U.S. Army Corps of Engineers
Charleston District

APPENDIX I

CHARLESTON HARBOR POST 45

CHARLESTON, SOUTH CAROLINA

Hardbottom Resources

03 October 2014

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1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE) is currently conducting a feasibility study for the expanding the navigational channels of Charleston Harbor. As a result of deepening and/or extending the navigation channel beyond its current, authorized depth of 45 feet, areas that were not previously directly impacted along the margins of the channel and further offshore would be affected. Specifically, hardbottom habitats in these areas would be impacted. As described in the Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267), the EFH provisions of the act support the nation's overall marine resource management goal of maintaining sustainable fisheries. The focus of the mitigation policy is to conserve and enhance EFH, and to avoid, minimize, or compensate for impacts to EFH due to development activities. A habitat equivalency analysis ("HEA;" explained below) has been prepared in order to develop a comprehensive mitigation plan that adequately offsets the ecological value of impacts. One candidate mitigation plan (i.e., the one used for evaluation in the HEA) includes the use of limestone material from the entrance channel to construct mitigation reefs along the margin of the Entrance Channel. This constructed hardbottom habitat will support a wide variety of invertebrates and fish species.

2.0 HABITAT EQUIVALENCY ANALYSIS (HEA) OVERVIEW

Ray (2008) noted that the focus of habitat restoration has evolved from simply replacing the physical *area* (i.e. acreage) of lost or damaged habitat to replacement of lost ecological *services* (e.g., functions and values). This change in perspective recognizes that not all parcels of habitat are of equal quality or yield the same quantity of services. A number of different techniques have been developed that can assist in estimating the appropriate amount of habitat to restore, including the Habitat Evaluation Procedure (HEP) (U.S. Fish and Wildlife Service 1980) and functional analysis based on hydrogeomorphic classification of wetlands, i.e., "HGM" (Smith et al. 1995). Unfortunately, these methods are specific to individual habitat types and may not be readily applicable to different spatial scales, especially in the marine environment. Estimates of precisely how much habitat should be restored (i.e., the replacement or mitigation ratio) have often been based primarily on value judgments and, as a result, have varied widely (Fonseca et al. 2000).

HEA can be used to scale (i.e., determine the appropriate quantity of) the compensatory mitigation measures that will be recommended for a project (King and Adler 1991). Compensatory mitigation is intended to replace the ecological services that are lost as a result of unavoidable impacts to resources affected by the project. Ecological services refer to the services performed by a resource for the benefit of other resources or the public, such as the provision of food and refuge for fish populations. The baseline for quantifying lost ecological services is the full complement of services that would have been provided absent project implementation. Lost ecological services are quantified as the reduction in the provision of services below this baseline.

It is important to supply compensatory mitigation commensurate with the type, level, and duration of lost services. The amount of compensatory mitigation needed to replace lost services depends, in part, on the ability of the affected resources to return to their baseline conditions. Factors relevant in that regard include the quantity of affected resources and how fast and how completely they return to their baseline conditions. The amount of compensatory mitigation also depends on the ability of the selected compensatory mitigation measures to replace lost services. Relevant factors for replacement include how fast the compensatory mitigation measures become fully functional, and the relative degree to which they provide additional ecological services.

HEA is specifically used in cases of habitat injury when the service of the injured area (prior to impact) is ecologically equivalent to the service that will be provided by the replacement habitat. This approach is termed “service-to-service” (Strange 2002) and assumes the public is willing to accept a one-to-one trade-off between the service lost and the service gained by the restoration (NOAA 1997). Multiple types of injuries can be quantified in an equivalent manner through the use of HEA (Dunford et al. 2004). The HEA method has been successfully used to determine compensatory mitigation for vessel groundings on coral reefs (Milon and Dodge 2001), federal dredging projects (see below), and seagrass damage (Fonseca et al. 1998; Fonseca et al. 2000).

King and Adler (1991) first described HEA as a methodology for calculating compensatory mitigation under Section 404 of the Clean Water Act. A more recent description of the methodology can be found in Allen, Chapman, and Lane (2005). Briefly, HEA scales (calculates, based on quantitative input and output) compensatory mitigation so that the total quantity of ecological services it provides is sufficient to offset the total quantity of lost ecological services resulting from the project impacts. When quantifying ecological services, it is important to note that services have a temporal dimension as well as a geographic dimension (e.g., a given area of coral habitat provides beneficial services over a period of time). Therefore, ecological services are quantified in HEA as units of measure such as acre-years. An acre-year refers to all the ecological services provided by one acre of habitat for one year. For example, 100 acre-years of services might be provided by one five-acre habitat over a period of 20 years, or by a ten-acre habitat over a ten-year period. This characterization captures not only the important aspect of the physical size of a resource, but also the fact that the period of time it continues to function is important as well.

The structure of HEA is relatively simple. Calculations of how much habitat to restore or replace are based on estimates of the total loss in services supplied by the damaged or lost habitat. Total loss is estimated from the degree of initial damage to the resource and the loss in service that occurs during the time between the initial damage and when the restored or replaced habitat becomes fully functional. Three critical pieces of information are necessary to make these calculations: (1) the nature of the service that has been damaged, (2) the extent of the initial damage, and (3) the rate at which recovery is likely to occur (Ray 2008).

This measure of ecological services is obviously specific to habitat, since different habitats provide different services. Therefore, it is important to select compensatory mitigation measures that *provide replacement services that are comparable to the lost services* (i.e., in-kind replacement). If that is not possible, some meaningful adjustment must be made to equate the replacement services to lost services (keeping the service-to-service approach in focus, as mentioned above).

Through this process of quantifying ecological services, HEA takes into account losses and gains that occur over different (damage and recruitment) timeframes to determine a scale of compensatory mitigation that is commensurate with the type, level, and duration of lost services. Because HEA accounts for all these important aspects, different compensatory mitigation projects will generally have different scales. For example, a compensatory mitigation project that becomes fully functional in five years will have a smaller indicated scale than one that requires ten years to become fully functional. Therefore, it is important that the compensatory mitigation projects selected for analysis be chosen carefully. HEA is not used to *select* compensatory mitigation projects, only to determine their scale.

Habitat equivalency analysis is specifically designed to determine the compensation the public is due to reconcile injuries to the ecosystem and the lost services the ecosystem provides to the biotic component. King (1997) noted, "when injured resources and/or services are primarily of indirect human use, the appropriate basis for evaluating and scaling the restoration is HEA." The public is considered to have been made whole for ecological losses when the scale of restoration needed to offset losses of resources and services is achieved. HEA establishes the service acre-year as the “common currency” for comparison of the public’s value of past injury and future restoration in a common time frame (Julius 1999). One “service acre-year,” as defined above, is one such “common currency.” The area of injured habitat, percent loss of ecological services, and duration of injury are considered in HEA to determine service acre-years (SAYs).

USACE and federal agencies (e.g., NOAA and USFWS) have agreed to the application of HEA for several federal navigation projects. Ray (2008) specifically describes the use of HEA by the Jacksonville District USACE for impacts associated with the Miami Harbor General Reevaluation Report and Final Environmental Impact Statement. He also summarized how HEA was used by the Honolulu District USACE for the Barber’s Point Harbor Modification, where plans included dredging and construction activities that would affect coral reef habitats including nearshore reef flats and reef-crest habitat. Currently, HEA is also being used by Jacksonville District to calculate impacts due to expansion of the federal project at Port Everglades, but its use is also common in other marine habitats. Peterson and Associates (2003) estimated the area of habitat necessary to replace unvegetated, estuarine bay bottom and the associated water column sacrificed as part of an expansion of the Craney Island Dredged Material Placement Area on the Elizabeth River, Virginia. HEA has also been used to scale restoration of salt marsh habitat damaged by failure of an oil pipeline at Lake Barre in coastal Louisiana (Penn and Tomasi 2002). HEA has also been used in other policy contexts involving the loss of ecological services. For example, it is widely used in natural resource damage assessments conducted under the Oil Pollution Act of 1990 (33 U.S.C. 2701 *et seq.*) and the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (42 U.S.C. 9601 *et seq.*).

When the approach described above is used for scaling losses of fish, birds, and other wildlife, the method is sometimes termed “resource equivalency analysis” (REA). REA is a resource-to-resource method that references the number of organisms lost and gained. NOAA has recently used the REA method to scale injuries to coral resources related to vessel groundings within the Florida Keys National Marine Sanctuary (FKNMS) by evaluating the losses only to the number of stony corals lost or injured and not the entire habitat affected. A similar approach was employed by NCRI (2003) for a cable injury to hardbottom resources in the vicinity of Hillsboro inlet in Broward County.

3.0 POST 45 PROJECT HARDBOTTOM DELINEATION AND IMPACTS

Hardbottom refers to a classification of coral communities that occur in temperate, subtropical, and tropical regions that lack the diversity, density, and reef development of other types of coral communities (SAFMC 1998). For the purposes of this investigation, hardbottom habitat is defined as exposed areas of rock or consolidated sediments, distinguished from surrounding unconsolidated sediments, which may or may not be characterized by a thin veneer of live or dead biota, generally located in the ocean rather than in the estuarine system. These hardbottom reefs are an important component of South Carolina’s offshore resources, which provide habitat and foraging grounds for a diverse array of invertebrate and fish species (Wenner et al. 1983; Sedberry and Van Dolah 1984). These communities support habitat-structuring sessile epifauna such as sponges (*Cliona spp., Ircinia campana, Haliclona oculata*), corals (*Leptogorgia virgulata, Lophogorgia hebes, Titanideum frauenfeildii*), bryozoans, and ascidians (Burgess et al. 2011; Van Dolah et al. 1997). Burgess et al. (2011) state that nearshore hardbottom habitat is typically patchy and surrounded by large expanses of sand, and that the reef organisms are often exposed to sediment movement resulting from winds, tides and storms.

Due to the structural complexity and more permanent nature of hardbottom habitat they are particularly important to fish and invertebrate species. Jaap (1984) states that fish comprise a major portion of the animal biomass on hardbottom and are important to the overall trophic structure. The fauna of hardbottom can be characterized by wrasses, damselfish, snappers, grunts, parrotfish, and sea basses. Closer inshore hardbottom support large numbers of temperate fish species, such as black sea bass, spottail, pinfish, and estuarine-dependent migratory species (Huntsman and Manooch 1978). Hardbottom habitat serves these species by providing refuge, spawning grounds, and nursery habitat.

For these reasons, it was important to document areas of hardbottom habitat and to determine how the various alternatives would impact any known habitat. In late 2012 through early 2013, Coastal Carolina University performed offshore surveys in support of cultural/historic and hardbottom resource investigation for the Post 45 study. This survey used side scan sonar, sub-bottom profiling, and magnetometer work coupled with ground-truthing via towed video transects. The survey mapping extended 75 m on either side of the entrance channel toe offshore and in the entire area proposed for channel extension (Figure 1). Details on this process can be found in the Cultural Resources Appendix of the Charleston Harbor Post 45 Feasibility Study. The study process was carefully coordinated with the resource agencies to ensure acceptability of methods. A draft of the report was provided for review and comment by the agencies and the final was made available in April 2013.

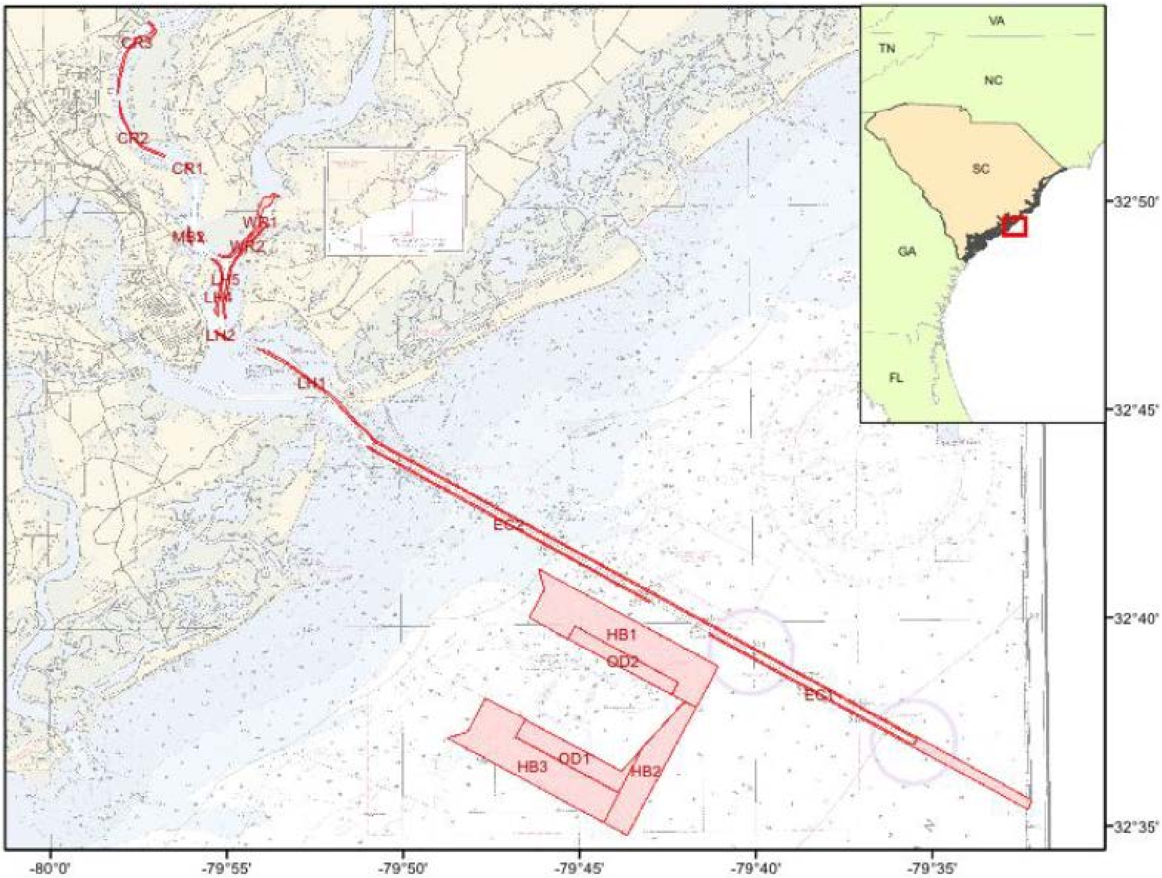

Figure 1. Vicinity of mapping corridors for hardbottom habitat in the proposed Charleston Harbor Entrance Channel extension and improvement areas

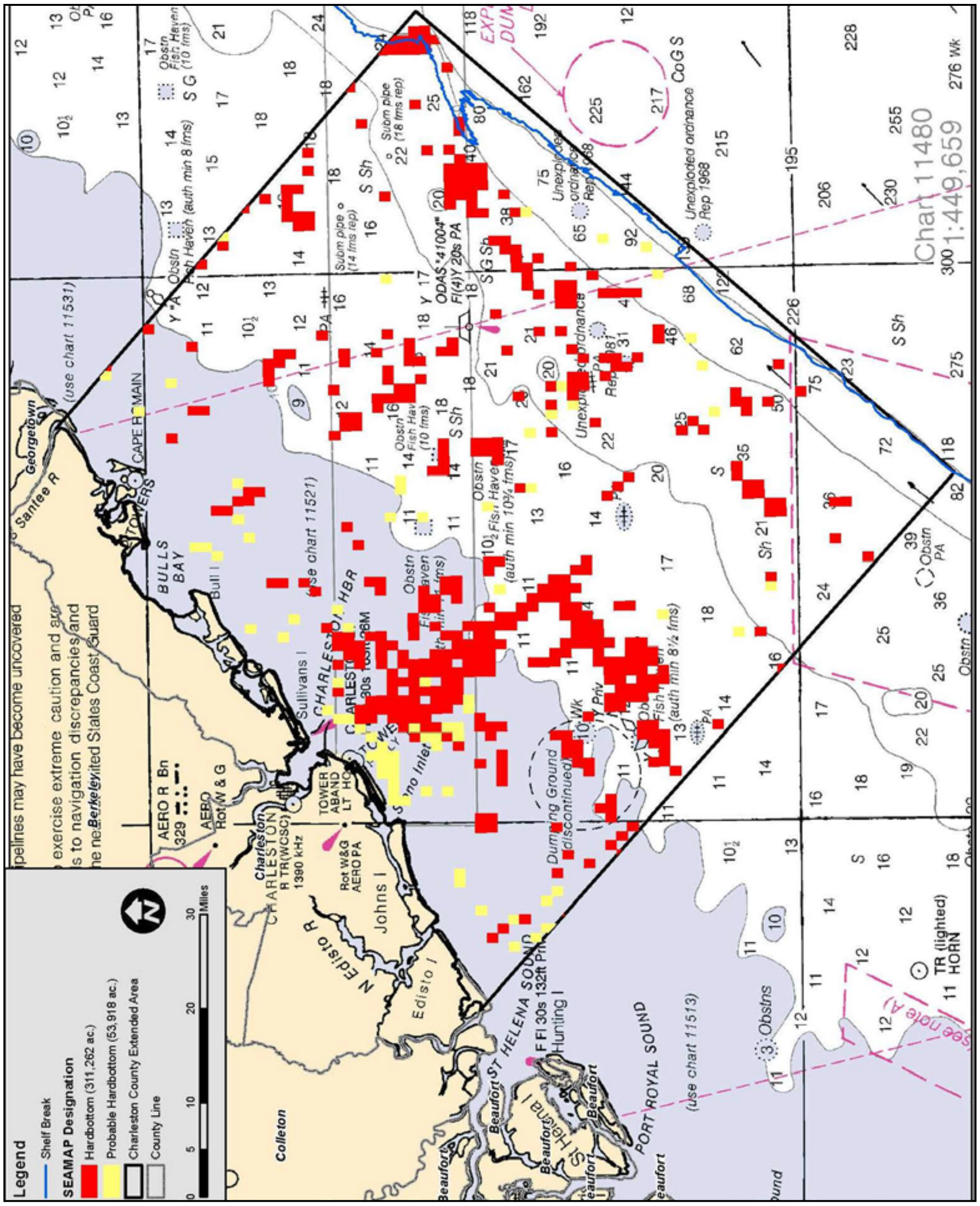

Figure 2. Charleston County hardbottom

The survey report classifies the following areas of habitat:

Hardbottom

Areas identified and mapped as "hardbottom" habitat exhibit strong indicators that hardbottom sea floor is present across several data types. Such areas are characteristically:

- *Mappable as coherent fields of high backscatter response of the sea floor. Hardbottom setting may exhibit a mottled backscatter response or clear fabric of linear patterns within an overall high backscatter response* *reflecting trends of outcroping substrate and patchy thin veneers of sediment within the hardbottom areas.*

- *Found within areas where surficial sediment thickness, between the sea floor and regionally coherent subsurface reflectors interpreted as the top of older and potentially indurated deposits, is minimal (0-1 m in thickness) on chirp sub-bottom profiles.*

- *Locations with clear patches of high backscatter sea floor frequently exhibiting irregular mounds and/or strong linear ledges and/or relief locally high enough to result in a shadow effect to the incident acoustic signal and full resolution (not mosaicked) side scan records.*

- *Found to have physical outcrops of indurated substrate visible on video camera transects of the sea floor. Hardbottom habitats visually identified were parameterized by the relief of the outcropping substrate (high (>1 foot) and low relief) and by the presence of hardbottom invertebrate communities (extensive, sparse or no benthic growth evident).*

- *Fields mapped as "hardbottom" are not mapped as continuous or individual hardbottom outcrops but define areas where an abundance of outcrops and quality habitat is expected to exist interspersed with patches of course shelly/ sandy sediment.*

Probable Hardbottom

Areas mapped as "probable" hardbottom typically possessed most but not all of the characteristics of hardbottom listed above. As video documentation is limited to only a finite number of transects, heavier weighting is placed on the side scan and sub-bottom profile signals. Probable hardbottom on the following maps are expected to represent areas of transition away from areas confidently mapped as hard grounds where one or more signatures on side scan and chirp sub-bottom profiles is less confidently interpreted as hardbottoms. Typically these areas may be expected to have patches of outcropping sea floor but limited signals of high relief (high quality habitat).

Possible Hardbottom

Areas mapped as "possible" hardbottom were often defined as possessing minimal surficial sediment thickness (<1m thick) and exhibiting mappable high backscatter sea floor on full resolution and mosaicked side scan images. Relatively few ledges or signs of relief on the sea floor where identified in these areas on the full resolution side scan records. Video data, when available, documented no hard ground habitat supporting typical invertebrate communities. Review of video data from some of these areas showed evidence of clear erosion and deflation of the sea floor into older sediment that resulted in extensive shell lags frequently organized into large ripple fields. In other areas, particularly in the outer section of the channel extension very clear outcrops with considerable relief (up to 1 meter) were observed on side scan and video data but did not support typical hardbottom invertebrate communities. These areas appear to be outcrops of cohesive back-

barrier (salt marsh) depositions being actively exhumed by the modern ravinement (marine unconformity) surface but too unconsolidated to support typical hardbottom communities. As the surficial sediment in these areas is limited and is actively being eroded local areas of older more indurate substrate within these areas is certainly possible and should be expected locally.“

3.1 Direct Dredging Impacts

This analysis is based on two categories of direct impacts: side slopes and in-channel new impacts.

3.1.1 Side Slope Analysis

For the side slope analysis, it was determined and vetted at several Interagency Coordination Team (ICT) meetings, that only areas that were mapped as “hardbottom” or “probable hardbottom” would be used in the impact assessment. “Possible” habitat didn’t have any of the biological characteristics of hardbottom habitat as evidenced from video tows. Figures 3a (west portion of entrance channel) and 3b (the east) show the hardbottom and probable hardbottom habitat within the study area. Much of this habitat is along the margins of the existing navigation channel. In order to determine the impacts of the alternative plans on hardbottom habitat, a GIS analysis was performed, overlaying the various footprints of the alternatives on the hardbottom habitat polygons. The Entrance Channel alternatives include dredging the outer channel to authorized depths of 50’, 52’, or 54’ (i.e., actual depths of 54’, 56’, or 58’, including 2’ overdepth and 2’ advanced maintenance).

Figure 5 (showing tentatively selected plan, but a typical representation of all alternative plans) illustrates that the channel toe-to-toe width was 800 feet, while the “benches” in the channel “wings” were five feet less deep than the channel’s depth at the centerline. The idealized prism is based on a 4:1 foot slope. The “cut fill” (spatial analyst) tool was used to identify areas of existing substrate above the ideal prism. Then the areas of dredge cut for each alternative were clipped by the areas of probable or known hardbottom habitat to determine the areas where dredging would occur in hardbottom habitat areas. Of these areas, the majority of the acreage falls within the existing toe of the navigation channel and therefore will not be considered as impacts that require mitigation. Subtracting this area gives a smaller area of impact for each alternative.

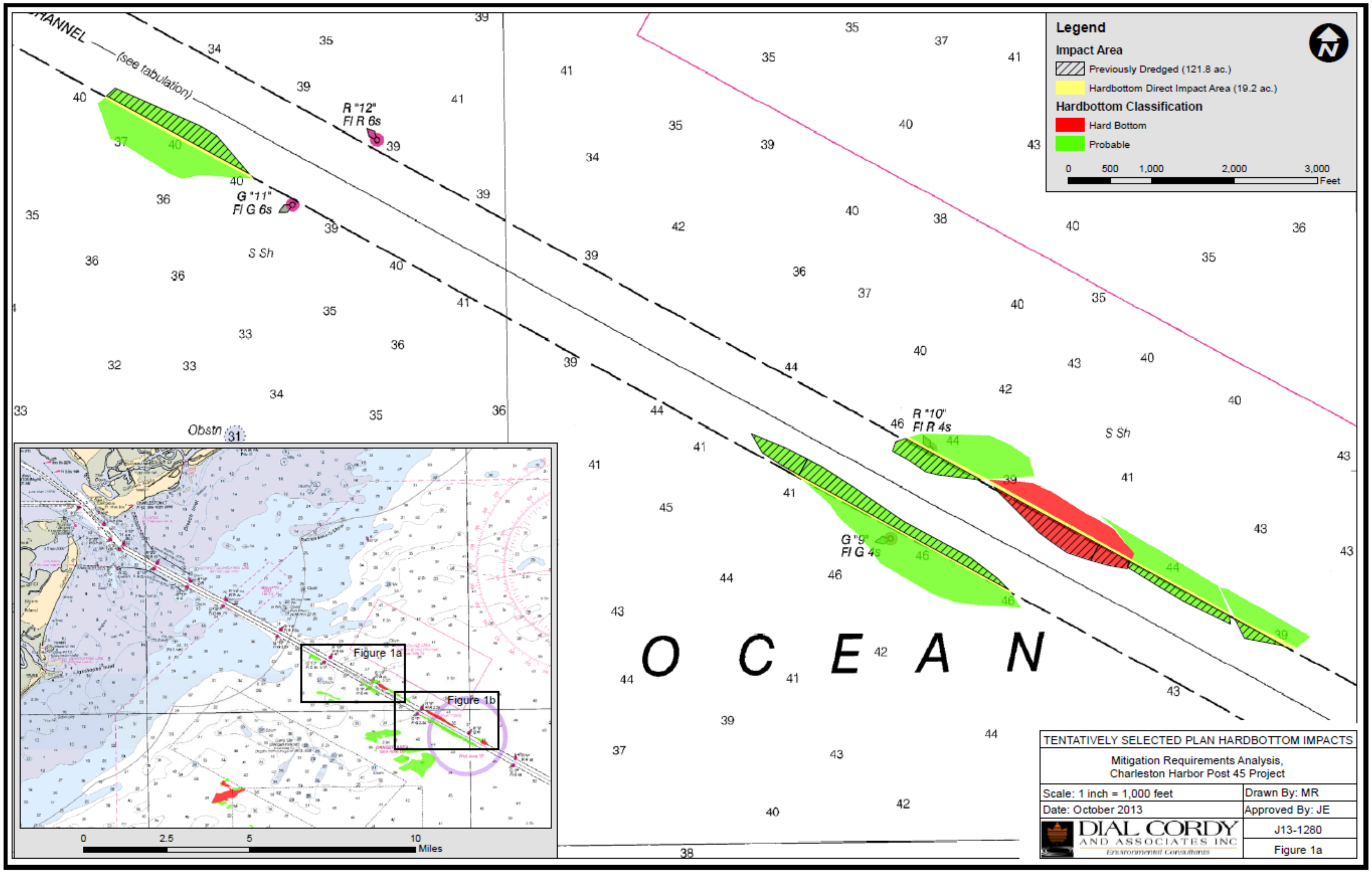

Figure 3a Hardbottom habitat adjacent to the Navigation Channel (west)

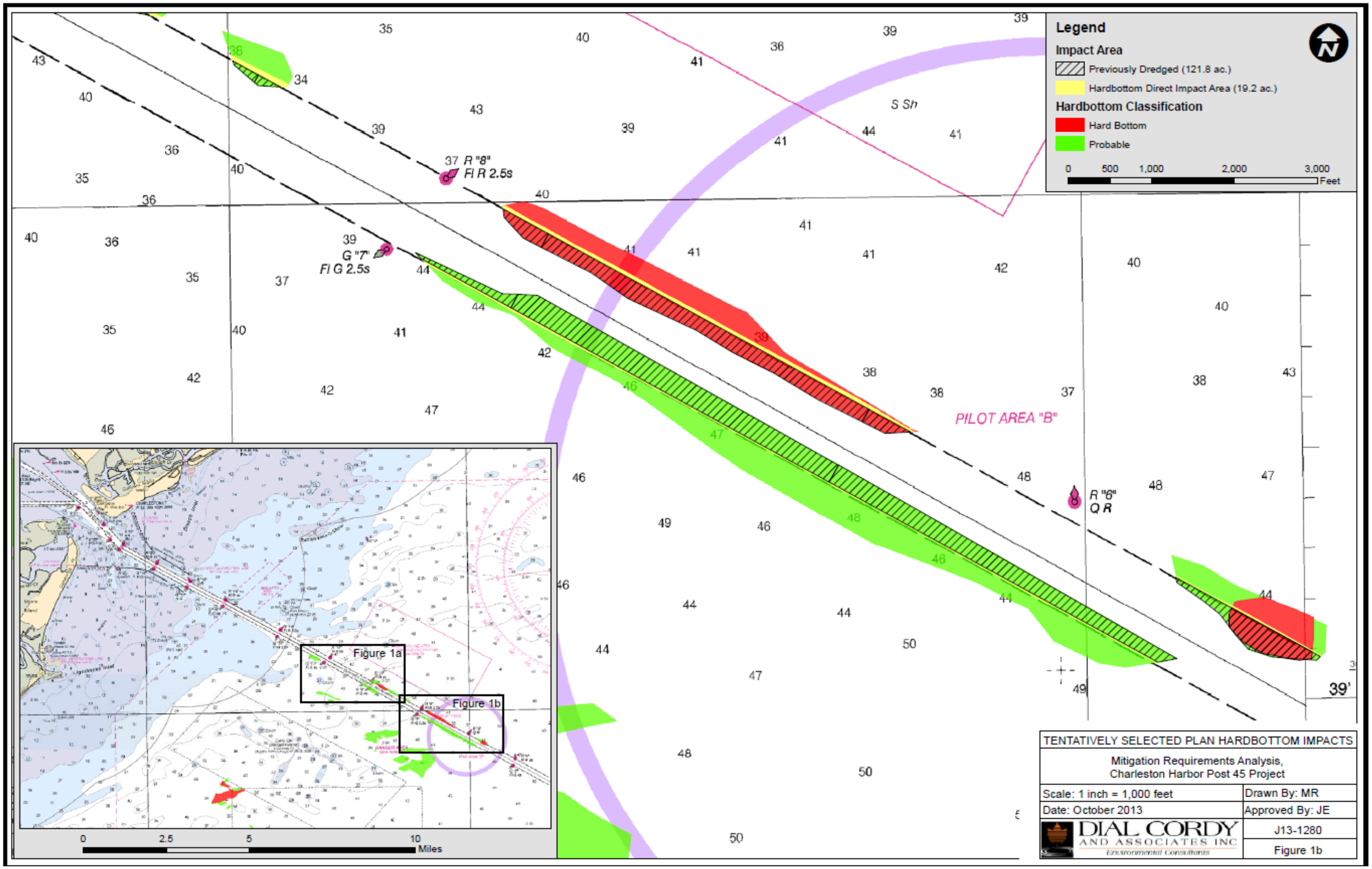

Figure 3b Hardbottom habitat adjacent to the Navigation Channel (east)

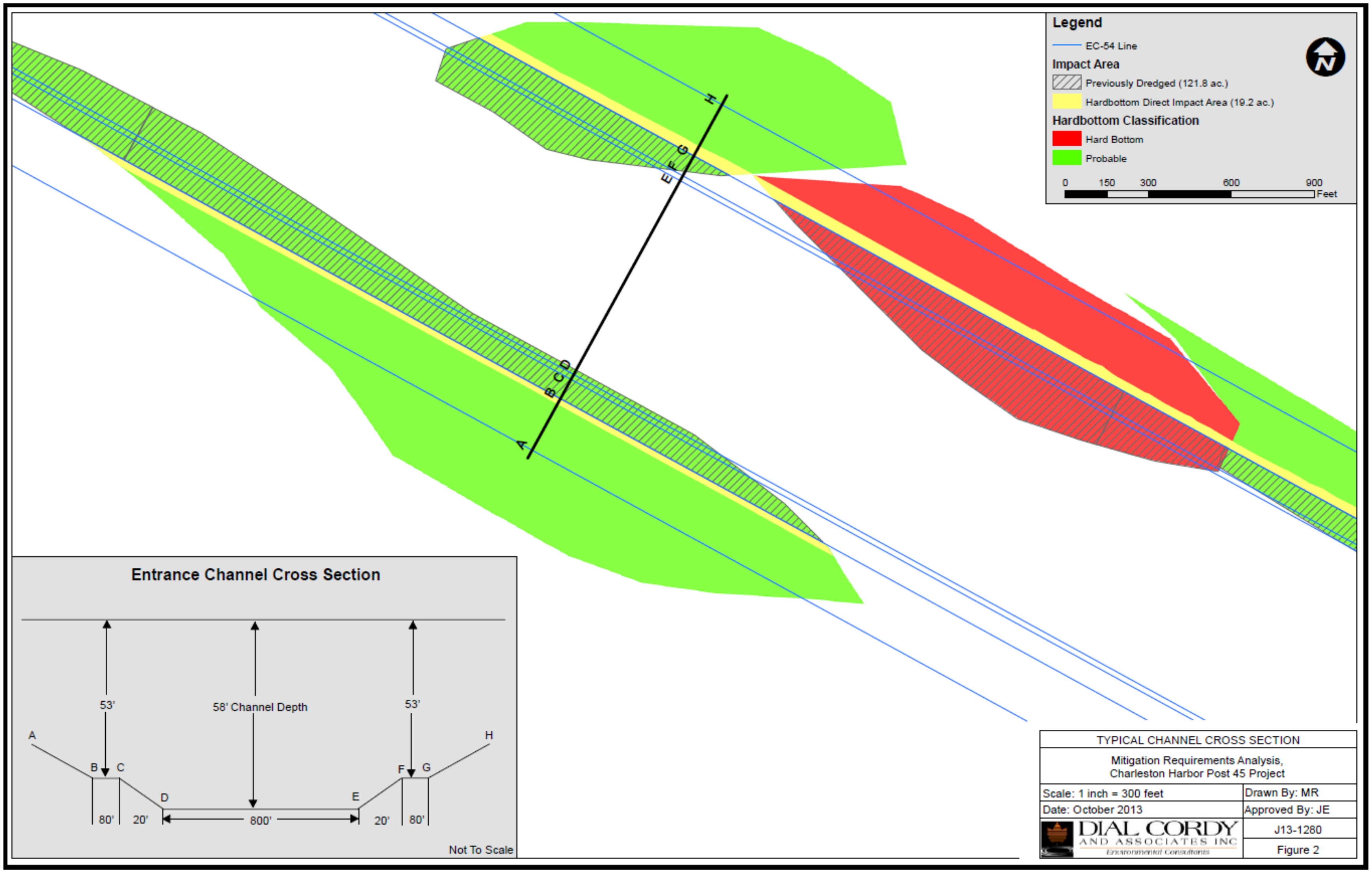

Figure 4. Typical Channel Cross Section

New impacts to hardbottom would result from extending the channel toe vertically down to the newly authorized depth. Doing this would result in the channel slope extending further outward. When this occurs in an area of hardbottom or probable hardbottom habitat, a direct dredging impact would occur. Early coordination with resource agencies resulted in the selection of an avoidance method that involved continuing the same side slope from the existing channel down to the new proposed depth (Figure 5). By doing this, all direct impacts to hardbottom habitat along the side slopes would be avoided. Impacts avoided range from roughly 8.5 acres to 19.2 acres of hardbottom habitat.

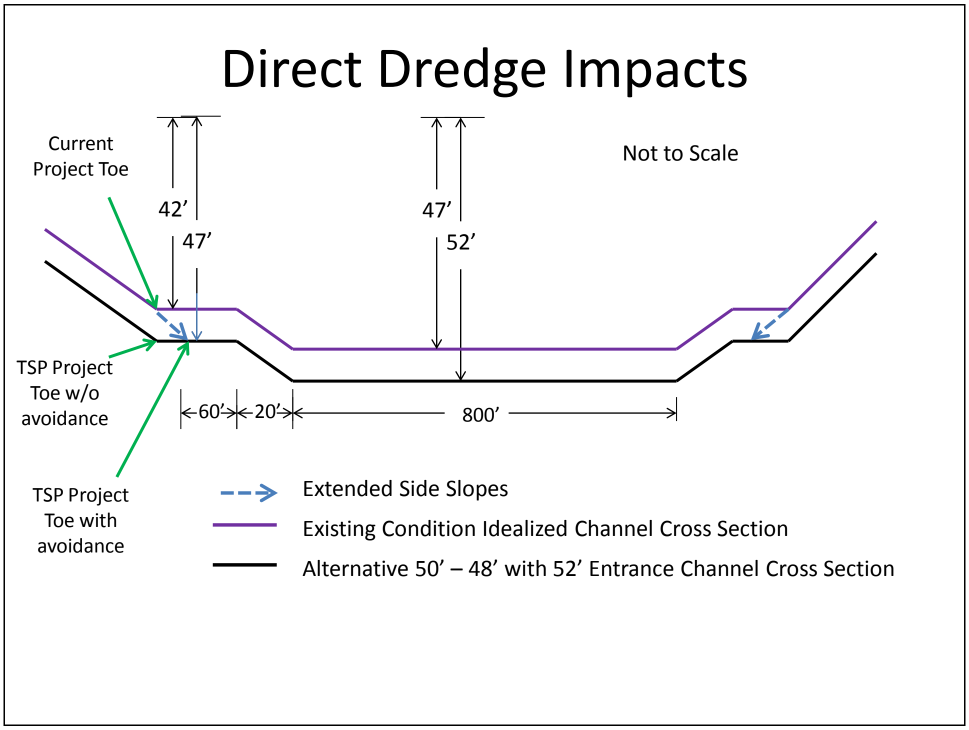

Figure 5. Proposed Side Slope Extension to Avoid Hardbottom Areas

3.1.2 In-Channel New Impacts

Another area of direct impacts to hardbottom habitat is from the previously undredged areas of the existing navigation channel. These areas are authorized to be maintained at 47'+2'+2', but due to existing deep water and lack of shoaling in some areas, some areas of the channel have not been dredged as either new work material or any maintenance dredging since the last deepening project (Figure 6). Hardbottom surveys were not performed within this area during the feasibility phase. Because of this, an alternative method had to be developed to determine an estimate of the amount of hardbottom present. This method was discussed and developed at an ICT meeting on 17 February 2014 with representatives from SCDNR, USFWS, and NMFS. The steps of this method are presented below:

1. Determine amount of rock at the bottom surface or within 1 ft of the surface
    a. Based on geotechnical analysis of top of rock and creating a surface of top of rock by creating a GIS Triangular Irregular Network (TIN)

2. Using the ESRI “clip” tool, clip the rock layer with a polygon representing areas that have not previously been dredged for either new or maintenance work.
3. Determined average percent hardbottom habitat within identified areas of hardbottom habitat.
    a. Used the CCU “hardbottom” classification
    b. Identified the video transects that correspond to those areas along the navigation channel (JD005 line 1 and JD006 line 1)
    c. Timed the amount of time that hardbottom was actually present in the videos (20% and 38%, respectively)
    d. Averaged the two to determine percent of hardbottom possible in the previously undredged areas (29%)
    e. Extracted geocoded data for those two lines. This data had attributes such as high growth, sparse, high relief, low relief, etc.
        i. 17.9 % of points were heavy growth.
        ii. 14.6% of points were high relief (138/944) (22 of the high relief were also classified as low relief)
        iii. 23.8% of points were low relief (225/944) (109 of the low relief were also classified as high relief)
4. Used an estimate of 29% to represent the percent of rock at or near the surface in undredged areas that might support a hardbottom invertebrate community.
5. Multiplied the % hardbottom by the acreage of rock from step 1 that falls in previously undredged areas.

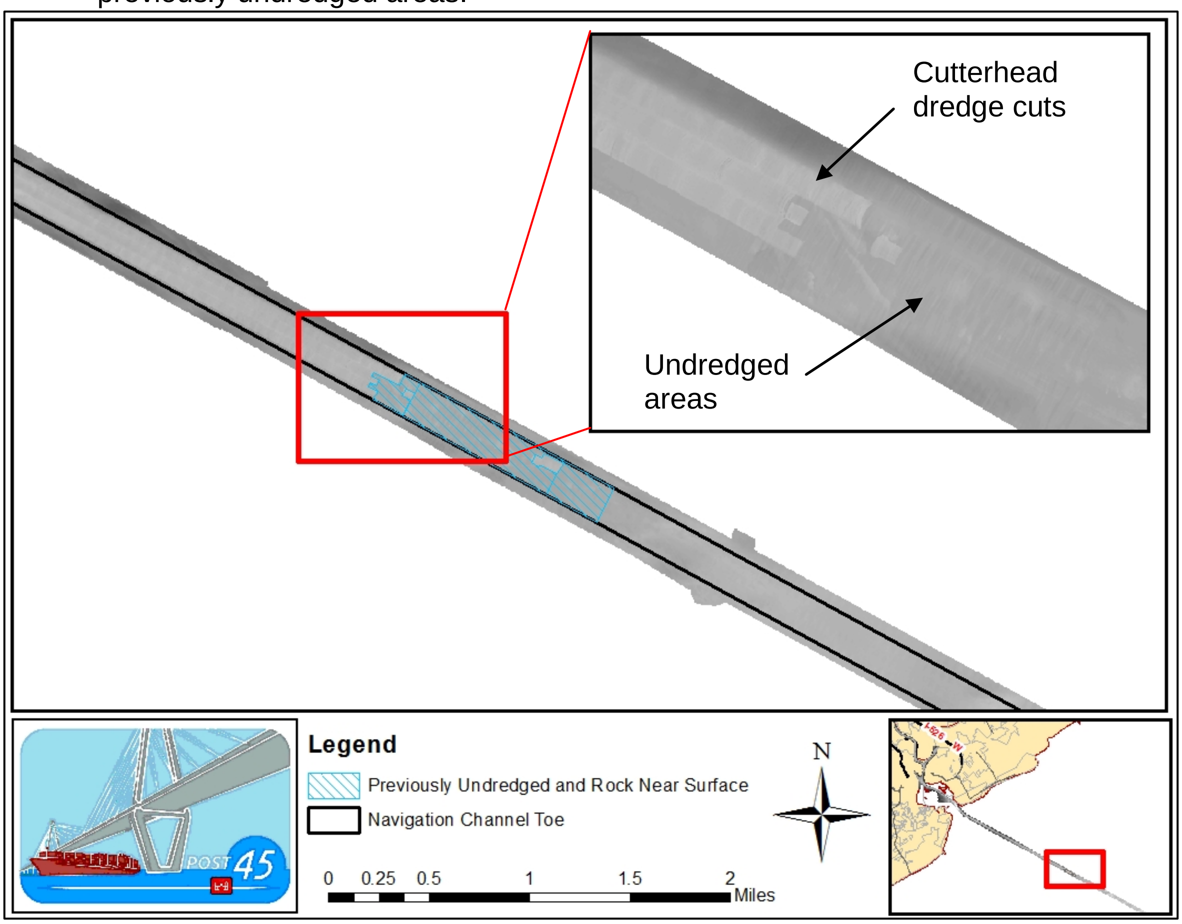

Figure 6. Location of previously undredged channel that has rock at or near the surface and could possibly contain live hardbottom communities

Through this analysis it was found that 98.6 acres of rock was present at the surface or within 1 foot of the surface. Taking the conservative estimate of 29% of this area representing hardbottom habitat, USACE anticipates mitigating for 28.6 acres of hardbottom habitat within the entrance channel (The number will be refined prior to construction – see Monitoring and Adaptive Management). This habitat represents areas that have not been previously dredged either from new work or maintenance dredging. Figure 7 demonstrates video tow track lines that were evaluated to determine the type of habitat in and around this area. The lines are labeled to show screen shots of the bottom habitat in these areas:

A. Dredged area: shows rock rubble left behind as a result of the previous dredging of new work material from 2000-2001.
B. Outside of channel: shows low relief larger community structure than in a similar undisturbed area within the navigation channel
C. Inside of undisturbed area of channel: shows low relief habitat and the relatively smaller size of the community compared to B. (presumably due to prop wash and impact of frequent ship disturbance)
D. Inside of undisturbed area of channel: shows low relief habitat and an area with an abundance of echinoderms.
E. Located on edge between dredged and undredged area of channel: demonstrates high relief habitat associated with higher relief structures.

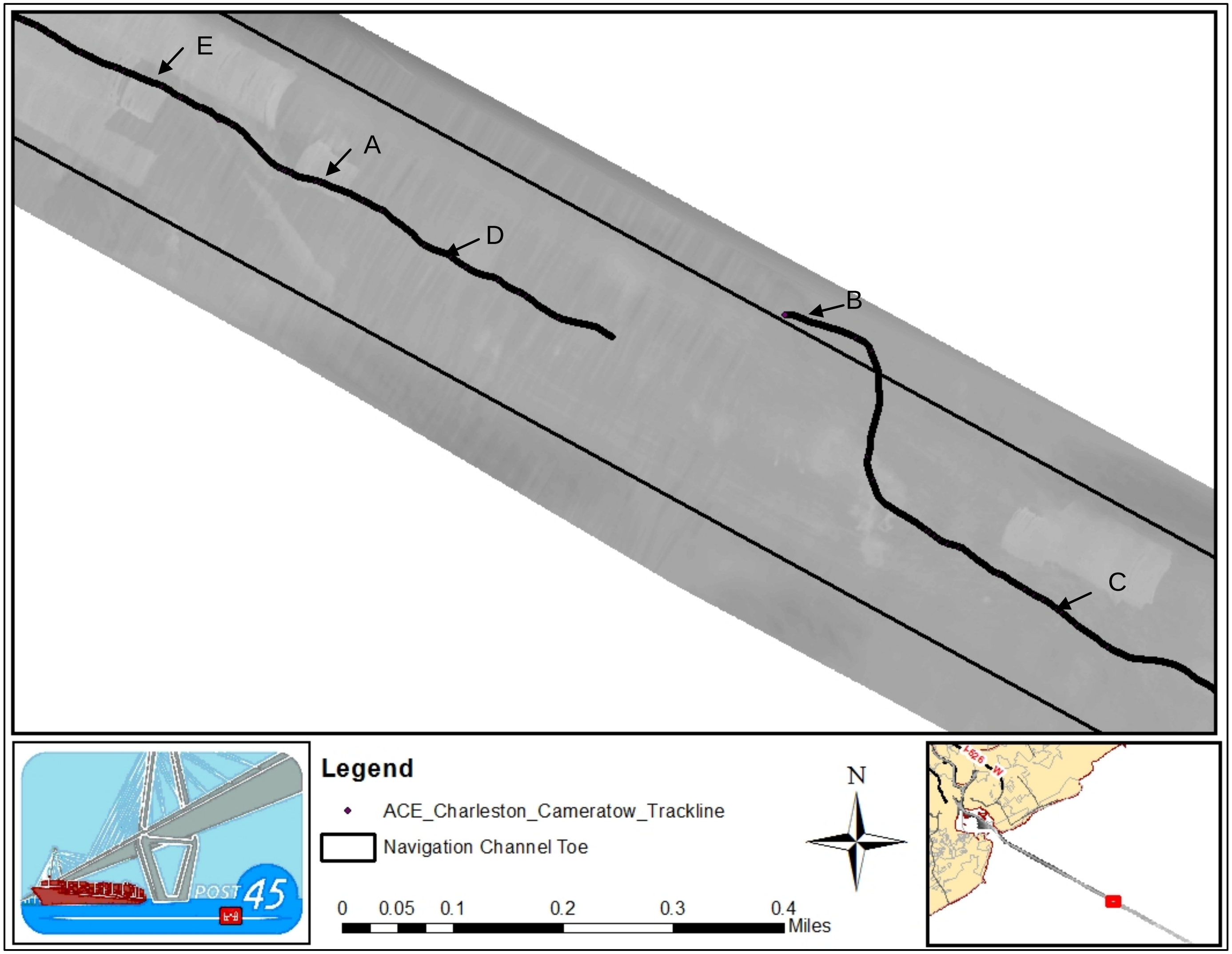

Figure 7. Previously undredged area of navigation channel


A
14/03/31 14:25:25
B
14/03/31 14:08:50
C
14/03/31 13:50:28
D
14/03/31 14:17:40
E
14/03/31 14:09:04

3.2 Indirect Impacts (Turbidity/Sedimentation during Construction)

Indirect impacts to hardbottom habitats near the dredging within the entrance channel are expected to be minimal and short term. These impacts would be due in large part to any turbidity resulting from the dredging of material from the Entrance Channel and any subsequent sedimentation that could occur on these reefs. These impacts would result in sub-lethal effects (injury, decreased fecundity, etc.) on the macroinvertebrate community. In a study of hardbottom habitat impacts from the Grand Strand Nourishment Project in 2007, SCDNR concluded that the temporal variability of macroinvertebrates at reference vs. impact sites made detection of significant impacts from the nourishment difficult to determine. Over the course of the study, macroinvertebrate cover increased similarly at the reference and impact sites. They indicate that this suggests a lack of impact, but qualify that by restating the inability to detect significant differences because of the natural variability in the environment. (Burgess et al., 2011) (CCU's monitoring). Additionally, a seven-year biological monitoring effort documented reef community changes before and during beach nourishment activities in Broward County. Results showed no effect of sand placement activities or dredging of borrow areas on corals or other biological components of adjacent reefs. In sum, the above reports suggest that corals were not measurably affected by adjacent dredging activities or sand placement during and after these activities. Because of this and the documented hardbottom communities in areas where dredging occurs (Figures 1a and 1b) the impacts from turbidity as a result of the construction phase will result in negligible to minor adverse temporal impacts. Along the margins of the channel there is 186.3 acres of hardbottom habitat. The temporary and minor indirect impacts to this habitat will be included in the HEA and an injury value of 5% will be applied to represent the injury incurred from turbidity/sedimentation during construction. The Jacksonville District used values of 2 and 5% injury from indirect impacts for the Port Everglades Navigation Study HEA Report, and ultimately opted to use a 2% injury to coral communities. In this case, a 5% impact will be noted to occur during the length of time of construction in the reaches where hardbottom habitat has been identified and is anticipated to be a conservative estimate based on other navigation projects in the South Atlantic.

4.0 PROPOSED MITIGATION FOR UNAVOIDABLE IMPACTS TO HARDBOTTOMS

In order to mitigate for anticipated impacts due to the implementation of the tentatively selected plan (or any of the other alternatives), USACE has evaluated a variety of alternatives. These alternatives are discussed within the Mitigation and Adaptive Management Appendix (Appendix P of the Main Report). The chosen alternative is discussed below.

4.1 General Overview of Proposed Mitigation Plan

The selected mitigation alternative involves depositing dredged limestone rock from the entrance channel within a designated mitigation area between the Charleston ODMDS and the entrance channel. The objective of the mitigation is to create a marine patch reef feature in mound formations that will replace the functions of the hardbottom dredged from the entrance channel. The designated mitigation area would be surveyed and reviewed prior to construction and must not contain existing hardbottom habitat or support other traditional uses of the marine environment such as trawling or sand mining areas. The material would be placed or discharged, likely by scow or barge to reach the designed configuration. An excavator or clamshell dredge would permit the largest diameter material to comprise the reef; however, a cutterhead suction dredge could also be used. USACE anticipates mitigating for 28.6 acres of hardbottom habitat within the entrance channel. This habitat represents areas that have not been previously dredged either from new work or maintenance dredging.

The proposed mitigation involves use of dredged material (limestone rock) transported to a designated area to construct a marine patch reef feature. Each placement will be surrounded by a halo of sand or native material. The ring of sand along with the hard substrate feature provides landscape and edge diversity, and foraging area. Reef morphology and material influences the relative value of refuge and forage functions, and reef utilization by benthic, epibenthic, and nektonic organisms. Reef patchiness will increase the edge to interior ratio, and may enhance use by organisms that favor edge regions, or decrease use by species requiring more interior habitat. The hard substrate and rugosity will provide attachment substrate for epifauna. In summary, the proposed Charleston Post 45 hardbottom mitigation patch reef is designed to replace the existing hardbottom that will be dredged as well as provide physical features/vertical structure to provide habitat diversity. Physical features which are believed to be important include material used, shape and landscape, substrate, relationship to currents, and size. While vertical relief is usually highly desirable, the harbottoms being impacted by the entrance channel dredging are not high relief reefs to begin with.

As discussed previously, the designated mitigation area adjacent to the Charleston entrance channel, between the Charleston ODMDS and the channel. Water depths in the mitigation area are between 35 and 50 feet. The new reef feature will consist of individual low relief mounds separated by existing bottom service area. The reef feature is designed to provide bathymetric anomalies, hard bottom surfaces material, habitat diversity, and stability. The reef to be constructed will not impair navigation clearances. Figure 8 shows bathymetry from the Shark River Reef offshore New Jersey. The Shark River Reef site contains almost 4 million cubic yards of dredged rock material. Ninety-six percent of the reef material on Shark River Reef is rock.

4.2 Mitigation Area Material Placement

Logistics of dredging and placement will be subject to many interdependent variables, such as dredge availability, placement site depth, travel distance , and attendant environmental conditions at the site. Specifics such as dredging location and depth, quantity, quality of material are generally project determined.

A simple patch reef design and a simple operational plan compatible with dredge plant and transportation capabilities is required. Accordingly, a grid placement plan will be used. The grid will consist of 300-foot by 300-foot cells. The cells will be two (2) across by eight (8) long. This would create approximately 33 acres of patch reef habitat (project footprint). The patch reef area would be 600 feet by 2,400 feet long. At a minimum one scow load of material dredged from rock areas would be discharged at about the center of each cell. At a minimum two scow loads of material dredged from rock areas would be discharged at about the center of each cell. Accordingly, the 16 cells would require 32 - 4,000 to 6,000 cy scow loads, or approximately 128,000 to 192,000 cy. Filling the scows to maximum capacity with each load is not a likely occurrence. The desired peak vertical relief is 3.5 – 4.5 feet and the desired aerial coverage within each cell is 75% coverage. However, placing the load directly on top of each other will be a challenge. Placing more than two loads in each cell can be done in order to make a higher mound or to cover more area. Filling the scows to maximum scow capacity with each load is not a likely occurrence. Additional loads could be placed on specific cells if the two loads do not achieve desired areal coverage. This will be monitored during construction and if necessary, will be adapted.

It is anticipated that the material will be dredged mechanically by a rock bucket clamshell dredge, in which case the rock may be removed in softball and larger basketball size pieces. The scows would be 4,000 to 6,000 cyd vessels. Dredged materials for the patch reef will be new work (not previously dredged) rock to the extent practicable, although some overlying and intermixed sediments will be dredged along with the rock. The scow will transport the dredged material to the placement location. A placement grid will be developed to provide the patch reef design. Grids will be divided into sequentially numbered cells. Each cell would be a placement target. One or more scow placements would occur in a manner that will produce discrete mounds. The heights of the mounds will depend on the characteristics of the dredged material (coarser materials do not spread out much on the bottom) (see Appendix 2 - STFATE analysis).

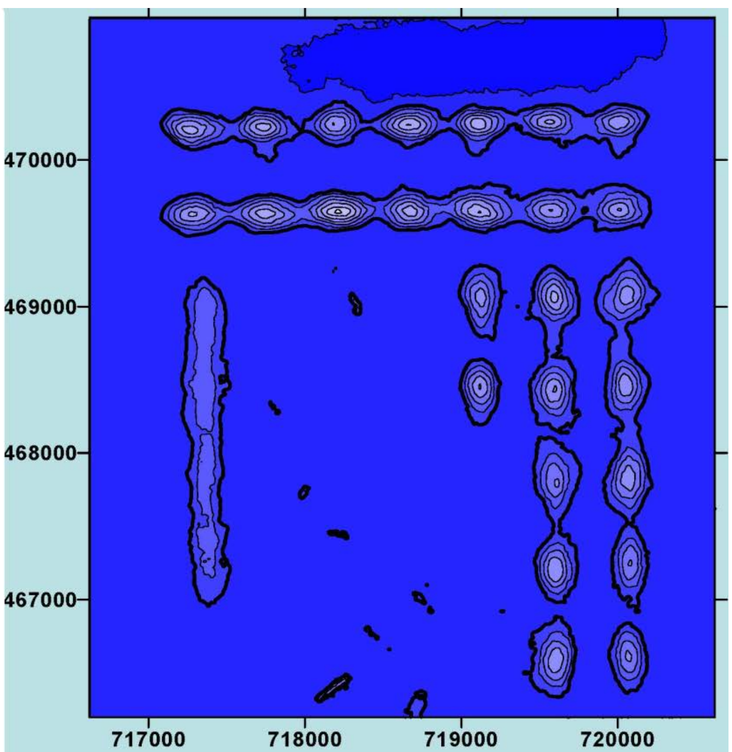

Figure 8. Bathymetry of Shark River Reef mounds, Constructed of rock dredged material.

4.3 Mitigation Area Location

The proposed location for the Charleston Post 45 Hardbottom mitigation area is in an area adjacent to the entrance channel (from where the substrate rock will be dredged) (Figure 9). It should be noted that USACE will construct 8 new 33-acre reef sites (only 1 required for compensatory mitigation, as described above). Four will be located along the north side of the channel and 4 will be located along the south side of the channel. For a theoretical depiction of the location of these reefs see Figure 9. Prior to construction the locations of these reefs will be refined and coordinated with the resource agencies. At the request of the SCDNR Artificial Reef Program, approximately 240,000 CY of rock material will also be deposited at the 25 acre Charleston Nearshore Reef site. These reefs will provide extensive bathymetric features located between approximately 6 nm offshore of Charleston Harbor out to approximately 10 nm. Two of the reefs will be constructed to optimize hardbottom habitat for use as mitigation sites (1 is required and the other is a contingency measure) and the other six sites will be specifically for beneficial use of dredged material. These locations, while only hypothetical until site refinement, will provide the mitigation area similar ocean environmental conditions as the hardbottoms impacted. Water depths are between about 35 and 50 feet. The proposed placement area avoids being too near the entrance channel and avoids the Charleston ODMDS. Return of material to the entrance channel or otherwise impacting navigation would not be acceptable. Locating the mitigation area within the ODMDS would not be acceptable as future use of the Charleston ODMDS is required and future disposal of dredged material over the mitigation area could void or reduce the benefits of the patch reef rock placement. Additional bottom surveys for cultural resources and existing hardbottom habitat will be required to site the reefs.

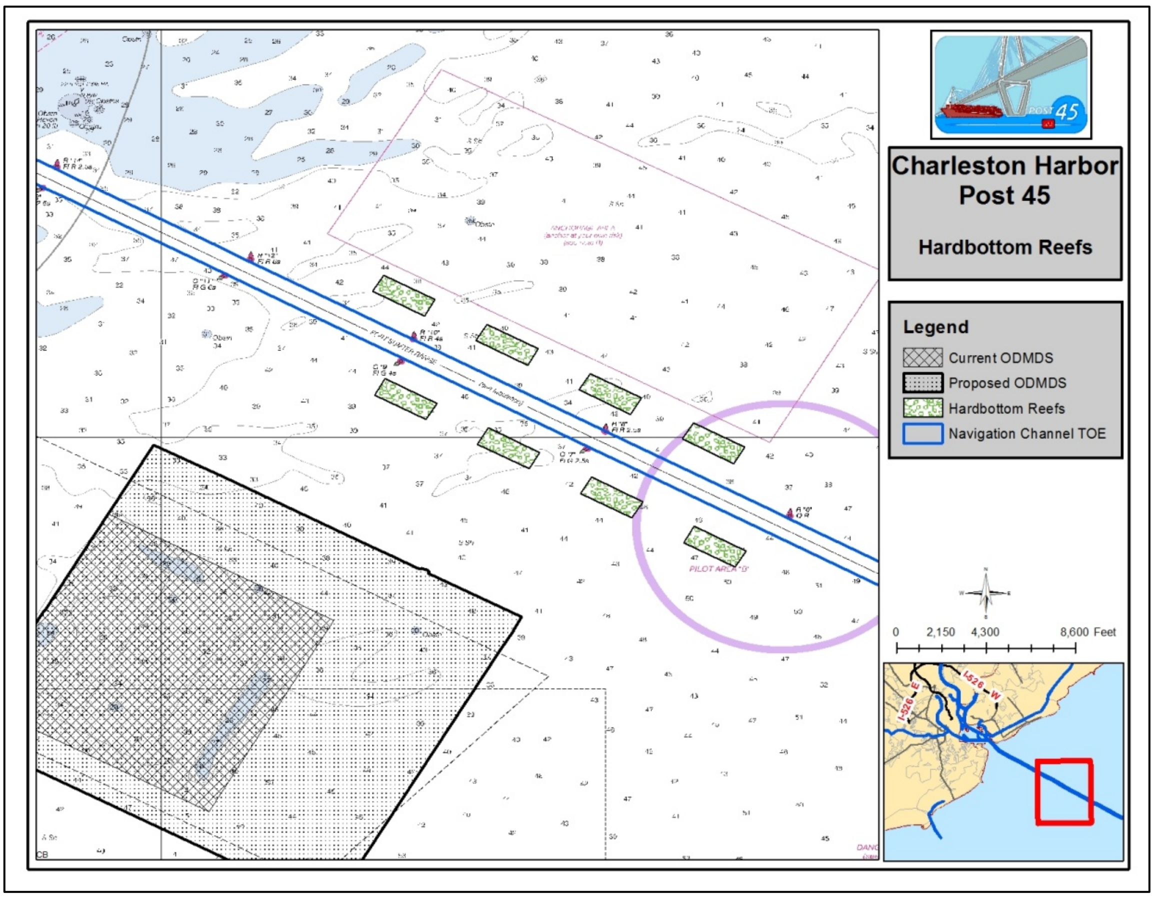

Figure 9. Location of hardbottom habitat mitigation reefs

4.4 Compliance with Environmental Requirements

Construction of the proposed mitigation area and 7 other reef sites will take place beyond the 3 nautical mile limit of the territorial sea. Therefore the proposed placement of dredged rock material is not an activity regulated under the Clean Water Act of 1972. Neither a Section 404(b)(1) evaluation nor a Section 401 Water Quality Certification is required. The placement of rock within the SCDNR Charleston nearshore reef is within the 3 mile limit and a separate 404(b)(1) has been prepared for that action.

Ocean dumping, the transportation of material for the purpose of disposal is regulated by the Marine, Protection, Research and Sanctuaries Act (MPRSA) of 1972, as amended, as implemented by EPA's Ocean Dumping Regulations and Criteria (40 CFR Part 220-228). However, the EPA regulations do not include the placing materials for the purpose of developing, maintaining, or harvesting fisheries resources; provided such placement is regulated under an authorized State or Federal program (40 CFR 220.1(c) (2). The placement of dredged material for the mitigation area will be regulated under Section 10 of the Rivers and Harbors Act of 1899 and 4(e) of the Outer Continental Shelf Lands Act of 1953. The proposed ocean transportation of dredged material is for the purpose of construction of mitigation and habitat enhancement, not disposal. Therefore, evaluation under Section 103 of MPRSA is not required. Concurrence by the National Oceanic and Atmospheric Administration (NOAA) and the U.S. Coast Guard is required by 40 CFR 220.1(2) and this Integrated Feasibility Report and Environmental Impact Statement is being coordinated with those agencies.

Mitigation Reef as an Artificial Reef. An artificial reef is a human-made underwater structure, typically built to promote marine life in areas. Regardless of construction method, artificial reefs generally provide hard surfaces where algae and invertebrates such as barnacles, corals, and oysters attach; the accumulation of attached marine life in turn provides intricate structure and food for assemblages of fish. Using this context, the proposed mitigation area and additional reefs could be considered artificial reefs.

SC Artificial Reef Program. Artificial reef development in South Carolina's coastal and offshore waters is managed through the South Carolina Department of Natural Resources, Marine Resources Division (MRD). The state's Marine Artificial Reef Program, first established in 1973, is a part of the MRD's Office of Fisheries Management (OFM). As of January 1996, the OFM held permits for the continued development of 38 artificial reef construction sites along the South Carolina coast. These sites are located in waters from 9 to 110 feet deep, ranging from inshore locations to areas as far as 35 miles offshore. Individual reef construction sites range from small areas to one square mile in size, with multiple reef structures placed within the boundaries of each area. All sites are located on flat featureless sand bottom which offered little interest to divers or fishermen prior to the placement of reef materials. Reef construction sites are selected to provide easy access to users while attempting to avoid possible conflicts with any other use of the bottom or waters near the permitted areas. Most reef sites are buoyed to assist in their location.

South Carolina's marine artificial reefs are constructed from a wide variety of materials ranging from various forms of suitable scrap to specifically designed and constructed reef habitat structures. Steelhulled vessels are the most commonly employed scrap material in reef construction. South Carolina artificial reefs clusters are located approximately 4 nmi NE, 5 nmi SW, and 6 nmi S, respectively from the proposed reefs. These reefs are made from a variety of materials. The Charleston Post 45 Integrated Feasibility Report and Environmental Impact Statement including the proposed reefs will be coordinated through the SC Artificial Reef Program.

Federal Artificial Reef Policy. The National Fishing Enhancement Act of 1984 (NFEA) establishes a national policy to promote and facilitate responsible and effective efforts to establish artificial reefs in U.S. waters. NFEA mandated the preparation of a National Artificial Reef Plan (NMFS, 1985) and gave the Corps of Engineers regulatory authority for artificial reef construction. The Corps of Engineers regulatory program (33 CFR Parts 320 through 330) requires that provisions for siting, construction, monitoring, operating and maintaining, and managing a proposed artificial reef be consistent with six standards as follows and the National Artificial Reef Plan:

1. The enhancement of fishery resources to the maximum extent practicable;
2. The facilitation of access and use by recreational and commercial fishermen;
3. The minimization of conflicts among competing uses of the navigable waters or waters overlying the outer continental shelf and of the resources in such;
4. The minimization of environmental risks and risks to personal health and property;
5. Generally accepted principles of international law; and
6. The preventing of any unreasonable obstruction to navigation.

The proposed Charleston Post 45 hardbottom mitigation patch reef and other reef sites will be constructed in a manner consistent with the national artificial reef standards. Information supplied in this report documents this determination.

USACE will coordinate with SCDNR and NMFS to use the available rock material to create more artificial reefs, where possible.

4.5 Recovery/Recruitment of Artificial Reefs

Wahl (1989) determined that after deployment, an artificial reef undergoes a successional process which involves the formation of a bacterial film and the recruitment of a variety of algal species and invertebrates. These communities consist of barnacles, hydroids, octocorals, bryozoans, sponges, and tunicates, among others (Wendt et al. 1989). The colonization of artificial reefs is affected by a number of components including proximity to natural habitats (Van Dolah et al. 1998), composition and texture of substrate, habitat complexity, water clarity, etc. Burgess et al. (2011) found that artificial reefs function similarly to natural ones and may converge with them over time. Dredging of hardbottom habitats has been labeled as one of the most harmful human activities to these habitats, causing dislocation of live rock and corals, and stress to sessile invertebrates (SAFMC 1998). Burgess et al. (2011) points out that some researchers believe that concrete reef structures have the potential to support epifaunal communities similar to those on natural reefs and are a useful tool in restoration practices. If artificial reefs can offer similar surface orientations, distances from the seabed, and complexity as natural reefs, their epifaunal communities can converge over time (Carr and Hixon 1997). Because sediments can inhibit sessile invertebrate growth, it has been suggested that artificial reefs should maximize vertical surfaces in order to maximize epifaunal growth (Burgess et al. 2011). In a study by Burgess (2008) in which two artificial reefs were compared to a natural reef, it was determined from video data that both artificial reefs began to develop invertebrate communities less than a month after deployment, and achieved full epifaunal cover by six months (corrected to *12 months* by author in email to Charleston District USACE on 7/1/2013). The reefs comprised 100 randomly placed reef cones created from a concrete aggregate. *Leptogorgia virgulata* is one of the most common octocorals found associated with hardbottom reefs in South Carolina. In a study of gorgonian morphology, age structure, and growth, Mitchell et al. (1993) determined that the mean age of *L. virgulata* was determined to by 3.1 years with a mean colony height of 189 mm, and suggests a growth rate of roughly 61mm/year.

For the creation of an artificial reef at the Grays Reef, a study by Fiaravanti-Score (1998) used limestone rocks collected from a quarry because of their similarity to the natural hardbottom found in the area. The species composition on the quarried rocks resembled the species composition of natural occurring live bottom, except for the occurrence of large sponges and corals. However, these species were not expected since they are slow growing and slow colonizers (SCWMRD 1984; Wendt et. al. 1989). The rocks were approximately 50% covered after only four months of deployment. The overall conclusion of the study was that quarried rock made better substrate than artificially made substrates.

However, some studies have found delayed recruitment and growth of large epifaunal organisms (George and Thomas 1979; Davis et al. 1982; Van Dolah et. al. 1984; Carter et. al. 1985). From a study of five artificial reefs (sunken vessels), Wendt et al. (1988) found that the development of a stable epifaunal community can be achieved in as few as 3.5 years. This finding coupled with the observation of rapid colonization of the natural substrates in the Fiaravanti-Score study make it apparent that where possible, USACE should try and use natural material dredged from the navigation channel as substrate for reef creation.

Since the dredged material anticipated for disposal consists of limestone rock, marl, and coquina, the material will serve as substrate for the recruitment of hardbottom epifauna. Since natural materials will be used for reef creation, they should facilitate a relatively quick recovery compared to artificially created substrates (Fiaravanti-Score thesis). Additionally, the vertical relief of the berm will provide valuable fish habitat for a variety of reef species.

5.0 ASSUMPTIONS USED IN MITIGATION REQUIREMENTS ANALYSIS

5.1 Impact/Dredging Interval

Based on the selected project's dredge depth, the construction will span a certain amount of time. Essentially, the less dredging required, the shorter the construction interval. In performance of the HEA, the construction interval is estimated by quarter-year. Specifically, dredging the 48/47- or 48/48-foot project would take only one quarter of a year; dredging the 50/47- or 50/48-foot project would require a half of a year, and the 52/47- or 52/48-year project would require three-quarters of a year. These "quarter-year" intervals were used in the calculation to denote the amount of time that partial functionality of the impacted habitats would remain until they were ultimately rendered 0% functional at the completion of dredging. These intervals are listed in a table presented in Section 6.0 below.

5.2 Recovery Rates

The time it will take each injury type to fully recover depends on the shape, or trajectory, of the recovery curve over time. These recovery trajectories are dependent on the species affected, the type and degree of injury, any primary restoration actions implemented, and the type of environment in which the injury and recovery occur. Data from the literature, field observations, and best professional judgment are used to develop these parameters. While the successions of most benthic ecosystems follow the law of sigmoidal growth, a linear recovery trajectory was used for all HEAs in this report. This is a common practice which has been applied for most recent HEAs performed by USACE to determine marine resource valuations (e.g., Port of Miami, Port Everglades, and Broward County Shore Protection Project).

For the Charleston Harbor Post 45 HEA, the USACE concentrated on the main constituents of the hardbottom benthic assemblage (octocorals, sponges, algae, bryozoans, etc.) as the representative proxy for the entire affected assemblage. The purpose of the mitigation policy is to conserve and enhance EFH, and to avoid, minimize, or compensate for impacts to EFH due to development activities. The USACE determined that the projected impact to this habitat is significant based on its general classification as Essential Fish Habitat under the Magnuson-Stevens Fishery Conservation and Management Act, as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267). Specific species are not used to determine the recovery time of the habitat. Rather, the recovery time is calculated by estimating the amount of time it would take the ecosystem to recover to the baseline condition. In this case, to be classified as hardbottom habitat with a similar level of ecosystem outputs. NOAA identifies this type of HEA as a "landscape context" HEA (NOAA 1995b), which affects whether the ecosystem will have the opportunity to supply many of the ecological and human services and strongly influences whether humans will value the opportunities for services. This landscape HEA approach provides an acceptable estimate of the recovery for the overall ecosystem and, provides an appropriate method to determine the required compensatory mitigation for the impacts of this project. Additionally, this approach considers the broad characterization of hardbottom habitat and its overall function as EFH, and supports the EFH provisions of the act by supporting the nation's overall marine resource management goal of maintaining sustainable fisheries.

As previously noted, Burgess et al. (2011) found that artificial reefs function similarly to natural reefs and their species assemblages converge over time. Using data from artificial reef structures, Wendt et al. (1988) found a convergence of species that are also common constituents of natural hardbottom communities in the South Atlantic Bight (Wenner et al., 1983; 1984). The fact that they were invariably present on all artificial reefs, regardless of substratum age, suggests that the development of a stable epifaunal community can be achieved in 3.5 years. Additionally, based on the growth rate (61mm/year) of the octocoral, *L. virgulata* (Mitchell et al. 1993), this common octocoral would be expected to reach an average height of 8.4 inches (213.4 mm) within a 3.5 year timeframe. Based on the reduced services provided by the impacted habitat that is currently exposed to frequent prop wash and wave/wake impacts from large ships compared to the services expected to be provided by the habitat at the mitigation site, 3.5 years is expected to be enough time for the mitigation site to provide functions of a similar nature and magnitude as the impacted hardbottom habitat currently provides. Thus, we have estimated full recovery back to a stable epifaunal community on the emplaced artificial structures to be 3.5 years based on Wendt et al. (1988).

The use of a projected 3.5 year recovery time is further supported by the location and citing of the impact site and the mitigation sites, respectively. The impacted habitat occurs within the existing entrance channel, where it is subjected to frequent (~7 trips/day) passing of large ships. Prop wash and pressure wakes from these ships generate turbulence which likely affects the growth of sessile invertebrates. These frequent impacts are similar to the less frequent effects from major storm events (i.e., hurricanes and nor'easters) that generate significant wave action. In a study by Mitchell et al. (1993), hurricane events were noted to have caused high mortality of octocoral colonies on reefs at 22 m and 1-1.5 m depth. The study further states that, "…*it seems likely that each storm had an impact on gorgonian populations*." Woodley et al. (1981) states that the effects of hurricanes on sessile communities depends on the shapes, sizes, and mechanical properties of the individuals. The mitigation site will be outside of the navigation channel, where the frequent short-term impacts associated with ship passage will not impede growth of the coral recruits. This location further supports the use of a 3.5 year recovery period.

5.3 Discounting

Federal Water Resource Development Projects covered under the "Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies" (P&G) are limited by the statement "monetary or NED outputs are discounted" (OMB Circular A-4). This means environmental outputs from HEA are not authorized to be discounted for any project covered by the P&G (published through the CEQ/Office of the White House).

Specifically, page E-154 c(1) [CE/ICA procedures] of the PGN states, "Ecosystem restoration outputs are not discounted, but should be computed on an average annual basis, taking into consideration that the outputs achieved are likely to vary over time." Therefore a 0% discount rate was used in all HEA calculations. Due to the lack of discounting for this project, the outputs from the HEA model will be referred to as, "Service Acre Years" instead of "Discounted Service Acre Years".

5.4 Initiation of Mitigation Site Construction

For the HEA calculations, USACE assumed that mitigation site construction will be initiated concurrently with dredging, as material will be directly transferred to the mitigation site as it becomes available. There is no time-lag from the initiation of construction (at the impact site) to the initiation of mitigation construction (along the margins of the Entrance Channel). However, for greater simplicity in running the model and to be as conservative as possible in providing habitat benefits, recolonization at the impact site was not assumed to begin until the entire project area has been dredged.

6.0 CALCULATION OF MITIGATION REQUIRED FOR POST 45 PROJECT

HEAs were performed following Kohler and Dodge (2006). Variables use for "level of services lost" and "recovery time" are listed in Table 1 below. For each category, there is a flow of interim *lost* services through time, which was used to calculate the services in acre-years (acre-yr), then added to determine the total hardbottom service losses (Table 2).

For the restoration/mitigation portion of the HEA calculations (hardbottom berm/reef at ODMDS), level of service lost and the recovery times are summarized in Table 1. For each category, there is a flow of interim services *gained* through time, which was used to calculate the services generated in acre-years. The HEA addresses the areas of new impact from deepening and extending Charleston Harbor's Federal Channel. Data sheets provided in Attachment 1 indicate years inclusively; since approximately 3.5 years is required for recovery, any year during which the recovery is ongoing is taken into account (i.e., if construction is completed in the third quarter of 2014, the addition of 3.5 years of time closes the recovery period in the year 2019 and is extended to 2064 to represent the 50-year life of the project).

Table 1 HEA assumptions and hardbottom service acre-years lost for direct impacts from various project alternatives

Alternative's Authorized Depth (ft)	Alternative's Actual Depth (ft)	Area of impact (acres)	Dredging interval (in "quarter-years")	Initial service loss	Equilibrium Service Level	Time to full recovery (yr)	Service loss (acre-yr)
50	54	28.6	1	100%	100%	3.5	1462.2
50*	52	28.6	1	100%	100%	3.5	1462.2
52	56	28.6	2	100%	100%	3.5	1458.6
54**	58	28.6	3	100%	100%	3.5	1455.0

*Two feet of advanced dredging not included in this alternative
**Tentatively selected plan

Table 2 HEA assumptions for hardbottom service acre-years gained for direct impacts from various project alternatives and mitigation requirement

Alternative's Authorized Depth for which mitigation was calculated	Alternative's Actual Depth (ft) for which mitigation was calculated	Initial service gained	Maximum Service Provision @ Maturity	Time to full recovery (yr)	Total SAYs gained	SAYs gained per unit area	Replacement habitat size (ac) [=SAYs lost/SAYs gained per unit area]
50	54	0%	100%	3.5	1430.0	50.0	**29.2**
50*	52	0%	100%	3.5	1430.0	50.0	**29.2**
52	56	0%	100%	3.5	1422.9	49.8	**29.3**
54**	58	0%	100%	3.5	1415.7	49.5	**29.4**

*Two feet of advanced dredging not included in this alternative
**Tentatively selected plan

Finally, for each alternative, the SAYs lost are divided by the SAYs gained per unit area to determine the mitigation requirement (acres). The resulting values are multiplied by the replacement habitat size unit (acre, in this case). Table 2 lists the mitigation requirements based on direct impacts from the various alternatives in the entrance channel. Table 3 lists the level of service lost and the recovery times resulting from indirect impacts. Table 4 lists the mitigation requirements based on the indirect impacts from the various alternatives in the entrance channel. Table 5 lists the total number of acres of required mitigation for each of the alternatives based on both direct and indirect impacts from the alternatives.

Table 3 HEA assumptions and hardbottom service acre-years lost for the indirect impacts of various project alternatives

Alternative's Authorized Depth (ft)	Alternative's Actual Depth (ft)	Area of impact (acres)	Dredging interval (in "quarter-years")	Initial service loss	Service Level after Impact	Time to full recovery (yr)	Service loss (acre-yr)
50	54	186.3	1	100%	95%	3.5	17.5
50*	52	186.3	1	100%	95%	3.5	17.5
52	56	186.3	2	100%	95%	3.5	18.6
54**	58	186.3	3	100%	95%	3.5	19.8

*Two feet of advanced dredging not included in this alternative
**Tentatively selected plan

The total amount of compensatory mitigation was determined by the sum of the impacts from Tables 2 and 4, and is shown together in Table 5. Should the tentatively selected plan (also the LPP) be selected for construction, 29.8 acres of mitigation would be required. This compensation area yields a stream of benefits that goes on for the life of the created hardbottom reef and covers both the direct dredging impacts and the indirect impacts from sedimentation and turbidity during construction. In practice, USACE may construct more than the required amount of artificial reef based on available rock from the channel.

Table 4 HEA assumptions for hardbottom service acre-years gained for the indirect impacts of various project alternatives and mitigation requirement

Alternative's Authorized Depth for which mitigation was calculated	Alternative's Actual Depth (ft) for which mitigation was calculated	Initial service gained	Maximum Service Provision @ Maturity	Time to full recovery (yr)	Total SAYs gained	SAYs gained per unit area	Replacement habitat size (ac) [=SAYs lost/SAYs gained per unit area]
50	54	0%	100%	3.5	9291.7	49.9	**0.4**
50*	52	0%	100%	3.5	9291.7	49.9	**0.4**
52	56	0%	100%	3.5	9268.4	49.8	**0.4**
54**	58	0%	100%	3.5	9221.9	49.5	**0.4**

*Two feet of advanced dredging not included in this alternative
**Tentatively selected plan

Table 5 HEA summary of mitigation requirements

Alternative's Authorized Depth for which mitigation was calculated	Alternative's Actual Depth (ft) for which mitigation was calculated	Mitigation Requirement from Direct Impacts (acres)	Mitigation Requirement from Indirect Impacts (acres)	**Total Mitigation Requirement (acres)**
50	54	29.2	0.4	**29.6**
50*	52	29.2	0.4	**29.6**
52	56	29.3	0.4	**29.7**
54**	58	29.4	0.4	**29.8**

7.0 MONITORING AND ADAPTIVE MANAGEMENT FOR HARDBOTTOM HABITAT MITIGATION

Based on the Implementation Guidance for Section 2039 of the Water Resources Development Act of 2007 (WRDA 2007), this monitoring plan includes a description of the monitoring activities, the criteria for success, and the estimated cost and duration of the monitoring. Each biological monitoring survey will include underwater documentation surveys of the mitigation area, including both *in situ* data collection and video documentation to record conditions observed during the survey. The monitoring plan will be designed to allow the habitat at the mitigation area to be compared to the impact area.

Pre-Construction Impact Refinement

Prior to project construction, hardbottom surveys will be performed in the anticipated impact area (Figure 6). The surveys will consist of detailed side scan sonar, sub-bottom profiling and multibeam data collection. They will be conducted in the same manner as the hardbottom classification study for the Post 45 feasibility study (Gayes et al., 2013). Additionally, video tows will be conducted using a submersible camera equipped with GPS. The camera should be positioned to look downward and in front of the tow so as to avoid turbid water from disturbance. After data collection, all video should be reviewed. Changes in bottom type should noted by time (position). Video should be coded by stopping video tape every 5 seconds and describing and coding the field of view similar to table 2.2 in the following report: http://myscmap.sc.gov/marine/mrri/environ/pdf/2006HardBottomReef.pdf. Data should be processed according to SCDNR and Coastal Carolina University specifications for hardbottom interpretation. After the areas of hardbottom are identified, 5 randomly selected sites will be identified for either diver or Remotely Operated Vehicle (ROV) surveys to further define the habitat. Each site will be surveyed along a 20 m transect line and recorded with a GPS. Surficial sediment thickness will be measured by using a grab sampler. Video data will be analyzed for fish utilization and the sponge/coral communities inhabiting each site. The video camera will be equipped with lights and a measuring stick or calibrated lasers to aid in quantifying invertebrate size. Surveys will be reviewed to assess abundance and diversity (which takes into account richness and evenness) of sessile corals, sponges and finfish from the sites. Presence/absence should be recorded during each interval for massive sponges including *Ircinia* sp., encrusting sponges, and the soft corals *Leptogorgia* sp. and *Titanideum* sp.

Pre-Construction Mitigation Site Refinement

As discussed in the Hardbottom Impacts, Mitigation, and HEA Report, it is anticipated that roughly 30 acres of habitat will be created to compensate for the in-channel impacts. Prior to project construction, hardbottom and cultural resource surveys will be performed between the ODMDS and the Navigation Channel to locate a 30 acre site that will not impact existing resources (Figure x). The surveys will consist of detailed side scan sonar, sub-bottom profiling and multibeam data collection. Additionally, video tows will be conducted with GPS. The camera should be positioned to look downward and in front of the tow so as to avoid turbid water from disturbance. After data collection, all video should be reviewed. Changes in bottom type should noted by time (position). Video should be coded by stopping video tape every 5 seconds and describing and coding the field of view similar to table 2.2 in the following report: http://myscmap.sc.gov/marine/mrri/environ/pdf/2006HardBottomReef.pdf. Data should be processed according to SCDNR and Coastal Carolina University specifications for hardbottom interpretation. The least costly (based on construction methods/dredging and disposal costs) 30 acre location will be selected within this broader area for the mitigation reef. If SCDNR identifies priority sites for reef creation, those sites will be given higher priority for this project as long as they are not further than the travel distance to the ODMDS.

Monitoring during Construction

A real-time placement monitoring/verification system (Dredging Quality Management (DQM)) will be used to direct placement within specific patterns and tolerances as well as monitor how the placement actually occurred. The use of DQM is required for USACE federal navigation projects that use a scow or hopper dredge to dispose of material in an ODMDS. For actual placement, the dredging contractor will be provided specific discharge targets. The contractor will be required to slow for placement. Coming to a complete stop is likely not desirable in that as some motion is required to maintain steerage. Information regarding vessel loads, vessel tracks, and discharge time and location records is recorded and maintained in the DQM system. The DQM system will provide 24/7 coverage of operations, improve project management and oversight, and create a standard base for avoiding disputes.

Bathymetric surveys will be completed twice during construction of the reef to ensure that each of the cells in the mitigation reef plan are obtaining a peak vertical relief of 4-5 feet. If the cells are not reaching the desired relief with two scow loads, additional scows will be directed to those sites.

Post-Construction Monitoring

25% (4 cells) of the mitigation reef cells will be analyzed similar to the methods described above in “Pre-Construction Impact Refinement”. The cells will be chosen either randomly or strategically based on input from SCDNR and NMFS. Monitoring will occur within 6 months of completion of the reef and will continue once a year for 4 years in order to fully account for the anticipated 3.5 years to recovery. Monitoring should be completed, when possible, during the winter months to take advantage of better water column visibility. If the ecological success criteria are met prior to the completion of four years of monitoring, monitoring efforts may be ceased. If success criteria are not met at the end of 4 years, USACE will meet with SCDNR and NMFS to determine corrective actions (discussed below). Habitat Equivalency Analysis will be used to determine the amount of corrective action / adaptive management needed.

Success Criteria

The goal of the mitigation reef is to compensate for the lost ecological function of the hardbottom habitat at the impact reef as it pertains to essential fish habitat. Average community characteristics from the 5 sites in the impacted area will be used to establish detailed performance criteria for the mitigation reef. Criteria for success of the mitigation hardbottom habitat will be based upon the abundance and diversity of sessile invertebrates at the impact site. The success of the mitigation reef will be determined by comparing these parameters to the impacted site. Appropriate parametric and/or non-parametric statistics shall be employed in order to demonstrate mitigation success. SCDNR recommends that a realistic measure of success is “greater diversity and complexity over time and trending towards similarity with the impacted site pre-construction cover” (SCDNR email dated 20 May 2014). NMFS recommends the following parameters be used for measuring success:

- % cover by sessile invertebrates (i.e., encrusting inverts, coral and sponges)
- Sessile species size, abundance, and diversity (i.e., richness and evenness)
- Fish assemblage abundance and diversity

USACE will meet with representatives from NMFS and SCDNR to refine success criteria and to ensure the plan is considers all agency comments.

Adaptive Management

If success criteria are not met at the end of 4 years, USACE will meet with SCDNR and NMFS to determine corrective actions. Possible corrective actions include creating more artificial reef in coordination with SCDNR Artificial Reef Program or by possible mitigation reef enhancements based on best available science. Habitat Equivalency Analysis will be used to determine the amount of corrective action / adaptive management needed. It should be noted that any additional artificial reefs created as a result of the proposed project can, and should, be factored into the HEA to determine adaptive management needs.

7.0 GLOSSARY

Baseline – the original level of services provided by either the injured habitat (pre-injury) or the compensatory habitat (pre-restoration).

Compensatory restoration – the actions taken to enhance resources beyond baseline conditions to compensate for the loss of services at a damaged site.

Discounting – an economic procedure that weights past and future benefits or costs such that they are comparable with present benefits and costs.

Habitat Equivalency Analysis (HEA) – a framework for determining the area required for compensatory restoration, specifically used in cases of habitat injury when the service of the injured area is ecologically equivalent to the service that will be provided by the replacement habitat.

Metric – an attribute that provides a means of measuring relative differences in the quality and quantity of services provided by baseline, injured, and compensatory habitats to evaluate whether or not a restoration project has been successful.

Primary restoration – the actions taken to increase the recovery rate of the damaged site.

Resource equivalency analysis (REA) – a HEA approach similar to the service-to-service approach that is specifically used for scaling losses of fish, birds, and other wildlife.

Service-to-service approach – An HEA method used in cases of habitat injury when the service of the injured area is ecologically equivalent to the service that will be provided by the replacement habitat.

Services – although there are many types of services, applicable to habitat equivalency analysis are ecological services, such as fish rearing areas, which in turn support human services, such as recreational fishing.

8.0 REFERENCES

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ATTACHMENT 1:

HEA Data

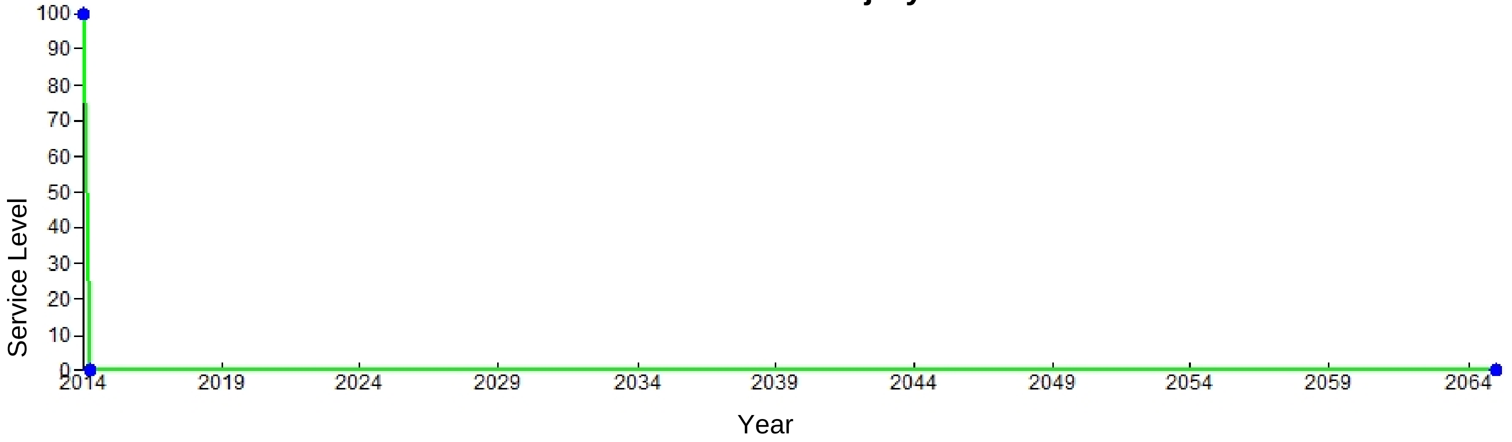
VISUAL_HEA HABITAT EQUIVALENCY ANALYSIS

Sitename: indirect impacts
Run date: 3/25/2014 1:00:30 PM
HEA datafile:

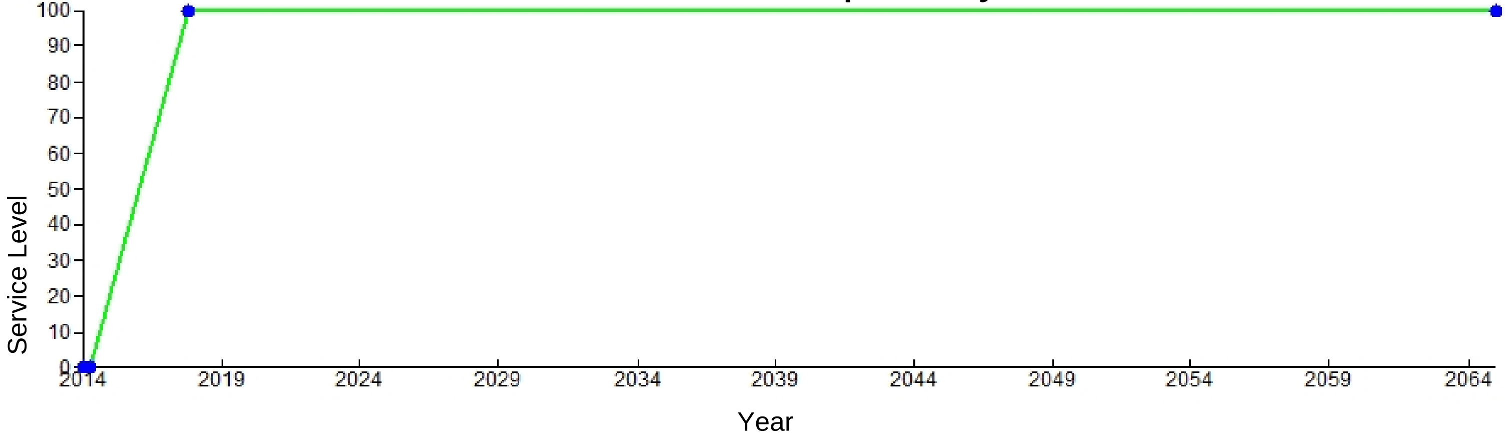
Current year: 2014
Number of area units injured: 28.6
Area units: acre
Time units: quarter

Discount rate(%): 0.000
Pre-injury service level (%): 100.00%
Pre-restoration service level (%): 0.00%
Value ratio (injured/restored): 1.00

Service losses at the Injury Area



Service Gains at the Compensatory Area



Service losses at the Injury Area

Year	% Services lost Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS lost
2014.00	.00%	100.00%	50.00%	3.575	1.000	3.575
2014.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2014.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2014.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.50	100.00%	100.00%	100.00%	7.150	1.000	7.150

Service Gains at the Compensatory Area

Year	% Services gained Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS gained
2014.00	.00%	.00%	0.00%	0.000	1.000	0.000
2014.25	.00%	7.14%	3.57%	0.255	1.000	0.255
2014.50	7.14%	14.29%	10.71%	0.766	1.000	0.766
2014.75	14.29%	21.43%	17.86%	1.277	1.000	1.277
2015.00	21.43%	28.57%	25.00%	1.788	1.000	1.788
2015.25	28.57%	35.71%	32.14%	2.298	1.000	2.298
2015.50	35.71%	42.86%	39.29%	2.809	1.000	2.809
2015.75	42.86%	50.00%	46.43%	3.320	1.000	3.320
2016.00	50.00%	57.14%	53.57%	3.830	1.000	3.830
2016.25	57.14%	64.29%	60.71%	4.341	1.000	4.341
2016.50	64.29%	71.43%	67.86%	4.852	1.000	4.852
2016.75	71.43%	78.57%	75.00%	5.363	1.000	5.363
2017.00	78.57%	85.71%	82.14%	5.873	1.000	5.873
2017.25	85.71%	92.86%	89.29%	6.384	1.000	6.384
2017.50	92.86%	100.00%	96.43%	6.895	1.000	6.895
2017.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.50	100.00%	100.00%	100.00%	7.150	1.000	7.150

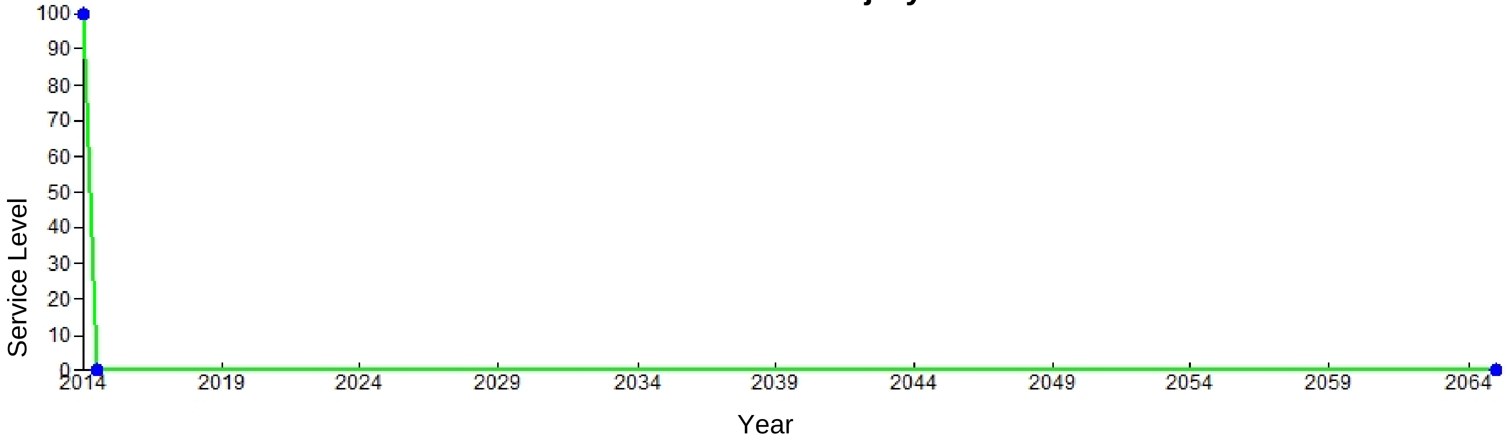
VISUAL_HEA HABITAT EQUIVALENCY ANALYSIS

Sitename: indirect impacts
Run date: 3/25/2014 12:58:35 PM
HEA datafile:

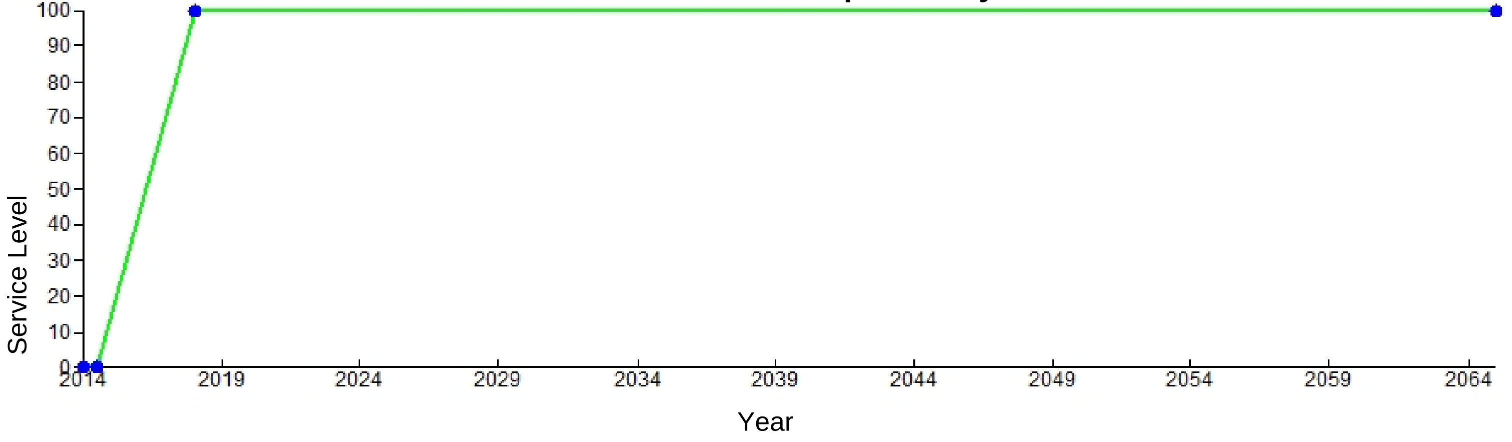
Current year: 2014
Number of area units injured: 28.6
Area units: acre
Time units: quarter

Discount rate(%): 0.000
Pre-injury service level (%): 100.00%
Pre-restoration service level (%): 0.00%
Value ratio (injured/restored): 1.00

Service losses at the Injury Area



Service Gains at the Compensatory Area



Service losses at the Injury Area

Year	% Services lost Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS lost
2014.00	.00%	50.00%	25.00%	1.788	1.000	1.788
2014.25	50.00%	100.00%	75.00%	5.363	1.000	5.363
2014.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2014.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.50	100.00%	100.00%	100.00%	7.150	1.000	7.150

Service Gains at the Compensatory Area

Year	% Services gained Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS gained
2014.00	.00%	.00%	0.00%	0.000	1.000	0.000
2014.25	.00%	.00%	0.00%	0.000	1.000	0.000
2014.50	.00%	7.14%	3.57%	0.255	1.000	0.255
2014.75	7.14%	14.29%	10.71%	0.766	1.000	0.766
2015.00	14.29%	21.43%	17.86%	1.277	1.000	1.277
2015.25	21.43%	28.57%	25.00%	1.788	1.000	1.788
2015.50	28.57%	35.71%	32.14%	2.298	1.000	2.298
2015.75	35.71%	42.86%	39.29%	2.809	1.000	2.809
2016.00	42.86%	50.00%	46.43%	3.320	1.000	3.320
2016.25	50.00%	57.14%	53.57%	3.830	1.000	3.830
2016.50	57.14%	64.29%	60.71%	4.341	1.000	4.341
2016.75	64.29%	71.43%	67.86%	4.852	1.000	4.852
2017.00	71.43%	78.57%	75.00%	5.363	1.000	5.363
2017.25	78.57%	85.71%	82.14%	5.873	1.000	5.873
2017.50	85.71%	92.86%	89.29%	6.384	1.000	6.384
2017.75	92.86%	100.00%	96.43%	6.895	1.000	6.895
2018.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.50	100.00%	100.00%	100.00%	7.150	1.000	7.150

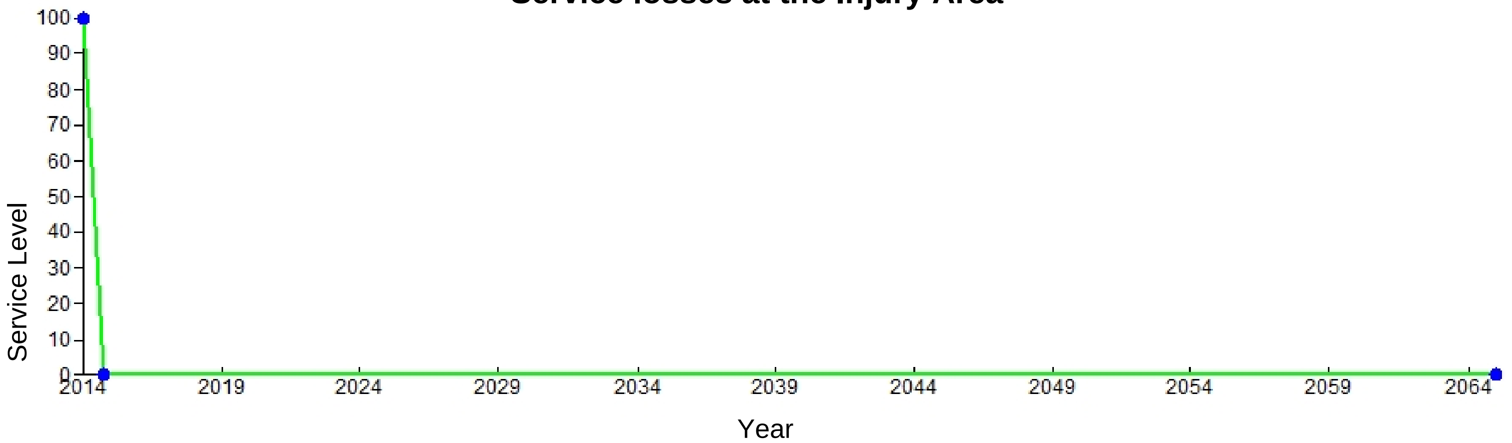
VISUAL_HEA HABITAT EQUIVALENCY ANALYSIS

Sitename: indirect impacts
Run date: 3/25/2014 12:56:50 PM
HEA datafile:

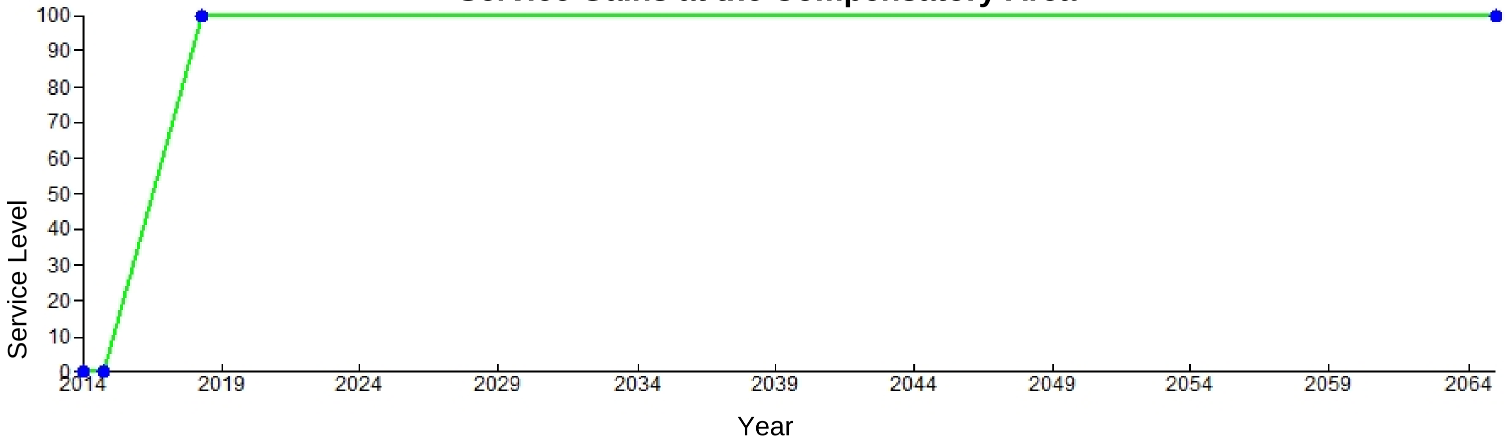
Current year: 2014
Number of area units injured: 28.6
Area units: acre
Time units: quarter

Discount rate(%): 0.000
Pre-injury service level (%): 100.00%
Pre-restoration service level (%): 0.00%
Value ratio (injured/restored): 1.00

Service losses at the Injury Area



Service Gains at the Compensatory Area



Service losses at the Injury Area

Year	% Services lost					
	Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS lost
2014.00	.00%	33.33%	16.67%	1.192	1.000	1.192
2014.25	33.33%	66.67%	50.00%	3.575	1.000	3.575
2014.50	66.67%	100.00%	83.33%	5.958	1.000	5.958
2014.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2015.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2016.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2017.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.50	100.00%	100.00%	100.00%	7.150	1.000	7.150

Service Gains at the Compensatory Area

Year	% Services gained					
	Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS gained
2014.00	.00%	.00%	0.00%	0.000	1.000	0.000
2014.25	.00%	.00%	0.00%	0.000	1.000	0.000
2014.50	.00%	.00%	0.00%	0.000	1.000	0.000
2014.75	.00%	7.14%	3.57%	0.255	1.000	0.255
2015.00	7.14%	14.29%	10.71%	0.766	1.000	0.766
2015.25	14.29%	21.43%	17.86%	1.277	1.000	1.277
2015.50	21.43%	28.57%	25.00%	1.788	1.000	1.788
2015.75	28.57%	35.71%	32.14%	2.298	1.000	2.298
2016.00	35.71%	42.86%	39.29%	2.809	1.000	2.809
2016.25	42.86%	50.00%	46.43%	3.320	1.000	3.320
2016.50	50.00%	57.14%	53.57%	3.830	1.000	3.830
2016.75	57.14%	64.29%	60.71%	4.341	1.000	4.341
2017.00	64.29%	71.43%	67.86%	4.852	1.000	4.852
2017.25	71.43%	78.57%	75.00%	5.363	1.000	5.363
2017.50	78.57%	85.71%	82.14%	5.873	1.000	5.873
2017.75	85.71%	92.86%	89.29%	6.384	1.000	6.384
2018.00	92.86%	100.00%	96.43%	6.895	1.000	6.895
2018.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2018.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2019.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2020.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2021.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2022.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2023.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2024.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.50	100.00%	100.00%	100.00%	7.150	1.000	7.150
2025.75	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.00	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.25	100.00%	100.00%	100.00%	7.150	1.000	7.150
2026.50	100.00%	100.00%	100.00%	7.150	1.000	7.150

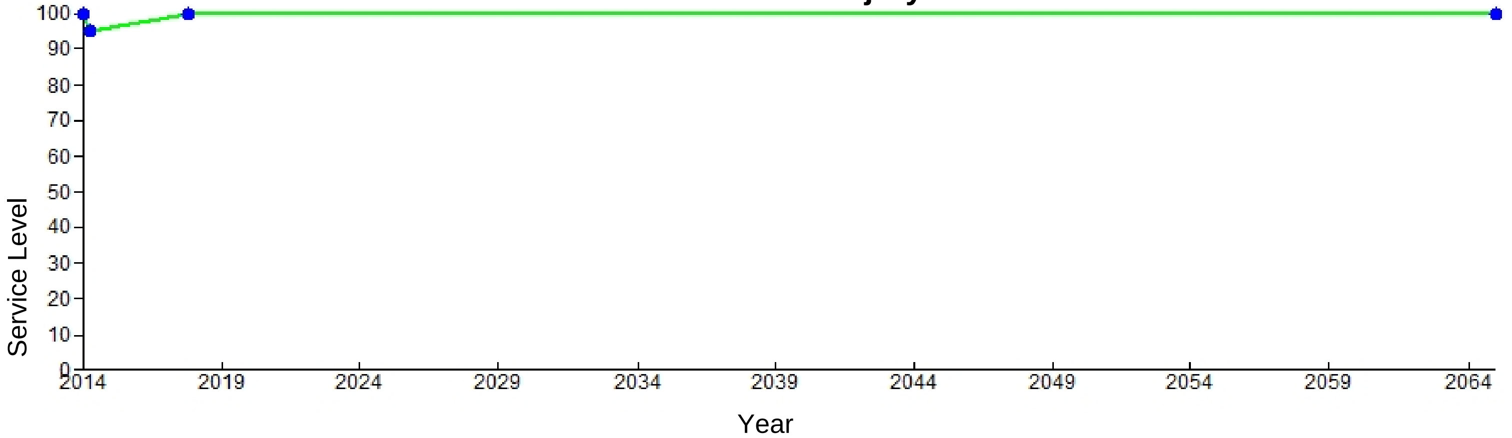
VISUAL_HEA HABITAT EQUIVALENCY ANALYSIS

Sitename: indirect impacts
Run date: 3/25/2014 1:10:49 PM
HEA datafile:

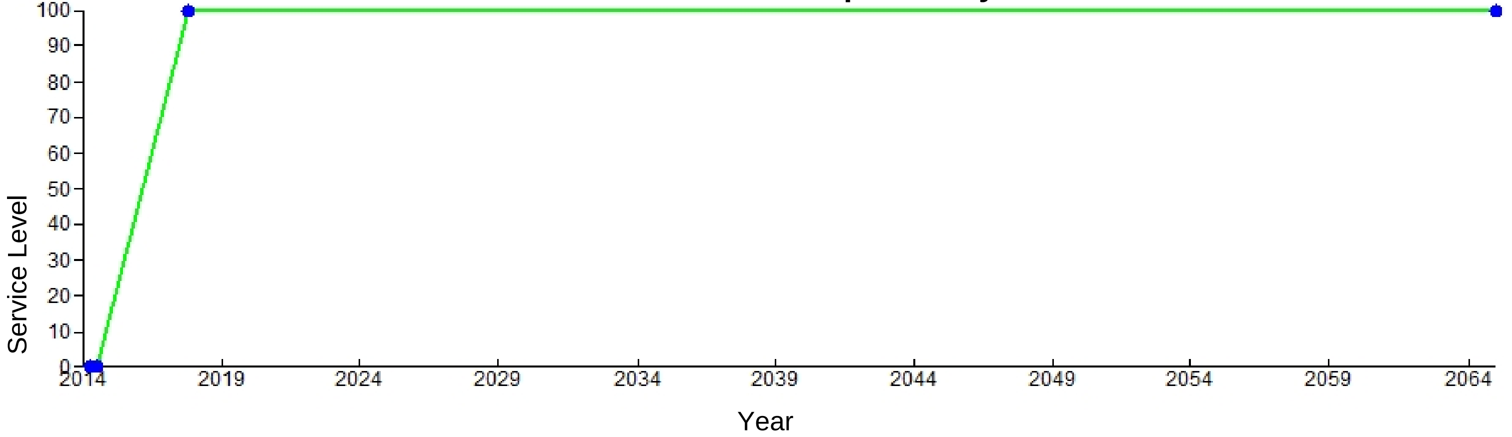
Current year: 2014
Number of area units injured: 186.3
Area units: acre
Time units: quarter

Discount rate(%): 0.000
Pre-injury service level (%): 100.00%
Pre-restoration service level (%): 0.00%
Value ratio (injured/restored): 1.00

Service losses at the Injury Area



Service Gains at the Compensatory Area



Service losses at the Injury Area

Year	% Services lost Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS lost
2014.00	.00%	5.00%	2.50%	1.164	1.000	1.164
2014.25	5.00%	4.64%	4.82%	2.246	1.000	2.246
2014.50	4.64%	4.29%	4.46%	2.079	1.000	2.079
2014.75	4.29%	3.93%	4.11%	1.913	1.000	1.913
2015.00	3.93%	3.57%	3.75%	1.747	1.000	1.747
2015.25	3.57%	3.21%	3.39%	1.580	1.000	1.580
2015.50	3.21%	2.86%	3.04%	1.414	1.000	1.414
2015.75	2.86%	2.50%	2.68%	1.248	1.000	1.248
2016.00	2.50%	2.14%	2.32%	1.081	1.000	1.081
2016.25	2.14%	1.79%	1.96%	0.915	1.000	0.915
2016.50	1.79%	1.43%	1.61%	0.749	1.000	0.749
2016.75	1.43%	1.07%	1.25%	0.582	1.000	0.582
2017.00	1.07%	.71%	0.89%	0.416	1.000	0.416
2017.25	.71%	.36%	0.54%	0.250	1.000	0.250
2017.50	.36%	.00%	0.18%	0.083	1.000	0.083
2017.75	.00%	.00%	0.00%	0.000	1.000	0.000
2018.00	.00%	.00%	0.00%	0.000	1.000	0.000
2018.25	.00%	.00%	0.00%	0.000	1.000	0.000
2018.50	.00%	.00%	0.00%	0.000	1.000	0.000
2018.75	.00%	.00%	0.00%	0.000	1.000	0.000
2019.00	.00%	.00%	0.00%	0.000	1.000	0.000
2019.25	.00%	.00%	0.00%	0.000	1.000	0.000
2019.50	.00%	.00%	0.00%	0.000	1.000	0.000
2019.75	.00%	.00%	0.00%	0.000	1.000	0.000
2020.00	.00%	.00%	0.00%	0.000	1.000	0.000
2020.25	.00%	.00%	0.00%	0.000	1.000	0.000
2020.50	.00%	.00%	0.00%	0.000	1.000	0.000
2020.75	.00%	.00%	0.00%	0.000	1.000	0.000
2021.00	.00%	.00%	0.00%	0.000	1.000	0.000
2021.25	.00%	.00%	0.00%	0.000	1.000	0.000
2021.50	.00%	.00%	0.00%	0.000	1.000	0.000
2021.75	.00%	.00%	0.00%	0.000	1.000	0.000
2022.00	.00%	.00%	0.00%	0.000	1.000	0.000
2022.25	.00%	.00%	0.00%	0.000	1.000	0.000
2022.50	.00%	.00%	0.00%	0.000	1.000	0.000
2022.75	.00%	.00%	0.00%	0.000	1.000	0.000
2023.00	.00%	.00%	0.00%	0.000	1.000	0.000
2023.25	.00%	.00%	0.00%	0.000	1.000	0.000
2023.50	.00%	.00%	0.00%	0.000	1.000	0.000
2023.75	.00%	.00%	0.00%	0.000	1.000	0.000
2024.00	.00%	.00%	0.00%	0.000	1.000	0.000
2024.25	.00%	.00%	0.00%	0.000	1.000	0.000
2024.50	.00%	.00%	0.00%	0.000	1.000	0.000
2024.75	.00%	.00%	0.00%	0.000	1.000	0.000
2025.00	.00%	.00%	0.00%	0.000	1.000	0.000
2025.25	.00%	.00%	0.00%	0.000	1.000	0.000
2025.50	.00%	.00%	0.00%	0.000	1.000	0.000
2025.75	.00%	.00%	0.00%	0.000	1.000	0.000
2026.00	.00%	.00%	0.00%	0.000	1.000	0.000
2026.25	.00%	.00%	0.00%	0.000	1.000	0.000
2026.50	.00%	.00%	0.00%	0.000	1.000	0.000

Service Gains at the Compensatory Area

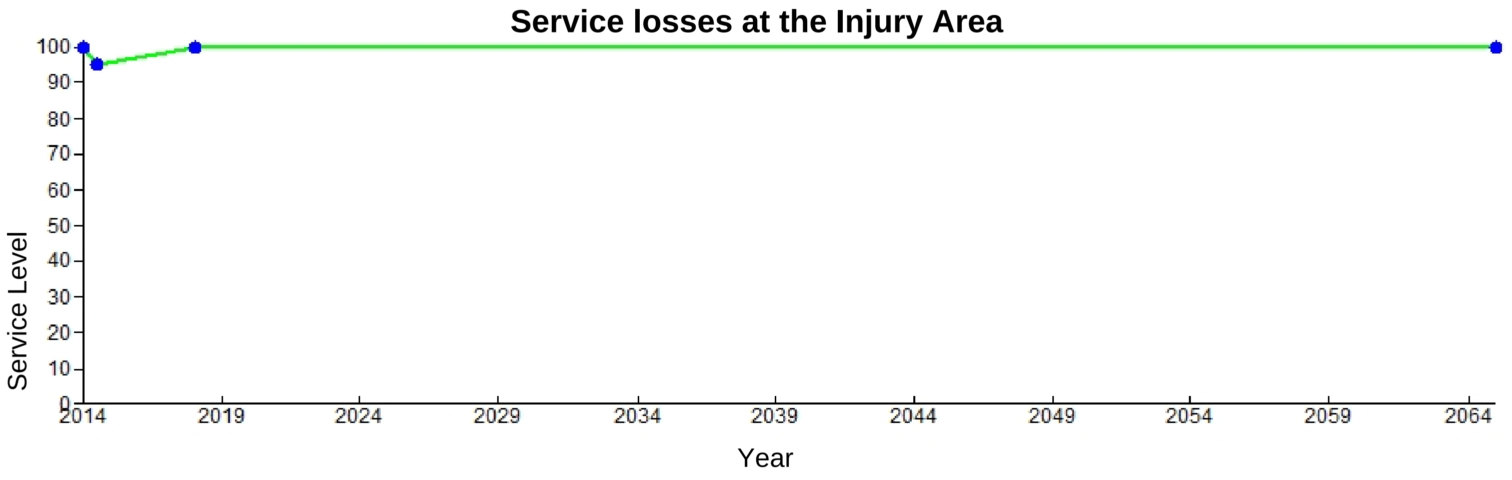
Year	% Services gained Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS gained
2014.25	.00%	.00%	0.00%	0.000	1.000	0.000
2014.50	.00%	7.69%	3.85%	1.791	1.000	1.791
2014.75	7.69%	15.38%	11.54%	5.374	1.000	5.374
2015.00	15.38%	23.08%	19.23%	8.957	1.000	8.957
2015.25	23.08%	30.77%	26.92%	12.539	1.000	12.539
2015.50	30.77%	38.46%	34.62%	16.122	1.000	16.122
2015.75	38.46%	46.15%	42.31%	19.705	1.000	19.705
2016.00	46.15%	53.85%	50.00%	23.288	1.000	23.288
2016.25	53.85%	61.54%	57.69%	26.870	1.000	26.870
2016.50	61.54%	69.23%	65.38%	30.453	1.000	30.453
2016.75	69.23%	76.92%	73.08%	34.036	1.000	34.036
2017.00	76.92%	84.62%	80.77%	37.618	1.000	37.618
2017.25	84.62%	92.31%	88.46%	41.201	1.000	41.201
2017.50	92.31%	100.00%	96.15%	44.784	1.000	44.784
2017.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.75	100.00%	100.00%	100.00%	46.575	1.000	46.575

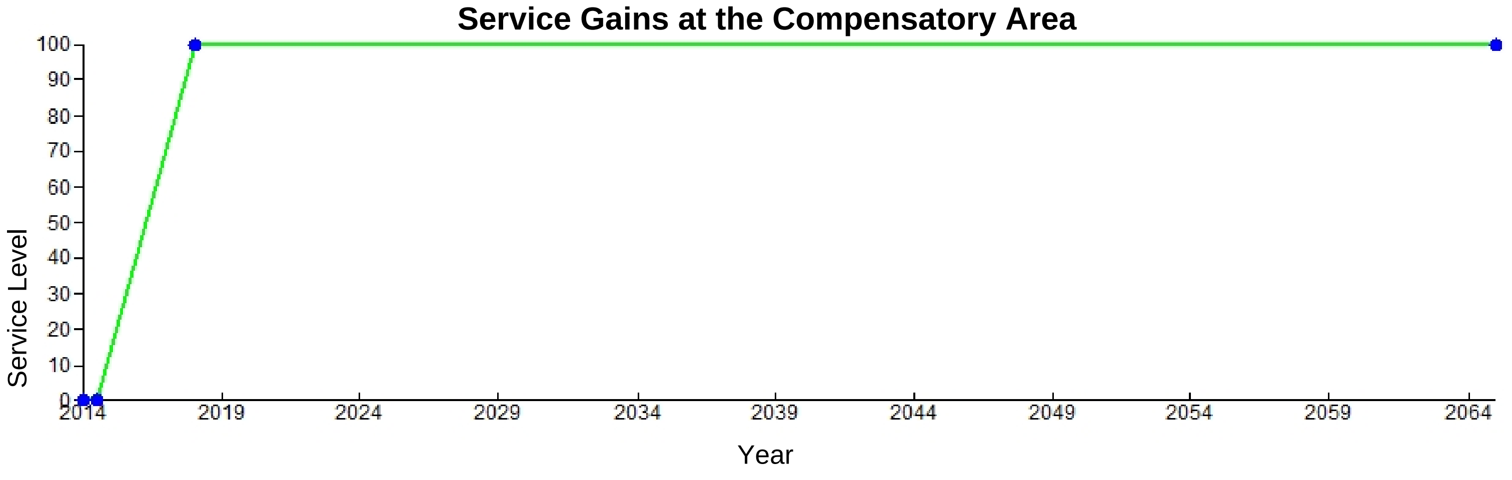
VISUAL_HEA HABITAT EQUIVALENCY ANALYSIS

Sitename: indirect impacts
Run date: 3/25/2014 1:08:59 PM
HEA datafile:

Current year: 2014
Number of area units injured: 186.3
Area units: acre
Time units: quarter

Discount rate(%): 0.000
Pre-injury service level (%): 100.00%
Pre-restoration service level (%): 0.00%
Value ratio (injured/restored): 1.00





Service losses at the Injury Area

Year	% Services lost Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS lost
2014.00	.00%	2.50%	1.25%	0.582	1.000	0.582
2014.25	2.50%	5.00%	3.75%	1.747	1.000	1.747
2014.50	5.00%	4.64%	4.82%	2.246	1.000	2.246
2014.75	4.64%	4.29%	4.46%	2.079	1.000	2.079
2015.00	4.29%	3.93%	4.11%	1.913	1.000	1.913
2015.25	3.93%	3.57%	3.75%	1.747	1.000	1.747
2015.50	3.57%	3.21%	3.39%	1.580	1.000	1.580
2015.75	3.21%	2.86%	3.04%	1.414	1.000	1.414
2016.00	2.86%	2.50%	2.68%	1.248	1.000	1.248
2016.25	2.50%	2.14%	2.32%	1.081	1.000	1.081
2016.50	2.14%	1.79%	1.96%	0.915	1.000	0.915
2016.75	1.79%	1.43%	1.61%	0.749	1.000	0.749
2017.00	1.43%	1.07%	1.25%	0.582	1.000	0.582
2017.25	1.07%	.71%	0.89%	0.416	1.000	0.416
2017.50	.71%	.36%	0.54%	0.250	1.000	0.250
2017.75	.36%	.00%	0.18%	0.083	1.000	0.083
2018.00	.00%	.00%	0.00%	0.000	1.000	0.000
2018.25	.00%	.00%	0.00%	0.000	1.000	0.000
2018.50	.00%	.00%	0.00%	0.000	1.000	0.000
2018.75	.00%	.00%	0.00%	0.000	1.000	0.000
2019.00	.00%	.00%	0.00%	0.000	1.000	0.000
2019.25	.00%	.00%	0.00%	0.000	1.000	0.000
2019.50	.00%	.00%	0.00%	0.000	1.000	0.000
2019.75	.00%	.00%	0.00%	0.000	1.000	0.000
2020.00	.00%	.00%	0.00%	0.000	1.000	0.000
2020.25	.00%	.00%	0.00%	0.000	1.000	0.000
2020.50	.00%	.00%	0.00%	0.000	1.000	0.000
2020.75	.00%	.00%	0.00%	0.000	1.000	0.000
2021.00	.00%	.00%	0.00%	0.000	1.000	0.000
2021.25	.00%	.00%	0.00%	0.000	1.000	0.000
2021.50	.00%	.00%	0.00%	0.000	1.000	0.000
2021.75	.00%	.00%	0.00%	0.000	1.000	0.000
2022.00	.00%	.00%	0.00%	0.000	1.000	0.000
2022.25	.00%	.00%	0.00%	0.000	1.000	0.000
2022.50	.00%	.00%	0.00%	0.000	1.000	0.000
2022.75	.00%	.00%	0.00%	0.000	1.000	0.000
2023.00	.00%	.00%	0.00%	0.000	1.000	0.000
2023.25	.00%	.00%	0.00%	0.000	1.000	0.000
2023.50	.00%	.00%	0.00%	0.000	1.000	0.000
2023.75	.00%	.00%	0.00%	0.000	1.000	0.000
2024.00	.00%	.00%	0.00%	0.000	1.000	0.000
2024.25	.00%	.00%	0.00%	0.000	1.000	0.000
2024.50	.00%	.00%	0.00%	0.000	1.000	0.000
2024.75	.00%	.00%	0.00%	0.000	1.000	0.000
2025.00	.00%	.00%	0.00%	0.000	1.000	0.000
2025.25	.00%	.00%	0.00%	0.000	1.000	0.000
2025.50	.00%	.00%	0.00%	0.000	1.000	0.000
2025.75	.00%	.00%	0.00%	0.000	1.000	0.000
2026.00	.00%	.00%	0.00%	0.000	1.000	0.000
2026.25	.00%	.00%	0.00%	0.000	1.000	0.000
2026.50	.00%	.00%	0.00%	0.000	1.000	0.000

Service Gains at the Compensatory Area

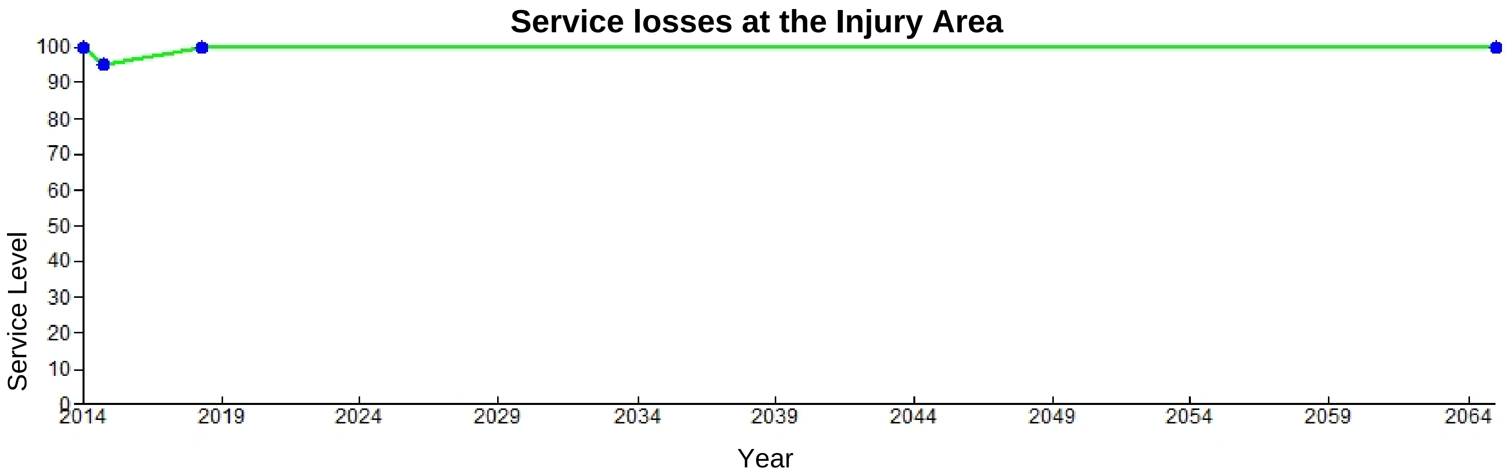
Year	% Services gained Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS gained
2014.00	.00%	.00%	0.00%	0.000	1.000	0.000
2014.25	.00%	.00%	0.00%	0.000	1.000	0.000
2014.50	.00%	7.14%	3.57%	1.663	1.000	1.663
2014.75	7.14%	14.29%	10.71%	4.990	1.000	4.990
2015.00	14.29%	21.43%	17.86%	8.317	1.000	8.317
2015.25	21.43%	28.57%	25.00%	11.644	1.000	11.644
2015.50	28.57%	35.71%	32.14%	14.971	1.000	14.971
2015.75	35.71%	42.86%	39.29%	18.297	1.000	18.297
2016.00	42.86%	50.00%	46.43%	21.624	1.000	21.624
2016.25	50.00%	57.14%	53.57%	24.951	1.000	24.951
2016.50	57.14%	64.29%	60.71%	28.278	1.000	28.278
2016.75	64.29%	71.43%	67.86%	31.604	1.000	31.604
2017.00	71.43%	78.57%	75.00%	34.931	1.000	34.931
2017.25	78.57%	85.71%	82.14%	38.258	1.000	38.258
2017.50	85.71%	92.86%	89.29%	41.585	1.000	41.585
2017.75	92.86%	100.00%	96.43%	44.912	1.000	44.912
2018.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.50	100.00%	100.00%	100.00%	46.575	1.000	46.575

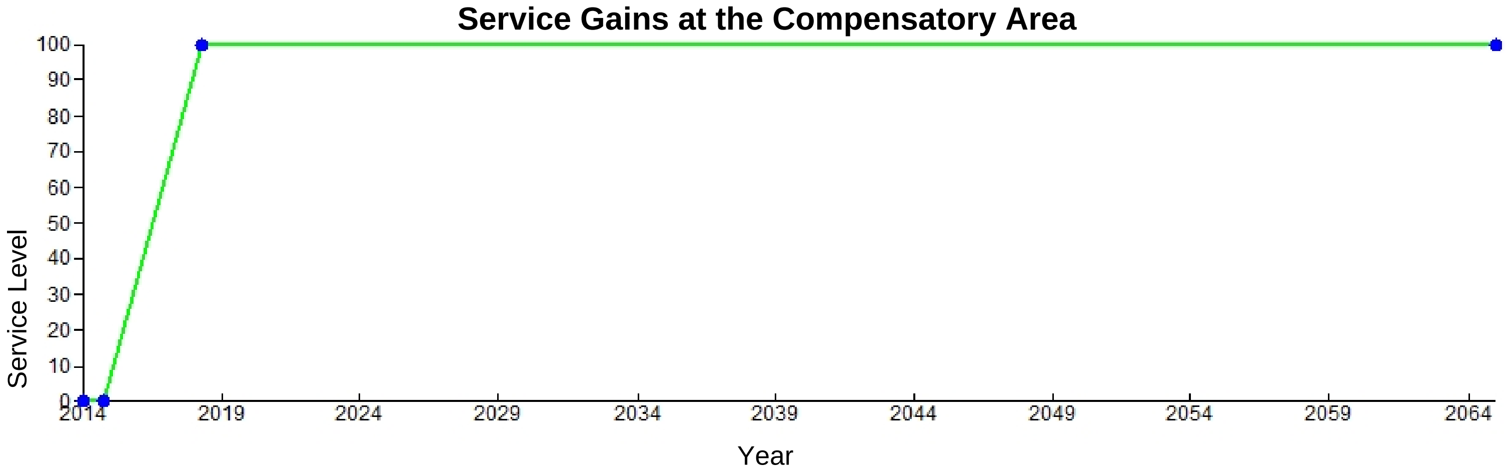
VISUAL_HEA HABITAT EQUIVALENCY ANALYSIS

Sitename: indirect impacts
Run date: 3/25/2014 1:07:15 PM
HEA datafile:

Current year: 2014
Number of area units injured: 186.3
Area units: acre
Time units: quarter

Discount rate(%): 0.000
Pre-injury service level (%): 100.00%
Pre-restoration service level (%): 0.00%
Value ratio (injured/restored): 1.00





Service losses at the Injury Area

Year	% Services lost Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS lost
2014.00	.00%	1.67%	0.83%	0.388	1.000	0.388
2014.25	1.67%	3.33%	2.50%	1.164	1.000	1.164
2014.50	3.33%	5.00%	4.17%	1.941	1.000	1.941
2014.75	5.00%	4.64%	4.82%	2.246	1.000	2.246
2015.00	4.64%	4.29%	4.46%	2.079	1.000	2.079
2015.25	4.29%	3.93%	4.11%	1.913	1.000	1.913
2015.50	3.93%	3.57%	3.75%	1.747	1.000	1.747
2015.75	3.57%	3.21%	3.39%	1.580	1.000	1.580
2016.00	3.21%	2.86%	3.04%	1.414	1.000	1.414
2016.25	2.86%	2.50%	2.68%	1.248	1.000	1.248
2016.50	2.50%	2.14%	2.32%	1.081	1.000	1.081
2016.75	2.14%	1.79%	1.96%	0.915	1.000	0.915
2017.00	1.79%	1.43%	1.61%	0.749	1.000	0.749
2017.25	1.43%	1.07%	1.25%	0.582	1.000	0.582
2017.50	1.07%	.71%	0.89%	0.416	1.000	0.416
2017.75	.71%	.36%	0.54%	0.250	1.000	0.250
2018.00	.36%	.00%	0.18%	0.083	1.000	0.083
2018.25	.00%	.00%	0.00%	0.000	1.000	0.000
2018.50	.00%	.00%	0.00%	0.000	1.000	0.000
2018.75	.00%	.00%	0.00%	0.000	1.000	0.000
2019.00	.00%	.00%	0.00%	0.000	1.000	0.000
2019.25	.00%	.00%	0.00%	0.000	1.000	0.000
2019.50	.00%	.00%	0.00%	0.000	1.000	0.000
2019.75	.00%	.00%	0.00%	0.000	1.000	0.000
2020.00	.00%	.00%	0.00%	0.000	1.000	0.000
2020.25	.00%	.00%	0.00%	0.000	1.000	0.000
2020.50	.00%	.00%	0.00%	0.000	1.000	0.000
2020.75	.00%	.00%	0.00%	0.000	1.000	0.000
2021.00	.00%	.00%	0.00%	0.000	1.000	0.000
2021.25	.00%	.00%	0.00%	0.000	1.000	0.000
2021.50	.00%	.00%	0.00%	0.000	1.000	0.000
2021.75	.00%	.00%	0.00%	0.000	1.000	0.000
2022.00	.00%	.00%	0.00%	0.000	1.000	0.000
2022.25	.00%	.00%	0.00%	0.000	1.000	0.000
2022.50	.00%	.00%	0.00%	0.000	1.000	0.000
2022.75	.00%	.00%	0.00%	0.000	1.000	0.000
2023.00	.00%	.00%	0.00%	0.000	1.000	0.000
2023.25	.00%	.00%	0.00%	0.000	1.000	0.000
2023.50	.00%	.00%	0.00%	0.000	1.000	0.000
2023.75	.00%	.00%	0.00%	0.000	1.000	0.000
2024.00	.00%	.00%	0.00%	0.000	1.000	0.000
2024.25	.00%	.00%	0.00%	0.000	1.000	0.000
2024.50	.00%	.00%	0.00%	0.000	1.000	0.000
2024.75	.00%	.00%	0.00%	0.000	1.000	0.000
2025.00	.00%	.00%	0.00%	0.000	1.000	0.000
2025.25	.00%	.00%	0.00%	0.000	1.000	0.000
2025.50	.00%	.00%	0.00%	0.000	1.000	0.000
2025.75	.00%	.00%	0.00%	0.000	1.000	0.000
2026.00	.00%	.00%	0.00%	0.000	1.000	0.000
2026.25	.00%	.00%	0.00%	0.000	1.000	0.000
2026.50	.00%	.00%	0.00%	0.000	1.000	0.000

Service Gains at the Compensatory Area

Year	% Services gained Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS gained
2014.00	.00%	.00%	0.00%	0.000	1.000	0.000
2014.25	.00%	.00%	0.00%	0.000	1.000	0.000
2014.50	.00%	.00%	0.00%	0.000	1.000	0.000
2014.75	.00%	7.14%	3.57%	1.663	1.000	1.663
2015.00	7.14%	14.29%	10.71%	4.990	1.000	4.990
2015.25	14.29%	21.43%	17.86%	8.317	1.000	8.317
2015.50	21.43%	28.57%	25.00%	11.644	1.000	11.644
2015.75	28.57%	35.71%	32.14%	14.971	1.000	14.971
2016.00	35.71%	42.86%	39.29%	18.297	1.000	18.297
2016.25	42.86%	50.00%	46.43%	21.624	1.000	21.624
2016.50	50.00%	57.14%	53.57%	24.951	1.000	24.951
2016.75	57.14%	64.29%	60.71%	28.278	1.000	28.278
2017.00	64.29%	71.43%	67.86%	31.604	1.000	31.604
2017.25	71.43%	78.57%	75.00%	34.931	1.000	34.931
2017.50	78.57%	85.71%	82.14%	38.258	1.000	38.258
2017.75	85.71%	92.86%	89.29%	41.585	1.000	41.585
2018.00	92.86%	100.00%	96.43%	44.912	1.000	44.912
2018.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.50	100.00%	100.00%	100.00%	46.575	1.000	46.575

ATTACHMENT 2:

STFATE Analysis

Service Gains at the Compensatory Area

Year	% Services gained Beginning	End	Mean	Raw SAYS lost	Discount Factor	Discounted SAYS gained
2014.00	.00%	.00%	0.00%	0.000	1.000	0.000
2014.25	.00%	.00%	0.00%	0.000	1.000	0.000
2014.50	.00%	.00%	0.00%	0.000	1.000	0.000
2014.75	.00%	7.14%	3.57%	1.663	1.000	1.663
2015.00	7.14%	14.29%	10.71%	4.990	1.000	4.990
2015.25	14.29%	21.43%	17.86%	8.317	1.000	8.317
2015.50	21.43%	28.57%	25.00%	11.644	1.000	11.644
2015.75	28.57%	35.71%	32.14%	14.971	1.000	14.971
2016.00	35.71%	42.86%	39.29%	18.297	1.000	18.297
2016.25	42.86%	50.00%	46.43%	21.624	1.000	21.624
2016.50	50.00%	57.14%	53.57%	24.951	1.000	24.951
2016.75	57.14%	64.29%	60.71%	28.278	1.000	28.278
2017.00	64.29%	71.43%	67.86%	31.604	1.000	31.604
2017.25	71.43%	78.57%	75.00%	34.931	1.000	34.931
2017.50	78.57%	85.71%	82.14%	38.258	1.000	38.258
2017.75	85.71%	92.86%	89.29%	41.585	1.000	41.585
2018.00	92.86%	100.00%	96.43%	44.912	1.000	44.912
2018.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2018.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2019.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2020.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2021.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2022.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2023.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2024.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.50	100.00%	100.00%	100.00%	46.575	1.000	46.575
2025.75	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.00	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.25	100.00%	100.00%	100.00%	46.575	1.000	46.575
2026.50	100.00%	100.00%	100.00%	46.575	1.000	46.575

APPENDIX 2:

STFATE Analysis

Appendix B: Simulation of Cutterhead-Dredged Rock Placement with STFATE

ABSTRACT

Simulations were conducted with the Short-Term FATE of dredged material model (STFATE) to estimate bottom relief and footprint of 6- to 10-inch diameter rock placed from a 6000 CY split-hull scow in 40 ft water depth. Settling velocities of individual rock were estimated to verify that the physics of the descent phase in STFATE were modeled appropriately. The resulting heights of the mound ranged from 3.7-4.5 ft, and the resulting footprint (defined as the 1-ft contour) ranged from 250 to 310 ft. The simulations indicated very little difference in results between 6 and 10 inch rock. The greater influence on the results was the longitudinal spreading of material associated with time to empty the scow contents and similarly vessel speed at time of placement.

BACKGROUND

This analysis evaluates the bottom footprint of dredged limestone rocks released from a 6000 CY dump scow in approximately 40 ft water depth. The dredged/blasted rocks are estimated to range in diameter from 6-10 inches (15-25 cm). The estimated footprint of deposited rock was evaluated with empirical settling velocity estimates and the Short-Term FATE (STFATE) of dredged material model.

METHODS

The Short-Term FATE (STFATE) of dredged material model simulates the descent and spread of dredged material from the placement vessel to the bed. The descent phase of the placement is simulated by the model as a negatively buoyant fluid suspension of solids. For this mode of descent, the vertical velocity of the negatively buoyant cloud must be significantly larger than the individual settling velocities of the individual particles (in this case, rocks). To evaluate whether the rock would behave as a negatively buoyant cloud as assumed by the STFATE model, the settling velocity of individual rocks was compared to the settling velocity of the descending plume of rocks released from a split-hull scow.

Individual Particle Settling

The size and settling velocity of 10-inch limestone rock, significantly exceeds the laminar flow assumptions of Stokes law expressed as $Re_p = \frac{w_s d}{\nu} << 1$ (where Re_p is particle Reynolds number, w_s is particle settling velocity, *d* is nominal particle diameter, and *v* is kinematic velocity of the fluid medium). Stokes settling velocity expression has been extended to particle Reynolds numbers as high as 800 by Oseen (19xx) and Schiller-Naumann (19xx) as summarized in Graf (1971). In addition to the large Reynolds numbers of the blasted rock under consideration (on the order of 10^5-10^6), the smooth and spherical assumptions for shape and surface roughness are questionable. Other approaches to the settling velocity problem well outside the Stokes regime are generally empirical in nature. Dietrich (1982) developed a settling velocity expression empirically derived from a large dataset of natural particles with varying size, shape and surface texture. The size of the rock considered in this study is still slightly outside the range of sizes considered by Dietrich, but Dietrich's method is considered sufficient for an approximate estimate of settling velocity.

The following rock characteristics were assumed in the application of Dietrich's method for estimating individual settling velocities of the rock:

(a) nominal diameter of the rock between 6-10 inches,
(b) density of limestone of 2600 kg/m^3,
(c) Corey Shape Factor of 0.7 (common shape of natural pebbles)

($csf = \frac{c}{\sqrt{ab}}$, where *a*,*b*,*c* are the long, intermediate, and short particle axis lengths, respectively), and

(d) Powers Roundness Index of 2.0 (characteristic of crushed grains).

The resulting settling velocities of individual rocks range from 3.8 to 5.4 ft/s. Assuming that the porosity (volume of voids/total volume) is 0.4, the bulk density of the material to be released is 1.97 g/cm^3, and typical dimensions of a 6000 CY split hull scow, the descent velocity of the dense plume was estimated with STFATE to be 21-23 ft/s, significantly larger than the individual particle settling velocity.

STFATE Simulations

The STFATE simulations were executed to represent placement of 6 to 10 inch diameter rock from a 6000 CY split hull scow in 40 ft water depth. The related input parameters are provided in Table 1. The scow dimensions of the Weeks Marine #264 (a 6600 CY, ocean certified scow) were applied as a representative vessel in the 6000-CY class. Given the scow dimensions and projected loading, the loaded draft was 22.1 ft. Vessel velocity at time of release was 2 knots, and the vessel was projected to take 30-60 seconds to fully release the load of rock. Four simulations were executed, representing rock sizes of 6 and 10 inch and release times of 30 and 60 seconds.

Table 1. STFATE Key Parameters

Barge (Weeks #264)	
Max Capacity	6600 CY
Vessel length	286 ft
Vessel beam	62 ft
Bin length	180 ft
Bin width	46.5 ft
Speed during release	2 knots
Material Description	
Specific Gravity	2.60 g/cm^3
Volume Concentration	0.6
Fall Velocity	3.8 to 5.4 ft/s
Depositional Void Ratio	0.667
Critical Shear Stress for Deposition	2.7 to 4.5 lbf/ft^2
Site Description	
Depth (constant)	40 ft
Water density	1.025 g/cm^3
Water velocity	0.0 ft/s

RESULTS

The results of the 6- and 10-inch rock simulations (Table 2) were virtually identical and are grouped together for clarity. Contours of the deposited rock thickness on the bed for the 30- and 60-sec release times are presented in Fig. 1 and 2, respectively. The stronger influence on maximum mound height and lateral and longitudinal spreading of the rock on the seabed is associated with the time required for all rock to exit the scow. With a 60-sec release period, the maximum rock thickness decreases from 4.5 to 3.7 ft, the lateral dimensions of the 1-ft contour decrease from 254 to 237 ft, and the longitudinal dimensions of that contour increase from 274 to 309 ft. Doubling of vessel speed from 2 knots to 4 knots would have a similar impact on the footprint as doubling of the release time.

Table 2. Results

	Contour (ft)		
	1	2	3.5
30-sec release (6&10 " rock)			
Max thickness = 4.5 ft			
Dimensions (lateral), ft	254	186	102
Dimensions (longitudinal), ft	274	201	110
60-sec release (6&10 " rock)			
Max thickness = 3.7 ft			
Dimensions (lateral), ft	237	161	38
Dimensions (longitudinal), ft	309	217	62

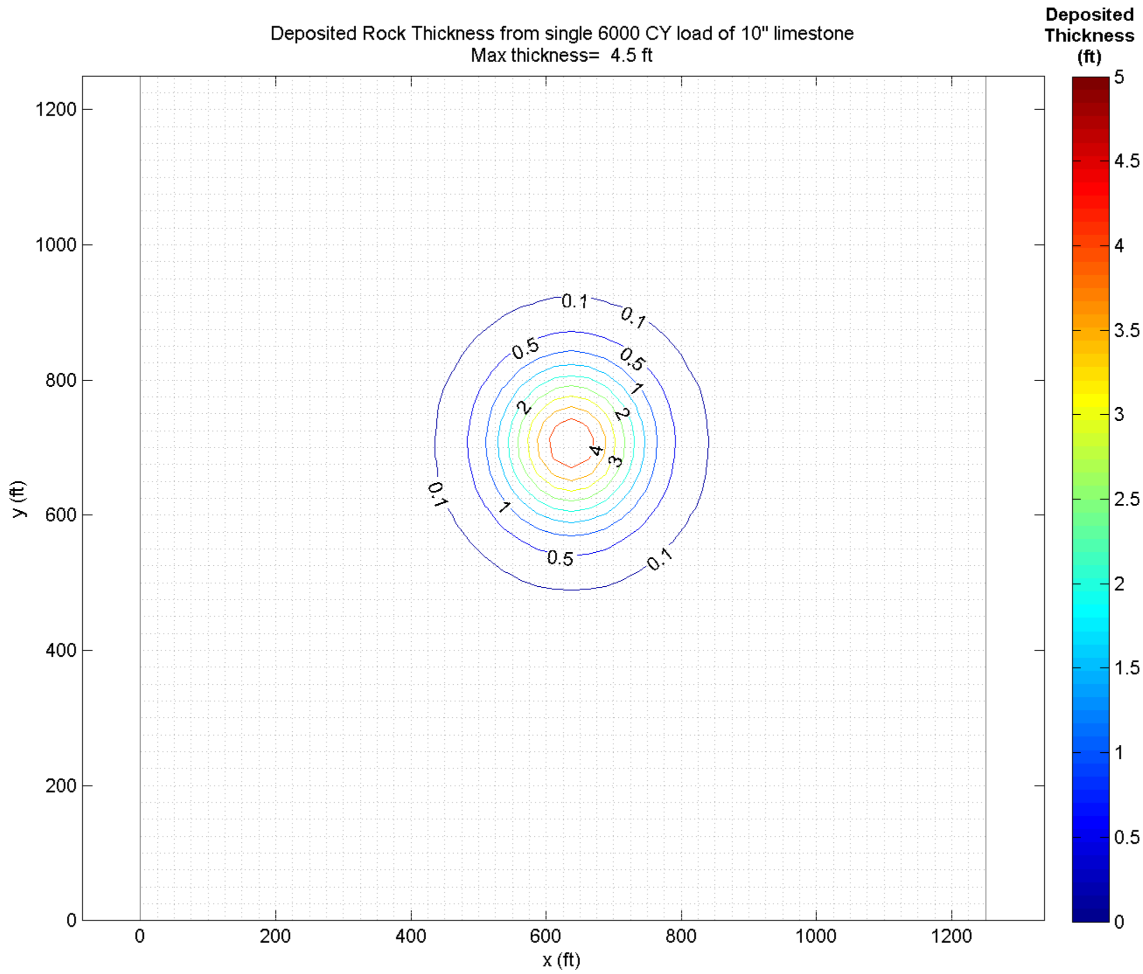


Fig. 1 Contours of rock thickness for 6000 CY of 10-inch diameter limestone placed in 40 ft depth at a vessel speed of 2 knots. Release time of the rock is 30-sec.

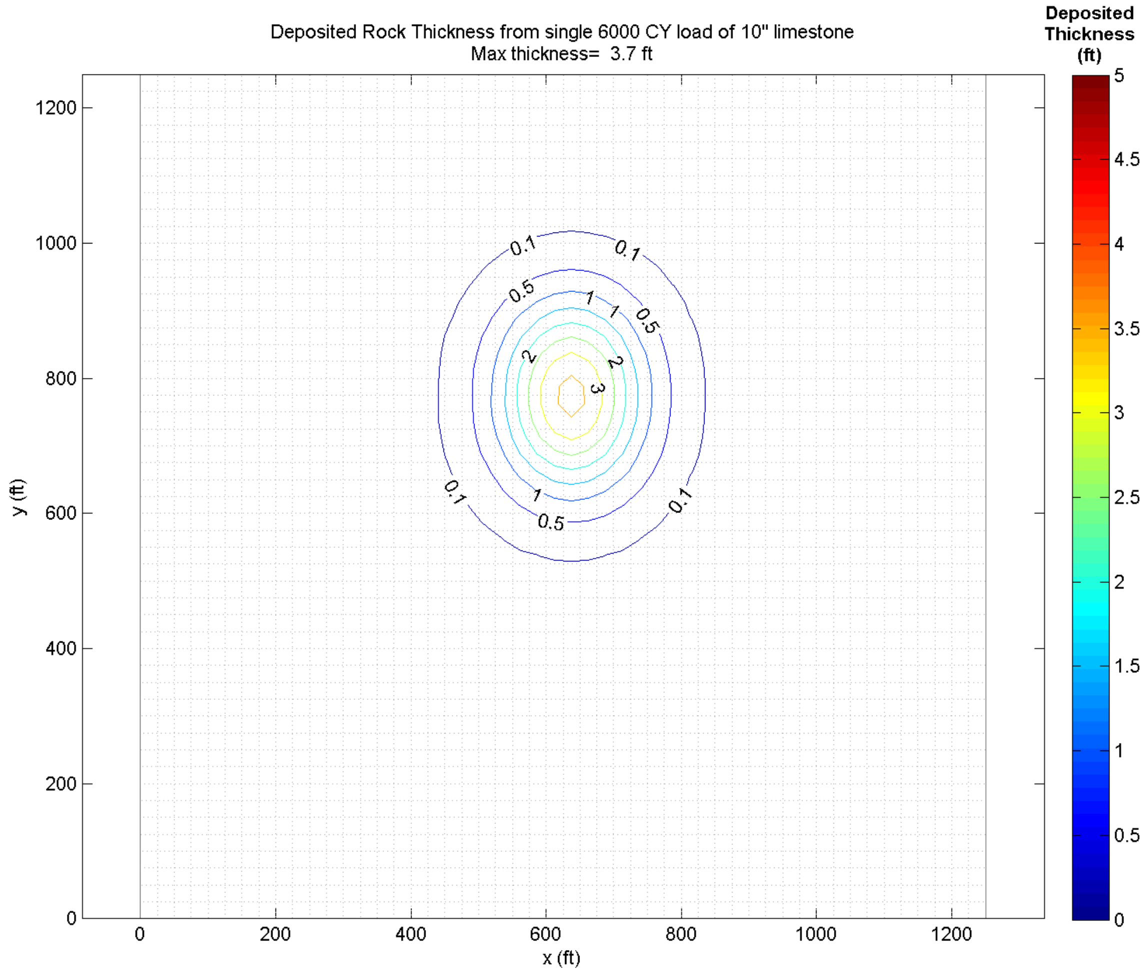


Fig. 2 Contours of rock thickness for 6000 CY of 10-inch diameter limestone placed in 40 ft depth at a vessel speed of 2 knots. Release time of the rock is 60-sec.