US Army Corps of Engineers ®
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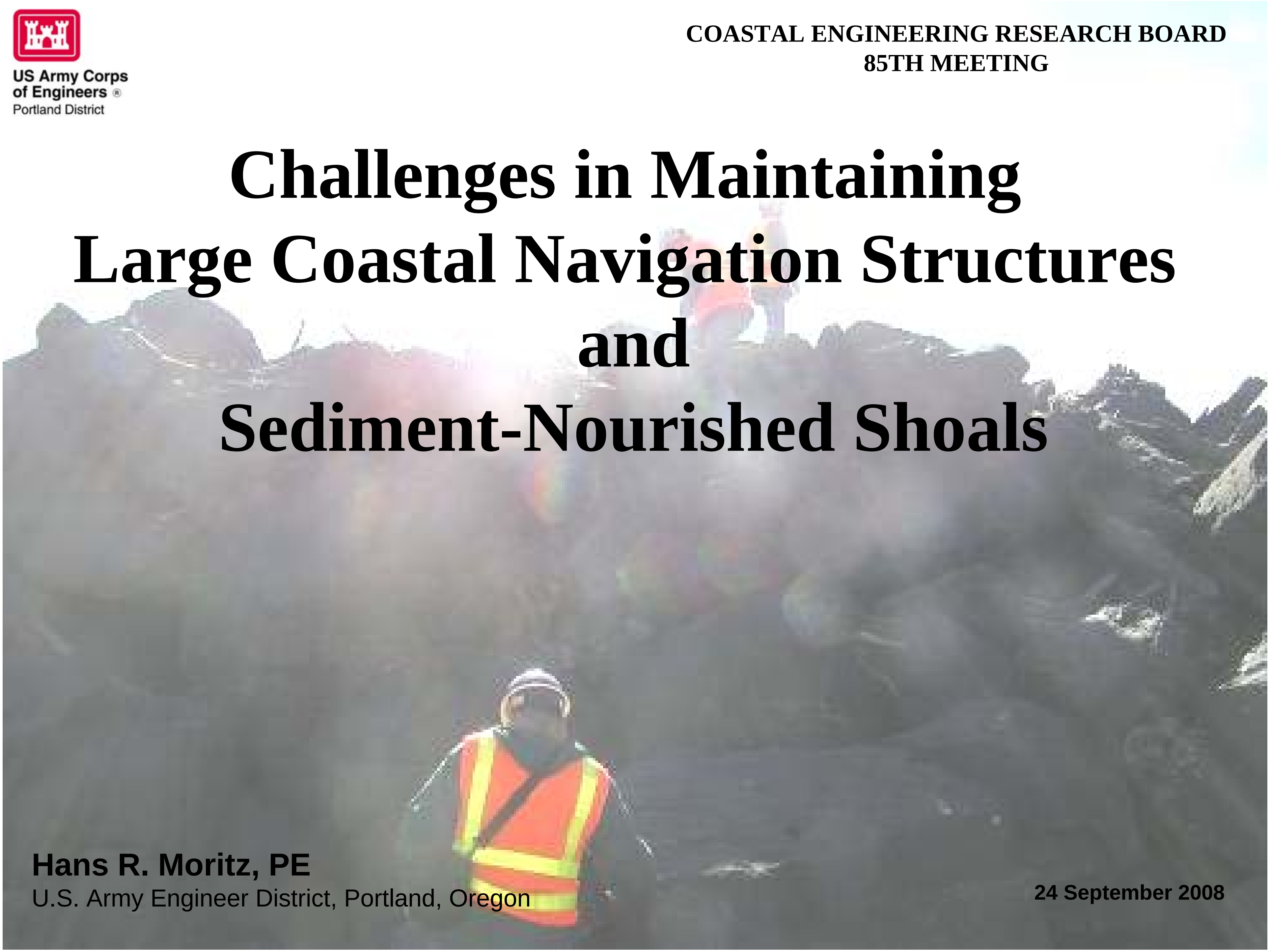
COASTAL ENGINEERING RESEARCH BOARD
85TH MEETING



Challenges in Maintaining Large Coastal Navigation Structures and Sediment-Nourished Shoals

Hans R. Moritz, PE
U.S. Army Engineer District, Portland, Oregon

24 September 2008

Conclusions

Many coastal navigation structures have performed well, but are now in a condition of high vulnerability due to deferred maintenance.

High vulnerability leads to an uncertain future: Active Monitoring informs real-time risk management. Intervention options = fix as fails → systems based solutions.

Dredged material (sand) can be used to augment the sediment budget of eroding tidal shoals at Inlets: IMPROVE long term resiliency of the inlet's morphology and navigation infrastructure = RSM. May not address active jetty damage

Requires flexibility - adapt to environmental forcing, structure response, natural resource impacts, and stakeholder concerns.

Major Rehabilitation: restores a Structure's Life-Cycle and address system risk. Major Rehab requires a Stochastic Reliability-based Life Cycle Simulation to evaluate structures subjected to complex loading scenarios.

Match the Tool with the Task

Coastal Jetties

Secure Consistent and Safe Navigation Channel from Ocean to Inland Waters

1) **Constrict Flow through inlet – Stabilize Inlet and shoals**
2) **Use scour to promote the Authorized Channel Depth**
3) **Protect inlet from excessive Wave and Current action**
4) **Minimize Negative Consequences to estuary, adjacent shoreline, jetties**

Four Approaches for Dealing with Coastal Navigation Infrastructure

- may also be applicable to other projects

Increasing Commitment to Systems-based Management = Increased Sustainability

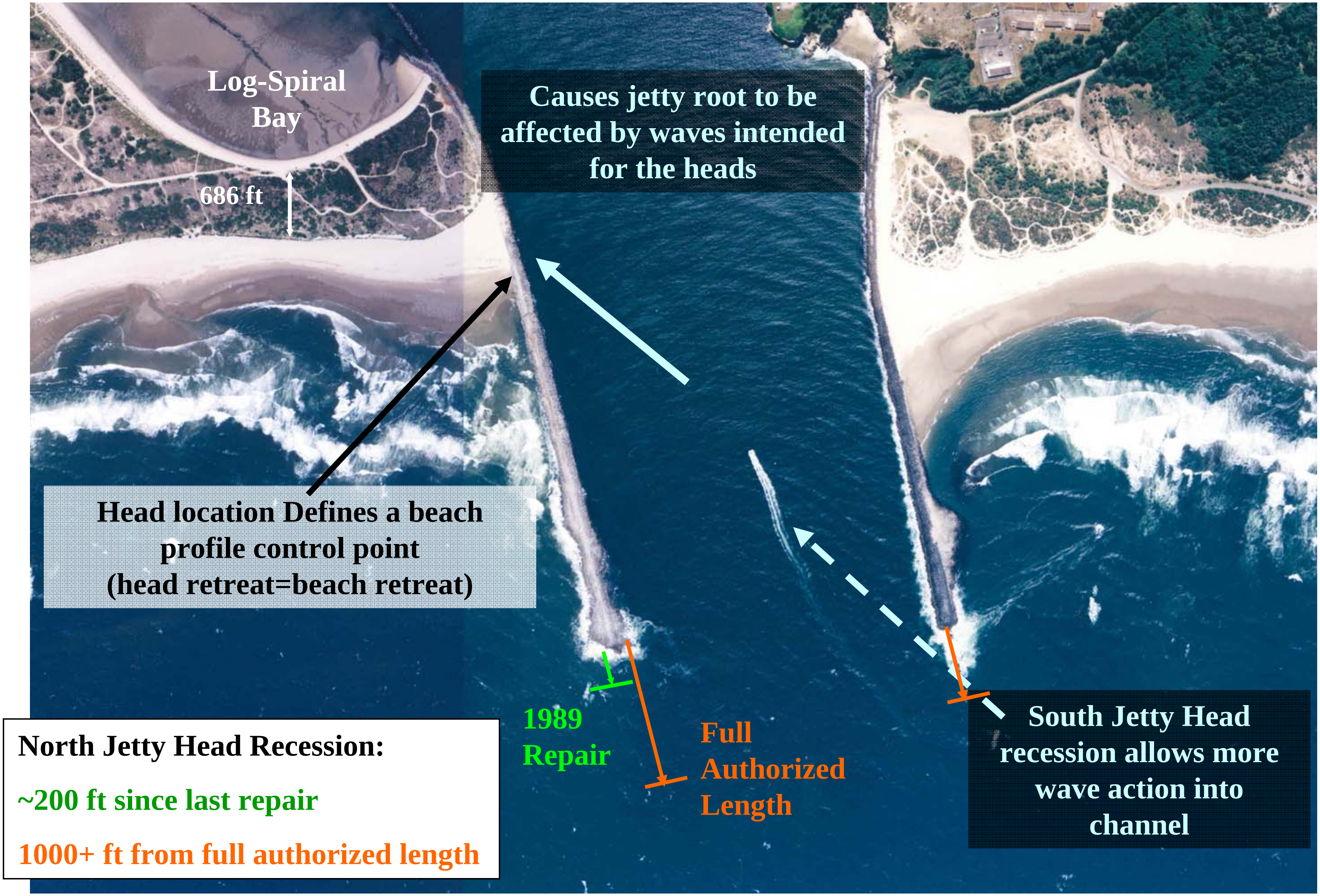
Deferred Intervention: Repair Structure AFTER it loses function.
Continually operating with high risk.
Not sustainable

Preventative or Adaptive Repairs: Repair Structure to PREVENT function loss; adapt repairs to changing conditions.
Failure to act in time = Deferred Intervention

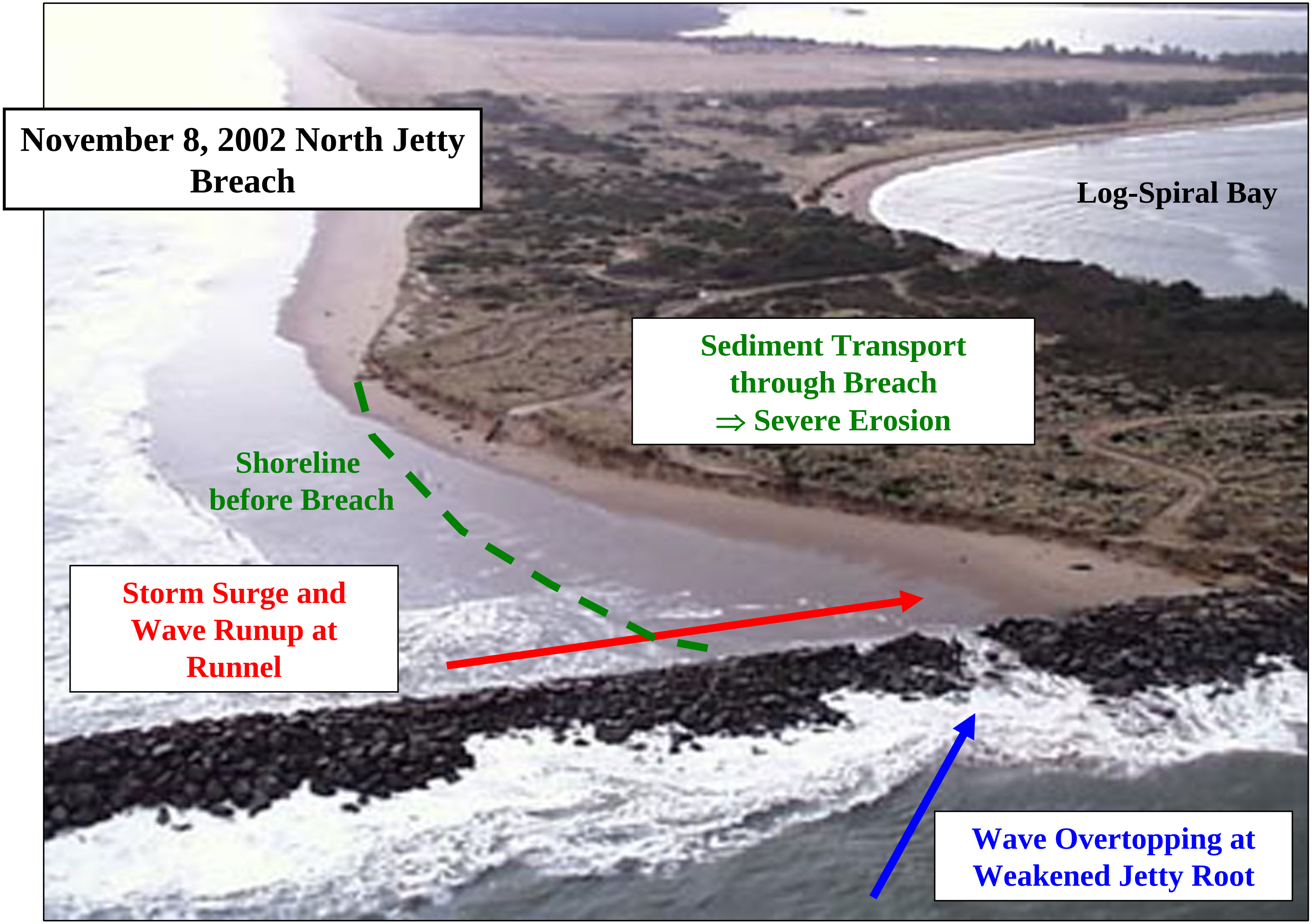
Morphology Augmentation/Stabilization: Use dredged material (implement RSM) to IMPROVE THE RESILIENCY of a Structure and reduce hydraulic loading.
Requires flexible Systems-based approach.

Structure Rehabilitation: Rebuild the Structure cross-section and augment with engineering features to RESTORE SERVICE LIFE.
Requires rigid Systems-based approach.

Vulnerability due to Jetty Head Recession

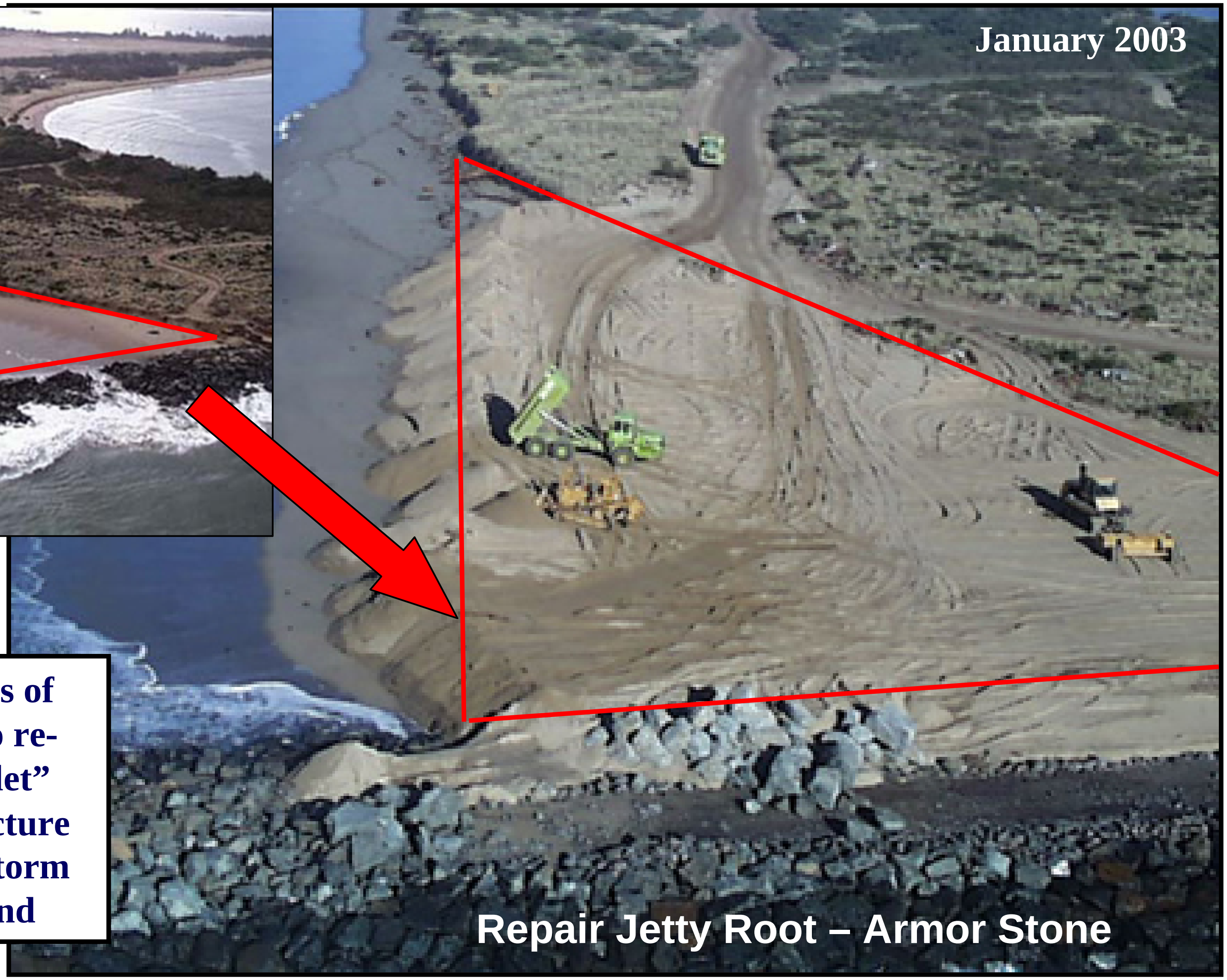


Emergency Jetty Root Repair : 2002

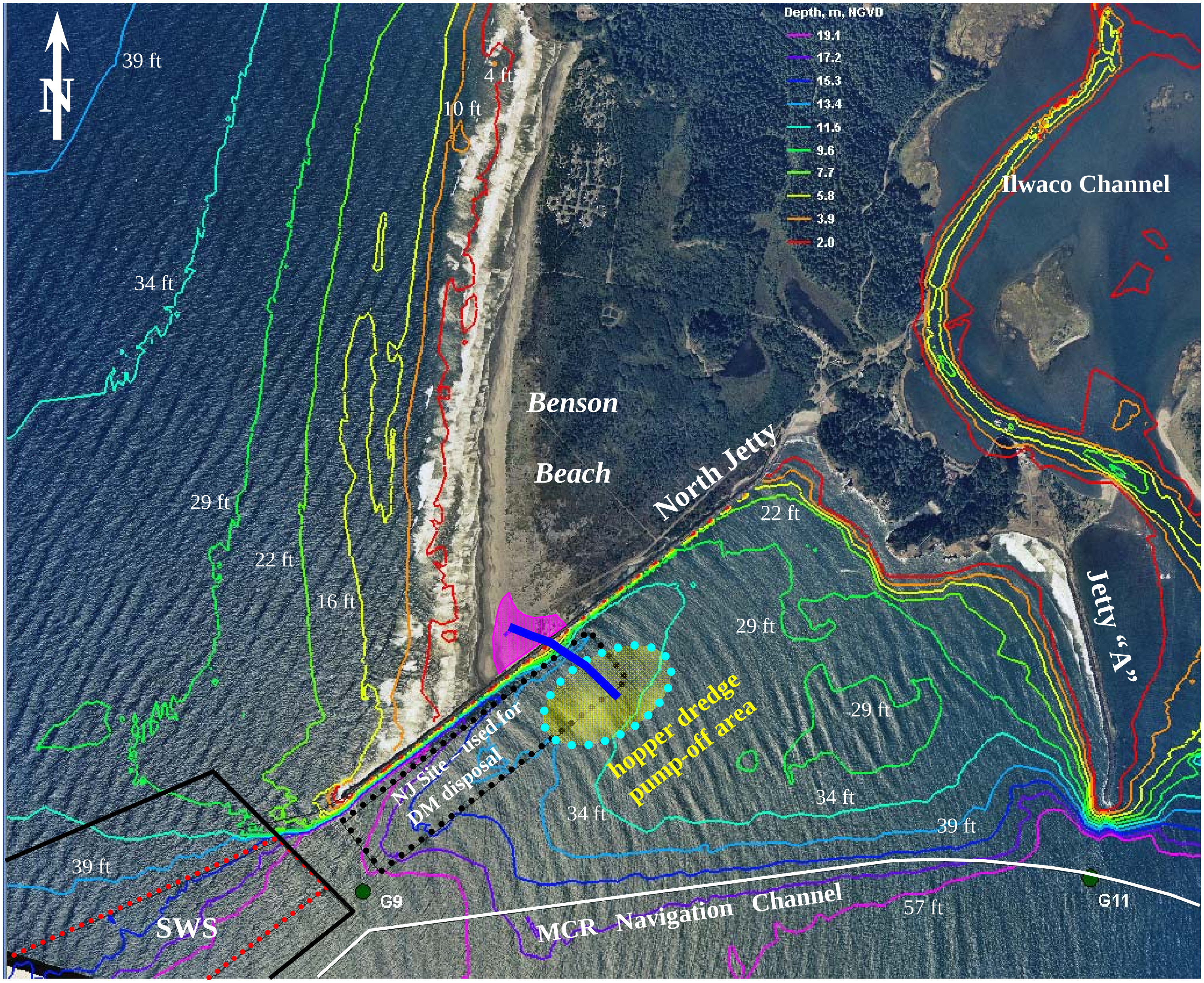



Tidal Flow through Jetty Widens Breach Quickly
High tide flow through jetty root transports ~ 40,000 cubic yards of sand into channel

Emergency Jetty Root Repair



50,000 cubic yards of material placed to re-create a "sand fillet"
⇒ Protecting structure for remainder of storm season and beyond



Mouth of the Columbia River

North Jetty Berm Repair 2008

= North Jetty Berm Repair 2008 placement area – 125,000 CY

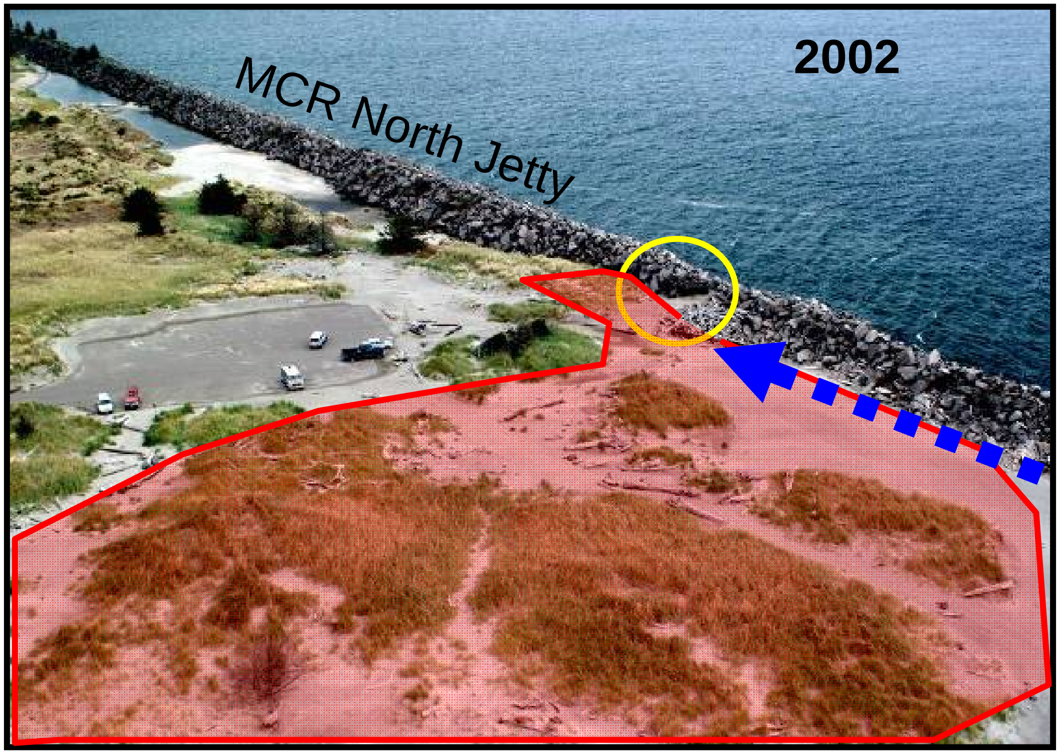
= Pump-ashore pipeline location

Scale

1,000 ft

0 ft NAVD = +0.2 ft MLLW

Contour data (ft NAVD) are based on 1999 -2003, contour elevations east of north jetty are approximate.

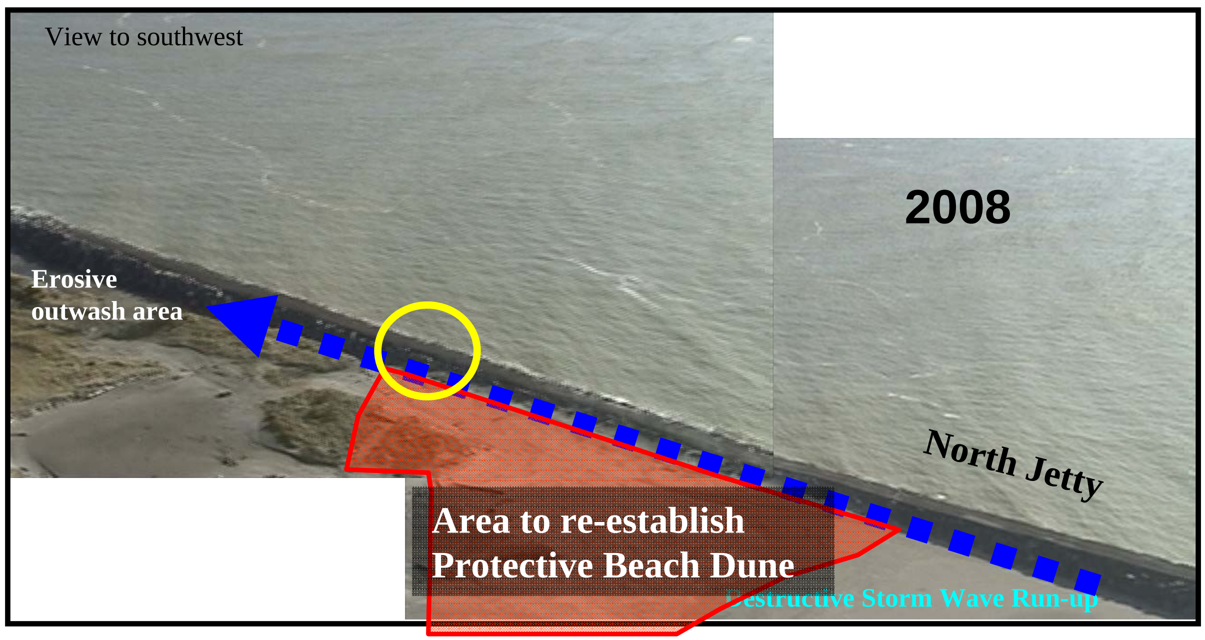


Sept 2002, the Fore Dune along North Jetty was in fair condition;

Acting to intercept storm surge flow before attacking the landward (vulnerable) area of the north jetty

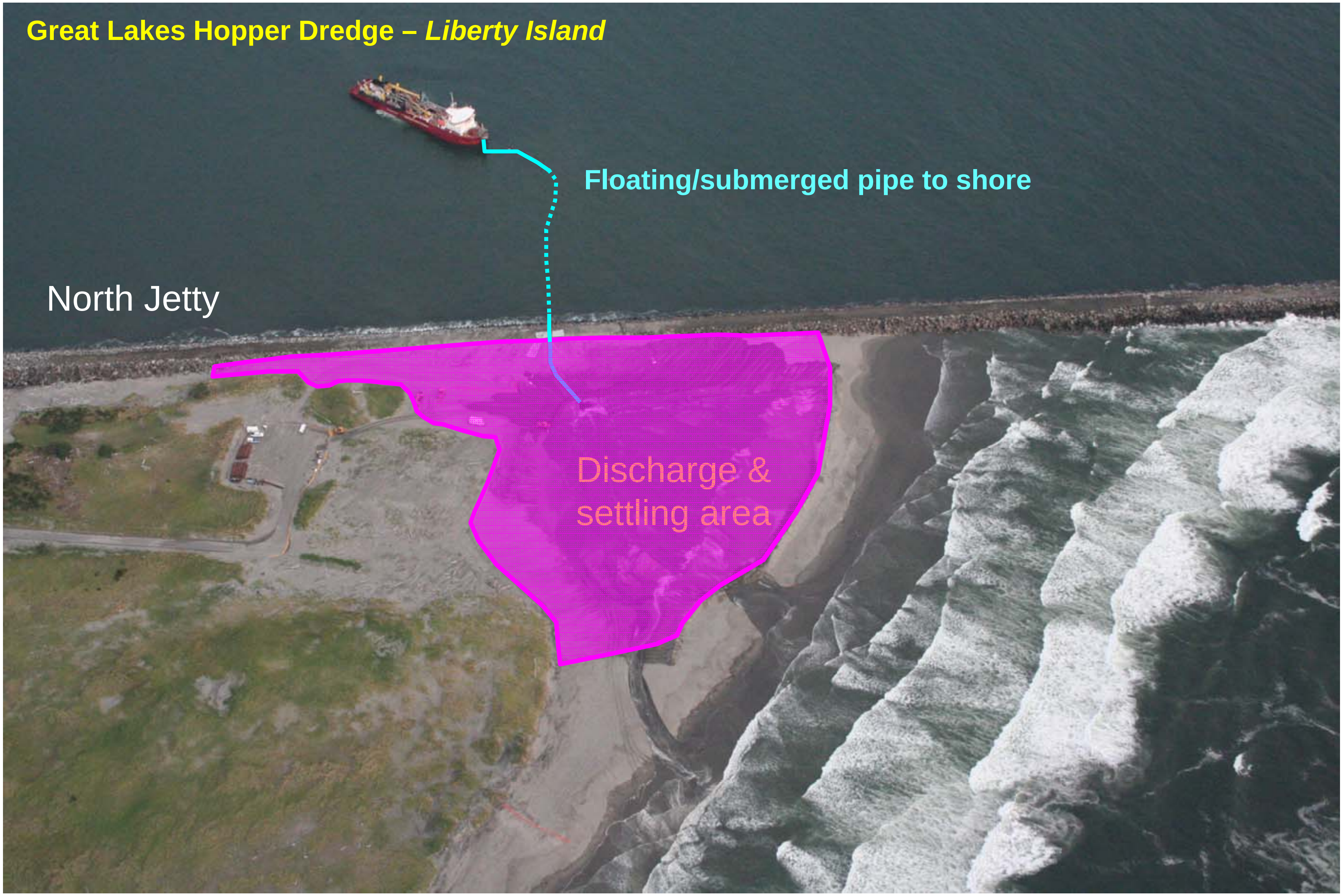
In 2008, the fore dune along the North Jetty is non-existent (area affected shown in RED)

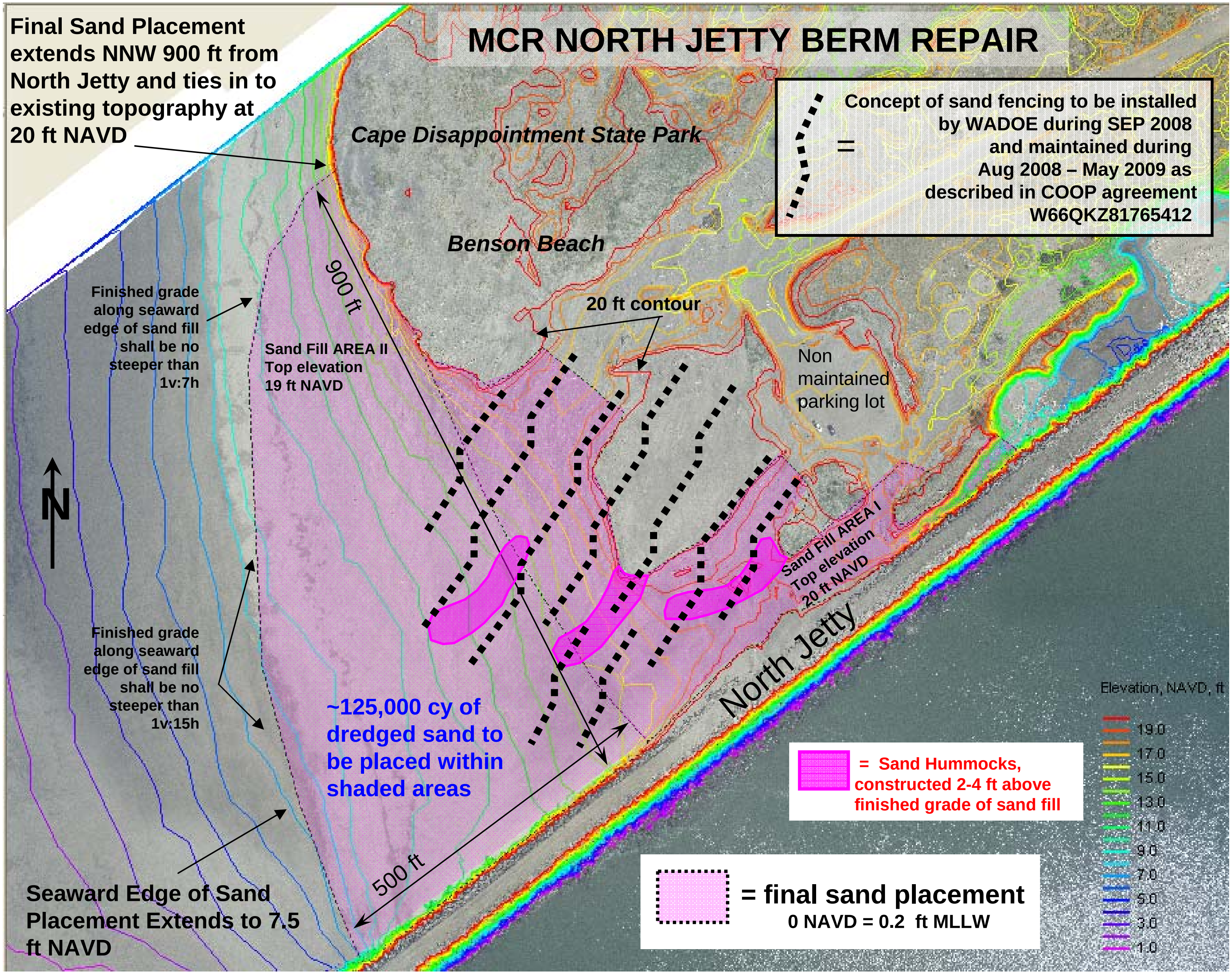
storm-driven hydraulic action (tide + storm surge + IG Transients) passes along the landward area of the north jetty, acting to destabilize the jetty.



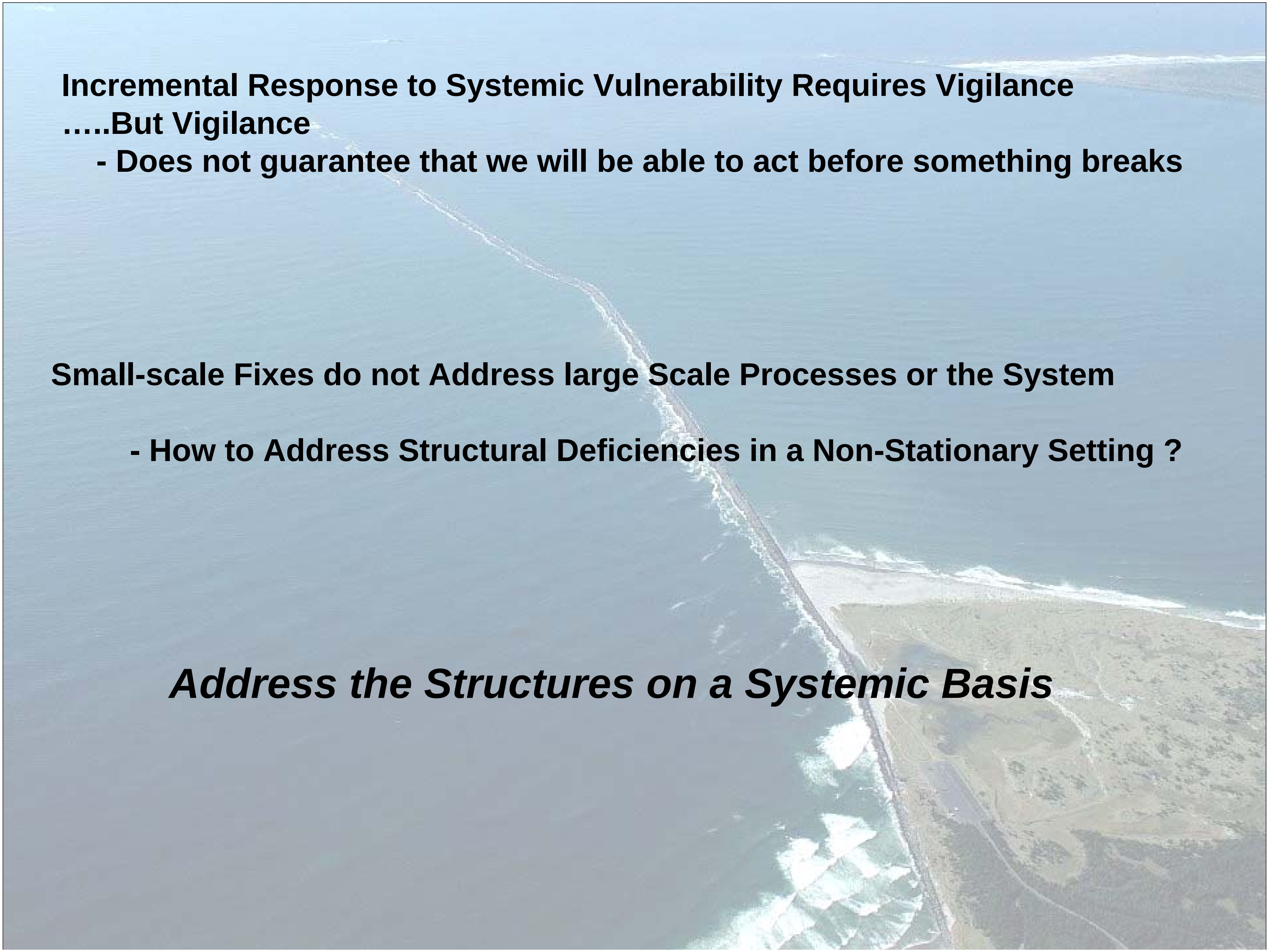
North Jetty Berm Repair Hopper Dredge Pump-out Activity: 2008

125,000 cy placed - **90% retained in project template**





MCR NORTH JETTY BERM REPAIR
Final Sand Placement extends NNW 900 ft from North Jetty and ties in to existing topography at 20 ft NAVD
Cape Disappointment State Park
Concept of sand fencing to be installed by WADOE during SEP 2008 and maintained during Aug 2008 – May 2009 as described in COOP agreement W66QKZ81765412
=
Benson Beach
900 ft
20 ft contour
Finished grade along seaward edge of sand fill shall be no steeper than 1v:7h
Sand Fill AREA II Top elevation 19 ft NAVD
Non maintained parking lot
N
Sand Fill AREA I Top elevation 20 ft NAVD
Finished grade along seaward edge of sand fill shall be no steeper than 1v:15h
North Jetty
~125,000 cy of dredged sand to be placed within shaded areas
Elevation, NAVD, ft
19.0
17.0
15.0
13.0
11.0
9.0
7.0
5.0
3.0
1.0
= Sand Hummocks, constructed 2-4 ft above finished grade of sand fill
500 ft
Seaward Edge of Sand Placement Extends to 7.5 ft NAVD
= final sand placement
0 NAVD = 0.2 ft MLLW


Incremental Response to Systemic Vulnerability Requires Vigilance
…..But Vigilance
- Does not guarantee that we will be able to act before something breaks
Small-scale Fixes do not Address large Scale Processes or the System
- How to Address Structural Deficiencies in a Non-Stationary Setting ?
Address the Structures on a Systemic Basis

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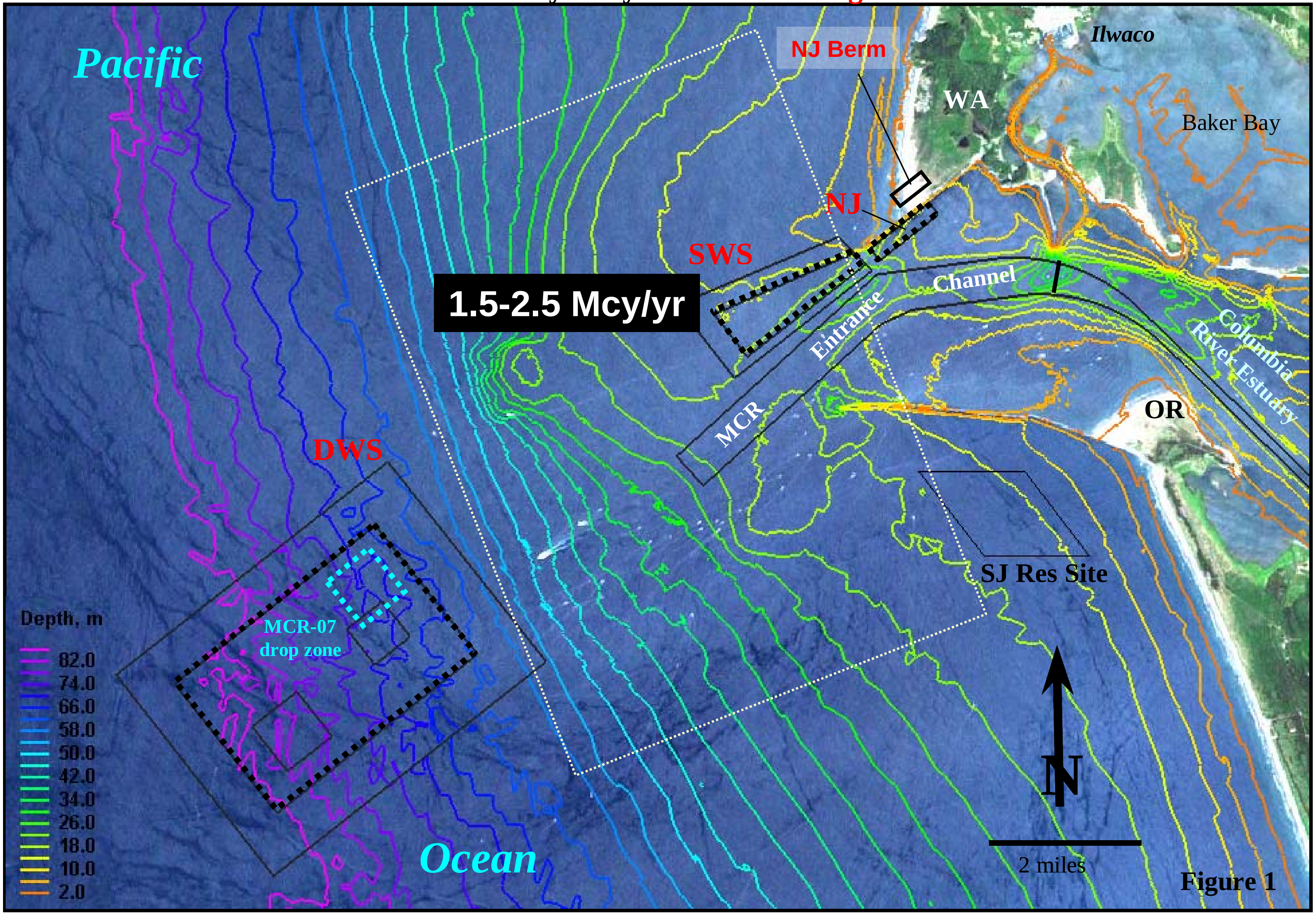
Lead Engineer, MCR Jetty Construction - 1903

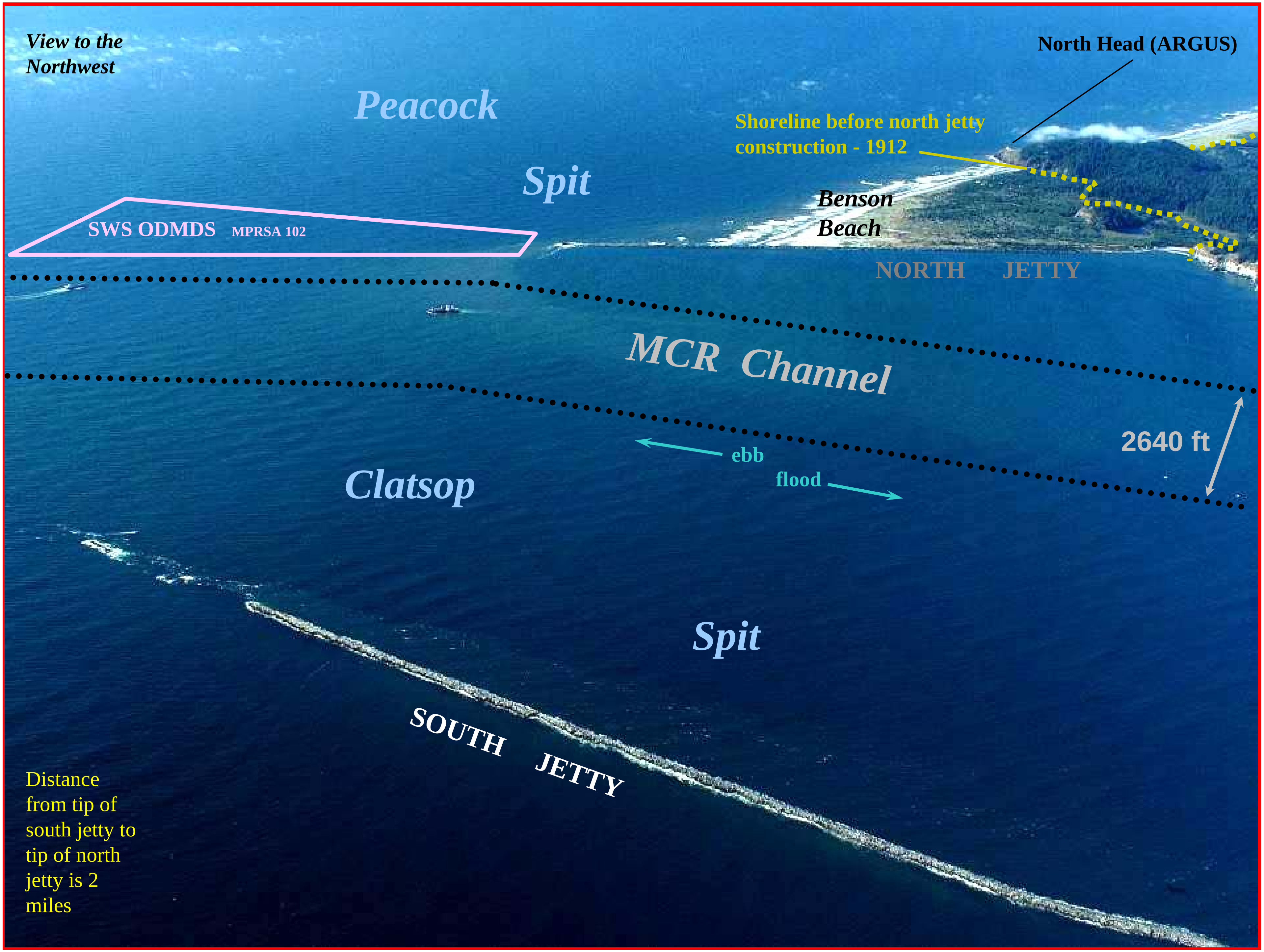
"The jetty is a long, thin, narrow backbone of solid material, resting upon a very doubtful foundation, against which the forces of Nature have accumulated large quantities of the shifting sand.

These shoals break the force of the waves and protect the jetty from destruction. Jetty integrity and the permanence of the channel over the bar depend upon the amount of this sand that can be accumulated."

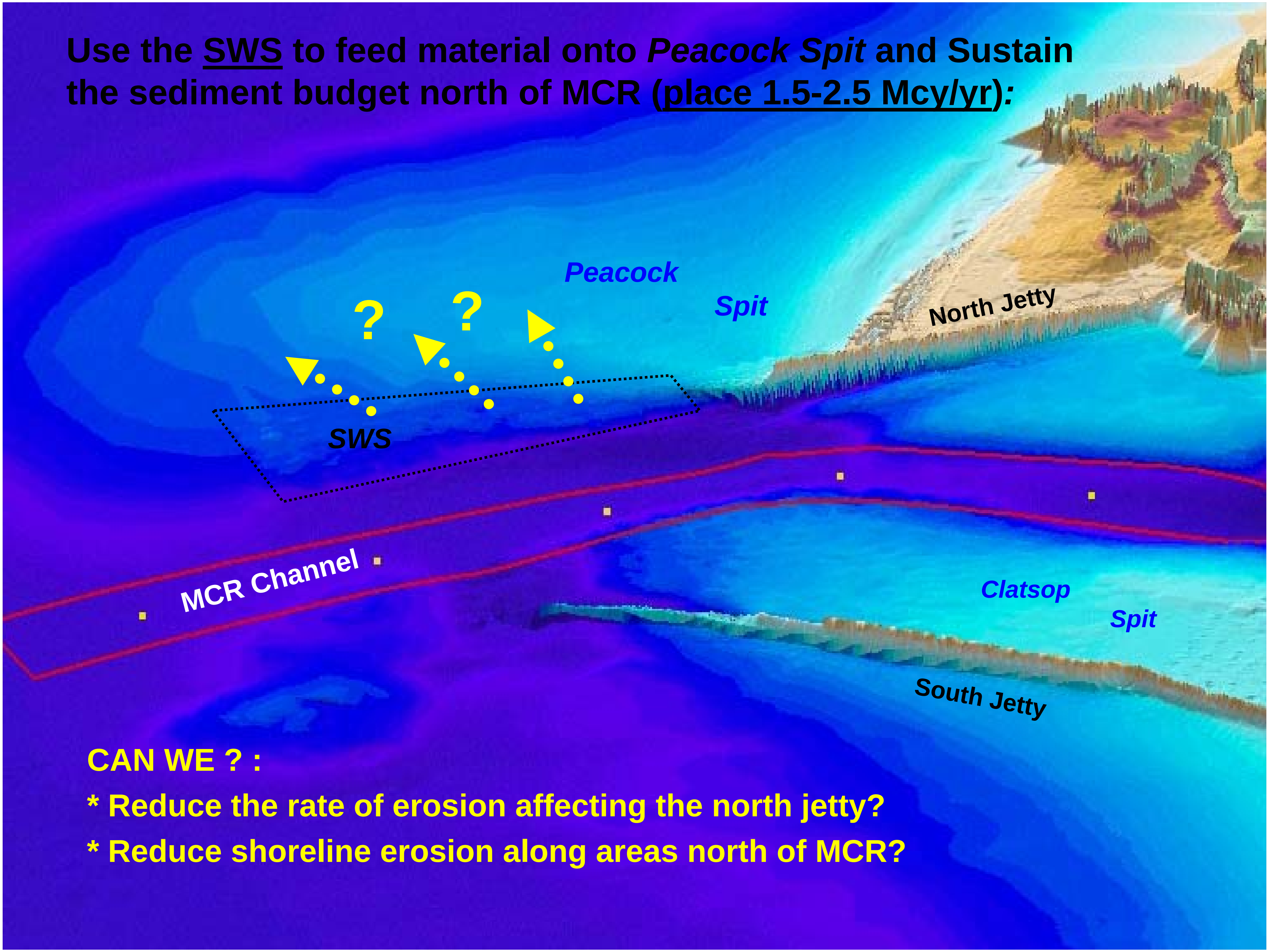
Mouth of the Columbia River - Bathymetry and 2008 Dredged Material Placement Sites



DWS= Deep Water Site, 102 MPRSA
SWS= Shallow Water Site, 102 MPRSA
NJ = North Jetty disposal site, 404 CWA
White Box = Bathymetry change shown in Fig 34
SJ Res. Site = South Jetty research site
NJ Berm = North Jetty protection site, fig 1a


View to the Northwest
North Head (ARGUS)
Peacock
Shoreline before north jetty construction - 1912
Spit
Benson Beach
SWS ODMDS MPRSA 102
NORTH JETTY
MCR Channel
2640 ft
ebb
flood
Clatsop
Spit
SOUTH JETTY
Distance from tip of south jetty to tip of north jetty is 2 miles

Use the <u>SWS</u> to feed material onto *Peacock Spit* and Sustain the sediment budget north of MCR (<u>place 1.5-2.5 Mcy/yr</u>):



CAN WE ? :

*** Reduce the rate of erosion affecting the north jetty?**

*** Reduce shoreline erosion along areas north of MCR?**


Hopper Dredges working at MCR
Essayons
Sugar Island
3-5 Million cy of Sand Dredged from MCR Each Year
MCR Maintenance Dredging is Performed during June-Sept
$2.50 – $3.50 / cubic yard

Split-Hull Hopper Hopper dredge Placing dredged Material in Open Water

Utilization of MCR Dredged Material Disposal Sites

Governed by a Regimented System of Protocols: EPA – USACE - Stakeholders

US Army Corps of Engineers
Portland District

EPA

2008 Annual Use Plan

Management of Open Water Dredged Material Disposal Sites
Mouth of the Columbia River, OR and WA

1. Purpose

The year-to-year management of open water dredged material disposal sites located at the mouth of the Columbia River (MCR) is controlled and documented through the preparation and adherence to an Annual Use Plan. This Annual Use Plan (AUP) serves as the primary mechanism for evaluating disposal site capacity and managing dredged material placement. The AUP is revised for each dredging and disposal season, as required by disposal site designation [USEPA 2005]. It is prepared by USACE and reviewed and approved by USEPA, Region 10.

This document is the 2008 AUP for utilizing ocean dredged material disposal sites (ODMDS) located offshore the mouth of the Columbia River. Only dredged material determined to be suitable for unconfined in-water disposal, through application of the current Sediment Evaluation Framework (SEF) for the Pacific Northwest region, may be placed at the sites described within this AUP. The total volume of dredged material to be placed within MCR disposal sites during 2008 is expected to be 3-4.5 million cubic yards (MCY). During 2008, the dredged material that is to be placed within available MCR disposal sites will originate from the MCR federal navigation channel.

2. Background

Each year, the Corps of Engineers-Portland District dredges 3-5 MCY of sand at the mouth of the Columbia River (MCR) to maintain the inlet's 6-mile long deep draft navigation channel (figure 1). Most of the dredging occurs between river mile –2.0 and +2.5. The dredged material is fine-medium sand (0.19-0.25 mm) and fine-grained material (passing a 230 mesh sieve) content is 3% or less. The dredged sand is placed at two EPA designated ODMDS [USEPA 2005], or at sites available under Section 404 of the Clean Water Act (404 site). Due to the exposed ocean conditions at MCR, only ocean-going hopper dredges can perform dredging and disposal at MCR. Dredging is limited to June-November when wave conditions are favorable for working on the bar. Refer to Appendix A for additional information describing the MCR navigation project, dredged material disposal sites, and hopper dredge operating characteristics. Appendix B summarizes the use of MCR disposal site during 2007 in context to the bathymetry changes that have occurred during 1997-2008. The term "bathymetry" refers to topography of the seabed. Appendix B also summarizes special studies conducted during 2007, associated with MCR-ODMDS use and potential impacts.

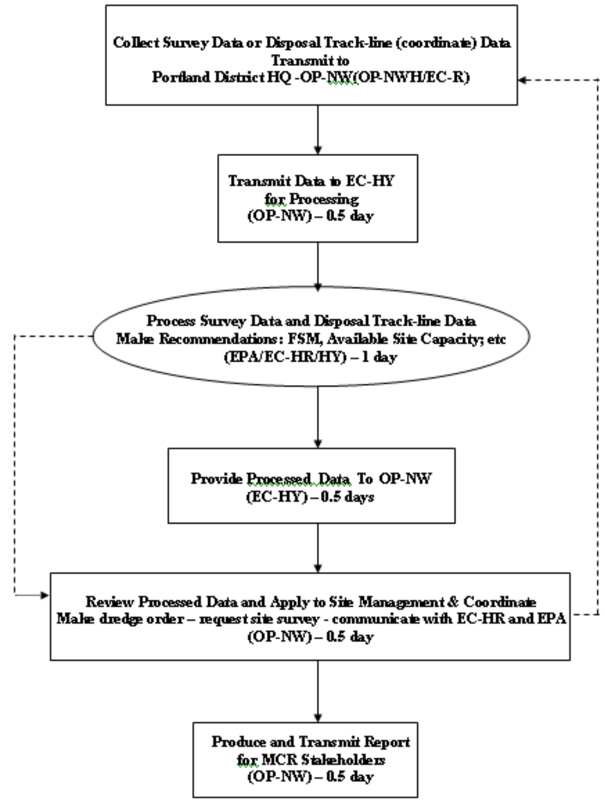


Figure 2. Flow diagram describing the procedure of processing monitoring data and using the processed data to manage disposal site capacity, at a frequency of 1 week or greater. Offices shown in () are assigned responsibility for task; expected duration of task is specified. FSM = Frequency for Site Monitoring.

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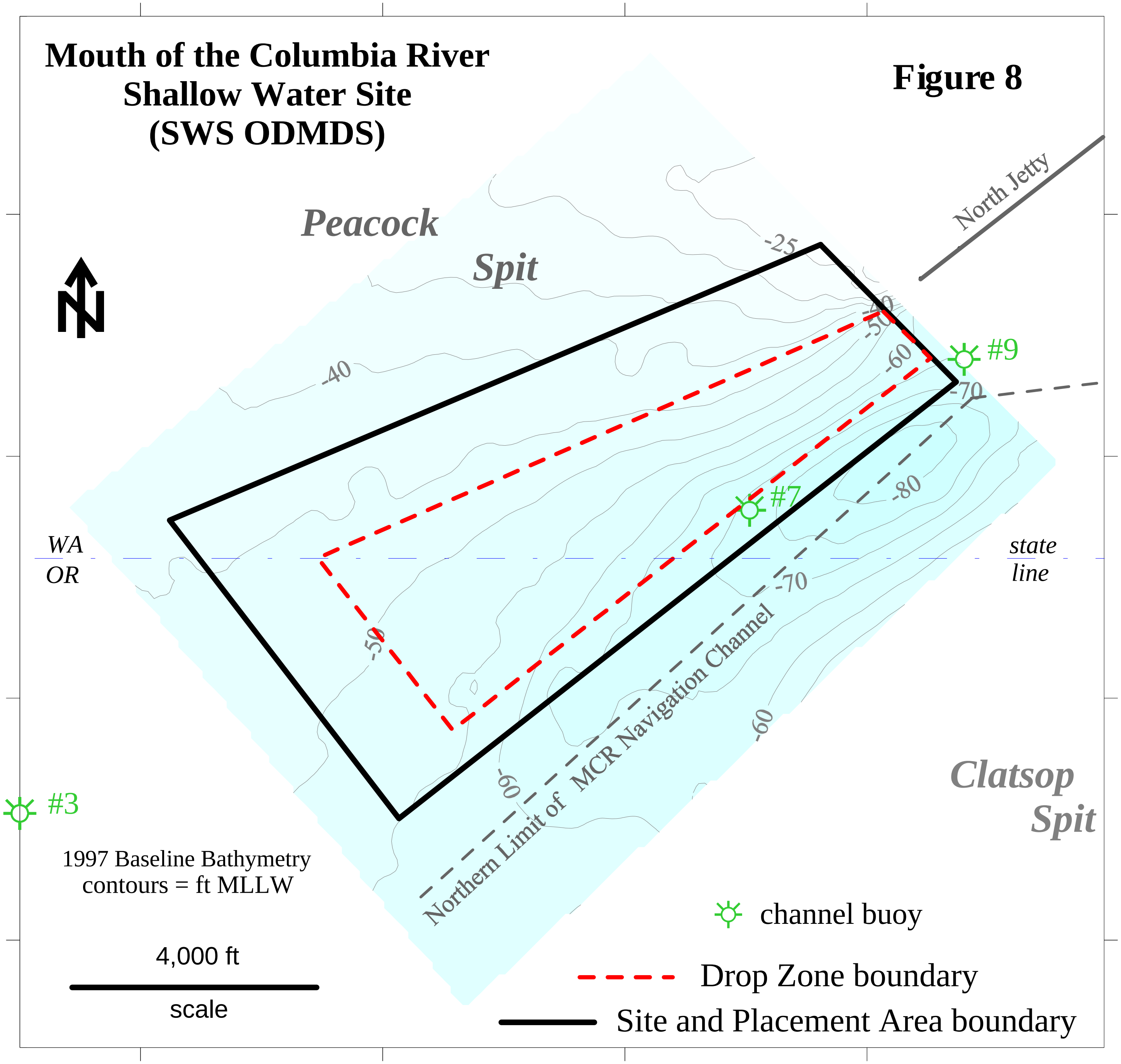
Site Management

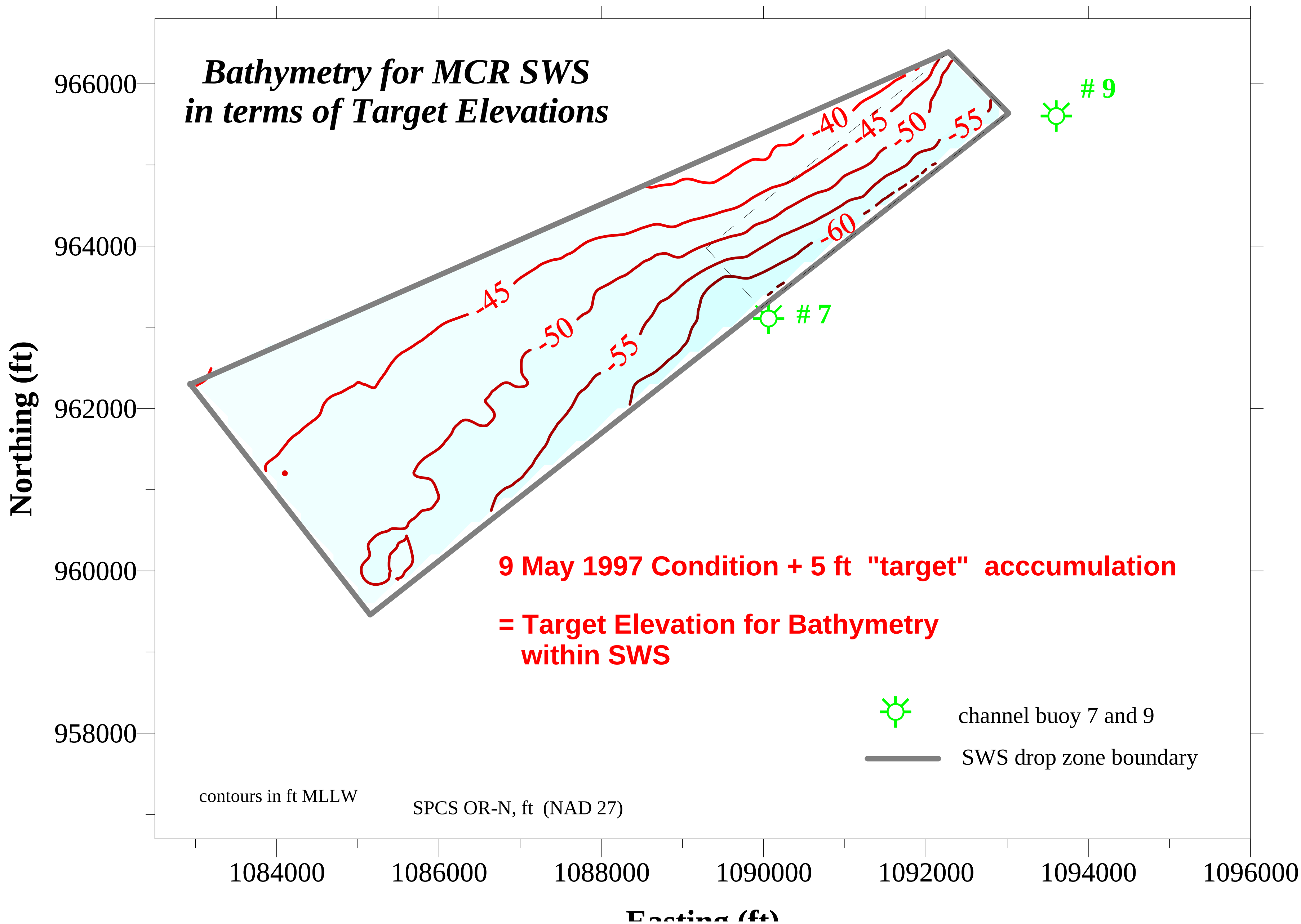
- Annual Use Plan prepared by the Corps and approved by USEPA
  - Information needed: size of contract hopper dredge, channel shoaling & disposal site capacity

- Placement priorities
  - Control mounding to avoid potential increases in wave height
  - Safe operation of hopper dredges & survey boats
  - Minimize impacts to marine resources
  - Minimize interference to other uses - commercial and recreational fishing & commercial navigation
  - Beneficial use of dredged material – Augment MCR Morphology and shoreland Sediment budget - protect of the North Jetty from undermining.

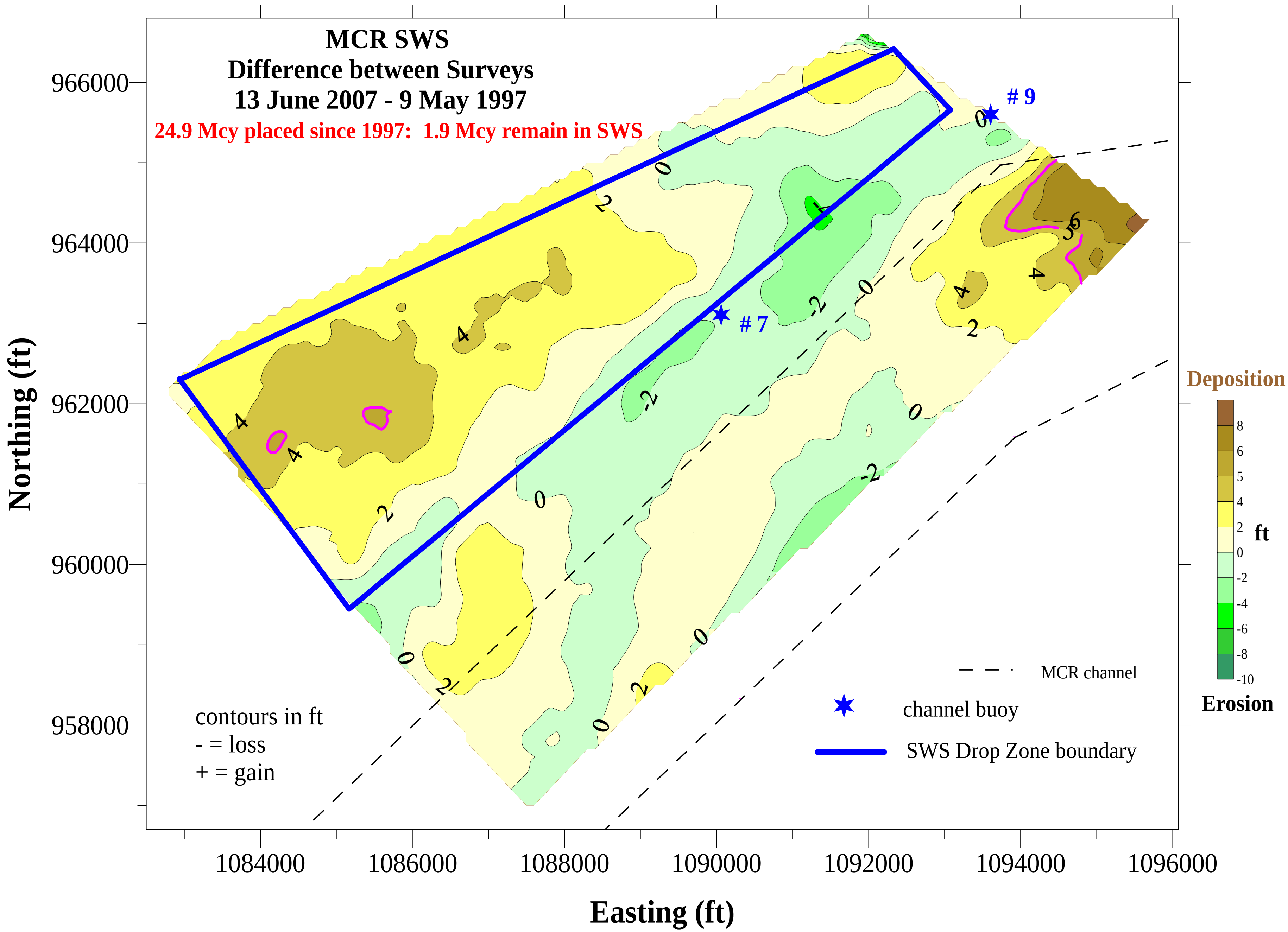
BASELINE CONDITION

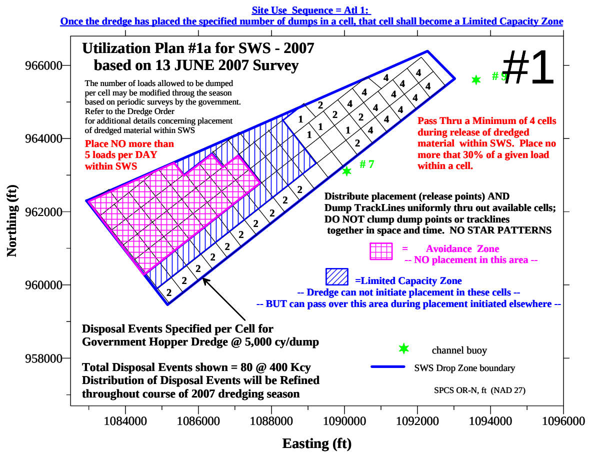


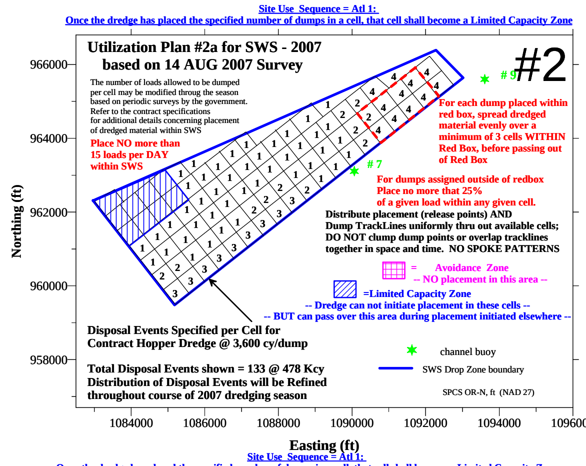
BASELINE CONDITION

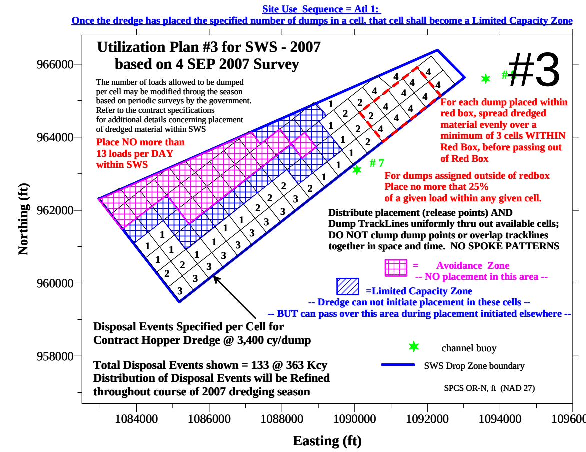


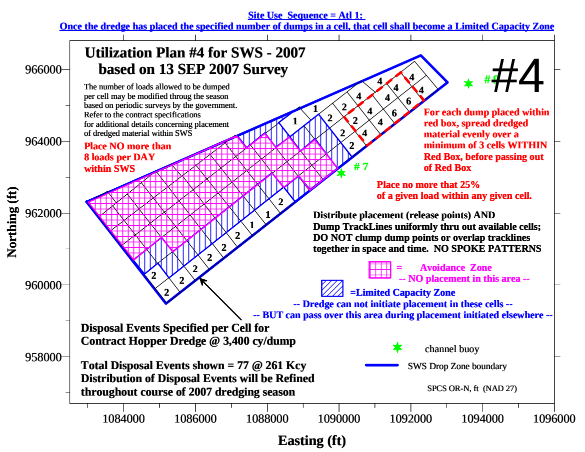
Bathymetry for MCR SWS
in terms of Target Elevations
966000
964000
962000
960000
958000
Northing (ft)
1084000
1086000
1088000
1090000
1092000
1094000
1096000
Easting (ft)
-40
-45
-50
-55
-60
9
7
9 May 1997 Condition + 5 ft "target" acccumulation
= Target Elevation for Bathymetry
within SWS
channel buoy 7 and 9
SWS drop zone boundary
contours in ft MLLW
SPCS OR-N, ft (NAD 27)

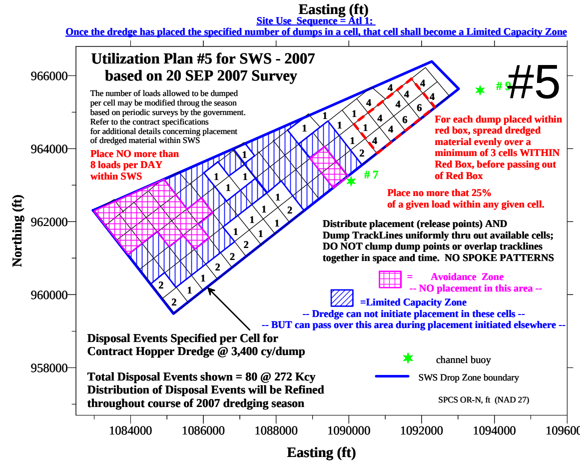

MCR SWS
Difference between Surveys
13 June 2007 - 9 May 1997
24.9 Mcy placed since 1997: 1.9 Mcy remain in SWS
9
7
contours in ft
- = loss
+ = gain
MCR channel
channel buoy
SWS Drop Zone boundary
Deposition
ft
Erosion
8
6
5
4
2
0
-2
-4
-6
-8
-10
966000
964000
962000
960000
958000
Northing (ft)
1084000
1086000
1088000
1090000
1092000
1094000
1096000
Easting (ft)

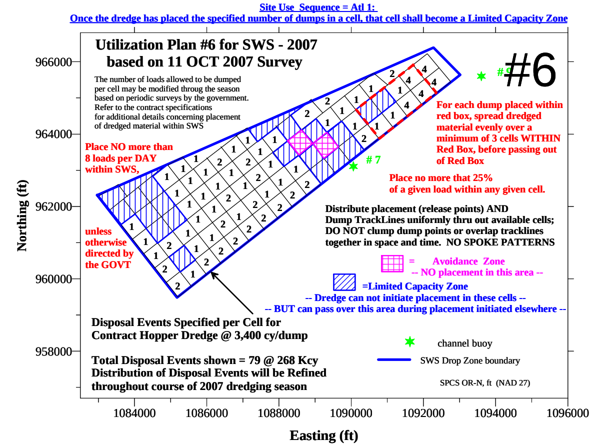


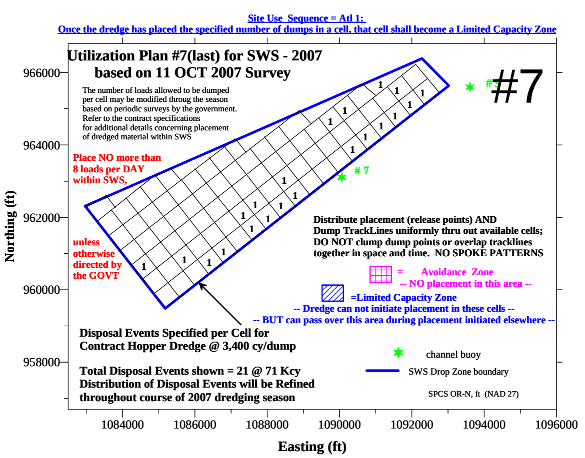




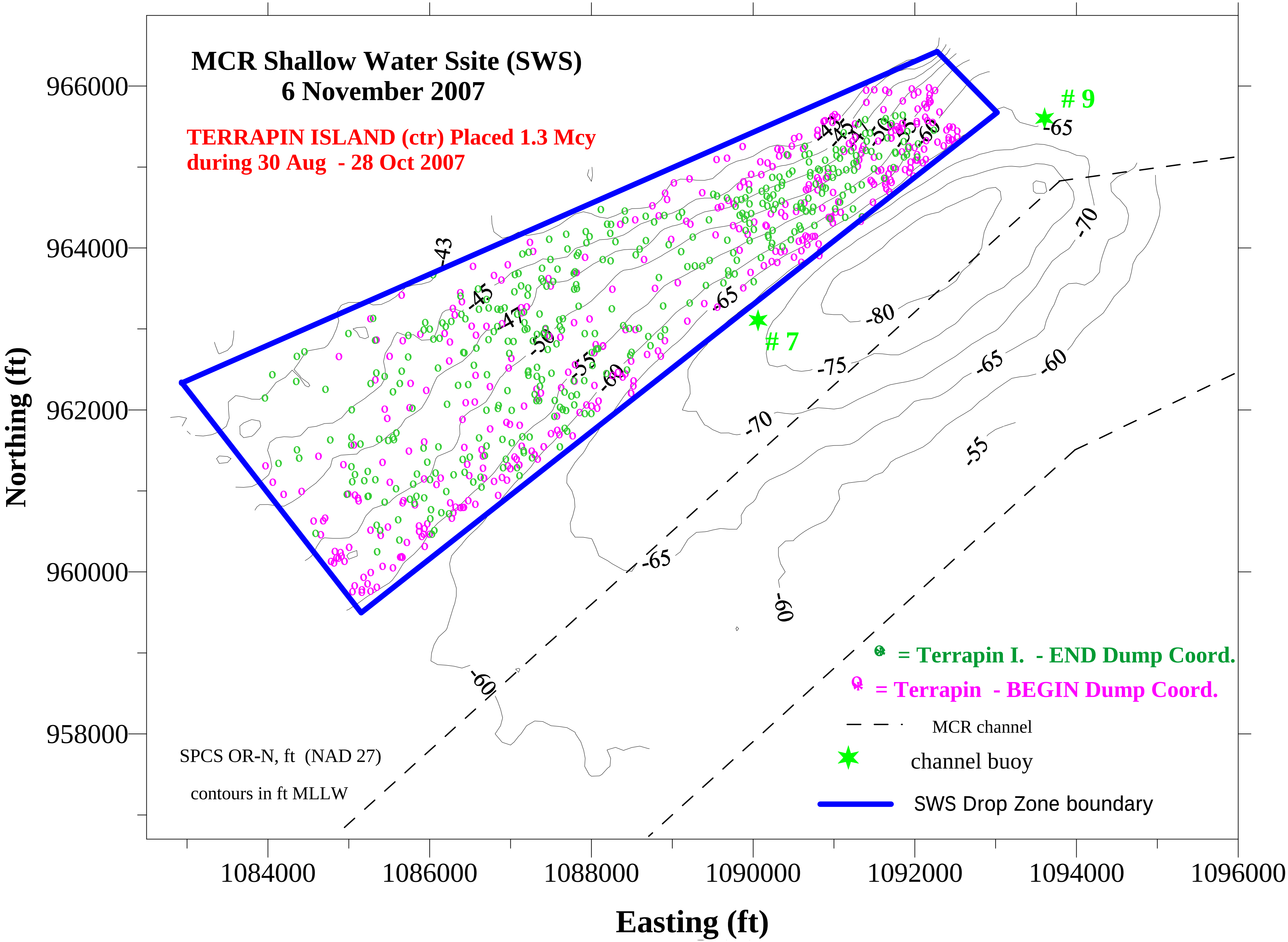




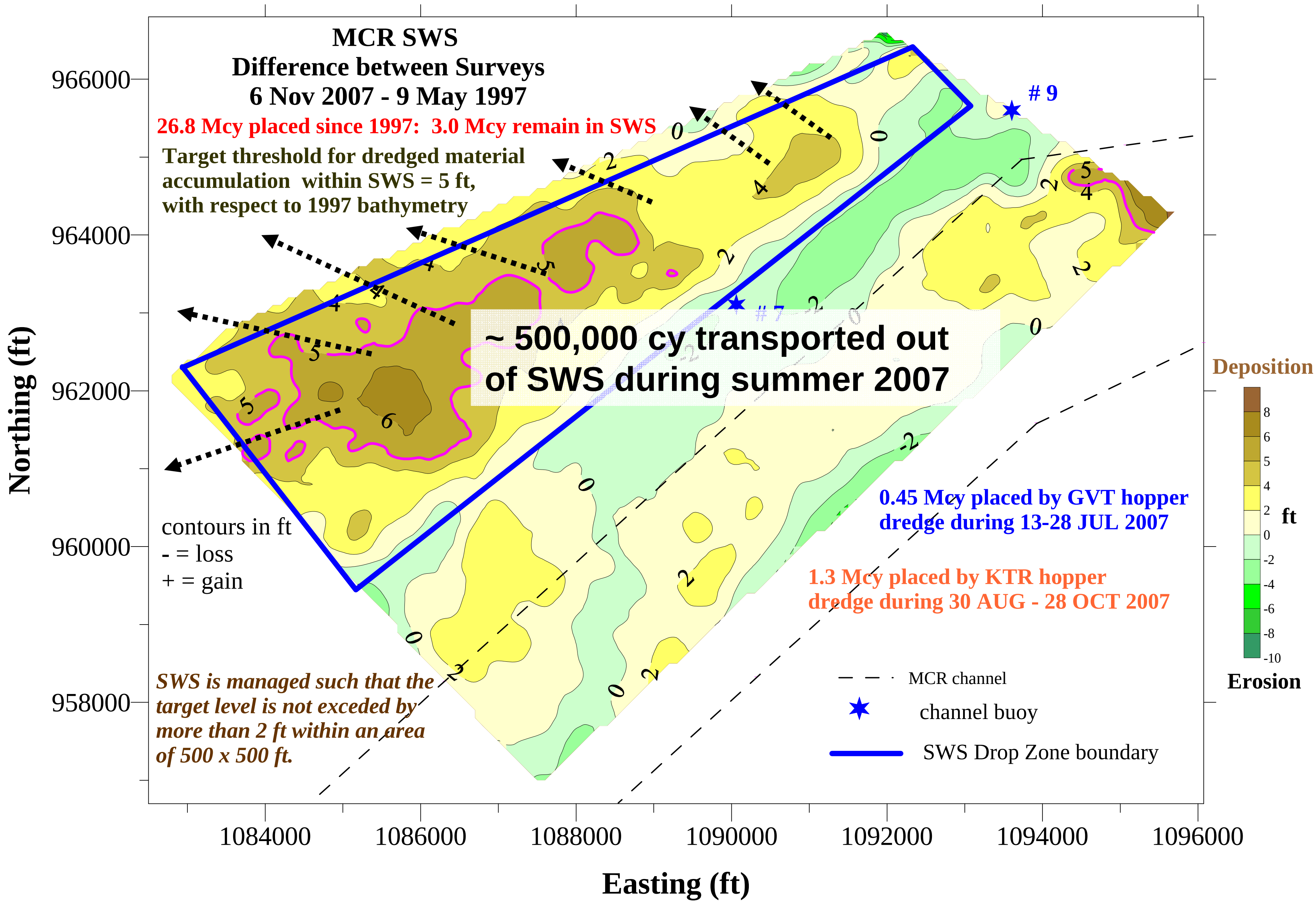


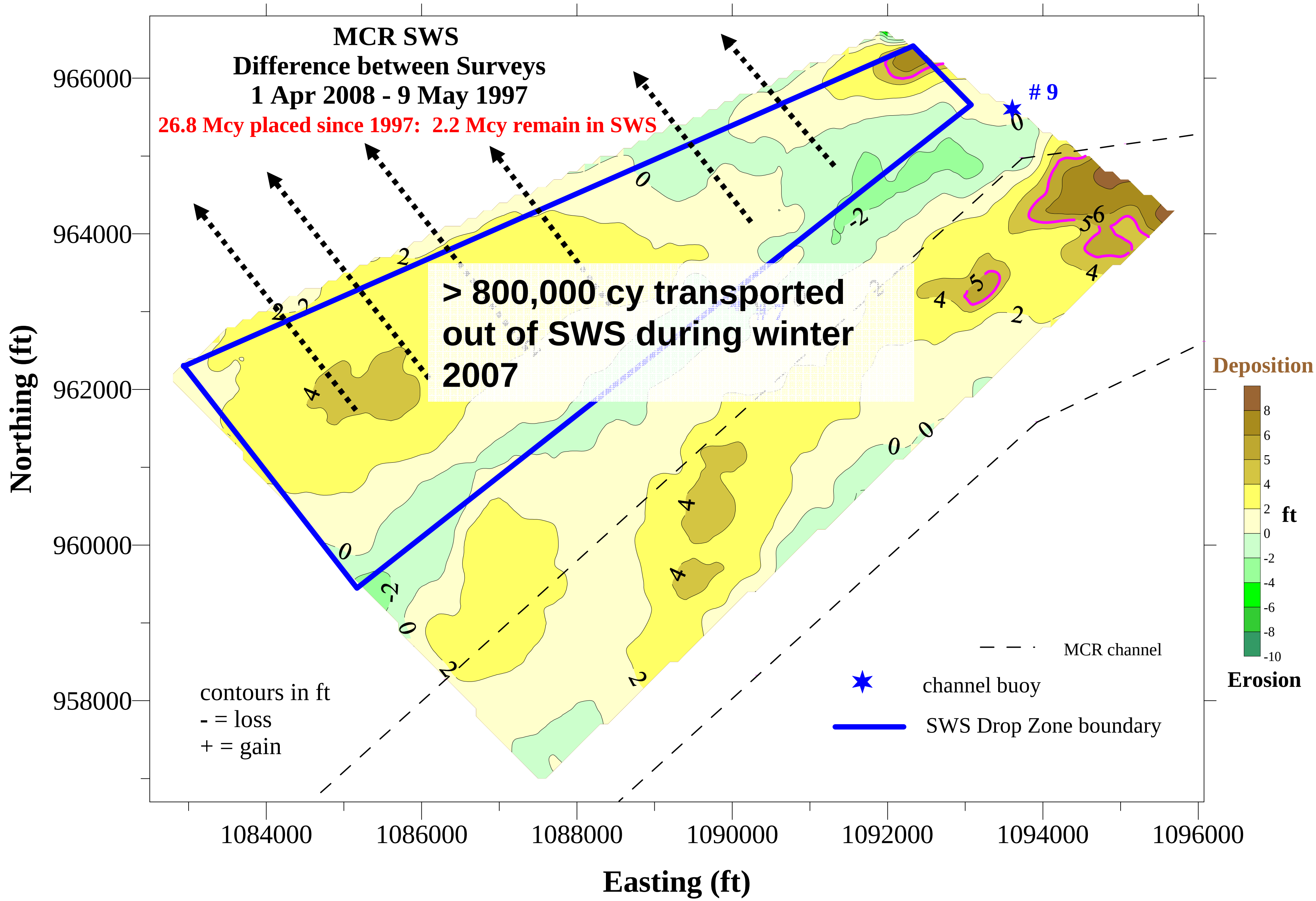


7 dump plans were used to guide dredged material placement within the SWS during 2007. Plan #1 applied to the government dredge for 424 K cubic yards, during 15 – 28 July. Plans #2-7 applied to the contract dredge for 1.3 M cubic yards during 30 Aug – 28 Oct.



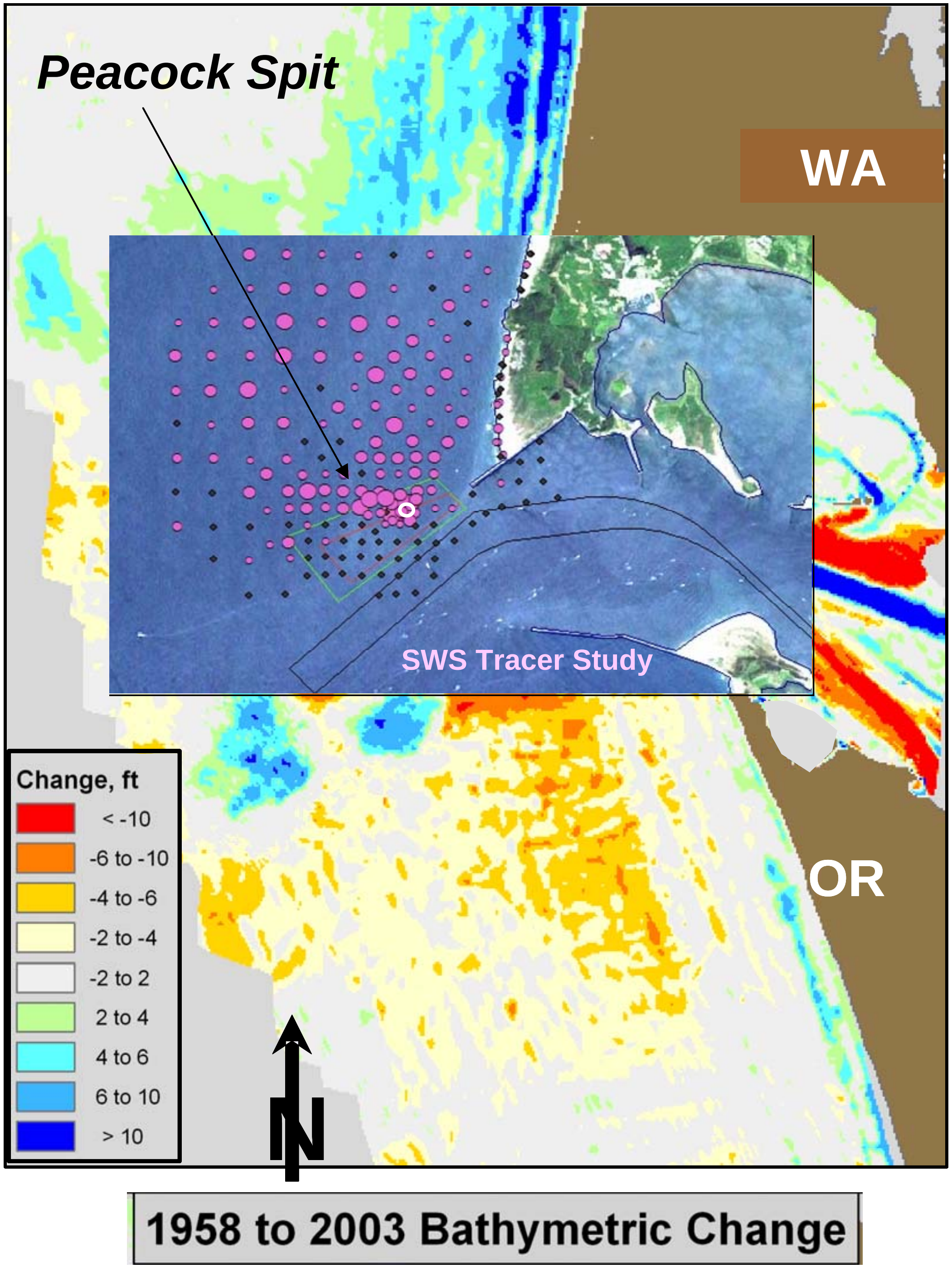
MCR Shallow Water Ssite (SWS)
6 November 2007
TERRAPIN ISLAND (ctr) Placed 1.3 Mcy
during 30 Aug - 28 Oct 2007
9
7
-43
-45
-47
-50
-55
-60
-65
-70
-75
-80
= Terrapin I. - END Dump Coord.
= Terrapin - BEGIN Dump Coord.
MCR channel
channel buoy
SWS Drop Zone boundary
SPCS OR-N, ft (NAD 27)
contours in ft MLLW
966000
964000
962000
960000
958000
1084000
1086000
1088000
1090000
1092000
1094000
1096000
Northing (ft)
Easting (ft)


MCR SWS
Difference between Surveys
6 Nov 2007 - 9 May 1997
26.8 Mcy placed since 1997: 3.0 Mcy remain in SWS
Target threshold for dredged material accumulation within SWS = 5 ft, with respect to 1997 bathymetry
~ 500,000 cy transported out of SWS during summer 2007
# 9
# 7
contours in ft
- = loss
+ = gain
0.45 Mcy placed by GVT hopper dredge during 13-28 JUL 2007
1.3 Mcy placed by KTR hopper dredge during 30 AUG - 28 OCT 2007
SWS is managed such that the target level is not exceded by more than 2 ft within an area of 500 x 500 ft.
MCR channel
channel buoy
SWS Drop Zone boundary
Deposition
Erosion
ft
8
6
5
4
2
0
-2
-4
-6
-8
-10
966000
964000
962000
960000
958000
1084000
1086000
1088000
1090000
1092000
1094000
1096000
Northing (ft)
Easting (ft)



MCR SWS
Difference between Surveys
1 Apr 2008 - 9 May 1997
26.8 Mcy placed since 1997: 2.2 Mcy remain in SWS
> 800,000 cy transported out of SWS during winter 2007
9
Deposition
ft
Erosion
MCR channel
channel buoy
SWS Drop Zone boundary
contours in ft
- = loss
+ = gain
Northing (ft)
Easting (ft)


Dredged Material Placement within SWS
1997-2008: 27 Million cy has been placed -----
2.5 M cy remain within SWS



Use of the SWS has reduced the rate of recession affecting Peacock Spit.

Sustain the Spits/shoals, and they will protect the jetties and inlet.

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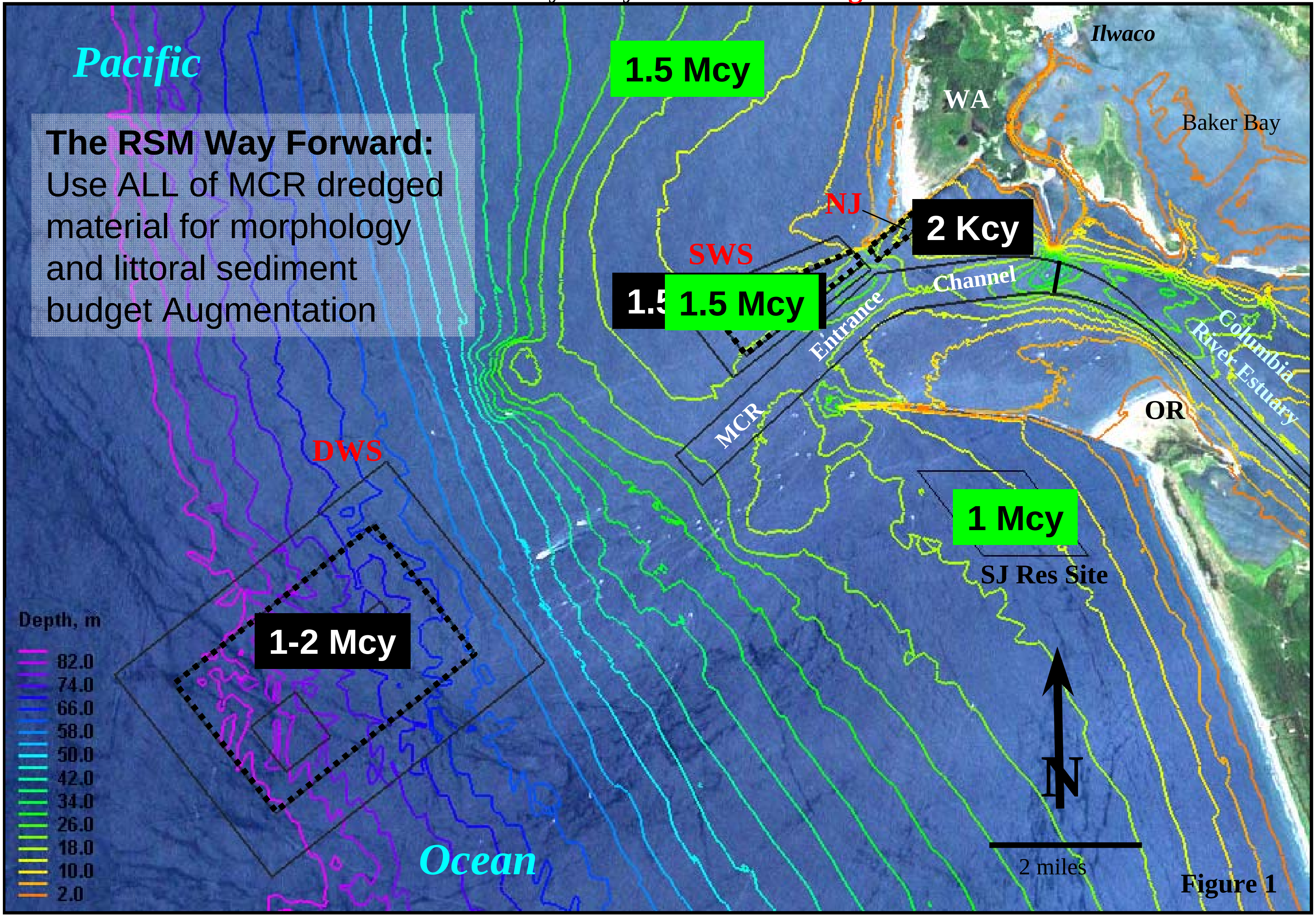
MCR Morphology Augmentation

- **We CAN we use sand dredged at MCR to "protect" the North Jetty and sustain the inlet:** **SWS has prevented lowering of Peacock Spit by 4-8 ft**

- **We CAN use sand dredged at MCR to augment the littoral Budget north of the inlet:** **12-25 Million cy introduced into littoral drift of WA since 1997 ---- 50-120% of material placed each year is transported out of SWS**

*** We CAN place MCR dredged sand in water depth of 40 - 60 ft depth and have positive impact on nearshore zone:** **Shown by Tracer Study and bathymetry change analysis.**

Mouth of the Columbia River - Bathymetry and 2007 Dredged Material Placement Sites



DWS= Deep Water Site, 102 MPRSA
SWS= Shallow Water Site, 102 MPRSA

NJ Site = North Jetty disposal site, 404 CWA

SJ Res. Site = South Jetty research site, restricted use by EPA permit

MCR Jetties *appear* to have performed well, based on past expenditures
-annualized maintenance has been less than 0.5% per year (DEFERRAL)

Present damage is too extensive and rate of degradation too high for Preventative Repairs

SHOAL AUGMENTATION NOT ENOUGH
-Institute *Major Rehabilitation* Evaluation

Major Rehabilitation Requires reliability-based analysis
- **Burns Harbor Breakwater Major Rehab Report (Chicago District)**

MAJOR REHAB Reports are NOT Easy to Complete – Requires dedicated multidisciplinary effort from a TEAM intimately familiar with the project of interest

Stochastic Reliability-based Life Cycle Simulation

Account for Non-Stationary Processes & Responses Affecting Structure Performance

Define Initial Conditions (Hindcast or Forecast)

Discretize Structure into 100 ft segments
Structure geometry and Design parameters – spatially variable
Shoreline Position – on each side of structure
Toe Elevation – spatially variable
Wave Forcing – spatially variable
Structure Damage Functions – variable based on sustained damage
Maintenance Strategy – Threshold based

Performance Modes are Addressed on each side of structure

Waves – Incident & Overtopping
Foundation / Toe Scour

Annually Accumulate Damages to Upper and Lower X-Section

– Adjust X-section geometry based on Damage; coupled to Performance modes
– Simulate Life-Cycle using Monte Carlo approach

- **Engineering Features** – Jetty Head, spurs, root stabilization
- **Rehab Alternatives** – Spatial variation and phased implementation
- **Maintenance Strategies** – Options

Stochastic Reliability-based Life Cycle Simulations

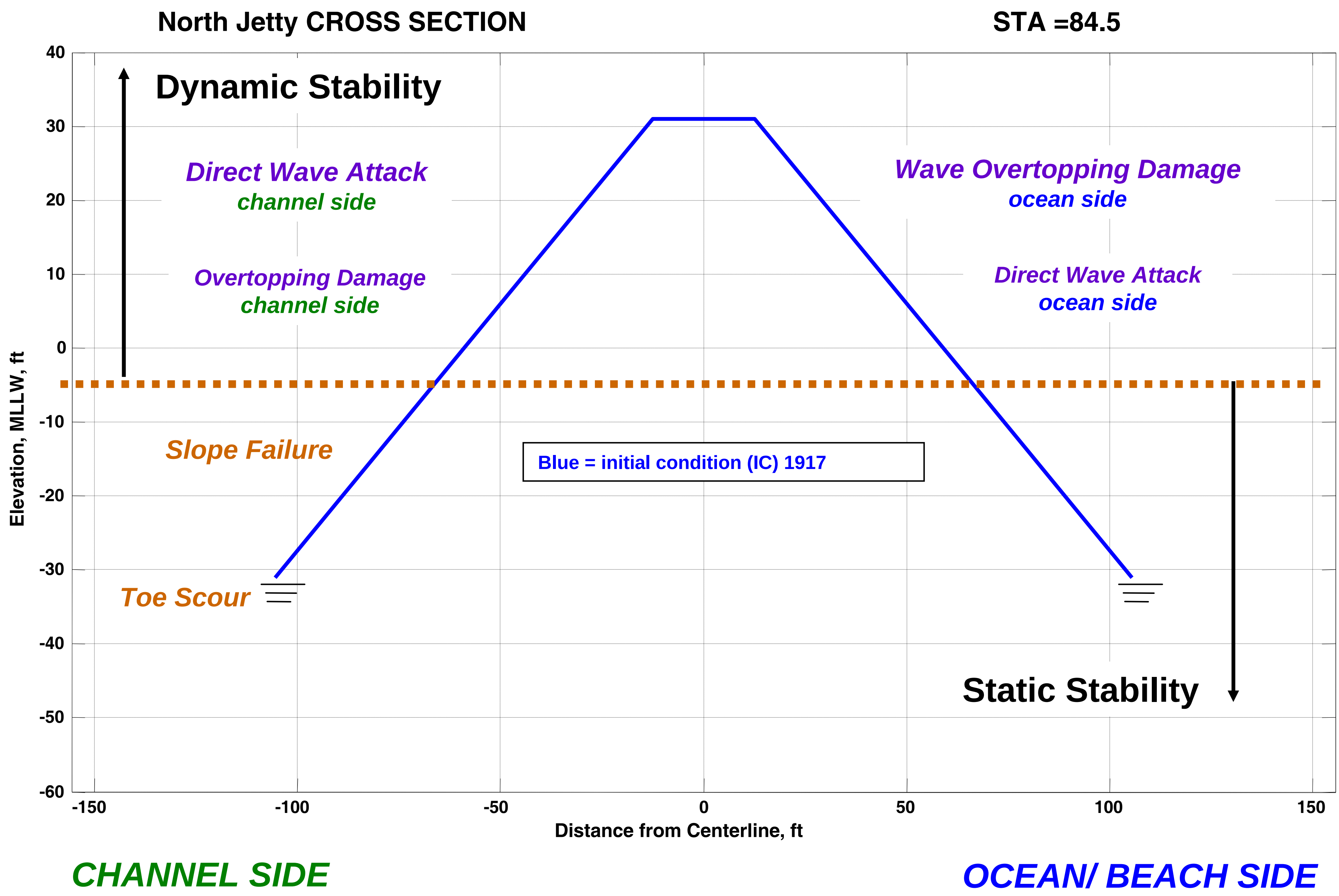
Model Application Steps

1) Simulate Structure's Previous Life-Cycle – <u>Hindcast</u>: Calibrate Model
– Model replicates observed life-cycle costs and timing & location of observed repairs

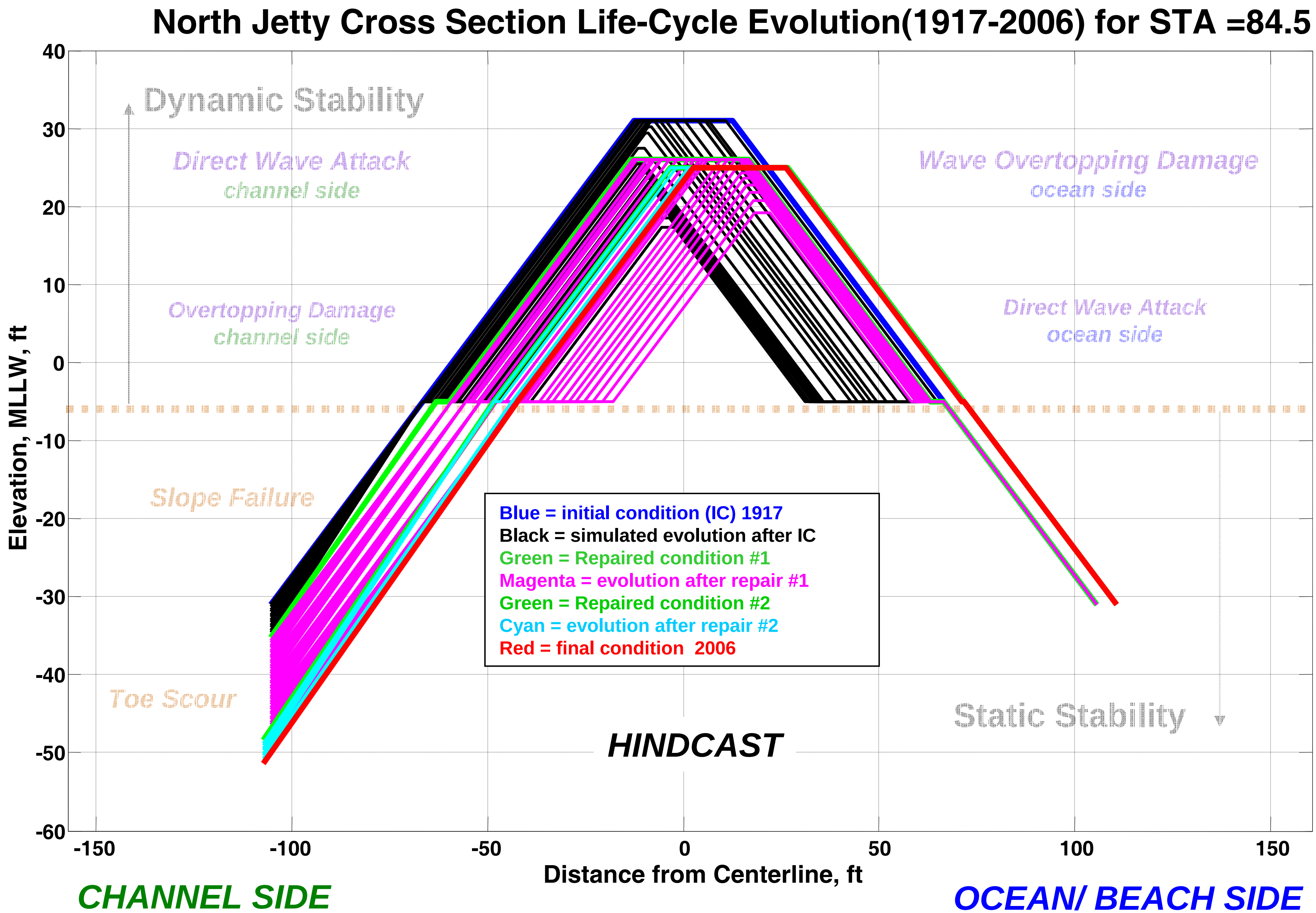
Key inputs = actual repair history; location, timing, frequency, and cost

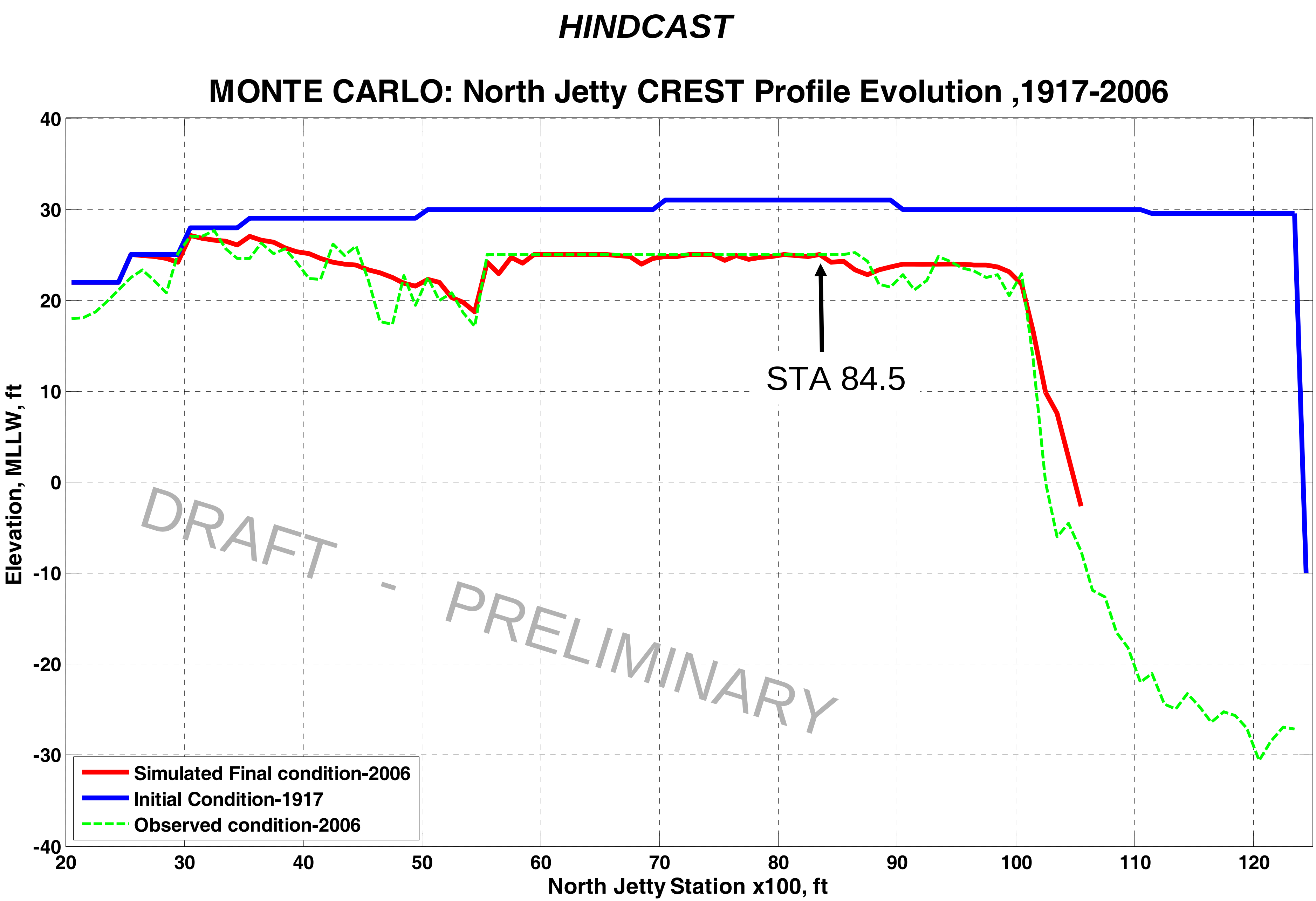
2) Simulate Future Life-Cycle – <u>Forecast</u>: Establish Base Condition
Evaluate potential maintenance scenarios
– Select the Base Condition which is most likely to be implemented in a "without project" framework

3) Simulate Future Life-Cycle – <u>Forecast</u>: Rehab Alternative Analysis
Evaluate alternatives by life cycle cost (monetized risk) and other metrics.
– Select the Rehab Alternative Which achieves best Life-Cycle performance

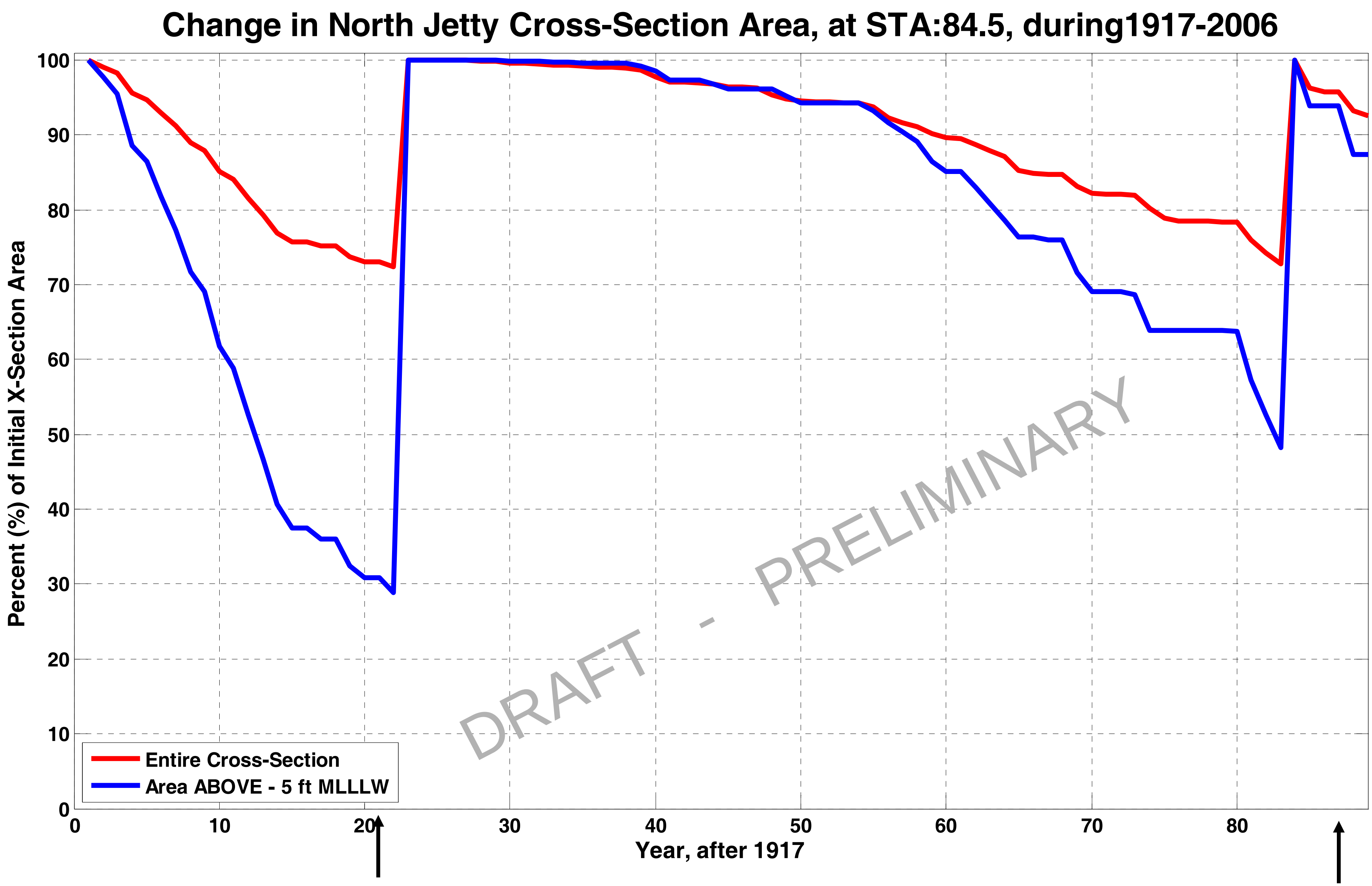


North Jetty CROSS SECTION
STA =84.5
Dynamic Stability
Direct Wave Attack
channel side
Overtopping Damage
channel side
Wave Overtopping Damage
ocean side
Direct Wave Attack
ocean side
Slope Failure
Blue = initial condition (IC) 1917
Toe Scour
Static Stability
40
30
20
10
0
-10
-20
-30
-40
-50
-60
Elevation, MLLW, ft
-150
-100
-50
0
50
100
150
Distance from Centerline, ft
CHANNEL SIDE
OCEAN/ BEACH SIDE


North Jetty Cross Section Life-Cycle Evolution(1917-2006) for STA =84.5
Dynamic Stability
Direct Wave Attack
channel side
Overtopping Damage
channel side
Wave Overtopping Damage
ocean side
Direct Wave Attack
ocean side
Slope Failure
Toe Scour
Static Stability
Blue = initial condition (IC) 1917
Black = simulated evolution after IC
Green = Repaired condition #1
Magenta = evolution after repair #1
Green = Repaired condition #2
Cyan = evolution after repair #2
Red = final condition 2006
HINDCAST
Elevation, MLLW, ft
Distance from Centerline, ft
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-150
-100
-50
0
50
100
150
CHANNEL SIDE
OCEAN/ BEACH SIDE

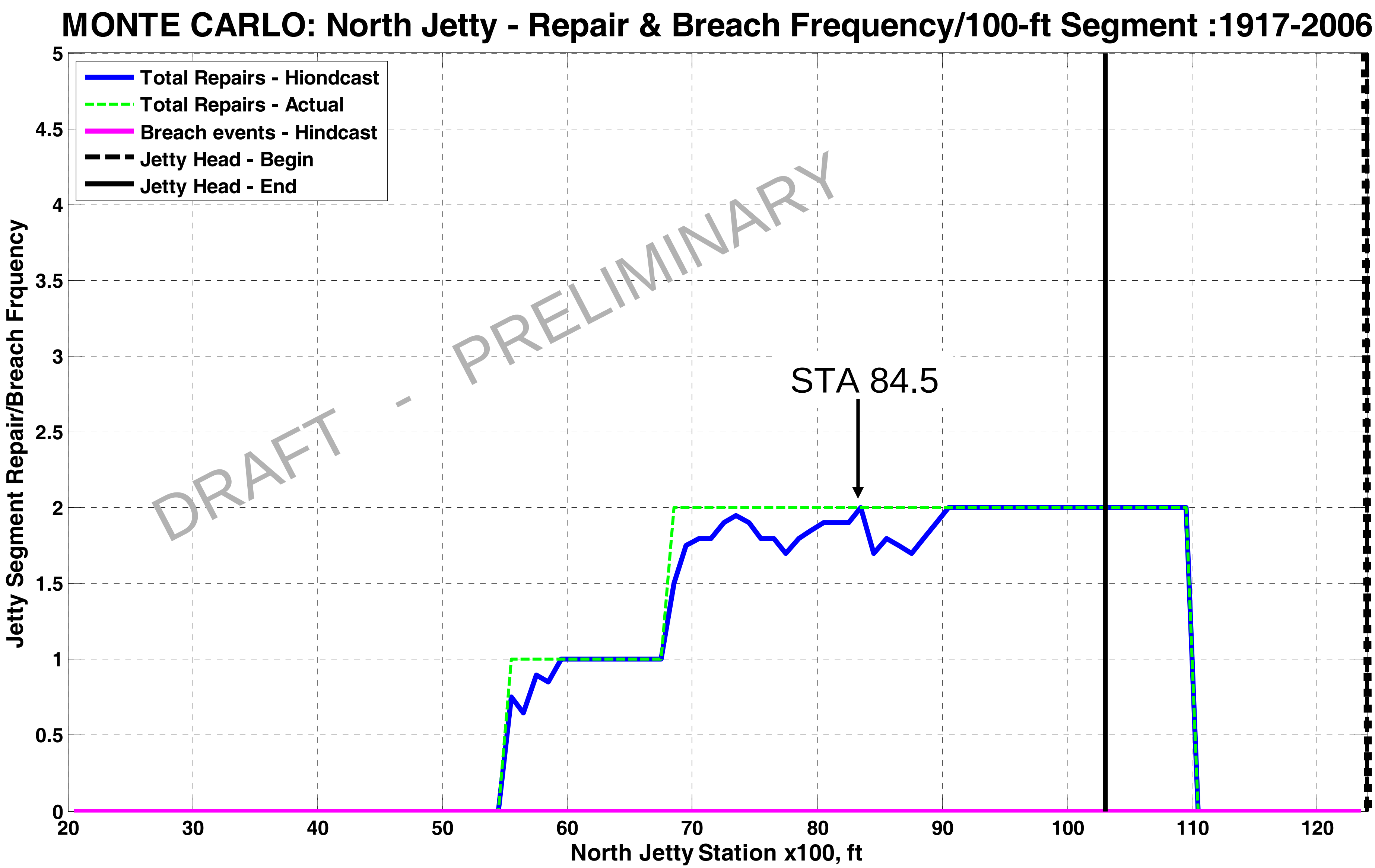

HINDCAST
MONTE CARLO: North Jetty CREST Profile Evolution ,1917-2006
Elevation, MLLW, ft
North Jetty Station x100, ft
STA 84.5
DRAFT - PRELIMINARY
Simulated Final condition-2006
Initial Condition-1917
Observed condition-2006
40
30
20
10
0
-10
-20
-30
-40
20
30
40
50
60
70
80
90
100
110
120

HINDCAST

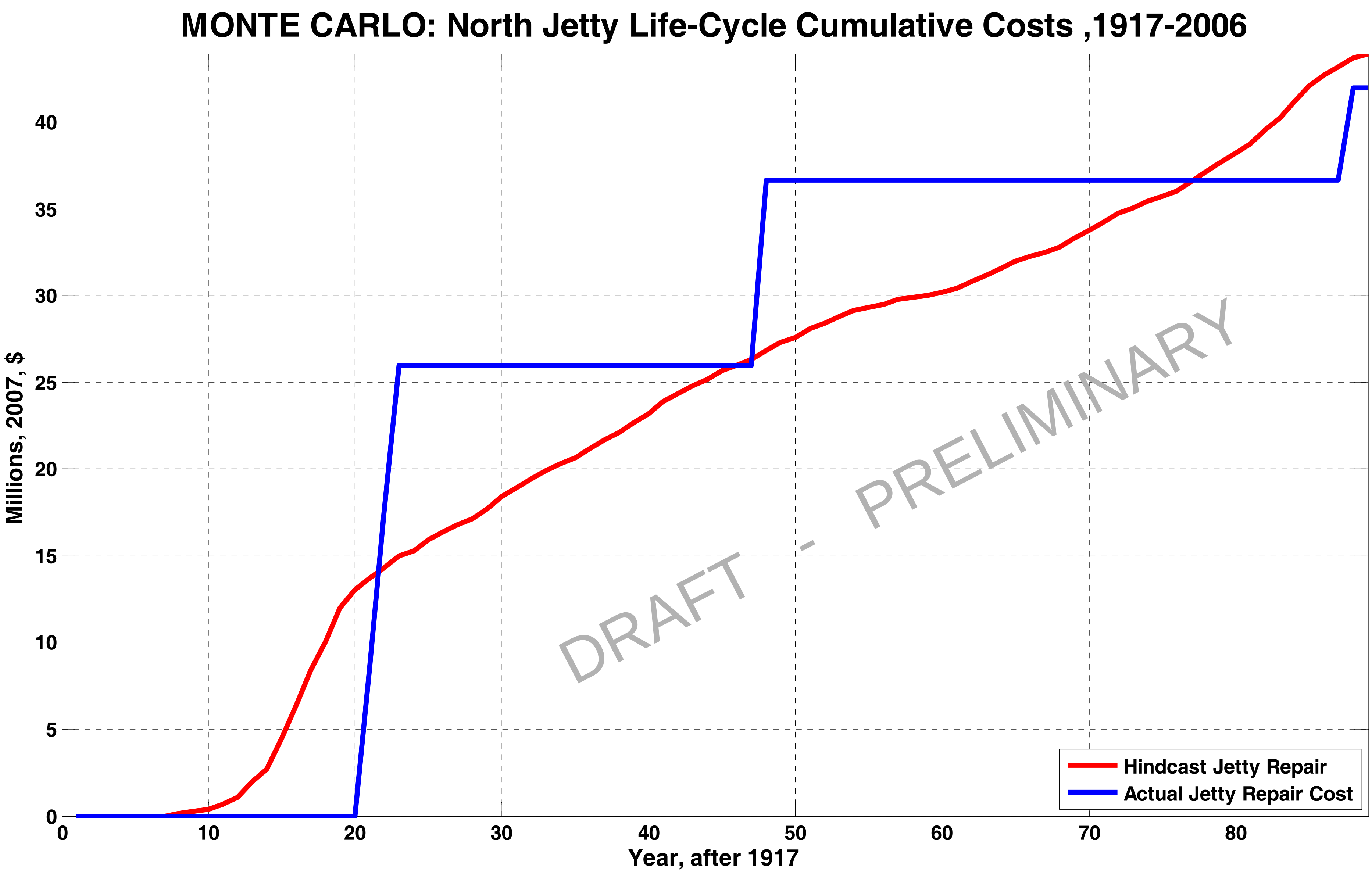


Change in North Jetty Cross-Section Area, at STA:84.5, during1917-2006
Percent (%) of Initial X-Section Area
Year, after 1917
0
10
20
30
40
50
60
70
80
90
100
Entire Cross-Section
Area ABOVE - 5 ft MLLLW
DRAFT - PRELIMINARY

HINDCAST

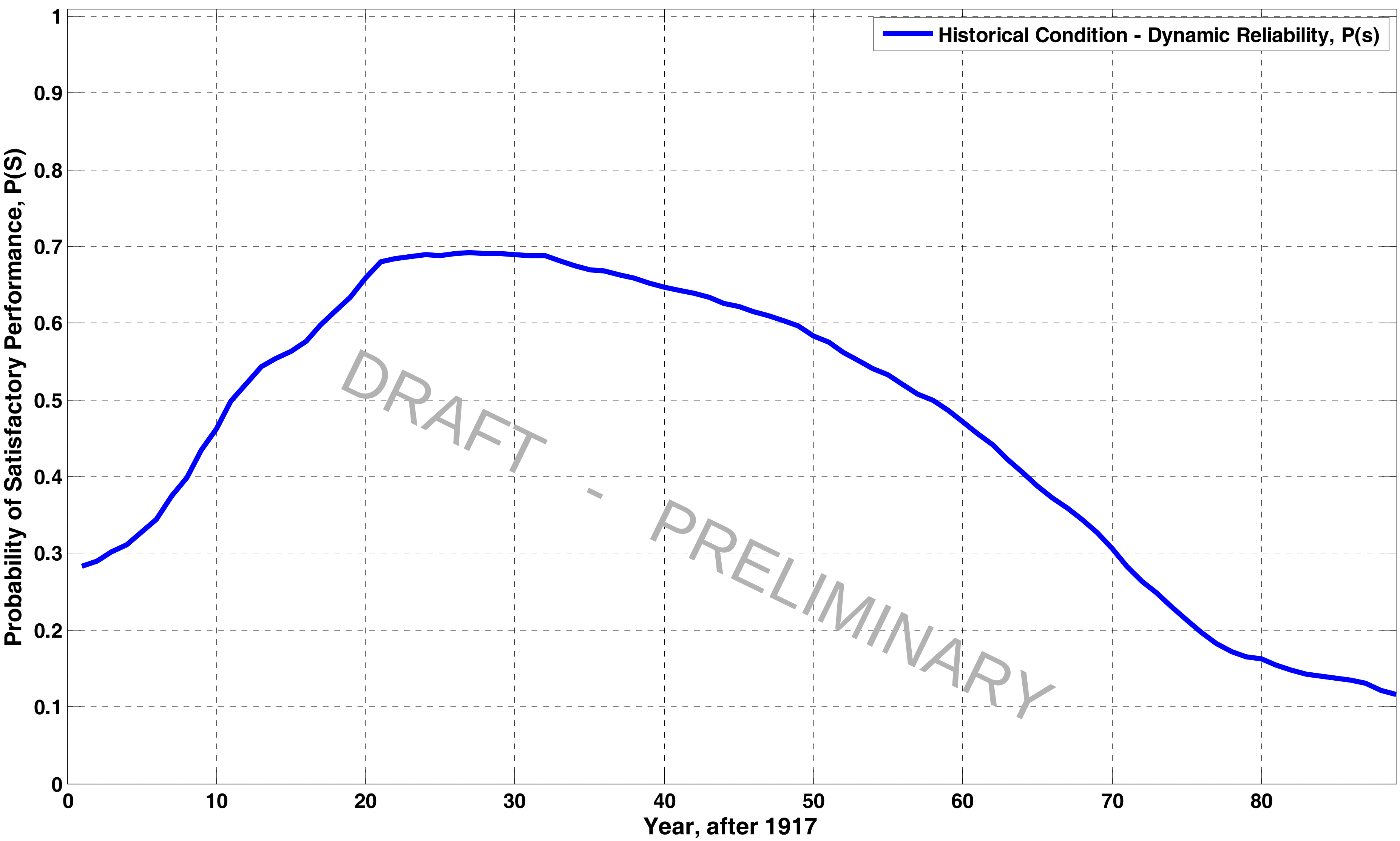

MONTE CARLO: North Jetty - Repair & Breach Frequency/100-ft Segment :1917-2006
Total Repairs - Hiondcast
Total Repairs - Actual
Breach events - Hindcast
Jetty Head - Begin
Jetty Head - End
DRAFT - PRELIMINARY
STA 84.5
Jetty Segment Repair/Breach Frquency
North Jetty Station x100, ft
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
20
30
40
50
60
70
80
90
100
110
120

HINDCAST

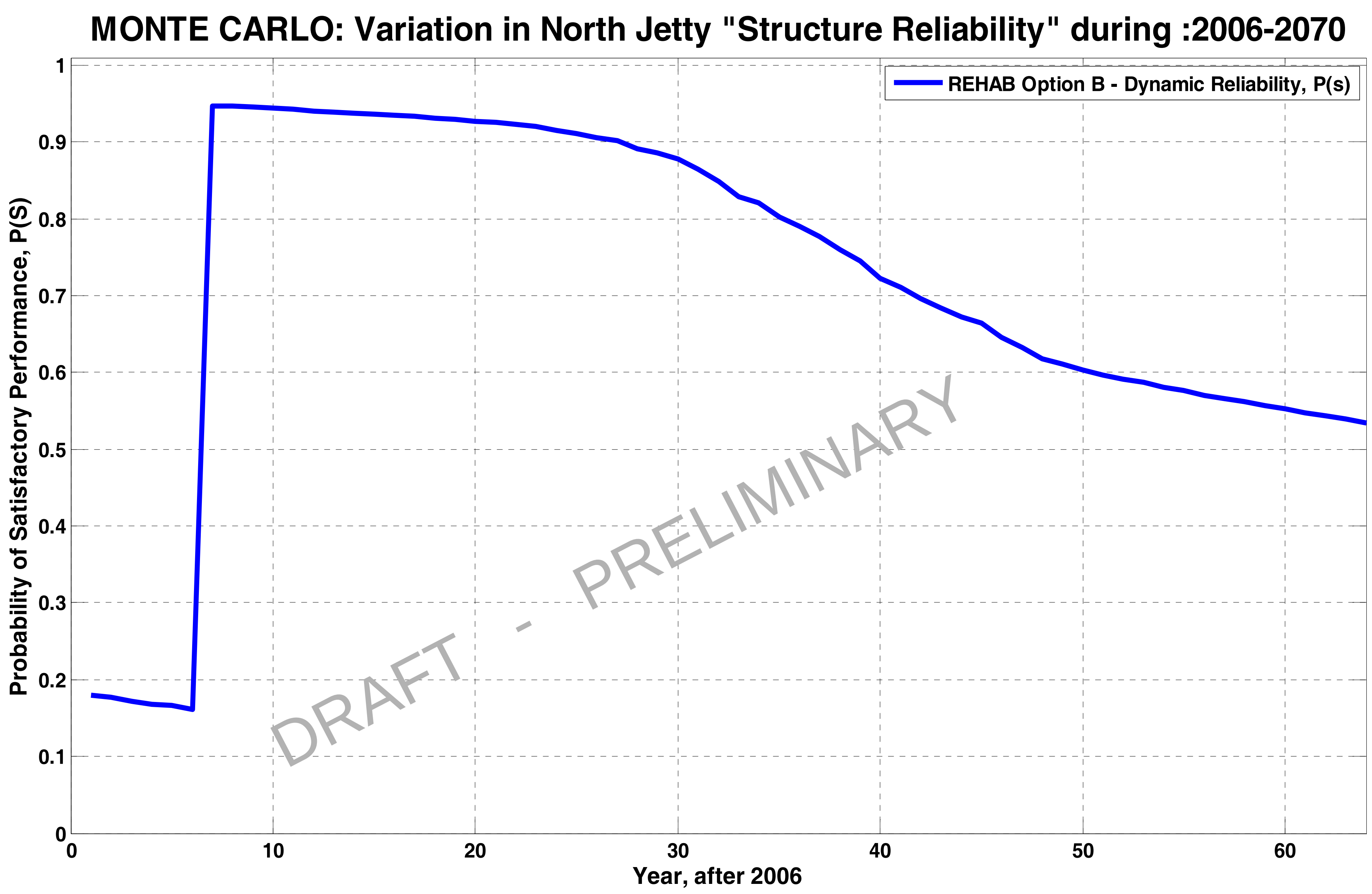

MONTE CARLO: North Jetty Life-Cycle Cumulative Costs ,1917-2006
Millions, 2007, $
Year, after 1917
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
60
70
80
Hindcast Jetty Repair
Actual Jetty Repair Cost
DRAFT - PRELIMINARY

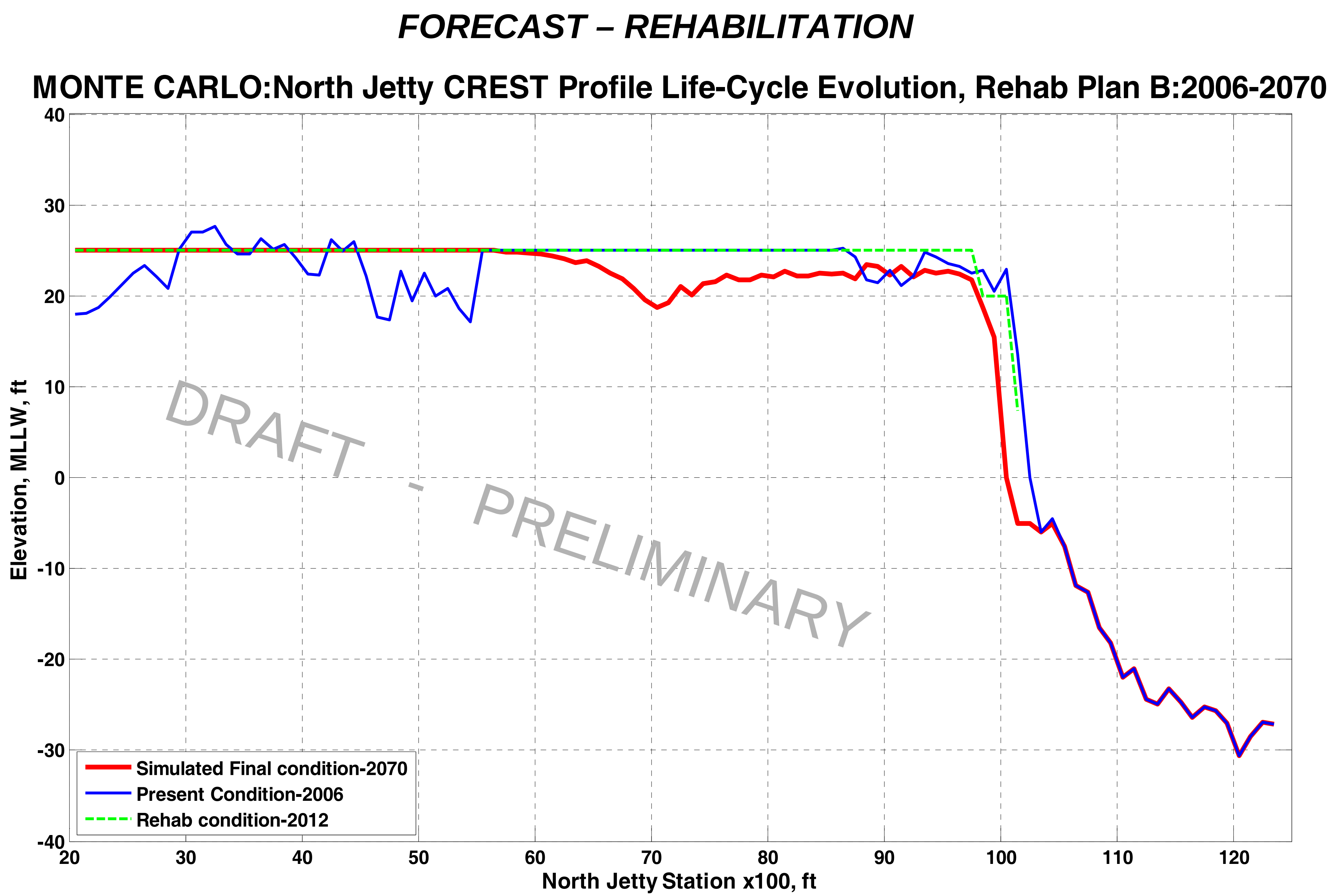
HINDCAST

MONTE CARLO: Variation in North Jetty "Structure Reliability" during :1917-2006



FORECAST – REHABILITATION




FORECAST – REHABILITATION
MONTE CARLO:North Jetty CREST Profile Life-Cycle Evolution, Rehab Plan B:2006-2070
Elevation, MLLW, ft
North Jetty Station x100, ft
40
30
20
10
0
-10
-20
-30
-40
20
30
40
50
60
70
80
90
100
110
120
Simulated Final condition-2070
Present Condition-2006
Rehab condition-2012
DRAFT - PRELIMINARY

Conclusions

Many coastal navigation structures have performed well, but are now in a condition of high vulnerability due to deferred maintenance.

High vulnerability leads to an uncertain future: Active Monitoring informs real-time risk management. Intervention options = fix as fails ⟶ systems based solutions.

Dredged material (sand) can be used to augment the sediment budget of eroding tidal shoals at Inlets: IMPROVE long term resiliency of the inlet's morphology and navigation infrastructure = RSM. May not address active jetty damage

Requires flexibility - adapt to environmental forcing, structure response, natural resource impacts, and stakeholder concerns.

Major Rehabilitation: restores a Structure's Life-Cycle and address system risk. Major Rehab requires a Stochastic Reliability-based Life Cycle Simulation to evaluate structures subjected to complex loading scenarios.

Match the Tool with the Task

Cumulative Observed Life-Cycle Investment Costs - Jetty