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Naval Facilities Engineering Command Northwest

Draft

Summer 2020 Landfill and Shoreline Protection System Inspection Report

Operation and Maintenance

Site 10 North End Landfill

Naval magazine indian island

port hadlock, WASHINGTON

September 2020

Draft

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Operation and Maintenance Site 10 North End Landfill

Naval Magazine Indian Island

Port Hadlock, Washington

September 14, 2020

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Acronyms and Abbreviations

BT Beach Transect

DON Department of the Navy

EA EA Engineering, Science, and Technology, Inc., PBC

HDPE High-Density Polyethylene

hf horizontal feet

IC Institutional Control

LUC Land Use Control

NAVFAC Naval Facilities Engineering Command

NAVMAG Naval Magazine

O&M Operations and Maintenance

RCP Reinforced Concrete Pipe

SPS Shoreline Protection System

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# Introduction

Indian Island is located in Jefferson County, Washington (Figure 1-1). The island is approximately 5 miles in length and is occupied in its entirety by Naval Magazine (NAVMAG) Indian Island which is owned by the U.S. Navy. The island is primarily used for the handling and storage of naval ordnance. The Site 10 North End Landfill is an approximately 3.7-acre inactive landfill located on the northern-most point of the island.

Site 10 was the primary landfill for the island from about 1945 until the mid-1970s. The Record of Decision (URS 1995) remedies were implemented in 1995, and remedial activities were completed in May 1997. The Navy is responsible for performing maintenance and monitoring activities at the Site 10 North End Landfill and has performed periodic inspections of the shoreline protection system (SPS), landfill cap, and ancillary components since 1997.

EA Engineering, Science, and Technology, Inc., PBC (EA) has been contracted by Naval Facilities Engineering Command (NAVFAC) Northwest under Contract No. N44255-20-D-6006, Task Order N4425520F4125 to conduct long-term monitoring consisting of periodic monitoring, inspections, and maintenance of the Site 10 North End Landfill. Components of the SPS (geogrid integrity, geogrid vegetation, and erosion control structures) and landfill cap (integrity, vegetation, gas vents, drainage system, and perimeter road) were inspected on July 6, 2020. The inspection work was performed and documented using inspection forms in accordance with the requirements set forth in the Final Site 10 Operation and Maintenance Plan (Department of the Navy [DON] 2016a). Completed inspection forms are included in Appendix A.

The following inspection and maintenance elements are discussed in this report:

* SPS inspection findings and maintenance (Section 2)
* Landfill cap and ancillary systems inspection findings, maintenance, and land-use control (LUC)/institutional controls (ICs) inspection findings (Section 3)
* Beach erosion inspection findings and elevation survey beach transects (BT) (Section 4)
* Recommendations (Section 5)
* References cited in this document (Section 6).

The appendices to this report are:

* Appendix A, completed 2020 inspection forms
* Appendix B, historical photographs from June 2008 to June 2020 and photographs from this inspection (July 2020) for comparison
* Appendix C, current and historical beach transect survey data; and
* Appendix D, LUC checklist for NAVMAG Indian Island and an IC checklist for the Site 10 North End Landfill.

Figure 1-1. Vicinity Map

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# Shoreline Protection System

The SPS was designed and constructed in 1996/1997 along the toe of the landfill cap to protect the landfill cap system from erosion caused by wave action. The SPS runs the length of the landfill cap and is divided into three zones based on wave energy: a high-energy zone; a low-energy zone; and a very-low-energy zone. The SPS, shown in Figure 2-1, consists of a series of vegetated geogrids reinforced with armor rock in the low-energy and high-energy zones. An anchored log-revetment system was formerly located in the high/low-energy transition zone and in the low-energy zone further to the west. Repairs to the SPS since its construction have included extending the high-energy zone armor rock westward. As a result of these repairs, the high-energy zone armor rock now extends onto the area of the beach previously protected by the former log-revetment system. SPS enhancements completed in June 2019 (DON 2019a), included placing additional armor rock onto the shoreline between BT-8 and BT-10, and extending the armor rock westward beyond BT-10 as seen in Photographs 14 and 15 (Appendix B), and Figure 2‑2.

The semiannual inspection of the SPS was conducted in July 2020 in accordance with the Operations and Maintenance (O&M) Plan (DON 2016a). The survey BTs, shown as BT-1 through BT-11 in Figure 2-2, were developed for periodic elevation surveys as established in the original O&M Plan (Foster Wheeler 1997), and modified during the beach repair of 2003 (Tetra Tech 2004). Inspection results are discussed below. Beach erosion inspections are discussed in Section 4.

## Geogrid Conditions and Integrity

The geogrid was visually inspected by walking along the top and the base of the entire length of the geogrid. Geogrid lifts were visually inspected at each survey BT line location (Figure 2-2), and at any other location where visual indications warranted traversing (walking up and down) the geogrid layers and the dense vegetation covering the geogrid lifts. The 13 survey BTs, shown as BT-1 through BT-11 in Figure 2-2, were developed for periodic elevation surveys as established in the original O&M Plan (Foster Wheeler 1997), and modified during the beach repair of 2003 (Tetra Tech 2004). During the 2012 (DON 2012a), 2013 (DON 2013), and 2014 (DON 2015a) inspections, evidence of minor erosion at the top of the armor rock revetment and below the geogrid was observed in areas approximately 10 feet in length southwest of BT‑7.5 and just east of BT-5. These areas are now covered with vegetation that extends to BT‑3.

In general, the structural integrity of the geogrid was good and no visual evidence of settlement or soil piping (seep-caused erosion) was observed. Some sections of the geogrid, ranging from 2 to 15 feet in length and 7 to 10 inches in height, are exposed above the armor rock. Undercutting was observed in several locations. Exposure mainly consisted of missing topsoil on top of the geogrid and hollowing of soil inside of the geogrid. Inspection observations were as follows:

* A roughly 4- to 5-foot length of geogrid is exposed at BT-1 and mild slumping was observed to the east, most likely caused by overhanging vegetation (Photograph 37).
* A roughly 2-foot length of geogrid was exposed to the northwest of BT-2 (Photograph 38).
* A 10- to 15-foot length of exposed geogrid was observed between BT-7 and BT‑8.
* Exposed geogrid was observed for most of the distance between BT-8 and BT-10 (Photographs 39-41).

## Geogrid Vegetation

A wide variety of planted native vegetation appeared to be thriving on the geogrid top as well as at each geogrid lift. The planted species at the top of the geogrid were observed to be in good health. Plants doing well include the Nootka rose (*Rosa nutkana*) and American dune grass (*Elymus mollis*), with healthy stands scattered across the top of the geogrid. Healthy stands of American dune grass were also observed at the upland beach of the low-energy zone above the former log revetment system, as well as at parts of the quarry spall bench at the high-energy zone. These findings are consistent with the 2005 through 2019 observations (DON 2019a). This is an indication that the dune grasses are continuing to thrive and colonize the aggrading beach sediment along the low-energy zone at a sustainable rate.

The willows (Scouler [*Salix scouleriana*] and Hooker [*Salix hookeriana*]) planted on the geogrid lifts appear to be healthy. Many of the willows have reached a height of well over 15 feet, as can be seen in many of the photographs in Appendix B.

Figure 2-1. Site 10 North End Landfill, Components of the Landfill Cap and Shoreline Protection System

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Figure 2-2. Site 10 North End Landfill, Survey Transect Locations

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## Invasive Weed Control Maintenance

Invasive shrub and herbaceous weed species can replace the native vegetation and pose a threat to the integrity of the geogrid. Inspectors found that invasive species were not prevalent on the quarry spall bench on top of the armor rock within the high-energy zone. One scotch broom was observed behind BT-3 near the Landfill Perimeter Road.

Varieties of other plants were present on the top lift of the geogrid with the prevalent species being common yarrow (Achillea millefolium L.) and hairy cat’s ear (Hypochaeris radicata L.). These species are considered weeds in domestic lawn environments but not in natural settings. These plants have not been removed since 2006 because they pose no threat to the geogrid integrity and are compatible with the natural site setting or site bioengineered vegetation.

Another native species planted at the site during construction of the geogrid is the entire-leaved gumweed (*Grindelia integrifolia*); a yellow-flowered plant that commonly occurs along rocky shores and salt marshes in marine shoreline habitats throughout the northwest region. Although this plant has a relatively substantial woody taproot, it does not pose a significant risk to the integrity of the cap or the erosion control elements and has been left in place. It occurs primarily around the outside of the perimeter road.

The problem weeds (lupine, Scotch broom, Himalayan blackberries, thistle, and small trees and shrubs) were manually removed (cut or pulled) from the landfill cap and perimeter areas during the inspection. In accordance with NAVMAG Indian Island Environmental directives, the vegetation was disposed of at a dump located on base along Bone Yard Road.

## Armor Rock Section

The original armor rock section was constructed in 1996 and extended from just before BT-2 to just beyond BT-7. The armor rock has been bolstered and extended six times since its installation and currently extends from between BT-1 and BT-2, to between BT‑10 and BT-11. Figures 2-1 and 2-2 show the approximate limits of the 2003, 2012, 2014, 2016, 2017, and 2019 rock rework and placement.

The armor rock was first extended approximately 55 feet westward toward the low‑energy zone through the transition zone in September 2003 (Tetra Tech 2004). Subsequent to that repair, between 2008 and 2010, erosion from waves breaking over the west end of the armor rock at the high/low-energy transition zone during high tide events, significantly eroded the soils surrounding the wellhead of groundwater monitoring well MW10-12, exposing most of the concrete seal (Photographs 1 and 2). The Summer 2011 inspection revealed that erosion had entirely exposed the monument, the concrete well seal, and a few inches of the PVC casing below the concrete seal (Photograph 3). On July 15, 2011, well MW10‑12 was decommissioned and on November 19, 2012, replacement well MW10-12R was installed at a nearby location, adjacent to the BT-8 survey marker at the top of the geogrid along the northern margin of the landfill perimeter road (DON 2012b).

During the Summer 2012 inspection, an approximately 3 feet wide by 3 feet deep section of undercutting of the lower embankment, just down-slope from the geogrid and extending up to the lowest lift of the geogrid, was observed at BT-8, a few feet east of former well MW10-12. In Fall 2012, NAVFAC Northwest extended the armor rock approximately 80 feet further to the west of the existing armor rock (i.e., approximately the mid-point between BT-8 and BT-9). This armor rock was added to bolster the lower embankment below the geogrid, thereby preventing further erosion of the lower embankment and/or geogrid at that location.

The armor was again bolstered and extended during June 2014 (DON 2014a, 2014b; and Photograph 4). The 2014 extension consisted of the addition of 3- to 4‑man rock near BT-8 and 2- to 4-inch quarry spall between BT-8 and BT-9. Some of the rocks placed in the high/low-energy transition zone in 2012, were moved in 2014 to more effective protective positions and additional armor rock and quarry spalls were added to protect against erosion. The quarry spalls added in 2014 have continued to move out of the armor rock to the north and west. No significant movement of the 4-man armor rock placed at BT-8 was evident; however, some of the smaller 2- to 3-man rock and much of the quarry spall between BT-8.5 and BT-10 moved downward to the beach from the locations observed in June 2015.

Based on observations during the June 2016 inspection, the Navy performed a shoreline repair in June 2016 to reinforce the existing armor rock between BT-8 and BT‑10. The repairs are shown in Photographs 5 and 6 and are documented in the Landfill and Shoreline Protection System Inspection Report for the June 2016 inspection and maintenance event (DON 2016b).

During the Winter 2016 inspection (DON 2017a), shifted rocks and undercutting were observed in the lower embankment below the lowest geogrid just west of where the low-energy shoreline armor rock ended between BT-9 and BT-10 (Photographs 7 and 8). In July of 2017 (DON 2017b), the undercut area extended approximately 35 feet parallel to the shoreline and was undercut to a maximum depth of 3 feet (Photograph 9). At that time, it was also noted that some of the armor rock between BT-8.5 and BT-10 had shifted, exposing small areas of beach between and below the rock (Photograph 10). Following the Summer 2017 inspection, NAVFAC Northwest extended the armor rock approximately 80 feet further to the west of the existing armor rock, to approximately BT‑10. The 2017 repairs are shown in Photographs 11 and 12.

During the Summer 2018 inspection (DON 2018a), the armor rock was observed to be in generally good condition; however, some of the rock placed in 2017 appeared to have shifted slightly resulting in gaps between the rocks between BT-9 and BT‑10. An erosional scarp had also developed between BT-10 and BT-11 (Photograph 13). Additionally, near BT‑2, some of the armor rock had migrated down the beach, exposing the geogrid mesh in the lower geogrid lifts in this area. Scattered quarry spalls and larger rocks were also observed to have migrated downslope between BT-5 and BT-7.5.

Based on observations made during the Summer 2018 inspection, the DON bolstered the armor rock in two places in June 2019 (DON 2019a). Approximately 211 tons of 3- and 4-man rock was added to the armor rock between BT-8 and BT‑11, and approximately 16 tons of 1- and 2-man rock was added between BT-1 and BT-2 (Photographs 14 and 15, respectively) as detailed in the Final SPS Enhancements Completion Report (DON 2019a).

During the Summer 2020 inspection, large gaps over 1 foot long were observed in the armor rock section between BT-8 and BT-11 (Photograph 34). Wave erosion appears to have removed/migrated large rocks in front of BT-7.5 and BT-8.5 and caused slight scouring of the shoreline.

## Log Revetment and Anchor System

The anchored log revetment system was originally placed in 1996 between BT-7 and BT-11 to protect the geogrid until the planted vegetation had become well established. Shoreline vegetation is now thriving. Therefore, the log revetment is no longer a required part of the remedy. Nearly all of the original the log revetment system has been covered by armor rock since the logs were placed.

Numerous abandoned anchors remain in place on the lower part of the beach. Anchors were either broken off or bent downward into the beach during the June 2014 maintenance and construction work. However, tidal processes have exposed some remaining anchors in beach areas between BT-10 and BT-7. Attempts were made to bend the anchors downward into the beach again during the June 2019 construction and maintenance work. EA inspected the former log revetment system area during low tide on July 6, 2020. The revetment system had one remaining log that appeared anchored between BT-10 and BT-11. The remaining logs have deteriorated to the point where they no longer serve a protective function. The most severe undercutting was observed behind the deteriorated logs between BT-9 and BT-11 (Photographs 31 through 33).

Only four broken and/or deteriorating logs were located between BT-8 and BT-11. The unanchored logs found in this area were likely deposited there during storms (recruited logs), as noted in previous inspection reports (DON 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012a, 2013, 2015a, 2015b, 2016b, 2017a, 2017b, 2018a, 2018b, and 2019b). During the June 2019 construction, some of the logs were temporarily moved to allow access to the upland end of the beach where there was an incipient erosional scarp. Following rock placement against the scarp between BT-10 and BT-11, the logs were replaced in front of the armor rock. Some sand deposition was observed around some of the logs between BT-10 and BT-11 (Photograph 36). This accretion appears to be shifting the large rocks in the armor wall away from the shoreline.

# Landfill Cap and Ancillary Systems

The semiannual inspection of the landfill cap and ancillary systems was conducted on July 6, 2020. Inspection results are discussed below. The overall physical condition of the landfill system is good. The cap itself required very minor weed removal consisting mostly of lupine, blackberry, thistle, and Scotch broom.

## Landfill Perimeter Road

The landfill perimeter road (Photographs 42 and 44) was observed to be in good condition. Several shallow (less than 4 inches deep) potholes were observed and documented on the perimeter road during inspection (Photograph 44). The potholes were not impeding access or affecting drainage. The road had sufficient gravel and there was no evidence of erosion on the road surface or improper drainage. An area of incipient rutting was noted along the inside of the east corner of the perimeter road. This is likely a result of rock delivery trucks for the June 2019 SPS enhancements not being able to navigate the tight corners while keeping their tires entirely on the perimeter road. Unless conditions are hampering access of security vehicles, no maintenance or repairs are currently required. Invasive species such as scotch broom and blackberry bushes were removed from the outer side of the perimeter road to prevent further growth onto the landfill cap. Several scotch brooms were removed from the perimeter road by the western half of the landfill.

## Landfill Drainage System

The landfill drainage system, consisting of high-density polyethylene (HDPE) culverts, concrete bypass culverts, and reinforced concrete pipe (RCP) storm drainpipes, was observed to be in good condition with no maintenance or repairs required at the time of the inspection.

### HDPE Culvert and Associated Bypass Culvert

The culverts were observed to be in good condition; the bypass culvert outfall was clear with grass upstream of the entrance. There was no evidence that the grass in the drainage swale was impeding the flow of water through these culverts. The grasses are most likely functioning as a bioswale. Photograph 45 depicts the flared end transition between the HDPE weir and the bypass pipe located in the swale along the southeast margin of the perimeter road. Mild sediment buildup was removed from the flared end transition. No repairs were required at the time of the inspection.

### RCP Storm Drain System

The RCP storm drain system, shown on Figure 3-1, was observed to be in good condition. RCP drain #6 located along the northeastern margin of the landfill cap was plugged with concrete in 2006. There was no apparent evidence that the remaining stormwater drains originating from the landfill cap perimeter ditch were impeded by vegetation or debris in any way. No repairs appeared to be warranted.

Photographs 46 and 47 depict the east and west ends, respectively, of the 24-inch culvert beneath the landfill access road near the parking lot. The culvert and ends were free of significant debris or vegetation that might otherwise restrict the flow of stormwater beneath the roadway. No other maintenance or repairs were required at the time of the inspection.

## Landfill Gas Collection System

The landfill gas collection system was observed to be in good condition, with no cracking or separation at the connection between the vent-pipe boot and concrete. Vent-pipe bird screens were inspected and found to be clean. There was no significant encroachment of weeds around or within the gas vent enclosures. No other maintenance or repairs were required at the time of the inspection.

## Water Supply Line and Irrigation System

The water supply line for the landfill cap and the temporary irrigation system for the geogrid of the SPS are not active. The irrigation system was disconnected in 1999 after it was damaged by freezing (Foster Wheeler 2000).

## Hillside and Access Road

The hillside and access road were in good condition with no rutting or potholes (Photographs 48 and 49). Slight sloping to the south east was observed on the access road. The hillside slope was mostly constant. No tension cracks, or seepage were observed on the hillside. No maintenance or repairs were required at the time of the inspection.

Figure 3-1. Site 10 North End Landfill, Stormwater Drainage System Components

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## Landfill Cap

Inspection of the landfill cap consisted of systematically walking the length of the landfill cap back and forth in a generally southeast-northwest oriented direction, and along the perimeter of the landfill drainage ditch. During the July 2020 inspection, the landfill cap was observed to be in good structural condition with no sunken or depressed areas. No moisture or standing water was observed on the surface of the landfill cap during the inspection.

During July 2008, an area on the central to eastern portion of the landfill cap had been disturbed where several inches of soil had been placed along with several wooden Caspian Tern decoys as part of a Caspian Tern nesting project. As noted in the 2009 through 2014 inspections, vegetation in the form of grasses, flowers, and weeds had generally reestablished itself on the disturbed surface of the landfill cap (DON 2009, 2010, 2011, 2012a, 2013, 2015a).

### Vegetation

The landfill cap vegetation appeared to be in good condition. The entire cap is covered with various species of grasses and weeds ranging from a few inches to approximately 20-34 inches in height (Photographs 50 and 51).

In general, the landfill cap was firm, and no excessive moisture was observed on the cap surface during the inspection. One lupine and several Nootka rose plants were found on the western to central side of the cap. No gumweed plants were observed in perimeter areas of the landfill cap, but as discussed earlier, gumweed is not considered invasive to the landfill cap. The common hairy cat’s ear and common yarrow were prevalent, but these pose no threat to the cap integrity. California poppy, which is not listed by either the Jefferson County or Washington State Noxious Weed Control Boards, was also distributed sparsely around the edge of the cap. Although regularly scheduled mowing of the landfill cap would likely provide a more cost-effective control for the weeds, it has been noted in the past that mowing often encourages the undesirable practice of driving motorized vehicles on the landfill cap. Therefore, future weed control will consist primarily of weed cutting and pulling.

### Maintenance

All vegetation that posed a threat to the landfill cap was removed. All lupine, blackberry vines, alder and fir seedlings, thistle, and Scotch broom encountered were removed from the cap. One and a half pickup-truck loads of weeds were removed from the site (landfill cap, drainage system, and geogrid) and transported to an activity-identified, on‑base vegetation waste disposal area off Bone Yard Road.

## Subgrade Inspection

Inspection of the subgrade of the landfill cap was not conducted due to the absence of any observed surface cracks or other evidence of settling or damage.

## Land Use Controls and Institutional Controls Inspections

LUC and IC inspections were conducted on July 6, 2020 for NAVMAG Indian Island (LUC) and the Site 10 North End Landfill (IC), respectively. Completed LUC and IC inspection checklists are included in Appendix D. The inspections revealed that LUC and IC requirements were appropriately implemented and were effective.

Two warning signs located along the beach perimeter were inspected. Both signs have been replaced since the Summer 2019 inspection and were in good condition. The warning text has been changed from “Warning. U.S. DON Property Restricted Area. Keep Out. No Landing of Boats” to “Warning. Restricted Area. Keep Out. Authorized Personnel Only” (Photographs 29 and 30).

# 

# Beach Erosion Inspection and Transect Surveys

Beach erosion inspections were conducted on July 6, 2020, during low tide events to enable the inspections to extend to the lower portions of the beach. Beach erosion inspections are conducted annually to determine whether erosion or deposition is occurring on the beach below the landfill and how this may affect the integrity of the remedy. This included a visual inspection and a detailed topographic survey of the beach and the site from each transect to identify changes from previous inspections.

During an inspection on March 6, 2018, following a storm event, a small erosional scarp approximately 15 feet long and 1 foot high in the lower embankment just above the beach and situated approximately halfway between BT-10 and BT-11, was observed. This scarp was repaired, and this area protected during the June 2019 SPS enhancements.

In early June 2019, two weeks prior to the beach erosion inspection, SPS enhancements were completed that added approximately 211 tons of 3- and 4-man rock to the armor rock between BT-8 and BT-11, and approximately 16 tons of 1- and 2‑man rock between BT-1 and BT-2 (DON 2019a). Additionally, rocks that had become displaced from their original locations were reworked back into the armor rock. Because of this rock placement and rework, the beach and embankment surrounding the geogrid did not show evidence of erosion during the Summer 2019 inspection. Photographs taken during the inspection are included in Appendix B.

In addition to areas with exposed geogrid mesh near BT-1, BT-2, and BT-7 through BT‑10, discussed in Section 2-1, the beach and embankment surrounding the geogrid showed evidence of mild erosion. Inspection observations were as follows:

* As previously mentioned, several gaps in the armor wall were found in front of BT-7.5 and BT-8.5 and severe undercutting was noted in front of BT-10 and BT‑11. Undercutting between BT-9 and BT-10 was measured to be a maximum of 7 inches deep.
* Undercutting approximately 5 to 7 inches deep was observed behind supporting logs between BT-10 and BT-11 (Photographs 31 through 33).
* Wave action appears to have eroded out scoops in the armor wall in front of BT‑7.5 and BT-8.5.
* Undercutting between BT-9 and BT-10 was measured to be a maximum of 7 inches.

## Beach Transect Elevation Survey

The annual survey of the geogrid, lower embankment, and beach areas along transects BT-1 through BT-11, was conducted on July 6 and 7, 2020. Data obtained during the survey were used to create BT elevation profiles (i.e., cross sections) for comparison to previous elevation surveys to determine elevation change (erosion or deposition) over time.

A RL-H4C Electric Level was used to survey horizontal and vertical points along each beach transect. The RL-H4C differs from the Trimble TS215 total station used in previous years. Survey elevations were tied into the survey markers located at the upper end of each survey transect shown in Figure 2-2. These markers served as the starting point for each survey profile.

The 2020 BT profiles were compared to those of previous years to evaluate if long-term changes (deposition and/or erosion) are occurring in response to the establishment of the Site 10 North End Landfill SPS. Elevation changes along each BT are summarized below. The elevation profiles for 2019 and 2020 are shown in Figures 4-1 and 4-2 while a more robust graphical comparison including BT profiles for 2009, 2015, 2016, 2017, 2018, 2019, and 2020 is provided in Appendix C.

* Profile BT-1 shows no significant changes in the area of the geogrid. From 2009 to 2016, there was significant deposition beyond approximately 80 horizontal feet (hf). This change most likely reflects a periodic migration of the sand bar extending northeast from the northeast shoreline of the landfill between BT-1 and BT-3. From 2016 to 2018, there was approximately 1 foot of accretion between approximately 20 hf and 40 hf. Since 2018, approximately half of this accretion has been eroded. The sand bar appears to have migrated approximately 1 foot southwest since 2018. The remainder of profile BT-1 is unchanged since 2016. Figure 4-1 shows the erosion between 20 hf and 40 hf.
* Profile BT-2 shows no significant changes in the area at the base of the geogrid out to approximately 35 hf. From 10 hf to 20 hf, the increase in the height of the profile reflects the addition of new armor rock added in early June 2019 (DON 2019a) to cover exposed geogrids in this area. At the same time, displaced rocks from the upper beach were pulled from the beach and added to this area, resulting in a lowering of the profile. Beyond approximately 35 hf, from 2009 to 2016, there was between 3 and 4 feet of erosion; likely reflecting the migration of the same sand bar noted at BT-1. Since 2016, there has been little change in this area. Figure 4-1 clearly shows where new rock was added, and existing rock moved from upper beach to the lower geogrid.
* Profile BT-3 shows no significant changes over time either on the geogrid or along the remainder of the profile. Between approximately 62 hf and 102 hf, there has been a gradual lowering of the profile, totaling less than 1 foot, since 2009. The 2020 data line position most likely reflects the difference in surveying gear used and not an actual rise in elevation as no accretion was noted in the field. Since 2016, there have been no significant changes in the profile. Figure 4-1 shows changes of up to 2 feet in the armor rock since 2018, which most likely represents different measuring points along the transect over time. Beyond the armor rock, the overall profile has changed little since 2018.
* Profile BT-4 shows no significant changes in the geogrid or along the remainder of the profile over time. The overall profile has changed little since 2009.
* Profile BT-5 shows no significant changes in the geogrid or along the remainder of the profile over time. Figure 4-1 shows areas at approximately 27 hf and 40 hf where the 2019 and 2020 profiles are between one and two feet lower than the 2018 profile. The 2019 and 2020 profiles in this area are much closer to the 2009, 2016, and 2017 profiles. Closer inspection of the armor rock in these areas revealed no apparent shifts in the armor rock, suggesting that these changes likely represent different measuring points along the transect over time.
* Profile BT-6 shows no significant changes in the geogrid or along the remainder of the profile over time. The rise in elevation at 35hf and 45 hf is most likely from different measuring points along the armor rock. The overall profile has changed little since 2019.
* Profile BT-7 shows a slight decrease in elevation at 70 hf. This dip is most likely due to natural sand scouring with tidal changes. Beyond this area there are no significant changes in the geogrid or along the remainder of the profile over time. The overall profile has changed little since 2019.
* Profile BT-7.5 shows no significant changes over time in the area of the geogrid. From 2009 to 2016, there was little change in the profile beyond 35 hf. Since 2016, the profile beyond 35 hf is lower by approximately 0.75 foot to 1 foot. The overall profile has changed little since 2019 (Figure 4-2).
* Profile BT-8 shows no significant changes in the area of the geogrid. Small changes observed in profile BT-8, between approximately 10 to 20 hf, reflect variations in the placement of the survey rod in the area of the armor rock, not a shifting of the armor rock itself. Since 2015, the profile beyond approximately 40 hf is mostly unchanged. A small increase in elevation around 120 hf, also seen in BT-8.5, could indicate an increase in sand being removed from the shoreline in front of BT-8. Since 2016, there have been several large recruited logs located above the beginning of the armor rock between approximately 15 hf and 23 hf. The overall profile has changed little since 2019.
* Profile BT-8.5 shows no significant changes in the area of the geogrid. The addition of new rock and placement of displaced rock back onto the armor rock during early June 2019 is clearly seen between 19 hf and 30 hf. From the top of the geogrid to 19 hf, there is no significant change from 2016 to 2020 along this profile. Observed changes reflect varying measurement locations along the profile from year to year. Since 2015, there has been a gradual lowering of the profile, up to 9 inches, from approximately 28 hf to 70 hf. A large sand deposit from 75 hf to 103 hf documented in 2016 appears to have moved beyond the limits of the survey. Figure 4-2 shows the addition of rock at the base of the armor rock since 2018. Beyond the armor rock, the overall profile has changed little since 2019.
* Profile BT-9 shows no significant changes in the area of the geogrid. The addition of new rock and placement of displaced rock back onto the armor rock during early June 2019 (DON 2019a) is clearly seen between approximately 24 hf and 30 hf. From 2015 to 2020, beyond the current toe of the armor rock, there has been up to 2 feet of erosion between 30 hf and 45 hf. Beyond 45 hf, the profile has changed little since 2015. Observed changes reflect varying measurement locations along the profile from year to year. Figure 4-2 shows that except for the area where new rock was added, the overall profile has changed little since 2018.
* Profile BT-10 shows no significant changes in the area of the geogrid. From 2015 to 2020, beyond the current toe of the armor rock, there has been 2 feet of erosion at 30 hf tapering down to less than 1 foot at 70 hf. Beyond 70 hf the profiles are unchanged. In 2016, there was a sand wave between 48 hf and 63 hf. In 2017, this sand wave had migrated beyond the limit of the survey. The 2019 increase in elevation from 18 hf to 35 hf suggests a difference in measuring points and likely shows the addition of new rock during early June 2019 placement at BT-10. Figure 4-2 shows the addition of rock in 2019 and the deepening of the profile since 2018 between 35 hf and 55 hf.
* At BT-11, there has been a gradual lowering of the profile beyond 55 hf since 2015. Beyond 100 hf the profile is 1 foot lower than it was in 2015. Figure 4-2, however, shows the overall profile has changed little since 2019.

The Site 10 O&M Plan (DON 2016a) section detailing beach erosion inspection states that “a net reduction of 6 to 9 inches in beach elevation over an area of 2,500 square feet that is sustained for multiple years” is an indicator that the beach is receding. The erosion at BT-7.5, BT-8.5, BT-9, BT-10, and BT-11 observed in the beach transect profiles over time indicates that both conditions of this criterion are being met.

Based upon observations and BT profile comparisons made during the 2019 inspections and BT surveys, none of the constructed SPS showed evidence of erosion. As previously discussed, the armor rock protecting the base of the geogrids in the low-energy zone between transects BT-7 and BT-11 has required periodic bolstering to prevent erosion of the lower embankment below the geogrids. The armor rock has been extended westward several times, most recently in 2019 (DON 2019a). While this armor rock has been successful at protecting the geogrids, it may be responsible for the general lowering of the beach profile seaward of it between transects BT-8 and BT-11.

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Figure 4-1. 2019 and 2020 Profile Beach Transects 1-7

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Figure 4-2. 2019 and 2020 Profile Beach Transects 7.5-11

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# Recommendations

Standard maintenance operations and inspections should continue as specified in the O&M Plan (DON 2016a). If necessary, a single storm-event inspection should be conducted on an as-needed basis (ideally, immediately following a severe storm occurring at high tide). Weed removal on the cap should continue to focus on herbaceous vegetation; shrubs and trees; weed species such as lupines, thistles, Scotch broom, red alder, madrona, and fir; and other identified invasive large-rooted weed species that may dominate the cap vegetative cover and damage the cap liner.

No mowing should be performed on the top of the geogrid. Invasive weeds such as thistles, teasel, Scotch broom, blackberry, madrona, and red alder should be removed from the landfill cap and adjacent areas, but other species should be left undisturbed. Subcontractors responsible for mowing at NAVMAG Indian Island should be made aware that mowing should not be conducted on the landfill cap.

The perimeter road should continue to be evaluated to determine whether road maintenance including grading and/or filling should be scheduled.

The shoreline protection log-revetment anchor system is no longer functioning and most of its original extent is now protected by armor rock. As recommended in past inspection reports, although the log revetment system no longer requires inspection, beach erosion surveys of this area should continue during annual inspection events and appropriate erosion mitigation/repair actions taken to ensure that significant erosion that could undercut the geogrid does not occur.

Abandoned anchors from the log revetment system remaining on the beach pose tripping hazards, especially for workers performing armor rock maintenance or routine inspections. Since they no longer perform a useful function, these anchors should be removed.

The addition of rock to the base of the geogrid in exposed areas is recommended to protect the geogrid and enhance the effectiveness of the SPS. Some of the rocks have migrated downward to the beach in the low and high energy shoreline protection system areas. It is recommended that future maintenance involve placing migrated rocks back in their original location.

Changes in the beach profile in the armor rock section of the SPS are not always apparent due to the variation of measuring points from year to year along a given beach transect. Painting three to four of the larger and presumably more stable rocks along each beach transect and returning to those rocks each year to monitor elevation changes will yield more comparable results and allow for a more accurate determination of change in the profile.

Some beach areas below the armor rock and lower embankment continue to erode from BT‑7.5 to BT-11. NAVFAC Northwest has considered long-term erosion abatement plans and, to that end, conducted engineering investigations of the beach during 2013. Details of those investigations, along with findings and recommendations, are documented in the SPS Repair Design Recommendation Report (Resolution Consultants 2013).

Based on the criterion provided in the Site 10 O&M Plan (DON 2016a), the beach from BT-7.5 to BT-11 is receding. BT-1 through BT-11 should be surveyed annually during a spring or summer low tide to fully document any changes occurring in the beach or SPS. Photographic documentation of the SPS at key areas (which has occurred during each inspection) provides decision makers with a better understanding of current conditions and erosion processes affecting the SPS over a period of several years. Therefore, continuation of photographic documentation is recommended to evaluate and monitor this system.

Future beach survey transects along BT-11 should begin at the most inland survey hub with an elevation of 7.04 feet. This hub location and elevation should be incorporated into the next revision of the Site 10 O&M Plan.

Future beach and landfill cap surveys should be conducted using an electronic total station. The O&M Plan (DON 2016a) specifies an interval of five feet between elevation measurements for beach transect surveys. Landfill cap surveys should also be conducted using this interval.

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APPENDIX a

COMPLETED INSPECTION FORMS

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APPENDIX B

INSPECTION PHOTOGRAPH LOG

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APPENDIX c

Current and historical BEACH transect survey data

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APPENDIX D

land use controls and institutional controls checklists

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