AGUA HEDIONDA LAGOON - OUTER BASIN

2020/21 MAINTENANCE DREDGE

AND BEACH NOURISHMENT CYCLE

SAND DEPOSITION PLAN

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Prepared for:

City of Carlsbad, California
in fulfillment of
Special Use Permit 06-10X2(A)

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EXECUTIVE SUMMARY

This sand deposition plan has been prepared in fulfillment of Conditions 7, 8, and 9 of the City of Carlsbad Special Use Permit (SUP) 06-10X2(A).

Cabrillo Power I LLC and Poseidon Resources (Channelside) LP plan to conduct maintenance dredging and beach nourishment in 2020/21 to remove a flood-tide shoal in the outer basin (also referred to as the West Basin) of Agua Hedionda Lagoon in order to maintain tidal exchange between the lagoon and ocean. Similar operations have been performed over the last six decades. Approximately 300,000 cubic yards (cy) of sand may be removed from the lagoon – outer basin. In keeping with past operations, the dredged sand will be placed on adjacent beaches: North Beach, Middle Beach, and South Beach. Operations will be conducted between October 2020 and April 2021.

Sand placement quantities for each receiver beach were determined by Dr. Scott Jenkins based on the current beach condition defined by a May 2020 beach profile survey. The amount of sand placed on each of the receiver beaches was optimized based on computations of equilibrium beach profiles using current conditions and maximizing recreational beach widths in proportion to use (i.e. North Beach is more heavily recreated than Middle or South Beaches), while avoiding impact to sensitive hard bottom habitat. In addition, the proposed sand deposition plan is designed to replace sand that has been eroded from the beaches since the 2018 dredge/beach nourishment event. Erosion losses on all three receiver beaches since the last dredge/beach nourishment cycle in 2018 total 295,274 cy, roughly equivalent to the total proposed dredge/beach nourishment quantities for 2020/21.

Based on this composite analysis, North Beach will receive 66% of dredged sand (approximately 200,00 cy), to be placed in a fill template configured as an elliptic cycloid equilibrium profile in order to maximize retention time. Middle and South Beach will receive 34% of the dredged material (approximately 100,00 cy) with an approximate distribution of 42% and 58%, respectively. The proposed sand placement quantities and approximate schedule are summarized below.

Beach Placement Quantities and Schedule[1]

Receiver Site	Approximate Placement Quantity	Approximate Schedule
North Beach	200,000 cy	October 2020 to December 2020
No. Inlet Jetty to Maple Ave	(125,000 cy)	
Maple Ave to Pine Ave	(75,000 cy)	
Middle Beach	42,000 cy	January 2021 to February 15, 2021
South Beach	58,000 cy	February 15, 2021 to March 2021[1]
Total	**300,000 cy**	

[1]Sand placement operations my extend beyond March 2021 if adverse weather conditions or equipment issues are encountered. No sand will be placed on beaches after April 15, 2021.

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1. INTRODUCTION

The rubble mound jetties at the Agua Hedionda Lagoon entrance were constructed in 1954 to maintain a stable inlet for the Encina Power Station (EPS) seawater intake (Shaw, 1980). Initial dredging to create the cooling water basin was conducted at the same time. Ongoing maintenance dredging performed during the last six decades has allowed the lagoon entrance to remain open to tidal exchange.

Since 1994, maintenance dredging has been conducted at intervals of one to four years to remove a flood-tide shoal that forms in the Agua Hedionda Lagoon - Outer Basin to maintain tidal exchange throughout the lagoon and provide cooling water flowrates required for EPS operations. The EPS discontinued operation in December 2018. However, maintenance dredging of the outer basin continues to be necessary to maintain tidal exchange throughout the lagoon and provide seawater to support the operation of the Claude “Bud” Lewis Carlsbad Desalination Plant. Between 1994 and 2015, approximately 3.3 million cubic yards (cy) of sediment were dredged from the outer basin and placed on neighboring beaches (Coastal Frontiers, 2017a). Individual dredge cycle quantities have ranged from 159,000 to 429,000 cy. The most recent operation, completed in 2018, accounted for 205,482 cy.

Cabrillo Power I LLC (Cabrillo) and Poseidon Resources (Channelside) LP (Poseidon) plan to conduct the next phase of maintenance dredging in 2020/2021. Consistent with past maintenance dredging events, sediment removed from the lagoon’s outer basin will be placed on adjacent beaches: North, Middle and South Beached. The work will be performed in accordance with the stipulations in the following permits:

- City of Carlsbad Special Use Permit (SUP) 06-10X2(A)
- US Army Corps of Engineers Permit SPL-2001-00328-RRS
- California Coastal Commission Coastal Development Permit
- San Diego Regional Water Quality Control Board 401 Water Quality Certification
- California Department of Parks and Recreation Right of Entry Permit
- California State Lands Commission Lease 932.1

This sand deposition plan has been prepared in fulfillment of Conditions 7, 8 and 9 of the City of Carlsbad SUP. The following sections provide a project description, summarize the project schedule, describe the sand placement quantity calculations, and summarize the findings.

2. PROJECT DESCRIPTION

Dredging will be limited to the Agua Hedionda Lagoon – Outer Basin, which is bordered on the east by the railroad bridge and on the west by Carlsbad Boulevard (**Figure 1**). In accordance with the SUP, up to 500,000 cy may be removed from the outer basin, but the present conditions indicate the dredge amount will be on the order of 300,000 cy, which is in the average range of dredging over the past 20 years, **(see Table-1)**. In keeping with past operations, the dredged sand will be placed on adjacent beaches: North Beach, Middle Beach, and South Beach (**Figure 1**). The amount of sand placed on each of the receiver beaches will be optimized based on computations of equilibrium beach profiles using current conditions and maximizing recreational beach widths in proportion to use (i.e. North Beach more heavily recreated than Middle or South Beaches), while avoiding impact to sensitive hard bottom habitat.

2.1 Dredging Operations

Dredging of the Agua Hedionda Lagoon - Outer Basin will be performed using a diesel-powered dredging hull barge. During operations, the dredge hull would be stabilized by wire cables that are secured to existing anchors on the shore of the lagoon.

2.2 Beach Placement Operations

The dredged material (slurry) will be pumped to each of the receiver beaches (North, Middle and South Beach; **Figure 1**) through a 20-inch diameter pipeline. A floating section of pipe will convey the slurry from the dredge to the lagoon shoreline, where it will connect with a land-based pipeline that will deliver the material to the receiver beach. **Figure 2** shows the approximate dredge pipeline routes for each receiver site. When material is placed at North Beach, the pipeline will traverse under the Carlsbad Boulevard Bridge and then north along the back of the beach as far as Pine Avenue. For the Middle and South Beach receiver sites, an existing underground pipe under Carlsbad Boulevard will be utilized. In the case of South Beach, the pipelines will be extended along the back of the beach at Carlsbad State Beach to reach the south side of the EPS discharge jetty. Depending on shoal conditions, the pipe to Middle Beach may traverse under the Carlsbad Boulevard Bridge and then south for a portion of the discharge time on Middle Beach.

As described above, the slurry arriving from the dredge discharge pipeline is a mix of sand and water. Temporary dikes and berms will be constructed at the discharge points to de-water the slurry and aid in the retention of sand at the receiver beaches. As currently envisioned, two dikes would be constructed – one that is perpendicular to the beach connected to one that is parallel to the beach (forming an "L"). The dredged slurry will be discharged behind the dikes. Where sand is not present on the existing beach an initial quantity of sand will be discharged on the highest portion of the beach and used to construct a dike. These methods have been used effectively in the past to promote sediment settling onto the beach instead of remaining in suspension and being transported back into the surf zone.

Table-1: Agua Hedionda Lagoon Dredging of the Outer (West) Basin, 1998-2018

Year	Dredging						Disposal		Comments
	Date		Volume cubic yard	Influx		Basin	Volume cubic yard	Location	
	Start	Finish		Days	Yds^3/Day				
1998	Dec-97	Feb-98	59,072	92	642	Middle	59,072	M	Modification
	Feb-98	Jul-98	214,509	150	1,430	Inner	120,710	M	Modification
							93,799	S	
1999	Feb-99	May-99	155,000	304	510	Outer	155,000	N	Maintenance
2000-01	Nov-00	Apr-01	*422,541*	701	603	Outer	141,346	N	Maintenance
							195,930	M	
							85,265	S	
2002-03	Dec-02	Apr-03	*354,266*	730	485	Outer	161,525	N	Maintenance
							131,377	M	
							61,364	S	
2004-05	Jan-05	Mar-05	348,151	704	495	Outer	100,487	N	Maintenance
							170,515	M	
							77,149	S	
2006-07	Jan-07	Apr-07	333,373	763	437	Outer	149,168	N	Maintenance
							121,038	M	
							63,167	S	
2008-09	Dec-08	Apr-09	299,328	733	408	Outer	104,141	N	Maintenance
							102,000	M	
							93,185	S	
2010-11	Dec-10	Apr-11	226,026	736	307	Outer	62,030	N	Maintenance
							93,696	M	
							70,300	S	
2014-15	Dec-14	Apr-15	294,661	736	400	Outer	64,968	N	Maintenance
							156,056	M	
							73,637	S	
							0	N	
2017-18	Oct-17	Apr-18	205,482	734	280	Outer	141,172	M	Maintenance
							64,310	S	
TOTAL			2,912,407				2,912,407		
AVERAGE			291,240						
MAINTENANCE TOTAL			**2,638,828**						

Figure 1. Project Location Map

Note: North Beach receiver site used only during maintenance dredge/beach nourishment cycles when sand placement is dictated by existing beach condition.

Figure 2. Dredge Discharge Pipeline Routes

Note: North Beach discharge pipeline installed only during maintenance dredge/beach nourishment cycles when sand placement is dictated by existing beach condition.

The dikes and berms also are used to ensure shoreline ocean turbidity does not exceed the limit as set in the San Diego Regional Water Quality Control Board 401 Water Quality Certifications.

The discharge point is directed according to the pre-determined sand deposition plan. Once the material is de-watered, front-end loaders spread the sand on the beach and into the required beach profile configuration. As required by Condition 9 of the SUP, the beach berm will be no taller than 6 ft on the eastern aspect and will be groomed and flattened to provide towel space. The material will be placed in such a manner that the beach profile slopes gradually to the surf zone. In the event that storm events begin to relocate the front aspect of the graded sand slope during the equilibration process, the berm and slope shall be regraded for public safety purposes. Material will not be placed in areas that will block existing drainage. In addition, a minimum 5-ft wide path of travel will be maintained between sand placement operations and sea walls (both public and private).

Target sand placement quantities for North, Middle, and South Beach were developed based on computations of equilibrium beach profiles using current conditions and maximizing recreational beach widths in proportion use, while avoiding impact to the sensitive hard bottom habitat. Presently, the three receiver beaches are within 36,198 cy of their carrying capacity **(see Section 4.2)**, which is the minimum amount of sand volume needed to maintain an equilibrium beach profile, otherwise known as the beach *critical mass*, (Jenkins and Inman, 2006). In addition, erosion losses on all three receiver beaches since the last beach nourishment cycle in 2018 total 295,274 cy **(see Table 4.)** Therefore, approximately 300,000 cy from the lagoon's outer basin is proposed to be dredged in order to avoid inlet closure in the near future and to replenish the sand on the North, Middle, and South Beaches. To maintain the greatest retention time of sand on the beach, the sand will be configured as an elliptic cycloid. This was the approach taken in 2018 beach nourishment cycle and will be continued in this sand deposition plan for 2020/21 beach nourishment cycle. These computations are detailed in **Appendix-B** and the resulting elliptic cycloid beach fill templates are plotted in **Appendix-C**.

As described above, approximately 200,000 cy (191,062 cy) of dredge material will be placed at North Beach and the remaining dredge material, of approximately 100,000 cy (99,761 cy), will be placed at Middle and South Beach with an approximate distribution of 42% and 58%, respectively **(see Table 2)**.

Table 2. Target Placement Quantities

Receiver Site	Approximate Placement Quantity
North Beach	191,062 cy
No. Inlet Jetty to Maple Ave.	120,830 cy
Maple Ave. to Pine Ave.	70,232 cy
Middle Beach	41,447 cy
South Beach	58,314 cy
TOTAL	290,823 cy

2.3 Summary of Project Equipment

The designated staging area for equipment and materials is on Fishing Beach located on the west shoreline of the outer basin. The following equipment will be utilized.

- Hydraulic dredge;
- Slurry discharge pipe;
    - Poly and Steel pipe within the lagoon (floating);
    - Poly pipe along the shoreline;
- Rubber tired loaders – one full time, second as needed; and
- Pickup truck (4x4), for support on the shoreline and public roadways.

2.4 Access and Pedestrian Control

Cabrillo and Poseidon regard safety of the public and personnel foremost over all other tasks. Portable signage will be used at each discharge location to advise pedestrians of current work. An example of this signage is provided in Figure 3 but will be modified to add Poseidon Resource and a revised the call number. This signage is relocated as the dredge slurry discharge point moves.

Figure 3. Example of Public Signage

No forms of public access to the shoreline will be blocked during sand deposition operations. Designated access ways, over or around obstructions, will be provided. Access for public safety vehicles also will be maintained. When discharging to South Beach, the piping is placed through an opening in the discharge channel fencing to ensure pedestrian safety. At no time will piping be placed on the pedestrian sidewalks along Carlsbad Boulevard. A monitor will be stationed at the north and south ends of the active work area to prevent foot traffic in the immediate discharge location. Appropriate signage and construction fencing will be used to identify the discharge location. The beach access areas will be left in a safe condition at the end of each workday. A flag crew will be utilized while moving or operating equipment on the beach. The pickup truck used to support the operation will utilize the shoreline and public roadways to avoid interference with pedestrian flow. As stipulated by Condition 9 of the SUP, a minimum 5-ft wide path of travel will be maintained between sand placement operations and sea walls (both public and private).

Discharge point relocation operations will be conducted during low pedestrian traffic times to the extent possible. In addition, project personnel will be available to answer any questions the public may have on the process.

2.5 Contact Information

The project is being conducted under the supervision of Ms. Josie McKinley. Her contact information is provided below.

Josie McKinley, Director of Project Development
Poseidon Water LLC
5780 Fleet Street, Suite 140
Carlsbad, CA 92008
(760) 655-3989 voice
(310) 991-3032 (cell)
jmckinley@poseidonwater.com

Should emergency response be necessary for the dredge/beach nourishment activity, you may contact Ms. McKinley, or follow the Hazardous Materials Business Plan Emergency Notification as provided to the Carlsbad Fire Department.

3. PROJECT SCHEDULE

The dredging and sand placement schedule shall be similar to past activities and conform with the requirements stipulated in the California Coastal Commission Coastal Development Permit. The anticipated schedule is shown in **Table 3**.

Table 3. Schedule for 2020/21 Dredge/Beach Nourishment Cycle

Activity	Approximate Dates
Dredging	October 2020 to April 15, 2021
Sand Placement	
North Beach	October 2020 to December 2020
Middle Beach	January 2021 to February 15, 2021
South Beach	February 15, 2021 to March 2021[1]
Total Period of Activity	**October 2020 to April 15 2021**

[1] Sand placement operations my extend beyond March 2021 if adverse weather conditions or equipment issues are encountered. No sand will be placed on beaches after April 15, 2021.

It is anticipated that all work will be conducted during daylight hours and between Monday and Friday. If the schedule is delayed by storm activity, work may be conducted during daylight hours on Saturdays with appropriate authorization. No activities are anticipated during evening hours or on Sundays.

4. SAND PLACEMENT QUANTITY DETERMINATION

4.1 Beach Profile Surveys

A post beach profile survey was conducted on 18 April 2018, immediately following completion of the 2017/2018 maintenance dredge and beach nourishment, as required by City of Carlsbad Special Use Permit (SUP) 06-10X2(A). This survey provided a baseline beach condition assessment. A new pre-beach nourishment profile survey was conducted on 13 May 2020, to document the current condition of the beaches, and to determine erosion rates and erosion patterns following the April 2018 baseline survey. Data were obtained on 15 beach profile transects (**Figure 4**). Thirteen of the transects had been surveyed in 2018 on behalf of Cabrillo Power, while two were surveyed for the first time in 2020. Six of the Transects (CB-800 to CB 0850) correspond to historical locations included in the SANDAG Shoreline Monitoring Program and the City of Carlsbad Beach Monitoring Program (Coastal Frontiers, 2017a; 2017b). The data acquisition and reduction methods were comparable to those employed on the beach profile surveys conducted under the aforementioned programs.

Survey control information was provided by Cabrillo prior to the field activities. The coordinates of the control points were confirmed at the time of the survey using real-time kinematic (RTK) GPS techniques.

Survey activities were conducted under ideal conditions, with offshore winds and waves typically less than 3 ft. Data were acquired along each transect from the landward limit of the sandy beach to wading depth, which typically corresponded to 8 to 15 ft below Mean Lower Low Water (MLLW) Datum depending on the prevailing water level. The beach and surf zone were surveyed using a total station and a survey rodman. The total station was used to determine the position and elevation of the beach at each location occupied by the rodman. Each transect was surveyed from the back-beach seaward through the surf zone until the survey rod no longer protruded above the water surface when held erect.

The data from the wading survey were processed using software developed by Trimble. The raw total station data were read by the software, and the coordinates and elevation of each data point were calculated. The electronic total station used to conduct the survey is capable of measuring elevation differences to within ±0.1 ft and ranges to within ±0.5 ft. However, because the swimmer was subjected to waves and currents in the surf zone, the horizontal position perpendicular to each transect (parallel to the shoreline) varied from minimal at short ranges to approximately ±15 ft at the offshore end.

The beach profile plots developed from the 18 April 2018 post-beach nourishment survey and the 13 May 2020 pre-beach nourishment survey data are provided in **Appendix A**.

Figure 4. Beach Profile Transect Locations

The range on each profile plot represents the distance in feet seaward of the transect origin measured along the transect alignment. The elevation is given in feet relative to MLLW (1983-2001 Epoch).

The beach profile survey data plotted in Appendix-A were loaded into AutoCad Civil 3-d to create 3-d models of the receiver beaches for 2018 post-beach nourishment condition and 2020 pre-beach nourishment conditions. **Figure-5a** shows the 3-d CAD model of the 2018 post-beach nourishment based on the 18 April 2018 beach profile survey; while **Figure 5b** plots the 3-d CAD model of the 2020 pre-beach nourishment based on the 13 May 2020 beach profile survey. By performing a spatial subtraction of the 13 May 2020 beach model from the 18 April 2018 model, an accurate assessment of the erosion that has occurred since the 2018 beach nourishment. **Table-4** presents a detailed break-down of the sand losses that have occurred along each surveyed reach between 18 April 2018 and 13 May 2020.

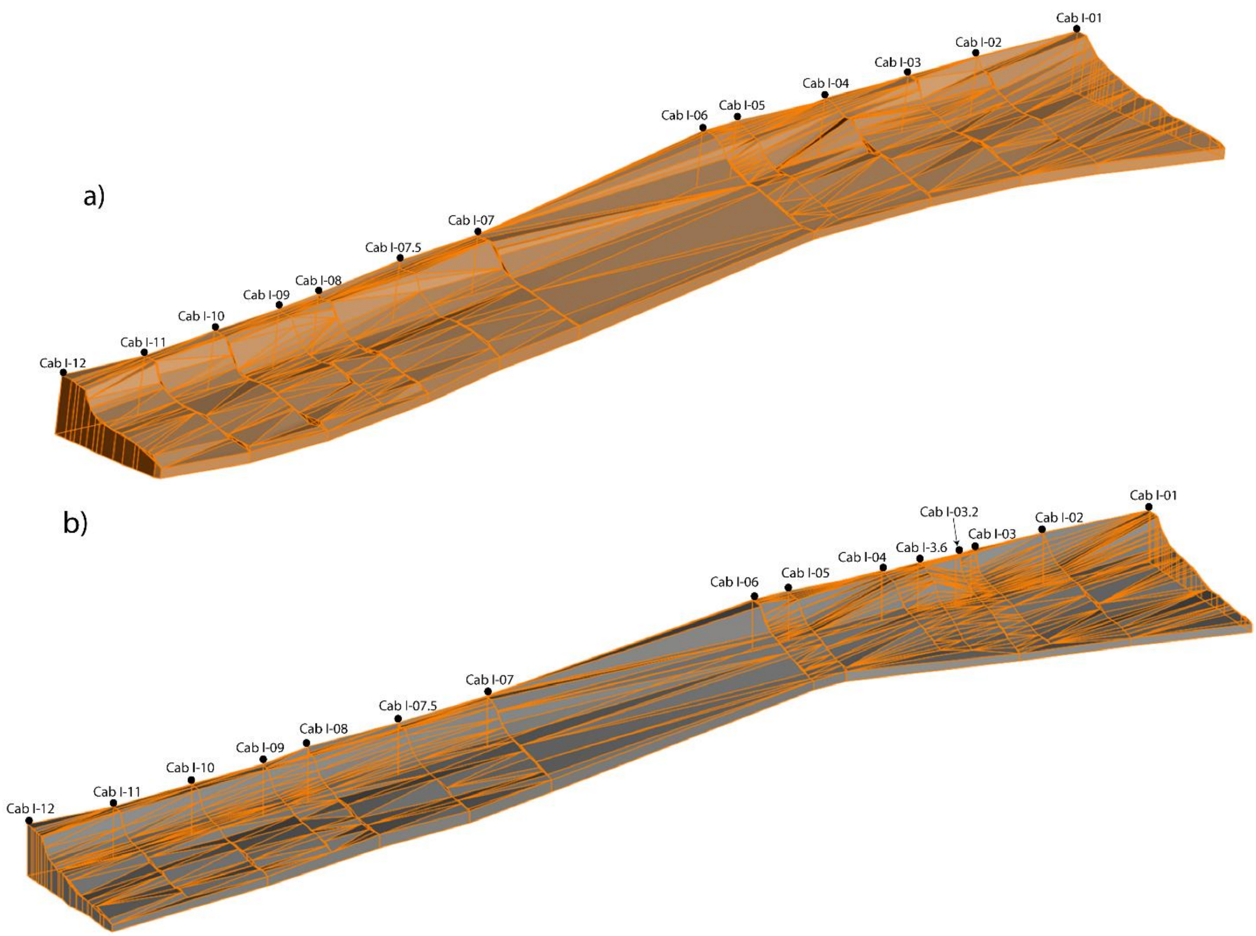

Figure-5: Three-dimensional CAD models of the receiver beaches: a) based on the 18 April 2018 post-beach nourishment survey, and b) based on the 13 May 2020 pre-beach nourishment survey.

Spatial subtraction of the 13 May 2020 model from the 28 April 2018 model produces a detailed assessment of sand losses, as given in Table-4.

Table 4: Sand Losses on the Receiver Beaches Between 22 April 2018 and 13 May 2020

Receiver Beach	Profile Range Line	Distance between Range Lines	Local Sand Loss ft^3/ft of shoreline	Sand Volume Lost between Range Lines, ft^3 & yds^3
South Beach	Cab I-01		-960	
		750.57		607,961.7 ft^3 = 22,517.1 yds^3
South Beach	Cab I-02		-660	
		513.50		430,056.3 ft^3 = 15,928.01 yds^3
South Beach	Cab I-03		-1015	
		648.92		637,563.9 ft^3 = 23,613.48 yds^3
Middle Beach	Cab I-04		-950	
		667.82		764,653.9 ft^3 = 28,320.5 yds^3
Middle Beach	Cab I-05		-1,340	
		259.91		327,746.5 ft^3 = 12,138.76 yds^3
Middle Beach	Cab I-06	Cab I-06 to South Inlet Jetty = 639.1 ft.	-1,182	
		North Inlet Jetty to Cab I-07 = 460.0 ft		
		2203.14		755,357.1 ft^3 = 27,976.2 yds^3
North Beach	Cab I-07		-1,664	
		1399.51		2,175,538.3 ft^3 = 80,575.5 yds^3
North Beach	Cab I-08		-1,445	
		350.56		451,346 ft^3 = 16,716.5 yds^3
North Beach	Cab I-09		-1,130	
		541.45		565,815.25 ft^3 = 20,956.1 yds^3
North Beach	Cab I-10		-960	
		609.00		621,180 ft^3 = 23,006.6 yds^3
North Beach	Cab I-11		-1020	
		728.00		635,180 ft^3 = 23,525.2 yds^3
North Beach	Cab I-012		-725	
Total Sand Loss South Beach				**1,675,581.9 ft^3 = 62,058.6 yds^3**
Total Sand Loss Middle Beach				**1,847,757.5 ft^3 = 68,435.5 yds^3**
Total Sand Loss Cab I-07 to I-10 (No. of Inlet Jetty to Maple Ave)				**3,192,698.7 ft^3 = 118,248.1 yds^3**
Total Sand Loss Cab I-10 to I-12				**1,256,358.6 ft^3 = 46,531.8 yds^3**

(Maple Ave to Pine Ave				
Total Sand Loss North Beach				**4,449,059.6 ft^3 = 164,779.9 yds^3**
Total Sand Loss				**7,972,390.9 ft^3 = 295,274.04 yds^3**

Inspection of **Table-4** indicates total erosion losses on all three receiver beaches since the last dredge/beach nourishment cycle in 2018 total 295,274 cy, roughly equivalent to the total proposed dredge/beach nourishment quantities for 2020/21, as stated in the Executive Summary. More sand has been lost to erosion since 2018 on North Beach, (where no sand was placed during the 2018 dredge/beach nourishment cycle), than was lost on Middle and South Beaches combined; i.e. 164,780 cy eroded from North Beach vs only 130,494 cy lost on Middle and South Beach combined (68,435 cy, lost on Middle Beach and 62,059 cy lost on South Beach). This was a significant consideration in posing the 2020/21 sand deposition plan summarized in the Executive Summary. Another point to highlight here is that the definition of the North Beach receiver beach has varied over the years, ever since North Beach disposal has been practiced, beginning in 1998. North Beach disposal originally extended from the north inlet jetty to Maple Ave. Later, City of Carlsbad Special Use Permit (SUP) 06-10X2(A) redefined the North Beach disposal site to be extended to Pine Ave. Therefore, **Table-4** sub-divides the North Beach site between the north inlet jetty at survey range Cab I-07 to Maple Ave. at survey range Cab I-10; and from Cab I-10 to Pine Ave. at Cab I-12. Since the 18 April 2018 post-beach nourishment survey, 118,248 cy of beach sand has been lost between the north inlet jetty and Maple Street, while 46,531.8 cy has been lost between Maple Street and Pine Ave.

In addition to the erosion losses that have occurred on the receiver beaches since the 2018 beach nourishment cycle, it is necessary to assess the remaining quantities of sand on the receiver beaches before beach nourishment quantities can be formulated. The carrying capacity of a beach is limited by the width of the wave-cut platform in the bedrock on which beach sands have accumulated over geologic time scales. To assess the residual sand volume, it is necessary to estimate the profile of the bedrock and basal conglomerate (aka, wave cut platform) on which the residual sand volume rests. Bed rock/basal conglomerate elevation profiles were derived from the composite minimum of SANDAG surveys 1997 -2012, (S97-S12) at transect CB-0800, CB-0810, CB-0820, CB-0830, CB-0840, and CB-0850. The composite minimums occurred during years when portions of the receiver beaches were partially stripped by severe erosion. The composite minimum profiles representing the wave-cut platform are plotted in Appendix-A in Figures A-1, 6, 8, 9, 13, and 16. These profiles were lofted as a 3-d solid in AutoCad Civil 3-d and embedded inside the 3-d CAD models of the receiver beaches in Figures 5a & b. By performing a spatial subtraction of the 13 May 2020 beach model from the bedrock profile model, a reasonably accurate assessment of the residual sand volume remaining on the receiver beaches can be made. **Table-5** presents a detailed break-down of the residual sand volume that remains as of 13 May 2020 along each surveyed reach of receiver beach.

Inspection of **Table-5** indicates total residual sand volume remaining on all three receiver beaches since the last dredge/beach nourishment cycle in 2018 total 314,438 cy. More residual sand volume remains on the combined Middle Beach and South Beach complex (189,360 cy, Middle Beach = 113,060 cy and South Beach = 76,300 cy) than on North Beach where remaining sand volume is only 125,078 cy. (This finding is likely due to beach stabilization by the 3 jetties along Middle and South Beaches). Thus, it is sensible to place more sand on North Beach during the forthcoming 2020/21 dredge/beach nourishment cycle, then on the Middle/ South Beach complex.

Table 5: Residual Sand Volume on the Receiver Beaches as of 13 May 2020 Survey

Receiver Beach	**Profile Range Line**	**Distance between Range Lines**	**Residual Sand Volume ft^3/ft of shoreline**	**Residual Sand Volume between Range Lines, ft^3 & yds^3**
South Beach	Cab I-01		+1630	
		Cab I-01 to South Discharge Jetty = 1,264 ft.		2,060,100 ft^3 = 76,300 yds^3
Middle Beach	Cab I-04		+1673	
		North Discharge Jetty to Cab I-06 = 1,576 ft		2,171,907 ft^3 = 80,441 yds^3
Middle Beach	Cab I-06		+1083	
		Cab I-06 to South Inlet Jetty = 639 ft.		880,713 ft^3 = 32,619 yds^3
		North Inlet Jetty to Cab I-07 = 460 ft	+982	452,007 ft^3 = 16,741 yds^3
North Beach	Cab I-07		+865	
		1,750 ft.		1,410,500 ft^3 = 52,241 yds^3
North Beach	Cab I-09		+747	
		1,878 ft.		1,514,607 ft^3 = 56,096 yds^3
North Beach	Cab I-012		+866	
Residual Sand South Beach				**2,060,100 ft^3 = 76,300 yds^3**
Residual Sand Middle Beach				**3,052,270 ft^3 = 113,060 yds^3**
Residual Sand Cab I-07 to I-10 No. of Inlet Jetty to Maple Ave.				**2,272,755.5 ft^3 = 84,176.1 yds^3**
Residual Sand Cab I-10 to I-12 Maple Ave. to Pine Ave.				**1,104,362 ft^3 = 40,902 yds^3**
Total Residual Sand North Beach				**3,377,106 ft^3 = 125,078 yds^3**
Total Residual Sand				**8,489,826 ft^3 = 314,438 yds^3**

4.2 Sand Quantity Calculation Methods and Results

The minimum sand loss rate occurs when beach fill volumes equal to the *critical mass*, which is the theoretical carrying capacity for supporting a beach profile in equilibrium. The carrying capacity of a beach is limited by the width of the wave-cut platform in the bedrock on which beach sands have accumulated over geologic time scales. The bedrock profiles Figures A-1, 6, 8, 9, 13, and 16 of Appendix-A indicate the wave-cut platform along Middle and South Beach is about 400 ft. to 500 ft. in width and only 300 ft. to 400 ft. in width along North Beach. The platforms are narrow because they were carved by wave action into erosion resistant bedrock formations during the present high-stand in sea level, and these narrow wave-cut platforms physically cannot hold large quantities of beach sand; and often become fully stripped during periods of high-energy winter waves.

The carrying capacity (or minimal sand volume for each beach) is determined by the critical mass (Jenkins and Inman, 2006 and Jenkins, *et al.*, 2007) based on the elliptic cycloid profile. The critical mass is calculated from maximum wave heights and sand grain sizes according to:

$$V_c = 1.23 \times 10^{-4} \left(h_c\right)^{2.1} \left(\frac{H_\infty}{\Lambda}\right)^{0.9}$$

with: $$h_c = \frac{K_e H_\infty}{\sinh k h_c} \left(\frac{D_o}{D_2}\right)^{\psi}$$

and: $$\Lambda = 2^{2/5} H_\infty^{1/5} \left(\sigma^2 / g\gamma\right)^{1/5}$$

Here h_c is the closure depth; ψ is a non-dimensional empirical parameter, D_2 is the shorerise median grain size; and D_o is a reference grain size ; $\sigma = 2\pi / T$ is radian frequency; k is the wave number; Λ is the shoaling factor relating breaker height to incident wave height $\Lambda = H_\infty / H_b$; g is acceleration of gravity; and γ is a factor relating the depth of wave breaking h_b to breaker height, $H_b = \gamma h_b$. For the critical mass calculations determining minimal placement volume, the following values for free parameters were used: $K_e \sim 2.0, \psi \sim 0.33$, and $D_o \sim 100 \mu m$. The minimal carrying capacities (critical mass) for each reach are summarized in **Table-6**.

The minimum sand placement quantities for each receiver beach were determined by comparing the existing beach condition with the critical mass sand volumes determined in **Appendix-B**. The results are summarized in **Table 6**. The volume calculations were performed with surface modeling software using the equations detailed in **Appendix-B**. It should be noted that the minimal carrying capacity for the reach of North Beach between the north inlet jetty and Maple

Ave is 79,500 cy, but when the North Beach disposal site is extended further north to Pine Ave, its minimal carrying capacity increase to 135,100 cy.

As indicated in **Table 6**, the residual sand volume above the wave cut platform at the time of the 13 May 2020 beach profile survey comparable to the critical mass calculated in Appendix-B. Only 14,698 cy of dredged sand would be needed on North Beach to re-establish minimal carrying capacity (critical mass), with all of the deficit in the Maple Ave to Pine Ave. reach. Presently Middle Beach requires just 21,540 cy of dredged sand to re-establish minimal carrying capacity (critical mass); while South Beach is over-built, with a surplus of 10,000 cy above its critical mass limit of 66,300 cy. Altogether only 36,198 cy of dredged sands are needed to restore all the receiver beaches to minimal carrying capacity, the reach along North Beach from the north inlet jetty to Maple Ave is presently holding an excess 4,676 cy over minimal carrying capacity (critical mass).

Table 6. Carrying Capacity and Target Sand Placement Volumes at Each Receiver Beach

Receiver Site	Minimal Carrying Capacity (Critical Mass)[1]	Sand Volume Lost April 2018 to May 2020	May 2020 Residual Sand Volume [2]	Placement Volume to Re-establish Critical Mass [3]	Optimal Sand Placement Volume [4]
North Beach	135,100 cy	164,780 cy			191,062 cy
North Jetty to Maple Ave.	79,500 cy	118,248 cy	84,176 cy	0 cy	120,830 cy
Maple Ave. to Pine Ave.	55,600 cy	46,532 cy	40,902 cy	14,698 cy	70,232 cy
Middle Beach	134,600 cy	68,435 cy	113,060 cy	21,540 cy	41,447 cy
South Beach	66,300 cy	62,059 cy	76,300 cy	0 cy	58,314 cy
TOTALS	336,000 cy	295,274 cy	314,438 cy	36,198 cy	290,823 cy

Notes:

1 Determined by critical mass per Appendix-B & Jenkins and Inman, (2006) and Jenkins (2017a, 2017b, 2017c).

2 Based difference between 1997-2012 composite minimum and May 2020 beach profile survey (Section 4.1).

3 Calculated as difference between sand volume needed to establish an equilibrium beach profile (Column-2) and the present residual sand volume (Column-4).

4 For purposes of maximizing retention time per unit beach fill, optimal sand placement volume should not exceed the minimum sand volume needed to re-establish an equilibrium beach profile (Column-2), and maximizing recreational beach widths in proportion to use, while avoiding impact to sensitive hard bottom habitat.

Optimal sand placement volumes are based on re-establishing carrying capacity, replacing sand that has been eroded from the beaches since the 2018 maintenance dredging, and maximizing recreational beach widths in proportion to use, while avoiding impact to sensitive hard bottom habitat.

Sand retention times will be maximized by using beach fill templates that approximate the elliptic cycloid beach profile, **Appendix-B**. The elliptic cycloid profile is the beach shape that can be sustained in an equilibrium state during the most severe wave events. Elliptic cycloid beach-fill templates for 13 of the 15 surveyed transects are developed in **Appendix-C** using the methodology detailed in **Appendix-B**. Two of the 15 were newly surveyed transects in May 2020 with no previous profile to estimate sand loss. The optimal sand placement volumes derived from these elliptic cycloidal beach fill templates are summarized in **Table-7**; and the increases in mean beach widths derived from these beach fill templates are listed in **Table-8**. North Beach is the most heavily recreated of the 3 receiver beaches due to ease of access from the Tamarack parking lot. Access to Middle and South Beach is limited by available parking along the west shoulder of Carlsbad Blvd. Therefore, the largest volume of dredged sand (191,062.2 cy) is allocated to North Beach using the elliptic cycloid beach fill templates (see **Table 7**) which will increase mean beach widths from between 150 – 185 ft. to 235 – 320 ft, (se **Table-8**). Lesser amounts are allocated to Middle and South Beach, with Middle Beach receiving 41,446.8 cy and South Beach receiving 58,313.9 cy, in proportion to the residual sand volumes indicated in **Table-5**. This allocation will increase beach widths on Middle Beach from 195-254 ft. to 223-278 ft, and South Beach from between 130 – 150 ft. to 215 – 233 ft. It should be noted that the heavier allocation of dredged sand to North Beach is consistent with beach nourishment plans approved in 1999, 2002 and 2006, (see **Table-1**), and due to the ocean's southern littoral drift, sand will be naturally transported from the North, Middle and South Beaches to beaches located downcoast.

Table 7: Required Beach fill to Achieve Cycloidal Equilibrium Beach Profiles as of 13 May 2020

Receiver Beach	Profile Range Line	Distance between Range Lines	Required Fill, ft^3/ft of shoreline	Beach Fill between Range Lines to Achieve Cycloidal Equilibrium Profiles ft^3 & yds^3
South Beach	Cab I-01		+860	
		750.57		624,098.9 ft^3 = 23,114.8 yds^3
South Beach	Cab I-02		+803	
		513.50		499,378.7 ft^3 = 18,495.5 yds^3
South Beach	Cab I-03		+1,142	
		648.92		450,999.4 ft^3 = 16,703.7 yds^3
Middle Beach	Cab I-04		+248	
		667.82		325,562.3 ft^3 = 12,057.9 yds^3
Middle Beach	Cab I-05		+727	
		259.91		212,606.4 ft^3 = 7,874.3 yds^3
Middle Beach	Cab I-06	Cab I-06 to South Inlet Jetty = 639.05 ft.	+909	
		2203.14		580,896.4 ft^3 = 21,514.7 yds^3
North Beach	Cab I-07		+1,459	
		1399.51		2,116,618.9 ft^3 = 78,393.3 yds^3
North Beach	Cab I-08		+1,566	
		350.56		505,367.3 ft^3 = 18,717.3 yds^3
North Beach	Cab I-09		+1,318	
		541.45		640,427.1 ft^3 = 23,719.5 yds^3
North Beach	Cab I-10		+1,048	
		609.00		778,058.4 ft^3 = 28,816.9 yds^3
North Beach	Cab I-11		+1,507	
		728.00		1,118,208 ft^3 = 41,415.1 yds^3
North Beach	Cab I-12		+1,565	
Beach Fill Required for South Beach				**1,574,477.1 ft^3 = 58,313.9 yds^3**
Beach Fill Required for Middle Beach				**1,119,065.1 ft^3 = 41,446.8 yds^3**
Beach Fill Required South of Inlet				**2,693,542.2 ft^3 = 99,760.7 yds^3**
Beach Fill Required Cab I-07 to I-10 No. Inlet Jetty to Maple Ave				**3,262,412.7 ft^3 = 120,830 yds^3**
Beach Fill Required Cab I-10 to I-12 Maple Ave to Pine Ave				**1,896,266.4 ft^3 = 70,232.1 yds^3**
Beach Fill Required for North Beach				**5,158,679.7 ft^3 = 191,062.2 yds^3**

Total Beach Fill Required to Achieve Equilibrium				**9,141,888.4 ft^3 = 290,822.9 yds^3**

Table 8: Mean Beach Widths per 13 May Survey and After 2020/21 Maintenance Dredge/Beach Nourishment

Receiver Beach	Profile Range Line	Distance between Range Lines	Beach widths 13 May 2020, ft.	*Beach widths per Elliptic Cycloid fill templates, ft.	Increase in Mean Beach Widths, Post-Beach Nourishment, ft.
South Beach	Cab I-01		150 ft.	215 ft.	65 ft.
		750.57			
South Beach	Cab I-02		130 ft.	222 ft.	92 ft.
		513.50			
South Beach	Cab I-03		130 ft.	233 ft.	103 ft.
		648.92			
Middle Beach	Cab I-04		254 ft.	278 ft.	24 ft.
		667.82			
Middle Beach	Cab I-05		208 ft.	250 ft.	42 ft.
		259.91			
Middle Beach	Cab I-06	Cab I-06 to South Inlet Jetty = 639 ft.	195 ft.	223 ft.	28 ft.
		North Inlet Jetty to Cab I-07 = 460.0 ft			
		2203.14			
North Beach	Cab I-07		185 ft.	253 ft.	68 ft.
		1399.51			
North Beach	Cab I-08		163 ft.	235 ft.	72 ft.
		350.56			
North Beach	Cab I-09		150 ft.	235 ft.	85 ft.
		541.45			
North Beach	Cab I-10		161 ft.	252 ft.	91 ft.
		609.00			
North Beach	Cab I-11		150 ft.	254 ft.	104 ft.
		728.00			
North Beach	Cab I-012		170 ft.	320 ft.	150 ft.

*Based on water elevations at mean sea level

5. SUMMARY

Cabrillo and Poseidon plan to conduct maintenance dredging in 2020/21 to remove a flood-tide shoal in the Agua Hedionda Lagoon - Outer Basin in order maintain the tidal exchange between the lagoon and the ocean and provide seawater to support the operation of the Claude "Bud" Lewis Carlsbad Desalination Plant. Similar operations have been performed over the last six decades. Approximately 300,000 cy of sand may be removed from the lagoon – outer basin. In keeping with past operations, the dredged sand will be placed on adjacent beaches: North Beach, Middle Beach, and South Beach. Operations will be conducted between October 2020 and April 2021.

Sand placement quantities for each receiver beach was determined based on an assessment of the minimal sand required to re-establish sand carrying capacity, residual sands remaining on the receiver beaches, and maximizing recreational beach widths in proportion to use, while avoiding impact to sensitive hard bottom habitat. The proposed sand placement quantities and approximate schedule are summarized in **Table-9**.

Table-9 Beach Placement Quantities and Schedule[1]

Receiver Site	Approximate Placement Quantity	Approximate Schedule
North Beach	200,000 cy	October 2020 to December 2020
No. Inlet Jetty to Maple Ave	(125,000 cy)	
Maple Ave to Pine Ave	(75,000 cy)	
Middle Beach	42,000 cy	January 2021 to February 15, 2021
South Beach	58,000 cy	February 15, 2021 to March 2021[1]
Total	**300,000 cy**	

[1]Sand placement operations my extend beyond March 2021 if adverse weather conditions or equipment issues are encountered. No sand will be placed on beaches after April 15, 2021.

6. REFERENCES

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Jenkins, S. A., 2017b, "Beach Equilibrium Analysis of Middle and South Beach Disposal Options for Dredged Sands from Agua Hedionda Lagoon, Carlsbad, CA," submitted to Cabrillo Power I LLC, 72 pp.

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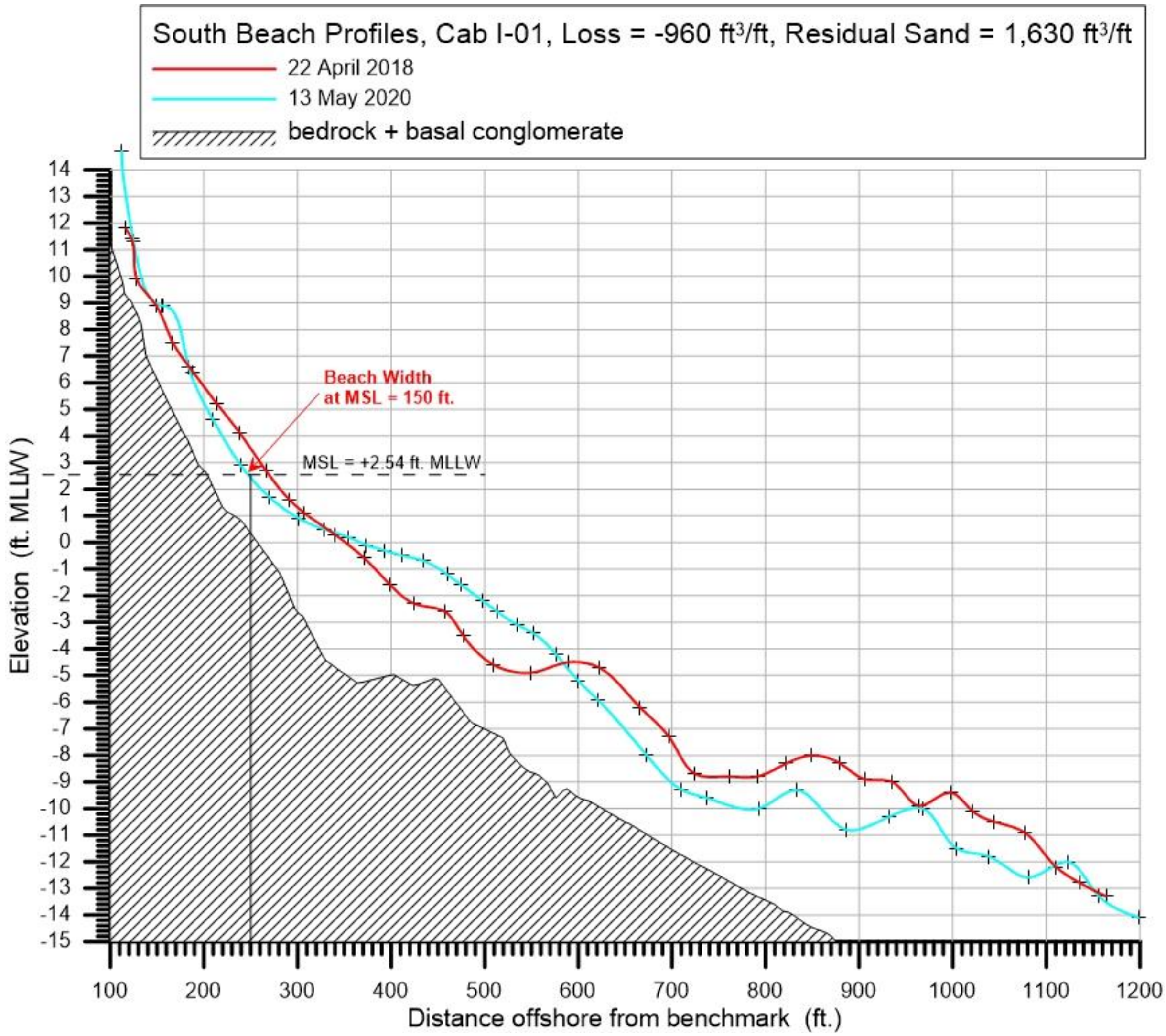
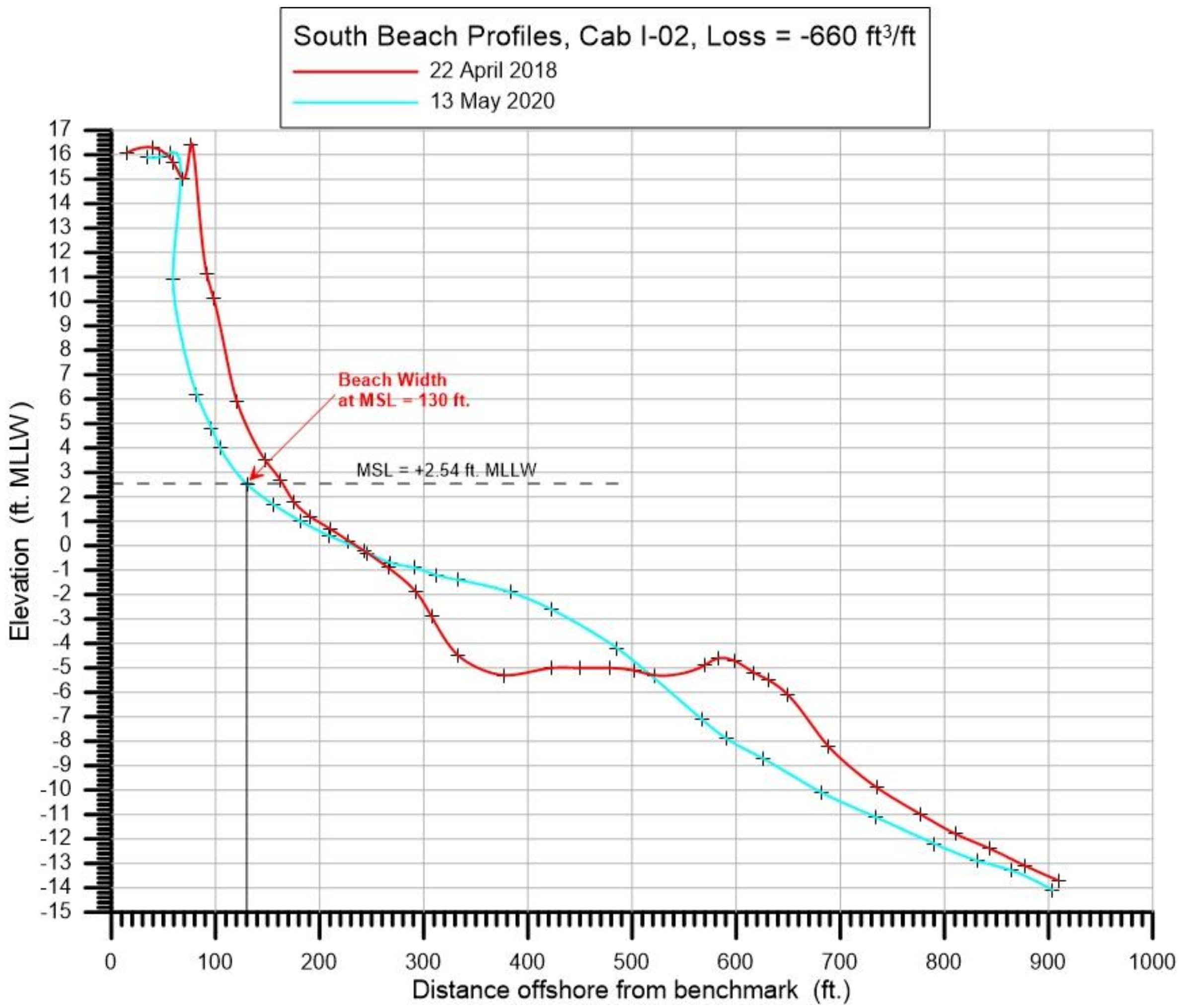
Appendix-A: Surveys at Beach Disposal Sites Following 2018 Maintenance Dredge/Beach Nourishment Cycle



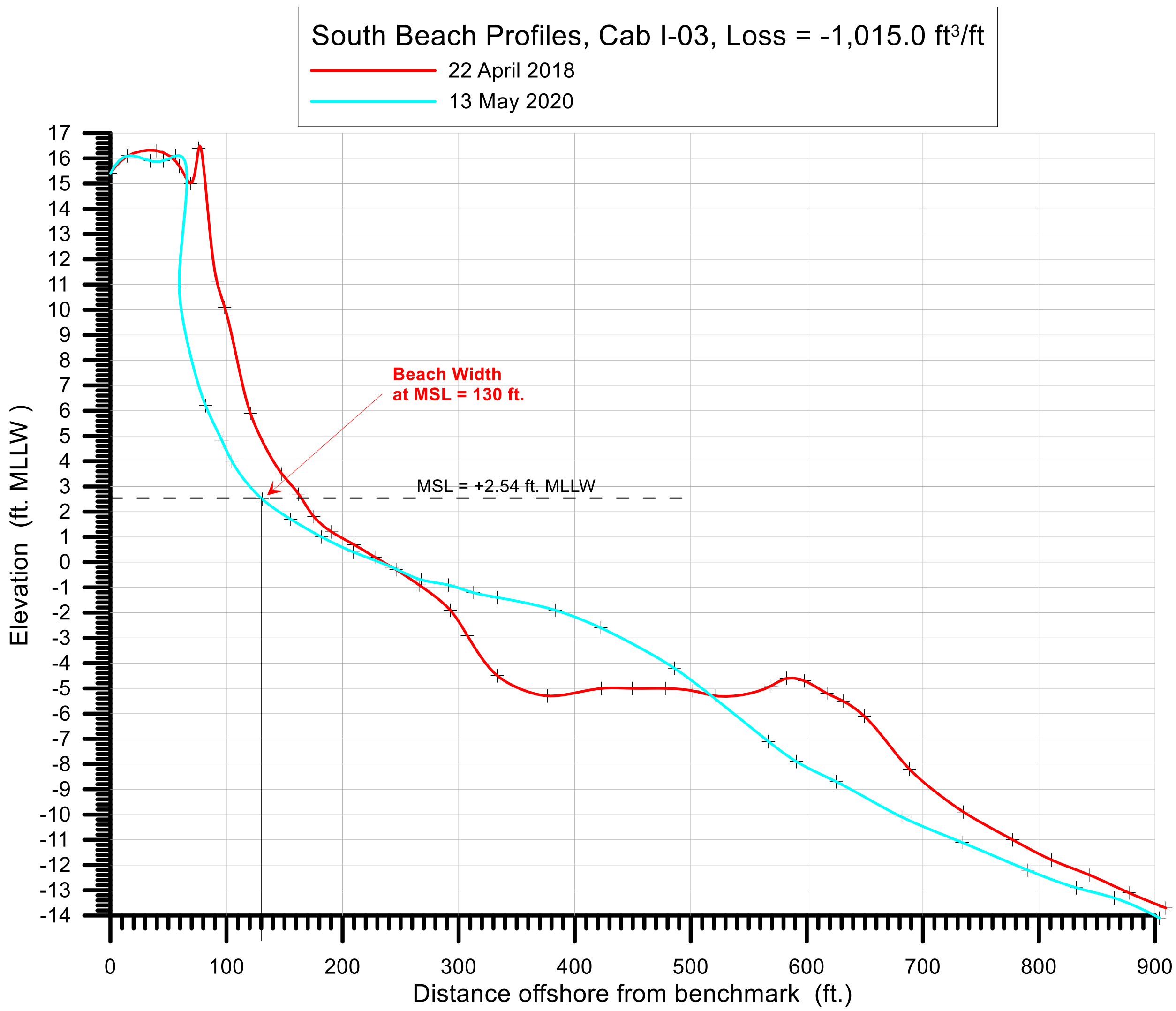
Coordinates of Benchmark:
Northing (ft): 1994408.5
Easting (ft): 6228847.4

Figure A-1: Measured beach profiles at survey range Cab I-01 on South Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment , (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020. Bed rock/basal conglomerate (hard bottom) elevation based on composite minimum of SANDAG surveys 1997 -2012, (S97-S12) at transect CB-0800



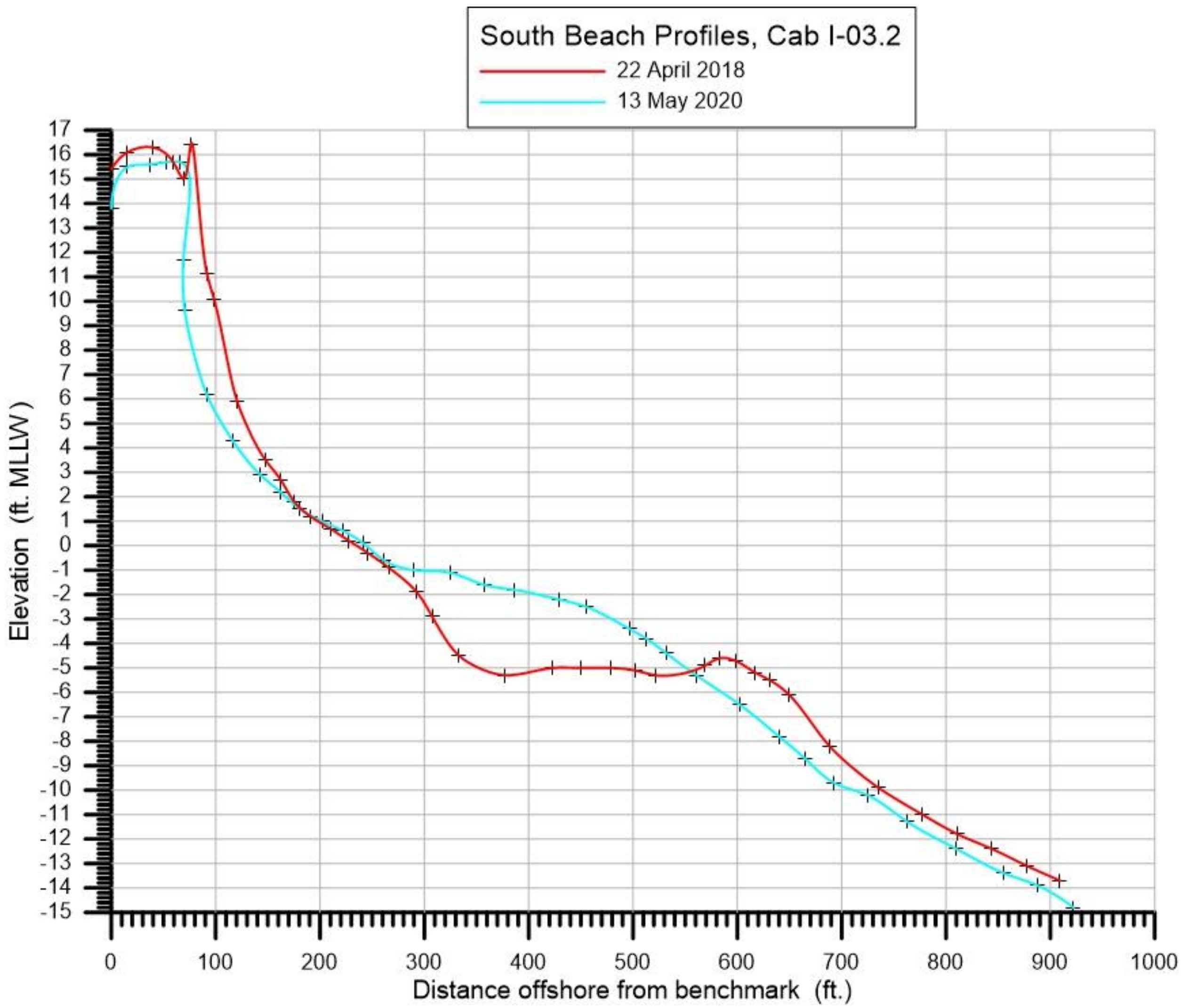
Coordinates of Benchmark:
Northing (ft): 1995102.9
Easting (ft): 6228562.5

Figure A-2: Measured beach profiles at survey range Cab I-02 on South Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020.



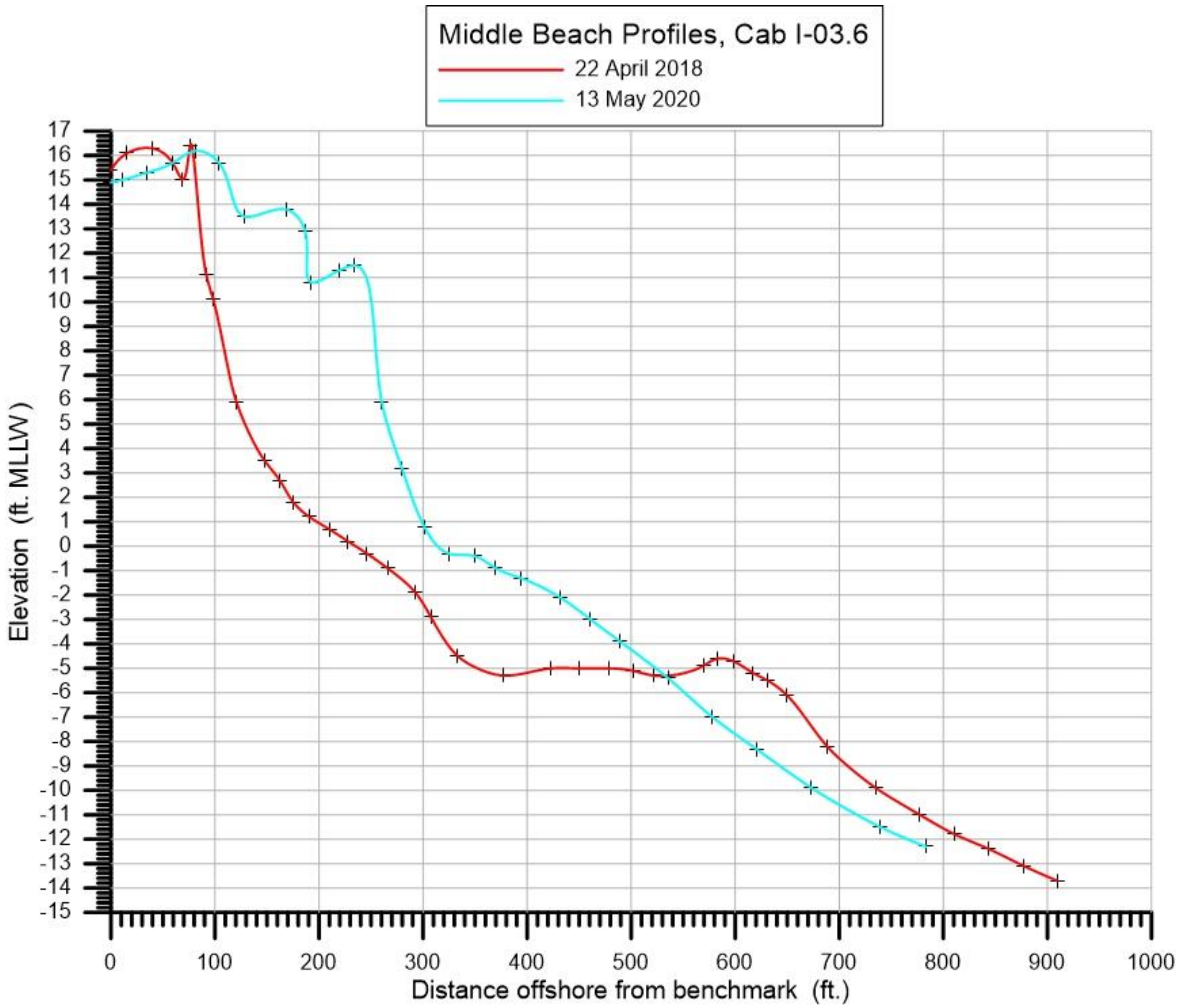
Coordinates of Benchmark:
Northing (ft): 1995576.9
Easting (ft): 6228365

Figure A-3: Measured beach profiles at survey range Cab I-03 on South Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020.



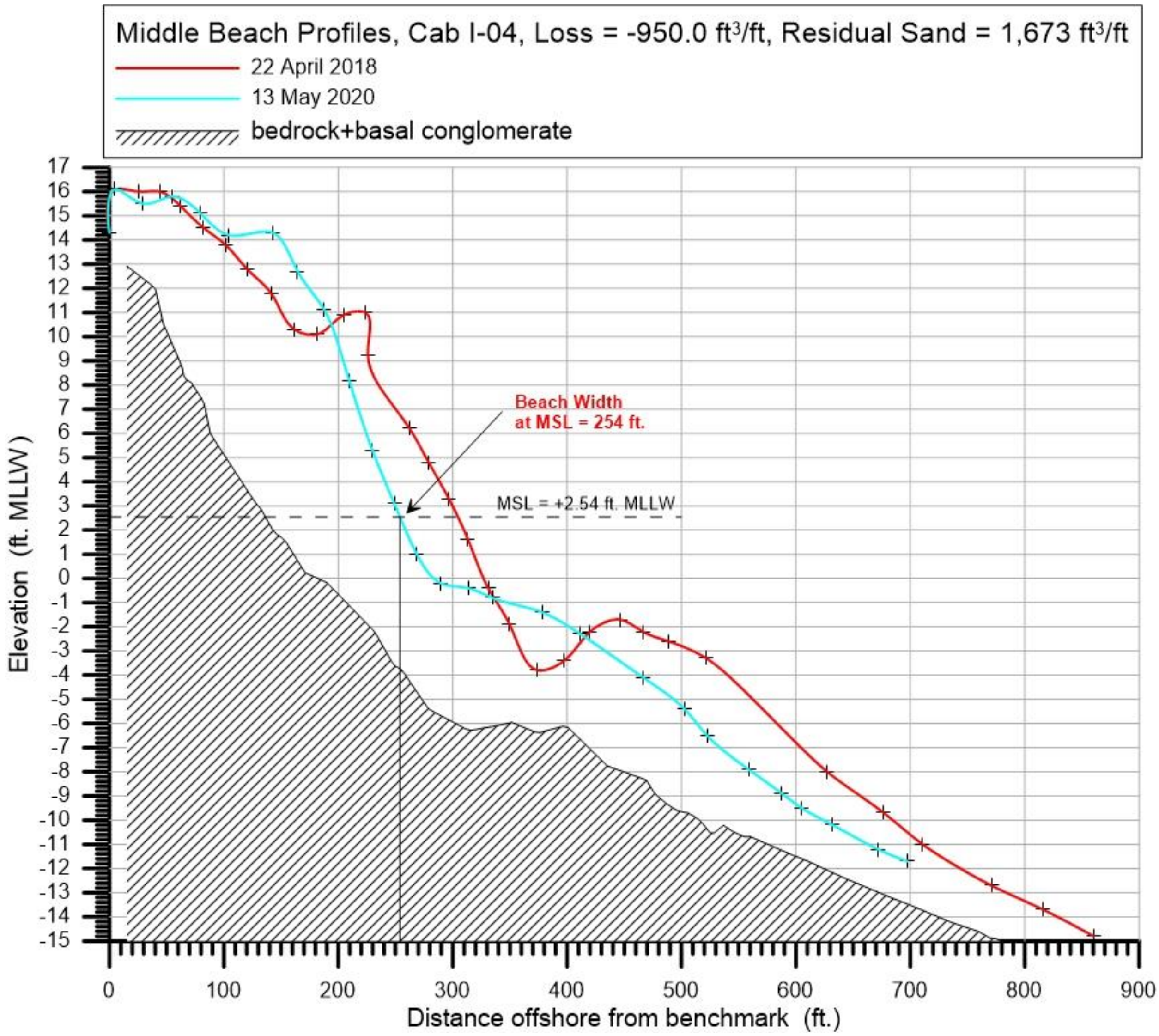
Coordinates of Benchmark:
Northing (ft): 1995677.7
Easting (ft): 6228319.9

Figure A-4 Measured beach profiles at survey range Cab I-03.2 on South Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020.



Coordinates of Benchmark:
Northing (ft): 1995925.1
Easting (ft): 6228209.1

Figure A-5: Measured beach profiles at survey range Cab I-03.6 on Middle Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020.



Coordinates of Benchmark:
Northing (ft): 1996164.9
Easting (ft): 6228090.5

Figure A-6: Measured beach profiles at survey range Cab I-04 on Middle Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020. Bed rock/basal conglomerate (hard bottom) elevation based on composite minimum of SANDAG surveys 1997 -2012, (S97-S12) at transect CB-0810

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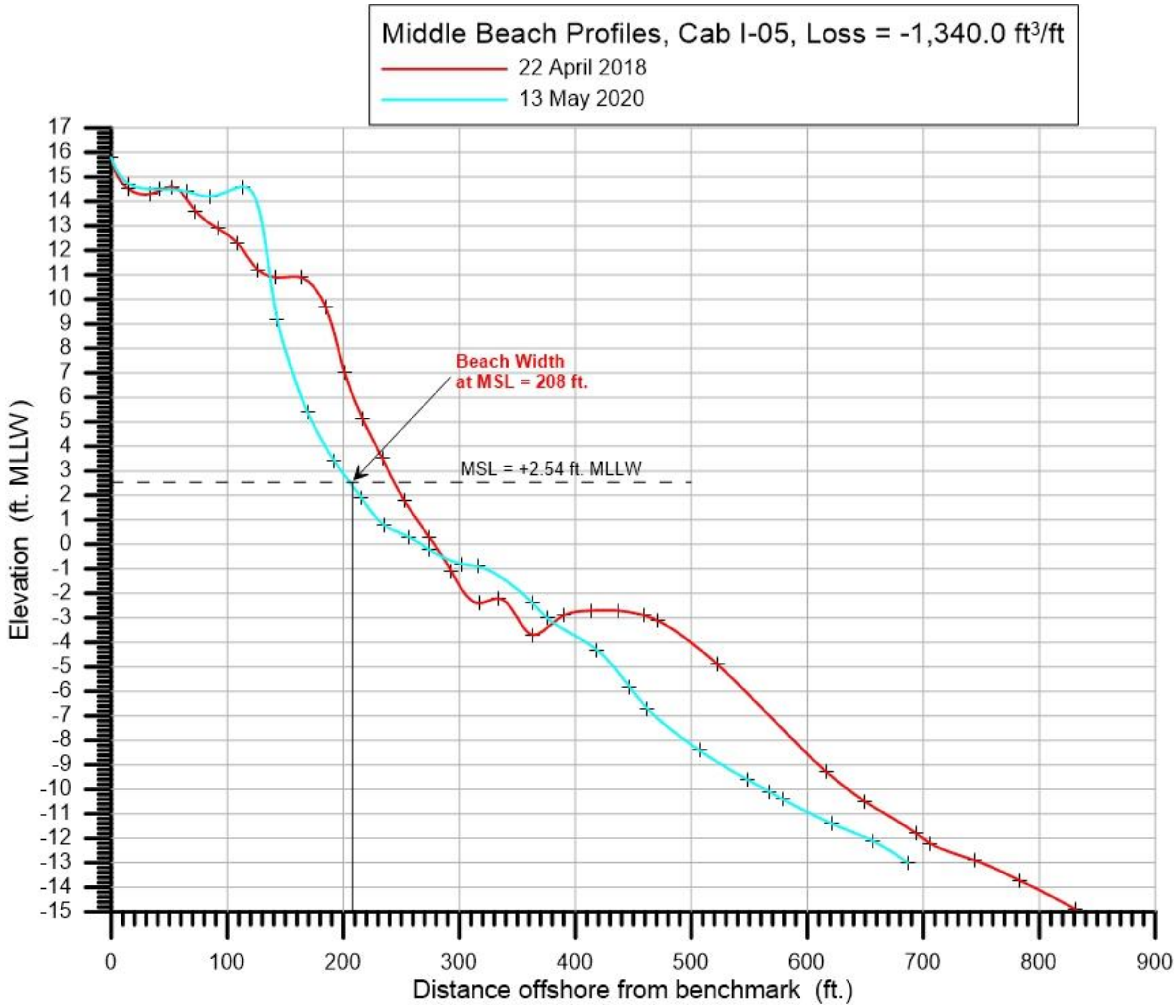
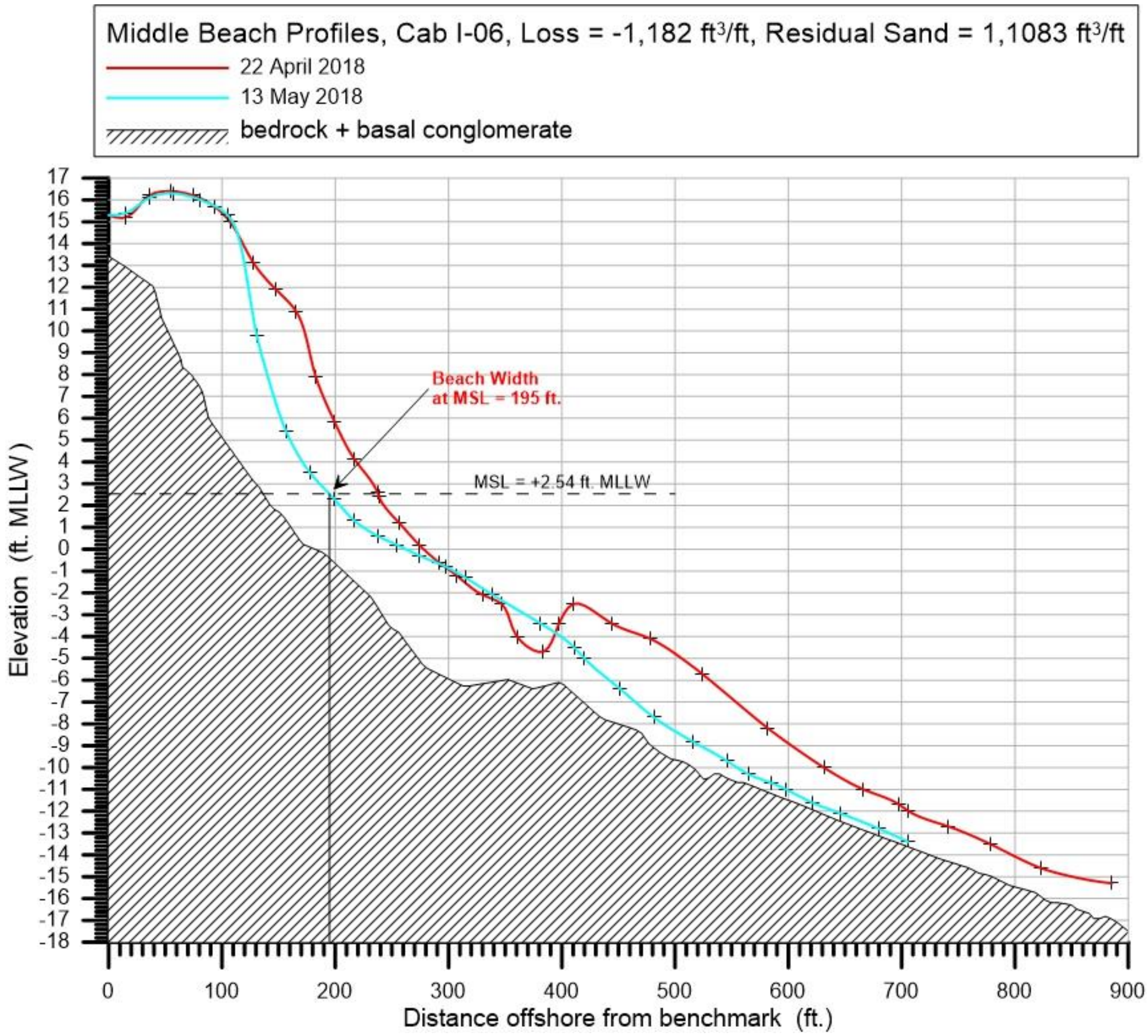


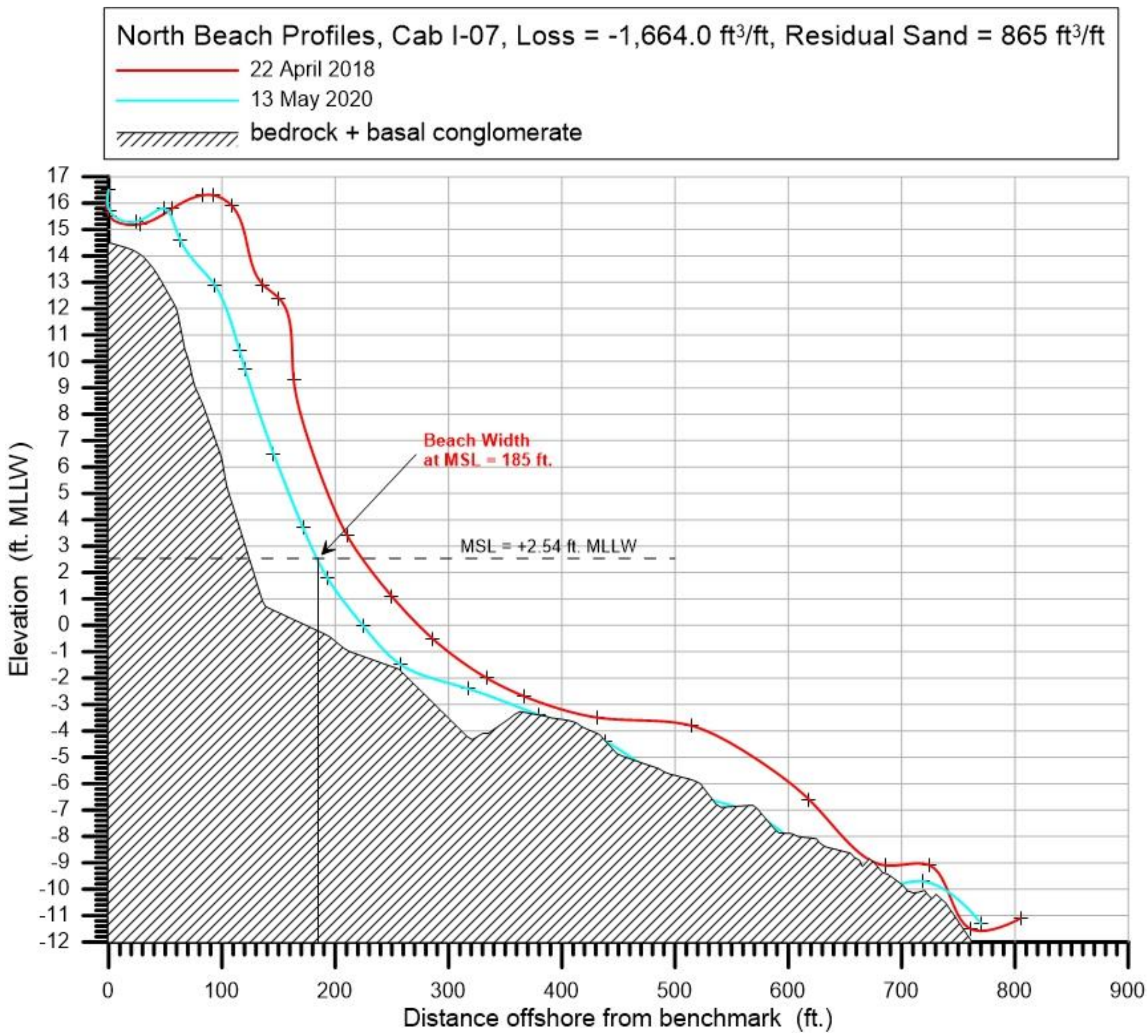
Coordinates of Benchmark:
Northing (ft): 1996778.5
Easting (ft): 6227826.9

Figure A-7: Measured beach profiles at survey range Cab I-05 on Middle Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020.



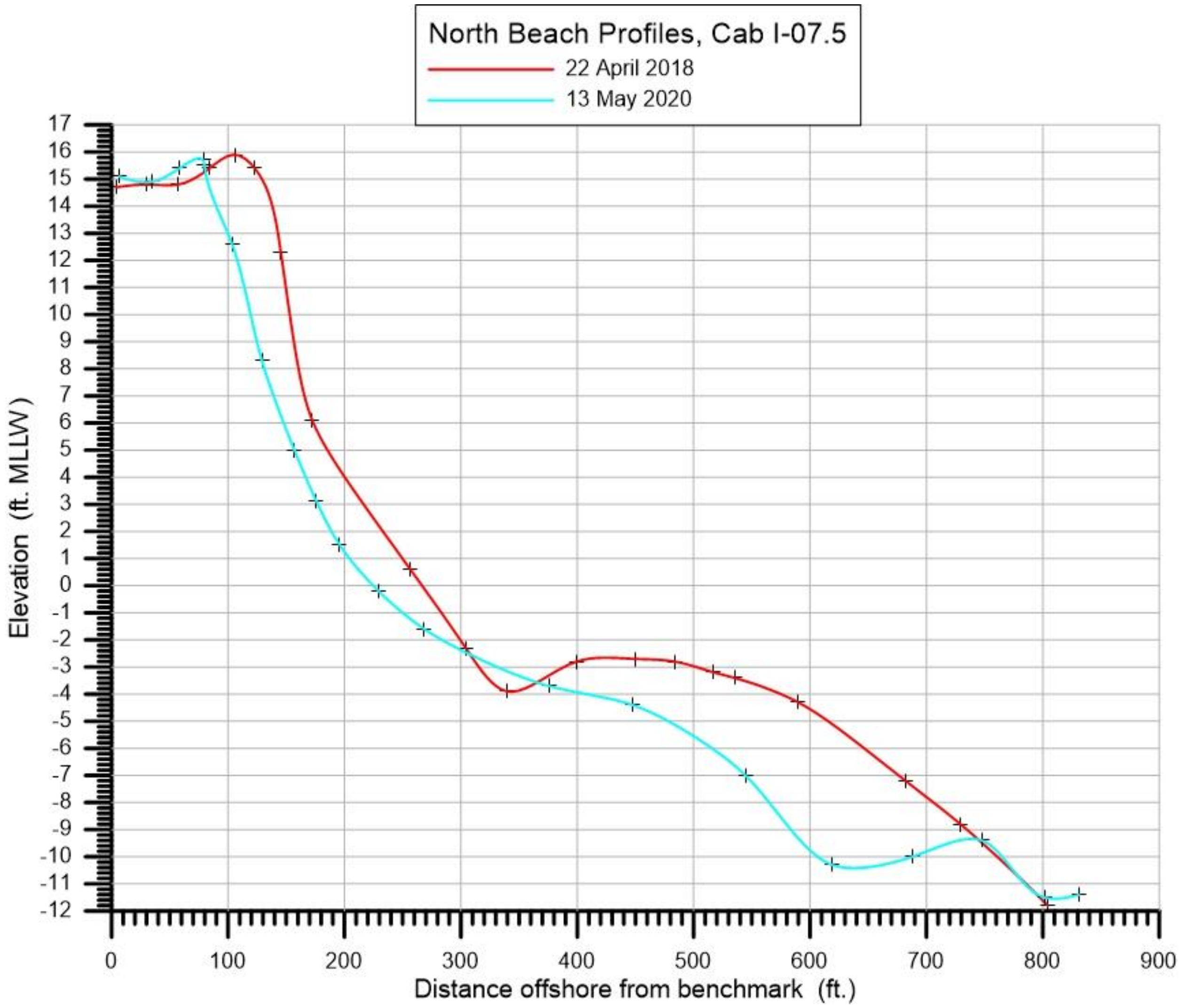
Coordinates of Benchmark:
Northing (ft): 1997015.5
Easting (ft): 6227720.2

Figure A-8: Measured beach profiles at survey range Cab I-06 on Middle Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020. Bed rock/basal conglomerate (hard bottom) elevation based on composite minimum of SANDAG surveys 1997 -2012, (S97-S12) at transect CB-0820



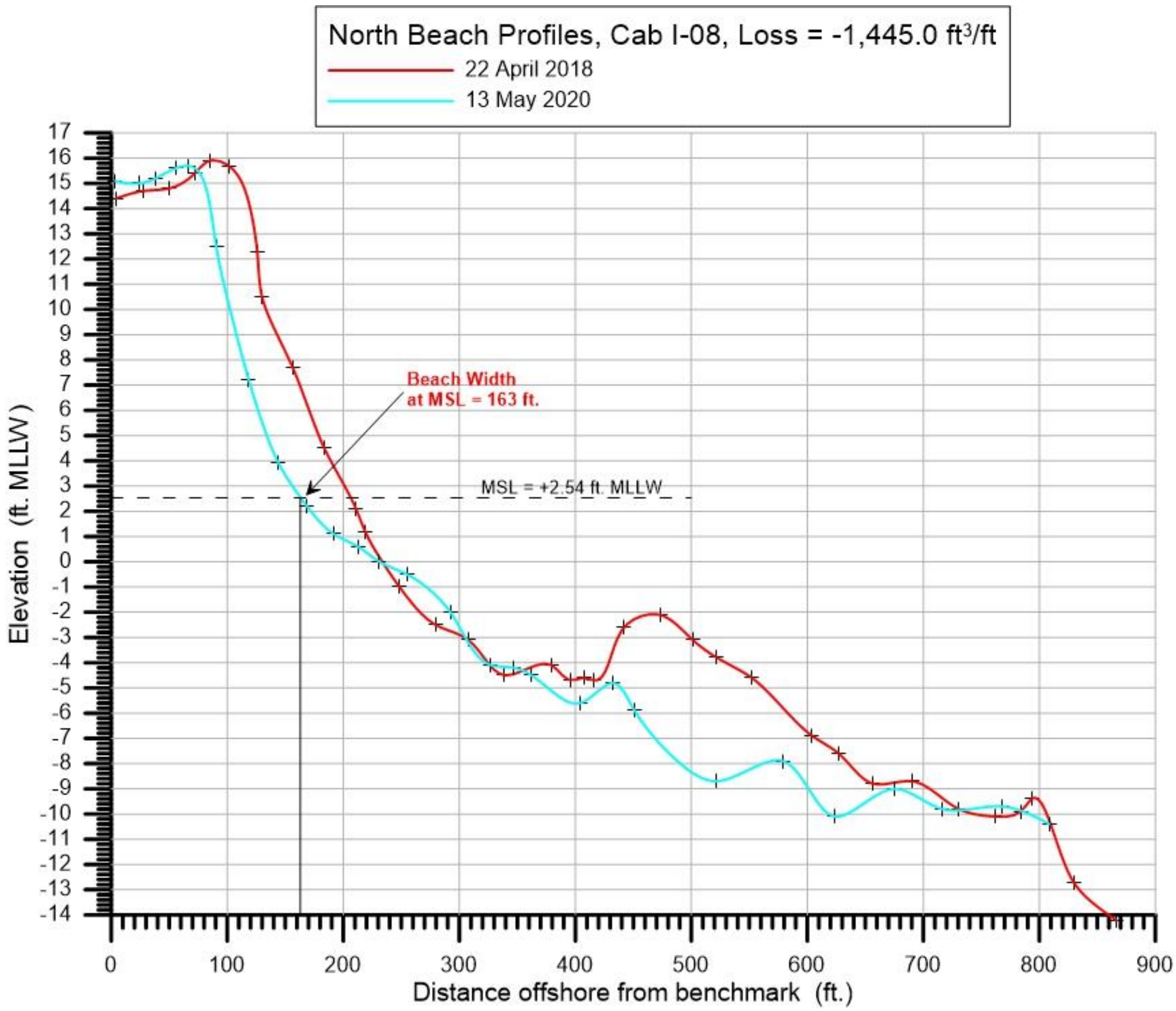
Coordinates of Benchmark:
Northing (ft): 1998772.8
Easting (ft): 6226391.4

Figure A-9: Measured beach profiles at survey range Cab I-07 on North Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020. Bed rock/basal conglomerate (hard bottom) elevation based on composite minimum of SANDAG surveys 1997 -2012, (S97-S12) at transect CB-0830



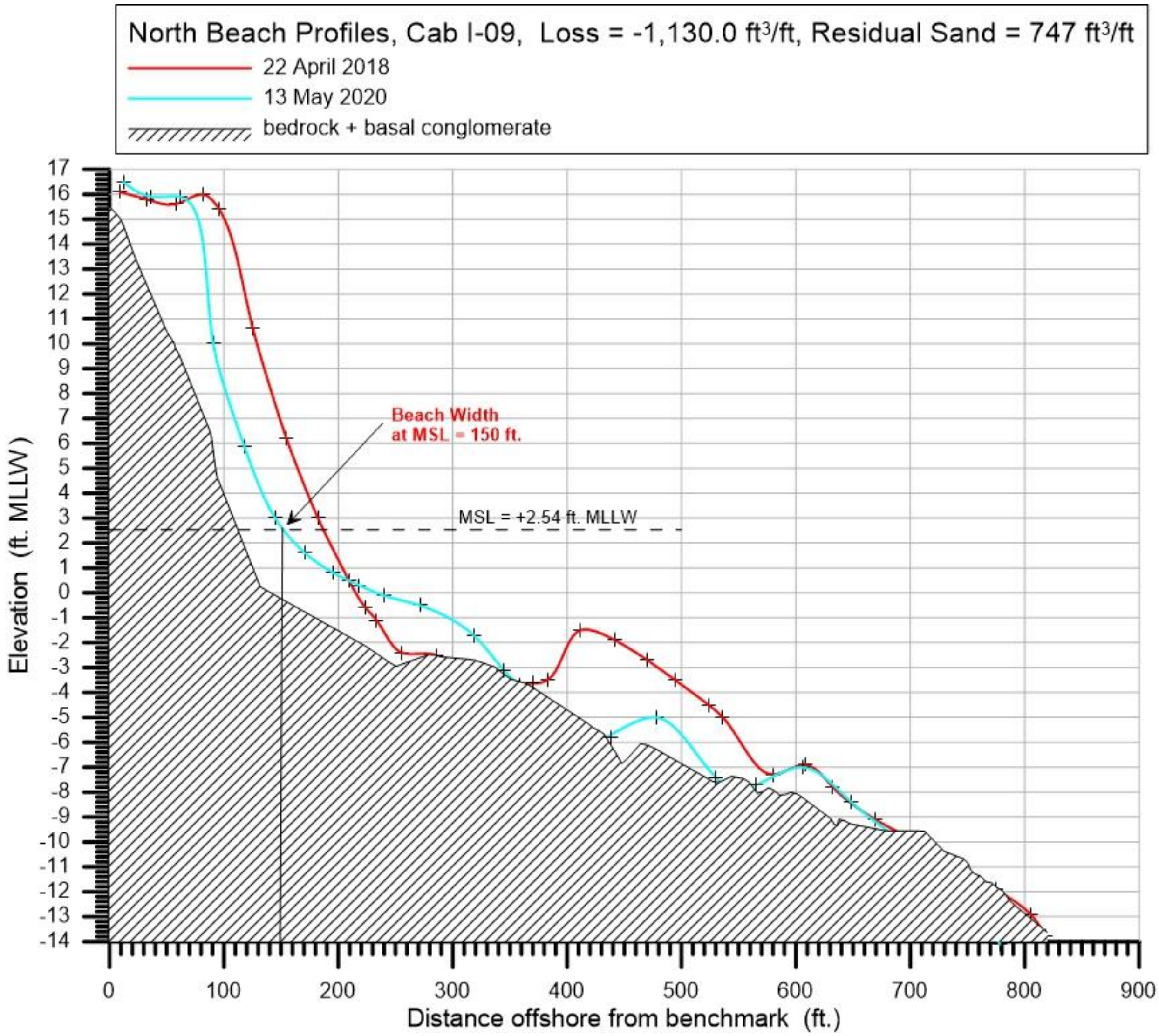
Coordinates of Benchmark:
Northing (ft): 1999373.5
Easting (ft): 6226032.4

Figure A-10: Measured beach profiles at survey range Cab I-07.5 on North Beach, after the most recent Agua Hedionda Lagoon - Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020.



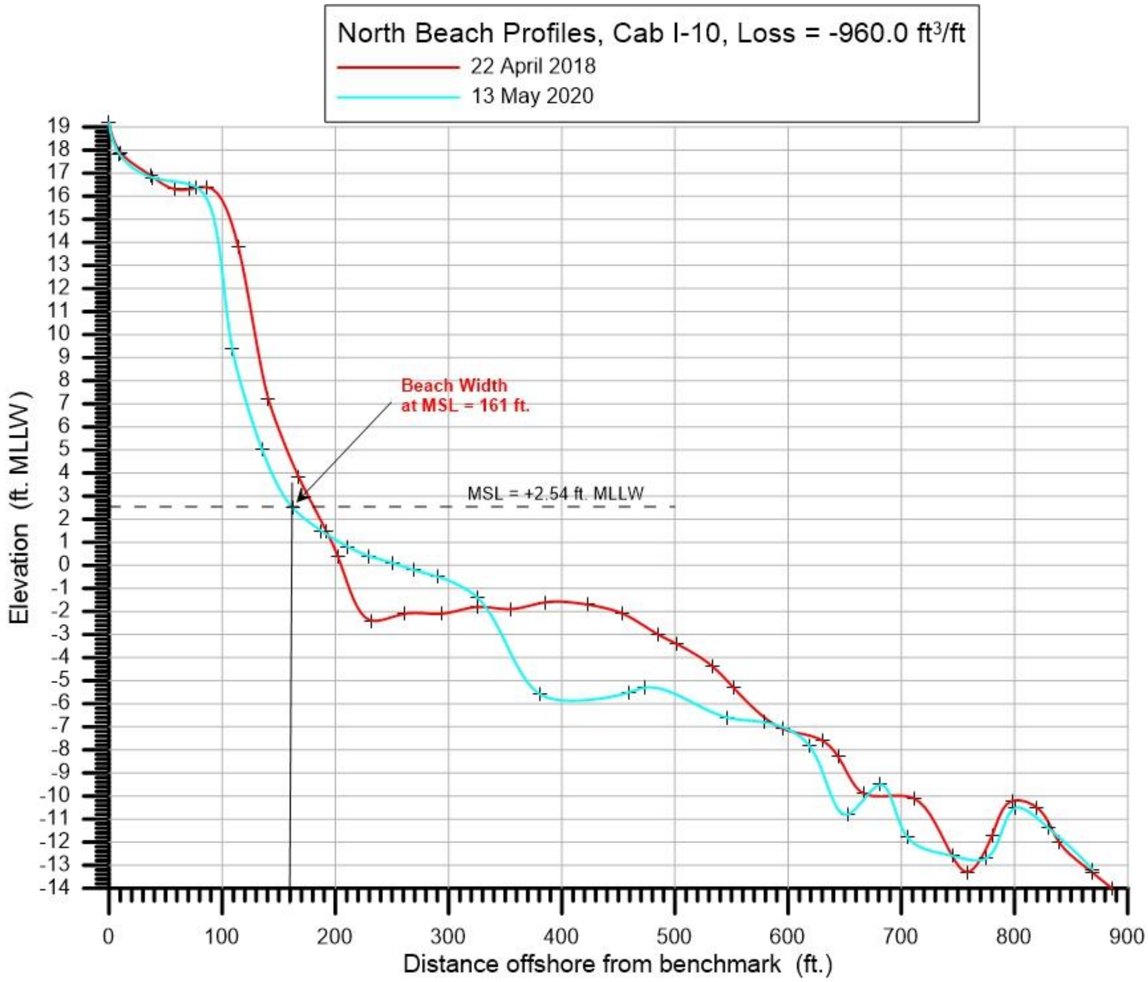
Coordinates of Benchmark:
Northing (ft): 1999973.2
Easting (ft): 6225671.9

Figure A-11: Measured beach profiles at survey range Cab I-08 on North Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020.



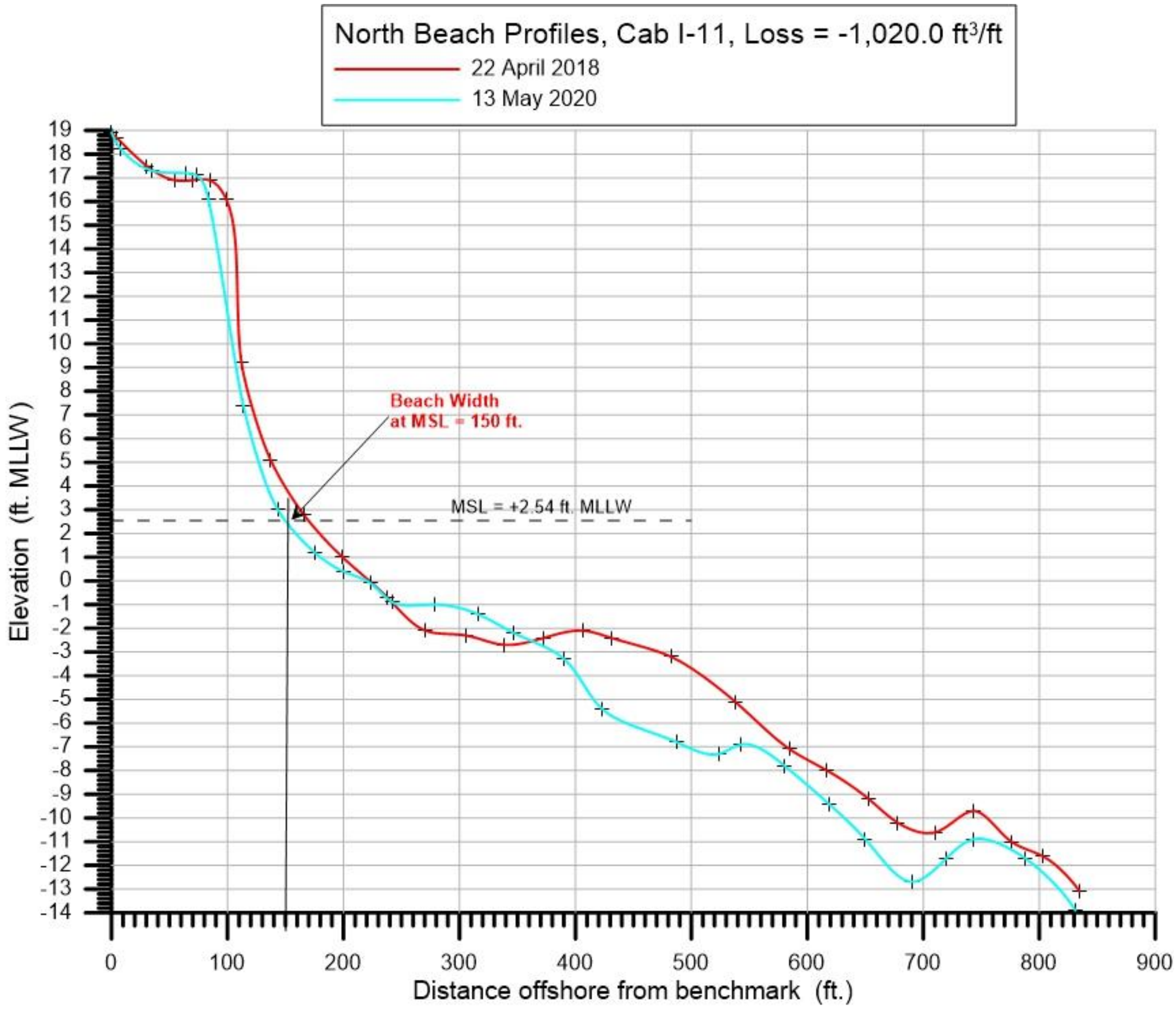
Coordinates of Benchmark:
Northing (ft): 2000268.7
Easting (ft): 6225483.3

Figure A-12: Measured beach profiles at survey range Cab I-09 on North Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020. Bed rock/basal conglomerate (hard bottom) elevation based on composite minimum of SANDAG surveys 1997 -2012, (S97-S12) at transect CB-0840



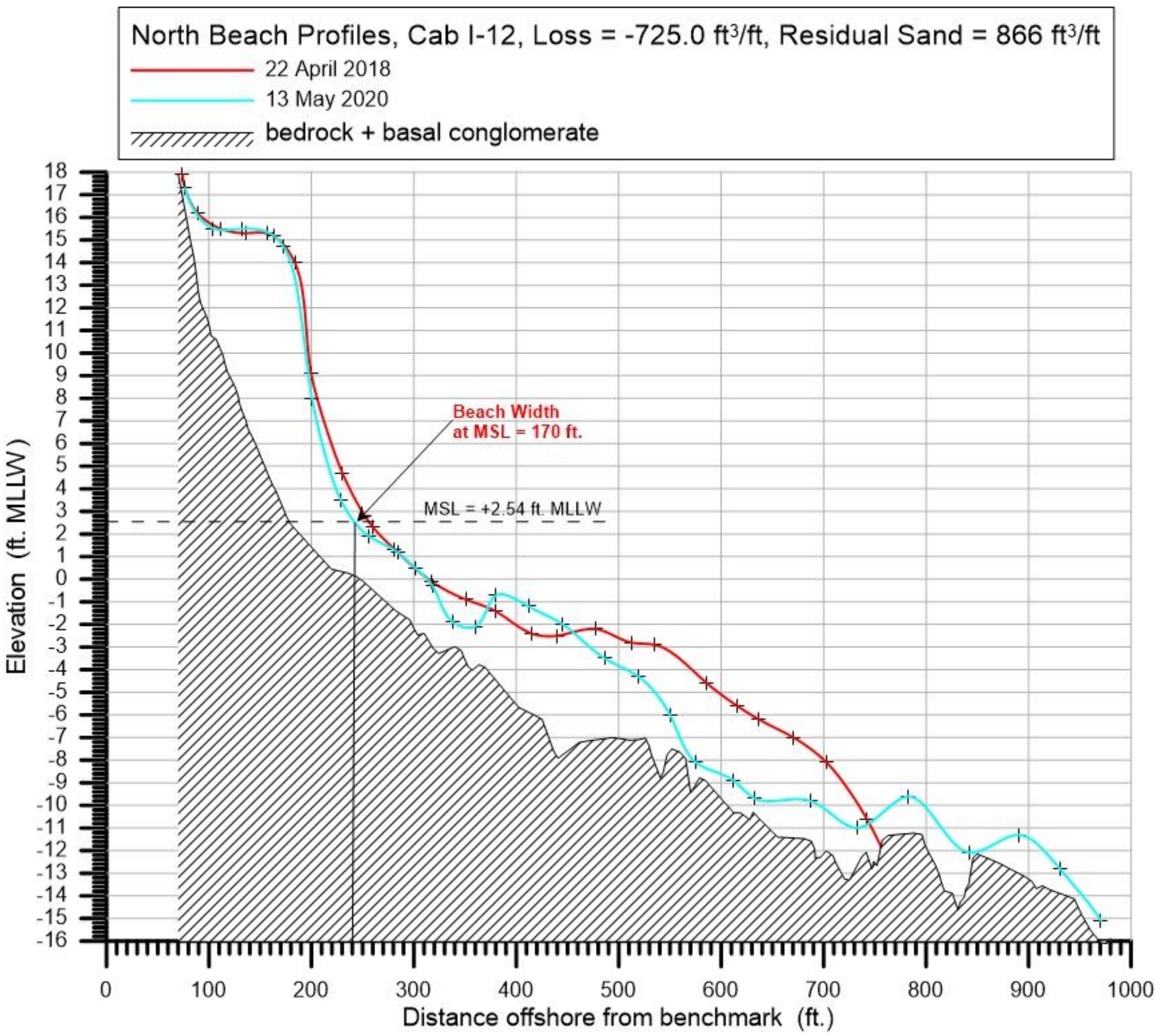
Coordinates of Benchmark:
Northing (ft): 2000741.1
Easting (ft): 6225218.1

Figure A-13: Measured beach profiles at survey range Cab I-10 on North Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020.



Coordinates of Benchmark:
Northing (ft): 2001257.9
Easting (ft): 6224917.9

Figure A-14: Measured beach profiles at survey range Cab I-11 on North Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020.



Coordinates of Benchmark:
Northing (ft): 2001823.9
Easting (ft): 6224695.8

Figure A-15: Measured beach profiles at survey range Cab I-12 on North Beach, after the most recent Agua Hedionda Lagoon – Outer Basin maintenance dredge/beach nourishment, (red line) on 22 April 2018; and prior to the 2020/2021 maintenance dredge/beach nourishment (blue line) on 13 May 2020. Bed rock/basal conglomerate (hard bottom) elevation based on composite minimum of SANDAG surveys 1997 -2012, (S97-S12) at transect CB-0850

Appendix-B: Elliptic Cycloid Equilibrium Profiles and Critical Mass

The critical mass is the minimum volume of sediment cover required to maintain equilibrium beach profiles and represents the nominal carrying capacity of a particular beach. When a long-term collection of beach profiles are plotted together over a broad range of wave heights, a well-defined envelope of variability becomes apparent, (Figure 11a). This envelope of profile variability is referred to as the *critical mass envelope*, and the volume of sand within critical mass envelope, V_c , increases with increasing wave height and period but decreases with increasing beach grain size, as shown in Figure B-1b. The critical mass envelope is always limited by the breadth of the wave cut platform which forms a hard-bottom boundary condition on the critical mass envelope. The best way to calculate the critical mass is to find the volume between the wave cut platform (or its layer of basal conglomerate) and the elliptic cycloid equilibrium profile that corresponds to the native beach grain size in combination with the wave height and period of the extreme event wave in the period of record. The volume integral between the surfaces of the wave cut platform and the extremal event elliptic cycloid then gives the critical mass volume.

The extremal elliptic cycloid equilibrium profile is a curve that is traced by a point on the circumference of a rolling ellipse, see Figure 12b. It is calculated from Jenkins and Inman (2006) using the following:

$$h = \frac{\pi\varepsilon\ x}{2I_e^{(2)}}\left(\frac{1-\cos\theta}{\theta-\sin\theta}\right)+Z_1 \qquad (1)$$

Note this has the same basic formulation of the original Dean (1977 and 1991) solutions in the U.S. Army Corps of Engineers *Coastal Engineering Manual* Here Z_1 is the elevation of the berm crest (see Figure 12a) given by Hunt's Formula [*Hunt*, 1959; *Guza and Thornton*, 1985; *Raubenheimer and Guza*, 1996]:

$$Z_1 = -\Gamma H_b \qquad (2)$$

In equation (2), Γ is the runup factor taken herein as $\Gamma = 0.76$, and H_b is the breaking wave height. The cycloid in (1) is based on the elliptic integral of the second kind that has an analytic approximation, $I_e^{(2)} = \sqrt{(2-e^2)/2}$, where *e* is the eccentricity of the ellipse given by $e = \sqrt{1-b^2/a^2}$, with, semi-major and semi-minor axes are *a*, *b,* (see Figure 12b). The wave parameter, ε , in equation (1) is given by:

$$\varepsilon = \sigma\left(\frac{H_b}{\gamma\, g}\right)^{1/2} \cong \frac{\sigma^{4/5}}{2^{1/5}}\left(\frac{H_\infty}{g\gamma}\right)^{2/5} \qquad (3)$$

here $\sigma = 2\pi$/period is radian frequency, H_∞ is incident wave height, g is the acceleration of gravity, and γ is the wave breaking criteria taken as γ = 0.8. The rolling angle of the ellipse is:

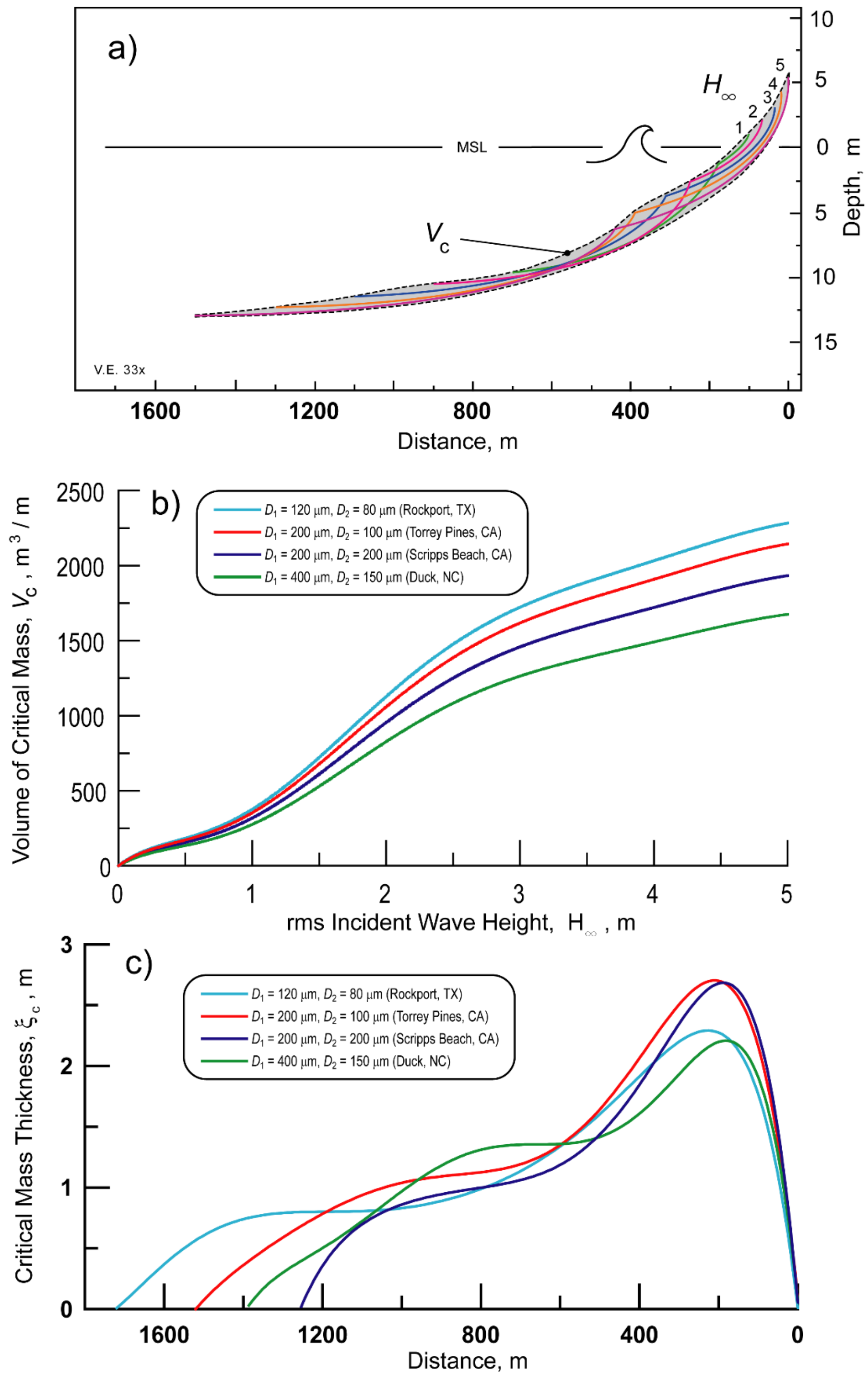


Figure B-1: Features of the critical mass of sand: a) critical mass envelope for waves ranging from 1m to 5m in height; b) volume of critical mass as a function of wave height and sediment grain size; c) variation in the thickness of the critical mass as a function of distance offshore.

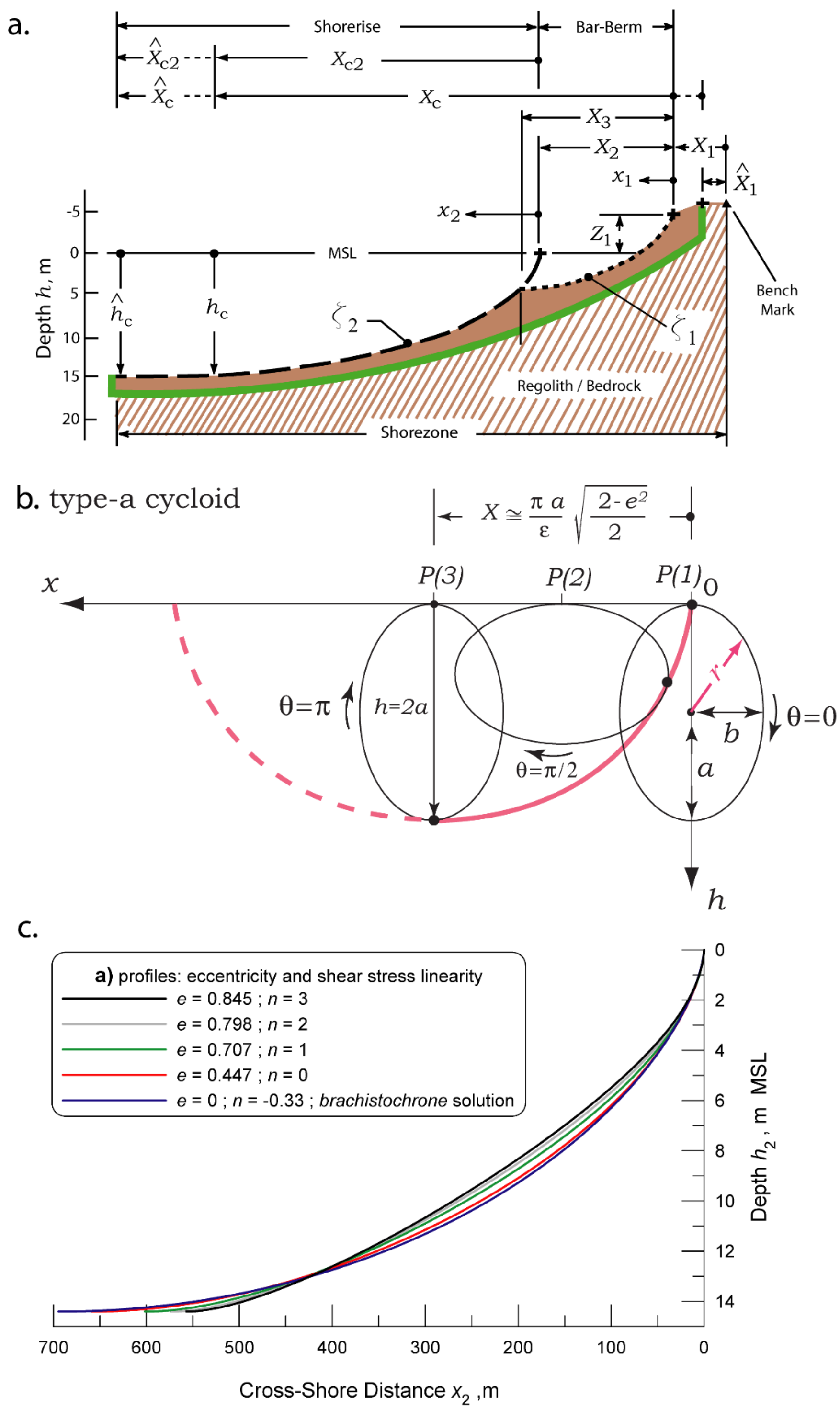


Figure B-2. Equilibrium beach profile theory: a) nomenclature, b) mathematical basis for an elliptic cycloid, c) Typical range of elliptic cycloids on a 700 m wide wave-cut platform.

$$\theta = \arccos\left[1 - 2\left(\frac{H_\infty}{\Lambda \gamma \, h_c}\right)^\alpha\right] \tag{4}$$

where Λ is the shoaling factor relating breaker height to incident wave height, $\Lambda = H_\infty / H_b$, which for shoaling Airy waves, becomes $\Lambda = 2^{2/5} H_\infty^{1/5} \left(\sigma^2 / g\gamma\right)^{1/5}$. The closure depth, h_c in equation (4) is grain size and wave period dependent and is given by:

$$h_c = \frac{K_e H_\infty}{\sinh k h_c}\left(\frac{D_0}{D_{50}}\right)^\psi \tag{5}$$

where $k = \sigma / \sqrt{g h_c}$ is the shallow water form of the wave number, K_e and ψ ~ 2.0 are non-dimensional empirical parameters, set at K_e = 2.0 and ψ ~ 0.33; D_{50} is the median grain size; and D_0 is a reference grain size taken as D_0 = 100 μ m. Equation (5) is transcendental and is solved numerically within the CEM.

Calculation of the extremal elliptic cycloid equilibrium profiles at North, Middle and South Beach requires knowledge of the characteristic median grain size, D_{50}, of the dredged sediments to be placed there. Recent sediment grain size analyses by Merkel, (2008) based on three sampling locations on the flood tide bar in the West Basin of Agua Hedionda Lagoon (Samples L1 – L3) were compared against native sediments on the three receiver beaches (RB1-RB3). These grain size distributions are plotted in Figure B-3. Note Middle and South Beach is represented by samples RB1. Grain sizes at the lagoon sample sites and beach sites were similar with median grain sizes of 0.32 millimeters (320 microns) on the food tide bar in the West Basin of Agua Hedionda, while residual sediments that still remained on Middle and South Beach prior to disposal of material from the 2008/09 dredging averaged 0.374 millimeters (374 microns).

To determine the highest waves to reach to effect North, Middle and South Beach disposal sites, the waves measured at ½ hour sampling intervals at CDIP Station 043 were back refracted into deep water from the monitoring location off Camp Pendleton, and then forward refracted into North, Middle and South Beach. An example of this procedure is shown in Figure B-4 for a wave occurring 8 January 2002. This effort produced a continuous wave record throughout the historic period when North, Middle and South Beach disposal of Agua Hedionda dredged sands was practiced, (1998-2015). The highest energy wave (extremal) event occurred in January 2007, when a Gulf of Alaska storm brought 4.8 m high waves approaching Carlsbad at 276 ^{0} with a 15 second periods, (Figure B-5). This extreme event wave was used to calculate the extremal elliptic cycloids and critical mass on North, Middle and South Beach.

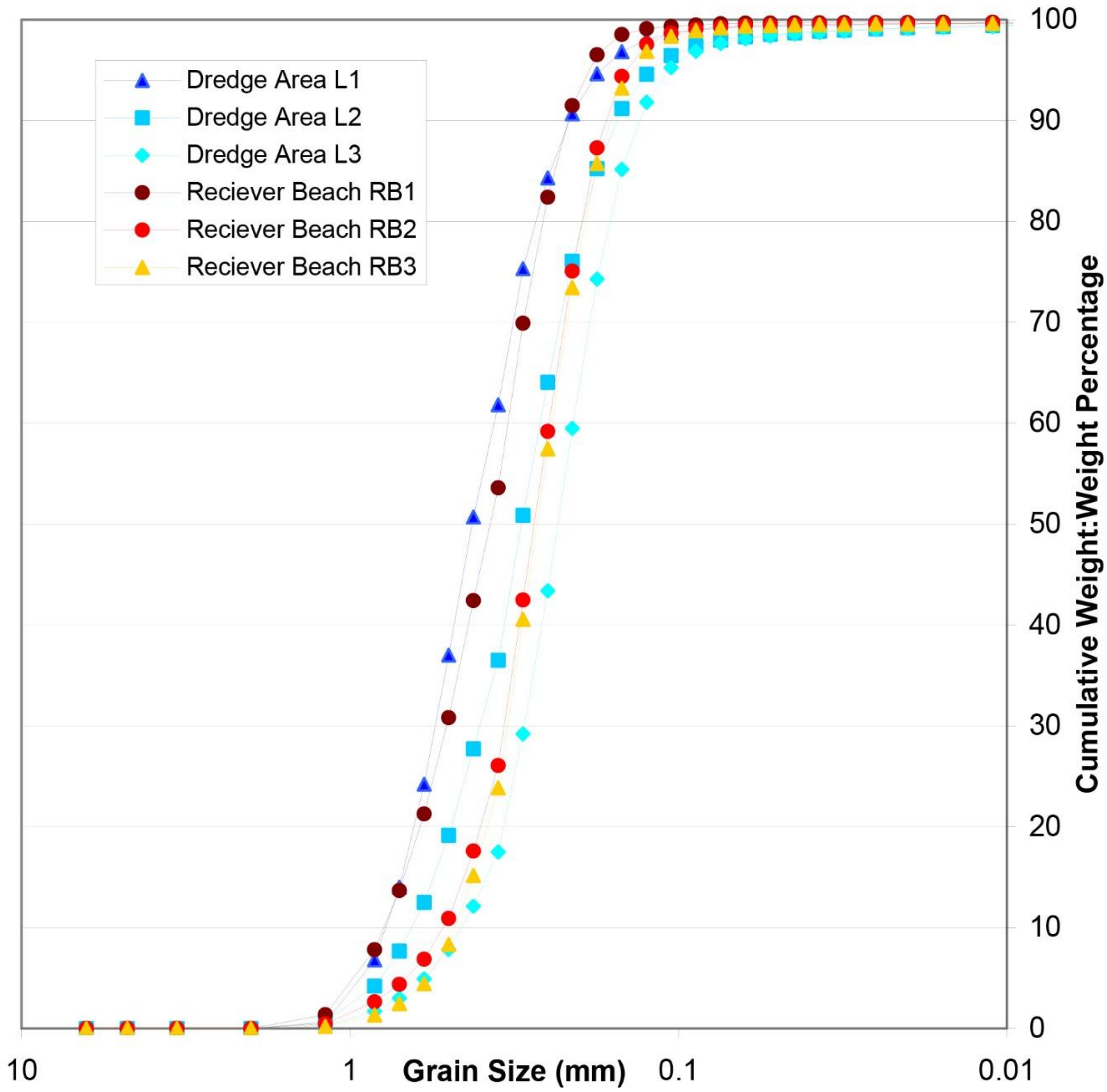


Figure B-3: Grain size distributions form Agua Hedionda Lagoon (Samples L1 – L3) and from the receiver beaches (RB1-RB3). Note Middle and South Beach is represented by samples RB1, (from Merkel, 2008).

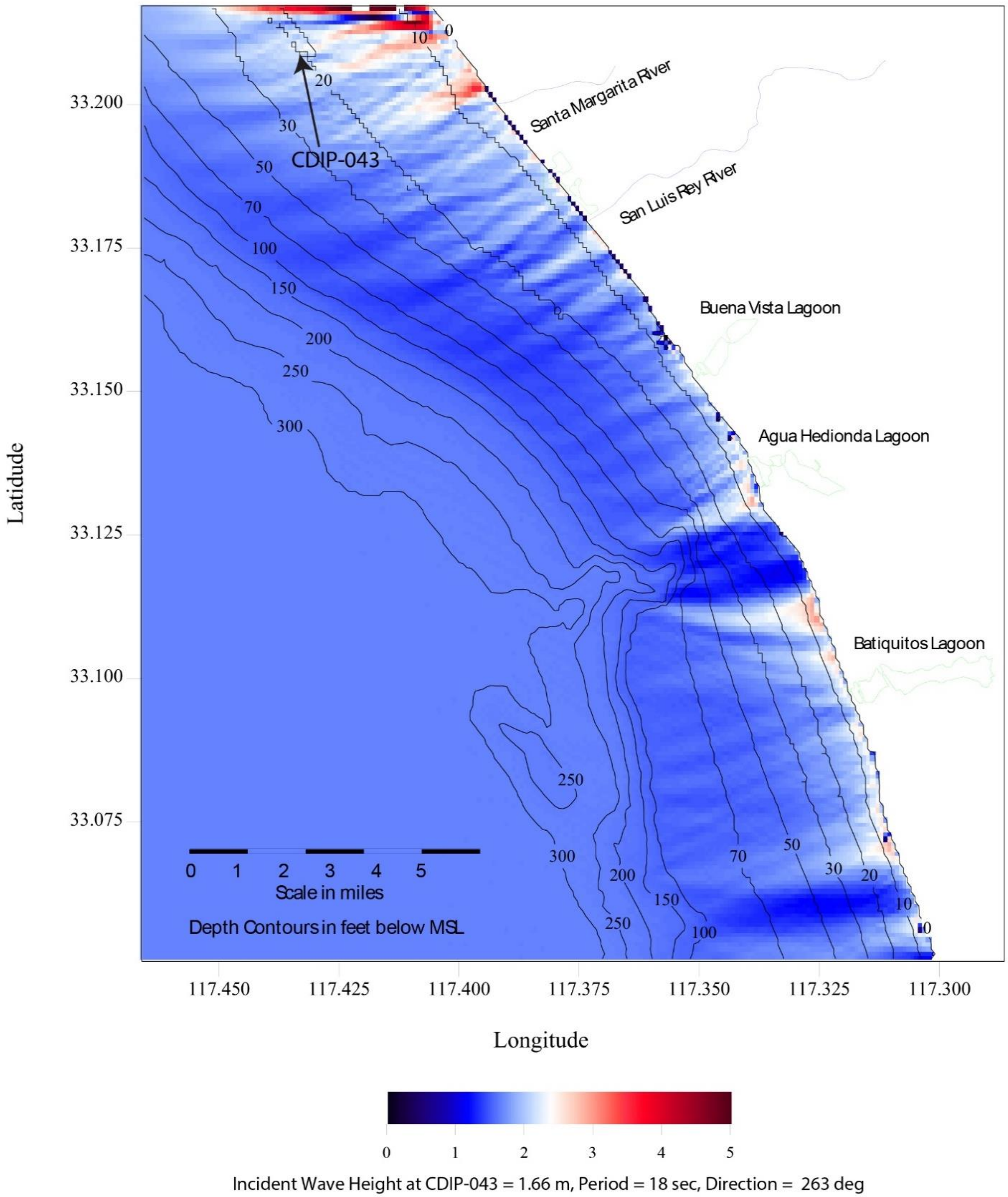
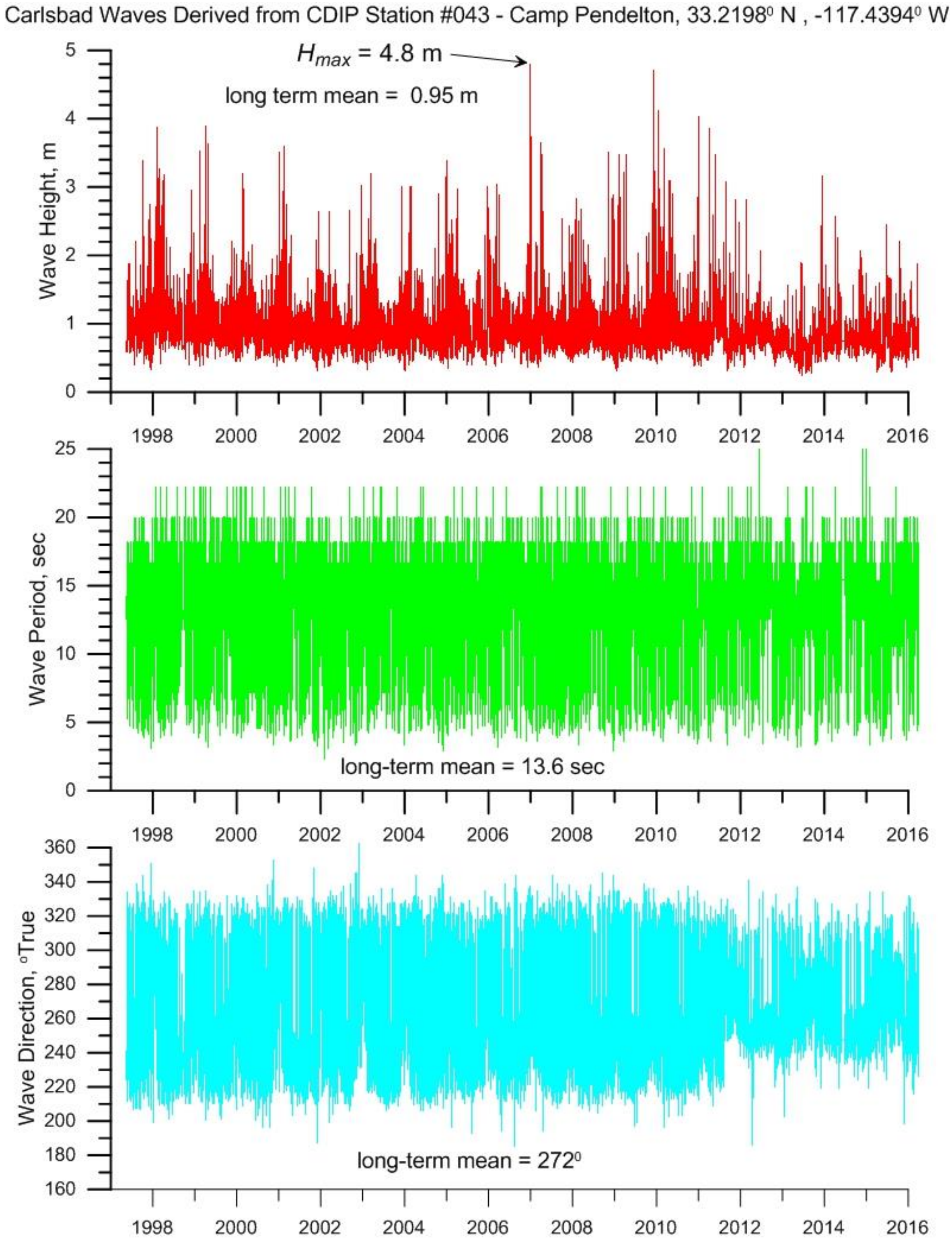


Figure B-4: Regional wave shoaling during 8 January 2002 from back-refraction of wave monitoring data at CDIP Station # 043 in 20 m local water depth offshore of Camp Pendleton.


Carlsbad Waves Derived from CDIP Station #043 - Camp Pendelton, 33.2198° N , -117.4394° W
H_max = 4.8 m
long term mean = 0.95 m
Wave Height, m
long-term mean = 13.6 sec
Wave Period, sec
long-term mean = 272°
Wave Direction, °True
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

Appendix B

Figure B-5: Shoaled significant wave heights, periods and directions at Carlsbad State Beach based on back refraction of wave monitoring data from CDIP Station 043 at Camp Pendleton for the period of record of Middle and South Beach disposal, 1998-2017.

To calculate the critical mass of North, Middle and South Beach, we combine the extremal waves with the D_{50} grain size values from Figure B-3 to solve equations (1) – (5) for the extremal elliptic cycloid profile. These extremal cycloid profiles are plotted in Appendix-C These profiles represent the beach shape that can be sustained in an equilibrium state during the most severe wave events of the period of record, 1998-2017. These profiles form the top of the critical mass envelope, while the most eroded profile (from composite minimum of SANDAG surveys 1997 -2012, (S97-S12) at transect CB-0800 - 850) define the bottom of critical mass envelope. When lofted in the AutoCad Civil 3-d software, the volume tool calculates the total critical mass envelope to hold of 336,000 cubic yards along all of the receiver beaches combined; with 135,100 cubic yards on North Beach, 134,600 cubic yards on Middle Beach and 66,300 cubic yards on South Beach. These volumes represent the minimal carrying capacity of the North, Middle and South Beach disposal sites, respectively. Lesser amounts of beach fill will not be able to sustain an equilibrium profile during the highest energy wave events; and without an equilibrium profile, the beach will not dissipate all the incident wave energy, and the excess wave energy will erode the beach. If North, Middle or South Beach are over-nourished with more than the critical mass of sand, then two processes will intervene: a) the excess sand will spill off the wave cut platform and be re-suspended over the rocky outcrops and hard bottom substrate offshore of the receiver beaches; and/or b) the excess sand will be swept away by the net longshore transport (littoral drift) which flows from north to south throughout the Oceanside Littoral Cell, thereby reducing sand residence time.

Appendix-C: Equilibrium Beach Fill Templates for 2020/21 Dredge/Beach Nourishment Cycle

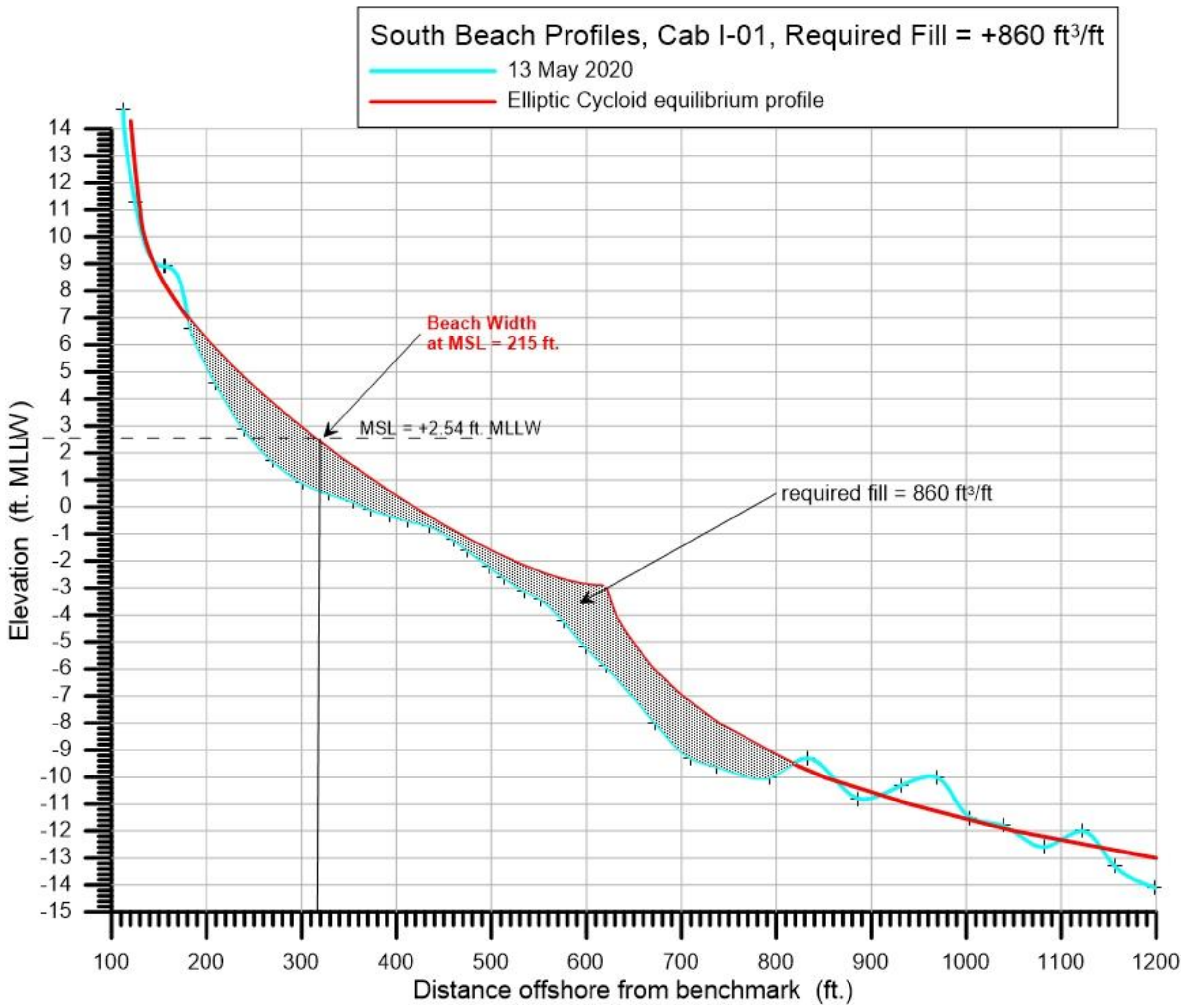


Figure C-1: Required beach fill at range line Cab I-01 on South Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period.

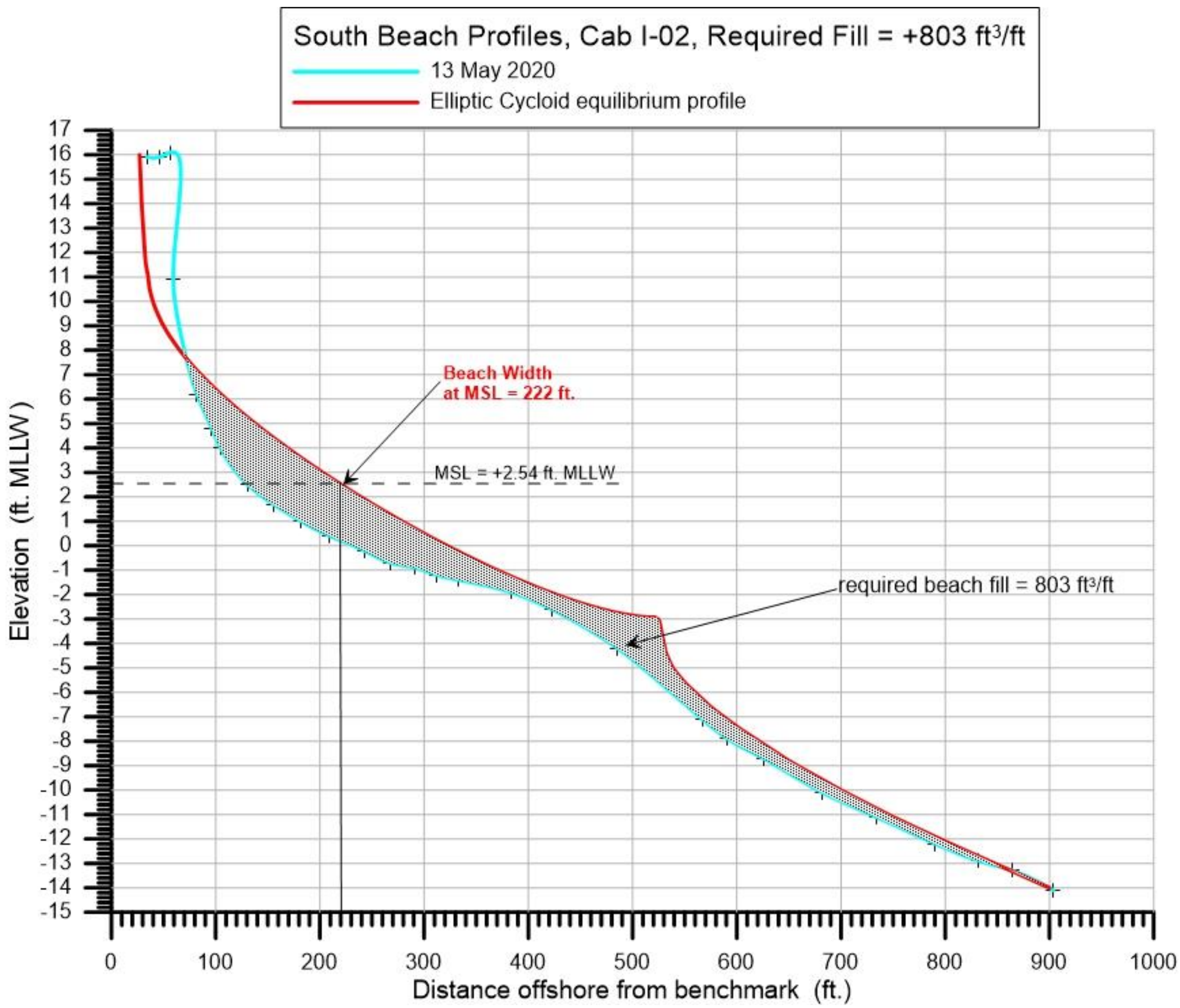


Figure C-2: Required beach fill at range line Cab I-02 on South Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period

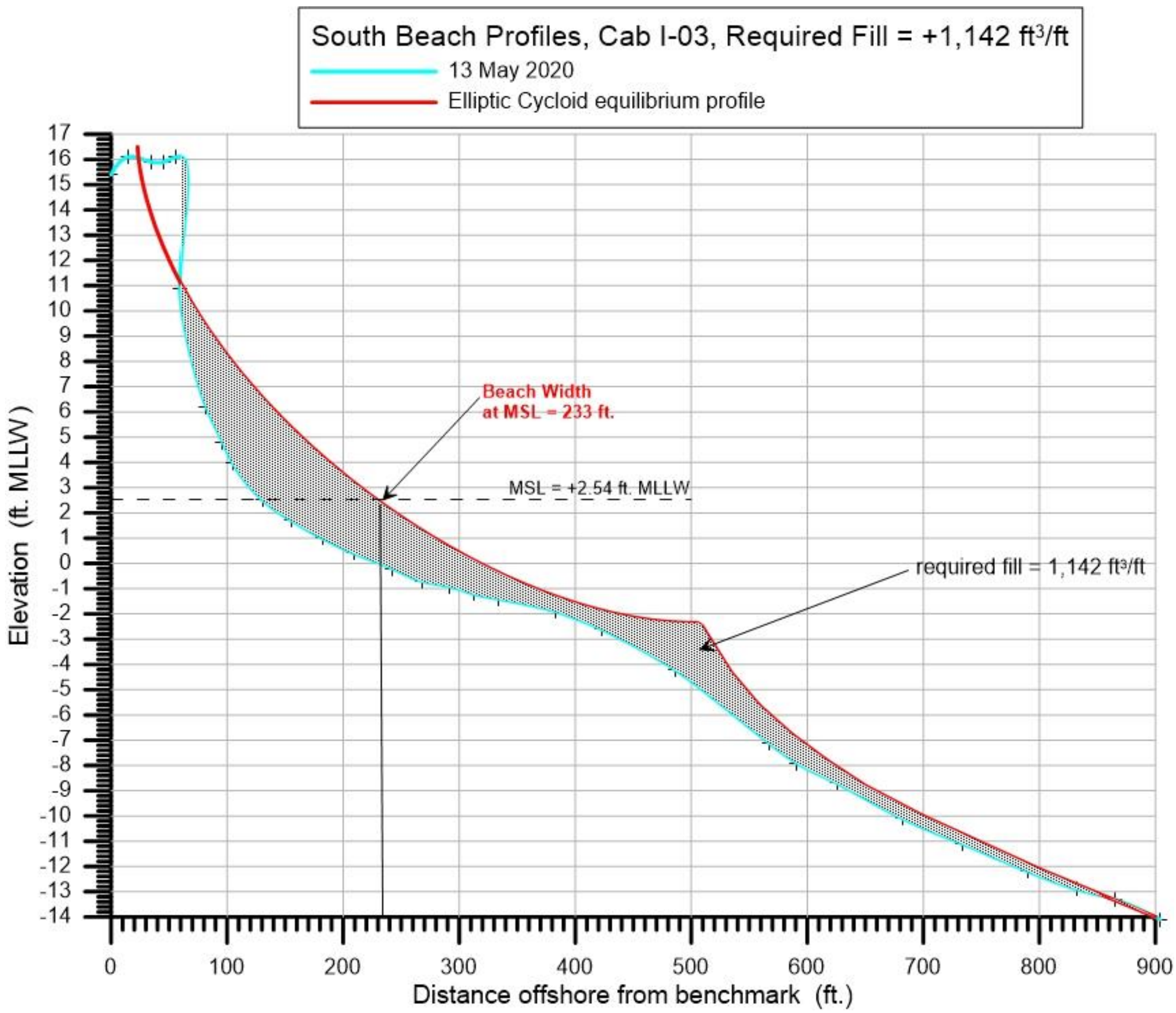


Figure C-3: Required beach fill at range line Cab I-03 on South Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period.

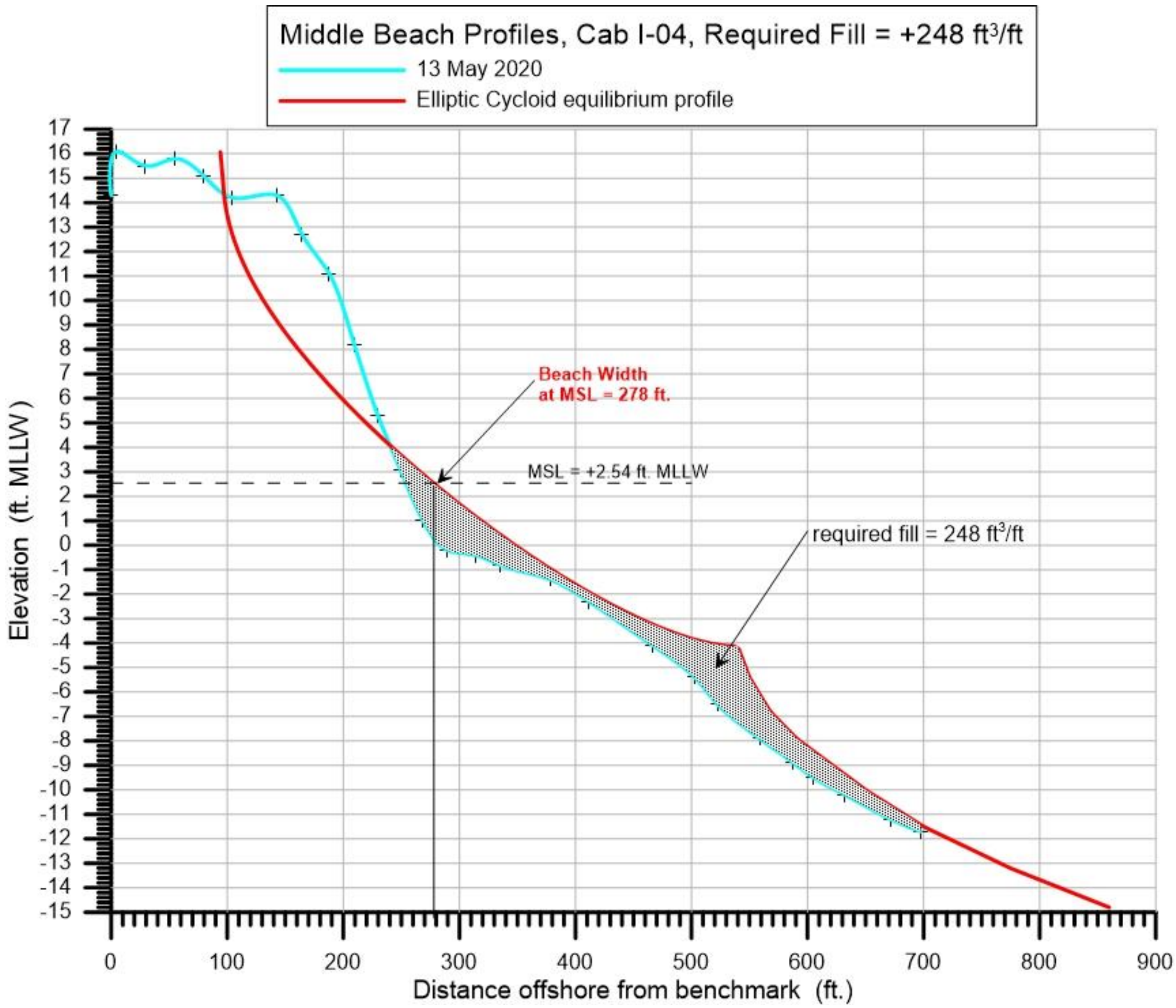


Figure C-4: Required beach fill at range line Cab I-04 on Middle Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period.

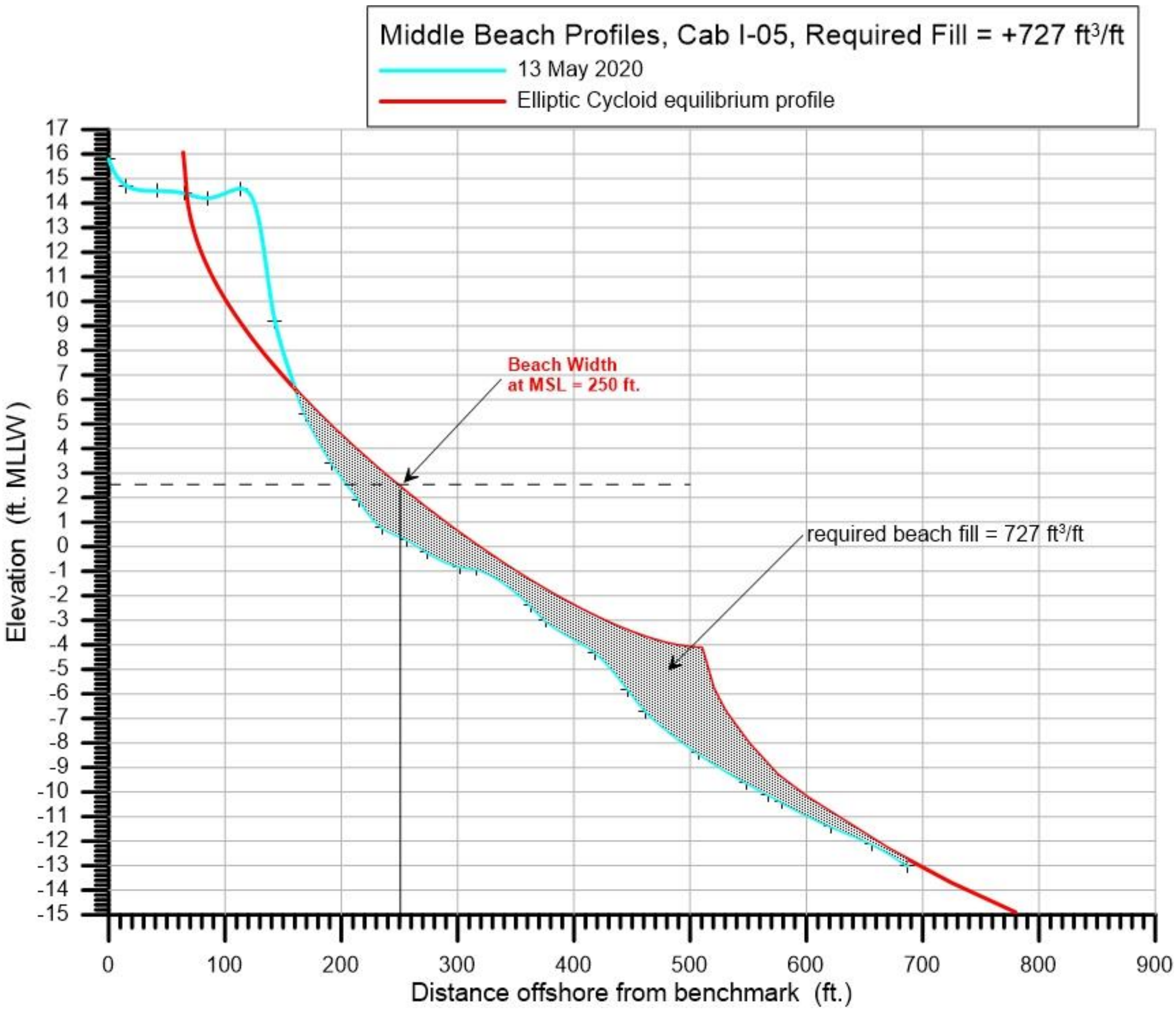


Figure C-5: Required beach fill at range line Cab I-05 on Middle Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period.

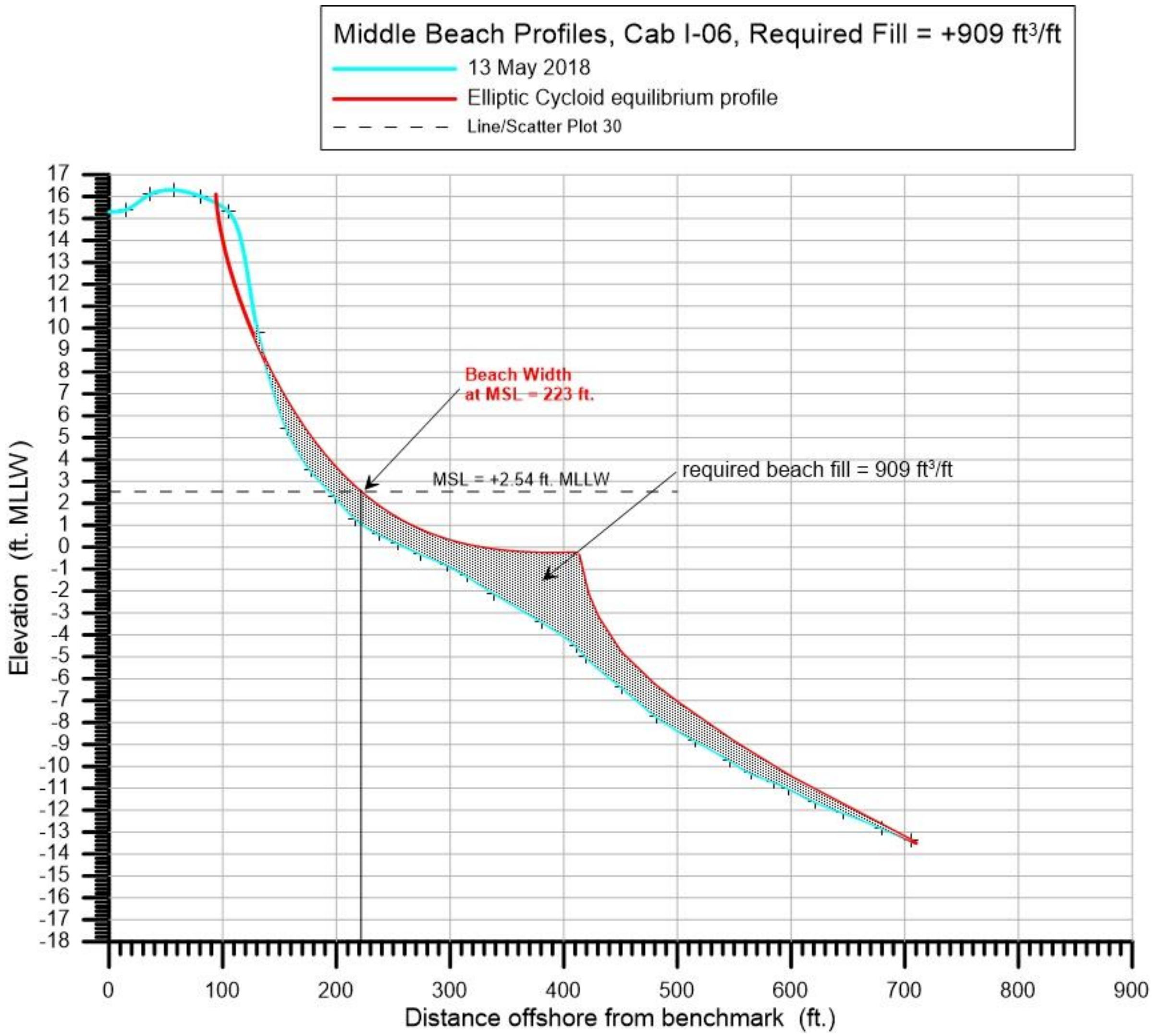


Figure C-6: Required beach fill at range line Cab I-06 on Middle Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period.

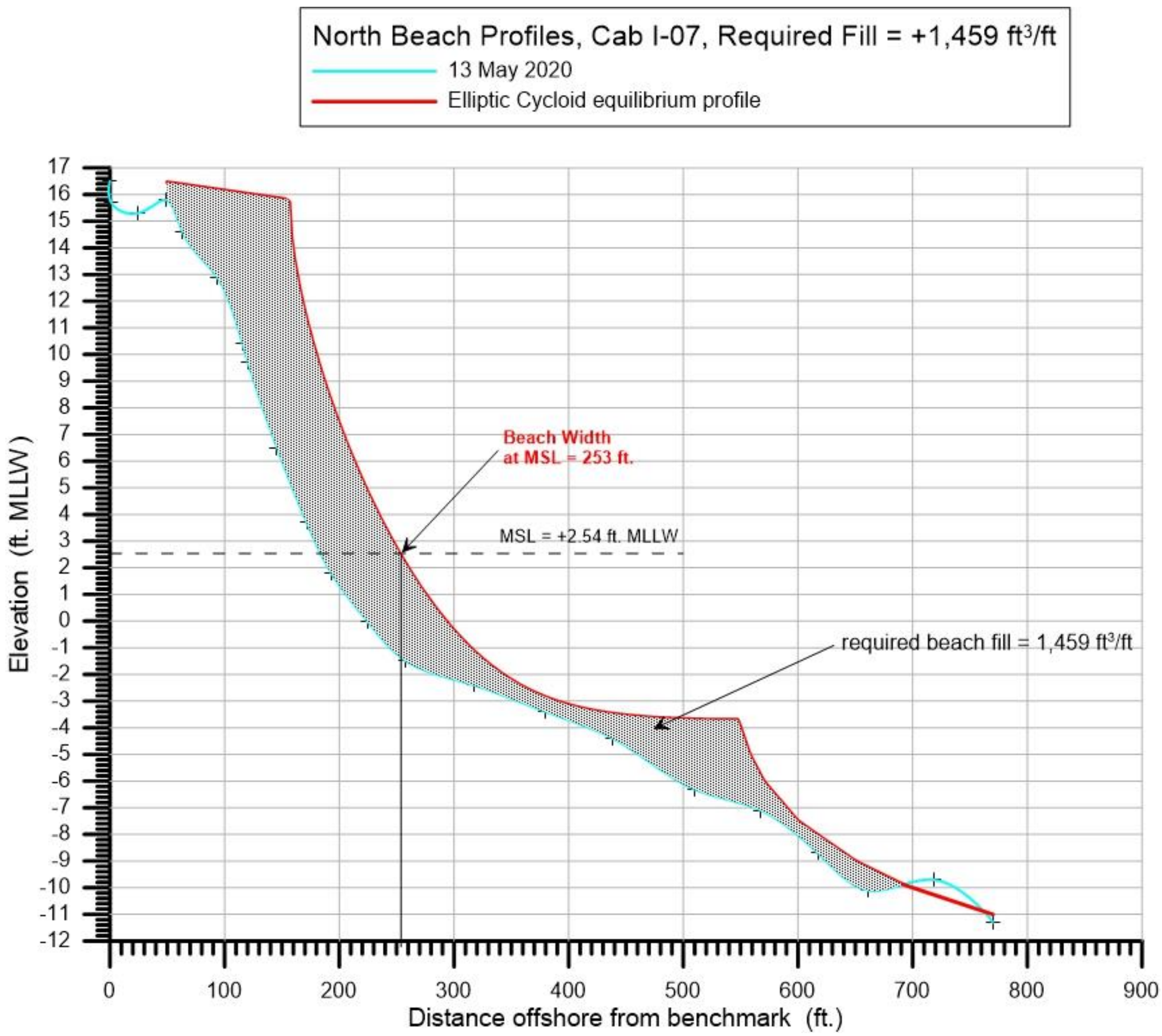


Figure C-7: Required beach fill at range line Cab I-07 on North Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period.

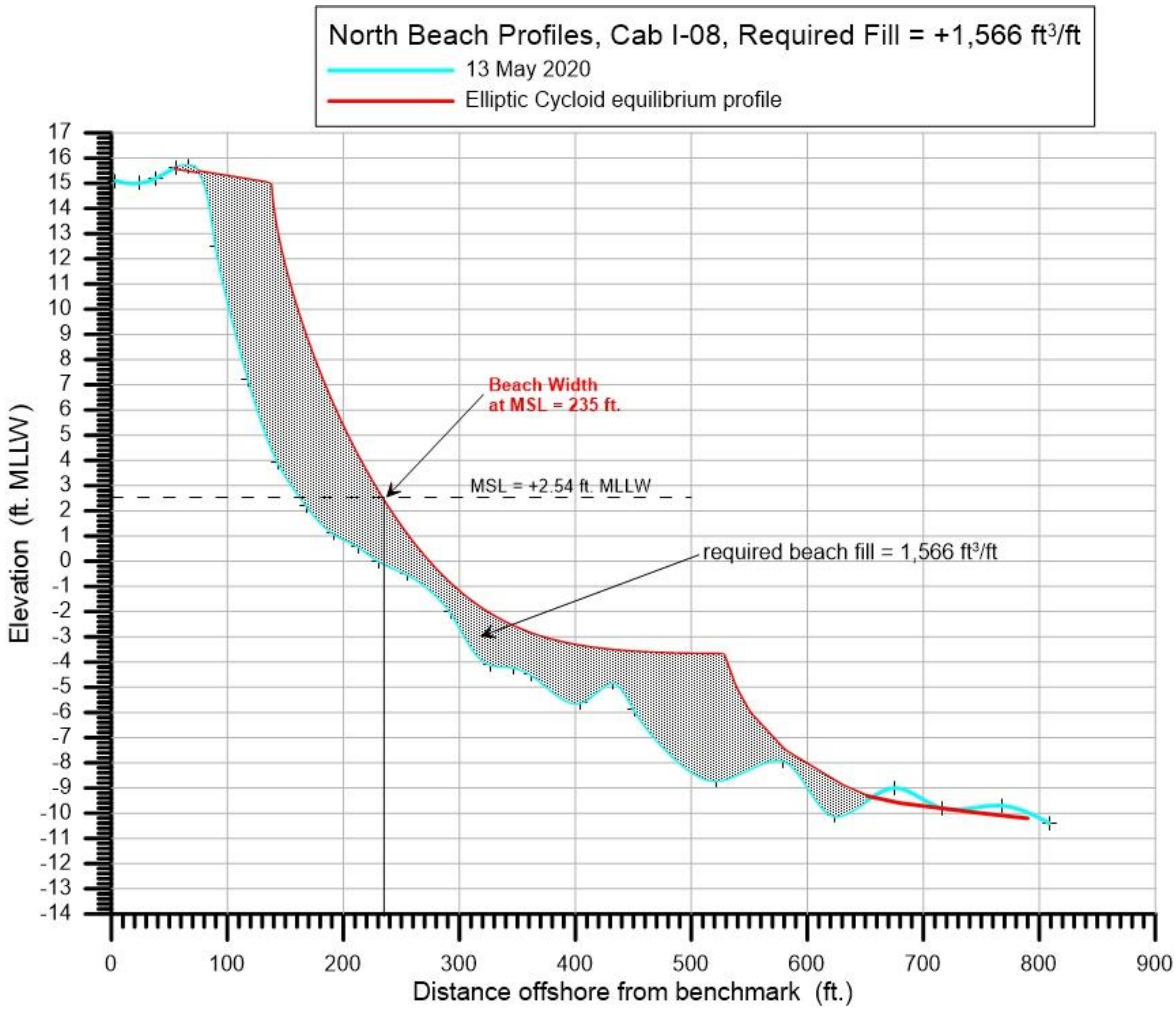


Figure C-8: Required beach fill at range line Cab I-08 on North Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period.

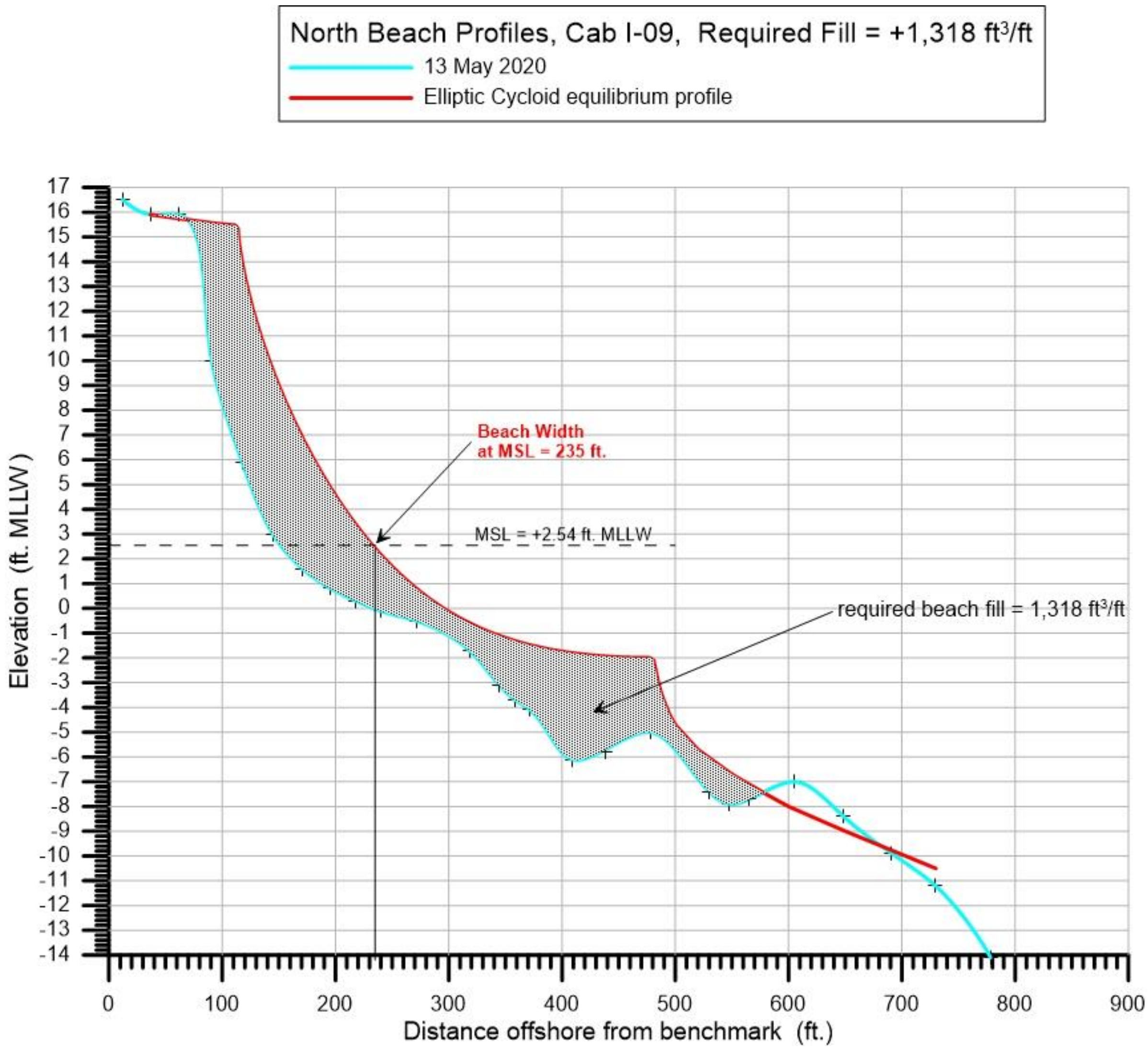


Figure C-9: Required beach fill at range line Cab I-09 on North Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period.

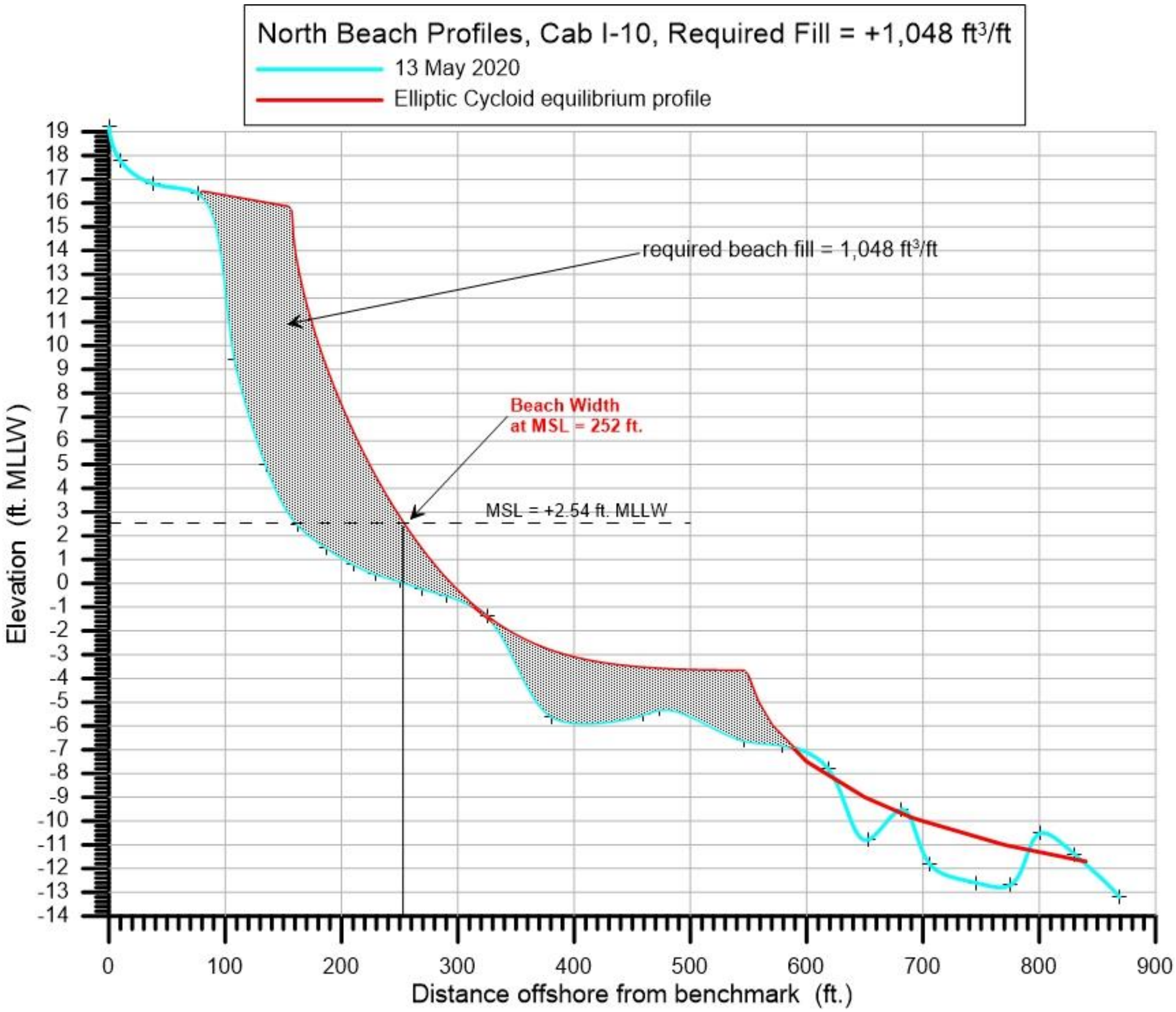


Figure C-10: Required beach fill at range line Cab I-10 on North Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period.

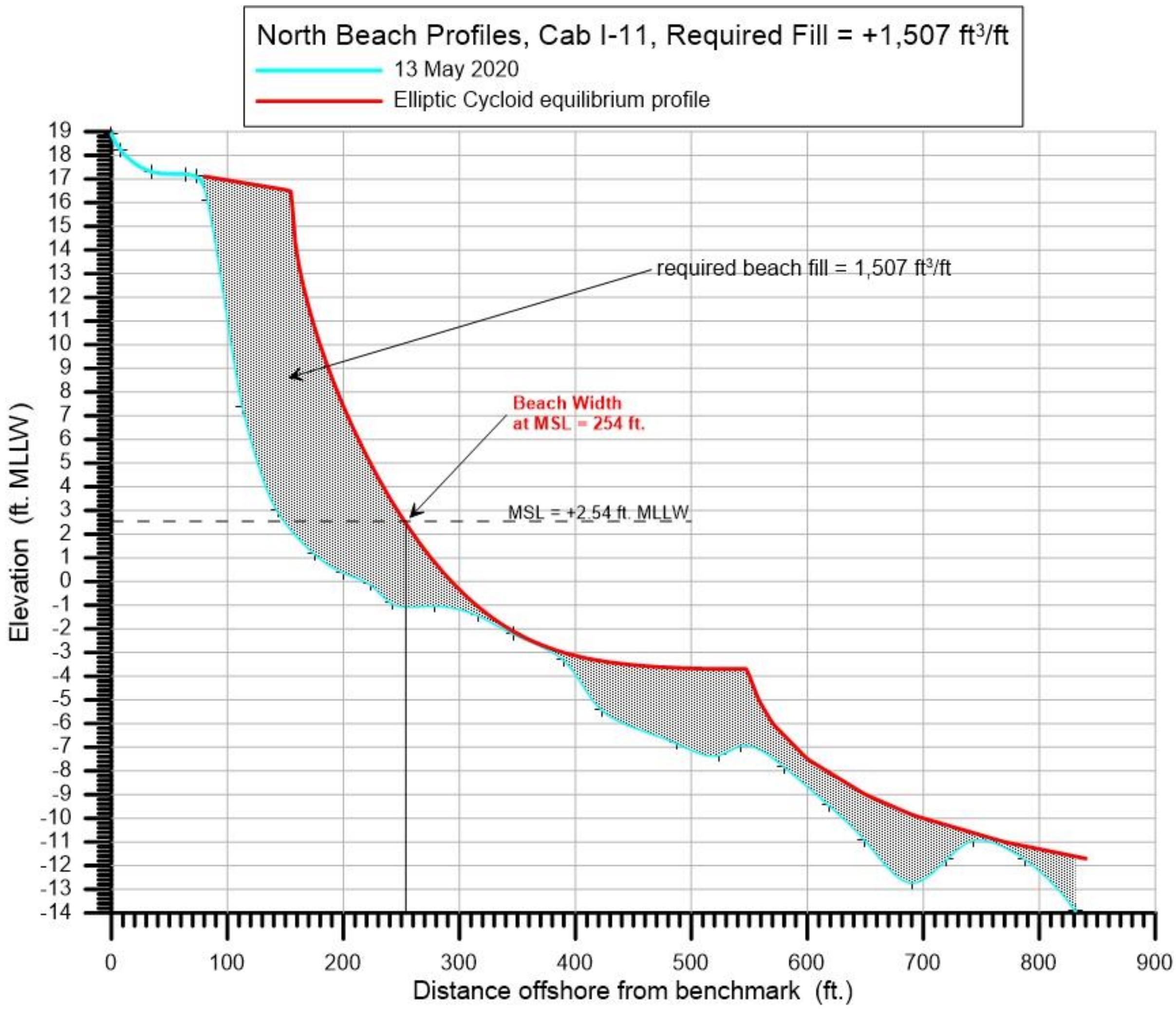


Figure C-11: Required beach fill at range line Cab I-11 on North Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period.

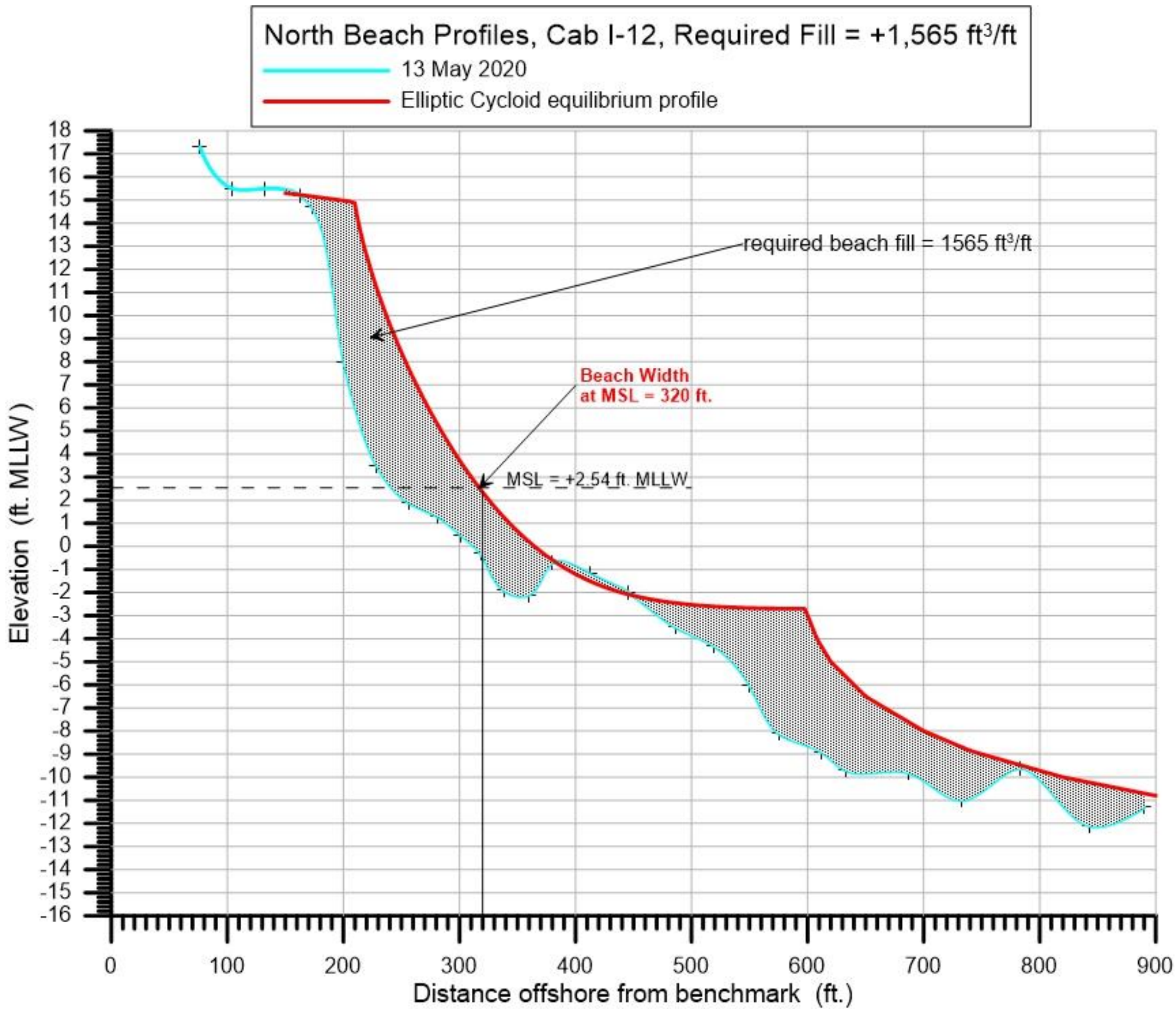


Figure C-12: Required beach fill at range line Cab I-12 on North Beach based on the extremal elliptic cycloid solution using a 4.8 m high design wave height with 15 second wave period