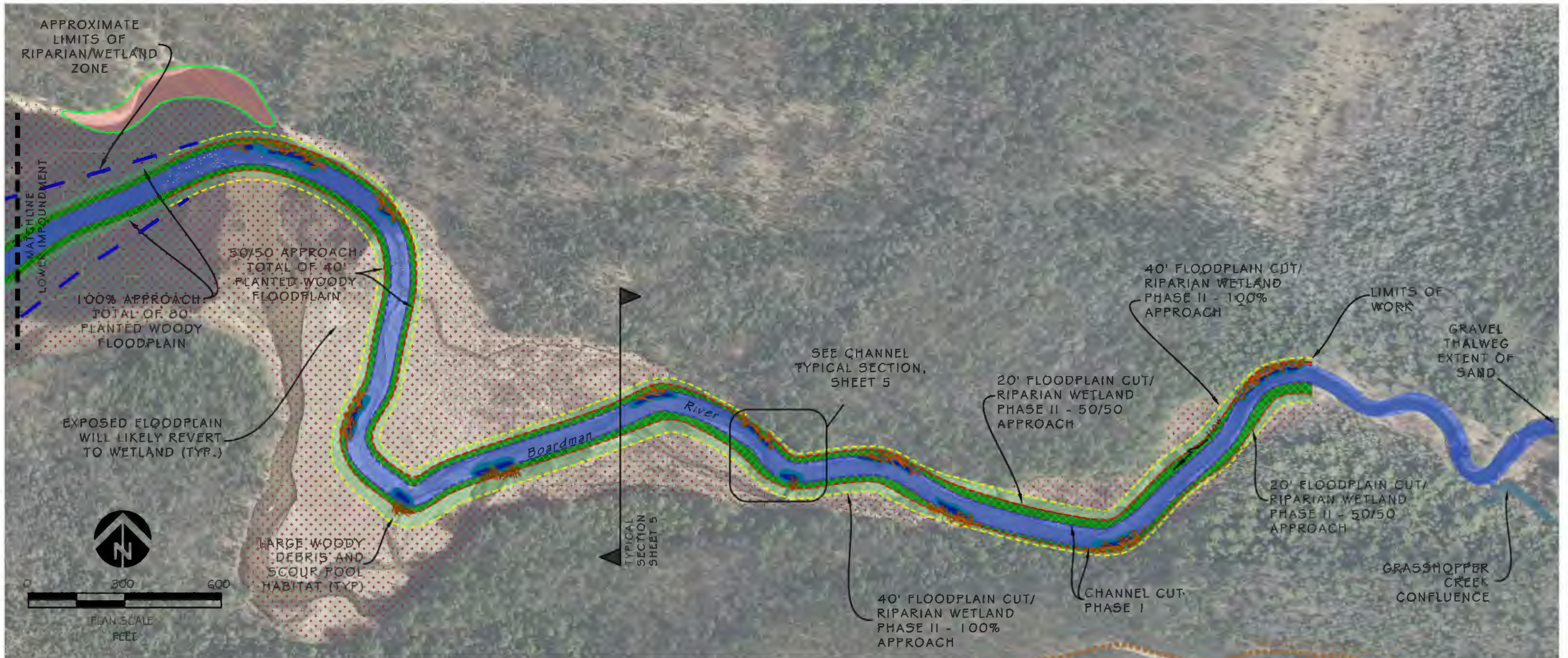
- Century Creek Passive Revegetation Area
- Stabilize North Slope - Amend Soil & Hydroseed
- Plant Woody Floodplain Zone 20' to Each Side of Channel
- Floodplain Wetland

100% Active Approach

- Vegetation
- 40-foot wide actively seeded and planted corridor
 - Management of invasive plants throughout
 - Seed all exposed impoundment areas
 - Native grasses, shrubs and trees
- In-channel Habitat
- Large wood installation (50 trees per 500 ft) in the form of small jams and placed key pieces
 - Construct bedforms such as pools, riffles, and runs
- Channel Banks
- Active stabilization using a variety of methods including grading, fabric placement, LWD
- Excavation / Sediment Management
- Excavate channel volume and associated 40' floodplain bench on either side of channel
 - Excavate microtopography and wetland features in floodplain

50/50 Approach - Active and Passive Blend

- Vegetation
- 20-foot wide actively seeded and planted corridor
 - Native grasses, shrubs and trees
 - Management of invasive plants throughout
- In-channel Habitat
- Large wood installation (50 trees per 500 ft) in the form of small jams and placed key pieces
 - Bedforms such as pools, riffles, and runs will develop over several flood events
- Channel Banks
- No bank treatment
- Excavation / Sediment Management
- Excavate channel volume and 20-foot wide floodplain bench on either side of the channel
 - Excavate microtopography and wetland features



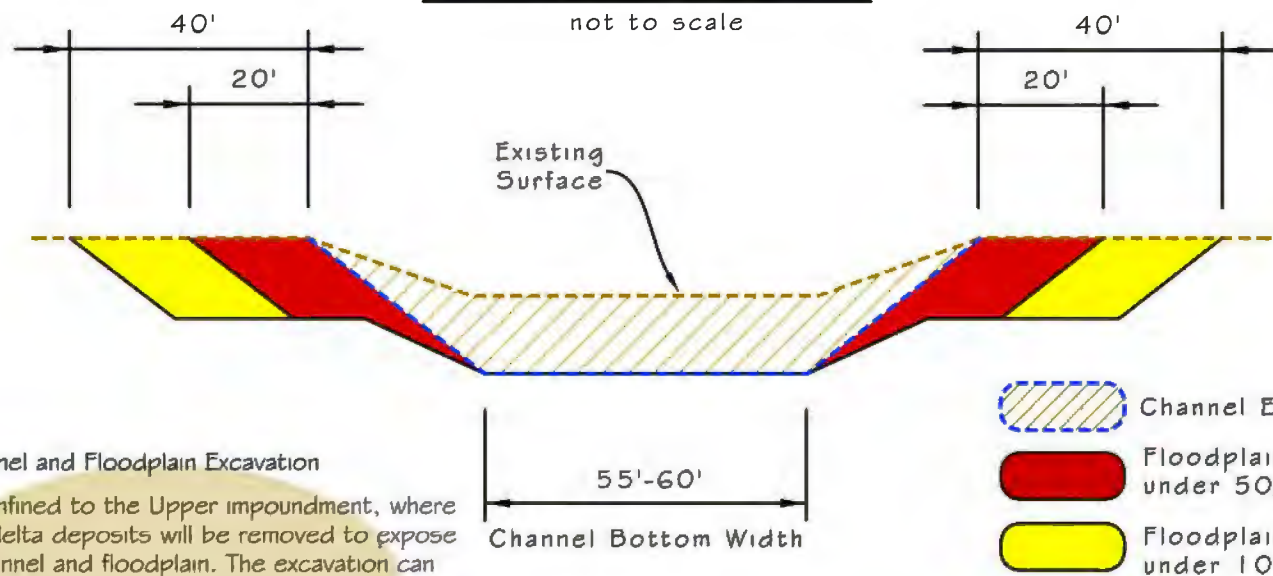
100% Active Approach:

LEGEND

50/50 Approach Active / Passive Blend:

- | | | | |
|---|--|--|---|
|  Century Creek Passive Revegetation Area |  Broadcast Native Floodplain Seed Mix over Newly Exposed Impoundment Area |  Century Creek Passive Revegetation Area |  Plant Woody Floodplain Zone 20' to Each Side of Channel |
|  Stabilize North Slope - Amend Soil & Hydroseed |  Plant Woody Floodplain Zone 40' to Each Side of Channel |  Stabilize North Slope - Amend Soil & Hydroseed | |

TYPICAL EXCAVATION SECTION



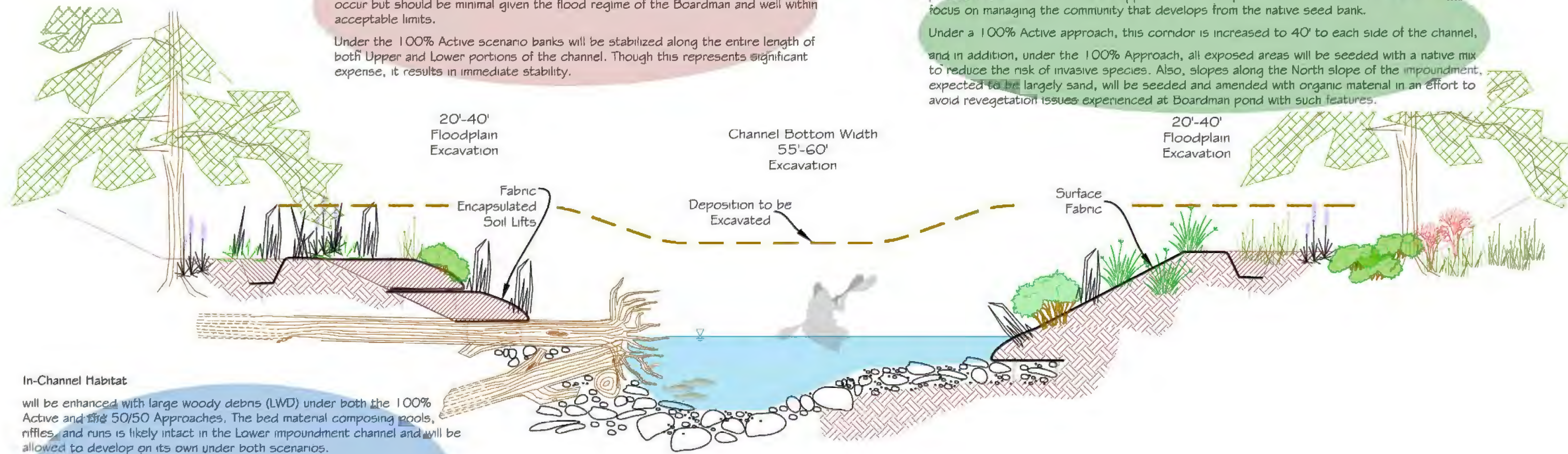
Channel and Floodplain Excavation

is confined to the Upper impoundment, where the delta deposits will be removed to expose a channel and floodplain. The excavation can proceed with the channel area first, to remove the most mobile sediment, then the floodplain second, if construction requires phasing. The Lower impoundment is assumed to include little accumulated sediment.

Bank Treatment

differs under the 100% Active approach and the 50/50 Approach. Under the latter, banks will be allowed to self stabilize, utilizing the assumed seed bank that exists in the exposed (Upper) or existing (Lower) pre-dam floodplain. Some erosion will likely occur but should be minimal given the flood regime of the Boardman and well within acceptable limits.

Under the 100% Active scenario banks will be stabilized along the entire length of both Upper and Lower portions of the channel. Though this represents significant expense, it results in immediate stability.



TYPICAL CONSTRUCTION SECTION

not to scale

In-Channel Habitat

will be enhanced with large woody debris (LWD) under both the 100% Active and the 50/50 Approaches. The bed material composing pools, riffles, and runs is likely intact in the Lower impoundment channel and will be allowed to develop on its own under both scenarios.

In the Upper Impoundment this material is present, but likely not organized into pools, riffles, and runs.

Under a 100% Active scenario, these features will be constructed using the existing material. Under a 50/50 Scenario, these features will be allowed to develop as floods re-organize the material in this section to a pre-dam form.

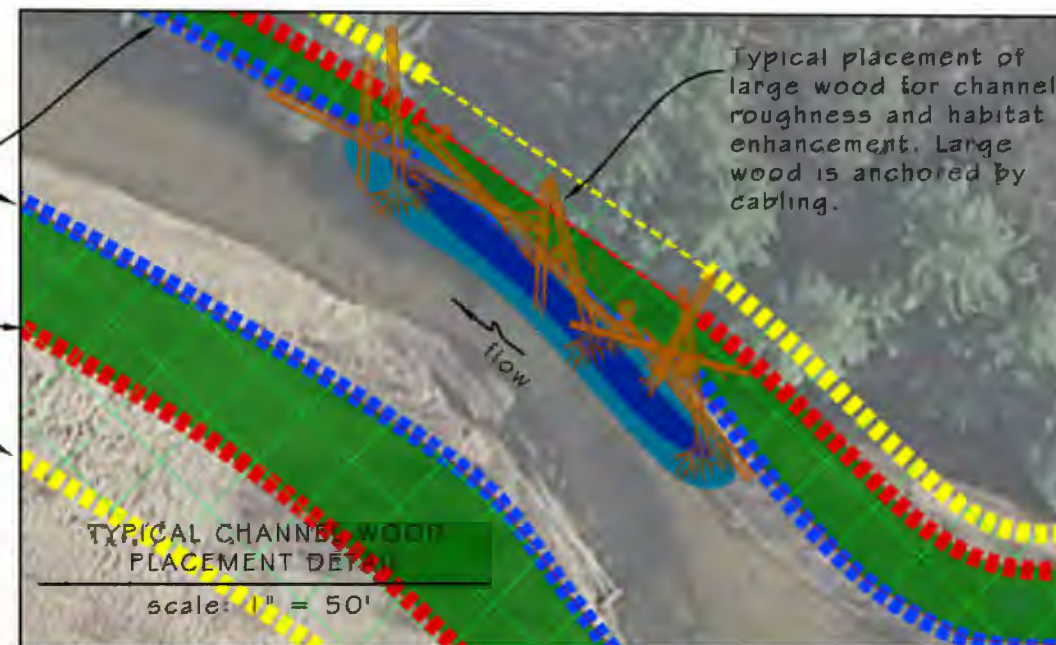
Plant Woody Floodplain Zone
20' to Each Side of Channel

Plant Woody Floodplain Zone
40' to Each Side of Channel

Channel Excavation

50/50 Floodplain Extents

100% Floodplain Extents



Typical placement of large wood for channel roughness and habitat enhancement. Large wood is anchored by cabling.

Revegetation and Management

under the 50/50 Approach, a corridor of 20' to each side of the channel will be actively planted and seeded in both the Upper and Lower impoundment. The area outside of this will focus on managing the community that develops from the native seed bank.

Under a 100% Active approach, this corridor is increased to 40' to each side of the channel, and in addition, under the 100% Approach, all exposed areas will be seeded with a native mix to reduce the risk of invasive species. Also, slopes along the North slope of the impoundment, expected to be largely sand, will be seeded and amended with organic material in an effort to avoid revegetation issues experienced at Boardman pond with such features.