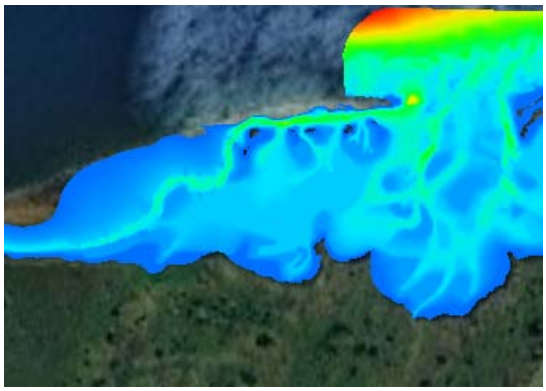

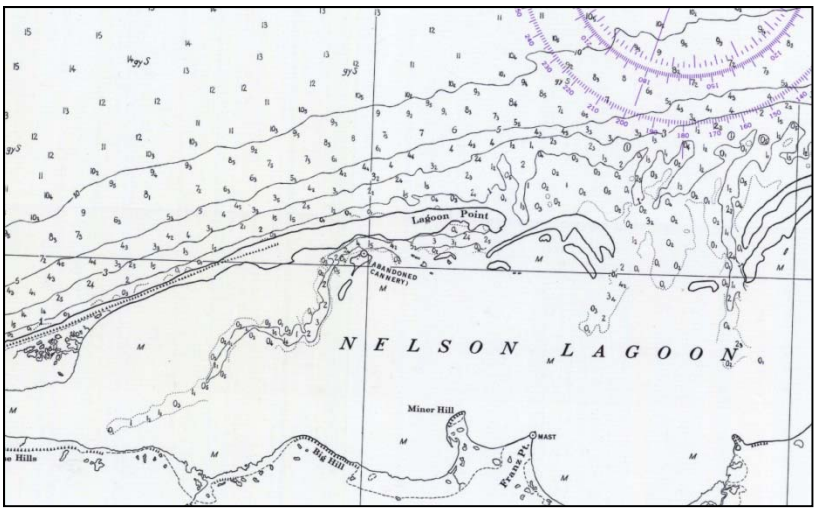

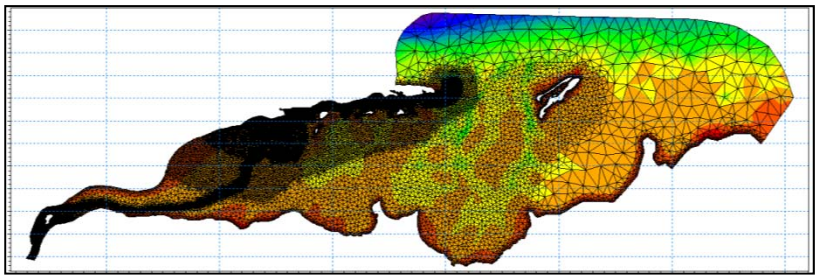

Nelson Lagoon Hazard Impact Assessment

Preliminary Numerical Modeling Addendum

Prepared For:

Aleutians East Borough

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Prepared By:

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April 2012

Acknowledgements

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Special thanks goes to the residents of Nelson Lagoon and the Aleutians East Borough for their assistance during the development of this assessment.

Nelson Lagoon Hazard Impact Assessment
Preliminary Model Addendum
April 2012

1 Introduction and Purpose

An engineering challenge at Nelson Lagoon is the overall lack of documented physical site information, along with limited confidence in identification and quantification of the primary erosion mechanisms. To support ongoing efforts to develop a shoreline protection system, a preliminary wind-wave and hydrodynamic numerical model was performed of the Nelson Lagoon water body, with a focus on the bay shoreline of the community of Nelson Lagoon. The purpose of this model was to provide an initial building block for subsequent more detailed modeling and associated design work for shoreline protection. The preliminary model can be thought of as a "rough draft" for subsequent modeling which will be improved through collection of field data, providing better accuracy and reliability for engineering design. To improve the model, field data to be collected include topography and bathymetry information, tidal current and wave measurements, and field verification of the model domain and physical boundary conditions. ***Note that the preliminary model developed as part of the current effort has not been calibrated or verified and should be used for qualitative purposes only.***

2 Summary of Results

The following are qualitative observations from the preliminary modeling. These observations may change as the model is improved with better field data. Actual model outputs have been provided as screen shots in Appendix A, "Spectral Wave Results," and Appendix B, "Hydrodynamic Results." Graphs and tables representing quantitative wave and current results at specific locations have not been included due to the preliminary nature of the model.

- Waves were modeled for windspeeds in excess of 68.7 mph. During windspeeds of this magnitude, waves nearshore to the community are depth-limited[1] and are highly dependent on water level/tide for two primary reasons: 1) deeper water allows larger waves to form and 2) low tide draws the shoreline far from the community and reduces the fetch significantly[2]. Under north winds, nearshore wave heights and potential for damage to the community are more severe during higher tides and storm surges.
- Tidal fluctuations transport large volumes of water in and out of Nelson Lagoon. However, stronger currents appear to be confined to the channel and not near the existing timber seawall, an area of significant concern to the community.
- The primary cause of erosion near the timber seawall is likely wave action, with tidal and storm currents playing lesser roles.
- Areas near the pier and airport runway appear to have potential for the largest waves compared to areas near residential area.

[1] Depth-limited refers to the height of a wave being limited by water depth.
[2] Fetch refers to the distance over water in which waves can develop.

3 Continued Work

As discussed previously, the preliminary model is an initial step towards design of a shoreline protection structure. The preliminary model has not been calibrated or verified and should not, at this level of development, be applied for design calculations. Additional effort is recommended to improve the model to a standard acceptable for design. The recommended additional steps are outlined below.

- *Obtain Updated Bathymetry* – The model domain/mesh was developed using limited available information such as historical nautical charts and inference of boundaries and shoals from aerial photographs. Model results are highly sensitive to bathymetry. Improved model accuracy requires accurate bathymetry. The shoreline near the community will require the most survey work. Spot elevations throughout Nelson Lagoon will also be required to gain a better understanding of the overall depths. With exception of the channel running through Nelson Lagoon (see Figure 1), there is no readily-available bathymetry within Nelson Lagoon.
- *Hydrodynamic Data* – Field collection of wave heights, water (tide) levels, and currents within Nelson Lagoon will be required to force, confidently calibrate, and verify the model.
- *Onsite Ground Truth of Domain* – Boundaries of the model domain were developed by inferring existing site conditions from aerial photography. An onsite ground truth of the boundaries would improve the overall domain. As an example of how ground truthing could improve the model domain, abrupt changes in grade are not always visible through aerial photography but are easily identified during a site visit. A gently-sloping shoreface should be modeled differently than a steep bluff.
- *Calibration/Verification* – After the above items have been completed, the model should be updated with the improved data and then calibrated and verified. After calibration and verification, the model could be applied to simulate a variety of design cases.

4 Model Description

The MIKE21 modeling software, developed by DHI, was applied to simulate wind wave development and water circulation (currents). Two modules of MIKE21 were used for the preliminary model, MIKE21 Spectral Wave (SW) model and MIKE21 Hydrodynamic (HD) model. Both modules utilized a flexible (unstructured) mesh. Models created with MIKE 21 SW can simulate wave growth, decay, and transformation of wind-generated waves and swell in offshore and coastal areas (DHI 2008). MIKE21 HD is generally applicable to the simulation of hydraulic and environmental phenomena in lakes, estuaries, bays, coastal areas and seas (DHI 2008).

5 Model Parameters

5.1 Model Domain

The wind-wave model and current model included the same model domain and utilized the same mesh. The model domain included a cursory approximation of Nelson Lagoon in its entirety as well as small portion of the Bering Sea. Figures 1 and 2 illustrate the model domain and mesh applied for the preliminary model.

Physical boundaries in the model were inferred from available aerial photography and were modeled as solid; water was not allowed to move through the boundaries. Bathymetry was inferred from National Oceanic and Atmospheric Administration Nautical Chart 8833 and available aerial photography. The resolution of the mesh was increased along the critical portion of the shoreline, the residental area to airport runway, to better resolve waves near the shoreline of interest. In addition, resolution was also increased within the channel running through the water body of Nelson Lagoon to better capture currents during the large tidal fluctuations.

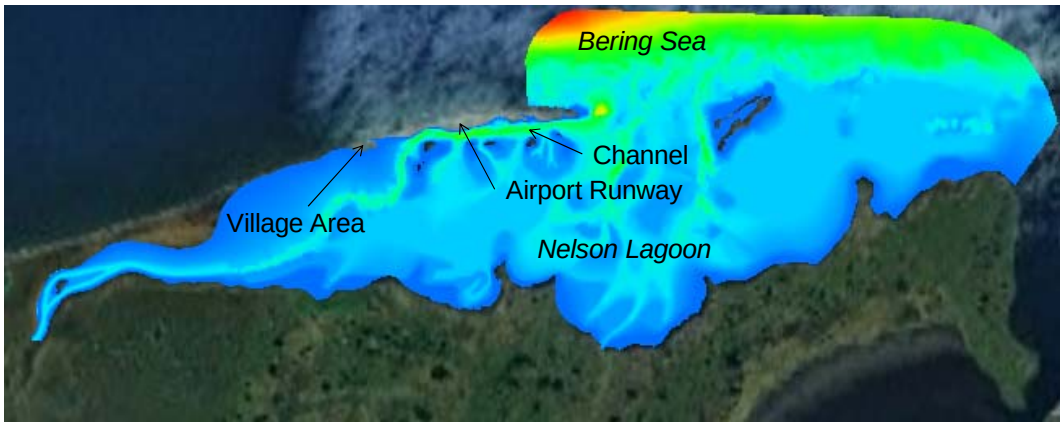
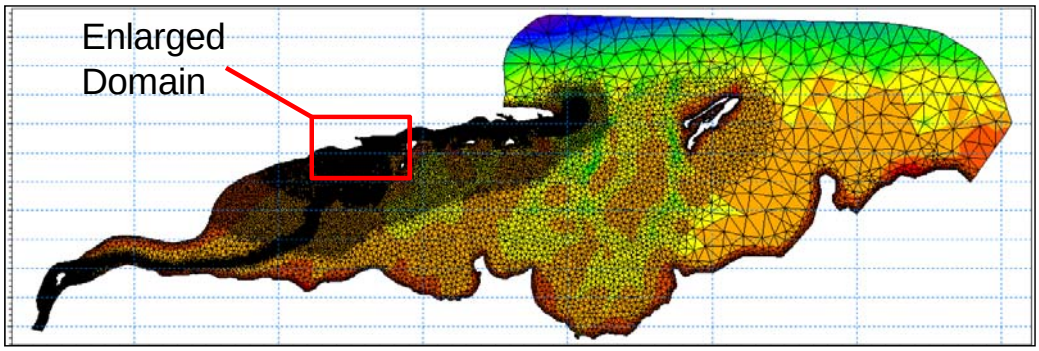
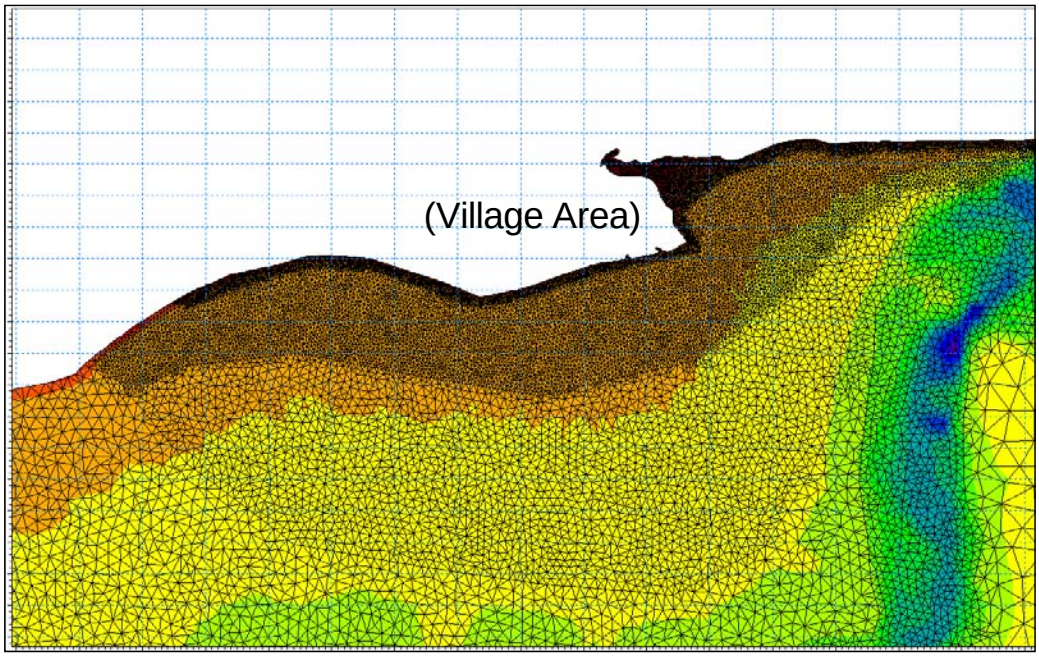


Figure 1. Model domain (same for both wave and current model)



Full Domain



Enlarged Domain

Figure 2. Preliminary model mesh. (Top) Full domain (Bottom) Enlarged domain near residental area

5.2 Wave Model Inputs

A 20-minute duration wind speed was modeled at 94.3 mph (42 m/s), 88.1 mph (39 m/s), 82.0 mph (36 m/s), 74.0 mph (33 m/s), and 68.7 mph (31 m/s) to match the 100-year, 50-year, 25-year, 10-year, and 5-year return period wind speeds (HDR 2011). For wave calculations, winds from directions likely to impact the critical portions of the shoreline (winds from the west to south to east – approximately 180 degrees) were considered for the analysis to better assess controlling wind directions. Water levels were also varied from 0 MLLW to +10 ft MLLW to assess sensitivity of wave heights to tide levels. In total, 1,155 model scenarios were run. Results shown in Appendix A only represent the most extreme cases (i.e. 100-year wind event, worst wind direction, etc.). Table 1 summarizes the range of input parameters that make up the various scenarios.

Table 1. Wave Model Input Parameters

Input Parameter	Range of Values Modeled	Interval
Wind Speed (mph)	68.7 to 94.3 mph (5 to 100-year return period)	Varied
Wind Direction (degrees)	85 to 175 degrees (clockwise from north)	5 - 10 degrees
Water Level (ft)	0 to 10 ft MLLW	1 ft

5.3 Hydrodynamic Model Inputs

The only forcing for the hydrodynamic model was fluctuation of the water level along the Bering Sea boundary. The fluctuating water level corresponded to the predicted tide at Port Moller from May 17, 2011 to May 22, 2011. A relatively large (spring) tide occurred during this time period. In addition, the reconnaissance site visit for the Hazard Impact Assessment occurred during this time period. Figure 3 is a plot of the predicted tide applied as the input parameter.

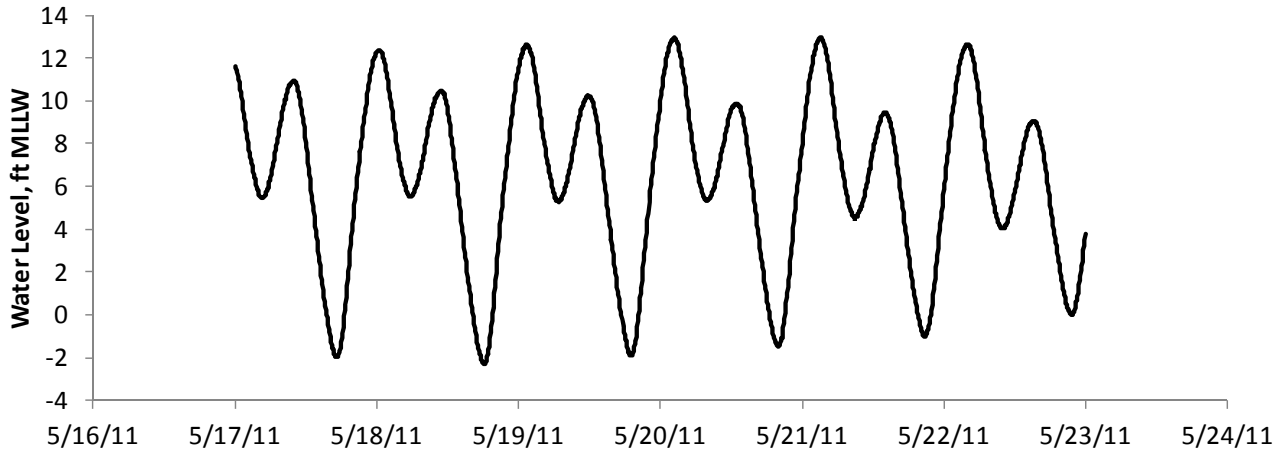


Figure 3. Water Level Input (Port Moller Predicted Tide 5/17 to 5/22/2011)

6 References

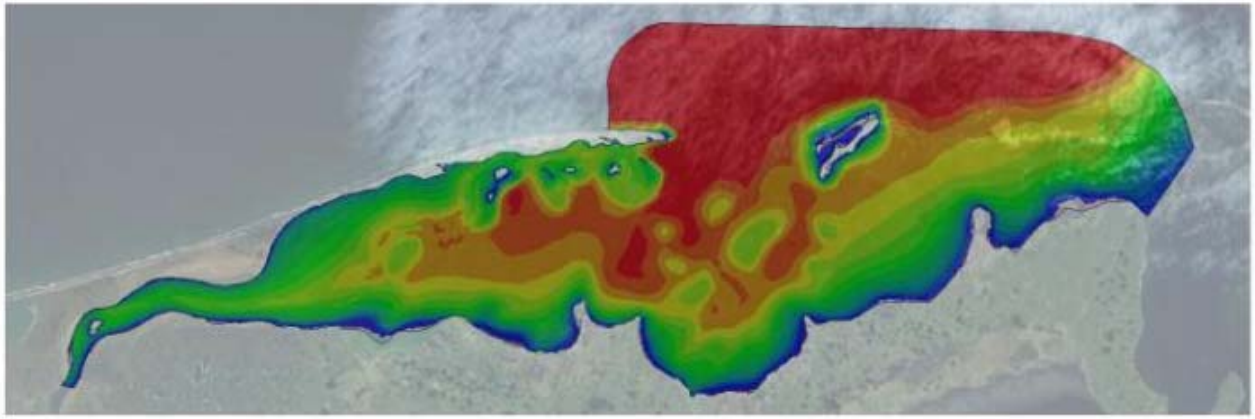
DHI (2008). MIKE 21 Flow Model FM Hydrodynamic Module and Spectral Wave Module User Guides, DHI Water and Environment, Denmark.

HDR (2011), Nelson Lagoon Hazard Impact Assessment, Anchorage, Alaska.

Appendix A

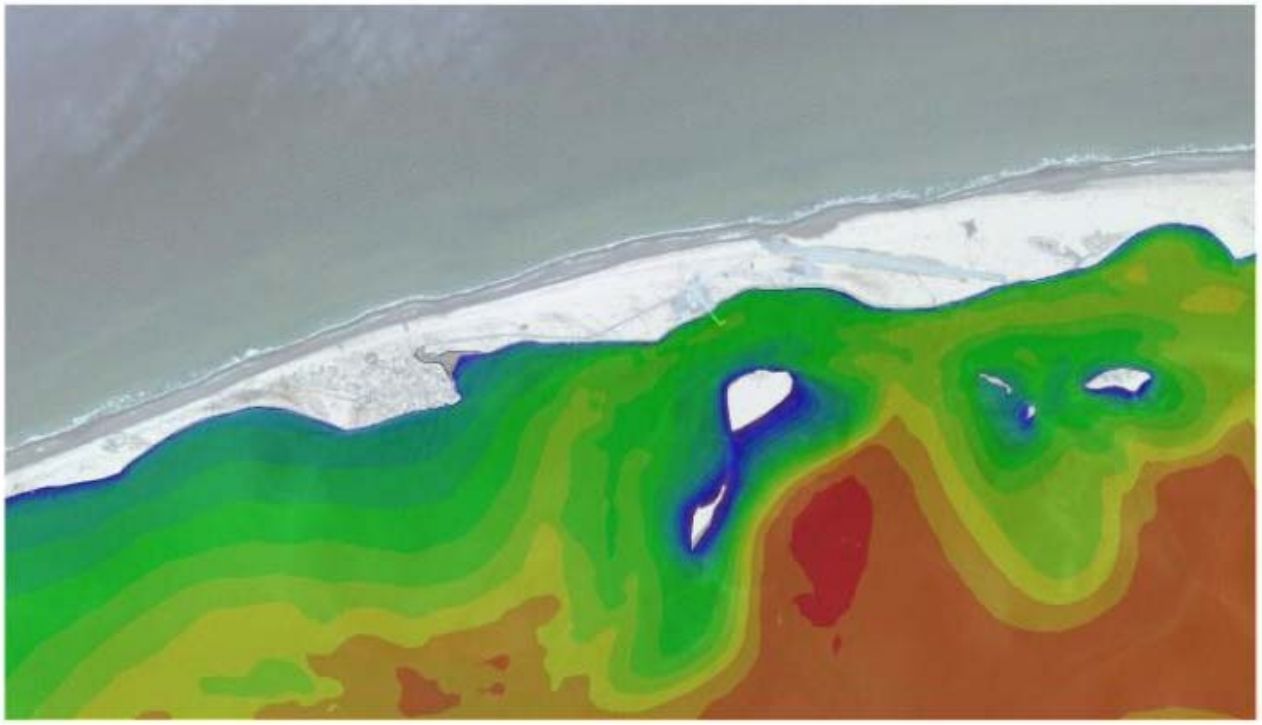
Spectral Wave Results

Varying Wind Speed

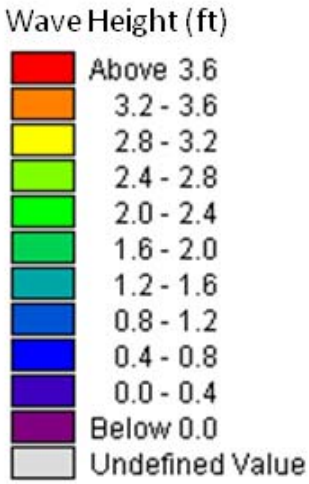


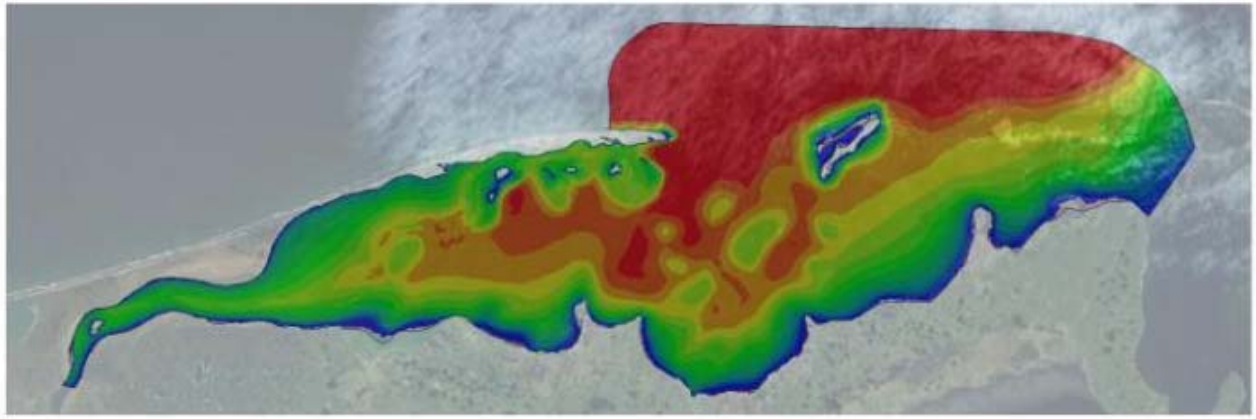
Wind Speed Return Period:
50 Year (88 mph)
Wind Direction:
130 degrees
Water Level:
+10 ft MLLW

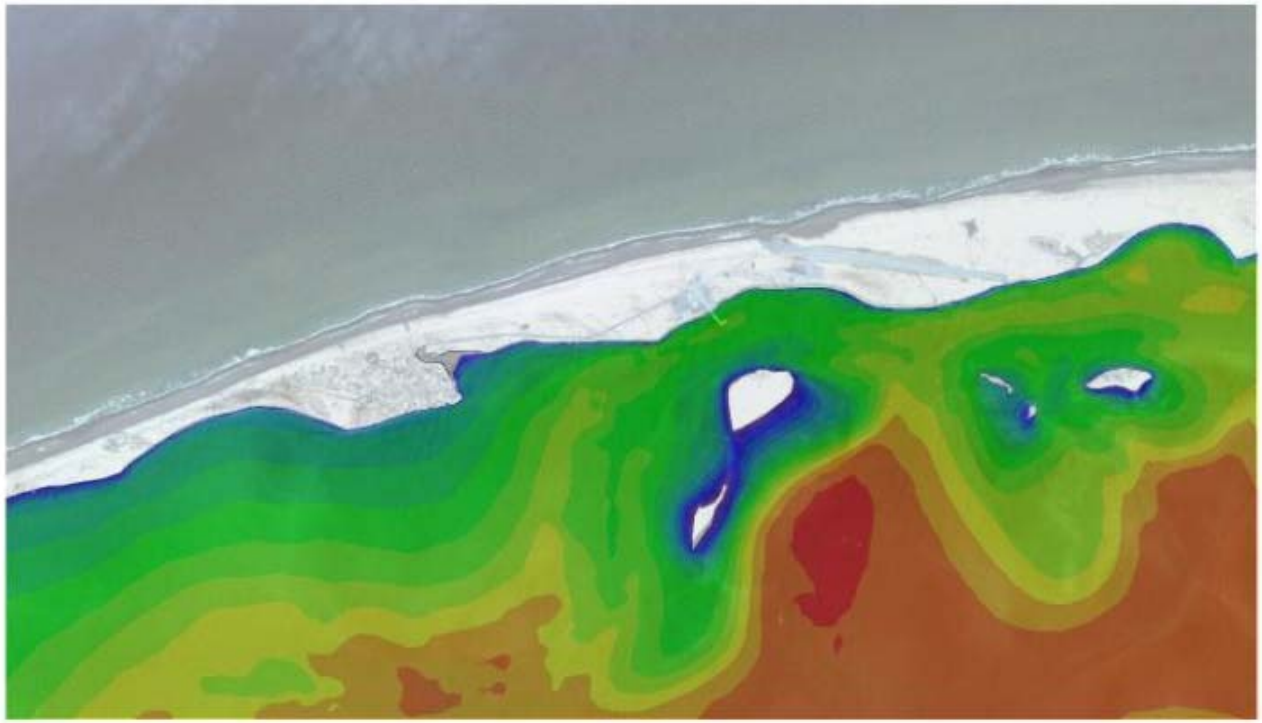
Top: Full Domain



Bottom: Enlarged Domain near community of Nelson Lagoon







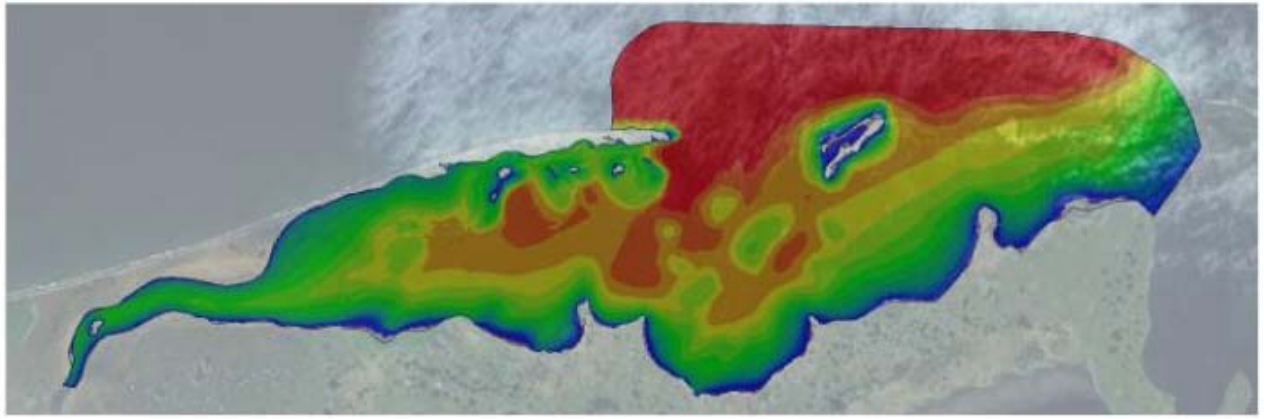
Wind Speed Return Period:
50 Year (88 mph)
Wind Direction:
130 degrees
Water Level:
+10 ft MLLW

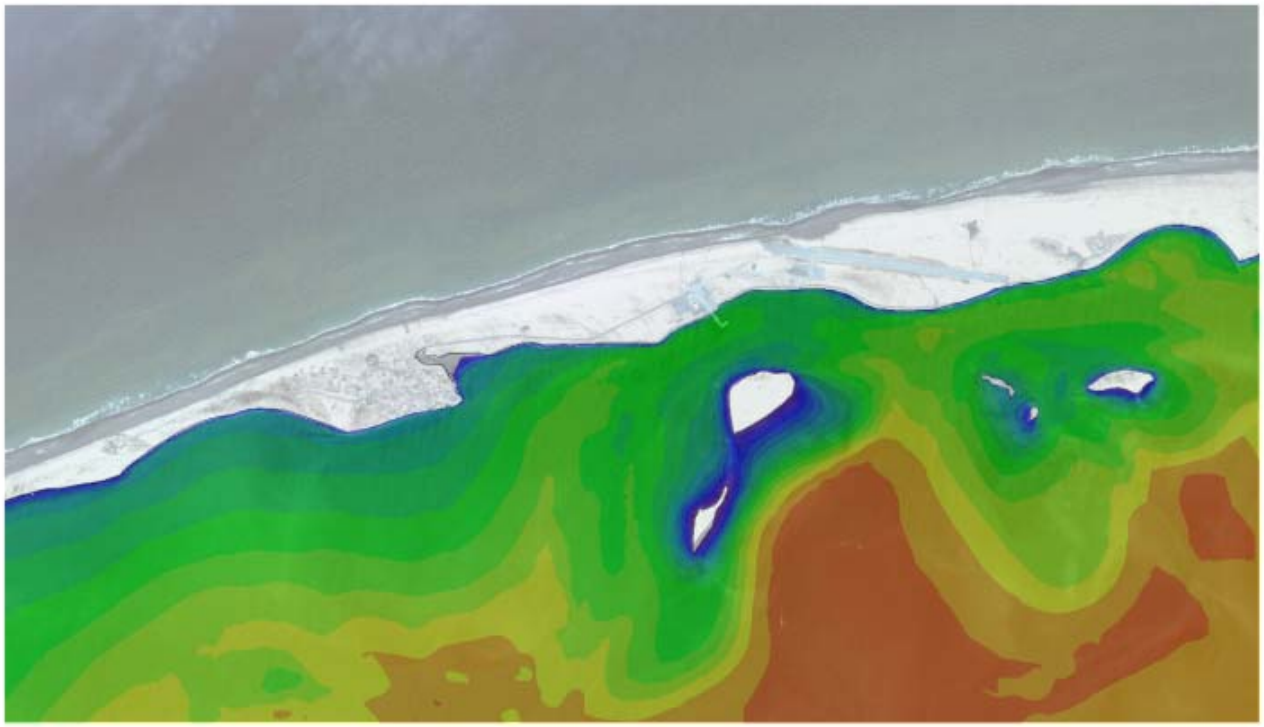
Top: Full Domain

Bottom: Enlarged Domain near community of Nelson Lagoon

Wave Height (ft)

- Above 3.6
- 3.2 - 3.6
- 2.8 - 3.2
- 2.4 - 2.8
- 2.0 - 2.4
- 1.6 - 2.0
- 1.2 - 1.6
- 0.8 - 1.2
- 0.4 - 0.8
- 0.0 - 0.4
- Below 0.0
- Undefined Value





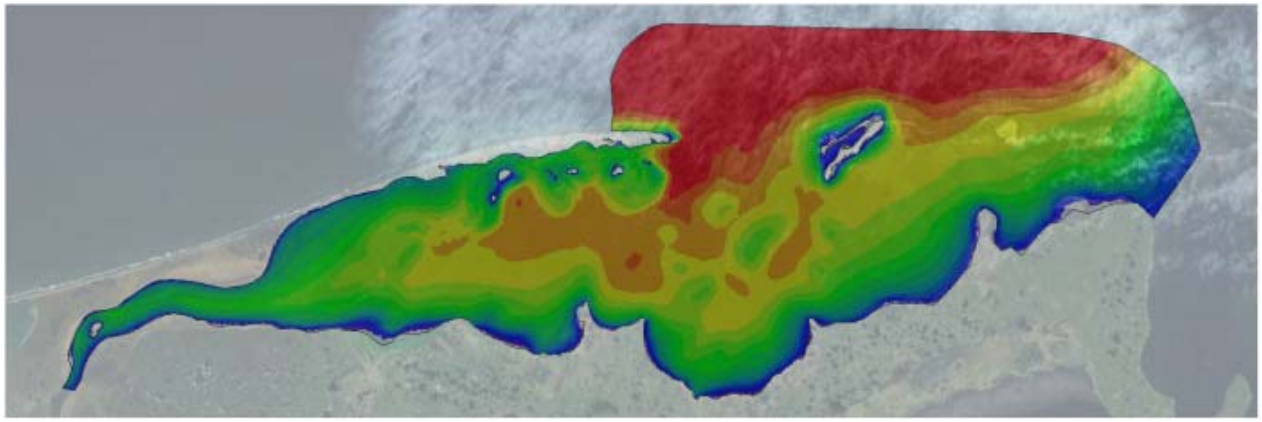
Wind Speed Return Period:
25 Year (82 mph)
Wind Direction:
130 degrees
Water Level:
+10 ft MLLW

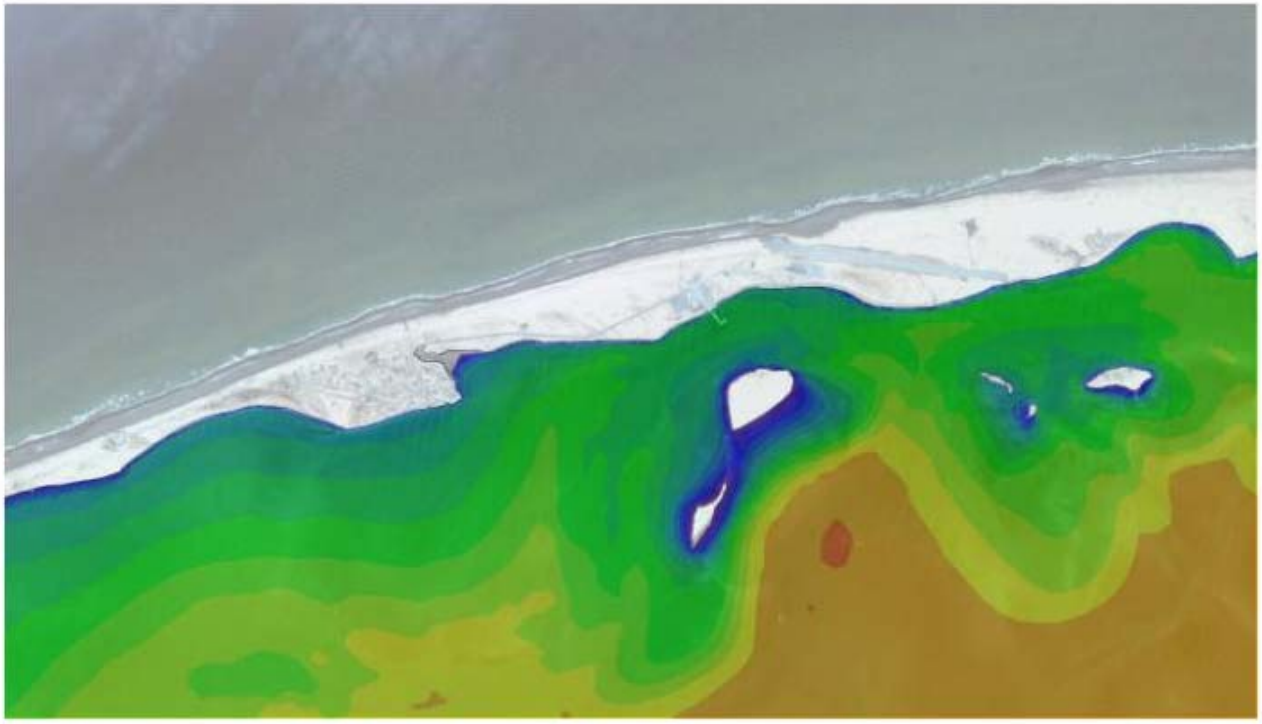
Top: Full Domain

Bottom: Enlarged Domain near community of Nelson Lagoon

Wave Height (ft)

- Above 3.6
- 3.2 - 3.6
- 2.8 - 3.2
- 2.4 - 2.8
- 2.0 - 2.4
- 1.6 - 2.0
- 1.2 - 1.6
- 0.8 - 1.2
- 0.4 - 0.8
- 0.0 - 0.4
- Below 0.0
- Undefined Value





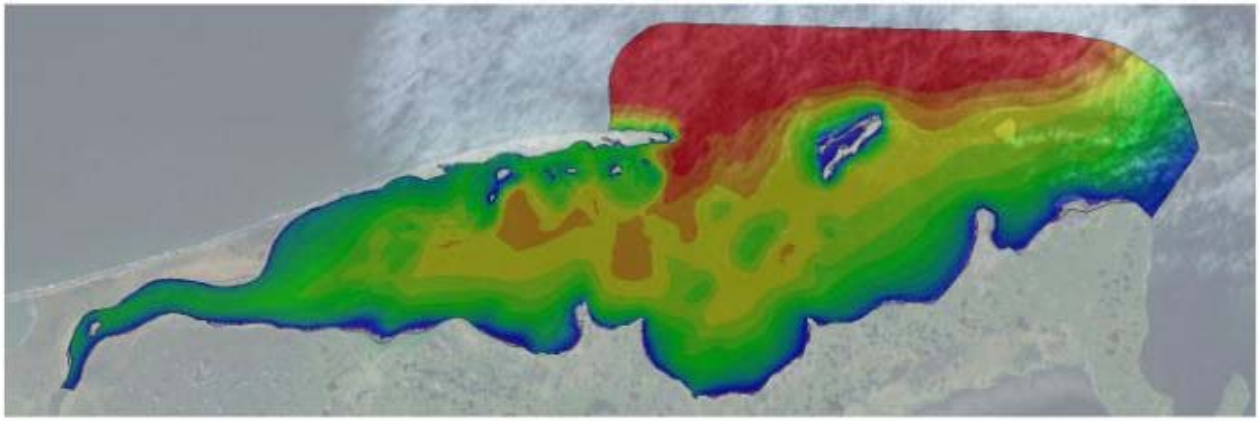
Wind Speed Return Period:
10 Year (74 mph)
Wind Direction:
130 degrees
Water Level:
+10 ft MLLW

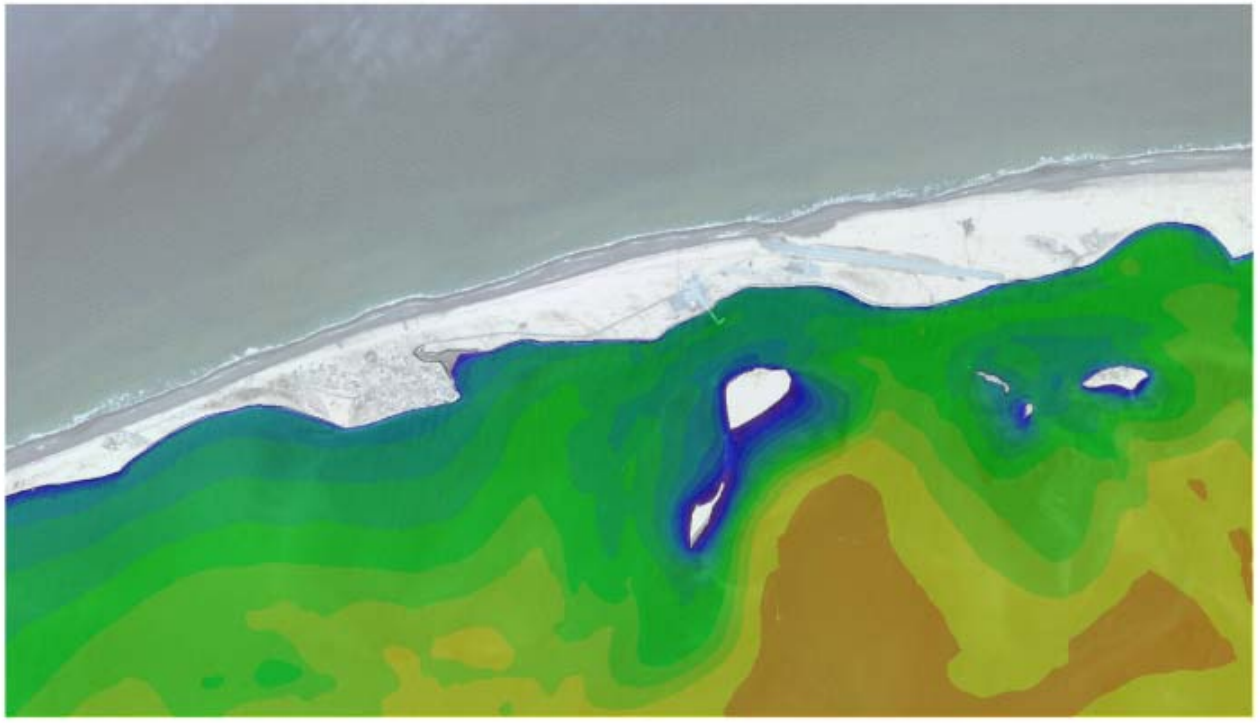
Top: Full Domain

Bottom: Enlarged Domain near community of Nelson Lagoon

Wave Height (ft)

- Above 3.6
- 3.2 - 3.6
- 2.8 - 3.2
- 2.4 - 2.8
- 2.0 - 2.4
- 1.6 - 2.0
- 1.2 - 1.6
- 0.8 - 1.2
- 0.4 - 0.8
- 0.0 - 0.4
- Below 0.0
- Undefined Value





Wind Speed Return Period:
5 Year (68 mph)
Wind Direction:
130 degrees
Water Level:
+10 ft MLLW

Top: Full Domain

Bottom: Enlarged Domain near community of Nelson Lagoon

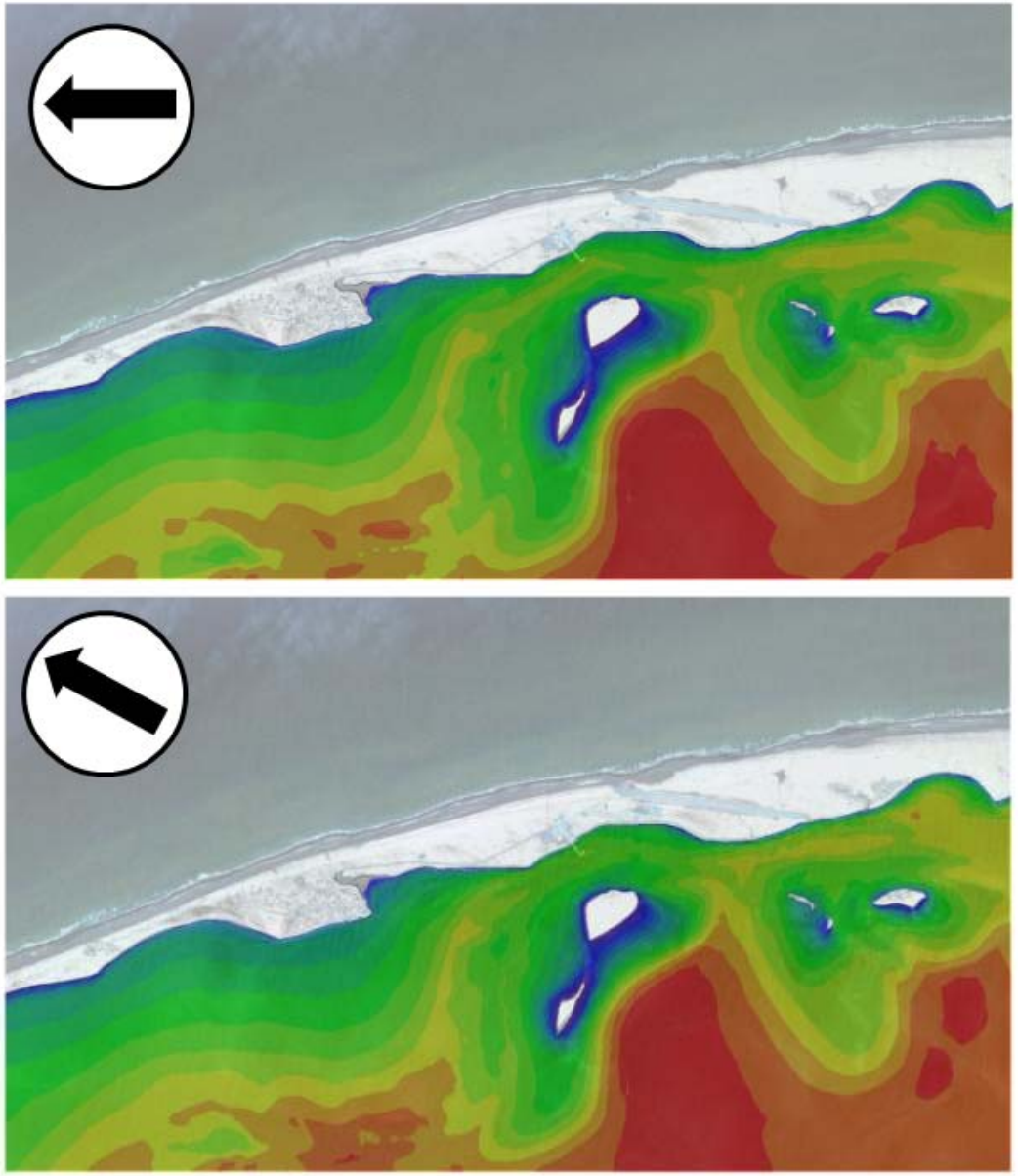
Wave Height (ft)

- Above 3.6
- 3.2 - 3.6
- 2.8 - 3.2
- 2.4 - 2.8
- 2.0 - 2.4
- 1.6 - 2.0
- 1.2 - 1.6
- 0.8 - 1.2
- 0.4 - 0.8
- 0.0 - 0.4
- Below 0.0
- Undefined Value

Appendix A

Spectral Wave Results

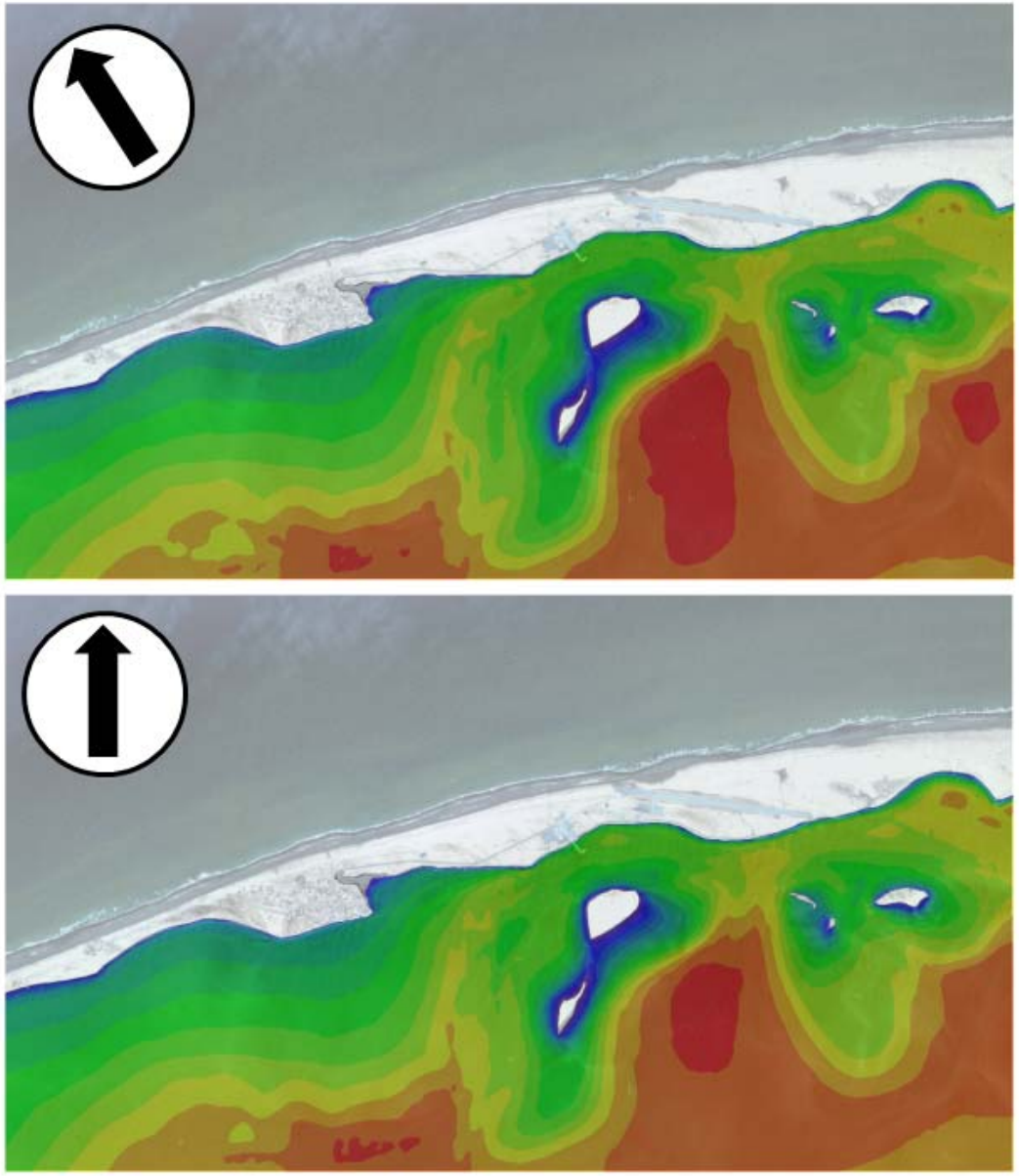
Varying Wind Direction



Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
90 degrees (Top)
120 degrees (Bottom)
Water Level:
+10 ft MLLW

Wave Height (ft)

- Above 3.6
- 3.2 - 3.6
- 2.8 - 3.2
- 2.4 - 2.8
- 2.0 - 2.4
- 1.6 - 2.0
- 1.2 - 1.6
- 0.8 - 1.2
- 0.4 - 0.8
- 0.0 - 0.4
- Below 0.0
- Undefined Value

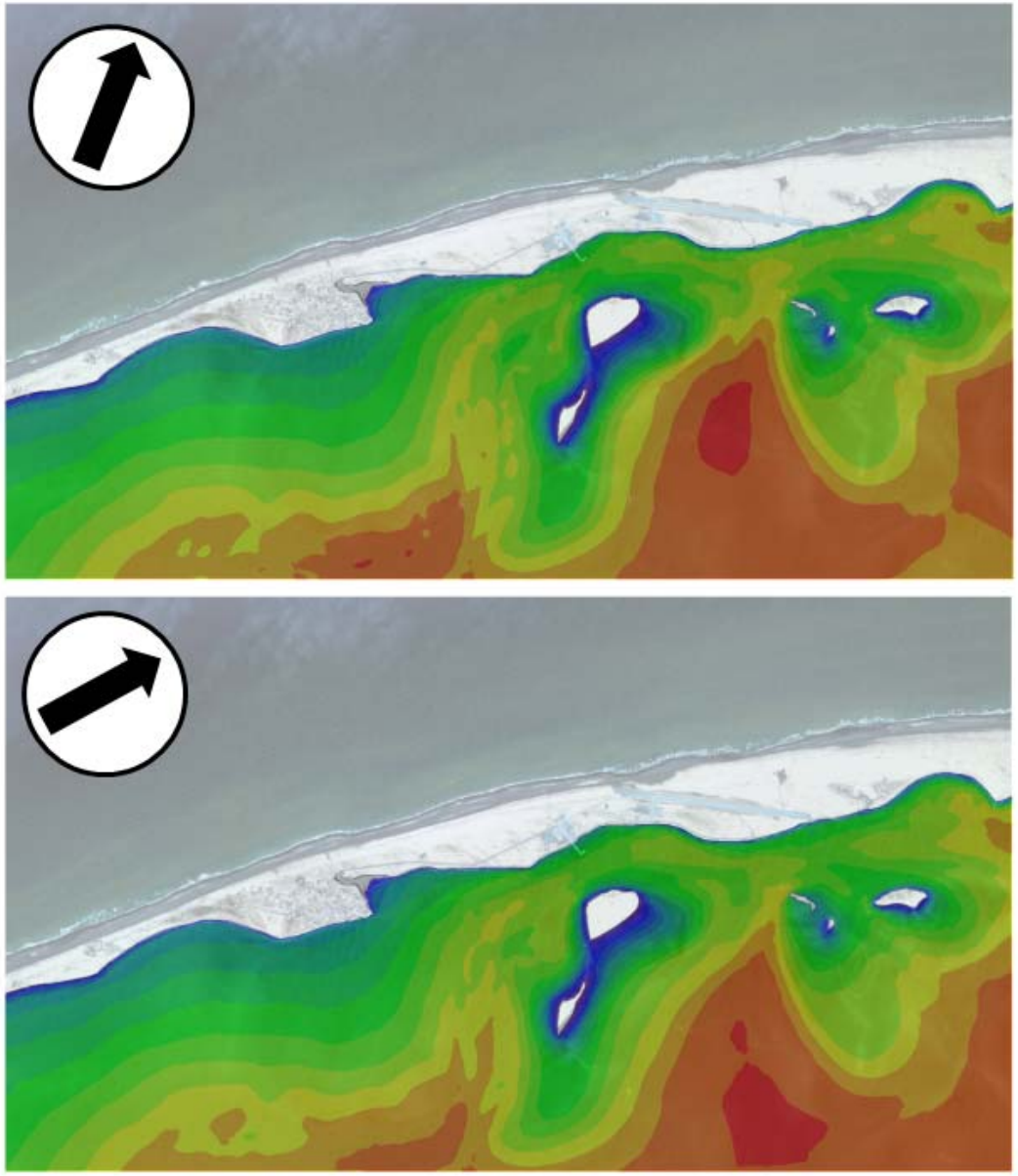


Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
150 degrees (Top)
180 degrees (Bottom)
Water Level:
+10 ft MLLW

Wave Height (ft)

- Above 3.6
- 3.2 - 3.6
- 2.8 - 3.2
- 2.4 - 2.8
- 2.0 - 2.4
- 1.6 - 2.0
- 1.2 - 1.6
- 0.8 - 1.2
- 0.4 - 0.8
- 0.0 - 0.4
- Below 0.0
- Undefined Value

22:40:00 1/9/2012 Time Step 1144 of 1154

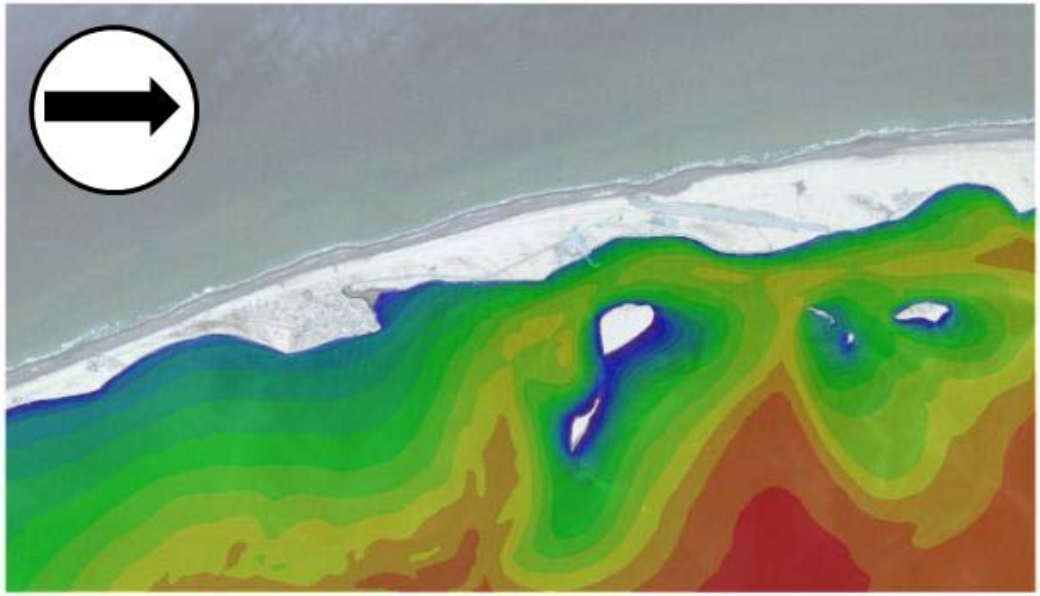


Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
210 degrees (Top)
240 degrees (Bottom)
Water Level:
+10 ft MLLW

Wave Height (ft)

- Above 3.6
- 3.2 - 3.6
- 2.8 - 3.2
- 2.4 - 2.8
- 2.0 - 2.4
- 1.6 - 2.0
- 1.2 - 1.6
- 0.8 - 1.2
- 0.4 - 0.8
- 0.0 - 0.4
- Below 0.0
- Undefined Value

23:40:00 1/8/2012 Time Step 1150 of 1154

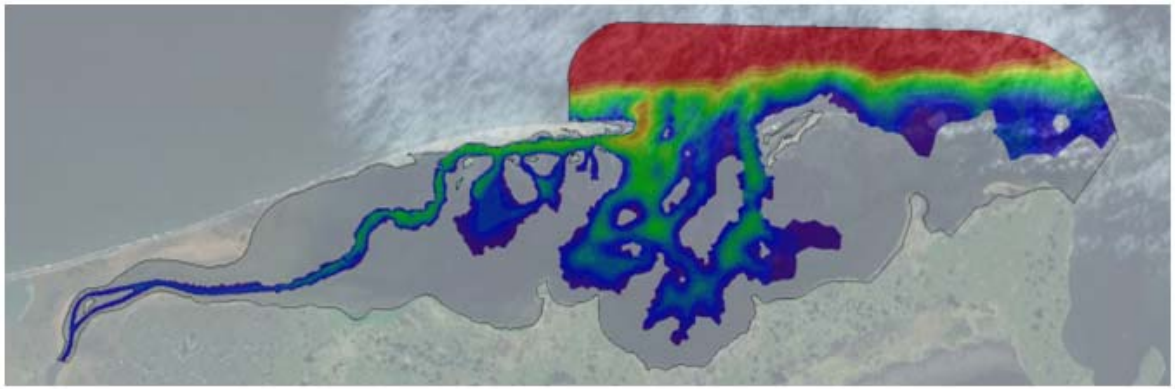


Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
270 degrees
Water Level:
+10 ft MLLW

Wave Height (ft)

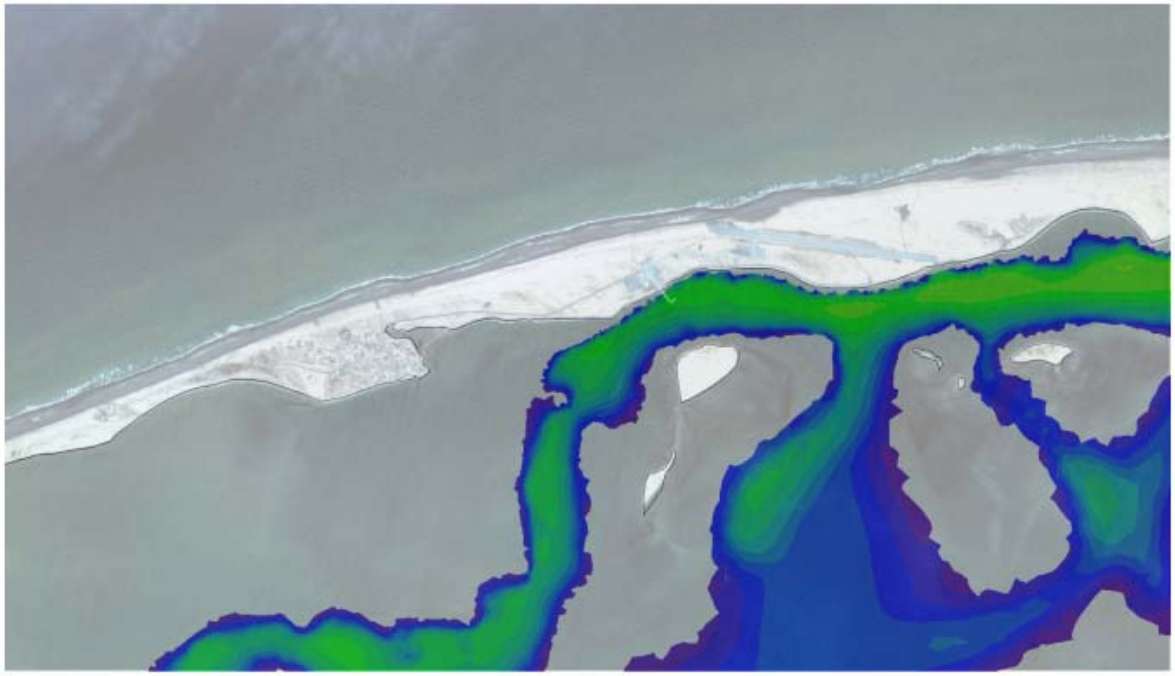
- Above 3.6
- 3.2 - 3.6
- 2.8 - 3.2
- 2.4 - 2.8
- 2.0 - 2.4
- 1.6 - 2.0
- 1.2 - 1.6
- 0.8 - 1.2
- 0.4 - 0.8
- 0.0 - 0.4
- Below 0.0
- Undefined Value

Appendix A
Spectral Wave Results
Varying Water Level

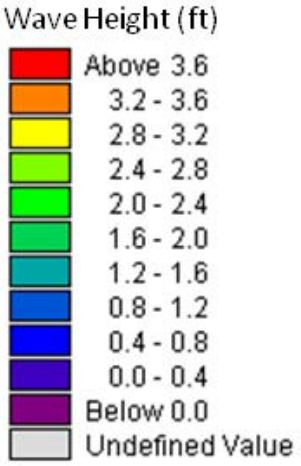


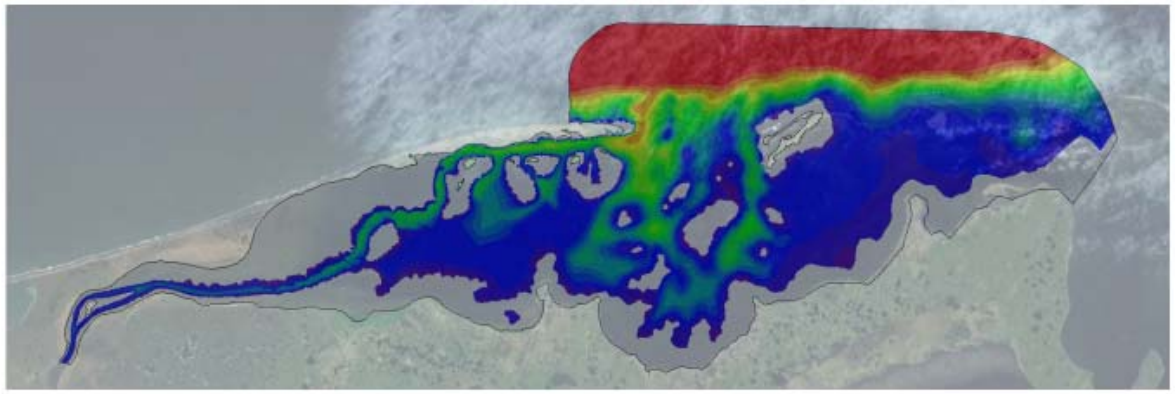
Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
0 ft MLLW

Top: Full Domain



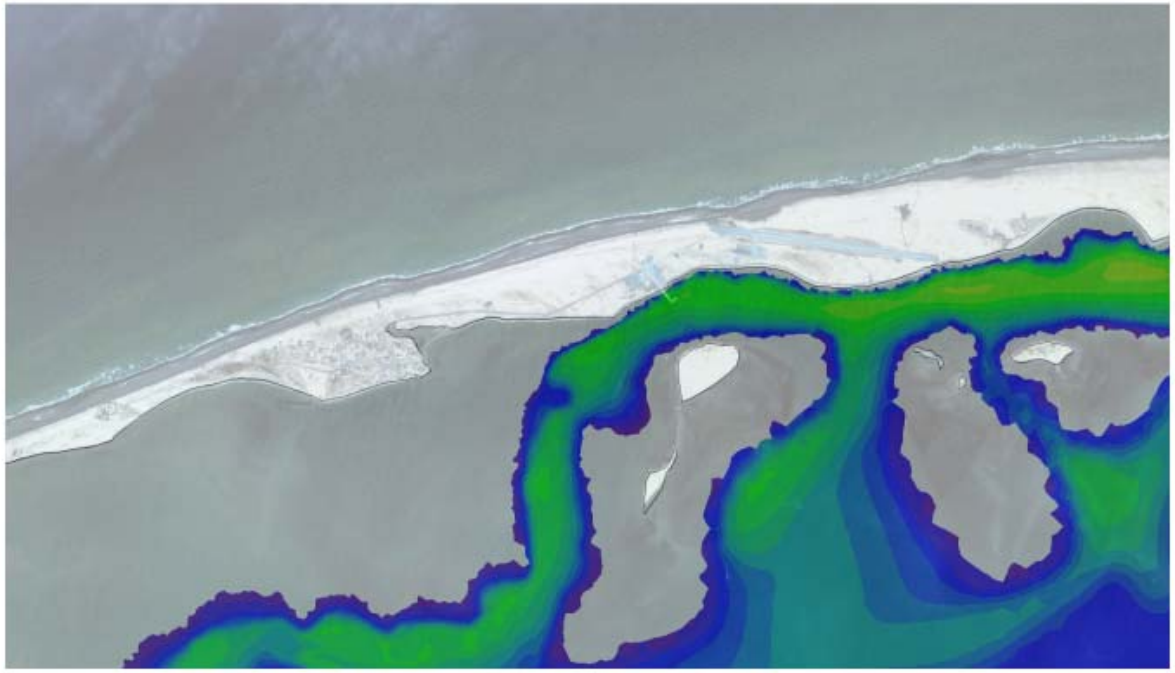
Bottom: Enlarged Domain near community of Nelson Lagoon



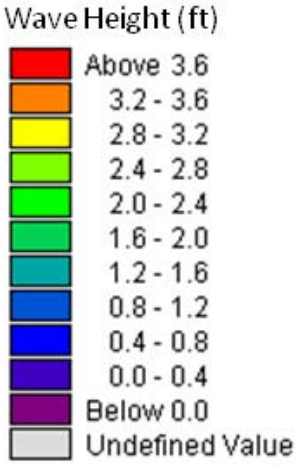


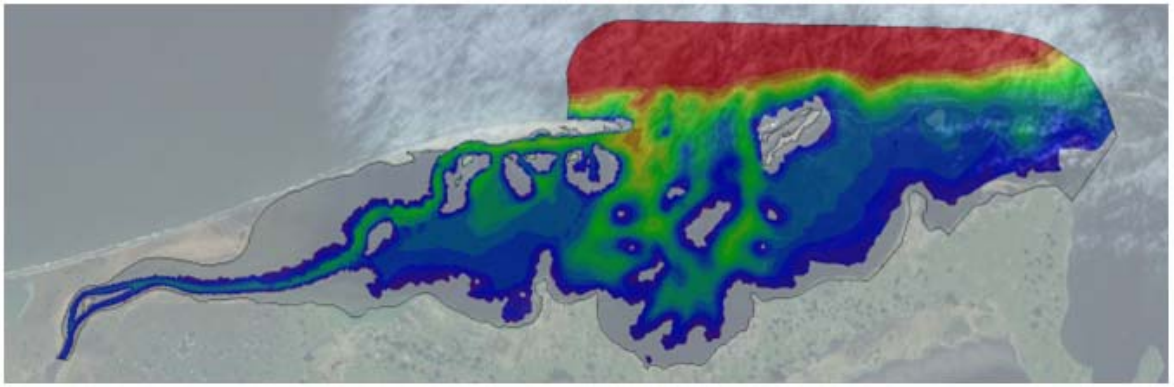
Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
+1 ft MLLW

Top: Full Domain



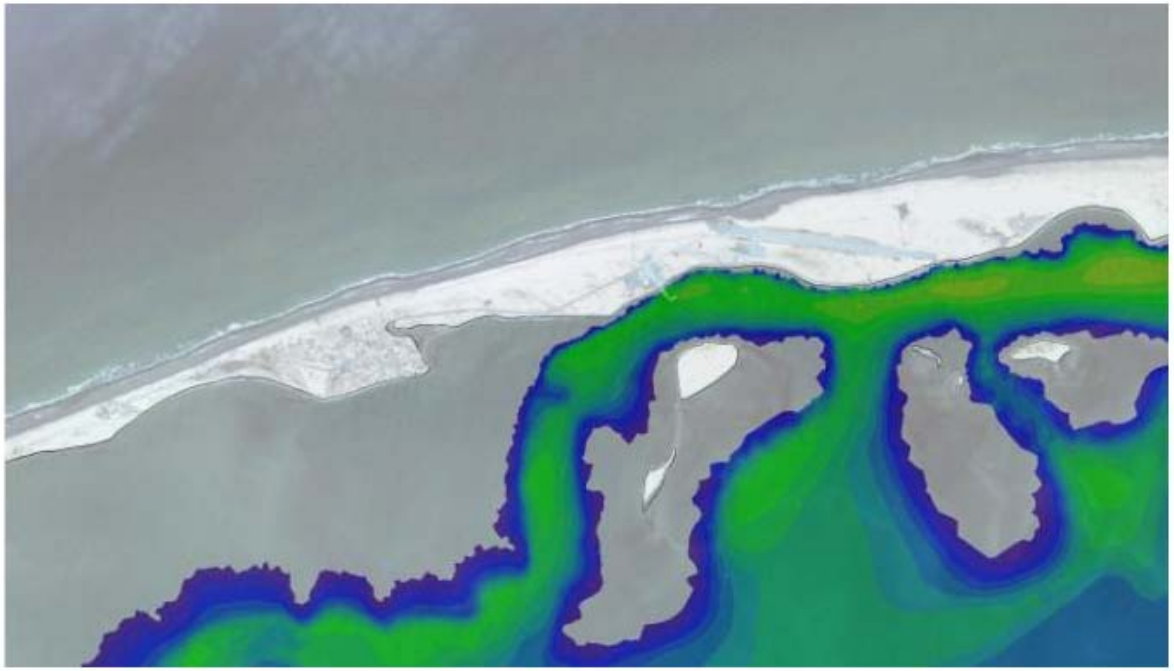
Bottom: Enlarged Domain near community of Nelson Lagoon



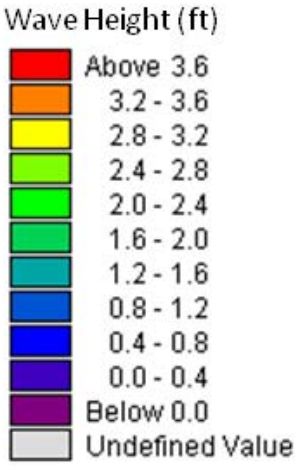


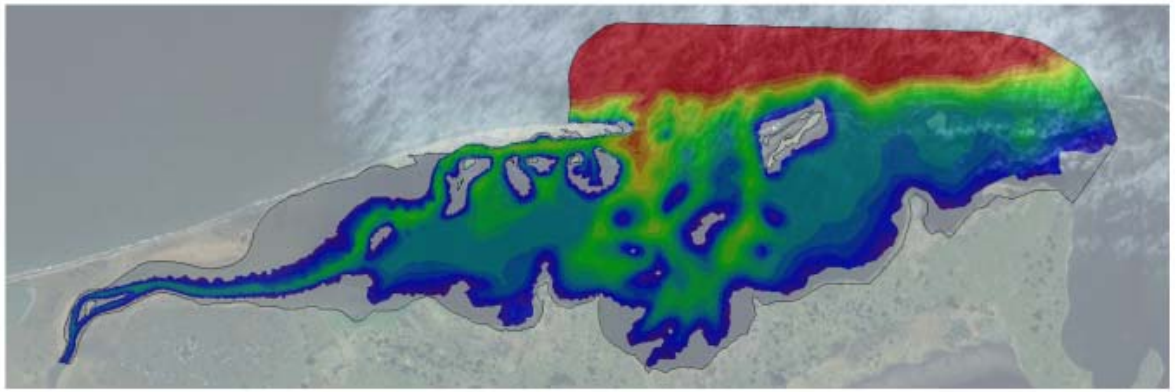
Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
+2 ft MLLW

Top: Full Domain



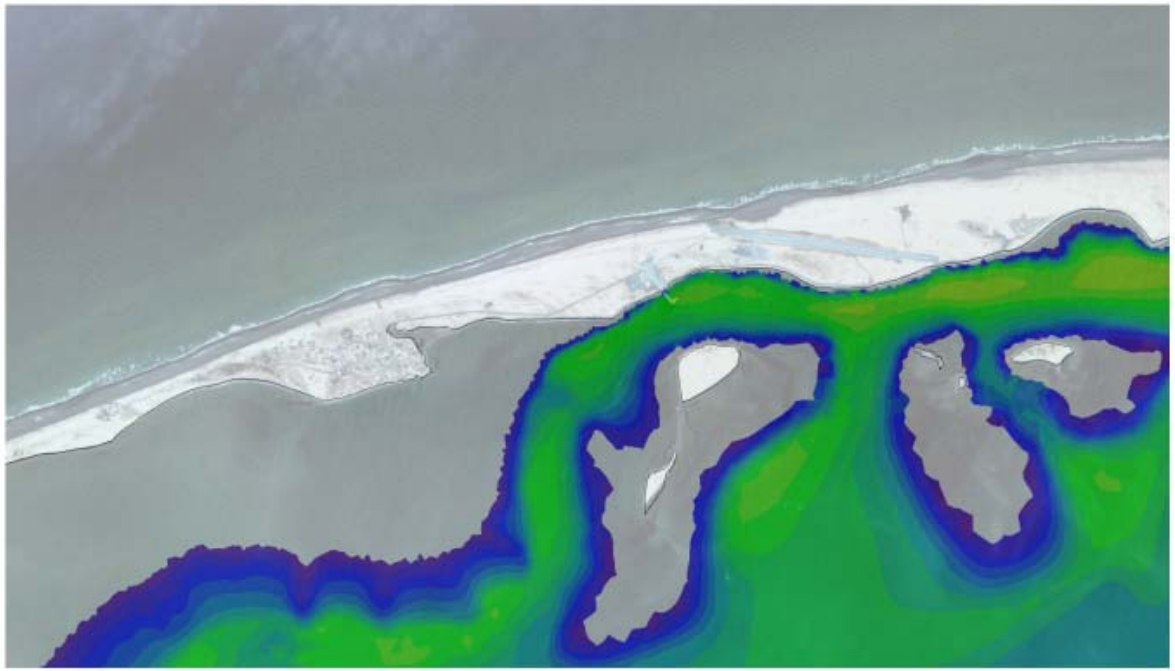
Bottom: Enlarged Domain near community of Nelson Lagoon





Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
+3 ft MLLW

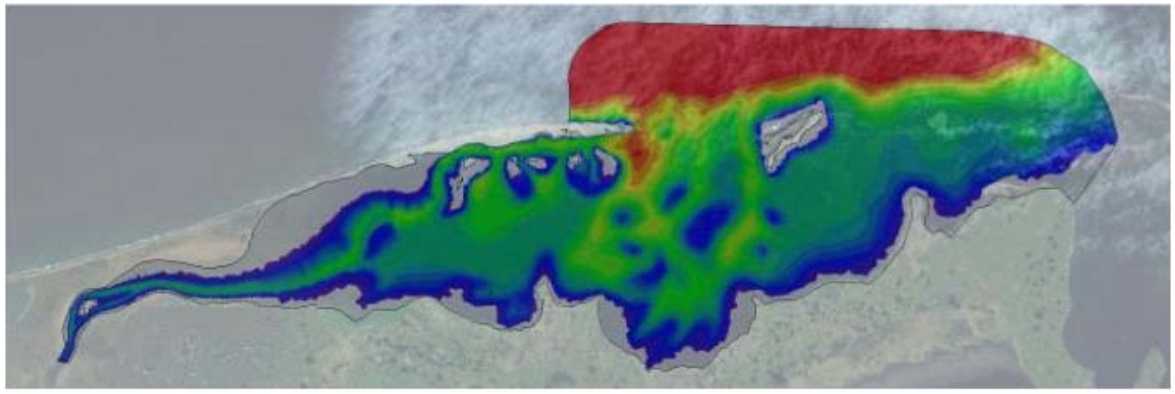
Top: Full Domain



Bottom: Enlarged Domain near community of Nelson Lagoon

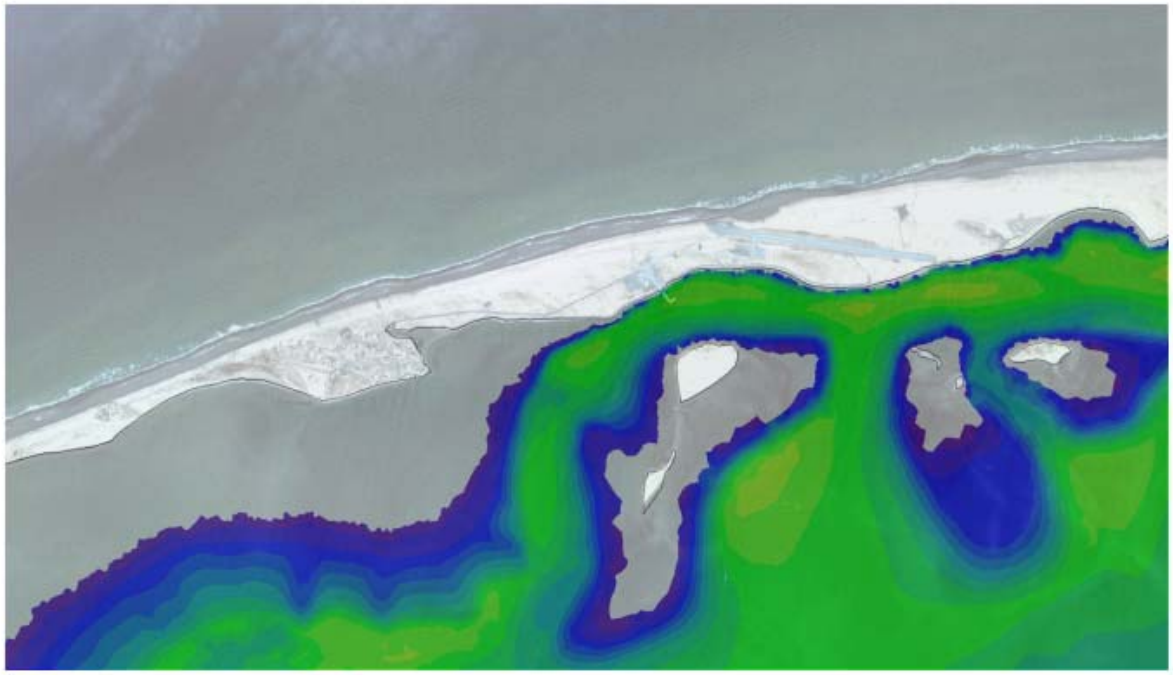
Wave Height (ft)

- Above 3.6
- 3.2 - 3.6
- 2.8 - 3.2
- 2.4 - 2.8
- 2.0 - 2.4
- 1.6 - 2.0
- 1.2 - 1.6
- 0.8 - 1.2
- 0.4 - 0.8
- 0.0 - 0.4
- Below 0.0
- Undefined Value

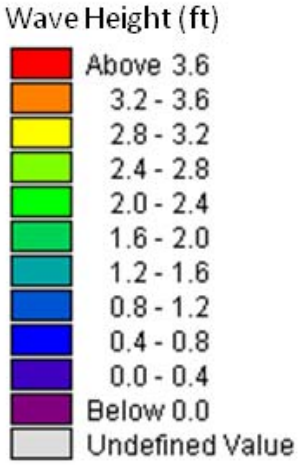


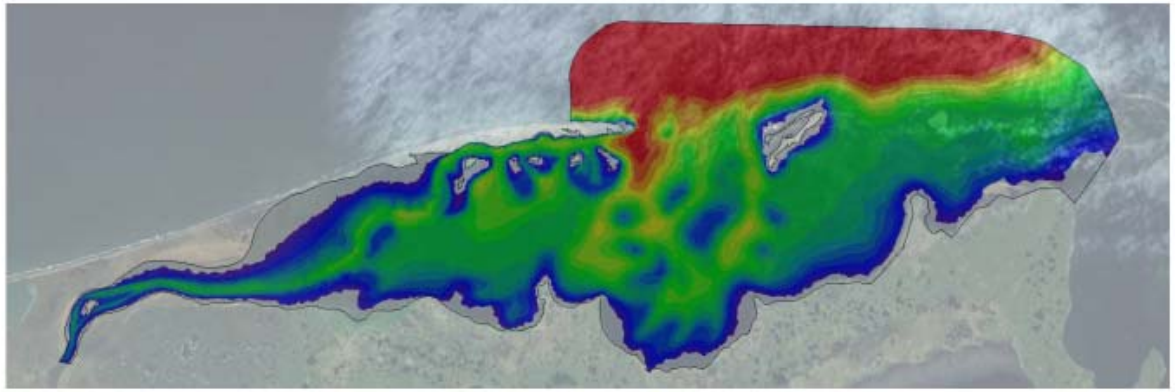
Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
+4 ft MLLW

Top: Full Domain



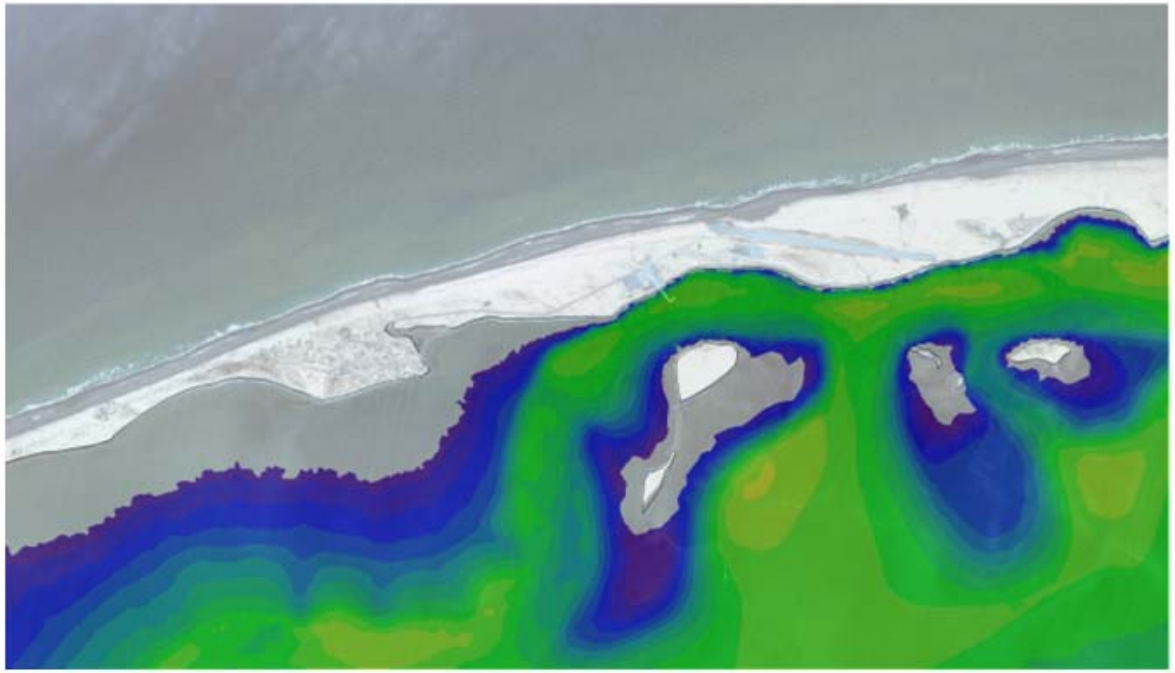
Bottom: Enlarged Domain near community of Nelson Lagoon



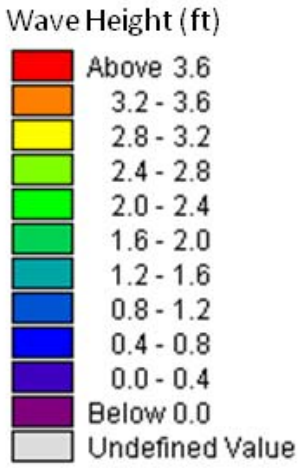


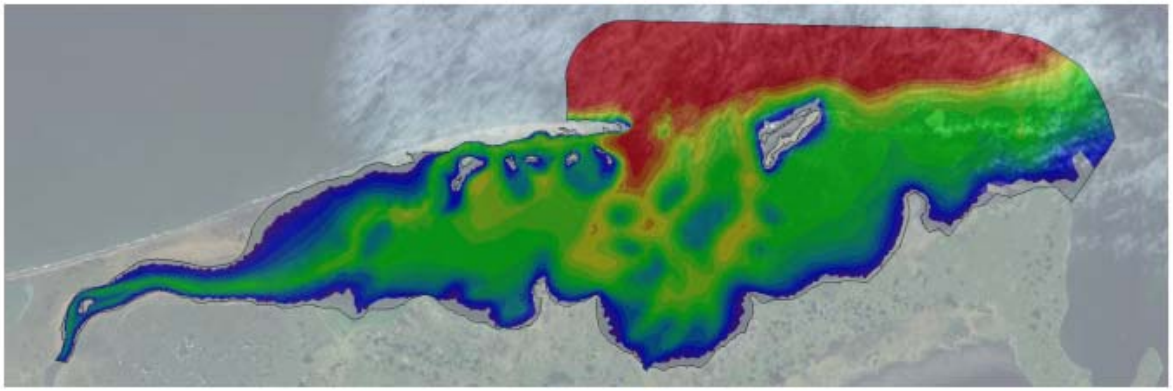
Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
+5 ft MLLW

Top: Full Domain



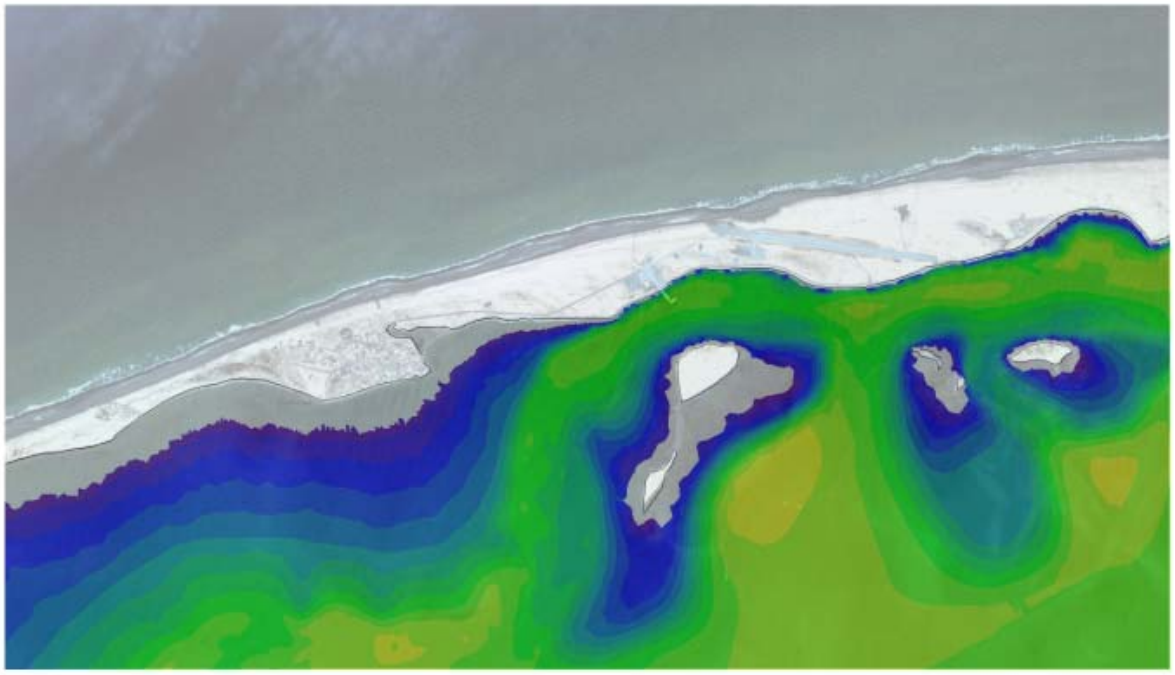
Bottom: Enlarged Domain near community of Nelson Lagoon



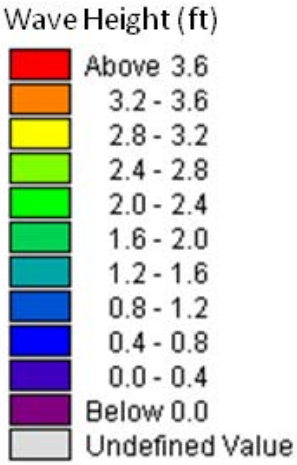


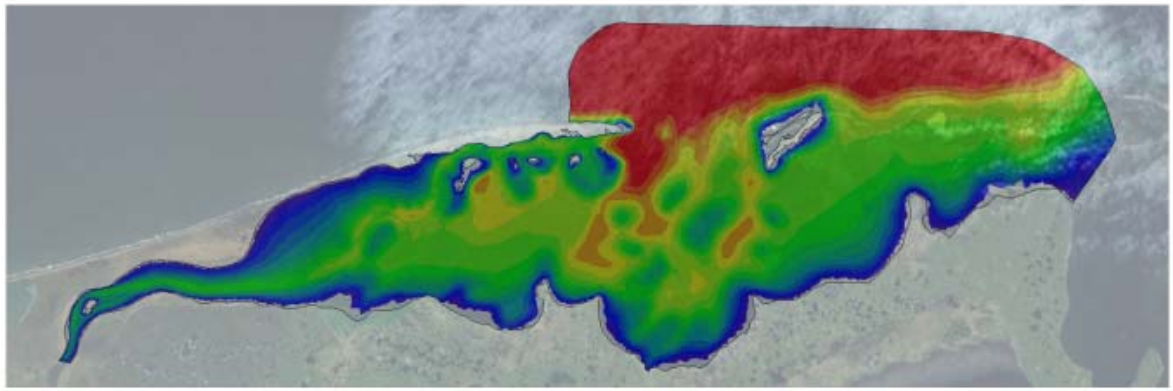
Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
+6 ft MLLW

Top: Full Domain



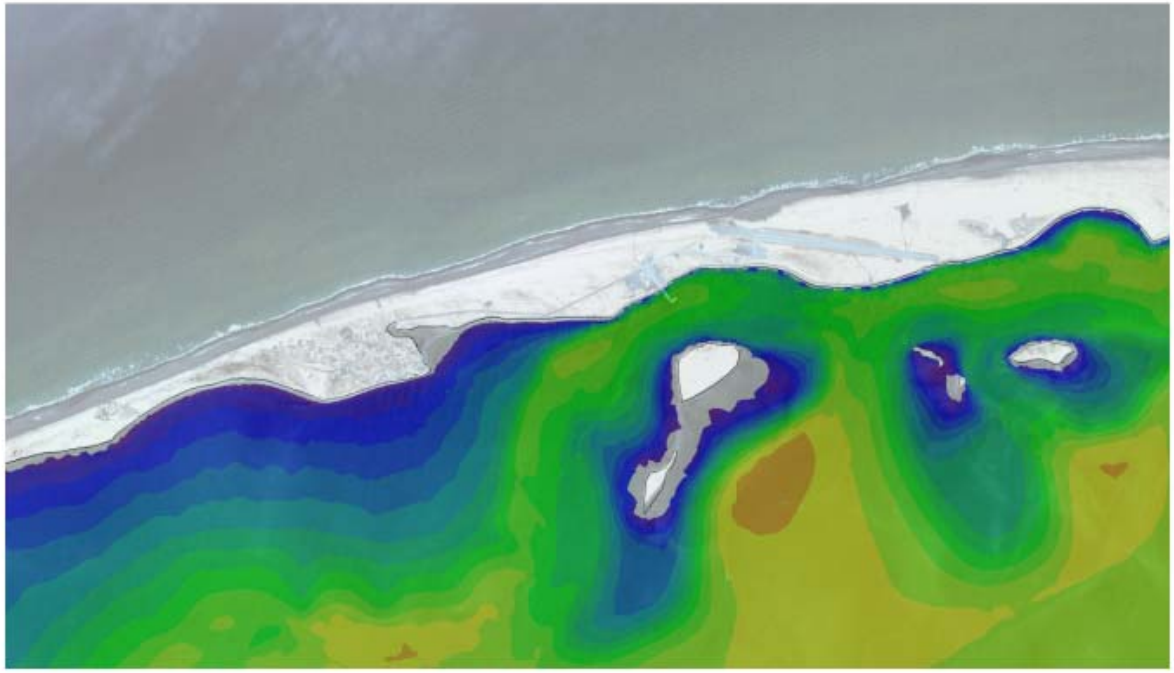
Bottom: Enlarged Domain near community of Nelson Lagoon



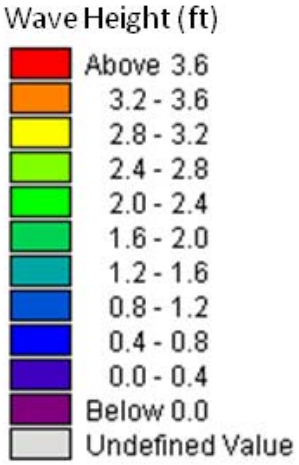


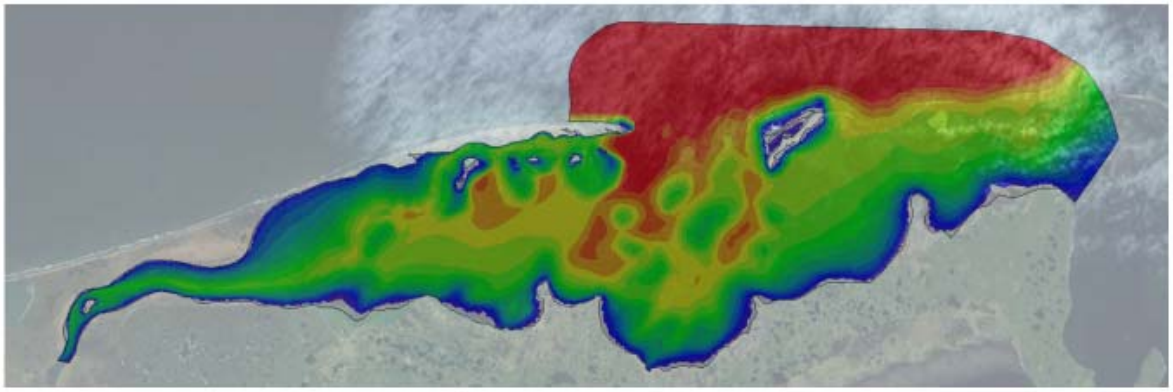
Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
+7 ft MLLW

Top: Full Domain



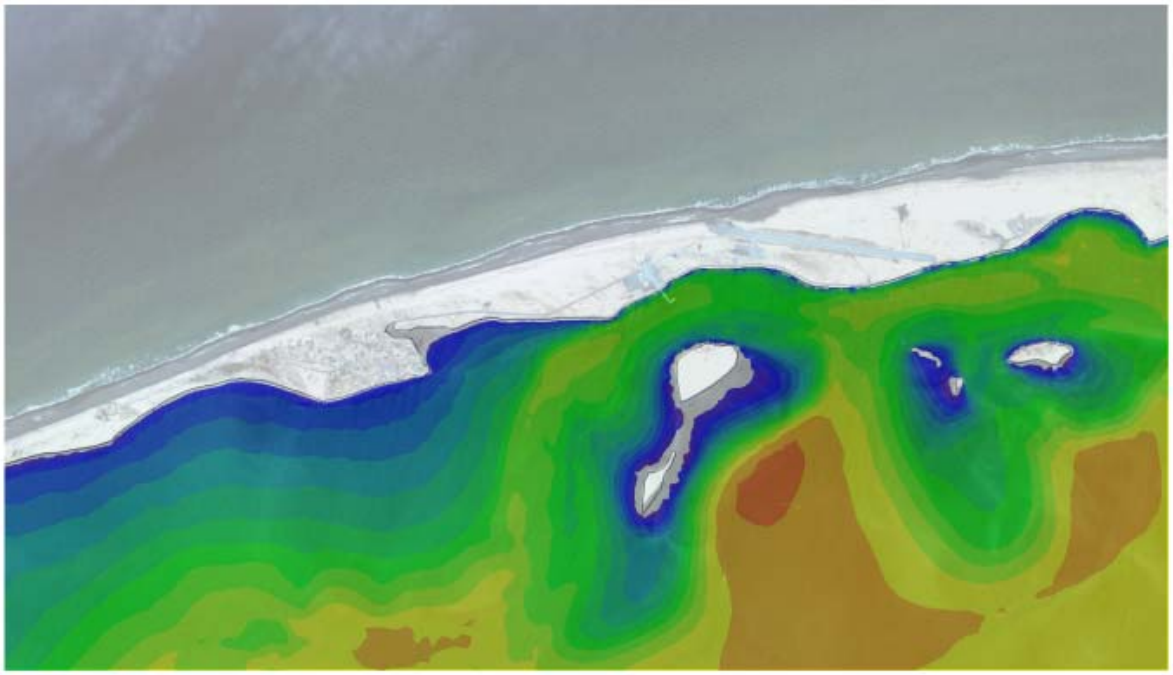
Bottom: Enlarged Domain near community of Nelson Lagoon



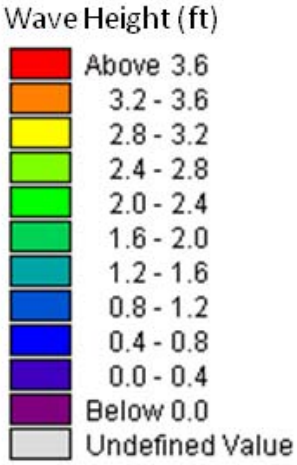


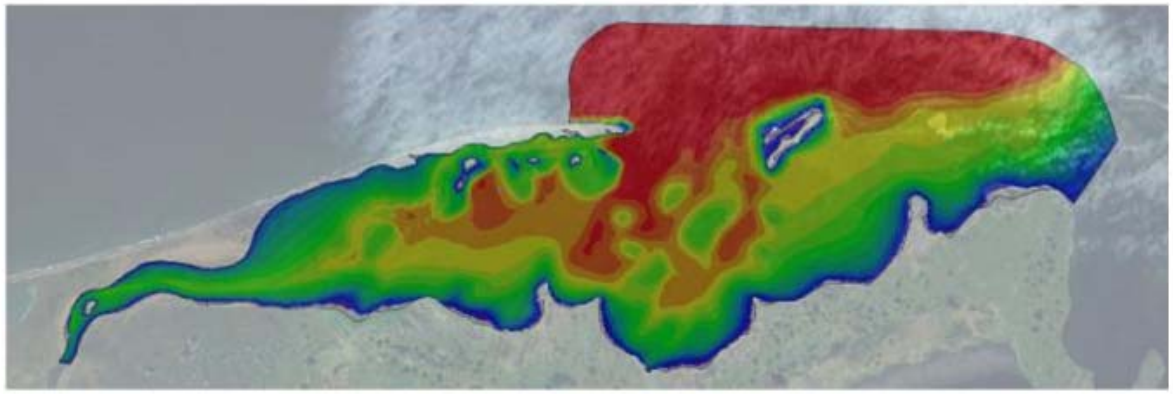
Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
+8 ft MLLW

Top: Full Domain



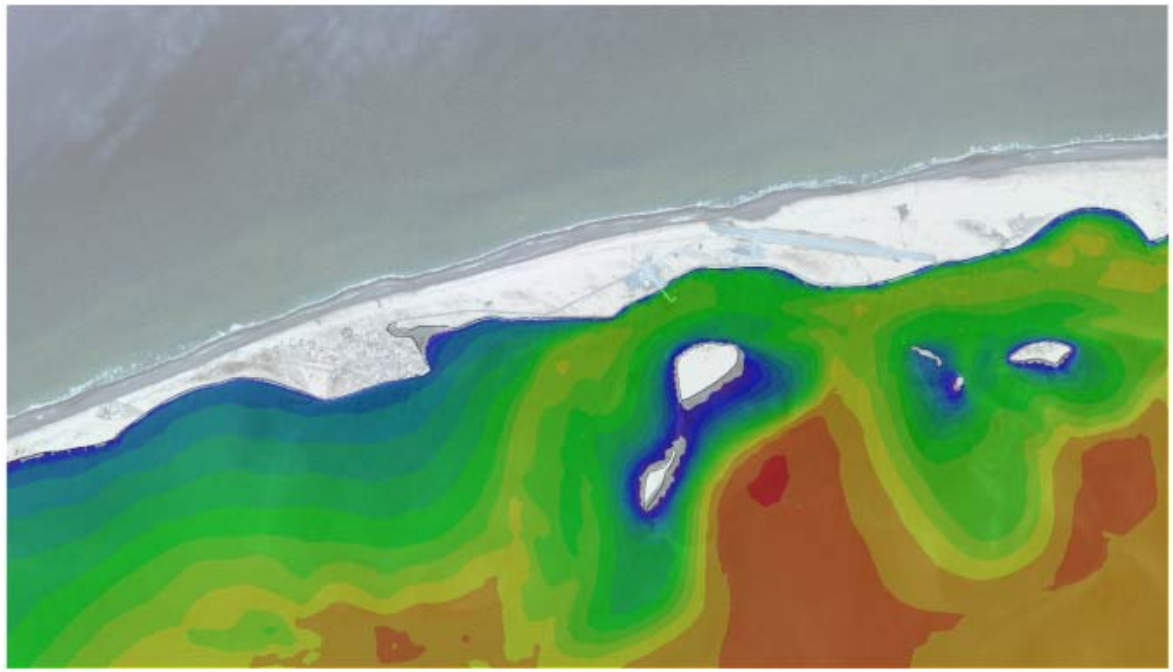
Bottom: Enlarged Domain near community of Nelson Lagoon



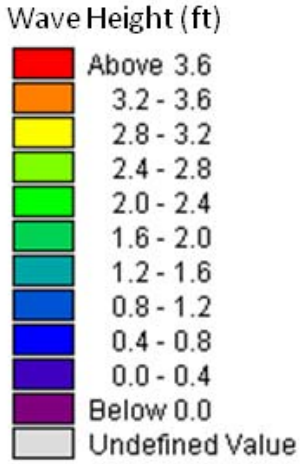


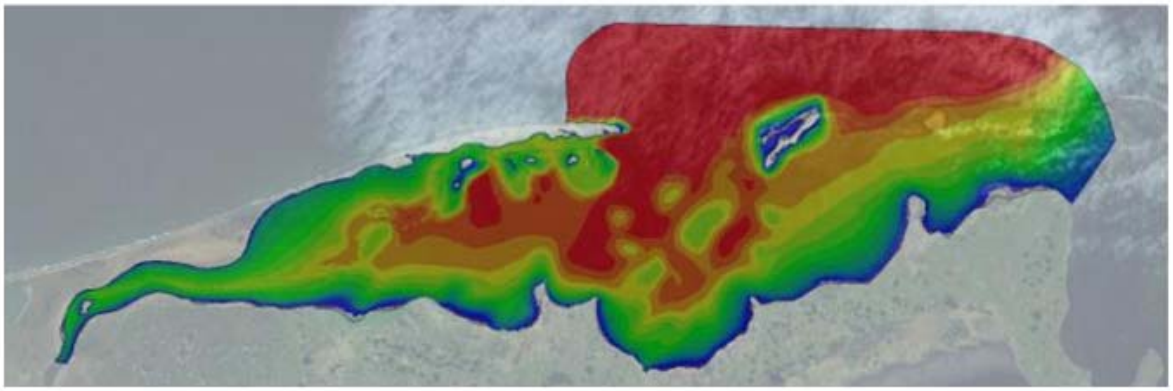
Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
+9 ft MLLW

Top: Full Domain



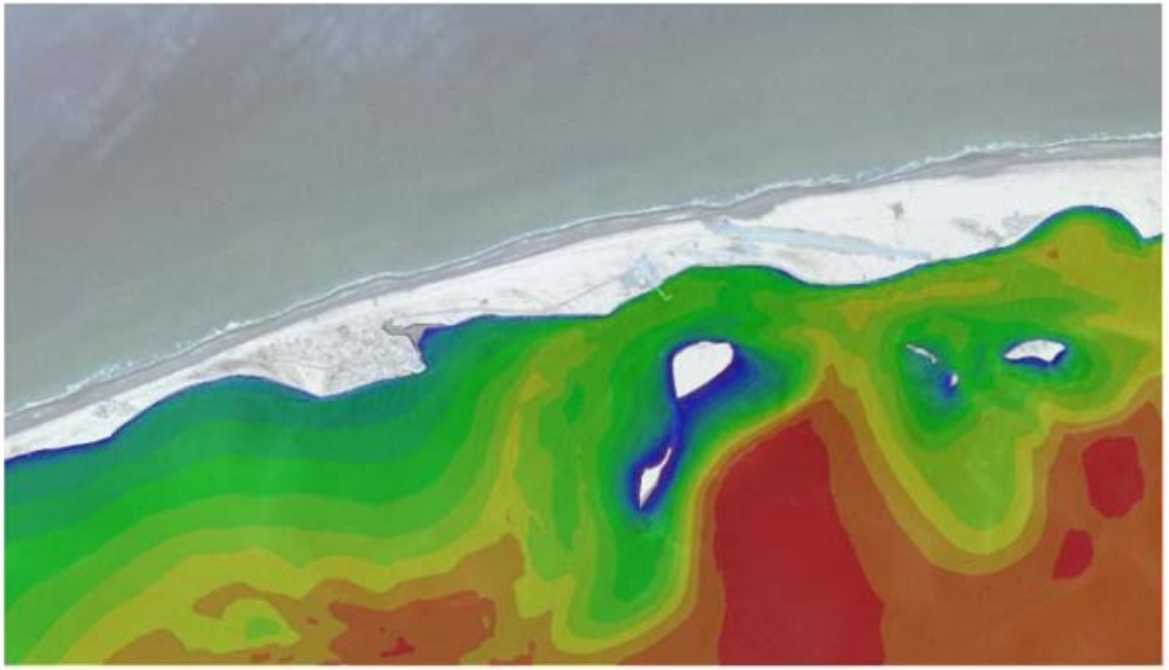
Bottom: Enlarged Domain near community of Nelson Lagoon



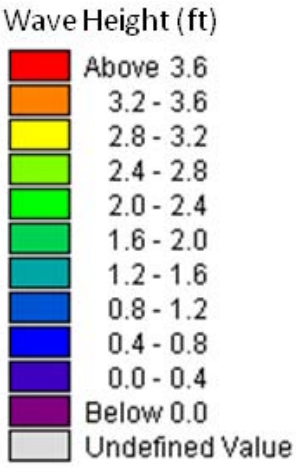


Wind Speed Return Period:
100 Year (94 mph)
Wind Direction:
130 degrees
Water Level:
+10 ft MLLW

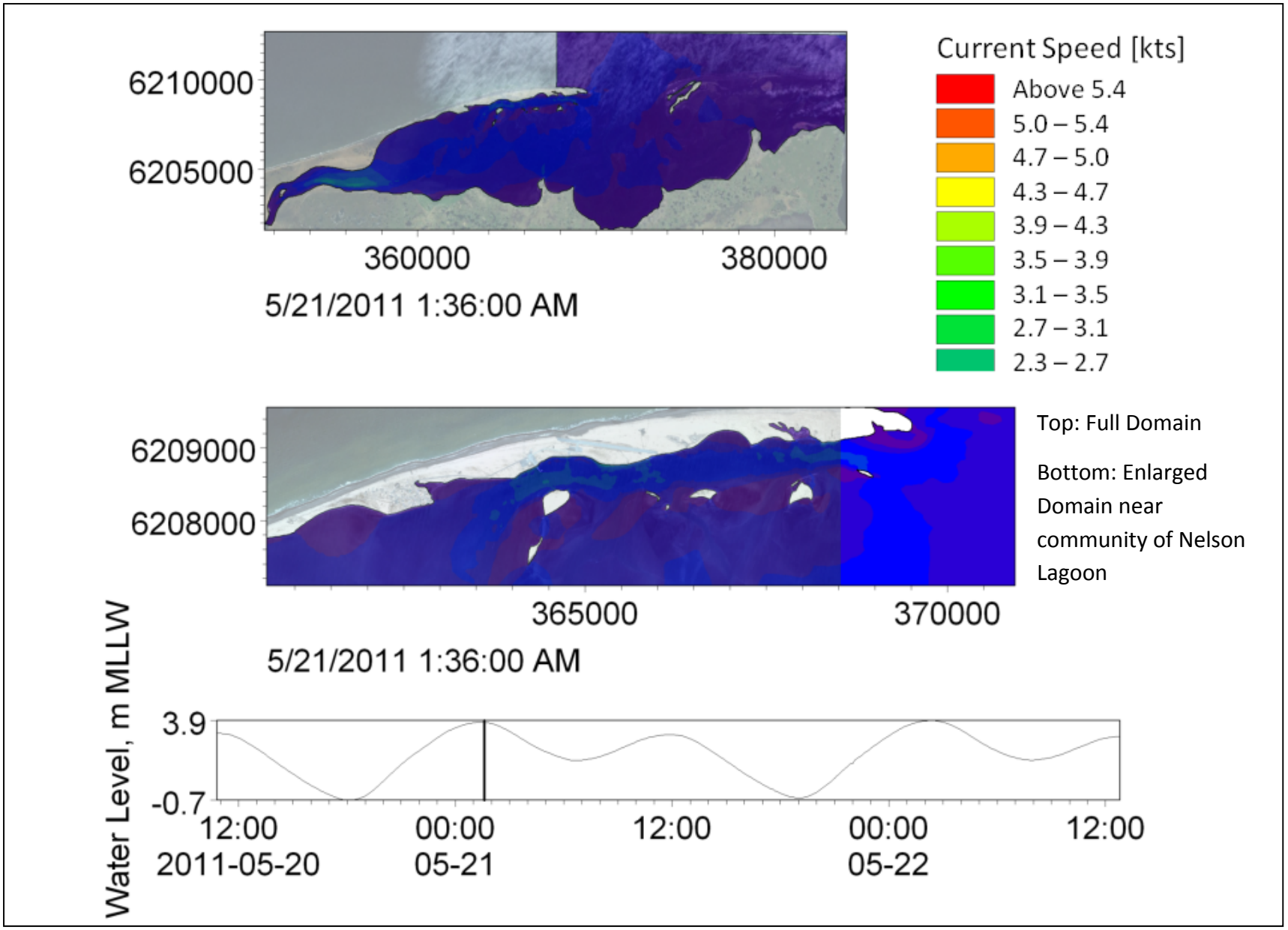
Top: Full Domain

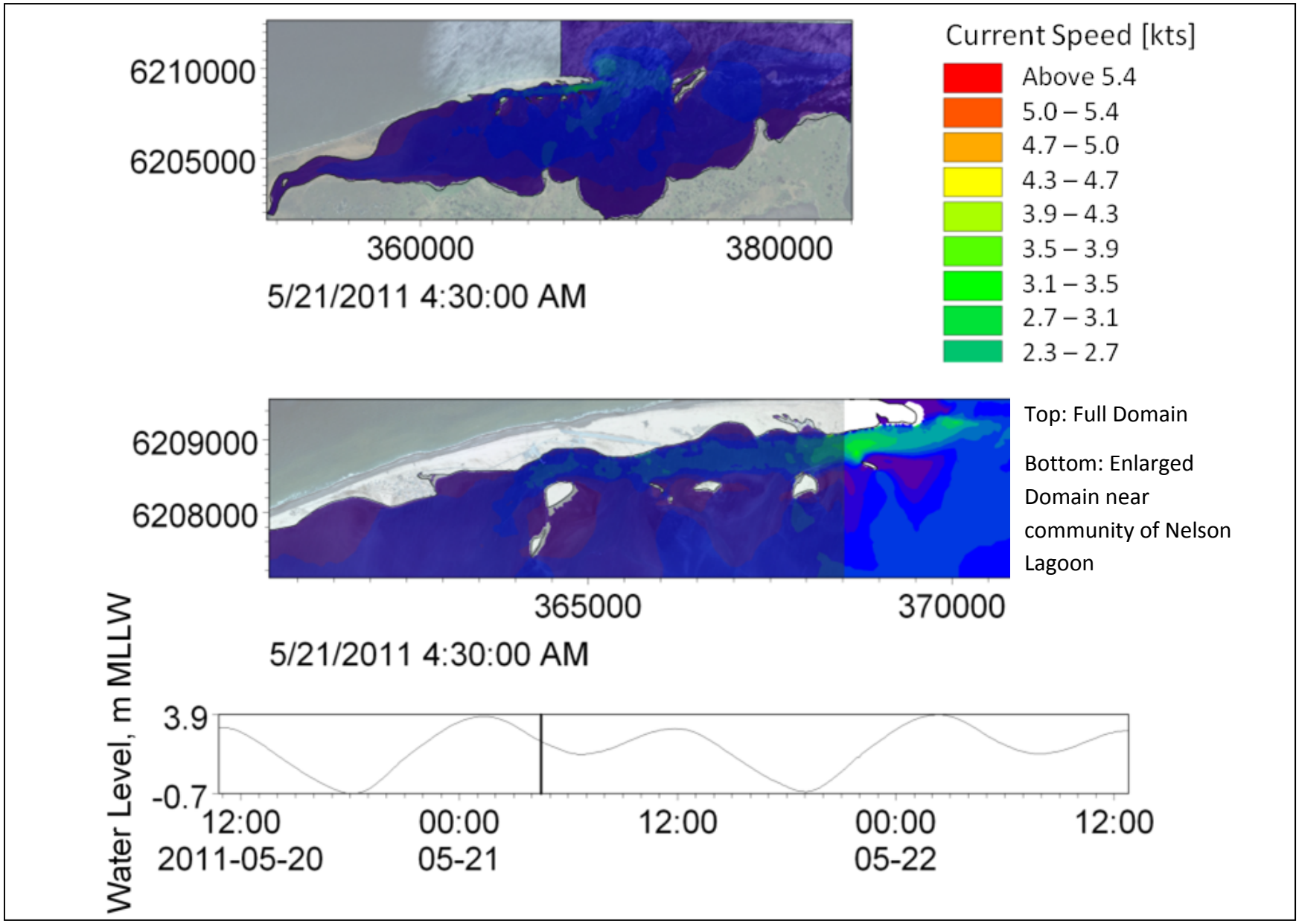


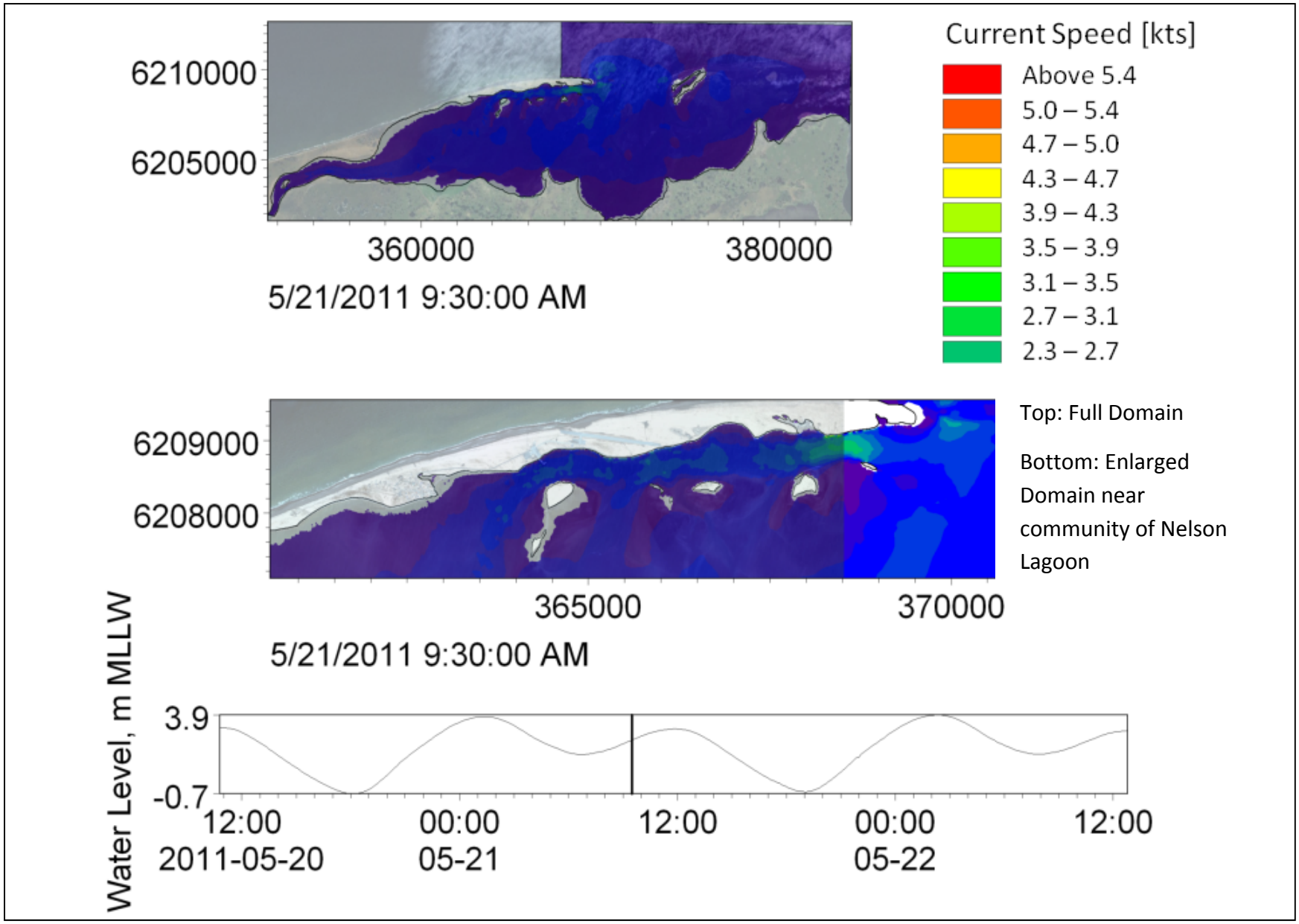
Bottom: Enlarged Domain near community of Nelson Lagoon



Appendix B
Hydrodynamic Results


6210000
6205000
360000
380000
5/21/2011 1:36:00 AM
Current Speed [kts]
Above 5.4
5.0 – 5.4
4.7 – 5.0
4.3 – 4.7
3.9 – 4.3
3.5 – 3.9
3.1 – 3.5
2.7 – 3.1
2.3 – 2.7
6209000
6208000
365000
370000
5/21/2011 1:36:00 AM
Top: Full Domain
Bottom: Enlarged Domain near community of Nelson Lagoon
Water Level, m MLLW
3.9
-0.7
12:00
2011-05-20
00:00
05-21
12:00
00:00
05-22
12:00


6210000
6205000
360000
380000
5/21/2011 4:30:00 AM
Current Speed [kts]
Above 5.4
5.0 – 5.4
4.7 – 5.0
4.3 – 4.7
3.9 – 4.3
3.5 – 3.9
3.1 – 3.5
2.7 – 3.1
2.3 – 2.7
6209000
6208000
365000
370000
5/21/2011 4:30:00 AM
Top: Full Domain
Bottom: Enlarged Domain near community of Nelson Lagoon
Water Level, m MLLW
3.9
-0.7
12:00
2011-05-20
00:00
05-21
12:00
00:00
05-22
12:00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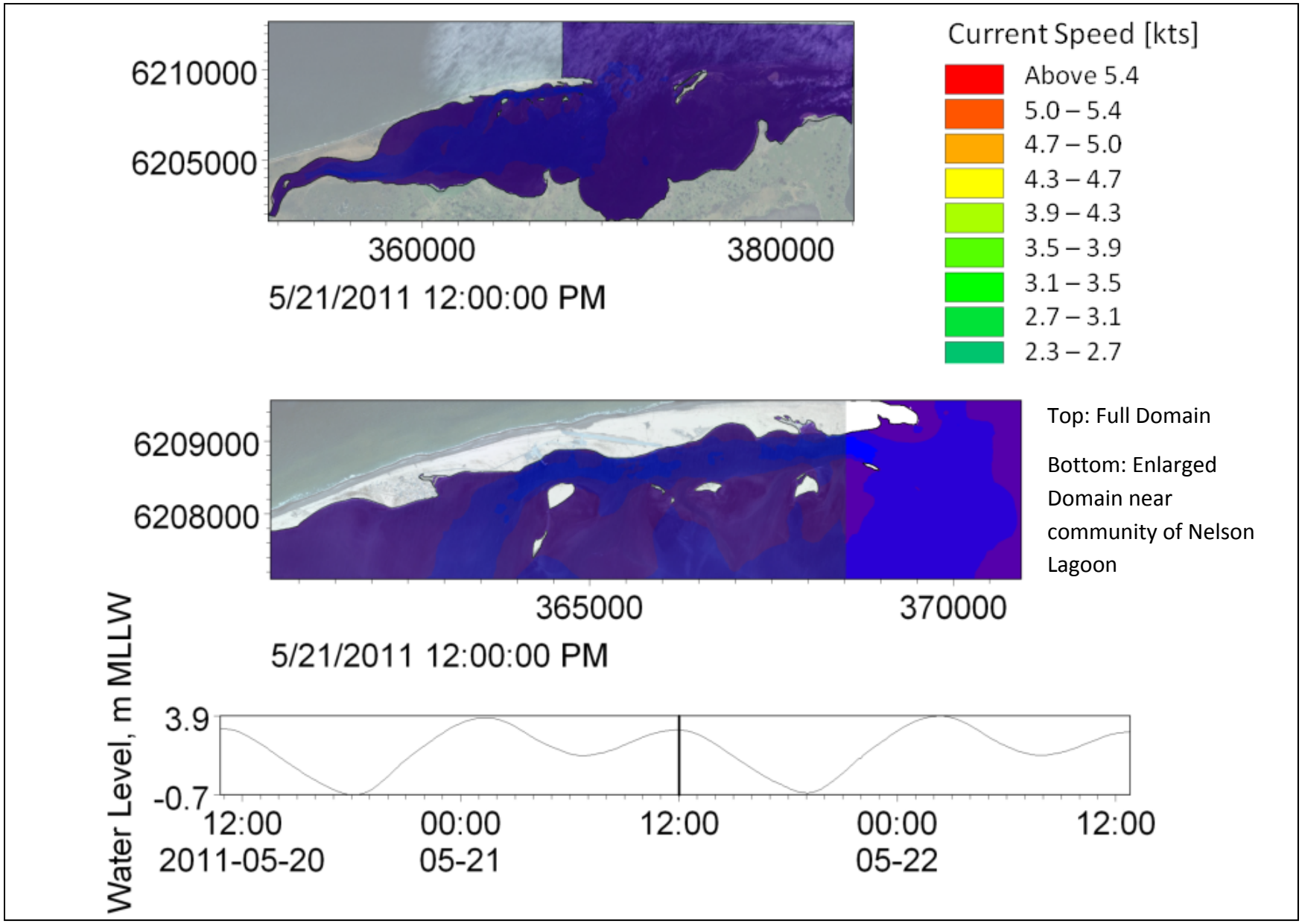
6205000
360000
380000
5/21/2011 9:30:00 AM
Current Speed [kts]
Above 5.4
5.0 – 5.4
4.7 – 5.0
4.3 – 4.7
3.9 – 4.3
3.5 – 3.9
3.1 – 3.5
2.7 – 3.1
2.3 – 2.7
6209000
6208000
365000
370000
5/21/2011 9:30:00 AM
Top: Full Domain
Bottom: Enlarged Domain near community of Nelson Lagoon
Water Level, m MLLW
3.9
-0.7
12:00
2011-05-20
00:00
05-21
12:00
00:00
05-22
12:00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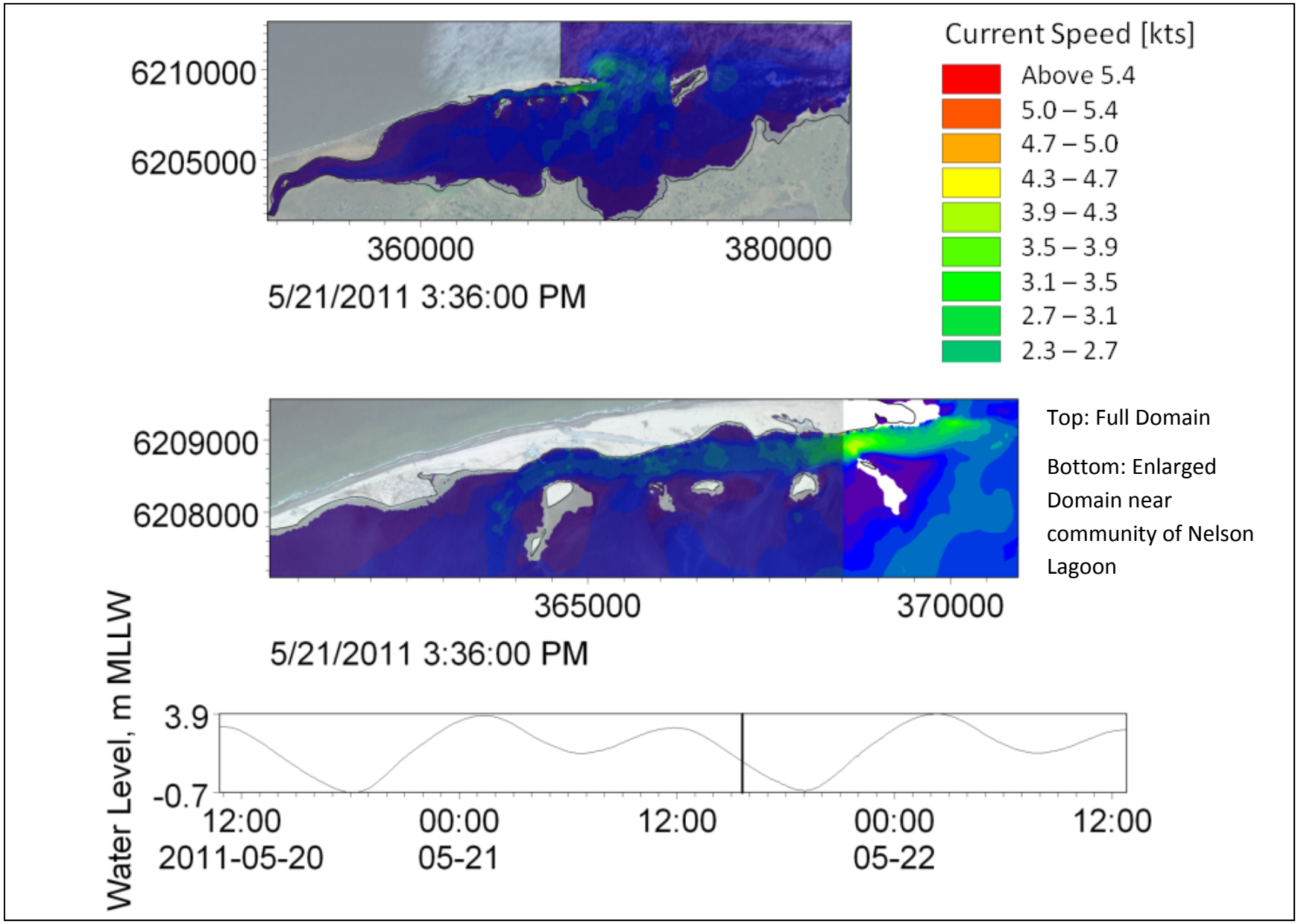
360000
380000
5/21/2011 12:00:00 PM
Current Speed [kts]
Above 5.4
5.0 – 5.4
4.7 – 5.0
4.3 – 4.7
3.9 – 4.3
3.5 – 3.9
3.1 – 3.5
2.7 – 3.1
2.3 – 2.7
6209000
6208000
365000
370000
5/21/2011 12:00:00 PM
Top: Full Domain
Bottom: Enlarged Domain near community of Nelson Lagoon
Water Level, m MLLW
3.9
-0.7
12:00
2011-05-20
00:00
05-21
12:00
00:00
05-22
12:00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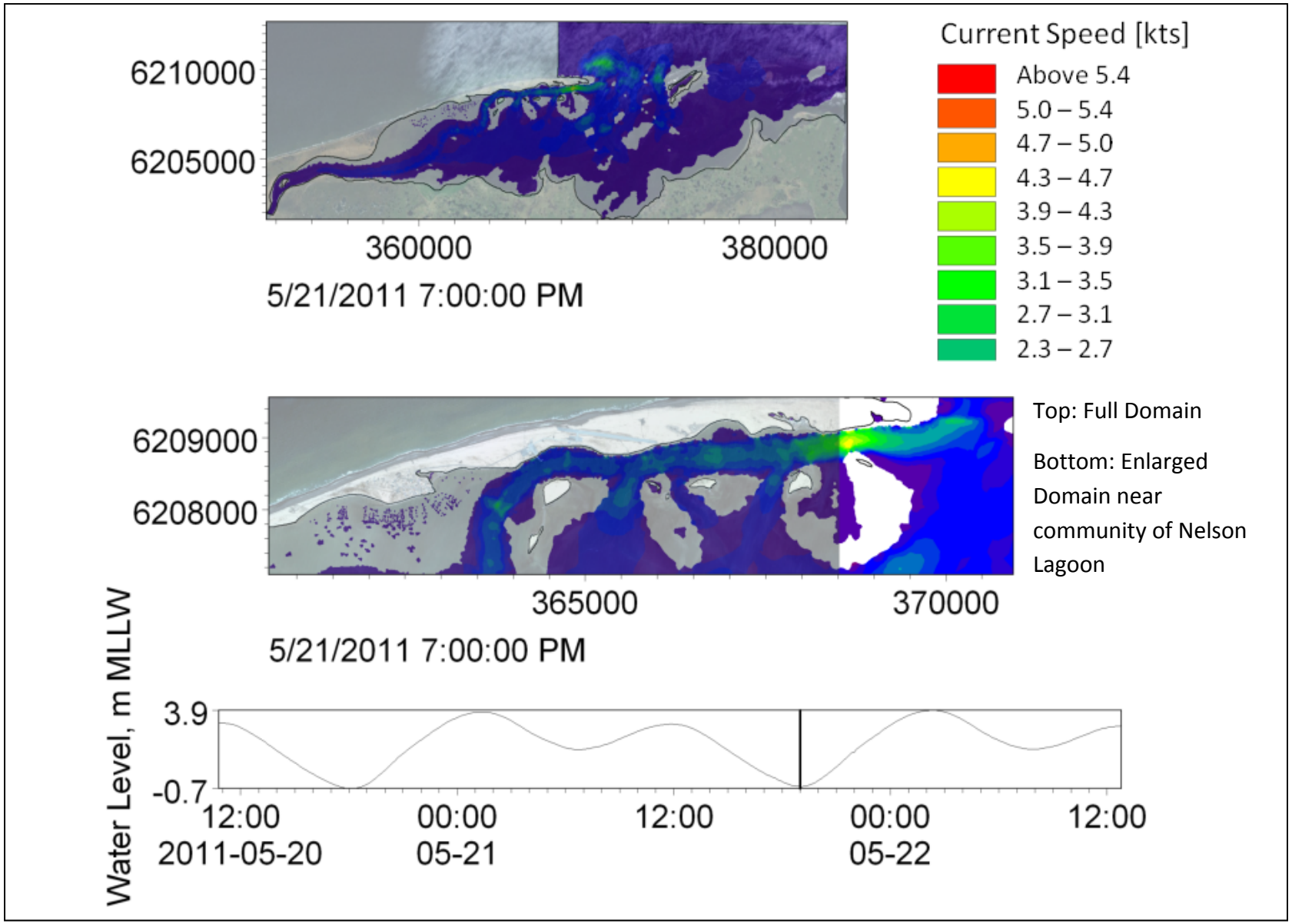
Current Speed [kts]
Above 5.4
5.0 – 5.4
4.7 – 5.0
4.3 – 4.7
3.9 – 4.3
3.5 – 3.9
3.1 – 3.5
2.7 – 3.1
2.3 – 2.7
6209000
6208000
365000
370000
5/21/2011 3:36:00 PM
Top: Full Domain
Bottom: Enlarged Domain near community of Nelson Lagoon
Water Level, m MLLW
3.9
-0.7
12:00
2011-05-20
00:00
05-21
12:00
00:00
05-22
12:00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Current Speed [kts]
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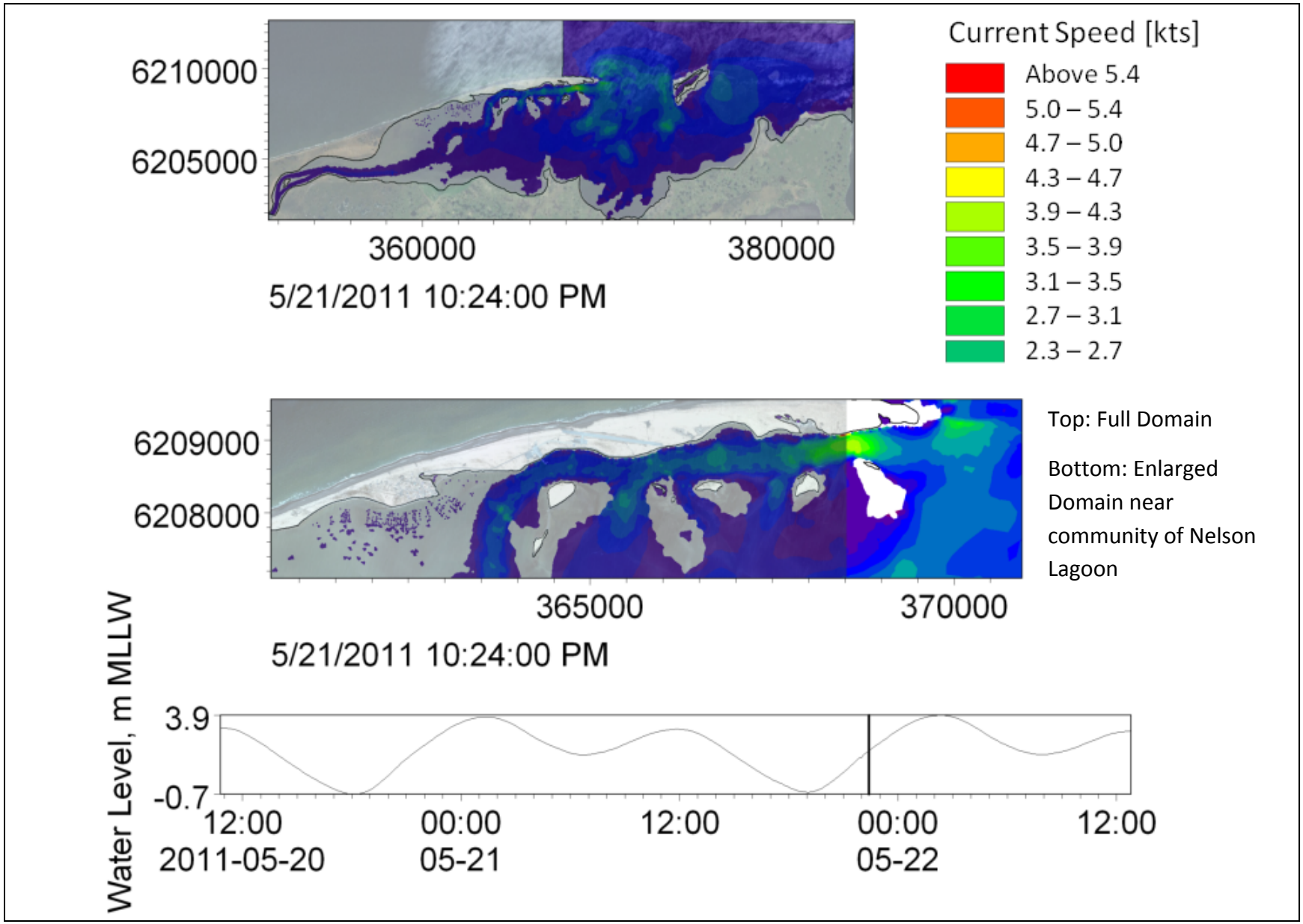
5.0 – 5.4
4.7 – 5.0
4.3 – 4.7
3.9 – 4.3
3.5 – 3.9
3.1 – 3.5
2.7 – 3.1
2.3 – 2.7
6209000
6208000
365000
370000
5/21/2011 7:00:00 PM
Top: Full Domain
Bottom: Enlarged Domain near community of Nelson Lagoon
Water Level, m MLLW
3.9
-0.7
12:00
2011-05-20
00:00
05-21
12:00
00:00
05-22
12:00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4.7 – 5.0
4.3 – 4.7
3.9 – 4.3
3.5 – 3.9
3.1 – 3.5
2.7 – 3.1
2.3 – 2.7
6209000
6208000
365000
370000
5/21/2011 10:24:00 PM
Top: Full Domain
Bottom: Enlarged Domain near community of Nelson Lagoon
Water Level, m MLLW
3.9
-0.7
12:00
2011-05-20
00:00
05-21
12:00
00:00
05-22
12:00