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Supporting Bank and Near-bank Stabilization and Habitat Using Dredged Sediment: Documenting Best Practices

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Abstract

In-water beneficial use of dredged sediment provides the US Army Corps of Engineers (USACE) the opportunity to increase beneficial use while controlling costs. Beneficial use projects in riverine environments include bank and near-bank placement, where sediments can protect against bank erosion and support habitat diversity. While bank and near-bank placement of navigation dredged sediment to support river-bank stabilization and habitat is currently practiced, documented examples are sparse. Documenting successful projects can support advancing the practice across USACE. In addition, documentation identifies data gaps required to develop engineering and ecosystem restoration guidance using navigation-dredged sediment. This report documents five USACE and international case studies that successfully applied these practices: Ephemeral Island Creation on the Upper Mississippi River; Gravel Island Creation on the Danube River; Gravel Bar Creation on the Tombigbee River; Wetland Habitat Restoration on the Sacramento-San Joaquin River Delta; and Island and Wetland Creation on the Lower Columbia River Estuary. Increased bank and near-bank placement can have multiple benefits, including reduced dredge volumes that would otherwise increase as banks erode, improved sustainable dredged sediment management strategies, expanded ecosystem restoration opportunities, and improved flood risk management. Data collected from site monitoring can be applied to support development of USACE engineering and ecosystem restoration guidance.

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Preface

This report is part of a larger study, "Supporting Bank Stabilization and Riverine Habitat Using Dredged Sediment." This project was funded by the USACE Engineering Research and Development Center (ERDC), Dredging Operations and Environmental Research (DOER) program. Dr. Todd Bridges was the DOER program manager.

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1 Introduction

1.1 Purpose

Beneficial use of dredged material is an objective of the US Army Corps of Engineers (USACE) with a goal of 70% beneficial use by the year 2030.* Beneficial use projects often provide important environmental and economic values, but upland projects are often expensive. In-water beneficial use provides USACE the opportunity to increase beneficial use while controlling costs. Beneficial use projects in riverine environments include bank and near-bank placement, where sediments can protect against bank erosion and support habitat diversity. Increased near-bank placement can achieve other benefits as well, including reduced dredge volumes that would otherwise increase as banks erode, improved sustainable dredged sediment management strategies, expanded ecosystem restoration opportunities, and improved flood risk management. Bank and near-bank placement of navigation dredged sediment to support bank stabilization and habitat restoration is currently practiced, yet documented examples are sparse.

This technical report documents five USACE and international case studies that successfully applied these practices, and support broadening the practice across USACE. Data collected from site monitoring can be applied to support development of USACE engineering and ecosystem restoration guidance. Documenting successful projects can expand application by providing templates for other sites. In addition, documentation identifies data gaps required to develop engineering and ecosystem restoration guidance using navigation-dredged sediment.

1.2 Background

Many shorelines along navigation channels are losing nearshore habitat due to reduced sediment supply, river channelization, increased wave energy, and other physical perturbations. Navigation channel maintenance dredging often utilizes side-casting of dredged sediment for cost-efficiency, which is designed to cost-effectively relocate dredged sediment

* Personal Communication. LTG Scott Spellmon, Position needed here, July 2021.

by rapidly moving sediments downstream (Cox et al. 2011). Many reaches where this method is practiced have issues with bank stability and decreased near-bank habitat diversity due to impingement of vessel wake and reduced sediment supply. Returning dredged sediment in the thalweg or near the channel does not significantly improve nearshore regions that are sediment starved. Similar issues occur at river reaches where dredged sediment is placed upland, which isolates sediment from the regional sediment system.

Instead, placing sediment intentionally in the nearshore environment waterways can provide ecosystem benefits as well as reduce and offset bank erosion. USACE and other organizations have been developing nature-based solutions that support nearshore habitat and bank stabilization using dredged sediment. Dynamic features created by strategic placement (berms and mounds) support fish habitat, diverse flora, and bank stabilization. These dynamic structures may also be designed to create secondary channels and quiescent water areas which increase habitat diversity. Degradation of these structures by natural hydrodynamic forces can be addressed during subsequent dredging cycles, thus supporting sustainable dredged sediment management solutions. Despite some success in creating near-bank habitat, documentation of these successes is scant, and no information exists providing guidance for designing and constructing such nature-based structures.

Developing sustainable and resilient river infrastructure requires the USACE to apply innovative approaches to engineering and operating infrastructure. Through the Engineering with Nature® (EWN®) initiative (www.engineeringwithnature.org), the USACE is developing and demonstrating, through multiple projects, the capabilities needed to achieve sustainable project outcomes.

1.3 Objectives

Bank and near-bank placement of navigation dredged sediment to support river-bank stabilization and habitat is practiced within USACE and internationally. This report supports the larger USACE objectives of increasing (1) beneficial use of dredged sediment, (2) ecosystem restoration, and (3) bank stabilization for flood risk management. The objective of this report is to identify and document case studies of bank and near-bank placement of dredged material best practices worldwide. By documenting these beneficial use projects, bank and near-bank dredged sediment placement projects Corps-wide should be increased. The case studies occurred at different times, with differing construction and post-construction monitoring objectives. Therefore, they are not provided in a uniform format, but rather structured to emphasize the monitoring objectives for each specific project. A subset of these case studies will be identified for further investigation for monitoring and collecting appropriate data sets required to develop engineering and ecosystem restoration guidance.

2 Case Studies

2.1 Case study selection criteria

Table 1 identifies five projects that exemplify how near-bank placement of navigation dredged sediment to support bank stabilization and habitat have been successfully implemented in practice. Each project demonstrates the added benefits (economic, environmental, and social) that can result from forward thinking, planning, and collaboration to maximize the success of placing dredged sediment near river banks.

Table 1. Overview of presented case studies.

Case Study	Project/ Goal	Riverine System	Location	Project Start Date
1	Ephemeral Island Creation	Middle Mississippi River	Missouri, USA	2010
2	Gravel Island Creation	Danube River	Austria, EU	2012
3	Gravel Bar Creation	Tombigbee River	Mississippi, USA	1985
4	Wetland Habitat Restoration	Sacramento-San Joaquin River Delta	California, USA	1985
5	Island and Wetland Creation	Lower Columbia River Estuary	Washington, USA	2020

2.2 Case Study #1: Ephemeral Island Creation in the Mississippi River, Missouri

This case study provides an example of how nature-based features derived from dredged material placement can be used to create ephemeral island habitat in off-channel areas for a variety of species. It also highlights some challenges that occur with conducting natural enhancement with dredged material placement. This project was initiated in FY2011 (Federal fiscal year beginning 1 October 2010). The Middle Mississippi River (MMR, defined as the reach of the Mississippi between the confluences with the Ohio and Missouri Rivers) is home to a variety of fish and bird species, including the endangered pallid sturgeon (*Scaphirhynchus albus*) and least tern (*Sternula antillarum*). Island creation is a goal for the USACE St. Louis District (MVS) and its partners as a means of increasing side channel habitat available on the MMR. A main finding of the 1976 Environmental Impact Statement (EIS) on the Regulating Works Project, the primary navigation maintenance project on MMR, was that significant side channel loss had resulted from efforts to concentrate flows and channelize the MMR to improve navigation. Furthermore, bank revetments have locked in geometry and prevent channel meandering, removing the natural mechanism for the formation of new side channels. As such, this habitat cannot be naturally regained. The further deterioration of side channels predicted in the 1976 EIS has not come to pass (USACE St. Louis District 2017), but improvement is desired. Beyond re-establishing a critical habitat type, ephemeral islands disrupt wavewash scour of banks and serve as a sacrificial sediment supply instead of bank material

2.2.1 Collaboration and partnering

The River Resources Action Team, a collaborative partnership between the USACE St. Louis District (MVS), the US Fish and Wildlife Service, Illinois Department of Natural Resources, and the Missouri Department of Conservation focused on the sustainable management of the Mississippi River, decided to attempt ephemeral island creation on the MMR using dredged sediment.

In attempting island creation, the MVS and their agency partners thought they could place material in the best environmental way possible given the dredging need. The dredge effort was funded by MVS' Biological Opinion Project, a restoration project initiated to offset environmental degradation associated with ongoing maintenance of the 9-ft navigation channel, and ongoing Operation and Maintenance (O&M) funding for dredging the navigation channel. The effort is summarized in MVS Fiscal Year 2013 Annual Progress Report for the Implementation of the Biological Opinion (USACE 2014).

2.2.2 Floating, flexible dredge pipe application

The MVS purchased approximately 800 m of floating, flexible dredge pipe in 2009 to facilitate dredged placement in the desired areas. Previously, the MVS relied on approximately 253 m of steel pipe that required connection in a straight line; the flexible pipe provided the length and flexibility to maneuver around shoals and river training structures. Initially, placement with the flexible pipe was infeasible due to required heights and difficulty staying on spot. This was resolved in September 2011 when a temporary spill barge was finished. Research conducted by Cox et al. (2011) into island size and stability based on existing islands within the MMR was used to inform placement design.

The right descending bank of River Mile (RM) 103.5 was selected for the first island creation attempt. This site was selected in close coordination with MVS' environmental partners because of dredging needs and compatible river training structures nearby. Approximately 76,500 m^3 (100,000 yd^3) of material was placed in November 2011 (Figures 1-3). The resulting island had an approximate top elevation of 107.29 m NGVD29, which is approximately 4.57 m above MVS' Low Water Reference Plane (LWRP) for that location. Based on the guidance from Cox et al. (2011), this put the island in the ephemeral island range (< +6.1 m LWRP) for the MMR. The resulting island was approximately 4 ha (10 acres) in size; for reference, the other islands on the MMR varied in size from 0.4 to 850 ha (1 to 2,100 acres) in the analysis. Pre- and post-construction surveys of the site were used to monitor the stability of the placed material. Monitoring in May 2012 revealed the island's top elevation had eroded approximately 3.05 m to 104.24 m NGVD29 since construction, likely due to three inundation cycles since placement (Figure 4). Evaluation of surveys showed that the placed material had completely eroded away within 2.5 years.

Figure 1. Island construction and observation timeline, showing approximate water surface elevation, estimated maximum sandbar elevation, and the Low Water Reference Plane set by the USACE MVS. (Adapted from USACE 2014)

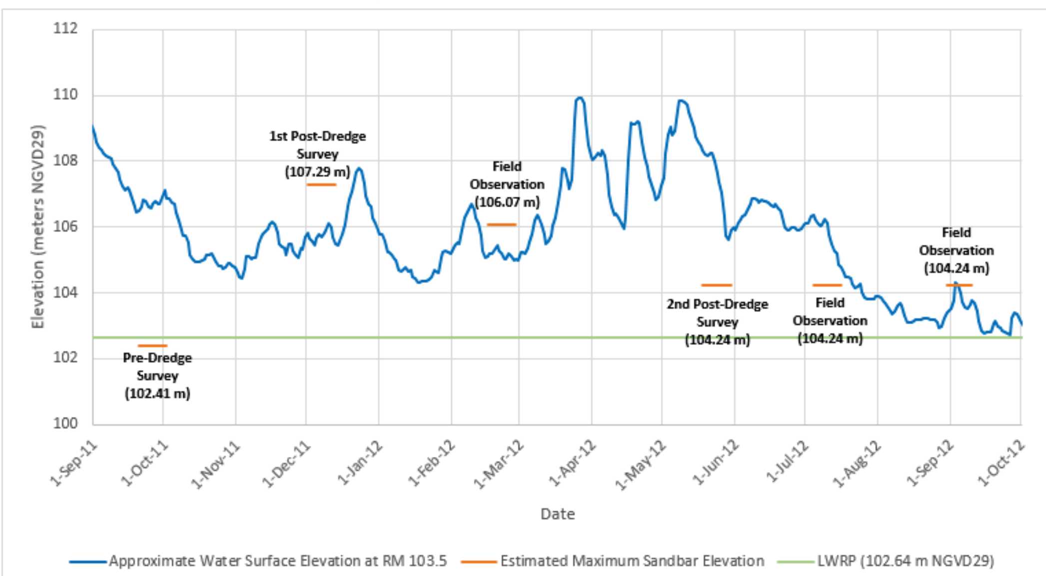
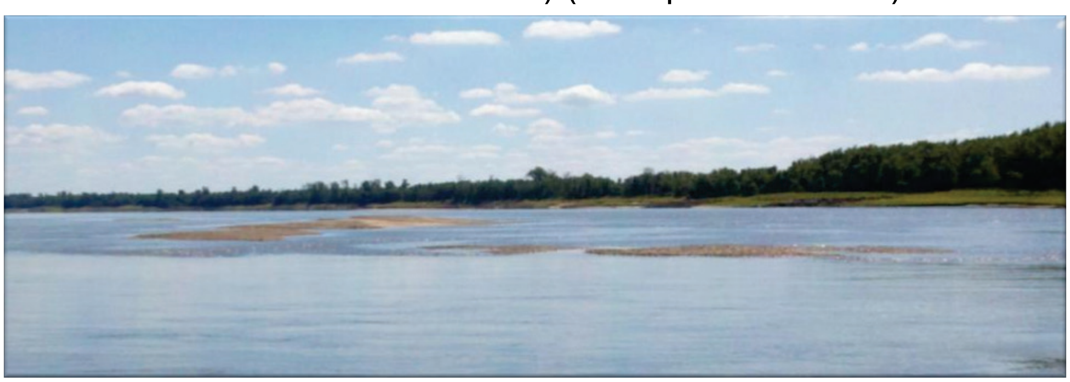


Figure 2. Island construction November 8, 2011 (river elevation ~ 105.16 m NGVD29) where approximately 76,5000 cubic meters of material was placed at River Mile (RM) 103.5 along the right descending bank. (USACE picture from 2011)

Figure 3. The island roughly one month after construction completion on December 7, 2011 (river elevation ~ 105.46 m NGVD29). (USACE picture from 2011)

Figure 4. The island after multiple overtopping events on September 10, 2012 (river elevation ~103.63 m NGVD29). (USACE picture from 2012)



2.2.3 Fish sampling

Fish sampling occurred after placement of the dredged material to determine if fish were making use of the new habitat. The site was sampled four times post-construction: 22 February 2012 (island exposed), 25 May

2012 (island submerged), 9 July 2012 (island submerged), and 10 September 2012 (island exposed) (USACE 2013). Trawl and electrofishing runs were performed on each side of the island. Between the four sampling efforts, 625 fish were collected comprising of 18 different species (Table 2).

Table 2. Species identified by sampling campaigns post-construction of the island by sampling type. (Adapted from USACE 2013)

Species	Scientific name	Trawling	Electrofishing
22 February 2012 Sample (sandbar exposed)			
Goldeye	*Hiodon alosoides*		2
Gizzard shad	*Dorosoma cepedianum*		3
Grass carp	*Ctenopharyngodon idella*		2
Silver chub	*Macrhybopsis storeriana*	3	
Emerald shiner	*Notropis atherinoides*		1
25 May 2012 Sample (sandbar submerged)			
Shovelnose sturgeon	*Scaphirhynchus platorynchus*	1	
9 July 2012 Sample (sandbar submerged)			
Goldeye	*Hiodon alosoides*	3	
Sturgeon chub	*Macrhybopsis gelida*	6	
Silver chub	*Macrhybopsis storeriana*	1	
Blue catfish	*Ictalurus furcatus*	3	
Channel catfish	*Ictalurus punctatus*	2	
10 September 2012 Sample (sandbar exposed)			
Longnose gar	*Lepisosteus osseus*		4
Shortnose gar	*Lepisosteus platostomus*		3
Gizzard shad	*Dorosoma cepedianum*		5
Shoal chub	*Macrhybopsis hyostoma*	9	
Emerald shiner	*Notropis atherinoides*	97	1
River shiner	*Notropis blennius*	1	
Channel shiner	*Notropis wickliffi*	446	
River carpsucker	*Carpiodes carpio*		5
Blue sucker	*Cycleptus elongatus*	1	4
Shorthead redhorse	*Moxostoma macrolepidotum*		1
Blue catfish	*Ictalurus furcatus*	1	
Channel catfish	*Ictalurus punctatus*	1	9
Freshwater drum	*Aplodinotus grunniens*		10

2.2.4 Additional applications

Additional beneficial dredged material placement efforts were attempted in September 2013. Three different placements were made: (1) ~ 76,500 m^3 (100,000 yd^3) was placed inside the chevron (a "U"-shaped, rubble rock river training structure open upstream) along the right bank at RM 103.7 (Figure 5), (2) ~ 230,000 m^3 (300,000 yd^3) was placed downstream of the chevron along the right bank at RM 103, and (3) ~ 86,000 m^3 (113,000 yd^3) was placed along the right bank at RM 100 at Liberty Island (USACE 2018). Placing the material inside the chevron allows it to better establish the downstream sandbar when the chevron is overtopped and may lead to the creation of a protected island under the right conditions. Post-construction surveys were conducted in May 2014 and May 2016. The May 2016 survey revealed the placed material in all three areas had fully eroded, leaving the sites back in their pre-placement conditions.

Figure 5. Filled chevron and downstream placement in visible in November 2013 Google Earth imagery. (from Google Earth Pro 2021)

The MVS had some success in utilizing the flexible dredge pipe for beneficial use of dredged material within the O&M dredging program, using the pipe for better material placement at dozens of sites. However, completing large new projects for ephemeral island creation has been a challenge for several reasons. The MMR within MVS has experienced multiple prolonged high-water events that have reduced dredging requirements. The MVS practices "just-in-time" dredging, which can make dredging more reactive than proactive; thus, there is often insufficient time to construct in-water placement designs at locations not a dredging priority for navigation. Lastly, the flexible dredge pipe has a longer setup time (due to increased time to connect lengths of pipe) and the flexible pipe cannot be used in icy weather. Potential sites where the flexible dredge pipe is preferred (including for future island creation efforts) continue to be identified, agreed upon, and put into a dredging master plan document. Operationally, a permanent spill barge was constructed for better control of the placement location of dredged material including the ability to build higher. Quick connections for the flexible dredge pipe have also been purchased to reduce pipe assembly time.

2.2.5 Project summary

The MVS continues to look for ways to improve the mobilization/ demobilization time of the flexible dredge pipe to increase pipe usage and beneficial sediment use. Island habitat remains a limited resource on the MMR, and island creation remains a high priority for the MVS and relevant resource agencies.

2.3 Case Study #2: Gravel Island creation on the Danube River, Austria

The main objectives of the river engineering measures on the Danube east of Vienna (Austria) are stabilization of the river bed and thus a prevention of continuous deepening of the river bed, improvement of shipping conditions, and increasing the ecological functionality of Donau-Auen National Park. These goals are to be achieved while also ensuring flood protection in the project area.

From February 2012 to July 2014, a pilot project was implemented at Bad Deutsch-Altenburg (Hainburg, Austria) (Viadonau 2016, 2020). Several river engineering measures were evaluated simultaneously, including coarsening of the Danube sediment, optimization of low water regulation, reconnection of a side branch, and bank dismantling. Part of these measures included the adaptation of the low water regulation of the Danube River (km 1886.9 - 1886.4) and creation of a gravel island in front of the left bank. The specific measures investigated were:

- removal of three orthogonal groynes (a.k.a. dikes);
- construction of two declining groynes (new);
- lowering of the new groynes to regulation low water (RNW) + 90 cm;
- complete removal of the groyne roots so the groynes are not connected to the banks of the Danube; and
- creation of a longitudinally stretched gravel island parallel to the Danube bank.

The measures in this area formed a back channel between the gravel island and the bank of the Danube (Figure 7). This channel is well connected to the main stem of the Danube and protected from waves caused by shipping, which makes the structure ecologically important. The measures were accompanied by scientific monitoring, which also included algae, macrozoobenthos, and fish.

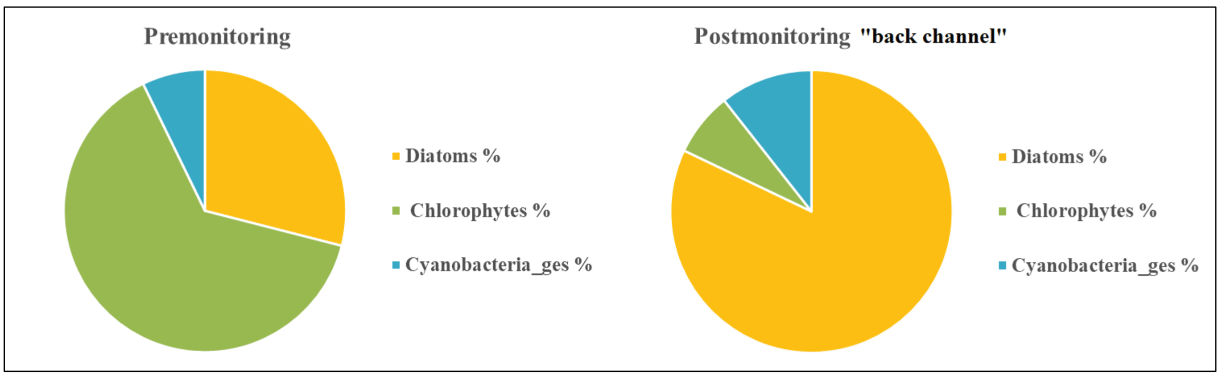
Figure 6. Bank area before (left) and one year after (right) the Pilot Project was completed at Bad Deutsch-Altenburg (Photo: Viadonau).

2.3.1 Algae

The development of pelagic and benthic algae biomass and species composition around the gravel island and the back channel was investigated by taking water and substrate samples several times in 2006 (pre-monitoring) and 2015 (post-monitoring). For the benthic algae, an area of 15 cm² was scraped off hard substrate with a scalpel, water samples were filtered, and the pelagic algae were collected on a filter. In addition to the fluorometric determination of the chlorophyll-a content (Steinmann et al. 2011), a pigment analysis was carried out to determine the species composition of algae.

Before low water regulation was optimized, the groyne fields tended to have silt deposits. Residual water areas or pools were created that were decoupled from the main stem, especially during low water conditions. The pelagic algae community was dominated by Chrysophyceae (golden algae), which are not typical for the main river of the Danube. During the adaptation of the bank areas and the creation of a gravel island, a permanent back channel was formed (Figure 7). The sedimented groyne field was eroded and the decoupled pools disappeared. As a result, the pelagic algae community changed dramatically. They are now dominated by Diatomeen (diatoms), which are characteristic of this type of river. Also, the benthic algae in the back channel developed from Chlorophyceae (green algae) dominated to a diatom-dominated community (Figure 8) which is typical of rivers in the region.

Figure 7. Average distribution (N = 10) of the benthic algae in the bank zone on the left bank at river km 1886.8 before (left picture) and after implementation of the measures (right picture) (@ WasserCluster Lunz/ research team Hein).



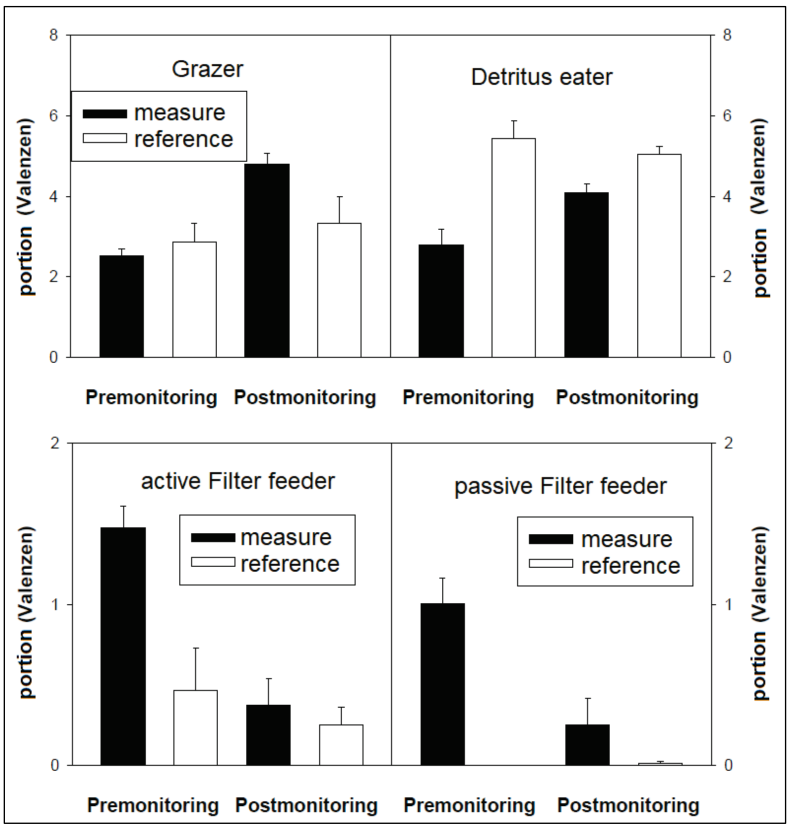
The diatoms declined and green algae increased again only during longer periods of low water. Restructuring of the bank zones to a back channel also led to a habitat well-connected to the main river of the Danube. The resulting higher algae biomass (compared to the main stem) would be available over a longer period as a food basis for the river's food web (e.g., insect larvae, snails, mussels, and fish).

2.3.2 Macrozoobenthos

The Macrozoobenthos survey was done by using a Hess sampler, which was buried approximately 10 cm into the substrate. The top 10 cm of the substrate was agitated, and the organisms were driven by the current into the net with the collecting container. Collected organisms were removed for further processing. Samples were taken around the pilot project as well as in an untouched reference section. Thus, it was possible to exclude supra-regional (project-independent) influences.

Comparison of the bank areas where the riprap was removed reveals a clear short-term effect from the measure (Figure 9). The community (composition of the taxa and feeding groups) of the gravelly bank areas in post-monitoring differs significantly from the community of riprap from pre-monitoring. A significant decrease of filter feeders (especially neozoa *Corophium curvispinum*) could be shown. Conversely, the proportion of Oligochaeta increased, which increased the detritus eaters in total. The grazers also showed a significant increase on the gravel bank.

Figure 8. Portion of grazers, detritus eaters, and passive and active filter feeders for pre- and post-monitoring in the area of measures and reference (gravel bank versus riprap) (@ WasserCluster Lunz/ research team Hein).



After the removal of the riprap, the composition of Macrozoobenthos species corresponded to comparable banks with natural substrate.

2.3.3 Fish

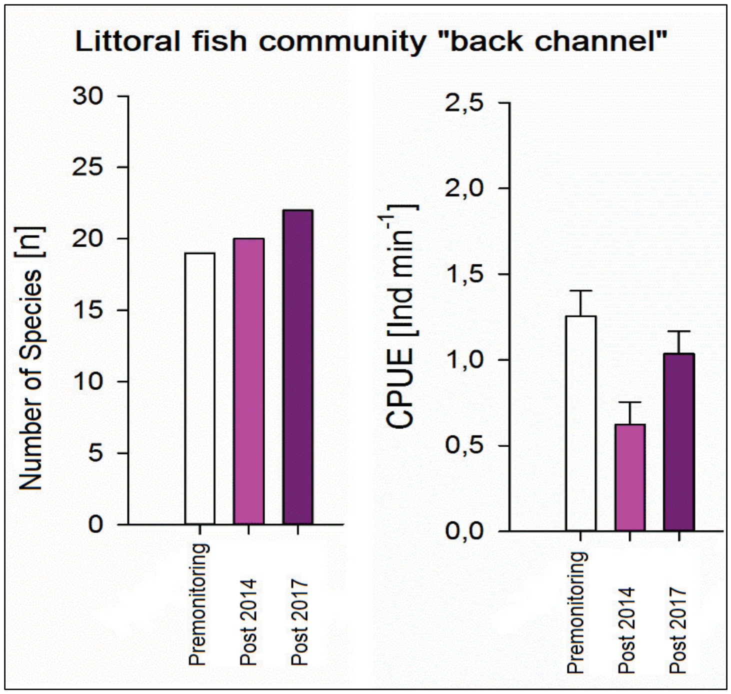
The development of the fish coenosis in the back channel should be seen against the background of the overall development of the Danube. On the Danube east of Vienna, a significant decline in fish biomass has been observed in recent years. Of course, this also influences the development of the Pilot Project Bad Deutsch-Altenburg (Tögel and Baumgartner 2016).

To investigate the back channel, the littoral fish community (electro-fishing by anode) and the sublittoral fish community (electro-fishing by boat) were sampled. There was a preliminary examination in 2006 (pre-monitoring) and two follow-up examinations in 2014 and 2017.

2.3.3.1 Littoral fish community

In the back channel behind the new gravel island, increases in the mean and total numbers of species in the littoral fish community were recorded and compared to pre-monitoring. The abundance, however, decreased slightly (Figure 10). The largest decline was the populations of Bleak (*Alburnus alburnus*), Ide (*Leuciscus idus*), Round Goby (*Neogobius melanostomus*), Bighead Goby (*Neogobius kessleri*), and Vimba Bream (*Vimba vimba*). The decline in Neogobius species should, however, be positive, as these are non-native fish species (neozoa) in the Danube. There was a significant increase in Dace (*Leuciscus leuciscus*), Whitefin Gudgeons (*Gobio albipinnatus*), White Bream (*Abramis bjoerkna*), and Asp (*Aspius aspius*), which are rheophilic fish species typical to the Danube. In total, the relative share of the rheophile and eurytopic fish guild rose at the expense of the neozoa. A fish community more typical to the Danube emerged.

Figure 6. Comparison of the total number and abundance of littoral fish species (measured as catch per unit effort [CPUE]) in the back channel (pre-monitoring 2006, follow-up examinations 2014 and 2017) (@ Universität Wien/ research team Keckeis).



2.3.3.2 Sublittoral fish community

For the sublittoral fish community, the number of species decreased in the back channel compared to the preliminary examination. However, the abundance increased slightly (Figure 11). Some species such as Barbel (*Barbus barbus*), Asp (*Aspius aspius*), Nase (*Chondrostoma nasus*; Figure 12), Bream (*Abramis brama*), and Bleak (*Alburnus alburnus*) could be found in significantly higher abundances. These are rheophilic fish species, which are typical to the Danube east of Vienna. Rheophilic and eurytopic species increased in absolute numbers.

Figure 10. Comparison of the total number and abundance of sublittoral species (measured as catch per unit effort [CPUE]) in the back channel (pre-monitoring 2006, follow-up examinations 2014 and 2017) (@ Universität Wien/ research team Keckeis).

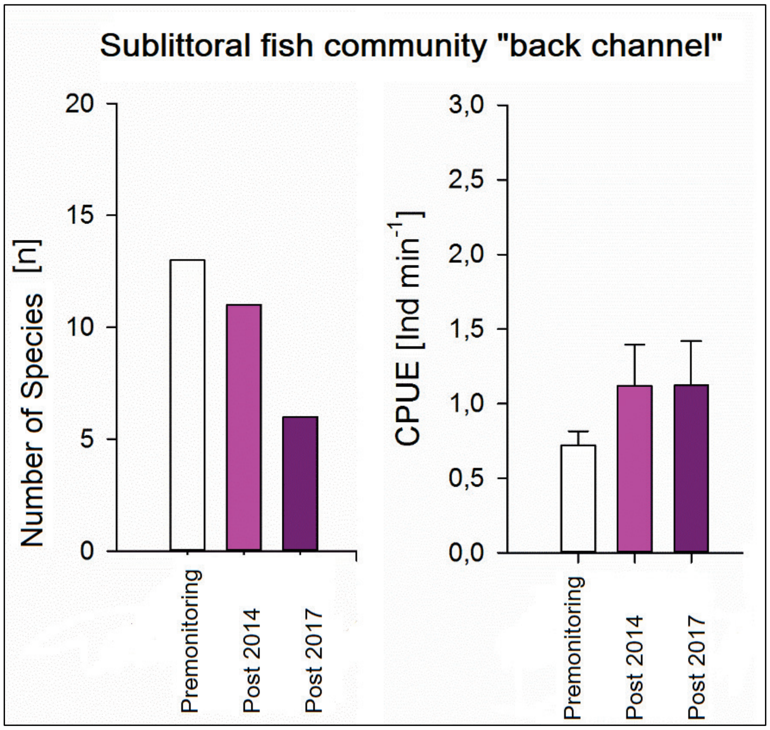


Figure 11. The Nase (*Chondrostoma nasus*) is a rheophilic native species in the Austrian Danube (Photo: Clemens Ratschan).

2.3.4 Project summary

The measures taken in the Danube River (km 1886.9 to 1886.4) with the adaptation of the low water regulation (removal of three orthogonal groynes, construction of two declining groynes (new), lowering of groynes, removal of groyne roots, deposition of a gravel island and thus creation of a back channel) resulted in numerous ecological advantages, which are listed below.

- The deposition of a longitudinally stretched gravel island and simultaneous lowering of the groyne roots resulted in a well-connected back channel parallel to the main stem of the Danube.
- The gravel island protects the back channel from waves caused by shipping. Thus, the back channel can serve as habitat for rheophilic aquatic species.
- Regarding algae, a river-typical diatom community developed in the back channel.
- The total biomass of the algae is higher in the back channel than in the main river, but well connected with it; thus, it can serve as a food base for the entire aquatic fauna of the Danube.
- The macrozoobenthos colonization changed in the areas where the riprap was removed and replaced by a natural gravel bank. Here, the density of the filtering neozoa species *Corophium curvispinum* decreased and the proportion of oligochaetes (detritus eaters) and grazers increased significantly. The macrozoobenthos community is now similar to that of natural banks.
- Due to the permanent connection of the back channel to the main river of the Danube, the macrozoobenthos can serve year-round as a food base for the Danube's ecosystem.
- The littoral fish community in the back channel came closer to a species community more typical to the Danube. The relative proportion of the rheophile and eurytopic fish guild rose sharply, while non-native fish declined.
- In the sublittoral fish community, the number of species decreased in the back channel, which is due mainly to a decline in eurytopic species. The abundance, however, increased. Rheophilic native species such as Barbel (*Barbus barbus*), Asp (*Aspius aspius*), Nase (*Chondrostoma nasus*), Bream (*Abramis brama*), and Bleak (*Alburnus alburnus*) were found in significantly higher abundances.

- The newly created gravel island can also serve as a breeding area for gravel breeders such as sandpiper (*Actitis hypoleucos*) or little ringed plover (*Charadrius dubius*).

To achieve a "dynamic state of equilibrium" in the project area, a slight adaptation of the groynes was necessary in winter 2016/2017. Since then, it has been possible to achieve the described ecological advantages without impairing low water regulation of the Danube. At the same time, the reduction in the number of groynes and the height of the groynes resulted in a widening effect that relieved the Danube floor. To date, the tendency of the Danube river bed to deepen has been stopped in this area. The “Lessons Identified” of this pilot project have already flowed into similar hydraulic engineering projects.

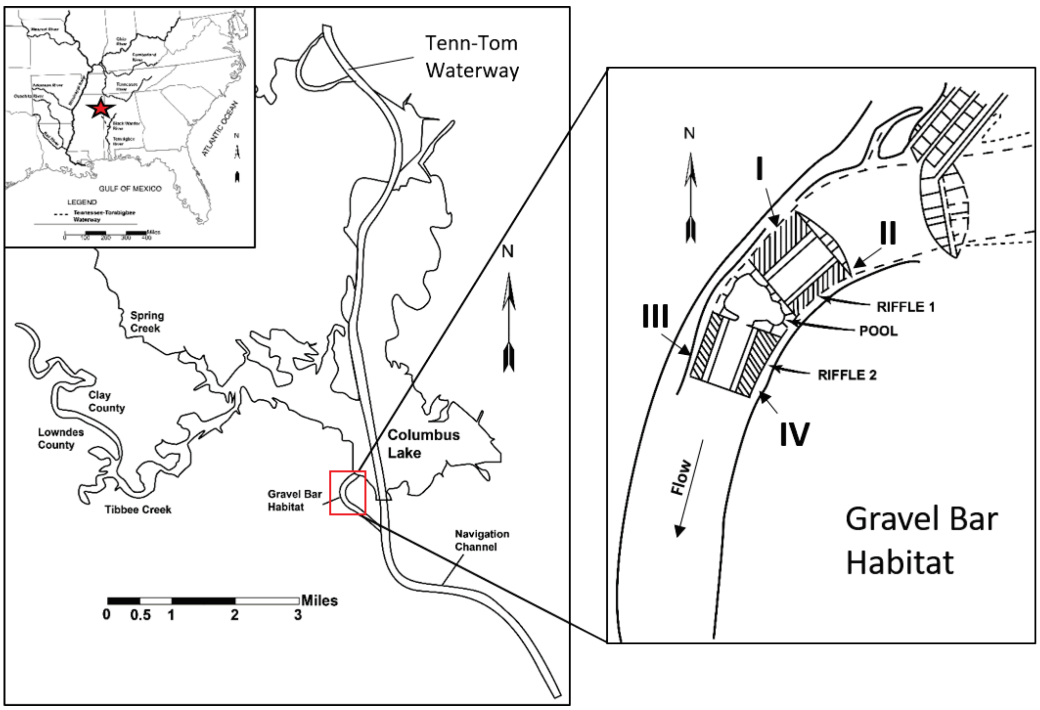
Figure 7. Optimized groyne field Pilot Project Bad Deutsch- Altenburg, upstream (Photo: Viadonau/Zinner).

Figure 13. Optimized groyne field Pilot Project Bad Deutsch- Altenburg, downstream (Photo: Viadonau/Zinner).

2.4 Case Study #3: Gravel bar habitat in the Tombigbee River, Mississippi

This case study provides an example of how nature-based features derived from dredged material placement can be used to create riffle and pool features along a river bank line to create a gravel bottom habitat for a variety of aquatic species. The historic project was initiated >30 years ago, offering a unique opportunity to highlight changes observed in habitats, which can take decades for some species (e.g., freshwater mussels) to become established. Habitat in the Tombigbee River (Tennessee, USA) is known for supporting diverse aquatic species (minnows, darters, snails, oligochaetes, and aquatic insects), some of which are listed as threatened or endangered in the states of Mississippi and Alabama (e.g., inflated heelsplitter mussel [*Potamilus inflatus*]; crystal darter [*Crystallaria asprella*]) (MMNS 2014). Swift currents and gravel substrates are considered essential habitats for many of these species (e.g., fish and mollusks; Miller et al. 1983). Yet, riffle pool habitat in the Tombigbee River has been extensively altered due to the lock and dam infrastructure modifications to the riverine waterway supporting navigation connectivity. From these modifications, navigation is possible from the Tennessee River to the Tombigbee River (Tenn-Tom Waterway) that flows from north Tennessee to the Gulf of Mexico (McClure et al. 1985; Okeef et al. 2007; Figure 15). Therefore, habitat improvement efforts were undertaken in the Tenn-Tom to provide increased habitat quality through creation of riffle-pool habitat types using dredged sediments and gravel substrate (Miller et al. 1983; Miller 2006).

Figure 14. Gravel bar habitat location on the Tombigbee River, Mississippi USA and schematic cross section of the gravel bar design. Roman numerals in the right image denote the locations of the four gravel bar features constructed for this project. Figure adapted from Miller et al. (2006).



The creation of a riffle-pool structure on the Tombigbee River (RM 232.9) was completed in 1985 directly below the minimum-flow release structure in the John C. Stennis Lock and Dam (formally Columbus Dam). The design was informed by an existing gravel bar in the Buttahatchie River and extensive chemical, physical, and biological investigations of the Tombigbee River (Miller et al. 1988). The design goal was to support habitat requirements of aquatic species though intentional alignment of water depths, velocity, and substrate types (Table 3). Dredged sediments (primarily sand) from the Tenn-Tom were used to fill the upper end of the channel to target elevations, then capped with 2- to 80-mm coarse gravel substrate sourced locally from an upland site and barged to the location (Miller et al. 2006). Since the gravel bar completion in March 1985, several investigations have observed the subsequent habitation of freshwater fish, mussels, snails, worms, and aquatic insects on the structures (Miller et al. 1988; Bingham and Miller 1989; Miller 2006).

Table 3. Riffle-pool design characteristics and targeted species habitat suitability type (as defined in Miller et al. 1983).

Parameter	Bar I	Bar II	Bar III	Bar IV	Pools
Design Characteristics					
length, m	46	46	46	46	30
width, m	53	53	53	53	30
channel width, m	18	18	23	35	-
channel depth, m	0.45-1.18	0.45-1.18	0.45-0.88	0.45-0.88	-
Substrate composition					
gravel diameter, cm (%)	2.5-12.7 (80)	2.5-7.6 (60)	2.5-7.6 (40)	2.5-7.6 (20)	a
sand (%)	20	40	60	80	a
Water velocity, m/s	0.45	0.45	0.45	0.3	<1
Target Species Suitability					
Molluscs					
large, thick-shelled molluscs	X				
smaller mussels		X		X	
thick-shelled bivalves			X		
preferred mussel habitat[b]				X	
thin-shelled mussels					X
Non-molluscan macroinvertebrates					
mayflies	X	X	X	X	X
trichoptera	X	X	X	X	
beetles	X	X	X	X	
dipterans	X	X	X	X	X
dragonfly	X	X	X	X	
oligochaetes					X
amphipods					X
isopods					X

[a]pool areas designed to gradually fill with fines

[b]as defined by Kaskie (1971); (e.g., *Ligumia recta*, *Lampsilis anodontoides*)

2.4.1 Freshwater mussels

Due to the time-scale necessary for mussels to become established in newly created habitats (decades), the first intensive mussel survey in the gravel bars was conducted 16 yr after construction (August 2001) (Miller 2006). Results from this survey indicated that 13 different species of mussels were present in the gravel beds at a density of 0.18 live mussels/m^2 (Miller 2006). Of the 390 total mussels collected from the sampling effort, the dominant species were *Obliquaria reflexa* (n=217) and *Plectomerus dombeyanus* (n=129), which are both native to the region (Miller 2006).

Although comparable densities of mussels in rivers in the US can range from 50-100 individuals/m^2 (Payne and Miller 2001), these data indicate a positive trend in mussels colonizing the habitat features.

2.4.2 Macroinvertebrates

Miller et al. (1986) observed rapid colonization (< 4 months) of macro invertebrates in the gravel bars, with the Riffle 1 (bars I, II) and Riffle 2 (bars III, IV) having 19 and 21 taxa, respectively. The dominant assemblage based on biomass in the first year was in the family Chironomidae (*Glyptotendipes* sp.), which comprised more than 90 percent of the assemblage, and shifted to a larger biomass of bivalves within two years (Miller et al. 1988; Miller 2006). Additionally, abundant oligochaete diversity was observed in the gravel bars between 1985-1987, with 28 species of oligochaetes identified in the families Naididae and Tubificidae (Bingham and Miller 1989). Mean macroinvertebrate density continued to improve in the gravel bars each year following construction, with an increase from 10,000 to 45,000 individuals/m^2 from 1985 to 1988, respectively (Miller 2006).

2.4.3 Fish

Fish density in the gravel bar features more than doubled in the years following construction, from 1,150 to 2,893 fish/ha in 1985 and 1986, respectively (Miller et al. 1988). Fish diversity was also high within the riffle-pool habitat within the first two years after construction, with 39 different species of fish observed in the gravel bars and 25 different species observed in the river directly adjacent to the structures. Dominant fish species included native shad (*Doromosa cepedianum*; *D. petenenpe*), blue gill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), bullhead minnow (*Pimephales vigilax*), white crappie (*Pomoxis annularis*), and orange-spotted sunfish (*Lepomis humilis*) (Miller et al. 1988). Interestingly, two uncommon species of fish were also observed including the crystal darter (*Ammocrypta asprella*), a species listed as endangered by the state of Mississippi, and the native blue sucker (*Cycleptus elongatus*) which is considered uncommon in the Tombigbee River (Miller et al. 1988). Within two years of construction, the gravel bars supported a significantly higher fish species richness as compared to a nearby rip-rapped flume and downstream of the river channel (Miller 2006).

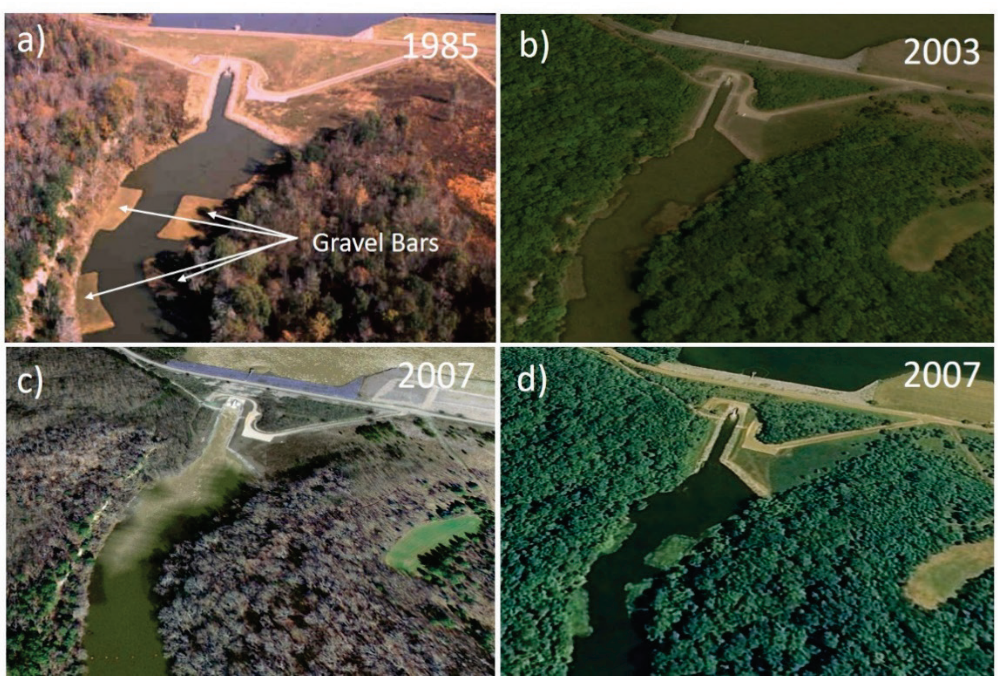
2.4.4 Project summary

Key observations of the riffle-pool habitat creation identified by Miller et al. (1988) through the lens of EWN are listed below.

- Consideration should be given to enriching fine-grained riverine sediments with larger particles (i.e., riprap, cobble, gravel) to support more diverse benthic species.
- Colonization of non-molluscan macroinvertebrates occurred rapidly following construction (within months).
- Nature-based gravel bottom features in riverine systems can support invertebrates as a food source for fish and higher organisms soon after construction.

The Tombigbee River project is a good example of how near-bank placement of navigation dredged sediment can support river bank stabilization and habitat. The project features have retained their intended function over time (Figure 16) and are a demonstration of how environmental benefits can be achieved from forward thinking and planning to maximize the success of placing dredged sediment near river banks.

Figure 15. Gravel bar habitat in the Tombigbee River: a) 1985, immediately after construction (image sourced from Miller et al. 2006); b) 2003; c) 2007 during high water; d) 2007 during low water. Source: 33°31'20.97"N 88°29'55.72"W. Google Earth.



2.5 Case study #4: Donlon Island, Sacramento-San Joaquin River Delta, California

This case study provides an example of how dredged material from a federal navigation channel was placed in an adjacent open water area to restore wildlife and fisheries habitats. This study was typical in that original native habitats adjacent to a federal navigation channel had historically been replaced by agricultural production made possible by constructing islands bordered by levees. The resultant landscape was defined by steep-banked waterways with little shallow water; thus, vegetation was limited to narrow bands along levee edges, unless further displaced by hardened bank protection structures.

Donlon Island is a 95-ha (230 ac) island in the Sacramento–San Joaquin Delta (delta), located in extreme southwestern Sacramento County at RM 7 on the San Joaquin River. It is one of several sites in the delta that were historically breached to reclaim areas previously used for agriculture by the construction of levees. Levees built at Donlon in 1910-1920 (and also perhaps earlier in 1870-1880) to create the agricultural land were breached in 1937 to help restore the historical delta wetlands in the area (Simenstad et al. 2000). To help facilitate the restoration of Donlon Island, nine dredged material islands were built in 1985 as part of a USACE Sacramento District restoration project that beneficially used dredged sediment from the adjacent Stockton Deep Water Ship channel.

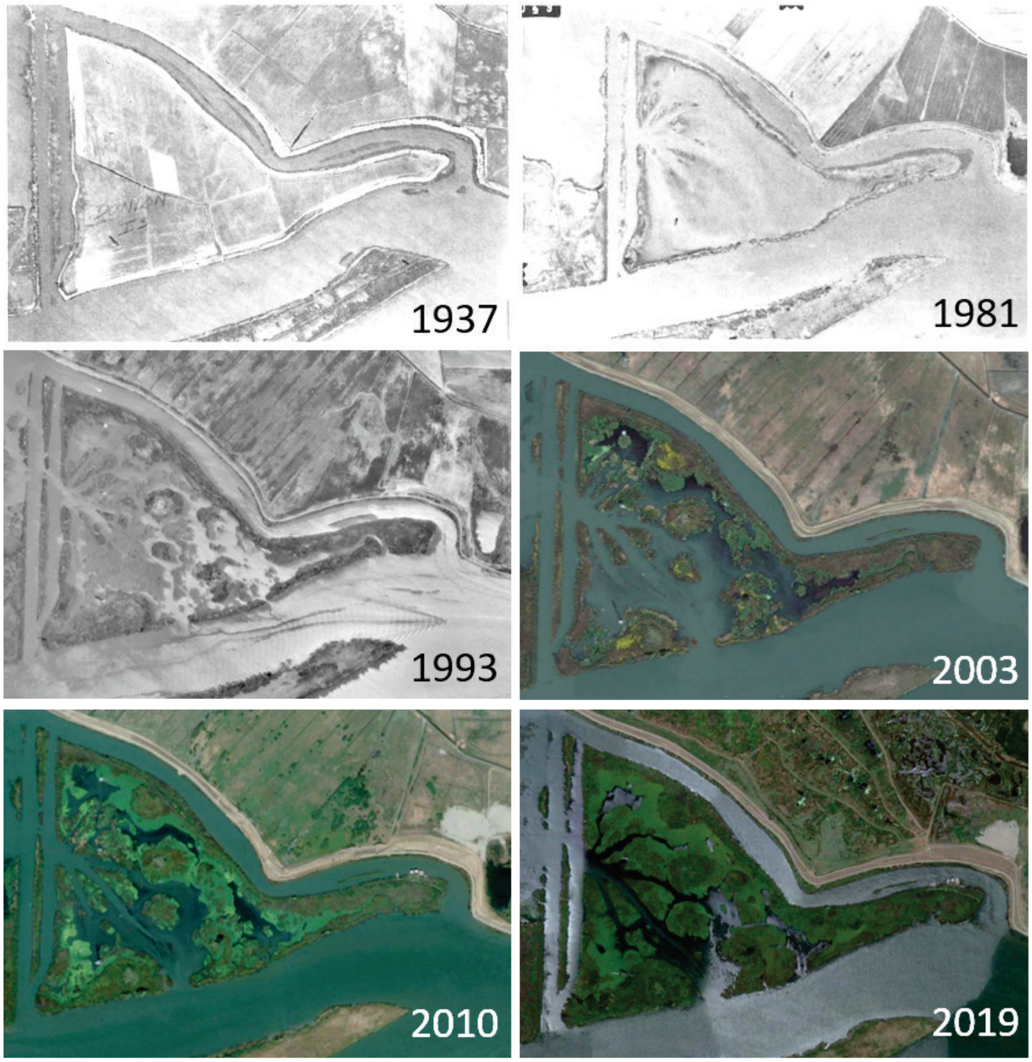
Dredged material (400,000 m^3 [525,000 yd^3]; England et al. 1990) was placed in a manner that would convert the open water portions of the island to a combination of marshland, open water, and upland features that would enhance habitat for a wide variety of wildlife (Figures 17 and 18). The nine islands created ranged from 0.7 to 5.3 ha in size, and totaled 32.3 ha overall (England et al. 1988, 1989). The balance of Section 2.5 provides information on the successes and lessons learned from that restoration effort.

Figure 16. Aerial image of Donlon Island immediately after placement in 1985 to create nine dredged material islands (from England et al. 1990).

2.5.1 Habitat types and vegetation

Donlon Island is bounded on all three sides by an old levee (Figure 18) that had been breached in several locations. Prior to the beneficial use placement in 1985, the interior of the island was primarily open water with small, scattered islands of bulrush (*Scirpus* sp.), remnants of the original natural tule marsh (England et al. 1988). The authors noted that the tules often occurred between mean water level and 0.4 m (1.5 ft) above mean water level.

Figure 17. Satellite image time series of Donlon Island from 1937 to 2019. The dredged material was placed on the island in 1985 (see also Figure 17). Source: 38°1'55.28"N 121°46'43.18"W. Google Earth.



In a study performed during 1997–99, Simenstad et al. (2000) evaluated the patterns and rates driving development of the tule marsh, as it is the predominant historical native habitat type targeted by wetland restoration initiatives in the delta. (Tule is the common name for two species of native bulrushes [including *Scirpus californicus*] that grow in shallow water of marshes, muddy shores, and lakes that are indigenous to the area.)

The dredged sediment placed at Donlon Island showed no meaningful elevation change (from March 1998 to June 1999) while there was over 30 mm of accretion measured at the surface. Simenstad et al. (2000) noted that while sediment is accumulating, there were processes below the surface counterbalancing the accretion, thereby maintaining a relatively constant elevation.

The results from Simenstad et al. (2000) at Donlon Island indicated that raising bed elevations via beneficial use placement accelerated vegetation establishment. Native tule marsh vegetation was observed to rapidly colonize bare soil at emerging intertidal elevations but submerged and floating aquatic vegetation, including introduced species such as water hyacinth (*Eichhornia crassipes*) and *Egeria densa*, dominated subtidal habitats.

By 1987, multiple plant species had rapidly colonized the bare ground created by the placement of dredged material at Donlon Island (England et al. 1988, 1989). One of the most desirable groups of species that established were native riparian shrubs and trees. Several tree species established were thought to eventually lead to the development of rings of willow (*Salix* sp.), white alder (*Alnus rhombifolia*), and Fremont cottonwood (*Populus fremontii*) riparian vegetation around all but the very lowest islands. These thickets were observed where surface elevations were between 0.4 and 0.9 m (1.5 and 3.0 ft) above mean water level. The successful colonization of these species precluded the need for a separate mitigation effort to plant this vegetation type. Several noxious plant species were also established, including the giant reed (*Arundo donax*) and cocklebur (*Xanthium canadense*). Overall, valuable wildlife habitat had been created in areas where only open water previously existed, as evidenced by the birds and fish that were observed utilizing the habitat as discussed below.

2.5.2 Avifauna

England et al. (1988) investigated bird use of the newly created habitat on and adjacent to the nine recently constructed islands at Donlon Island to quantify wildlife utilization. Bird surveys were conducted from April to June 1987 to document use by breeding species, late winter residents, and spring migrants. Total species observed during a given survey ranged from 16 to 32. The number of bird species observed increased with island size, height above mean water level, and vegetation complexity. A total of 44 species were observed across all surveys conducted.

Survey observations revealed that birds primarily used the nine islands for roosting and foraging; roughly 85–95% of all the birds observed were classified as such. Mudflats were the primary habitat used, with 63 to 98% of all bird observations utilizing this habitat type. The dominant species observed on all islands were gulls (e.g., Ring-billed Gull [*Larus delawarensis*]), terns (e.g., Caspian Tern [*Hydroprogne caspia*]), shorebirds (e.g., Western Sandpiper [*Calidris mauri*]), American coots (*Fulica americana*), and ducks (e.g., mallard [*Anas platyrhynchos*]); the roosting and foraging behavior was observed primarily at the water's edge. Various swallows were also observed foraging over the island.

Over a 3-yr study period conducted after the dredged material islands were created, the number of bird species breeding on the island was determined to be highly correlated (r^2=0.90) with the total acreage of vegetation present, a function of island size (England et al. 1990). Overall, as vegetation increased, the number of breeding birds increased. The correlation between hectares of vegetation and the number of breeding bird species was thought to result from the correlation between island height, shape, and size. Since large, dome-shaped islands have greater surface area within moderate tidal ranges, and greater topographic relief than small dome-shaped islands, this leads to the development of more habitat types and greater vegetative cover to serve as bird habitat. An exception to this rule would be a large, flat island with a crown elevation at approximately mean water level. Such an island would develop into a stand of primarily tule vegetation and, although large, could support fewer types of breeding birds compared with similar sized island with higher topographic relief and habitat diversity (England et al. 1990). It was expected that the avifauna would change considerably as habitat establishment and development continued in the future. This information can be useful when designing future islands with the goal of creating habitat value.

Little information was found after the 1987-1989 monitoring studies by England et al. (1990) had concluded. A notable exception was the 2007 report funded by the California Department of Fish and Game reporting a breeding colony of the double-crested cormorant (*Phalacrocorax auritas*) at Donlon Island (EDAW 2007). Because of the proximity of Donlon Island to the adjacent Lower Sherman Island Wildlife Area (LSIWA) and the similarity of habitats at Donlon Island and the wildlife area, species observed at Donlon Island were considered likely to be present at the LSIWA as well. It was recommended that Donlon Island area be included in the LSIWA for this reason.

2.5.3 Fish

The local fishery was sampled to determine the fish utilizing the island post-restoration (England et al. 1988). The results from the sampling effort indicated the shallow water interior of Donlon Island was utilized by species of small, presumably resident fish such as tule perch (*Hysterocarpus traski*), starry flounder (*Platichthys stellatus*), and Mississippi silversides (*Menidia beryllina*) and by juvenile anadromous fish such as striped bass (*Morone saxatilis*). The tule perch, starry flounder, and striped bass are California natives. The presence of small resident and juvenile anadromous fish suggested the area may be used as a nursery or holdover. Based on the species and life stages observed, the shallow, slow-moving waters created by the placement of the dredged material islands were considered to provide protection from large predatory fish moving in the deeper channels, an abundance of food including tidally inundated herbaceous plants, and a resting area away from swift, deep-water channels.

In a review of three years of sampling data for fish caught at Donlon Island, a notable increase in the number of fish caught were observed (England et al. 1990). As the cover, foraging, and reproductive habitats had developed, fish utilization concomitantly increased. These data indicated fishery resources at Donlon Island had improved since dredged material placement in 1985, suggesting productive fishery habitat was created. Such protected and productive habitat was considered conducive for benthic algae and phytoplankton growth due to the increased availability of sunlight on submerged substrates. The abundant algae, phytoplankton, zooplankton, macroinvertebrates, plant material, and detritus observed by the authors were considered key factors for supporting the wide variety of fish species observed.

While not comprehensive, these studies support the conclusion that valuable fish habitat developed, and the placement of the dredged material combined with the subsequent development of the habitat formed had substantially improved the fisheries resource.

2.5.4 Guidelines for future restoration efforts

England et al. (1990) made some key observations for guiding future beneficial use projects based on lessons learned from the three years of monitoring at Donlon Island post-placement. The authors noted that elevation, size, shape, and slope of the placed dredged material, along with soil type, can be designed in ways that can influence wildlife habitat that will develop.

The habitats developed on Donlon Island were also strongly associated with elevation relative to mean water level. A slight change in elevation can alter the habitat type that develops along with its associated biota. In the California delta region, these patterns are influenced by tidal fluctuations: the relatively xeric higher elevations are subject to little or no tidal fluctuation, whereas the lower elevations are mesic to aquatic depending on extent of inundation. Therefore, differences in the time an area is submerged played a key role in determining the vegetative communities and associated biota that colonized the area.

2.5.5 Project summary

Key findings from the studies investigating the wildlife and fishery habitats created at Donlon Island were:

- New tule marsh and riparian vegetation had established through natural colonization and considerable habitat development had occurred during the first 3-5 years after placement of dredged material.
- The newly created islands were being used by a wide variety of birds and fish. The number of bird species generally increased proportionally with the extent and complexity of the habitats available on the nine islands created.
- Elevation, size, shape, and slope of the dredged material placed along with the soil type are design parameters that can be used to aid the development of the desired wildlife habitat (e.g., marsh, shallow water, riparian, upland, etc.).

The Donlon Island project is a good example of how near-bank placement of dredged sediment from an adjacent federal navigation channel can support habitat restoration efforts. This historical project from the mid-1980’s has overall maintained its intended function.

The presence of non-native aquatic plant species indicates mitigation efforts ensuring growth of native plants may be needed to increase habitat value. In addition, designing the sediment placements to meet specific habitat restoration objectives up front should be pursued so project success can be more easily tracked and quantified. The presence of a breeding colony of the double-crested cormorant (*P. auritas*) and subsequent recommendation that the island be included in the adjacent Wildlife Area indicate the ongoing success of the project.

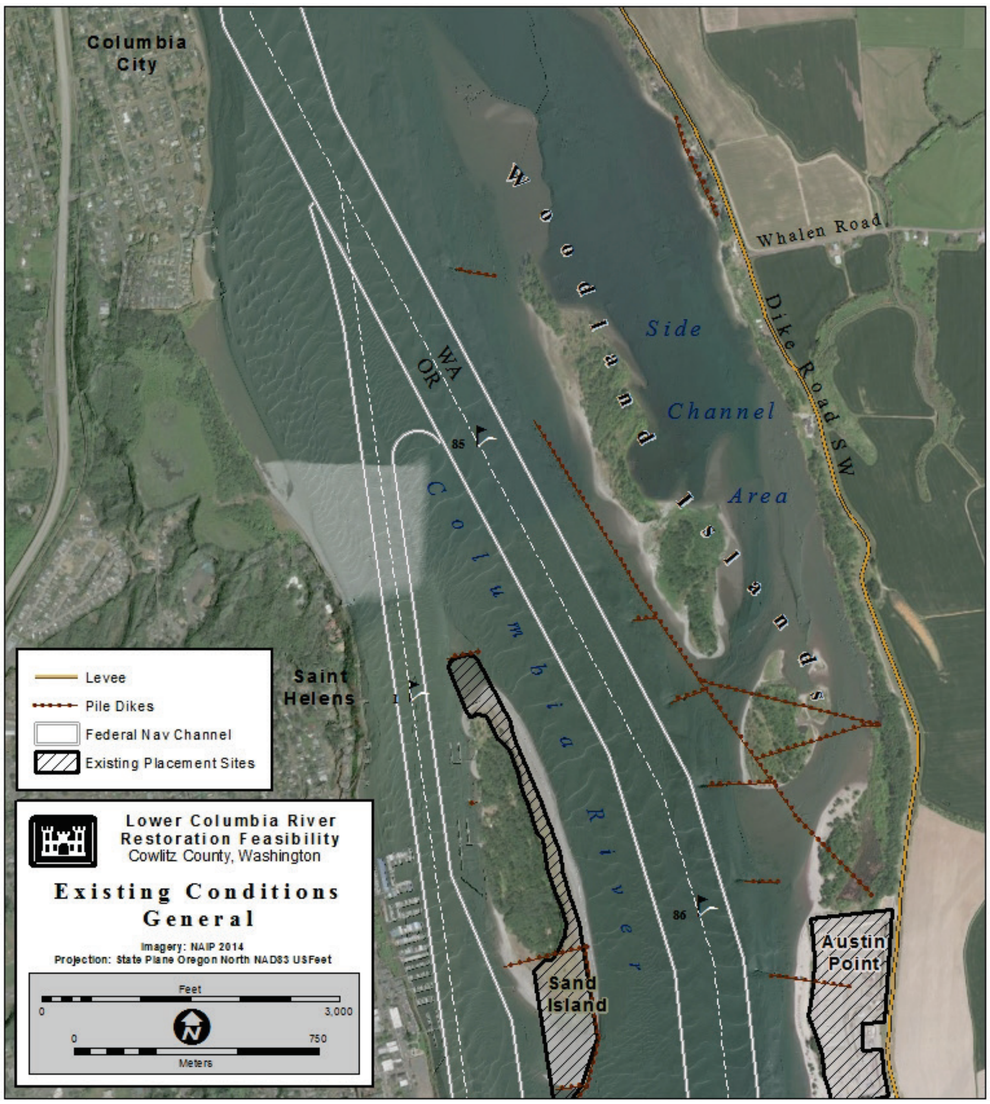
2.6 Case study #5: Woodland Islands, Lower Columbia River Estuary

The Lower Columbia River (LCR) has been modified by numerous human activities over the past 150 years. Diking, dredging, and the construction of river training structures, along with dam operations, upriver diversions, and channel deepening, have affected the hydrologic and geomorphic processes that sustain the river ecosystem, resulting in the loss of as much as 70% of wetland habitats in the region (Fresh et al. 2005). This loss is meaningful, as the LCR provides habitat for a variety of anadromous and resident fish species. Research has shown the importance of these habitats along the lower river to support juvenile salmon, and the lack of such habitat along the river corridor as limiting salmon population recovery (Bottom et al. 2011; USACE Portland District 2020).

One means of restoring wetland and floodplain habitat in the LCR is through the beneficial use of sediment dredged from the adjacent federal navigation channel (FNC). This objective can be achieved by placing the dredged sediment such that semi-stable landforms remain in place sufficiently for plant communities to establish and intertidal habitats to form. When placed in a manner that optimizes self-sustaining natural processes, dredged sediment provides opportunities to create or enhance habitat with similar morphology to naturally formed wetlands and floodplains. Existing pile dikes can be retained to help stabilize the recently placed sediment and to encourage colonization of vegetation and subsequent formation of the desired above- and below-water habitats (Borde et al. 2011).

The Woodland Islands site is a good candidate for sediment placement because it consists of several small islands and a sheltered side channel area located between the FNC and the Washington side of the Columbia River shore from RM 86 to 84.5 near St. Helens, Oregon (Figure 19). In its current state, the string of small islands is situated near a pile dike network constructed in 1885 and are what remains of a larger island complex created by previous placement activities from the FNC at St. Helens Bar. What makes it a strong candidate to be restored through sediment beneficial use is the combination of favorable hydraulic conditions, opportunities for natural process to shape the desired habitats, logistical considerations, low likelihood of causing inadvertent impacts to the FNC, and the relatively large area available for project implementation. While degraded over time, the existing island complex offered a variety of habitat types including some low velocity, shallow water habitat in sheltered embayments located on the back side of the islands within the side channel area. Yet, the extent and complexity of the habitat within the greater side channel area remained limited (USACE Portland District 2020).

Figure 18. Aerial image pre-construction of the Woodland Islands complex near River Mile 86 on the Lower Columbia River at St. Helens, OR (from USACE 2020).



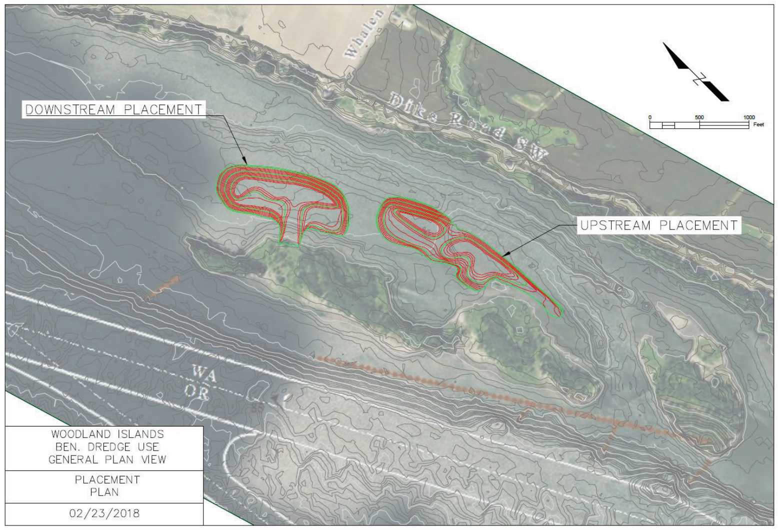
The stated purpose of the project was to beneficially use dredged sediment during routine maintenance of the FNC to restore and expand shallow water and riparian habitat for fish and wildlife species in accordance with Section 204 of WRDA 1992, as amended. The objective of the project was to restore shallow water and wetland habitats to help rebuild the Columbia River salmon species populations that are federally listed as threatened or endangered. The design and placement of the dredged sediment would also be expected to support waterfowl, shorebirds, neotropical migratory songbirds, native mammals, reptiles, amphibians, and non-listed aquatic species (USACE Portland District 2020).

2.6.1 Project description

This project involved placing dredged material on the back side of the existing middle Woodland Island complex to create low velocity shallow water and riparian shrub habitat. Planned project activities included placement of up to 306,000 m^3 (400,000 yd^3) of sediment dredged from the adjacent FNC. The final placement volume of 153,000 m^3 (200,000 yd^3), performed by the Port of Portland's hydraulic cutterhead dredge Oregon using a 30-in.-dia pipeline, was based on the availability of sediment during dredging and influenced the acreage of habitat created. Grading was performed to increase topographic complexity, promote habitat value and functionality, and encourage sediment stability. The first phase involved the placement and grading of dredged material, which was completed on 10 October 2020.

As part of the next phase, native willow stakes and other native species will be planted to create an even distribution of willow shrubs across the range of elevations (3 to 4.3 m; 10 to 14 ft NAVD88) to provide scrub-shrub habitat, help prevent invasive species establishment, and help stabilize the placed sediment. The created habitat will increase the aerial extent of, and is compatible with, the existing shallow water and wetland habitats on the back side of the island that is adjacent to the shoreline (Figure 20). The second phase will occur in two stages in winter 2021-22 and winter 2022-23 and will entail planting of native vegetation.

Figure 19. Planned terrain features (brown concentric lines) that were constructed using sediments dredged from the federal navigation channel. Only the downstream feature (see also Figure 21) was constructed due to the limited amount of dredged sediment available (from USACE Portland District 2020).



2.6.2 Project design considerations

The USACE Portland District (NWP) developed restoration planning and engineering design guidelines to support creation of wetland and floodplain habitat creation utilizing dredged material in the LCR (ESA PWA and PC Trask 2011). These guidelines were developed to facilitate restoration site selection, enable cost effective design of new habitat restoration and creation projects, and inform an adaptive management program for continued design refinement. The guidelines enabled NWP to identify locations such as Woodland Islands that optimize opportunities for developing habitats supporting ESA-listed salmon and other species on the LCR.

The initial project implementation plan allowed for construction of two morphological features along the embayment (east) side of Woodland Islands (Figure 20). Both features were designed to function when attached to existing islands, increasing habitat area while avoiding adverse circulation in adjacent areas. Due to shoaling encountered in the FNC along St Helens Bar, the volume of dredged material available for the Woodland Island project was reduced to around 153,000 m^3 (200,000 yd^3). Since there was only enough dredged sediment to construct one feature, the downstream feature was chosen because it needed less logistical support to implement, posed less risk of habitat trade-off and adverse current effects along the WA shoreline, offered greater protection of upstream areas from summer wave action, and provided a more pronounced “lift” in restored habitat area.

The final design drawings included a 50-ft-wide shallow water “shelf” extending from the connection to the existing island through most of the upstream “limb.” The shelf was set at elevations 5 to 6 ft Columbia River Datum (CRD) to create an intertidal terrace to support marsh and emergent ecology. The targeted top elevation was increased to 3.2 to 3.4 m (10.5 to 11 ft) CRD (not to exceed 12 ft or 3.7 m) to add stability, shelter effect, and to account for potential settlement.

2.6.3 Hydraulic modeling

An Adaptive Hydraulics (AdH) numerical model was created for the project to help quantify anticipated with-project changes in hydraulics and fluvial dynamics. Application of AdH for the Woodland Islands project used the 2D shallow water flow module to model both wet and dry conditions and changing tides, so it was able to model shallow marsh environments, beach slopes, and floodplains of interest. The AdH model was developed to simulate the hydraulic effects of a high-flow freshet event having an annual expected probability of 0.03 (30 to 35-yr return interval) for Columbia River flow passing the Bonneville Dam. The AdH model was used to simulate river hydraulics for both the Future With Project (FWP) condition for a high river flow (freshet) and low river flow (later summer) period, as well as the Existing Condition.

The results of the AdH modeling indicated the placed sediments can be expected to result in local hydraulic changes by restricting the flow area and increasing the shelter effect in the side channel. The model results also showed spatial changes in velocity occurring primarily during high and low flood conditions with minor or no effect in river current during low river flow conditions. The FWP terrain is not expected to adversely affect USACE O&M activities for the LCR FNC and may likely be beneficial for sustaining the sediment budget of Woodland Islands and the LCR (USACE Portland District 2020).

2.6.4 Analysis of climate change impacts

Two aspects of climate change were evaluated using a scenario-based approach at Woodland Islands: effects of future sea level change (SLC) on river stage; and effects of a wetter or dryer climate on tidal river flow. SLC influence on river stages were used to assess corresponding changes in habitat types for the project (USACE Portland District 2020). Results indicated that as the river stage is altered due to hydrology and SLC, habitat zones would adapt to accommodate associated changes in inundation. Habitat zones are expected to adjust differently to changes in river stages based on differences in terrain gradients within each habitat zone. Overall, the project site would not expect to be compromised within the project's 50-yr planning horizon (from 2020 to 2070).

The potential effects of future climate change on how a wetter or dryer climate could affect tidal river flow indicated that such flow changes translate into changes to river stage and current at the project site. Hydrology impacts on river stage (and stability) and current were also used to assess corresponding changes in habitat types. Based on the climate change scenarios evaluated, there would be minimal effects on the long-term stability and morphological evolution of the project as built. Finer-grained sediment fractions would be transported more readily by the increased current, but the estimated variation in river current was not predicted to be sufficient to meaningfully affect the project's terrain features.

A project adaptation horizon of 50-100 yr was also qualitatively evaluated to estimate climate preparedness and resilience of the as built project. At the end of the adaptive horizon (year = 2120 for High USACE SLR scenario), the base elevation for scrub-shrub habitat would be elevated from the present condition of 3.4 m (11 ft) NAVD88 to above the 4.3 m (14 ft) NAVD88 contour, which would exceed the as-built terrain extent, therefore ceasing to provide scrub-shrub habitat. This would result in terrain within the 3.4 to 4.3 m (11-14 ft) elevation to convert to marsh, with the former marsh terrain converting to intertidal habitat. In this manner, the as-built project has the capacity to adapt to lower elevation habitat suitable for salmon, making the habitat resilient under the climate change scenarios evaluated. The deeper water habitat is functional for salmonids even during lower flow periods during summer and fall, and as so was not predicted to be adversely affected by climate change. Since the as-built project incorporates adaptive capacity to accommodate the effects of future sea level and hydrology changes without compromising the project's intended ecological function, the project is expected to provide benefits under the climate change scenarios evaluated.

2.6.5 Added value of planting native vegetation

The decision to plant willows (i.e., Columbia River willow, *Salix fluviatilis*) in the next phase of the project rather than allowing natural processes to seed the placed sediment, met several cost and other project criteria. Willows will be planted in areas of the project site exposed to erosive forces that could compromise habitat restoration results, along the graded shoreline, and in areas cleared for construction. Planting willows will help establish the plants more rapidly than using seeds and was more acceptable to regulatory agencies and other area stakeholders. Planting native vegetation is common practice for ecosystem restoration activities in the area. It also addresses stakeholder concerns that the project would alter the aesthetics of a natural river and that of the Woodland Island complex by homeowners on the adjacent shore.

The project is also considered relatively efficient, as planting native willows will allow vegetation to establish sooner, mature faster, and therefore have a higher likelihood of outcompeting non-native species such as reed canary grass (*Phalaris arundinacea*) which provide little wildlife value.

Utilizing natural seed sources to establish vegetation is also not always successful when restoring wetlands in the region. If the project relied on seeds to establish native vegetation and they failed to sufficiently germinate, the project would then require supplemental plantings, thereby increasing costs and reducing efficiencies. For this reason, it is more efficient and cost effective to plant willows as part of the project design; this will also help reduce the likelihood that non-native species will establish, necessitating their removal in the future.

As a native species, the willows at the base of the food chain will attract other species to utilize the restored habitat, including warblers and other tropical migratory birds, amphibians, reptiles, and various life stages of salmonids and other fish species. Including plantings of native willows and grading post-placement increases stability and resiliency of the placed sediments in a manner that will better withstand shear forces and hydrodynamic conditions of the LCR.

The project is creating more wetlands and diversifying the types of habitats available to salmonids. The islands in their current state provide tidally submerged habitat that is relatively uniform with little vegetation.

The project elevated the submerged shoreline via dredged sediment placement sufficiently to allow light penetration while allowing inundation during the daily high tide. Plant species colonizing the tidal fringe would expand this habitat type, thereby increasing suitable habitat for salmon. Once established, trees and shrubs would provide shading to maintain cooler water during the summer months, and downed trees would provide woody debris which attract salmon prey species and provide areas for fish to hide and rest.

2.6.6 Effects of plantings and sediment placement on local hydrodynamics

An important aspect of the project was to assess the potential impacts to the hydrology of the LCR. These impacts were considered negligible, although once planted, the additional density and height of the willows are expected to increase roughness on the constructed features and in the side channel. The effect of increased roughness on the newly created features will accentuate local hydraulic effects and increase overall impacts of adding sediment in the side channel. Effects, both positive and negative, on navigation are expected to be negligible.

The presence of the planted willows and other native vegetation post-construction will help anchor the placed sediment, thereby reducing the risk of erosion and rate of deformation of the constructed features. The project will tend to concentrate the accumulation of fine sediments into the marsh flats and other low velocity areas in the future, which will facilitate wetland plant growth and development and provide additional plant anchoring benefits (USACE Portland District 2020).

To help preserve the restored habitats at the project site, the pile dikes bordering the FNC channel will be kept and maintained. Placement of dredged sediment between the existing pile dike and the FNC side of the island is being considered for future dredged material disposal. This would also contribute to the long-term stability of the island network, helping to reduce erosion and protect the restored habitat from local hydrodynamic conditions of the river. The USACE will maintain the pile dikes under its O&M program.

Placement activities are expected to result in short-term adverse impacts on fringe wetland vegetation and burial of existing benthic communities. The expansion of suitable habitat for salmonid and terrestrial species would far outweigh any potential short-term impacts of shoreline placement activity on the fringe vegetation. The project design required cutting a 30- to 45-m-wide path through the willow-dominated, shrub wetland portion of the island, but these areas would be replanted within a year and are expected to re-vegetate quickly. Overall, it is anticipated that the long-term establishment of larger and more diverse wetland and riparian system with salmonid rearing habitat in the side channel far outweigh the short-term impacts of dredged sediment placement.

2.6.7 Habitat features

The placement of dredged sediment has several direct environmental benefits. For example, it encourages the establishment of additional habitat and forage areas that would be utilized by federally listed species, thereby contributing to their recovery. Further, the new shoreline edge on the western side of the island (Figure 20) and its associated shallow water habitat attracts a variety of aquatic species, as this feature restores shallow water habitat on the eastern side of the island to its historic footprint.

The project design includes specifications for a future even distribution planting of willow shrubs across the range of elevations (3.4 to 4.3 m; 10 to 14 ft NAVD) to provide scrub-shrub habitat and to stabilize the placed dredged material. As noted in Section 2.6.3, willow plantings would not only help reduce sediment erosion, but they would also encourage rapid development of scrub-shrub and emergent wetland habitat. Once established, the willows will benefit species that utilize these habitats. The project was designed to restore habitat that would attract juvenile Chinook (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), and coho (*O. kisutch*) salmon. It is also anticipated that sockeye (*O. nerka*), chum (*O. keta*), eulachon (*Thaleichthys pacificus*), and river (*Lampetra ayresi*) and Pacific lamprey (*L. tridentate*) occurring elsewhere in the LCR may utilize the project site by feeding on prey attracted to the restored shrub fringe and forested wetland habitats.

2.6.8 Listed species

The project was designed to benefit salmon and other ESA-listed species (USACE Portland District 2020). Increasing the acreage of wetland vegetation is expected to benefit bull trout (*Salvelinus confluentus*), green sturgeon (*Acipenser medirostris*), and Pacific eulachon (*T. pacificus*) by providing cover, detritus, nutrient input to the food web, increased diversity of shallow water and wetland habitats, and increased prey resources. Restored upland and fringe wetland habitat is expected to benefit migratory birds such as bald eagles (*Haliaeetus leucocephalus*) and osprey (*Pandion haliaetus*). Expanding the island that is partially submerged would benefit brown pelicans (*Pelecanus occidentalis*) that visit during summer.

2.6.9 Monitoring and adaptive management

The USACE, along with its stakeholders and partners, has developed a monitoring plan that would implement an adaptive management approach for this project. The placement and grading of dredged material happened in the first phase of construction, which was initiated on 21 September 2020 and completed on 10 October 2020 (Figure 21). The second phase entails planting of native vegetation, which will occur in two stages in winter 2021-22 and winter 2022-23. As specified in the Feasibility Study & Final Environmental Assessment (USACE Portland District 2020), the project is targeting 60% survival of willow plantings from one to two years after initial planting, and riparian scrub/shrub habitat occurring along the shoreline should cover at least 75% of the inward side of the new embayment area after five years. Willow establishment and survival will be documented at years one or two, and 5 yr after initial planting, and plant species composition and cover will be monitored in years one or two, and five after construction.

Figure 20. Woodland Island downstream feature constructed in fall 2020 from dredged sediment and subsequent grading for restoring wetland habitats (Photo courtesy Columbia River Estuary Study Taskforce [CREST]).

If riparian habitat is less than 50% after five years post-construction, the Corps and non-Federal sponsor (Columbia River Estuary Study Taskforce [CREST]) will evaluate the trends of vegetation establishment and determine the cause(s). If willow survival is less than 60% one to two years after initial planting due to unavoidable factors such as mammal browsing, no new willows will be planted. Otherwise, new willows will be replanted to replace those lost. If riparian habitat is not establishing due to river flows and scour, no action will be taken. If riparian habitat is not becoming established because of the lack of shrub reproduction (e.g., a seed source), the Corps and CREST will discuss a suitable course of action; CREST will plant the vegetation. Funded separately, a robust effectiveness monitoring effort is evaluating changes in bathymetry, substrate, and benthic communities using a before/after treatment/control design.

2.6.10 Project summary

The Woodland Islands site consists of several small islands and a sheltered side channel area located between the FNC and the Washington side of the LCR shore near St. Helens, Oregon. The site was a good candidate for beneficially using dredged sediment to restored river island habitat due to its relatively large area suitable for placement, was near a reliable sediment source, and the paucity of wetland and floodplain habitat in the LCR. The objective of the project was to restore shallow water and wetland habitats to help rebuild federally listed salmon species populations and to support waterfowl, shorebirds, neotropical migratory songbirds, native mammals, reptiles, amphibians, and non-listed aquatic species.

An AdH numerical model was created for the project to help quantify anticipated with-project changes in hydraulics and fluvial dynamics. The results indicated the project is not expected to adversely affect USACE O&M activities for the LCR FNC while likely being beneficial for sustaining the sediment budget of Woodland Islands and the LCR.

Native willows will be planted in a subsequent phase beginning in winter 2021-2022 to meet several cost and other project criteria. They will be planted in areas prone to erode, along the graded shoreline, and areas cleared for construction. Planting willows to establish native plants more rapidly was more acceptable to regulatory agencies and stakeholders, addresses aesthetics concerns of a natural river and that of the Woodland Island complex by homeowners on the adjacent shore, and is common practice for ecosystem restoration activities in the region.

The placement of dredged sediment is resulting in several direct environmental benefits. It encourages the establishment of additional habitat and forage areas that would be utilized by federally listed species while the new shoreline edge on the western side of the island and associated restored shallow water habitat will attract a variety of aquatic species.

The USACE, along with its stakeholders and partners, has developed a monitoring plan that would implement an adaptive management approach for this project. The second phase entails planting of native vegetation, which will occur in two stages in winter 2021-22 and winter 2022-23. The monitoring plan specifies survival target of willow plantings and riparian scrub/shrub habitat coverage objectives that through adaptive management measures will enable establishment of native species post-construction.

3 Summary

USACE is changing the way it manages dredged sediment to increase beneficial use while providing benefits to USACE flood risk management and ecosystem restoration business lines. These projects demonstrate that more sustainable practices and outcomes can be achieved by working to intentionally align natural and engineering processes to efficiently and sustainably deliver economic, environmental, and social benefits associated with riverine bank stabilization projects. Selected projects were implemented over a diverse range of river conditions to assure at least one demonstration would be applicable in most riverine settings with navigation dredging and feasible conditions for alignment of engineering and natural processes. The highlighted projects demonstrate ecosystem diversity is achievable by considering natural processes in the engineering design. Sediment (dredged material) rehandling is minimized by accounting for natural hydrodynamic processes which might otherwise rapidly degrade the constructed feature. Furthermore, the projects are more sustainable because natural processes are aligned with human engineering ensuring improved sediment trapping, hydrodynamic processes, and resulting ecosystem response more considerate of the natural system function. Lessons learned from these projects help identify data gaps (e.g., identifying and quantifying the full range of project benefits) and support the development of engineering and ecosystem restoration guidance using navigation dredged sediment. Such innovative techniques can be integrated into USACE business practices of project design to manage the nation’s waterways and provide flood risk management and ecosystem co-benefits to navigation dredged sediment management projects more effectively.

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14. ABSTRACT

In-water beneficial use of dredged sediment provides the US Army Corps of Engineers (USACE) the opportunity to increase beneficial use while controlling costs. Beneficial use projects in riverine environments include bank and near-bank placement, where sediments can protect against bank erosion and support habitat diversity. While bank and near-bank placement of navigation dredged sediment to support river-bank stabilization and habitat is currently practiced, documented examples are sparse. Documenting successful projects can support advancing the practice across USACE. In addition, documentation identifies data gaps required to develop engineering and ecosystem restoration guidance using navigation-dredged sediment. This report documents five USACE and international case studies that successfully applied these practices: Ephemeral Island Creation on the Upper Mississippi River; Gravel Island Creation on the Danube River; Gravel Bar Creation on the Tombigbee River; Wetland Habitat Restoration on the Sacramento-San Joaquin River Delta; and Island and Wetland Creation on the Lower Columbia River Estuary. Increased bank and near-bank placement can have multiple benefits, including reduced dredge volumes that would otherwise increase as banks erode, improved sustainable dredged sediment management strategies, expanded ecosystem restoration opportunities, and improved flood risk management. Data collected from site monitoring can be applied to support development of USACE engineering and ecosystem restoration guidance.

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