

**Hatfield Marine Science Center  
Dynamic Revetment Project  
DSL permit # 45455-FP**

**Monitoring Report  
February, 2014**

February 25, 2014

Submitted by:  
Robert Cowen, Director  
Hatfield Marine Science Center  
Oregon State University  
[Robert.Cowen@oregonstate.edu](mailto:Robert.Cowen@oregonstate.edu)  
541-867-0211

Editor:  
Walt Nelson, US Environmental Protection Agency

Contributors:  
Beach Profiles:  
Jonathan Allan, Oregon Department of Geology and Mineral Industries

Fish:  
Scarlett Arbuckle, Oregon State University  
Heppell Laboratory, Oregon State University

Benthic Invertebrates and Vegetation:  
Christina Folger, US Environmental Protection Agency  
Walt Nelson, US Environmental Protection Agency

## Abstract

Stabilization of the Yaquina Bay shoreline along the northeastern edge of the Hatfield Marine Science Center (HMSC) campus became necessary to halt erosion that threatened both HMSC critical infrastructure (seawater storage tank) and public access to the HMSC Nature Trail. A Dynamic Revetment (gravel beach) was installed in November, 2011 on 260 feet of shoreline to mitigate erosion. Shoreline topographic and biological monitoring was initiated before and has continued after the project completion. Monitoring of beach profiles indicated that as of December 2013, the 2011 Dynamic Revetment Project (DRP) has successfully stabilized the shoreline in the project area, while rapid erosion has continued in the adjacent Reference beach area. Erosion in the unprotected Reference area in the period 2009-2013 has been as great as 9.6 m (31.5 ft). Beach profile data also indicated that the 2007 DRP continued to be successful in stabilizing further retreat of the shoreline. Monitoring of birds and marine mammals was discontinued in 2013 as planned. Monitoring of beach wrack invertebrates, fish, and vegetation continued. Per unit of beach wrack biomass, there was no significant difference in density of wrack invertebrates among the three study areas. Total amount of beach wrack was much sparser in the Reference area because of vertical beach scarps generated by erosion that appeared to limit wrack accumulation. As has been a consistent pattern, fish were significantly more abundant in the Reference area compared to the DRP. However, this pattern was present in the pre-project sampling, and the Reference area may have a higher degree of physical habitat complexity, resulting from root masses of trees that have been eroded onto the shore. Bottom dwelling Pacific Staghorn Sculpin tended to be somewhat more evenly distributed between the DRP and Reference areas, while pelagic Shiner Perch tended to be found more in the Reference area. Vegetation coverage was significantly greater and presence of non-living substrata was significantly less in the Reference area as compared to the DRP. These differences are consistent with pre-project site differences, probably resulting from a low area of the shoreline which allows increased flooding and associated disturbance in the DRP back shore area. Fish and wrack invertebrates, such as beach hoppers, were shown to utilize the DRP project area. Biological differences in fish and vegetation observed in year 2 of post-project monitoring tended to reflect differences in habitat that were present before the DRP project.

## Table of Contents

Abstract.....	2
1.0 HMSC Beach and Shoreline Monitoring .....	4
1.1 Background .....	4
2.0 Physical Parameters.....	5
2.1 Beach Profile Survey Methodology .....	5
2.2 Beach Profile Results .....	7
2.3 References .....	11
3.0 Biological Parameters.....	12
3.1 Density of Benthic Invertebrates .....	12
3.1.1 Benthic Invertebrate Sampling Methods.....	12
3.1.2 Invertebrate Results .....	12
3.2 Fish .....	13
3.2.1 Fish Sampling Methods.....	13
3.2.2 Fish Results.....	13
3.2.3 Discussion.....	17
3.3 Vegetation .....	18
3.3.1 Vegetation Methods .....	18
3.3.2 Vegetation Results .....	19
4.0 Current Status of Erosion in the Study Area .....	24
5.0 Disclaimer .....	29
Appendix 1: Beach Profile Survey Graphs .....	30

## **1.0 HMSC Beach and Shoreline Monitoring**

### **1.1 Background**

Stabilization of the Yaquina Bay shoreline along the northeastern edge of the Hatfield Marine Science Center (HMSC) campus became necessary in 2007 to halt erosion that threatened both HMSC critical infrastructure (seawater storage tank) and public access to the HMSC nature trail. The Hatfield Marine Science Center (HMSC) Estuary trail was constructed in 1988 and is unique to Newport since it provides the only trail for exploring the Yaquina Bay estuary from its banks, as well as being one of the longer accessible trails in the area for those with disabilities. Since the late 1990s/early 2000 the trail has experienced erosion from a combination of oceanographic processes including high frequency wind waves coupled with high tides and tidal currents associated with both the ebb and flood tide.

Among the range of solutions to coastal erosion, gravel beaches have long been recognized as an effective form of natural coastal protection, minimizing the potential for inundation from wave overtopping as well as exhibiting a remarkable degree of stability in the face of sustained wave attack (van Hijum, 1974; Nicholls and Webber, 1988; Allan et al., 2005; Komar and Allan, 2010). This is due to their high threshold of motion and because of the asymmetry (shape) of shoaling waves and swash velocities on the beach face, which results in a greater propensity for onshore particle movement compared with sand-size particles, forming a steeply sloping beach face. Once formed, the porous gravel beach is able to disrupt and dissipate the incident-wave energy, even during intense storms. As a result of these characteristics, artificially constructed gravel beaches have been suggested as a viable approach for protection from coastal erosion, variously termed “cobble berms” or “dynamic revetments” when used in such applications. Once formed, the gravel beach is considered to be dynamic in that the gravels may be moved about by waves and currents, adopting a morphology that will reflect those assailing forces. Gravel beaches are considered a “soft” form of coastal engineering to help mitigate erosion.

In 2006, the Oregon Department of Geology and Mineral Industries (DOGAMI) assisted HMSC with the design of a dynamic revetment project. The project was completed in March 2007 with the assistance of the Oregon Army National Guard IRT program and resulted in the stabilization of approximately 200 linear feet of the northeastern shoreline of HMSC. That shoreline section has remained stable since dynamic revetment implementation. Erosion continued at a lower rate to the south of the 2007 project area, but in the winter of 2009-2010, weather conditions resulted in rapid erosion of up to 13 ft along approximately 500 linear ft of shoreline. This erosion moved the shoreline to the edge of the nature trail in one location, and to within only 25 ft of portions of the seawater system infrastructure for HMSC. The seawater system supports the research of Oregon State University and the five federal and state agency programs co-located on site. The threat to critical public infrastructure required an additional erosion control effort utilizing the gravel shoreline technique.

Therefore, on November 10-11, 2011, an additional 260 ft of gravel beach was installed with the assistance of the Oregon Army National Guard. As a condition of the permit for installation, Oregon Department of State Lands required a monitoring program be put in place to assess both the geological performance and the biological impacts of the gravel beach installation (herein termed Dynamic Revetment Project or DRP). This report constitutes the third annual report on the monitoring program, representing two full years after project completion.

## **2.0 Physical Parameters**

### **2.1 Beach Profile Survey Methodology**

Beach profiles that are orientated perpendicular to the shoreline can be surveyed using a variety of approaches, including a simple graduated rod and chain, surveying level and staff, Total Station theodolite and reflective prism, Light Detection and Ranging (LIDAR) airborne altimetry, and Real-Time Kinematic Differential Global Positioning System (RTK-DGPS) technology. Traditional techniques such as leveling instruments and Total Stations are capable of providing accurate representations of the morphology of a beach, but are demanding in terms of time and effort. At the other end of the spectrum, high-resolution topographic surveys of the beach derived from LIDAR are ideal for capturing the 3-dimensional state of the beach, over an extended length of coast within a matter of hours. However, the LIDAR technology remains expensive and is impractical along small segments of shore, and more importantly, the high costs effectively limits the temporal resolution of the surveys and hence the ability of the end-user to understand short-term changes in the beach morphology.

Within this range of technologies, the application of RTK-DGPS for surveying the morphology of both the sub-aerial and sub-aqueous portions of the beach has effectively become the accepted standard [e.g. Ruggiero et al., 2005; Allan and Hart, 2008], and has been the surveying technique used in this study. The global Positioning System (GPS) is a worldwide radio-navigation system formed from a constellation of 24 satellites and their ground stations, originally developed by the US Department of Defense; in 2007 the Russian Government made their GLONASS satellite network available increasing the number of satellites to ~46 (as of February 2011). In its simplest form, GPS can be thought of as triangulation with the GPS satellites acting as reference points, enabling users to calculate their position to within several meters (e.g. using inexpensive off the shelf hand-held units), while survey grade GPS units are capable of providing positional and elevation measurements that are accurate to a centimeter. At least four satellites are needed mathematically to determine an exact position, although more satellites are generally available. The process is complicated since all GPS receivers are subject to error, which can significantly degrade the accuracy of the derived position. These errors include the GPS satellite orbit and clock drift plus signal delays caused by the atmosphere and ionosphere and multipath effects (where the signals bounce off features and create a poor signal). For example, hand-held autonomous receivers have positional accuracies that are typically less than about 10 m (<~30 ft), but can be improved to less than 5 m (<~15 ft) using the Wide Area Augmentation System (WAAS). This latter system is essentially a form of differential correction that accounts for the above errors, which is then broadcast through one of two geostationary satellites to WAAS enabled GPS receivers.

Greater survey accuracies are achieved with differential GPS (DGPS) using two or more GPS receivers to simultaneously track the same satellites enabling comparisons to be made between two sets of observations. One receiver is typically located over a known reference point and the position of an unknown point is determined relative to that reference point. With the more sophisticated 24-channel dual-frequency RTK-DGPS receivers, positional accuracies can be improved to the sub-centimeter level when operating in static mode and to within a few centimeters when in RTK mode (i.e. as the rover GPS is moved about). In this study we used Trimble© 24-channel dual-frequency R7/R8 GPS receivers. This system consists of a GPS base

station (R7), Zephyr Geodetic antenna (model 2), HPB450 radio modem, and R8 “rover” GPS (Figure 2.1). Trimble reports that both the R7/R8 and 5700/5800 GPS systems have horizontal errors of approximately  $\pm 1\text{-cm} + 1\text{ppm}$  (parts per million \* the baseline length) and  $\pm 2\text{-cm}$  in the vertical (Trimble, 2011).

To convert a space-based positioning system to a ground-based local grid coordinate system, a precise mathematical transformation is necessary. While some of these adjustments are accomplished by specifying the map projection, datum and geoid model prior to commencing a field survey, an additional transformation is necessary whereby the GPS measurements are tied to known ground control points. This latter step is called a GPS site calibration, such that the GPS measurements are calibrated to ground control points with known vertical and horizontal coordinates using a rigorous least-squares adjustments procedure. Performing the calibration is initially undertaken in the field using the Trimble TSC2 GPS controller and then re-evaluated in the office using Trimble’s Business Office software (v2.5).

Survey control at HMSC was provided by occupying two benchmarks established by National Geodetic Survey (NGS – Hamilton and 943 5380 tidal), and by the Coastal Field Office of DOGAMI (hmsc-crk & hmsc-pth). Coordinates assigned to these monuments were derived using a combination of approaches that included the Online Positioning User Service (OPUS) maintained by the NGS (<http://www.ngs.noaa.gov/OPUS/>) and the Oregon Real Time GPS Network (<http://www.theorgn.net/>) established by the Oregon Department of Transportation.

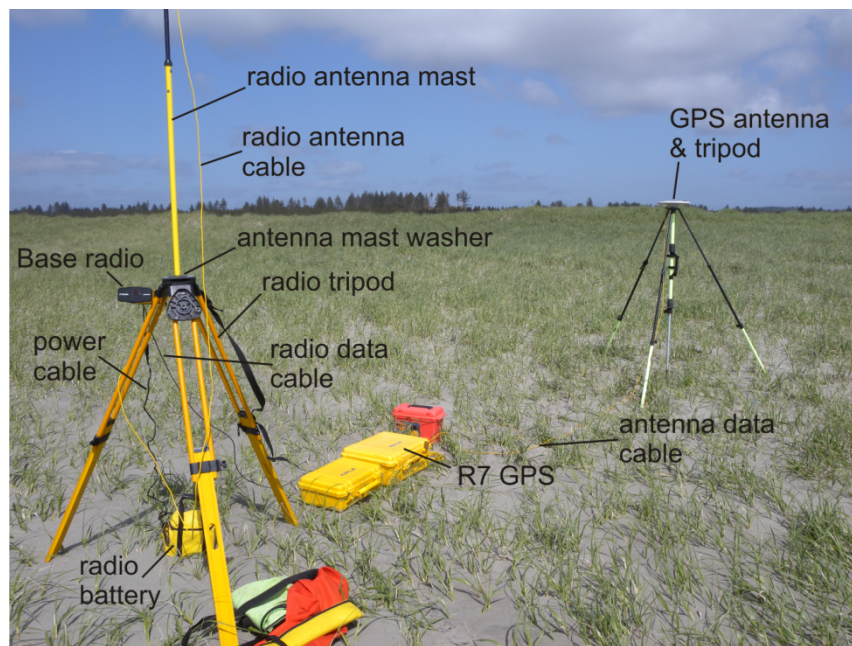


Figure 2.1. The Trimble R7 base station antenna in operation on the Clatsop Plains. Corrected GPS position and elevation information is transmitted by an HPB450 Pacific Crest radio to the R8 GPS rover unit.

## 2.2 Beach Profile Results

For the purposes of this study, we established 15 beach profile transect lines along the estuary trail (Figure 2.2), which extends from the HMSC wharf in the northwest, southward approximately 290 m (~950 ft). Of these, 5 of the lines were originally established in May 2006 (1-5) to document changes on the original gravel beach constructed there in late 2006, while the remaining 10 lines were established in July 2011. GPS Surveys were undertaken on the original profile 1-5 lines in May 2006, March 2007 and in September 2007 (Table 2.1). These data have been supplemented with high resolution terrain elevations extracted from a LIDAR dataset (8 points per m<sup>2</sup>) collected by DOGAMI for the Northern Oregon coast in July 2009. Table 1 presents the times when all surveys of the beach were carried out. As described in our previous report, subsequent future surveys will be confined to mid-late winter (~February/March timeframe) and in late summer (~September).

Table 2.1: Dates when beach surveys and mapping efforts were undertaken

Measurement Date	Type	Transects
May 19 2006	RTK-DGPS	1-5
March 16 2007	RTK-DGPS	1-5
September 6 2007	RTK-DGPS	1-5
July 19 2009	Lidar	All
July 13 2011	RTK-DGPS	All
December 19 2011	RTK-DGPS	All
January 13 2012	RTK-DGPS	All
May 7 2012	RTK-DGPS	All
December 21 2012	RTK-DGPS	All
May 5 2013	RTK-DGPS	All
August 19 2013	RTK-DGPS	All

Figures 2.3, 2.4 and 2.5 present the change over time as measured at the 2.4 m elevation contour for all the transect sites, with the study area having been divided into three study reaches: original dynamic revetment (Figure 2.3), expanded dynamic revetment (Figure 2.4), and control area (Figure 2.5). Individual profile responses and time stacks (EDA plots) of changes taking place at selected contour elevations can be accessed online using the NANOOS Beaches portal: <http://nvs.nanoos.org/BeachMapping>. To view these data, select “Newport” in the regions section of the web portal. From there it is possible to zoom in to obtain a close-up view of the HMSC campus and access the individual data plots.

For convenience, individual beach profile plots are reproduced in Appendix 1 of this report.

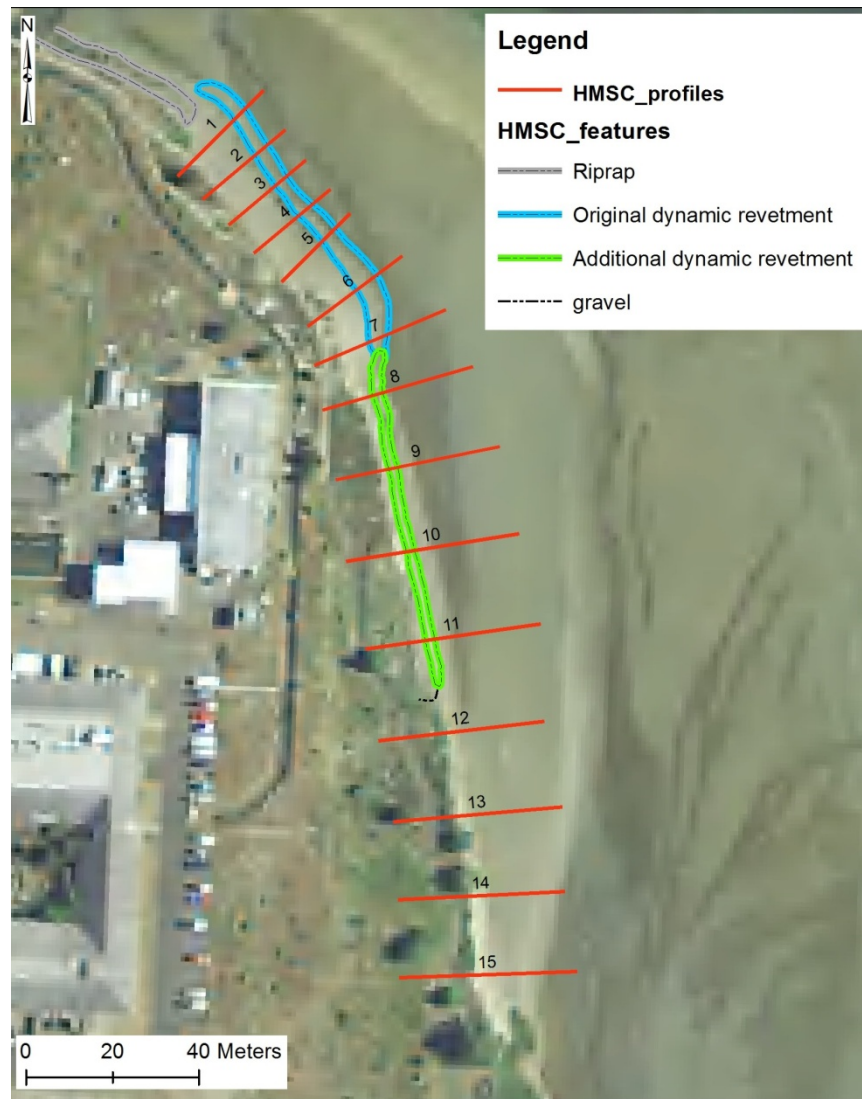


Figure 2.2: Location map showing the HMSC beach and shoreline monitoring network. Blue shaded dashed line denotes the cobble ‘lag’ toe of the original dynamic revetment, green shaded dashed line denotes the cobble ‘lag’ toe for the expanded section and grey shaded dashed line denotes the location of rip rap rock.

Figure 2.3, which depicts the measured changes in the original gravel beach area, indicates that the initial dynamic revetment design (blue dashed line in Figure 2.2), which included placement of gravel on the beach face and a lower cobble “lag” berm located at the juncture between the sandy beach and the inter-tidal mudflats, has been successful in stabilizing further retreat of the beach. This is characterized by the fact that there have been negligible changes to the gravel beach morphology over time.



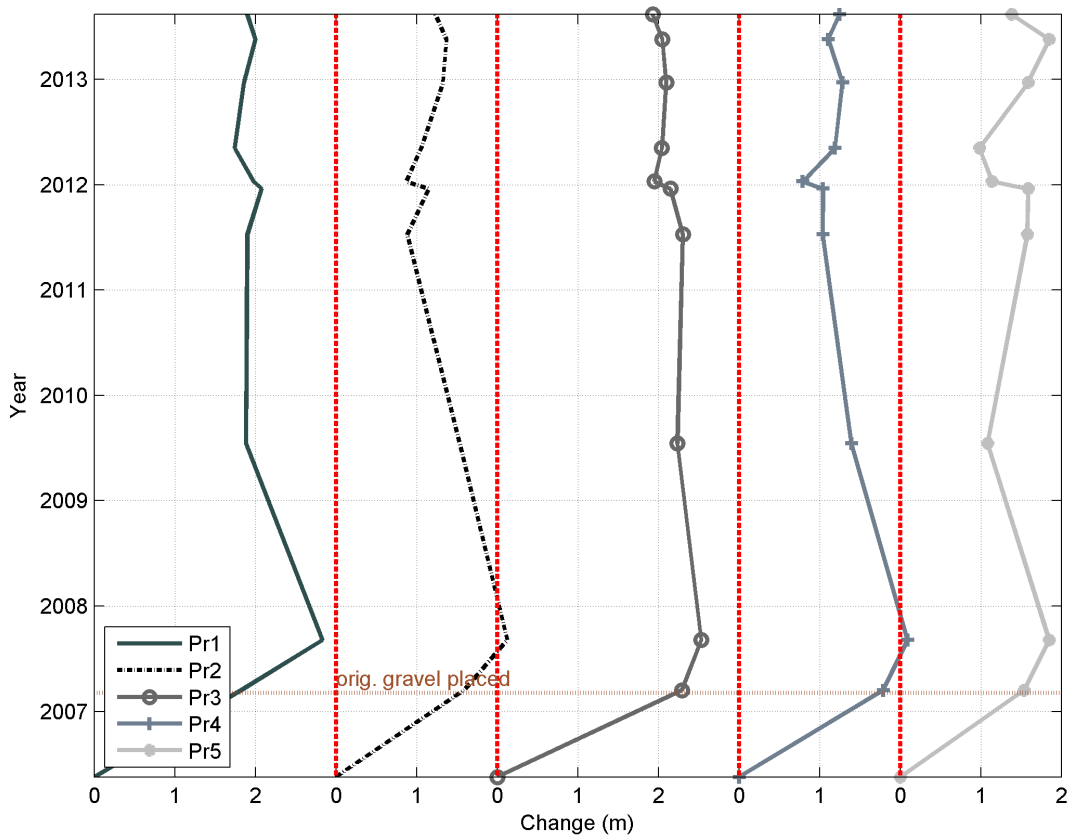


Figure 2.1: Transects 1 to 5 span the region where the original dynamic revetment/gravel beach was constructed. The zero line reflects the initial survey prior to construction of the gravel beach.

Further south, between Transects 6-11 (Figure 2.4), the beach survey data indicate that the expanded gravel beach section is also stable, such that erosion of the beach and backshore has essentially ceased. In Figures 2.4 and 2.5, the baseline for our current monitoring efforts is the 2009 LIDAR. Some sediment loss appears to be occurring in the vicinity of Transect 6 (Figure 2.4), although the amount of gravel loss is negligible. As noted in our previous report, we recommend that HMSC consider adding some additional gravel to this portion of the existing dynamic revetment in order to safe guard its volume.

In contrast, the southern “control” area continues to experience significant erosion (Figure 2.5), with some areas having eroded by 7.5 to 9.6 m (respectively HMSC 13 and 12), decreasing to -2.4 m at Transect 14 and -4 m at Transect 15. In the case of the two former transects, the current rate of erosion is unchanged from the period prior to gravel beach construction, which indicates that the erosion is independent of the recently constructed gravel beach. As noted in our earlier report, these changes reflect a complete landward translation of the entire beach profile. Hence, based on current patterns, we fully expect the erosion to continue to occur in the south.

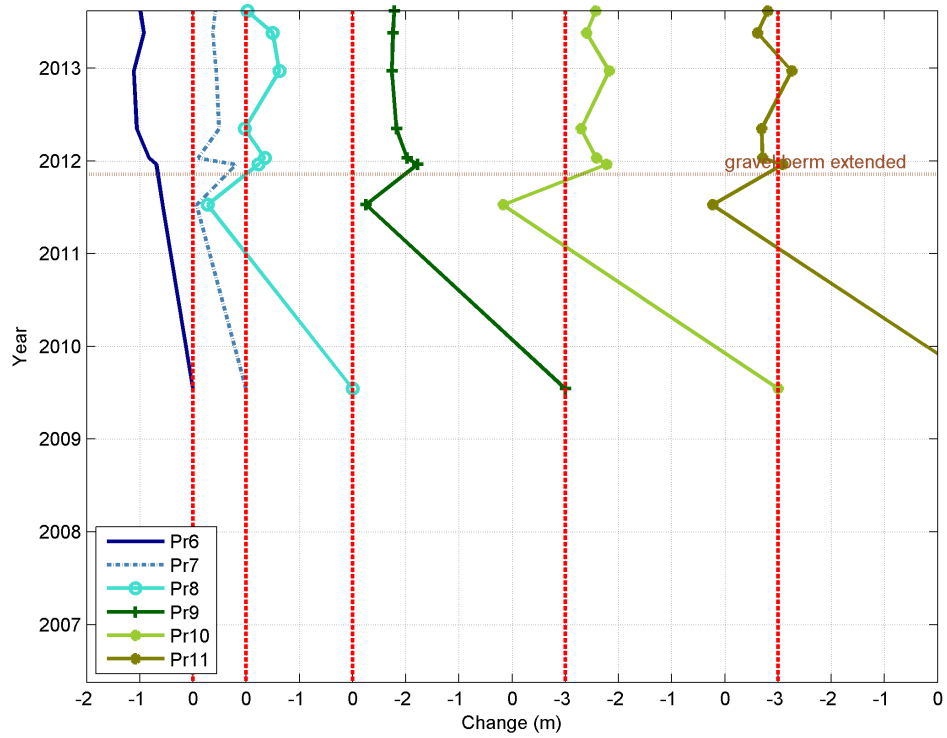


Figure 2.2: Transects 6 to 11 span the region where the expanded dynamic revetment/gravel beach was constructed. The zero line reflects the initial survey prior to construction of the gravel beach.

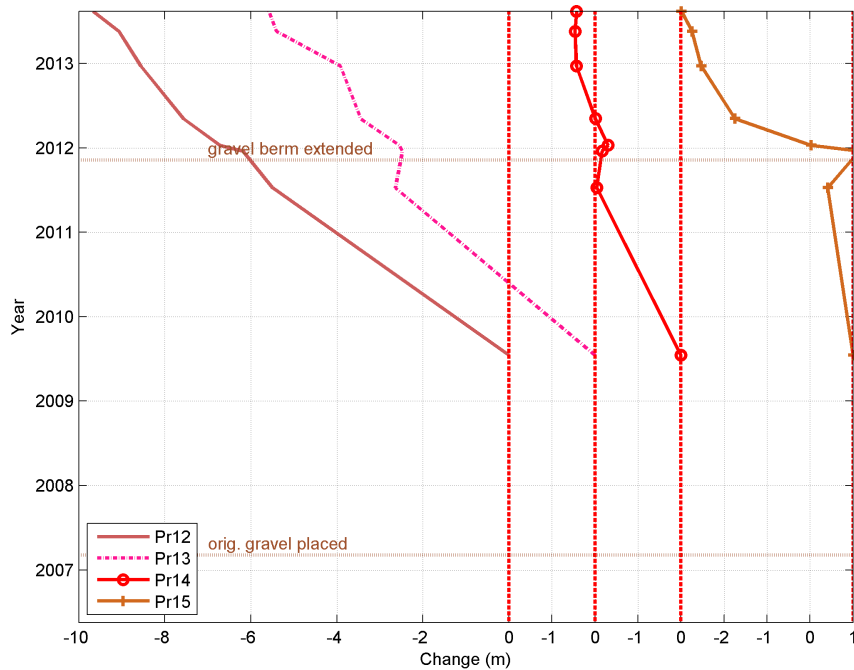


Figure 2.5: Transects 12 to 15 span the unprotected (control) region. The zero line reflects the initial survey prior to construction of the expanded gravel beach.

## 2.3 References

- Allan, J. C., and R. Hart (2008), Oregon beach and shoreline mapping and analysis program: 2007-2008 beach monitoring report. Rep. Open file report O-08-15, 60 pp, Oregon Department of Geology and Mineral Industries, Portland.  
[http://www.oregon.gov/ODOT/TD/TP\\_RES/docs/Reports/DynamicRevetments.pdf?ga=t](http://www.oregon.gov/ODOT/TD/TP_RES/docs/Reports/DynamicRevetments.pdf?ga=t)
- Allan, J. C., R. Hart, and R. Geitgey (2005), Dynamic revetments for coastal erosion stabilization: A feasibility analysis for application on the Oregon Coast, Special Paper Rep. SP-037, 71 pp, Oregon Department of Geology and Mineral Industries, Portland, Oregon.
- Komar, P. D., and J. C. Allan (2010), “Design with Nature” strategies for shore protection—The construction of a cobble berm and artificial dune in an Oregon State Park Rep., 117-126 pp, U.S. Geological Survey Scientific Investigations Report 2010-5254.
- Nicholls, R., and N. Webber (1988), Characteristics of shingle beaches with reference to Christchurch Bay, S. England, paper presented at Proceedings of the 21st Conference on Coastal Engineering, ASCE.
- Ruggiero, P., G. M. Kaminsky, G. Gelfenbaum, and B. Voight (2005), Seasonal to interannual morphodynamics along a high-energy dissipative littoral cell, *Journal of Coastal Research*, 21(3), 553-578.
- Trimble (2011), Trimble R7 & R8 GPS system Manuals Rep., 106 pp, Trimble Navigation Limited, Dayton, Ohio.
- van Hijum, E. (1974), Equilibrium profiles of coarse material under wave attack, paper presented at Proceedings 14th Conference on Coastal Engineering, ASCE

### **3.0 Biological Parameters**

#### **3.1 Density of Benthic Invertebrates**

##### **3.1.1 Benthic Invertebrate Sampling Methods**

In contrast to the pre-project benthic invertebrate characterization, infaunal sediment dwelling organisms were not sampled because sampling was only possible in the Reference area, and there was no valid comparison possible to the DRP area. Only wrack invertebrates were therefore compared. Mixed algae and seagrass samples were collected on 9/27/2013 from the wrack line deposited by the previous high tide at five random locations from the Reference beach, the DRP beach, and from the wrack line in the 2007 DRP area, termed DRP Reference. Samples of wrack were obtained by using scissors to cut segments of the wrack line which were rapidly placed in labeled plastic bags. Samples were processed by sorting live animals from the plant material over the next few days, with samples kept in a cold room at approximately 34 degrees F until processed. The wrack samples consisted mostly of green macroalgae and the seagrass, *Zostera marina*. Wrack samples were processed by a combination of rinsing, sieving and picking the wrack material in plastic tubs. The algae/seagrass biomass material was saved for each replicate and dried in an oven at 70° C for 5 days. The final dry weight of each wrack sample was determined. Organisms were sorted, identified and counted. Densities for wrack associated organisms are expressed per unit dry wrack biomass.

##### **3.1.2 Invertebrate Results**

Invertebrates associated with beach wrack were found within all three of the DRP study areas. Abundance was dominated by dipteran larvae and adult flies (wrack flies), and by talitrid amphipod crustaceans (beach hoppers) (Table 3.1). Juvenile mussels and snails that had settled on the algae prior to stranding were also found. A smaller number of other crustaceans, mites (Acari), and oligochaetes were also collected. Expressed as the number of individuals per g of plant dry-wt, there was no significant difference in density of wrack invertebrates among the three areas. Composition of wrack invertebrates was generally similar among the three areas, although the Reference area had considerably fewer dipteran larvae than the other two areas. Expressed per unit wrack biomass, dipteran larvae were about 7x more abundant in the DRP and 10x more abundant in the DRP Reference areas. However, only the difference between the Reference and DRP Reference was statistically significant (Kruskall Wallis ANOVA of Ranks with Tukey Pairwise Multiple Comparisons,  $p=0.02$ ).

As in 2012, deposition of wrack within the Reference area was inhibited due to the presence of vertical scarps along the shoreline from the rapid erosion. Wrack was sparser and very patchy in the Reference area, compared to either of the other two beach areas sampled, where continuous wrack lines were present. Thus while densities per unit biomass were comparable for most taxa, the total invertebrate abundance along the wrack line would have been much less in the reference area due to the limited quantities of wrack being accumulated.

Table 3.1. List of invertebrates collected in association with plant wrack deposited within the study area. DRP – 2011 project area, REF – Reference area, DRP REF – 2007 project area.

Sample	Talitridae	Mollusca	Oligochaeta	Insecta	Larval Insecta	Arachnida (Acari)	Other	Total	#/g algae dry wt
DRP 1	4	5		4	20			33	5.7
DRP 2	8	3		10	150	4		175	17.6
DRP 3	27	10	10	6	5	13		61	5.5
DRP 4	3	11		1	1	7		23	3.9
DRP 5	28	8		2	11	10		59	6.9
<b>Subtotal</b>	<b>70</b>	<b>37</b>	<b>10</b>	<b>23</b>	<b>187</b>	<b>34</b>	<b>0</b>	<b>351</b>	
REF 1	43	22	2		1	1	6	73	18.9
REF 2	7	2			11		6	26	4.9
REF 3	38	4				1	1	44	12.6
REF 4	7	1		3	1			12	7.0
REF 5	97						2	99	70.0
<b>Subtotal</b>	<b>192</b>	<b>29</b>	<b>2</b>	<b>3</b>	<b>13</b>	<b>2</b>	<b>15</b>	<b>254</b>	
DRP REF 1	9	15		17	25			66	11.0
DRP REF 2	10	13		10	45	2		80	11.0
DRP REF 3	29	8		7	58	3		105	7.8
DRP REF 4	25	34		10	150	3	1	223	24.6
DRP REF 5	3	8	3	12	30			53	5.9
<b>Subtotal</b>	<b>76</b>	<b>78</b>	<b>3</b>	<b>56</b>	<b>308</b>	<b>8</b>	<b>1</b>	<b>527</b>	

### 3.2 Fish

#### 3.2.1 Fish Sampling Methods

From January through November of 2013, intertidal fish were captured with a 50 ft shore seine towed perpendicularly to the shore for a distance of 50 ft at three permanent sites along the DRP shoreline and three permanent sites along the Reference shoreline. This sampling was performed once per month at spring high tide in order to sample as much of the high intertidal habitat as possible. All fish captured in the seine were held for no more than 15 minutes in a container of ambient bay water while they were measured and identified to the lowest possible taxonomic level before being released at the point of capture.

#### 3.2.2 Fish Results

During eleven months of sampling, a total of 12 taxa and 5375 individuals of fish and crabs were captured (Table 3.2). Seven species were represented by less than 10 individuals in the total collection (Table 3.2). Seven Chum Salmon (*Oncorhynchus keta*) were captured, all at station 2

within the DRP, during March 2013. There were 1124 individuals from 10 different species that were captured along the DRP shoreline (Sites 1-3), and 4250 individuals from 8 different taxa that were captured along the Reference shoreline (Sites 4-6). Approximately eighty percent of the total number of individuals captured in 2013 was collected from the reference shoreline sites, a figure that was comparable to that from 2012 (75%). Pacific Staghorn Sculpin, Whitebait Smelt, and Shiner Perch were the most abundant fishes captured (Table 3.2). In June, approximately equal numbers of juvenile Dungeness crab were collected in the two sampling areas. Pacific Staghorn Sculpin was captured throughout the year, generally in both areas (Figure 3.3). Shiner Perch and Whitebait Smelt were captured nearly sequentially in the spring and summer, respectively, with some overlap in May. Both were more commonly found in the Reference stations (Figures 3.4 and 3.5). Statistical comparisons indicated that there were significant differences both among dates and between areas in fish abundance and that there was no significant interaction term (Two-way ANOVA). Multiple comparison tests indicated that a number of pairwise monthly comparisons were significantly different, but the most important comparison was that mean monthly Reference abundance was significantly greater ( $p = 0.001$ ) than that in the DRP.

Table 3.2. A list of the total number of individuals of each species captured in 2013, during eleven months of sampling the DRP shoreline and the Reference shoreline sites.

<b>Species</b>	<b>Common Name</b>	<b>Total</b>
<i>Leptocottus armatus</i>	Pacific Staghorn Sculpin	2807
<i>Allosmerus elongatus</i>	Whitebait Smelt	1084
<i>Metacarcinus magister</i>	Dungeness crab (juv)	734
<i>Cymatogaster aggregata</i>	Shiner Perch	717
<i>Gasterosteus aculeatus</i>	Three-Spine Stickleback	9
<i>Oncorhynchus keta</i>	Chum Salmon	7
<i>Hemigrapsus oregonensis</i>	Shore Crab	6
<i>Parophrys vetulus</i>	English Sole	3
<i>Oligocottus maculosus</i>	Tidepool Sculpin	3
<i>Oligocottus snyderi</i>	Fluffy Sculpin	2
<i>Ophiodon elongatus</i>	Lingcod	1
Unidentified Larval Fish		1
Grand Total		5375

### Mean Monthly Seine Abundance

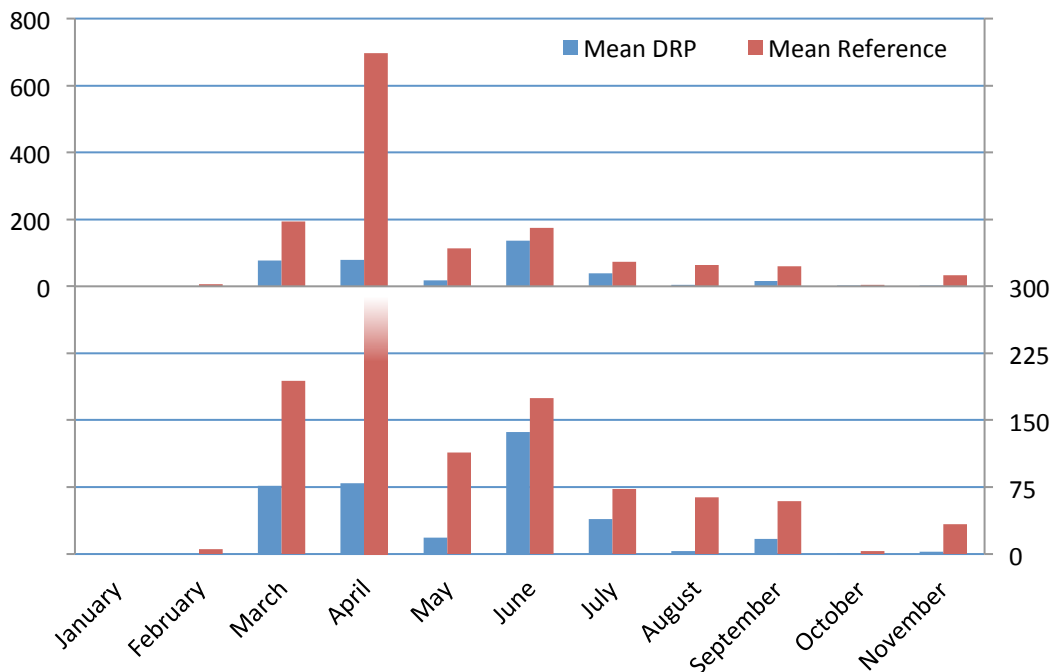


Figure 3.1: Top panel: Total number of individuals captured in both the DRP shoreline sites and the Reference shoreline sites during 2013. Bottom panel: The same, focusing on lower abundance sites.

### Total Seine Abundance By Site

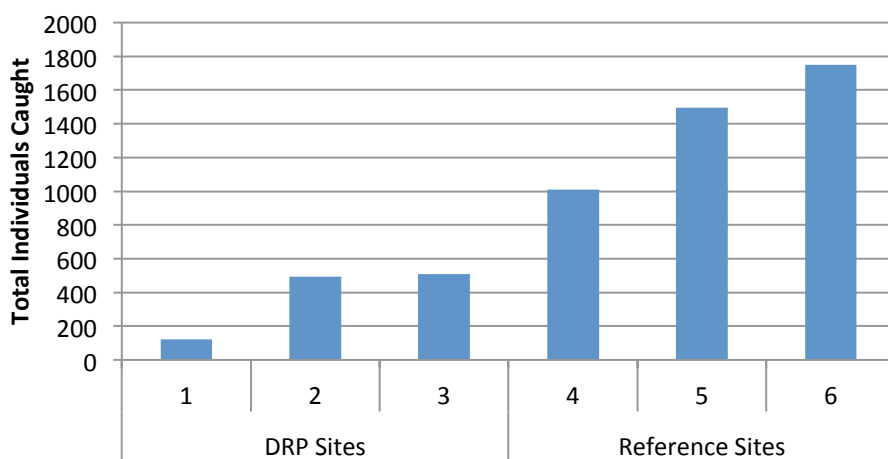


Figure 3.2: Total number of individuals caught at each sampling site in 2012. Sites 1-3 are within the DRP shoreline, sites 4-6 are in the Reference shoreline.

### Pacific Staghorn Sculpin

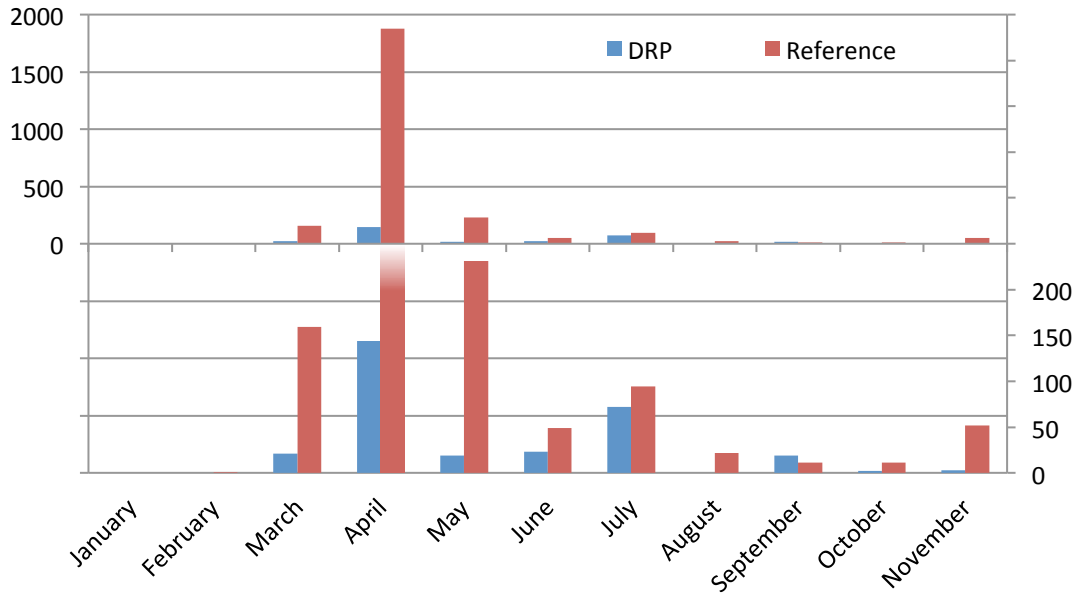


Figure 3.3: Top panel: Pacific Staghorn Sculpin (*Leptocottus armatus*) catch by month in the DRP shoreline sites and the Reference shoreline sites. Bottom panel: The same, focusing on lower abundance sites.

### Shiner Perch

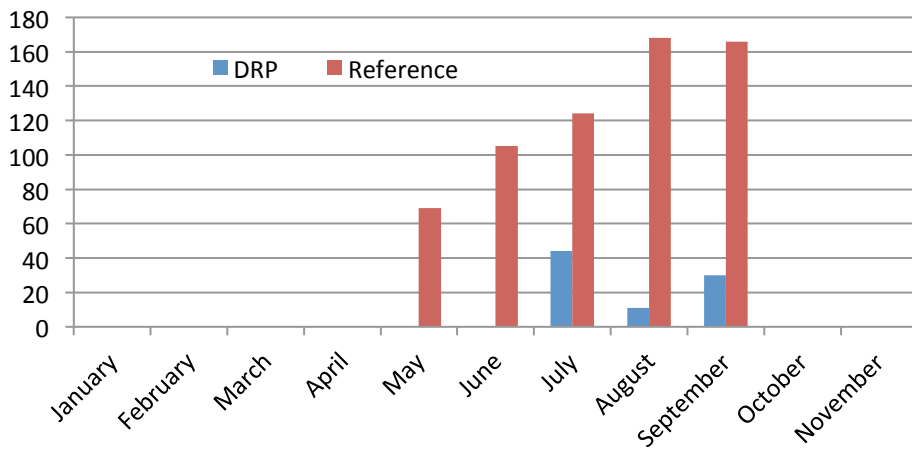


Figure 3.4: Shiner Perch (*Cymatogaster aggregata*) catch by month in the DRP shoreline sites and the Reference shoreline sites.



## Whitebait Smelt

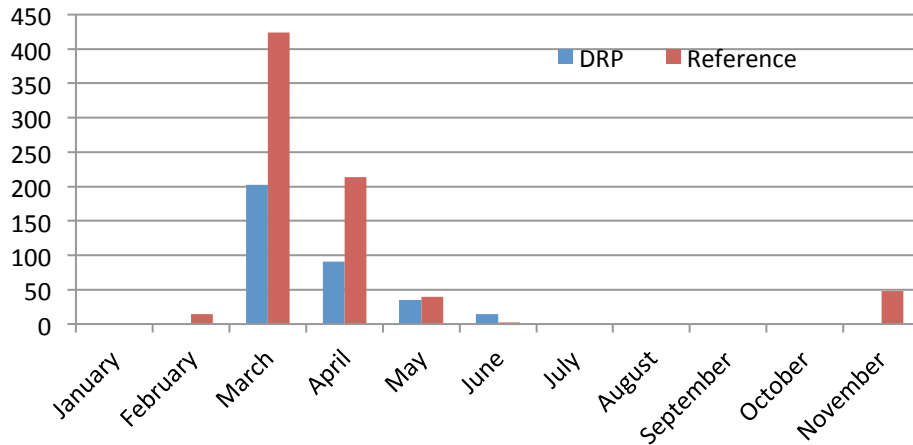


Figure 3.5: Whitebait Smelt (*Allosmerus elongatus*) catch by month in the DRP shoreline sites and the Reference shoreline sites.

### 3.2.3 Discussion

The results from the second year of post installation fish sampling were consistent with past results, in that more intertidal fish were captured along the Reference shoreline than the DRP shoreline. In contrast to previous years, where a large proportion of individuals were captured at site 4 within the Reference shoreline, other Reference sites were more similar to Site 4 in abundance in 2013. Reference sites 4 and 5 are immediately north and south, respectively, of trees whose root structures have been eroded such that the trees are now in the intertidal zone (Figure 3.6). The marsh bank at Site 6 has collapsed onto the shore and may also be offering some more complex habitat for fish, since total numbers collected were now comparable at this site too (Figure 3.2). However, there may also be some sampling bias between the DRP and reference areas. In sampling the DRP shoreline, it has been observed that the seine net could not closely contour all sections of the sea floor because of the prominent cobble toe at the base of the revetment. This may have provided fish an escape that was not present while sampling the sandy bottom of the reference shoreline. Thus, a portion of the intertidal fish population in the DRP sites may be absent from the sampling catch as a result of this gear limitation. Furthermore, we have observed demersal fish seeking refuge from our seine net in the interstitial spaces between the cobble stones of the revetment toe during our sampling. These refugia are not available in the sandy habitat of the reference shoreline, which may further explain the larger catch of intertidal fish at those sites.

The collections in 2013 were the first time salmonids have been recorded. All seven Chum Salmon were collected in the DRP area.

A.



B.



Figure 3.6: A. Trees near Reference site 4 for fish trawls showing intertidal structure added by collapsed trees, January 2013. B. View of eroded roots from second tree, February 2014.

### 3.3 Vegetation

#### 3.3.1 Vegetation Methods

To assess possible changes in shoreline vegetation following DRP installation, sampling was focused on the approximately 1 to 10 m wide strip of land between the paved HMSC estuary trail and the shoreline (Figure 3.6). This area contains mixed vegetation community types including high marsh, dune and terrestrial plants and shrubs. Six 1-m<sup>2</sup> quadrats were established within the DRP and Reference areas in October 2011 (Figure 3.6) and a labeled PVC stake was placed to mark the quadrat center. A Trimble R8 GNSS unit was used to establish horizontal and vertical positions of the center of each plot by performing an RTK survey with the ORGN network. Quadrat Reference 1 was lost to erosion prior to sampling. The remaining 11 quadrats were resampled on September 6-7, 2012. During 2013, Reference Quadrats 2 and 3 were lost to erosion. Quadrats 4 and 5 are now also threatened by erosion and may disappear within the next year. Therefore, new quadrats were established inland of the original plots as substitutes, and are designated as quadrats 1A, 2A, and 3A.

Vascular plant presence or absence (usually at the species level) was visually assessed by scanning one 0.25 -m<sup>2</sup> quadrat within each 1-m<sup>2</sup> quadrat (Figure 3.7). Plant percent cover was assessed by visually evaluating the percentage that each plant species contributed to the overall plant community present within the 1-m<sup>2</sup> quadrat. Percent cover estimates also considered non-

plant material such as open or bare ground and detrital material. Photographs were taken from several perspectives.

### 3.3.2 Vegetation Results

The three replacement plots in the Reference area were all at slightly higher elevation than the original quadrats (mean 3.15 m vs. 2.95 m, difference significant at  $p=0.02$ , t-test). However, mean elevation between the 2012 and 2013 set of Reference plots was not significantly different (mean 2.93 m vs. 3.03 m, not significant at  $p=0.34$ , t-test). Elevations in DRP quadrats was not significantly different from Reference quadrats (mean 2.9 m vs. 3.03 m, not significant at  $p=0.23$ , t-test). There were some differences in vegetation observed between the two areas. A total of twenty-seven plant taxa were identified in the 12 plots (Table 3.3). Eight plant taxa were found in both areas, nine taxa were only observed within the DRP area, and ten were only observed within the Reference area. Within the 0.25 m<sup>2</sup> quadrats, a grass, *Festuca rubra* (red fescue), was the most frequently occurring taxon in the DRP, while Douglas aster (*Symphyotrichum subspicatum*) was the most frequently occurring species in the Reference area.

Estimates of percent coverage of plants gave generally similar results to those obtained from the presence-absence data (Table 3.4). There was significantly greater (t-test,  $p < 0.001$ ) total coverage of vascular plants within quadrats from the Reference area, and conversely significantly greater (t-test,  $p < 0.001$ ) area of non-living cover in the DRP versus Reference area (17.3 vs 3). The grass *F. rubra* had the largest percent coverage in the DRP. *Spergularia spp.* and *Elymus mollis* (American dunegrass) were the next most abundant in terms of percent cover in the DRP. *Juncus breweri* (Brewer's rush), *F. rubra*, and *Ammophila arenaria* (European beachgrass) were the most extensive in the Reference area quadrats. Dominant species were generally similar to the 2012 survey in the DRP plots, with the top three species in percent area being the same. In the Reference quadrats, the relative representation of *Carex pansa* was somewhat reduced, most likely as a result of the forced relocation of three of the Reference quadrats.

The lower average vegetation cover at the DRP sites has been a consistent result during the monitoring and was present in the pre-project samples. DRP quadrats 1-3 occur at lower elevation than most other sample locations, and as described in the 2012 report, there is also a topographic low spot in the shoreline near beach profile 9 (Figure 2.1), which allows the back shore area to be more frequently flooded by fall and winter king tides. The patchy nature of vegetation at DRP 1 is shown in Figure 3.8, which also shows gravel that has moved into the quadrat from the adjacent beach by overwash. Note also in Figure 3.8 that vegetation is growing up through the gravel on the upper beach face.



Figure 3.6: Vegetation plots in DRP (red symbols, DRP 1-6) and Reference (yellow symbols, Ref 1-6) survey areas. Locations of fish sampling transects are shown as green (DRP, Fish 1-3) and orange (Reference, Fish 4-6) symbols.



Figure 3.7: Close up of 1-m<sup>2</sup> quadrat used to determine plant presence-absence with the 0.25-m<sup>2</sup> quadrat used to determine percentage cover of vegetation.



Figure 3.8: Vegetation monitoring Quadrat DRP 1, September 2013. Note presence of some gravel moved from top of berm landward into the quadrat, and the presence of vegetation on the upper beach face growing up through the gravel. View to northeast.

Table 3.3. Frequency of occurrence (presence/absence) of plant taxa and non-living material in the DRP and Reference areas, n = 6 (0.25-m<sup>2</sup>) quadrats for both DRP and Reference.

<b>Plant Taxon</b>	<b>DRP</b>	<b>Reference</b>
<i>Festuca rubra</i>	5	2
<i>Elymus mollis</i>	3	0
<i>Atriplex</i> spp.	2	0
<i>Spergularia</i> spp.	2	2
<i>Daucus</i> sp.	2	1
<i>Taraxacum</i> sp.	2	2
Moss (unidentified sp.)	1	0
<i>Achillea millefolium</i>	1	1
<i>Angelica lucida</i>	1	2
<i>Anthoxanthum odoratum</i>	1	0
<i>Grindelia stricta</i>	1	0
<i>Ammophila arenaria</i>	1	2
<i>Digitalis</i> sp.	1	0
<i>Anaphalis margaritacea</i>	1	0
<i>Cytisus scoparius</i>	1	0
<i>Rumex acetocella</i>	1	3
Unidentified weed	1	0
<i>Carex pansa</i>	0	1
<i>Carex opnupta</i>	0	1
<i>Deschampsia cespitosa</i>	0	1
<i>Jaumea carnosa</i>	0	1
<i>Juncus breweri</i>	0	3
<i>Sarcocornia perennis</i>	0	1
<i>Schedonorus phoenix</i>	0	1
<i>Symphyotrichum subspicatum</i>	0	4
<i>Trifolium</i> spp.	0	2
<i>Rubus</i> sp.	0	1

Table 3.4. Mean and standard deviation of percent coverage of plant taxa and non-living material in the DRP and Reference areas, n = 6 (1-m<sup>2</sup>) quadrats for both DRP and Reference.

<b>Plant Taxon</b>	DRP	Reference
<i>Festuca rubra</i>	26.0	12.3
<i>Spergularia spp.</i>	15.7	1.0
<i>Elymus mollis</i>	15.3	0.0
<i>Atriplex spp.</i>	5.8	0.0
<i>Rumex acetocella</i>	5.3	2.2
<i>Taraxacum sp.</i>	5.0	0.3
<i>Anthoxanthum odoratum</i>	3.8	0.0
<i>Angelica lucida</i>	1.7	1.8
<i>Digitalis sp.</i>	0.8	0.8
<i>Grindelia stricta</i>	0.7	5.0
Unidentified weed	0.7	0.2
<i>Ammophila arenaria</i>	0.5	12.0
<i>Daucus sp.</i>	0.5	0.5
<i>Anaphalis margaritacea</i>	0.3	0.0
Moss (Unidentified sp.)	0.2	0.5
<i>Achillea millefolium</i>	0.2	0.5
<i>Cytisus scoparius</i>	0.2	0.0
<i>Juncus breweri</i>	0.0	24.3
<i>Carex pansa</i>	0.0	6.7
<i>Sarcocornia perennis</i>	0.0	5.8
<i>Deschampsia cespitosa</i>	0.0	4.2
<i>Schedonorus phoenix</i>	0.0	4.2
<i>Rubus sp.</i>	0.0	3.7
<i>Symphyotrichum subspicatum</i>	0.0	3.3
<i>Carex opnupta</i>	0.0	2.8
<i>Jaumea carnosa</i>	0.0	2.5
<i>Distichlis spicata</i>	0.0	1.7
<i>Trifolium spp.</i>	0.0	0.5
<i>Hedera helix</i>	0.0	0.2
<b>Total Non-living</b>		
Bare ground/sand	13.2	0.0
Woody Debris	2.5	3.0
Dead plant matter	1.7	0.0

#### 4.0 Current Status of Erosion in the Study Area

As described in Section 2.2, as of February, 2014, both the 2007 and 2011 DRP shoreline sections appear mostly stable, while erosion has continued to occur in the Reference area immediately to the south of the DRP. “King” tides occurring from November – February have continued to roll back the shoreline vegetation, and steep vertical scarps at the vegetation edge are the norm along this shore section. Erosion in the unprotected Reference area in the period 2009-2013 has been as great as 9.6 m (31.5 ft). The effect of erosion during 2013 can be seen in comparison of Figures 4.1, 4.2 and 4.3, taken from a similar spot on the HMSC Nature Trail. Erosion in 2013 has continued to create vertical banks of collapsed sod, with salt marsh vegetation collapsing and being eroded away (Figure 4.4). Erosion has continued along the entire length of the Reference area, and has begun to erode low salt marsh habitat which has not been exposed to erosion before. Following King tides and high winds, large chunks of marsh sod had been uprooted from this area and transported hundreds of meters southward onto the sand flat opposite the HMSC picnic shelter. The erosion has also begun to curve in behind the southern end of the DRP and may threaten the stability of the DRP project in this area in the longer term (Figure 4.5).



Figure 4.1: View of collapsed section of HMSC nature trail, February 3, 2012.





Figure 4.2: View of collapsed section of HMSC nature trail, January 16, 2013. The trail has been completely washed out in the foreground. The trail information sign seen at the top of Figure 4.1 has been removed after erosion undermined the posts supporting it. An additional 60 feet of trail in the middle distance has been undermined and the asphalt has collapsed on the shore.



Figure 4.3: View of eroded section of HMSC nature trail, February 14, 2014. The trail has been completely washed out in the section shown in Figure 4.2, and collapsed asphalt has been removed. Another of the Reference area monitoring quadrats for the vegetation studies (PVC stake in center of picture) has been lost to erosion.



Figure 4.4: View to the south of the 2011 DRP in the Reference area (February 14, 2013), showing collapsed banks with 4 foot vertical scarps. In the upper left, erosion is now starting to attach low salt marsh habitat on the point and beyond which has not previously been exposed to erosion.

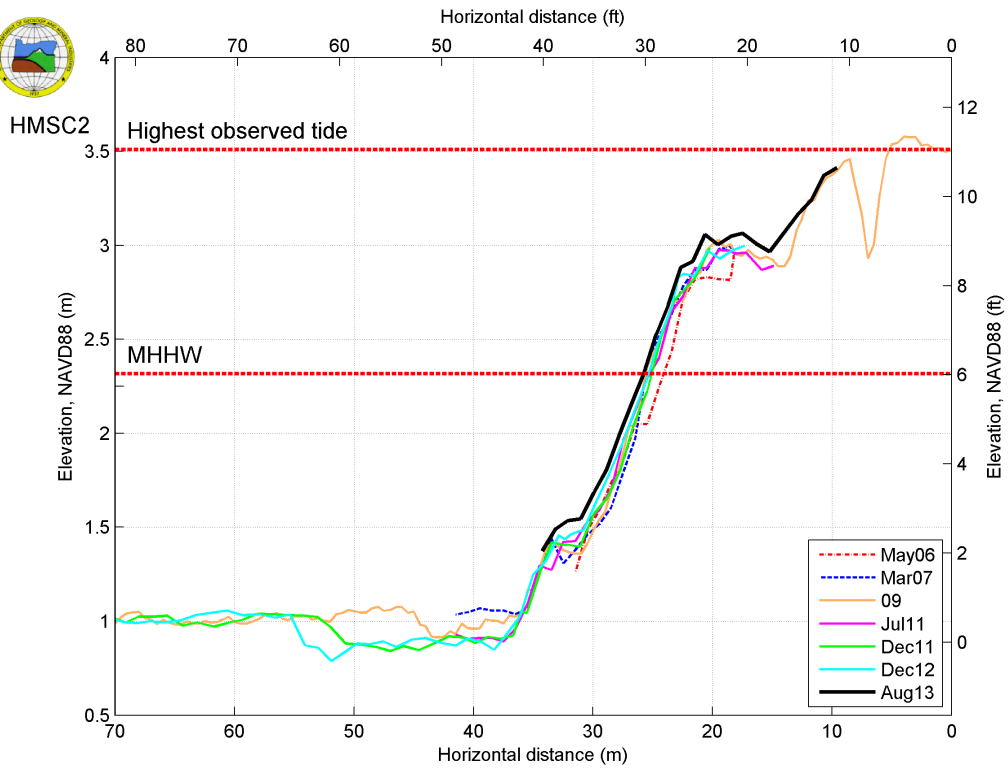
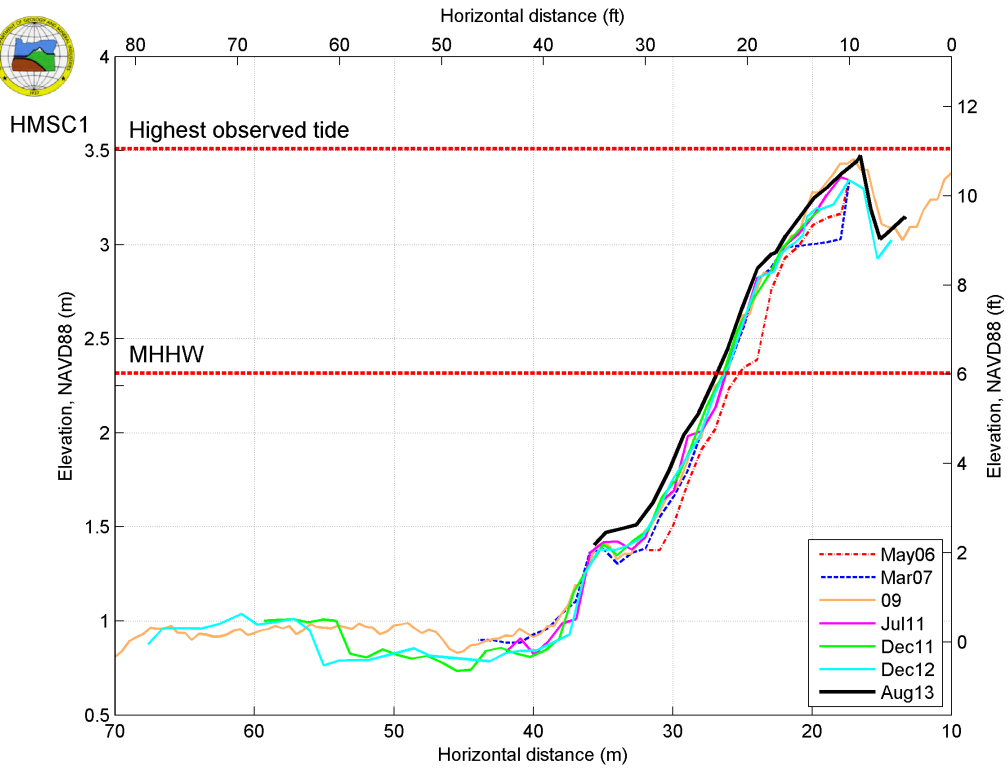


Figure 4.5: View of the southern end of the 2011 DRP (February 14, 2014). Erosion has removed high salt marsh vegetation and is beginning to erode shoreline protected by the DRP.

## **5.0 Disclaimer**

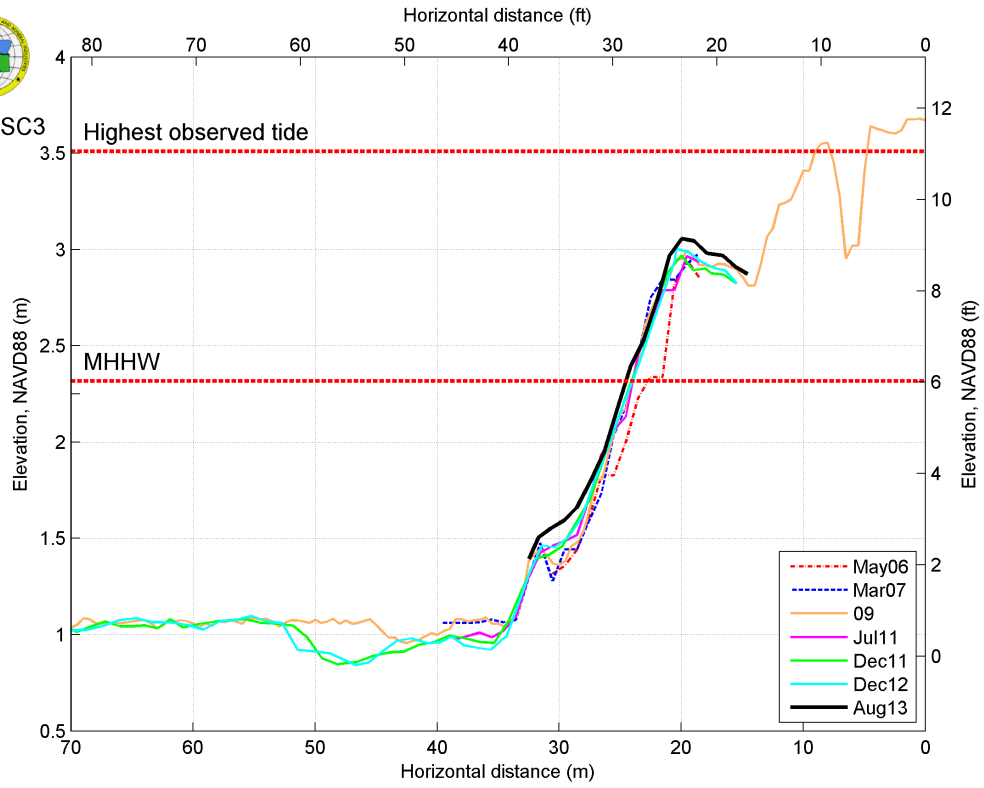
The information in this document contained in sections 3.1 and 3.3 has been subjected to review by the National Health and Environmental Effects Research Laboratory of US EPA and approved for publication. Approval does not signify that the contents reflect the views of the Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

# Appendix 1: Beach Profile Survey Graphs

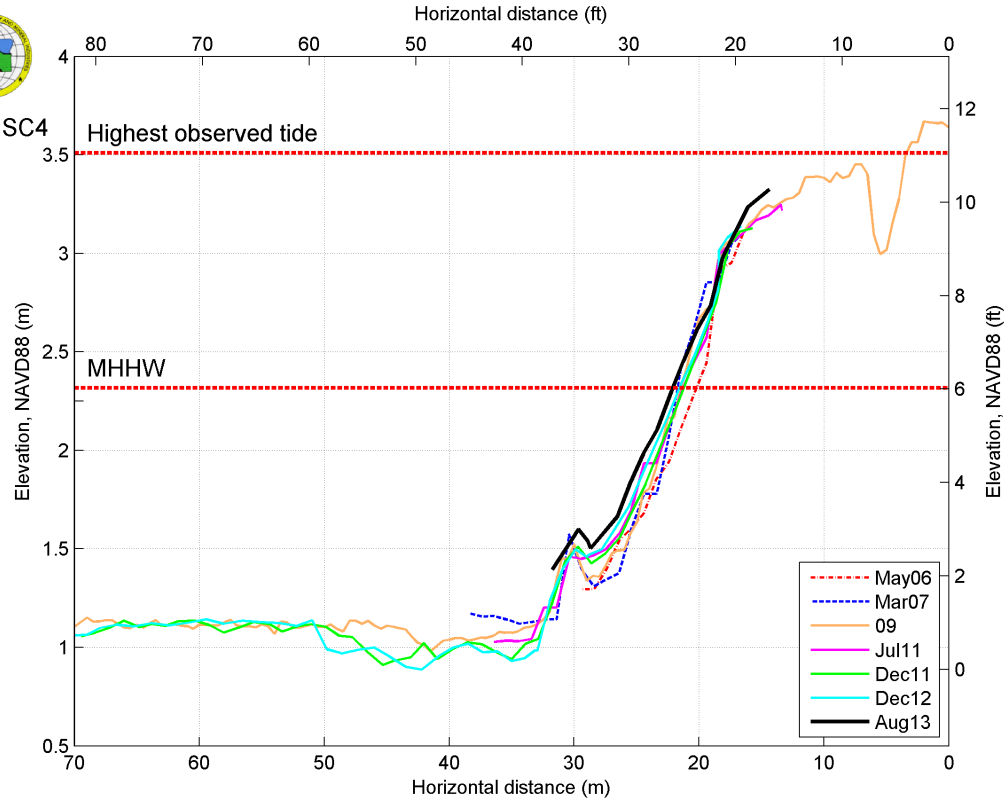




HMSC3

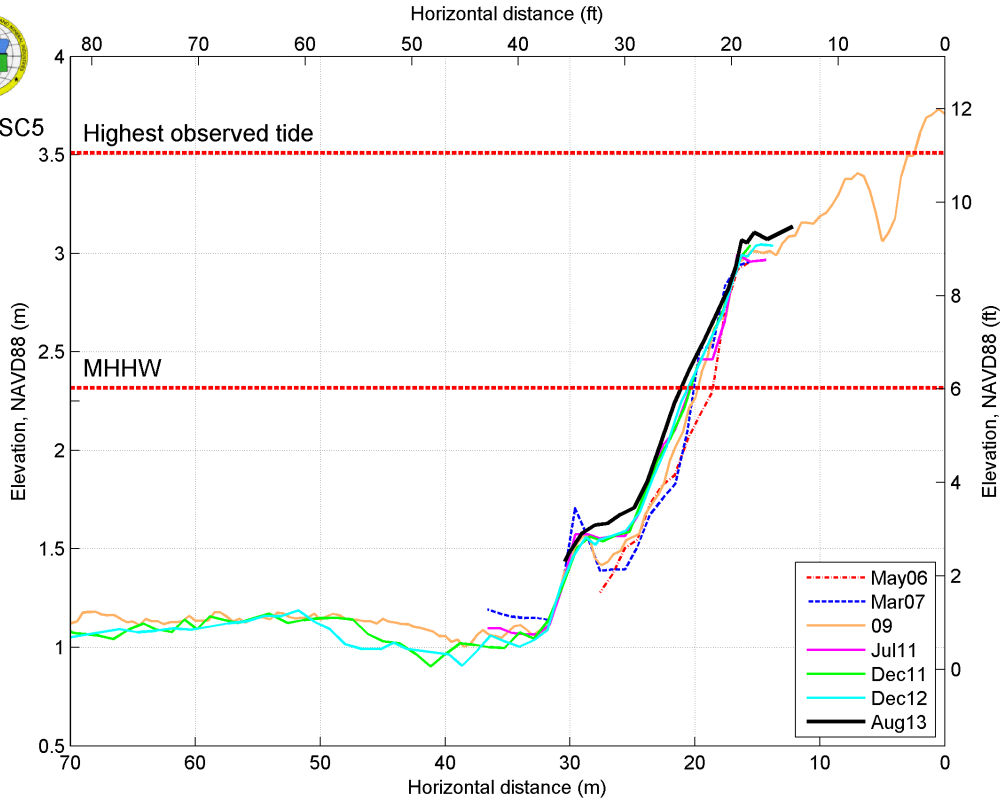


HMSC4

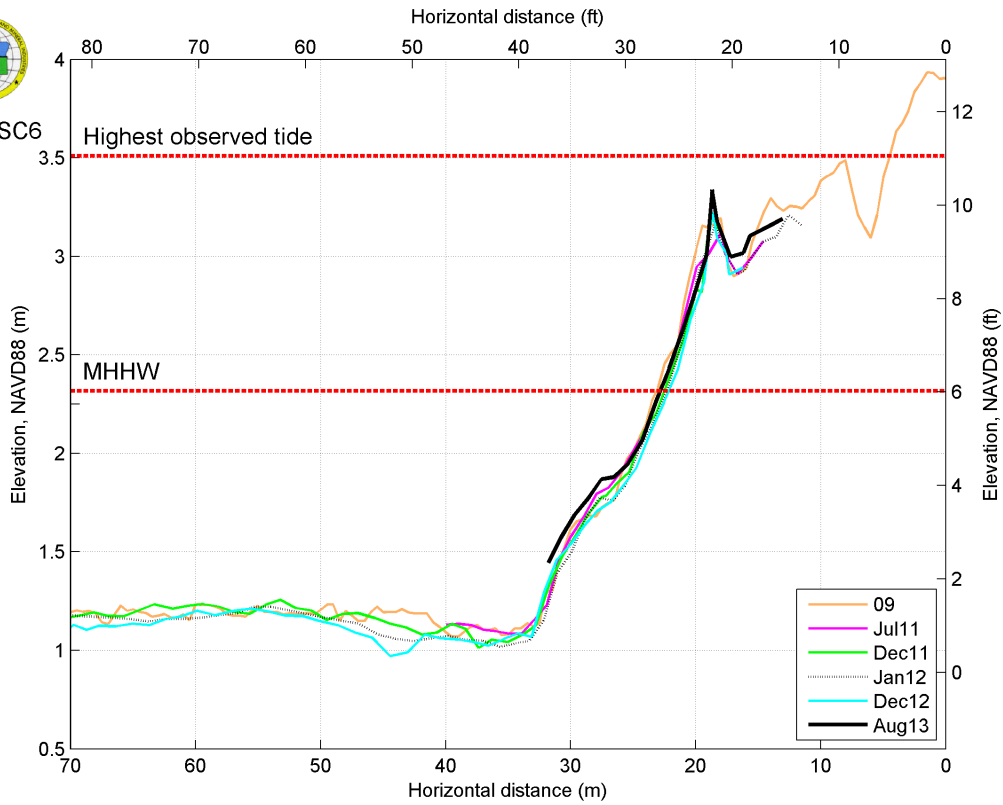




HMSC5



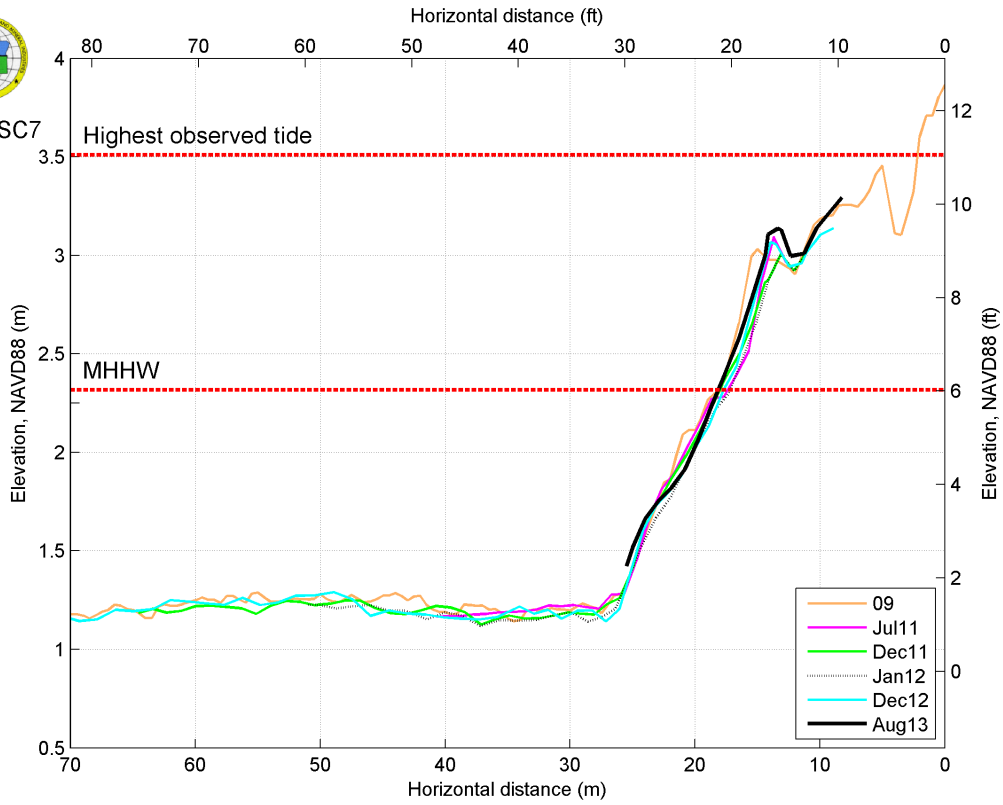
HMSC6



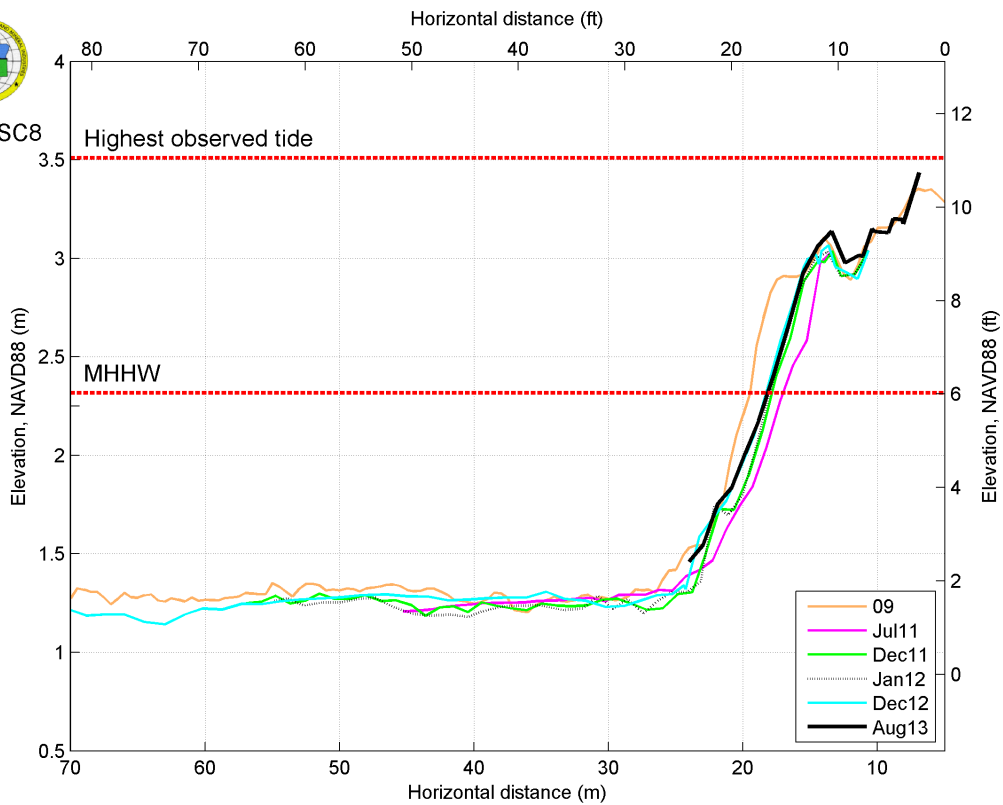




HMSC7

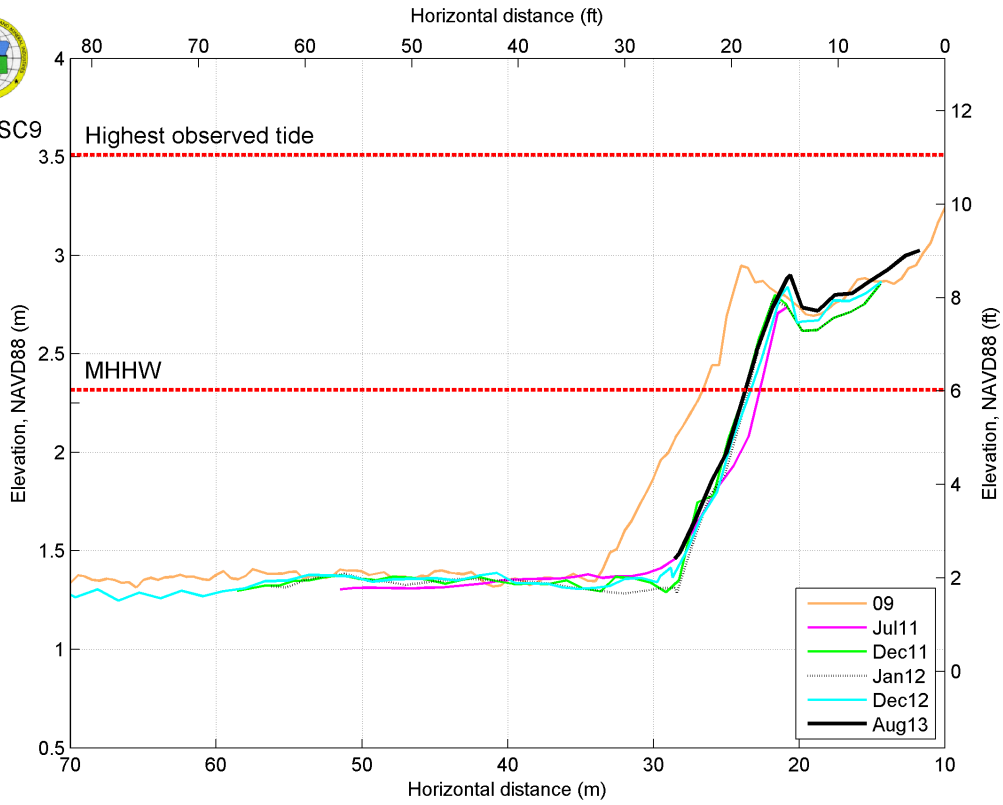


HMSC8





HMSC9



HMSC10

