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Evaluation of Sand Augmentation for Stabilizing Recreational Beaches and Storing Sand in Glen Canyon National Recreation Area

Environmental Science Division

Cover Images: (Clockwise from top left) (1) Shoreline erosion at Ropes Trail campsite; (2) Horseshoe Bend section of the Colorado River in Glen Canyon National Recreation Area; (3) Toilet next to eroding shoreline at Ferry Swale Campsite. [Photo Credit: Craig Ellsworth]

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Prepared for:
Western Area Power Administration
Colorado River Storage Project

August 2021

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ACKNOWLEDGMENTS

The work presented in this report was funded by the Western Area Power Administration under Contract No. DE-AC02-06CH11357.

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1 INTRODUCTION

The Glen Canyon reach of the Colorado River, located between Glen Canyon Dam and the confluence with the Paria River, has been in extreme sediment deficit since the closure of Glen Canyon Dam. Overall, the amount of sand supplied to the Colorado River in Grand Canyon National Park since completion of Glen Canyon Dam in 1963 is less than 10% of historic levels (USGS 2021). The reduction in sand supply has resulted in a substantial decrease in the number and size of sandbars within the Colorado River. Sandbars are an important aspect of the Glen and Grand Canyon river corridor because they serve as recreational campsites, provide aquatic and riparian habitats, and provide sand that may help protect archaeological sites (USGS 2021). Most of the sand input into the Colorado River downstream of Glen Canyon Dam comes from the Paria River (USGS 2021). Within the Glen Canyon reach, some sediment input also occurs from washes such as Honey Draw, Ferry Swale, and Waterholes Canyon but these inputs are relatively small, infrequent, and insufficient to maintain recreational camping beaches and preserve archeological sites in the Glen Canyon reach.

An experimental strategy that called for repeated releases of large volumes of water from the dam has been implemented under a “high-flow experiment” (HFE) protocol (DOI 2012) in an attempt to increase the size and numbers of sandbars in Grand Canyon. Although the HFE protocol appears to have increased the size of sandbars within Marble and Grand Canyon sections of the Colorado River (Grams et al, 2015), it has increased the transport of sand from the Glen Canyon reach, resulting in concerns about the potential for increasing the erosion of sandbars associated with camping beaches, archeological sites, and terraces in the Glen Canyon reach.

This white paper evaluates the potential for dredging riverbed sand to augment sand in adjacent shoreline areas as a means for rehabilitating camping beaches in Glen Canyon. This study may also inform the potential for use of this method elsewhere below Glen Canyon Dam rather than relying solely on HFEs, thereby reducing potential undesirable effects of HFEs including impacts to hydropower production, proliferation of nonnative fish (e.g., brown trout), scouring of the aquatic food base from the riverbed, and the potential for associated impacts on humpback chub, the rainbow trout fishery, and recreational opportunities below Glen Canyon Dam.

Beach augmentation (also known as beach nourishment or replenishment) has become a common method for counteracting effects of coastal and shoreline erosion and for enhancing recreational beaches in many areas. Beach augmentation generally consists of dredging sand from offshore areas and transporting it to onshore areas to address shoreline erosion, protect coastal structures, and improve recreational opportunities. It is anticipated that beach augmentation in the Glen Canyon reach could improve and maintain the recreational experience for people camping in Glen Canyon, help control vegetation encroachment on camping beaches, and help stabilize and protect archeological sites and terraces. Sand augmentation may also be a suitable method for addressing some of the current and future maintenance needs for campsite beaches and shorelines, including shoreline erosion, protection and stabilization of vault toilets that are at risk of failure, and provision of safe access points from the river. It is also anticipated that beach augmentation could be a cost-effective method for achieving some sediment-related resource goals, especially sand storage, when compared to the direct and indirect costs of conducting other sediment-related actions such as HFEs and reduced hydropower fluctuations.

This white paper describes a potential method for dredging sand from the riverbed for placement on campground beaches in the Glen Canyon reach of the Colorado River, identifies potential mitigation actions for controlling downstream impacts, and describes monitoring to evaluate an experimental test of beach augmentation. If there is a future decision to move forward with experimental dredging of sand from the riverbed for placement on one or more camping beaches in the Glen Canyon reach, a more detailed engineering, implementation, and monitoring plan would be developed.

2 STUDY SITES

The National Park Service (NPS) maintains five designated campsites along the Colorado River between the Glen Canyon Dam and Lee's Ferry (Figure 1). These sites provide primitive camping opportunities for recreational boaters on shoreline beach areas. Each campsite has a vault toilet and several fire rings.

At least three of these designated camping areas may be suitable for testing sand augmentation feasibility within the Glen Canyon reach of the Colorado River: (1) the Ropes Trail Campground located at RM -14, and (2) the Ferry Swale Campground at RM -11.5, and (3) the Horseshoe Bend Campground at RM -9. Preliminary observations of these sites indicate that there are shoreline areas where significant erosion has occurred and that there are nearshore sand deposits that could provide adequate sand for beach augmentation purposes (Figure 2). Figures 3-5 provide aerial images of these three campground areas. The vault toilet at the Ferry Swale campground is at risk of failure due to shoreline erosion and stabilizing the shoreline in this area using dredged sand could help address potential risk to this structures. The Ropes Trail campground has a vault toilet that is being considered for relocation to an area nearer to the river because it is currently located near culturally significant petroglyphs adorning an adjacent canyon wall. The current toilet location at the Ropes Trail campground is believed to encourage greater human traffic near the petroglyphs, thereby increasing the risk for disturbance or vandalism of these features. Sand augmentation could help stabilize and maintain a new toilet location at the Ropes Trail Campground.

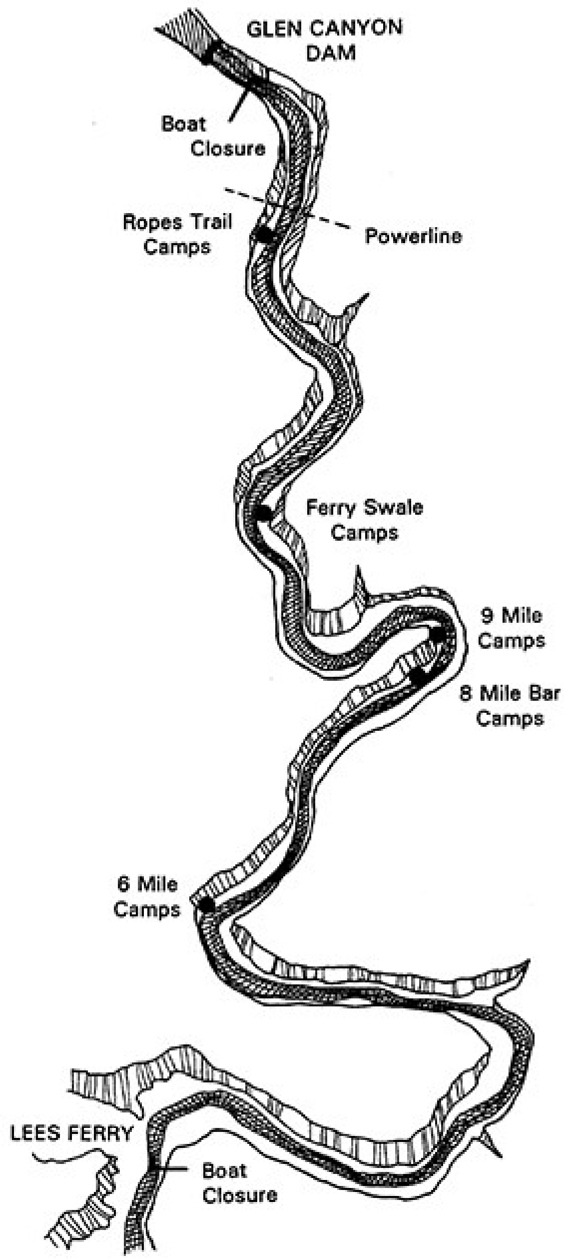

FIGURE 1 Map Showing Designated NPS Campsites on the Colorado River between Glen Canyon Dam and Lees Ferry. (Source: NPS)

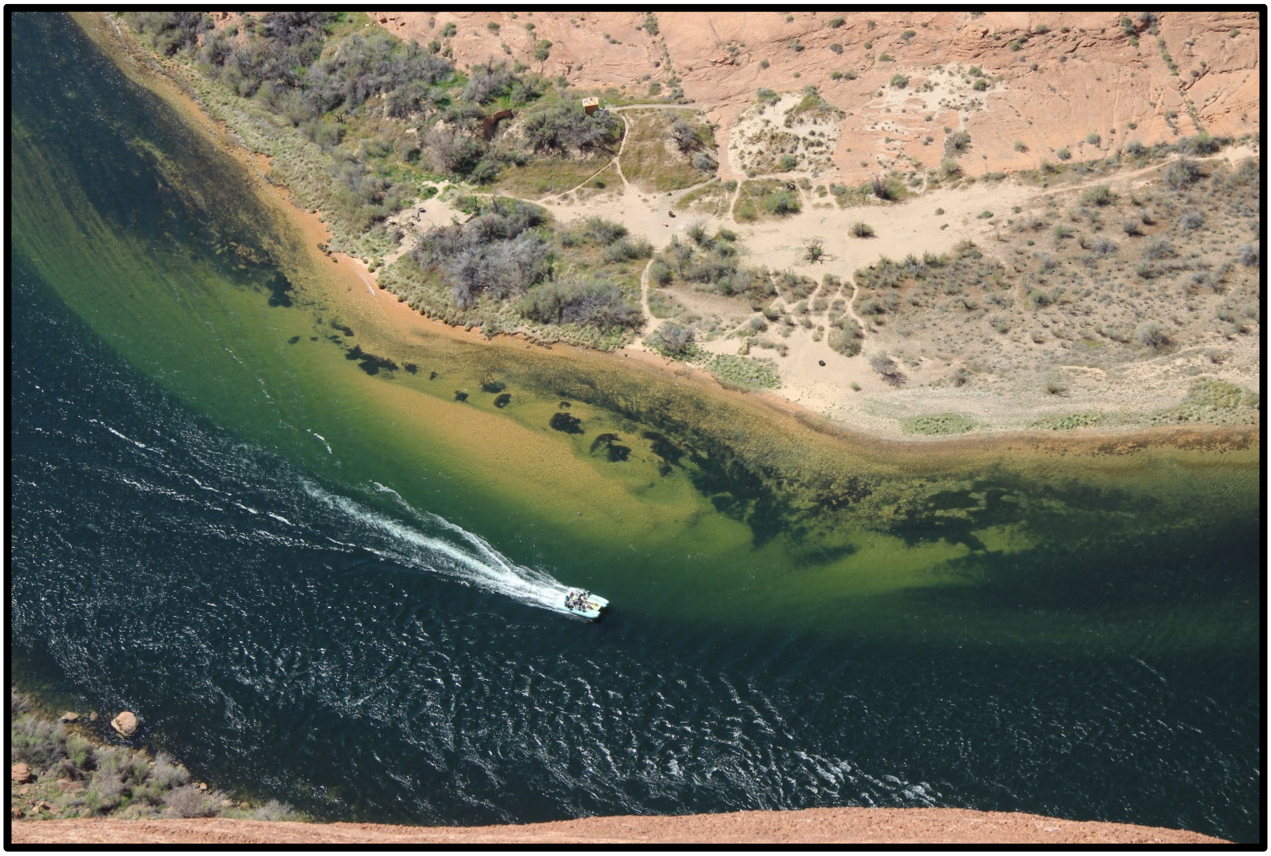

FIGURE 2 Aerial View Showing Nearshore Underwater Sand Deposits on River Right Next to the 9-Mile (Horseshoe Bend) Campground.

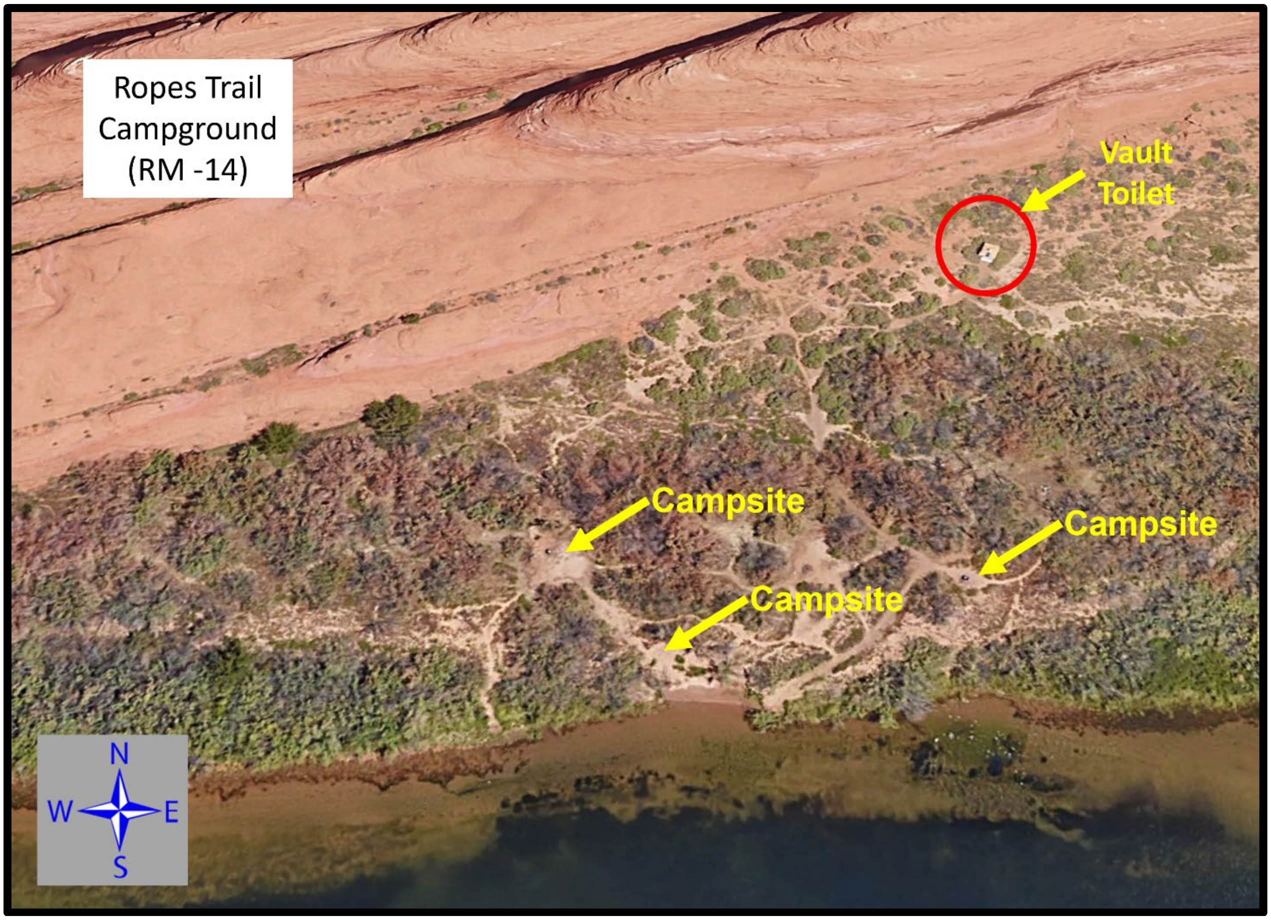

FIGURE 3 Aerial View of the Ropes Trail Campground on River Right in the Glen Canyon Reach of the Colorado River.

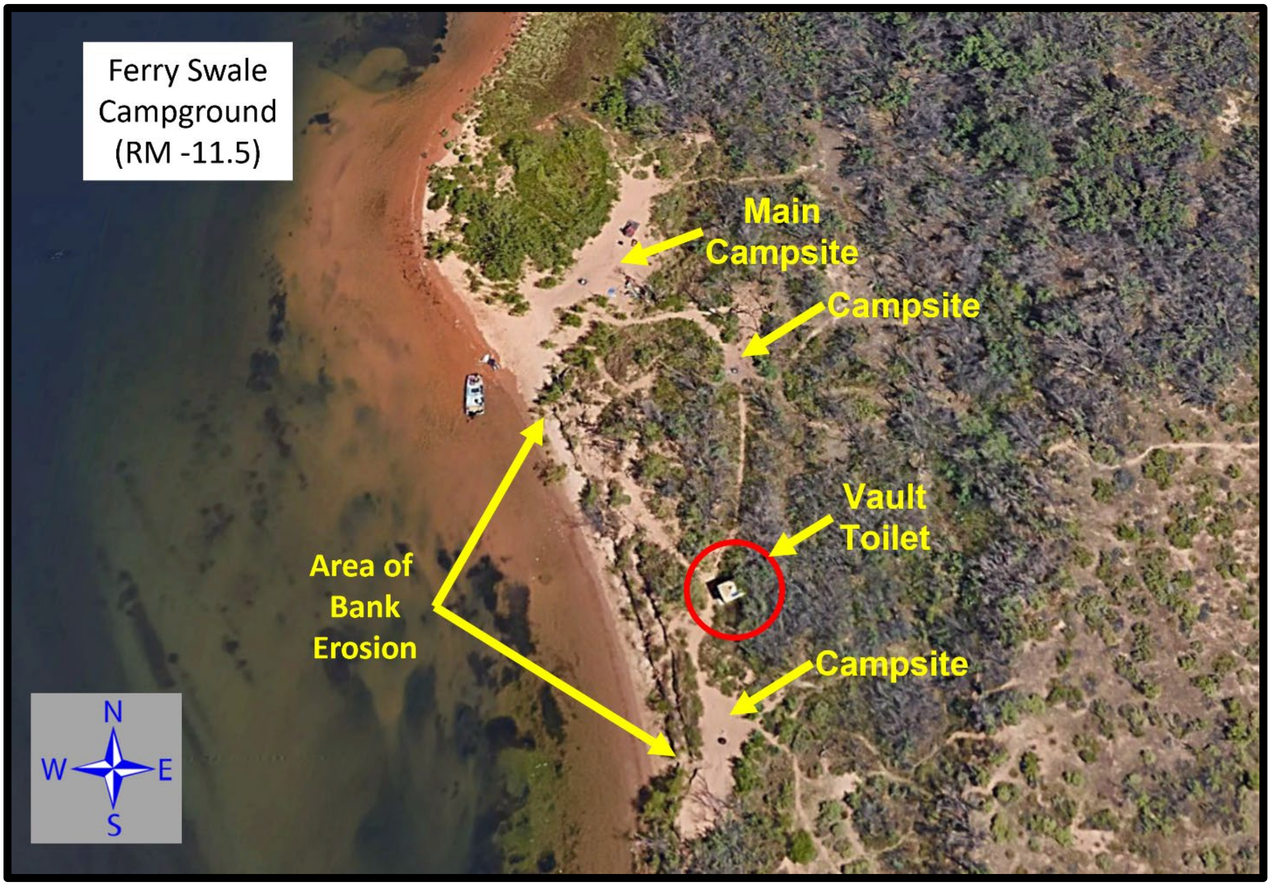

FIGURE 4 Aerial View of the Ferry Swale Campground on River Left in the Glen Canyon Reach of the Colorado River.

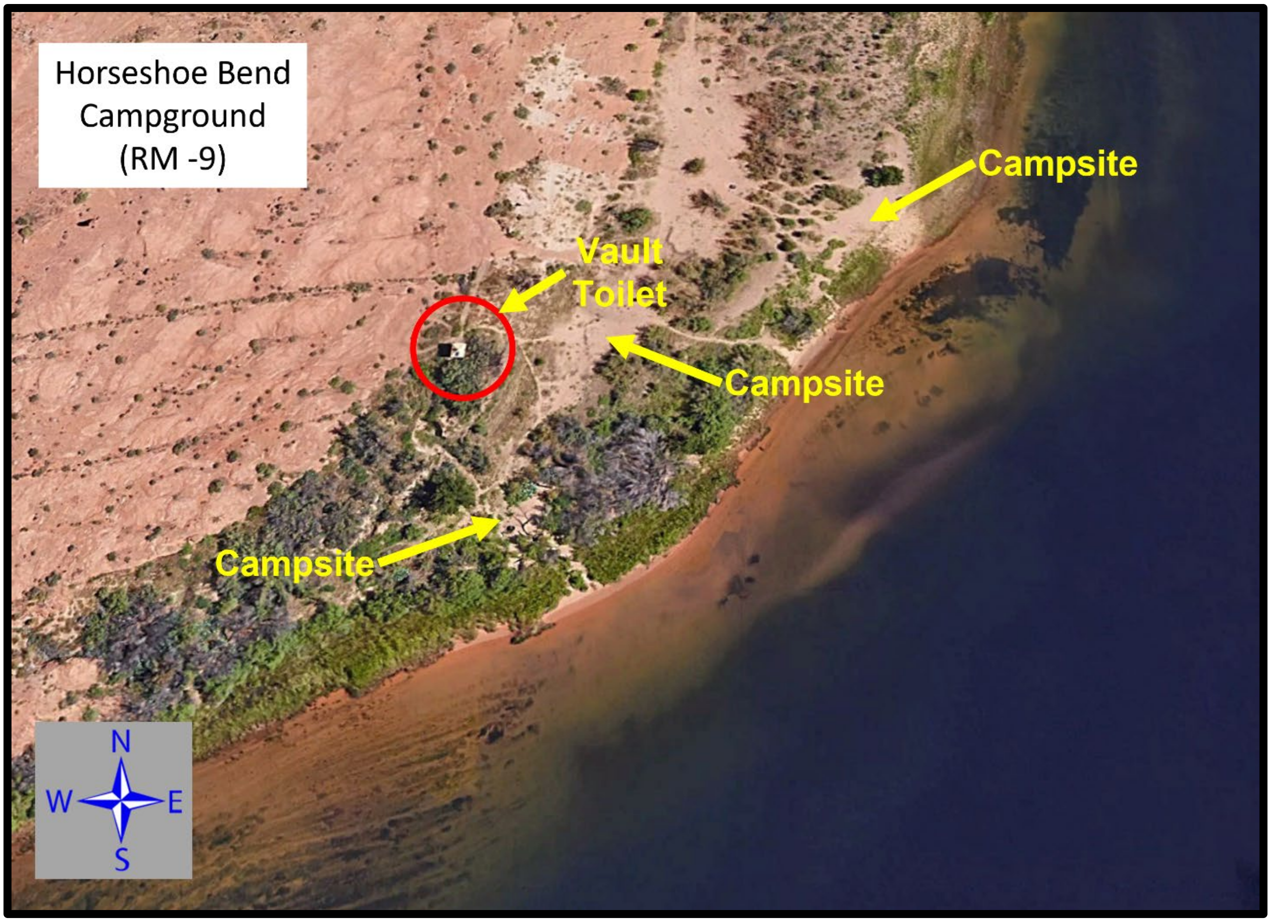

FIGURE 5 Aerial View of the 9-Mile (Horseshoe Bend) Campground on River Right in the Glen Canyon Reach of the Colorado River.

3 PROPOSED SAND AUGMENTATION EXPERIMENT

3.1 Overview

The proposed experiment would dredge sand from areas near the shoreline adjacent to one or more of the identified campground sites within the Glen Canyon reach of the Colorado River, move the dredged sand to desired shoreline areas in order to address shoreline erosion and build up camping areas, and then monitor the results of the sand augmentation.

3.2 Dredging, Draining, and Moving Sand

There are basically two general approaches to dredging: mechanical and hydraulic. Mechanical dredging involves removing sediment with machinery usually with an excavation bucket of some type. The most common types are an excavator or clamshell bucket. Hydraulic dredging involves the use of one or more pumps, often barge mounted, to move material in a slurry via a pipeline. Both can be very practical and efficient depending on the material type, depth, access to the dredging site and the distance to sediment dewatering and placement areas.

Mechanical dredging can be quick and accurate but is often limited to reach from the shoreline or barge. Long reach excavators are capable of reaching up to 50-70 feet and draglines a little further but less accurately. Barge mounted machinery sometimes requires loading dredged material into a hopper for transport to land. It is anticipated that mechanical dredging equipment would be difficult to transport to the proposed experiment sites due to the size and weight of the equipment and the limited access from either upstream or downstream locations within Lees Ferry.

Hydraulic dredging can be cost effective if the sediment is being placed nearby (within a couple thousand feet of the dredging location) and if there is a suitable onshore area for dewatering the sediment slurry (Figure 6) and returning clean water to the river. Dewatering technology has improved with the use of dewatering systems or geotextile tubes but a suitable location for such dewatering devices will need to be identified. There are several potential suppliers of small hydraulic dredges that might be suitable for the sand augmentation experiments. Small hydraulic dredges can be mounted on boats or rafts and operated by one or two technicians (Figure 7). Once sand has been dredged and adequately dewatered, it could be transported to a staging area or to final augmentation locations using portable construction conveyor systems (Figure 8).

FIGURE 6 Discharge of Sand Slurry from Hydraulic Dredge System.

FIGURE 7 Examples of Small Raft Mounted Hydraulic Dredge Systems.

FIGURE 8 Example of Portable Conveyor System for Moving Sand up an Incline.

Because of the relatively small areas to be evaluated and the likely expense and difficulty in transporting and setting up mechanical dredging equipment within the Glen Canyon reach, it is proposed that a small hydraulic dredge would be used to move sand from offshore locations to nearby beach areas. Since the sand deposits to be dredged are typically within slower-moving or eddy areas, a small boat-mounted dredge could be maintained in the appropriate position within the river channel using small motors and/or lines managed from shoreline locations.

For hydraulic dredging, it is necessary to remove water from the dredged sediments. A settling basin is one option, but using this method involves quite a bit of work before dredging can begin and an area at least twice as big as the total intended dredge volume typically needs to be created. The reason for this is because the transport water volume is a significant portion of the discharge slurry and the dewatering basin must be able to hold enough water to allow the dredge to continue excavating. Another potential method for allowing the water to drain from the dredged sediments would be to use geotubes or geobags. These are engineered fabric containers that are filled with the slurry of dredged sand and water. Hydraulic pressure from the dredging system helps to transport the sand along the inside of the container, while the water dissipates through the permeable engineered fabric (Lee et al. 2014). The sand settles out within the container by gravity. Geotubes can be obtained in a variety of sizes appropriate to the scale of the area being dredged and could be transported to the test campsites using rafts. Once water has drained through the membrane, the geotubes can be directly used to stabilize shoreline areas or can be opened to remove the retained sand and distribute it to areas where beach augmentation is desired. One additional possibility would be to establish screened platforms at the output location for the dredge piping that would allow water to drain while retaining a large proportion of the dredged sand. The size and configuration of the screening system would depend on the volume of the sand/water mix being discharged and the rate of discharge. Regardless of the type of water removal system implemented, it would be necessary to establish a route for conveying the removed water to the river or to a runoff area that would not erode additional shoreline areas or affect the turbidity of the river at the return area. Allowing the water to percolate into the ground behind a berm or sending the water down a cobble- or gravel-lined side channel may be an option for reducing the potential for erosion and turbidity. Dewatered sand could be moved to final locations using portable conveyor systems (Figure 8) or transported using carts, wheelbarrows, or sledges.

3.3 Beach Augmentation

Beach augmentation experiments would entail placing dredged sand in test plots located in selected campsite areas. It is envisioned that up to five test plots with surface areas up to approximately 500 m^2 (597 yd^3) would be established at each campsite area. Similarly, five areas of similar dimensions and pre-augmentation characteristics would be identified to serve as controls for comparison. At this time, it is anticipated that 6-12 inches (0.15-0.30 m) of sand depth would be added to the augmented areas. If it is assumed that there are five experimental augmentation plots, 375 to 750 m^3 (490 to 981 yd^3) of sand would be needed at each campsite area. At a potential sand dredging rate of 15 m^3 (20 yd^3) per hour, it would require 25 to 38 hours of dredge operation to obtain the needed sand. Following beach augmentation, initial measurements of plot locations, sand depth, and other plot characteristics would be recorded.

3.4 Shoreline Stabilization

Shoreline Stabilization experiments would entail placing dredged sand in areas that are experiencing shoreline erosion. Based upon the characteristics of the areas to be stabilized, consideration could be given to using natural materials such as rock riprap or buried revetments of rock or timber to further stabilize the shoreline areas and reduce future erosion of dredged sand (Figure 9A). The interstices of rock riprap could be covered with dredged sand to improve the natural appearance and keep sand in place. A buried revetment would involve placement of the natural material (e.g., rocks) in a trench excavated near the streambank and then backfilling with dredged sand (NPS 2019). The bottom of the trench should be located below the elevation of the ordinary high-water mark to provide sufficient toe-of-slope protection. If appropriate, re-seeding could be implemented to ensure that native vegetation cover exists from the top of the revetment down to the ordinary high-water mark. The goal would be to allow the streambank to erode to the buried revetment which then becomes the stabilized bank line.

There is also a potential for using engineered mesh support structures, known as geo-cell membranes, to stabilize shoreline areas (Figure 9B). The geo-cell membranes would be filled and buried with dredged sand. If it is assumed that shoreline areas of 50 m (55 yd) long and 10 m (11 yd) wide would be stabilized using sand fill that is 0.3 m (12 inches) deep, approximately 150 m^3 (196 yd^3) of sand fill would be needed at each campsite area. At a potential sand dredging rate of 15 m^3 (20 yd^3) per hour, it would require approximately 10 hours of dredge operation to obtain the needed sand for each area.

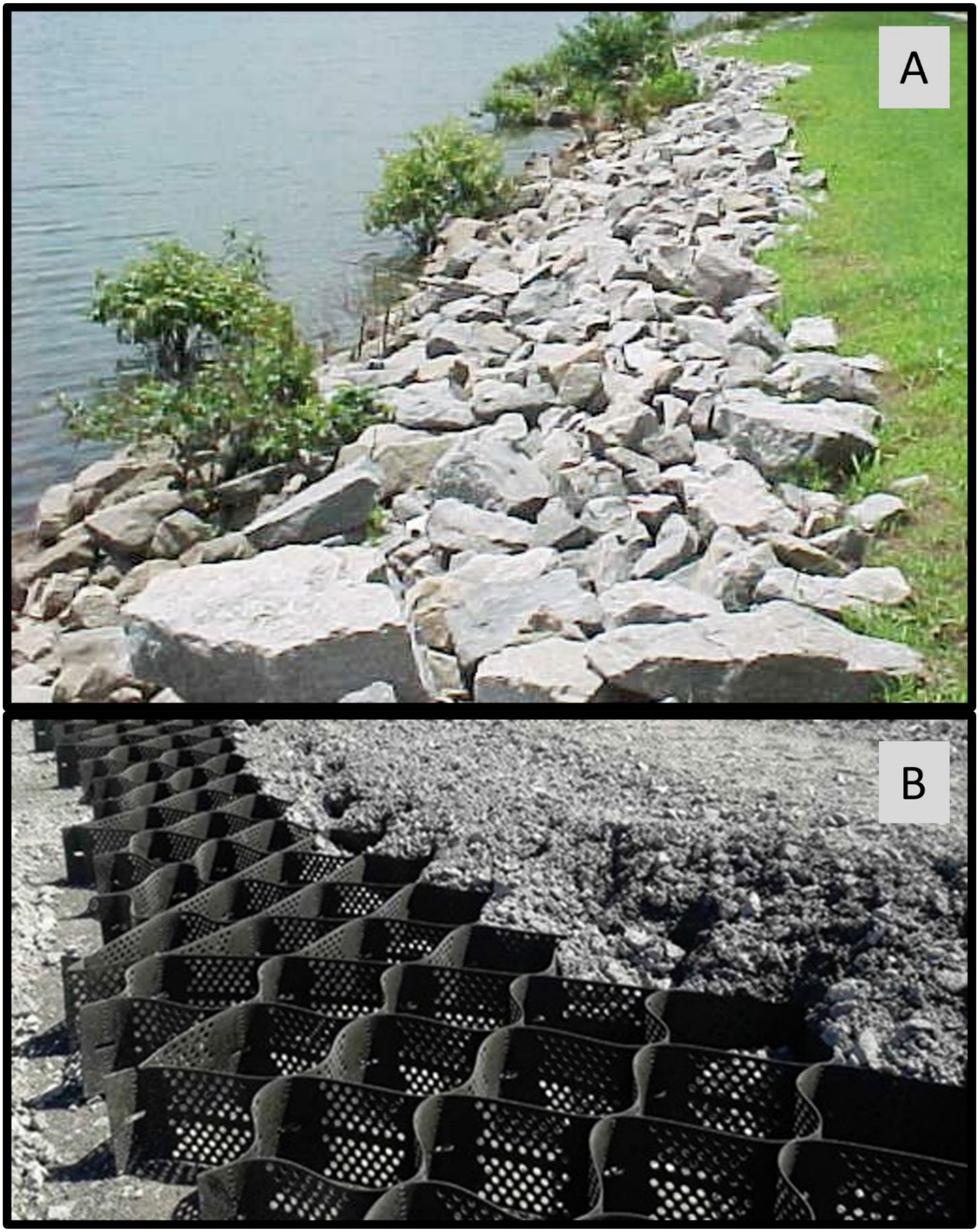

FIGURE 9 (A) Example of Rock Riprap used to Stabilize Shoreline Area. (B) Example of Geo-Cell Membranes for Use in Stabilizing Shoreline Areas.

4 MITIGATION MEASURES AND BEST MANAGEMENT PRACTICES, AND REGULATORY CONSIDERATIONS

Environmental impacts due to sand dredging and sand placement would be avoided by implementing various best management practices. This would include efforts to minimize the transport of sediment-laden water to downstream areas, avoiding activities that would exacerbate or contribute to shoreline erosion, and limiting activities (e.g., sand augmentation, placement of equipment, or routes for moving people or equipment) within areas containing sensitive native vegetation or resources of cultural significance. In addition, noise and other conditions that could significantly deter enjoyment of the natural environment by recreational users would be minimized to the extent possible. It may be necessary to plan activities during seasons where recreational traffic is expected to be lower.

Under the Federal Clean Water Act and Amendments, the U.S. Army Corps of Engineers USACE) regulates dredging in accordance with certain environmental criteria and appropriate permits may be required for any dredging or shoreline stabilization activities (NPS 2019, Reclamation 2015). In accordance with Section 404 of the Clean Water Act of 1972, the USACE regulates the discharge of dredged or fill material in waterways. The Colorado River and adjacent wetlands are waters subject to permit authority under Section 404 and 33 CFR 328.3(a). The basic premise is that no discharge of dredged or fill material would be permitted if: (1) a practicable alternative exists that is less damaging to the aquatic environment or (2) the nation's waters would be significantly degraded. In addition, placement of structures, or work (including discharge of dredged or fill materials and excavation) in, above, or below navigable waters that could obstruct navigability may require authorization from the USACE under Section 10 of the Rivers and Harbors Act. When applying for permits under these acts, it must be demonstrated that steps have been taken to avoid impacts to wetlands, streams, and other aquatic resources; that the potential impacts have been minimized; and that compensation will be provided for remaining unavoidable impacts. If it is determined that discharges will have only minimal adverse effects, a general permit may be suitable. If applicable, a general permit could eliminate the need for individual project review and could allow project activities to proceed with little or no delay as long as conditions for the general permit are met.

5 MONITORING OF AUGMENTATION AND STABILIZATION SUCCESS

Sand augmentation and shoreline stabilization areas would be monitored to evaluate the success of the experiments. This would include measures of use by campers, how long sand stays in the augmented areas, retention of sand at key elevations (e.g., above 20k cfs and above 45k cfs water lines), and the effectiveness for controlling vegetation encroachment in camping areas. This study would also measure rates of sand replenishment to the offshore dredging locations and a determination of whether mechanical maintenance of beaches could be expanded to protect other critical camping areas, terraces, or archeological sites below Glen Canyon Dam. It is anticipated that monitoring would be needed over several seasons and for at least two years to draw conclusions.

For sand augmentation areas, periodic field measurements would be conducted within experimental and control plots. In order to evaluate retention of sand, measurements of sand depth and sediment characteristics (e.g., grain size) would be collected. Evaluation of plant species composition and density within test plots would be used to evaluate whether sand augmentation alters vegetation encroachment or establishment. In order to evaluate whether recreational use of augmentation areas differs from non-augmented areas, camera monitoring stations could record the presence of tents within test and control plots by taking pictures at a set time in the late afternoon. Measures of beach augmentation success would also be evaluated relative to the topographic elevation in order to consider potential effects of operational releases from Glen Canyon Dam (e.g., 20K cfs and 45K cfs water line elevations).

Shoreline stabilization areas would be monitored using periodic measurements and observations of the depth of sand remaining in treated areas, scouring or undercutting of stabilized banks, and exposure of membranes, timbers, rocks, or other stabilization materials. The effectiveness of stabilization efforts relative to the topographic elevation would also be considered to evaluate differences based upon operational releases from Glen Canyon Dam.

The effect of dredging on the in-channel sand supply would also be monitored. This would entail periodic estimates of the volume of sand within areas where hydraulic dredging occurred to identify sand replenishment rates and whether sediment characteristics (e.g., sediment grain size) are affected. This information would allow identification of how often dredging activities might be possible. Additional biological characteristics of the dredged areas, such as the composition of aquatic invertebrate and aquatic vegetation communities, might also be of interest for periodic monitoring.

6 SUMMARY

This white paper identifies a potential experiment that could be conducted to evaluate whether sand within the active channel could be used to augment campsite beaches and stabilize erosive shoreline areas of the Colorado River between Glen Canyon Dam and Lees Ferry. In addition to identifying methods for dredging and relocating sand to campsite beaches and shoreline stabilization areas, a preliminary monitoring framework is identified for evaluating whether stabilization and augmentation efforts are successful. Identification of a method for placing sand in higher elevation areas without relying on specific releases (e.g., HFEs) from Glen Canyon Dam could reduce potential undesirable impacts to hydropower production, proliferation of nonnative fish (e.g., brown trout), and scouring of the aquatic food base from the riverbed.

Three campsite areas in the Glen Canyon Reach are proposed for the experimental evaluation: (1) the Ropes Trail Campground located at RM -14, and (2) the Ferry Swale Campground at RM -11.5, and (3) the Horseshoe Bend Campground at RM -9. These campsites receive heavy recreational use, have maintenance needs that might be addressed by sand augmentation and shoreline stabilization, and appear to have nearshore underwater sand deposits that may be suitable for supplying sand for augmentation and stabilization experiments.

Because of the relatively small areas to be addressed during the experiments and the likely expense and difficulty in transporting and setting up mechanical dredging equipment within the Glen Canyon reach, it is proposed that a small hydraulic dredge would be used to move sand from offshore locations to nearby beach areas. Small hydraulic dredges can be mounted on boats or rafts and operated by one or two technicians. The dredged sand would be placed in temporary dewatering basins or inside geotube membranes for dewatering. Once dredged sand has been adequately dewatered, it would be moved to the designated augmentation and shoreline stabilization locations. It is envisioned that up to five augmentation test plots with surface areas up to approximately 500 m^2 (597 yd^3) would be established at each campsite area. Shoreline stabilization test areas would be placed in locations where shoreline erosion and support for vault toilets need to be addressed as part of campsite maintenance activities.

Best management practices would be identified to address potential impacts from dredging, dewatering, and sand placement activities. This would include efforts to minimize transport of sediment-laden water to downstream areas, avoiding activities that would exacerbate or contribute to shoreline erosion, and avoidance of activities within areas containing sensitive native vegetation or resources of cultural significance. Depending on the scope of the experimental activities, the implementation of best management practices and mitigation measures and consultation with federal and state regulators, specific or general permits would be needed from the USACE under Section 404 of the Clean Water Act and under Section 10 of the Rivers and Harbors Act.

Sand augmentation and shoreline stabilization areas would be monitored to evaluate the success of the experiments. This would include periodic field measurements in experimental and control plots to assess recreational use by campers, how long sand is retained in augmented and stabilized areas and the differences in sand retention at key water line elevations. The effect of dredging on the in-channel sand supply, replenishment rates, and sediment characteristics would also be monitored using periodic measurements within dredged areas. Periodic measures of biological characteristics within dredged areas (e.g., the composition of aquatic invertebrates and aquatic vegetation) could also be conducted.

The goal of the proposed experiment would be to evaluate whether placement of dredged sand on shoreline areas could be an implementable and effective method for addressing campsite maintenance needs and identified needs for increasing placement and storage of sand supplies in shoreline areas within the Glen Canyon reach of the Colorado River. Utilizing dredged sand for augmenting campsites and stabilizing critical shoreline areas may be a cost- and time-efficient method for addressing critical maintenance needs for the NPS within the Glen Canyon reach where recreational use of campsite areas has been rapidly increasing. If there is a future decision to move forward with experimental dredging of sand from the riverbed for placement on one or more camping beaches in the Glen Canyon reach, a more detailed engineering, implementation, and monitoring plan would be prepared.

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