CAERNARVON – LAKE LERY
LAKE RIM RESTORATION PROJECT (BS-16)
BORROW SITE IMPACT ANALYSIS

FINAL
MAY 5, 2011

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Prepared for

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EXECUTIVE SUMMARY

STWAVE modeling was performed to evaluate the wave impacts of two proposed borrow areas in Lake Lery, Louisiana, as part of the Coastal Wetlands Planning Protection and Restoration Act Project BS-16: Caernarvon-Lake Lery Lake Rim Restoration Project. Lake Lery is an inland waterbody with the predominant influence on wave generation and propagation being surface winds. Proposed borrow area locations were provided by the Natural Resources Conservation Service (NRCS). Bathymetric data were obtained using field survey and geospatial gateway data. Seven modeling scenarios were identified based on statistical analysis of 40-year wind data. Wave modeling was carried out using the STWAVE nearshore wind-wave growth and propagation model.

There were no significant impacts to wave heights and wave direction changes along the shoreline for any of the seven modeled scenarios. Some impact was observed along the edge of the borrow areas but the impact was dissipated in the fetch between the borrow area and the shoreline. Since along-shore wave impacts correspond to longshore sediment transport pattern alterations, it can be concluded that there is no impact on the latter due to the proposed borrow area excavations.

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1.0 INTRODUCTION

STWAVE modeling was performed to evaluate the wave impacts of two proposed borrow areas in Lake Lery, Louisiana, as part of the Coastal Wetlands Planning Protection and Restoration Act Project BS-16: Caernarvon-Lake Lery Lake Rim Restoration Project (Louisiana Coastal Wetlands Conservation and Restoration Task Force 2009). Lake Lery is located in St. Bernard Parish and Plaquemines Parish, Louisiana. Figure 1.1 shows the project site and location of the two potential borrow sites. The approximate coordinates of the lake are Latitude 29.7991 and Longitude -89.8303. Marshes are located along the northern and southern shorelines of the lake. Oliver Canal, Creedmore Canal, Bayou Mandeville, Marine Canal, and Bayou Lery are the primary channels in the vicinity of Lake Lery (Figure 1.1). The lake experiences wind-induced waves that pose a risk of damage to shoreline and accelerated loss of adjacent, as well as interior, marshes. Two potential borrow areas are to be excavated within the lake with the excavated material being used for shoreline restoration. Locations of the proposed borrow areas were provided by the Natural Resources Conservation Service (NRCS). The depth of the proposed borrow areas was 10 ft below the existing bottom elevation. This report summarizes the wave modeling approach, procedures, results, and significant findings for the proposed borrow area excavations within Lake Lery.

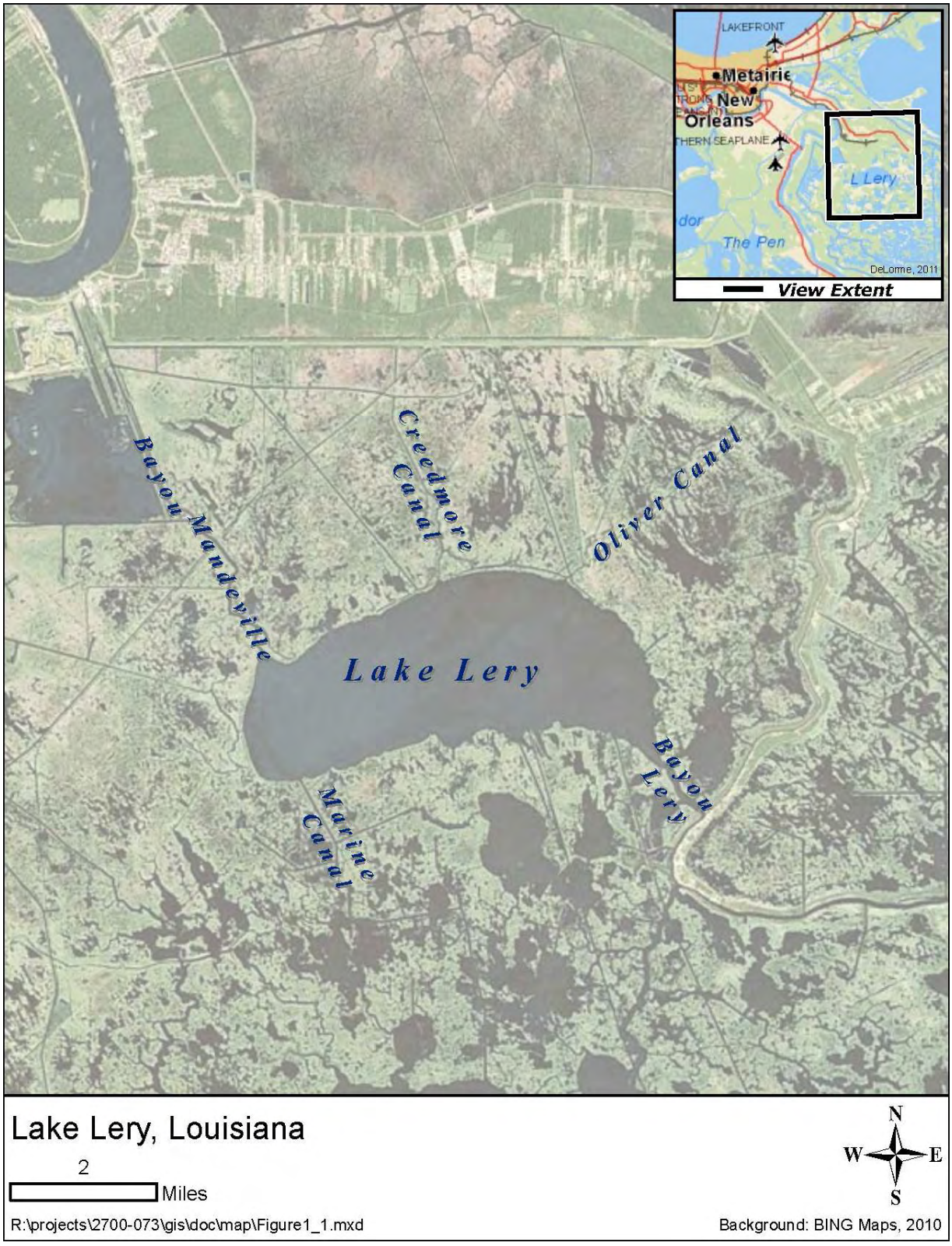

Figure 1.1. Project location map.

2.0 OBJECTIVES

The objective of this study was to evaluate impacts of potential borrow area excavations on wave heights, refraction (direction change), and sediment transport patterns. An appropriate wave model capable of simulating wave phenomena was to be selected and used to determine coastal changes over the length of the shoreline. If the model outputs indicated significant alterations in wave parameters and patterns, alternative runs were to be carried out to identify suitable borrow sites within the lake.

3.0 WAVE MODEL SELECTION

STWAVE (STeady-state spectral WAVE model) version 3.0 was chosen for this study since the model features directly corresponded to the requirements of the scope of work. Surface Modeling System (SMS) version 10.1 (Aquaveo Inc.), which allows for external execution of STWAVE 3.0 and provides pre- and post-processing tools, was used as the modeling interface.

STWAVE is a phase-averaged, steady-state, finite difference model (Resio 1987, 1988; Davis 1992; Smith et al. 1999, Smith et al. 2001). STWAVE incorporates near-shore wind-wave growth and propagation, radiation stress calculations, and identification of active wave-breaking regions. The main assumptions of the model are:

- Bottom slopes are mild;
- Wave reflection is negligible;
- Offshore wave conditions are spatially homogeneous;
- Waves, currents, and winds are steady;
- Refraction (i.e., wave direction change) and shoaling are linear;
- Currents are uniform vertically;
- Bottom friction is negligible; and
- Radiation stress (i.e., wave energy per unit area) is linear.

4.0 DATA COLLECTION AND ANALYSIS

4.1 Bathymetry

Existing topographic surface data were obtained from the NRCS Geospatial Data Gateway. T. Baker Smith, Inc. provided survey data for transects within the boundaries of the lake. The survey data were merged with the NRCS topographic map. A consolidated surface was developed from this merged surface for input bathymetry. Figures 4.1 and 4.2 show the bathymetry for the existing and proposed conditions, respectively. The proposed Borrow Area A is a pentagon with the following dimensions (clockwise starting from the pentagon base): 4,927 ft by 1,171 ft by 2,327 ft by 2,756 ft by 1,300 ft, located approximately 1,210 ft east of the western shoreline of Lake Lery. Borrow Area B abuts the southern shoreline, and is 5,274 ft long by 1,310 ft wide. The approximate areas of Borrow Areas A and B are 0.248 square mile each. The borrow material yield for an excavation depth of 10 ft and 1:1 side slopes will be approximately 2.65 million cubic yards from each borrow area.

The existing bathymetry in the vicinity of Borrow Area A is relatively uniform with depths increasing away from the shoreline, except at the southwestern end where the landmass protrusions and marsh-like extensions exist. The fetch (distance over which wind blows before the wind-induced wave reaches the shoreline) for Borrow Area A is 122 ft (400 m) and is, by and large, constant along the extents of Borrow Area A.

Borrow Area B is located offshore from an undulating coastline with multiple landmass projections and marsh-like extensions. The fetch of Borrow Area B varies between a few feet to up to 61 ft (200 m) towards the southwestern corner of Borrow Area B.

4.2 Wave and Current Data

Since Lake Lery is an inland lake with no hydraulically significant channel connections to the Gulf of Mexico, there are no tidal current influences on the lake. Wind-driven waves are the only significant inputs to the STWAVE model.

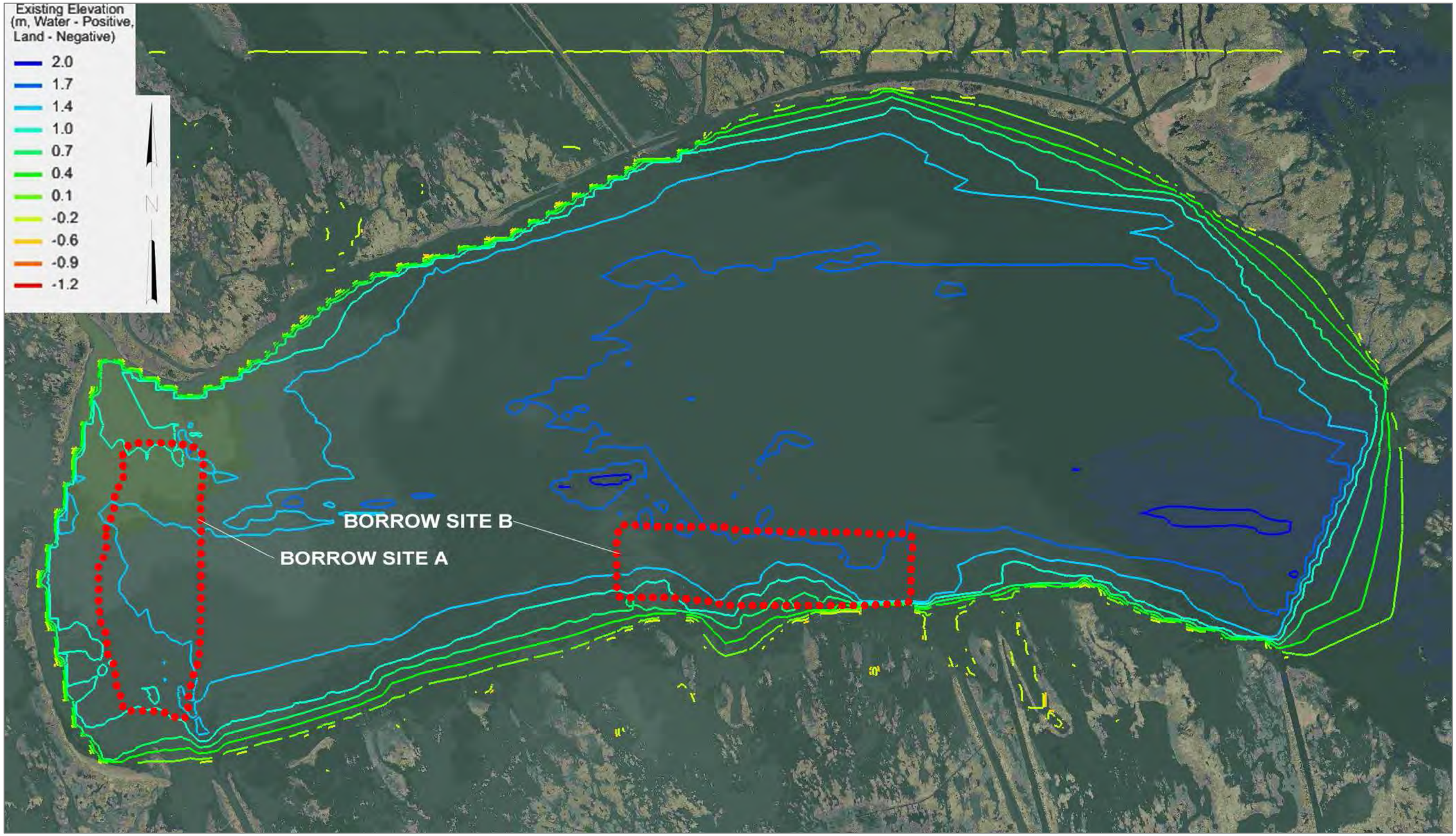

Figure 4.1. Existing bathymetry.

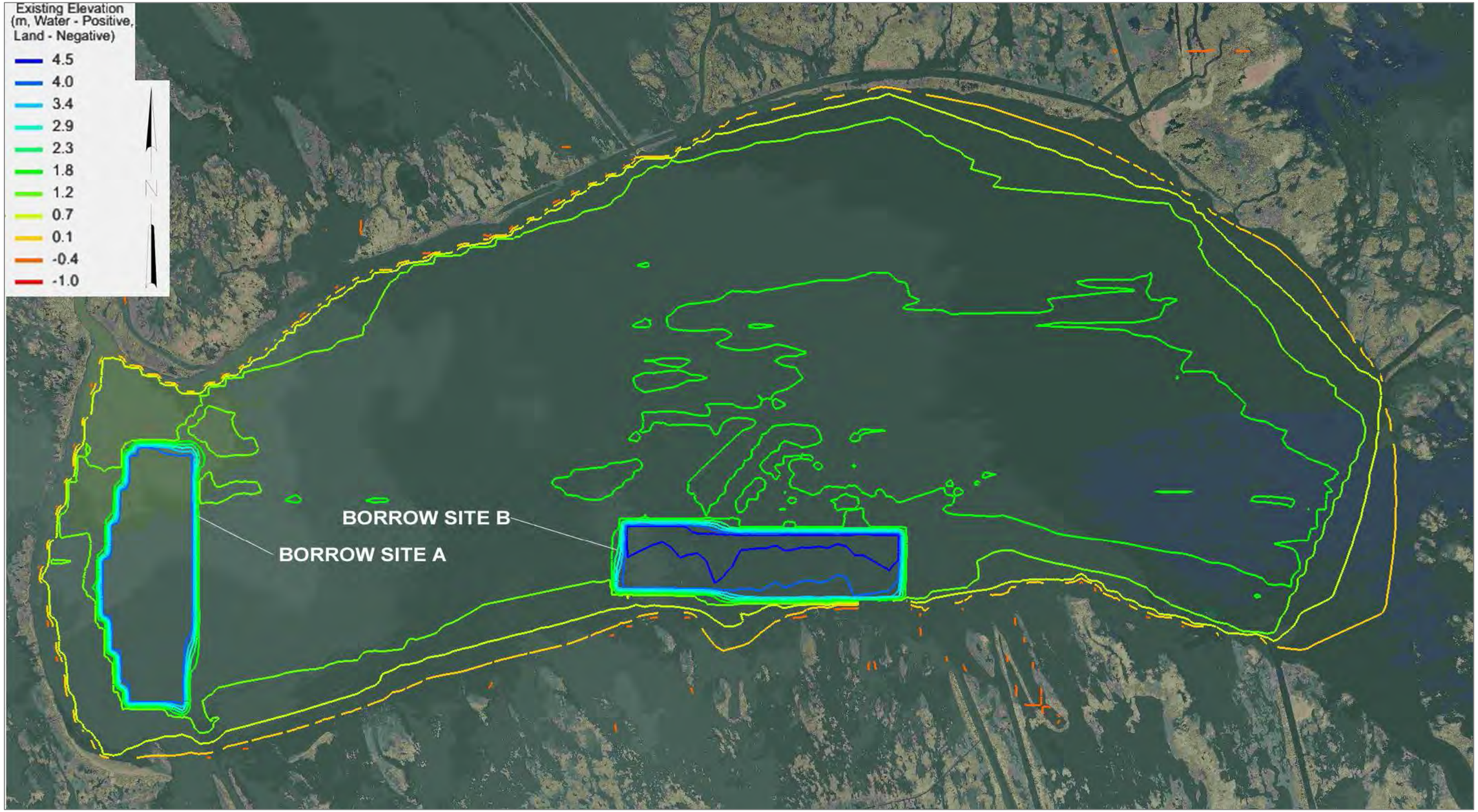

Figure 4.2. Proposed bathymetry.

4.3 Wind Data

Wind rose diagrams and wind data were obtained from the National Climatic Data Center (NCDC) National Environmental Satellite, Data, and Information Service (NESDIS) for the New Orleans Airport (Station 12916) and New Orleans Lakefront (Station 53917) locations. The stations are located approximately 30 and 20 miles northwest of Lake Lery, respectively. Statistical analysis of 40 years of wind data (1971 to 2011) excluding tropical storm and hurricane speed winds indicated the five dominant wind directions (DWD) listed in Table 4.1 based on wind rose diagrams.

The original scope of work required analyses of the 1-year and 20-year storm events. Use of wind speeds corresponding to rainfall for these events proved problematic because (1) there is no correlation between precipitation and wind speeds due to variations in relative humidity, and (2) if modeling had been done for these criteria, the impacts would be infinitesimal due to the very low wind speeds. Hence, the modeling scenarios were modified after discussion with NRCS to address statistically significant cases i.e., based on wind speeds corresponding to the 50% and 90% exceedance probabilities for the period of record. The 50% recurrence case was defined as winds blowing from the south-southeast (165º, clockwise due north – the meteorological convention), with a speed of 11.8 ft/s. The 90% recurrence case was defined as winds blowing from the south-southeast (170º) with a speed of 20.3 ft/s.

Table 4.1. Input parameters for STWAVE modeling scenarios.

Simulation Case*	Wind Direction		Wind Speed	
	Wind blowing from	Degrees	m/s	ft/s
DWD1	N	0	10.3	33.8
DWD2	NE	45	10.3	33.8
DWD3	E	90	10.3	33.8
DWD4	SSE	157.5	10.3	33.8
DWD5	S	180	10.3	33.8
50% Recurrence	SSE	165	3.60	11.8
90% Recurrence	SSE	170	6.19	20.3

* DWD cases are the dominant wind direction and speed derived from wind rose diagrams

5.0 STWAVE MODELING

5.1 Grid Definition

The model was set up and run using International System of Units (SI) units of measurement in accordance with SMS 10.1 requirements. Figures 5.1 and 5.2 show the computational grid superimposed on the bathymetry for existing and proposed conditions, respectively, in the SMS 10.1 interface.

A rectangular grid containing evenly spaced grid cells was designed with the origin at a Northing and Easting of 230233.89, 3297616.31. The horizontal reference coordinate system was Universal Transverse Mercator (UTM), North American Datum 1983 (NAD83), Zone 16 North, meters. The North American Vertical Datum of 1988 (NAVD88) was used as the vertical reference datum. The grid was made up of 171 columns (east-west) and 86 rows (north-south). Each grid cell was 164 ft (50 m) by 164 ft (50 m) and the entire computational grid was 14,104 ft (4,300 m) wide (north-south) by 28,044 ft (8,550 m) long (east-west). As per STWAVE 3.0 convention, positive elevation values indicate water, and negative values indicate land.

5.2 Project-Specific Model Assumptions

The following are the model assumptions for this project:

1. Both the northern and southern shoreline of Lake Lery were assumed to be affected by the borrow areas (requiring STWAVE be run in full-plane mode),
2. There was no tidal influence on waves – only source and propagation terms from wind were considered,
3. There is no bottom friction, and
4. Bottom slopes are mild.

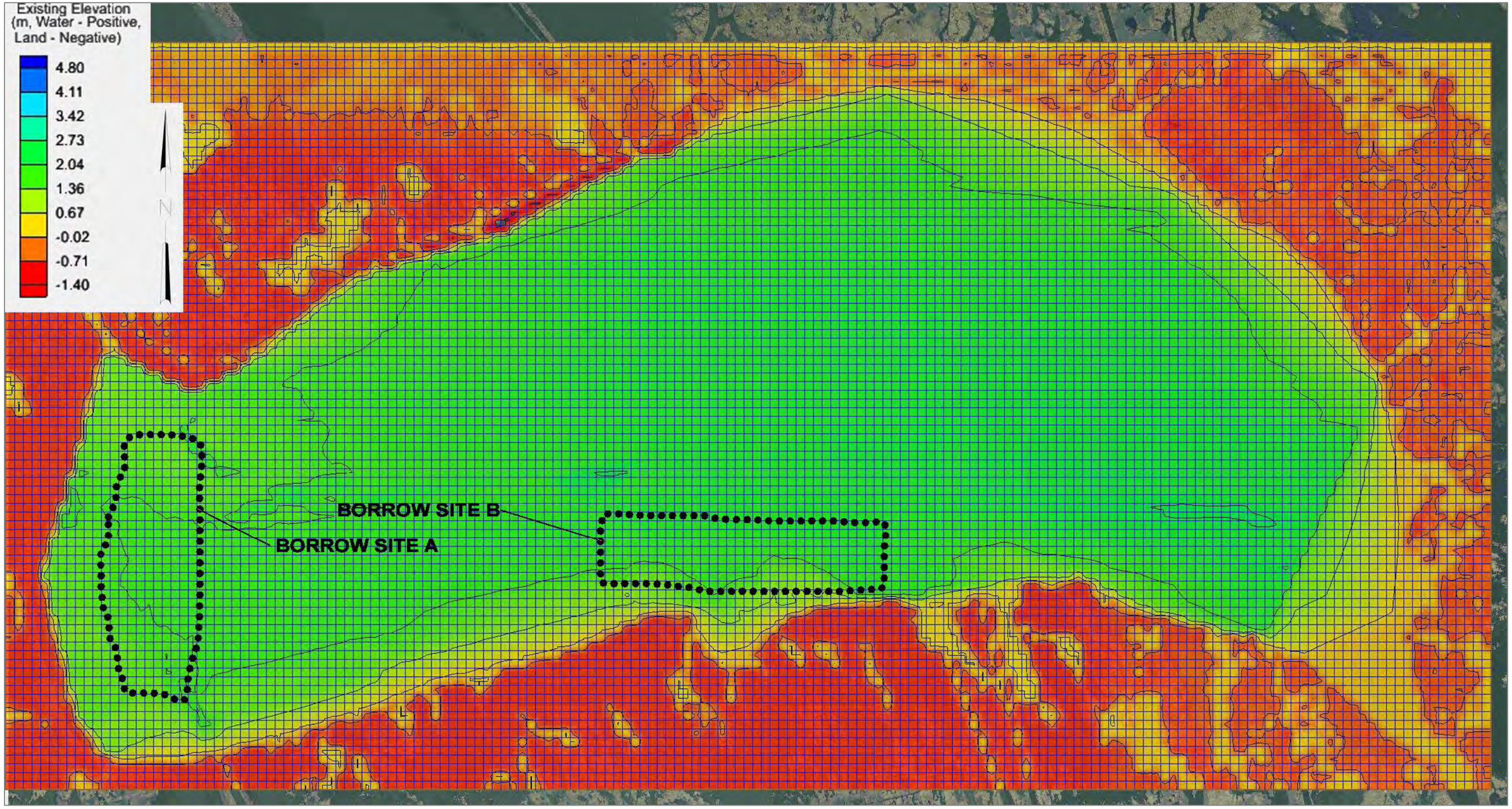

Figure 5.1 Computational grid for existing conditions.

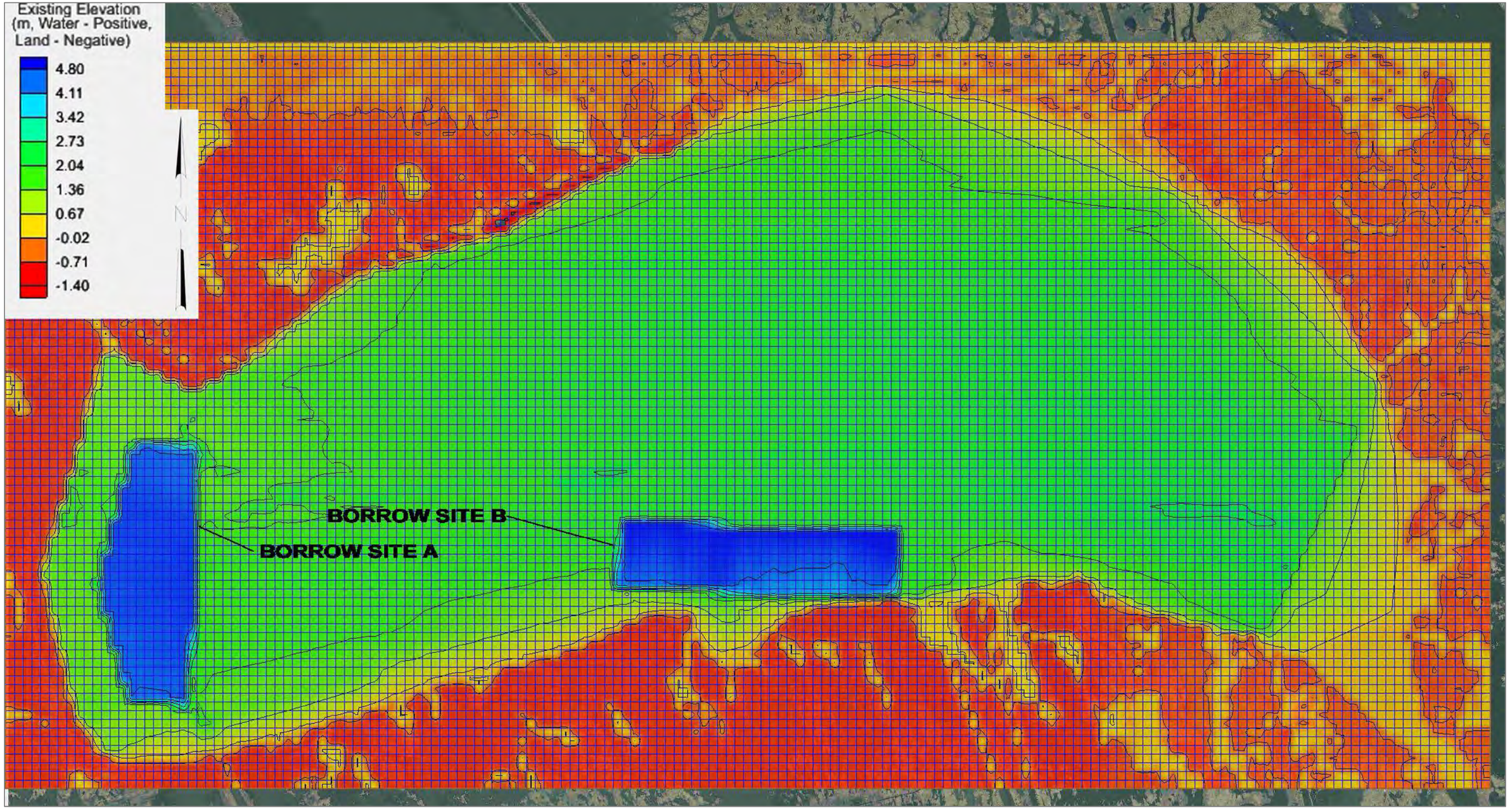

Figure 5.2. Computational grid for proposed conditions.

5.3 Results and Discussion

Simulations were run for all seven scenarios listed in Table 4.1 for both pre- and post-excavation grids. Wave height and direction differences were obtained by subtracting the wave height results for existing bathymetry from the proposed bathymetry for each case. Shoreline wave energy flux ratios were used to determine the alterations in longshore sediment transport patterns. The following is a discussion of STWAVE model results for the seven modeled scenarios. Figures showing the wave height and direction differences are presented in Appendix A.

5.3.1 Wave Height and Direction

Tables 5.1 and 5.2 summarize the differences in wave heights and directions (post-excavation minus pre-excavation) near the shoreline, within the borrow areas, and across the entire area of Lake Lery. Since it is a completely inland lake, STWAVE was run in full plane mode to evaluate the impacts along the entire lake shoreline.

Wave refraction occurs when wind-induced waves change direction as the depth decreases towards the shoreline. This is primarily due to velocity change with depth. As waves approach the shoreline at an angle, the wave base on one end drags the bottom before the other end, resulting in wave bending. Wind-induced waves bend to become more parallel with the shoreline. For shallow water depths, the wave heights are not more than 0.55 times the depth (Massel 1998).

Table 5.1. Summary of borrow area impacts on wave heights.

Case #	BORROW AREA A Maximum Wave Height Increase/Decrease		BORROW AREA B Maximum Wave Height Increase/Decrease		ENTIRE LAKE	
	Within Borrow Area (m)	Near Shoreline (m)	Within Borrow Area (m)	Near Shoreline (m)	Maximum Wave Height Increase (m)	Maximum Wave Height Decrease (m)
1	+0.024 / -0.032	-0.00 / +0.00	+0.038 / -0.018	-0.00 / +0.00	0.066	-0.06
2	+0.044 / -0.082	-0.00 / +0.00	+0.026 / -0.01	-0.00 / +0.00	0.062	-0.1
3	+0.052 / -0.028	-0.00 / +0.00	+0.02 / - 0.044	-0.00 / +0.00	0.084	-0.06
4	+0.015 / -0.045	-0.00 / +0.00	+0.015 / -0.12	-0.00 / +0.00	0.015	-0.12
5	+0.016 / 0.00	-0.00 / +0.00	+0.006 / -0.07	-0.00 / +0.00	0.016	-0.07
6	+0.006 / -0.018	-0.00 / +0.00	+0.018 / -0.078	-0.00 / +0.00	0.018	-0.09
7	0.00 / -0.06	-0.00 / +0.00	+0.015 / -0.105	-0.00 / +0.00	0.015	-0.12

Table 5.2. Summary of borrow area impacts on wave direction.

Case #	BORROW AREA A Maximum Wave Direction Change		BORROW AREA B Maximum Wave Direction Change		ENTIRE LAKE	
	Within Borrow Area (Degrees)	Near Shoreline (Degrees)	Within Borrow Area (Degrees)	Near Shoreline (Degrees)	Maximum Direction Increase (Degrees)	Maximum Direction Decrease (Degrees)
1	23	0.6	23	0.0	29	-25
2	24	0.5	16	0.0	32	-40
3	-20	0.4	20	0.0	160	-20
4	-34.7	0.4	10.3	0.0	46.3	-34.7
5	-30	0.6	10	0.0	50	-40
6	-28	0.5	16	0.0	49	-50
7	-31.5	0.5	20	0.0	36.6	-40

Wind-induced waves result in surface whirls, which cause pressure differences that break the flat surface. The waves start as small wrinkles and continue to grow. Small waves are steep in the beginning, but in the course of developing, they grow faster in length than in height. The most important factors controlling the growth of wind-driven waves are wind speed, wind duration, and fetch. When wind duration is not limiting its growth, wind speed and fetch determine the wave height. Bathymetry, especially the presence of sudden obstructions and transient structures, and marsh features (however small they are) strongly influence wave height, direction change, and breaking. For stronger winds, the wave propagation speed is comparable to the wind speed but for calmer winds, the former is always greater than the latter because the wind cannot feed energy to the waves.

Borrow Area A is located at almost a constant offset (400 m off the shoreline), except at the southwestern end where there are some land mass projections and marsh-like extensions. Depending on the wind direction, these can cause wave height and direction changes. On the other hand, Borrow Area B is located against an undulating shoreline with multiple such projections and extensions. The offset of Borrow Area B from these features ranges from few meters to up to 200 m towards the southwestern edge. As a consequence there will be varying changes (increases as well as decreases) in wind speeds and directions depending on the wind directions. For winds blowing perpendicular to the shoreline, this directly translates to varying fetch, the effects of which are discussed above. For winds blowing at an angle, waves will tend to align themselves parallel to the shoreline, and therefore have to refract by a larger angle. Therefore, more wave parameter variation is expected due to Borrow Area B than to Borrow Area A; based on wind direction and speeds, some of these impacts, though minor, could reach as far as the northern shoreline of Lake Lery.

5.3.2 Wave Energy

Waves in Lake Lery are wind-driven, long waves (wave length much greater than wave height), and therefore, linear wave theory is applicable. Since there are no tidal and current influences, the model was run with a zero spectra (no specific wave heights, frequency). Moreover, since there are no significant channel (current) inflows/outflows, wind-driven waves

are the only sources of wave energy for the project area. As mentioned earlier, the changes in wave heights were not significant for all modeled scenarios for both Borrow Areas A and B (i.e, had maximum increases of 2.5 inches). Therefore, though there were significant wave direction changes in certain areas for some scenarios, the resulting wave energy changes were not significant. Moreover, the available fetch was adequate to dissipate the wave energy, without causing adverse impacts to the shoreline as compared to existing conditions.

5.3.3 Sediment Transport Pattern

To determine the impacts of changes in wave height and direction caused by proposed borrow site excavations on the longshore sediment transport, analyses of wave energy flux ratios along the shoreline were performed. Alongshore energy flux influences the longshore sediment transport patterns (Dean and Dalrymple 2002). The flux per unit length of shoreline is given by the following equation:

$$F = \frac{1}{16}\rho g H^2 \sqrt{gh} \sin 2\theta$$

Where ρ = density of water,
g = acceleration due to gravity,
H = wave height,
h = water depth, and
θ = angle between wave ray and onshore direction (perpendicular to shore = 0).

Wave energy flux ratios (non-dimensional) were developed for each of the seven modeling scenarios based on the near-shore parameters. Since wave heights and water depth did not vary significantly between existing and proposed conditions, the flux ratios reduced to the ratio of the sine of twice the wave ray direction angles. From Table 5.2, the near shore deflection angles were zero for Borrow Area B, and 0.4º to 0.6º for Borrow Area A, and hence the wave energy flux ratios were 1 for all seven modeling scenarios for both sites. Therefore, it can be concluded that there will be no significant impact on the longshore sediment transport potential due to the proposed borrow area excavations.

6.0 CONCLUSIONS

Based on the STWAVE modeling performed for the seven dominant (statistically significant) scenarios, there will be no significant impacts to wave heights, direction, and longshore sediment transport patterns due to the excavation of the proposed borrow areas. There may be some localized increases and decreases in wave heights and directions due to the undulating southern shoreline and depth decrease along the western shoreline. However, these changes (increases and decreases) are not significant enough to be sustained over the available fetch and cause an impact along any of the shoreline. Pipelines present in the area will also be unaffected due to their layout and the very slight increase in wave heights.

7.0 REFERENCES

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Smith, J.M., D.T. Resio, and A.K. Zundel. 1999. *STWAVE: Steady-State Spectral Wave Model; Report 1: User's manual for STWAVE Version 2.0* [Instructional Report CHL-99-1]. US Army Corps of Engineers, Engineer Research and Development Center. Vicksburg, MS.

APPENDIX A

STWAVE Model Outputs

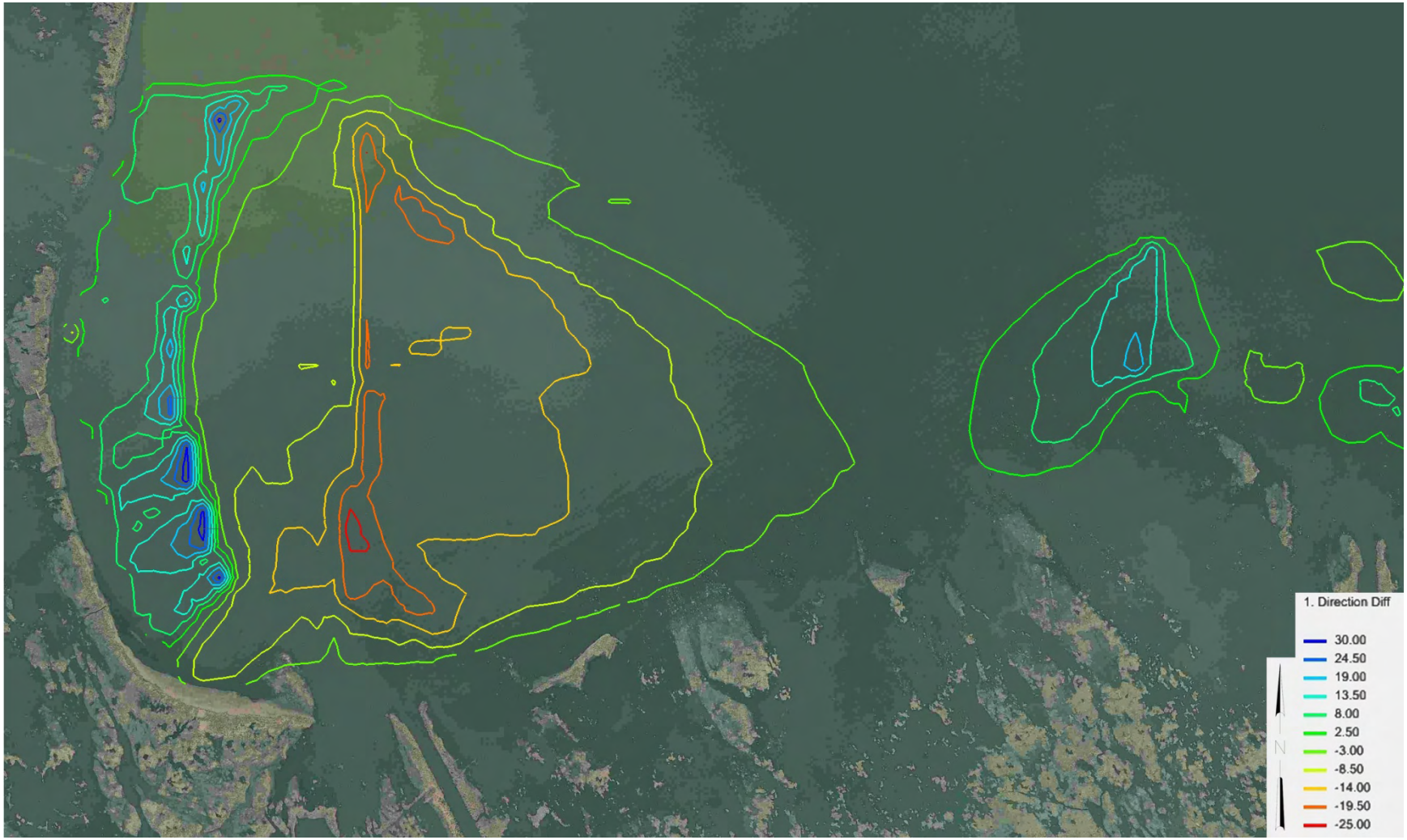

Figure A1. Borrow Area A Wave Direction Difference – Case 1 (units = meters).

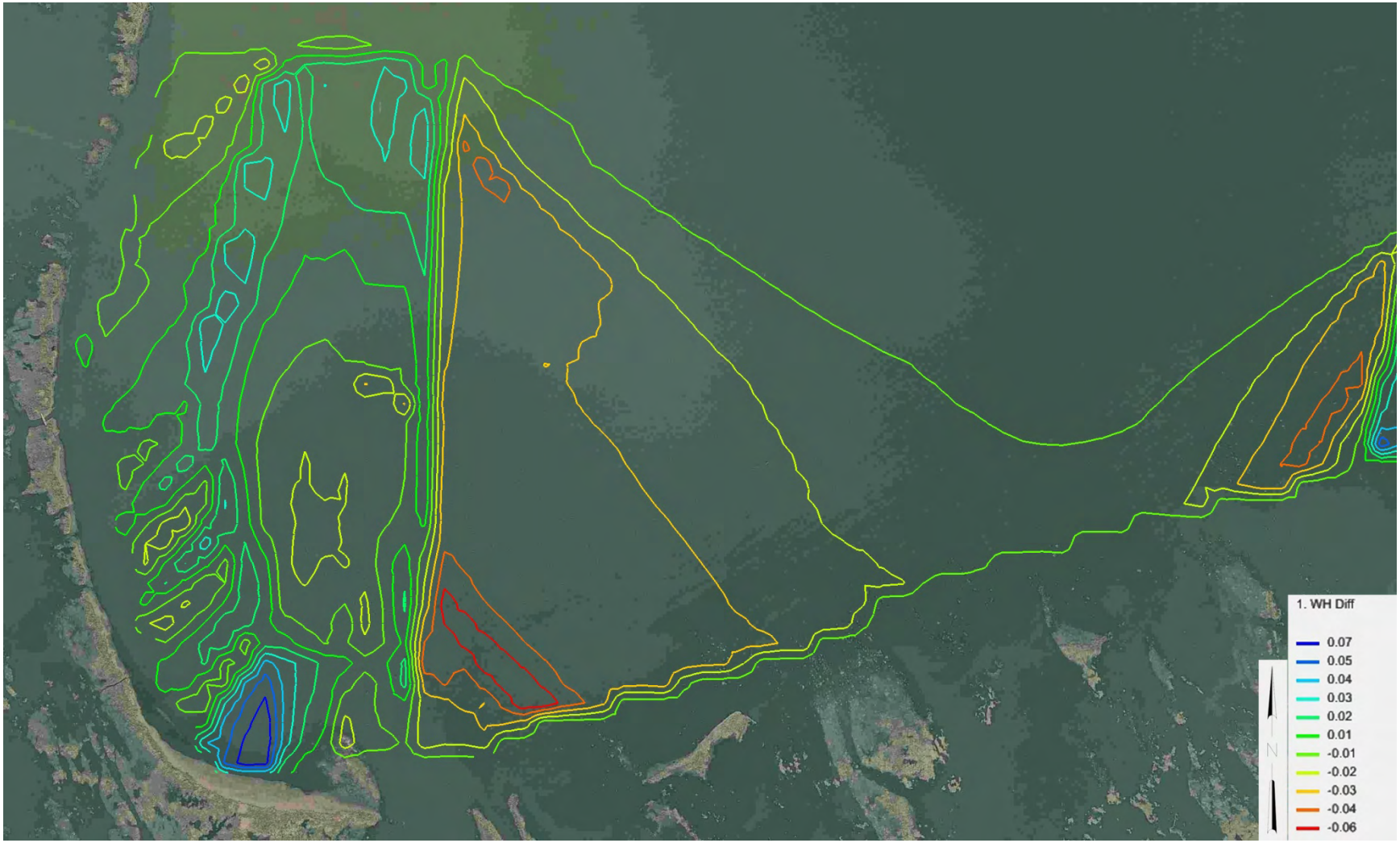

Figure A2. Borrow Area A Wave Height Difference – Case 1 (units = meters).

Figure A3. Borrow Area B Wave Direction Difference – Case 1 (units = meters).

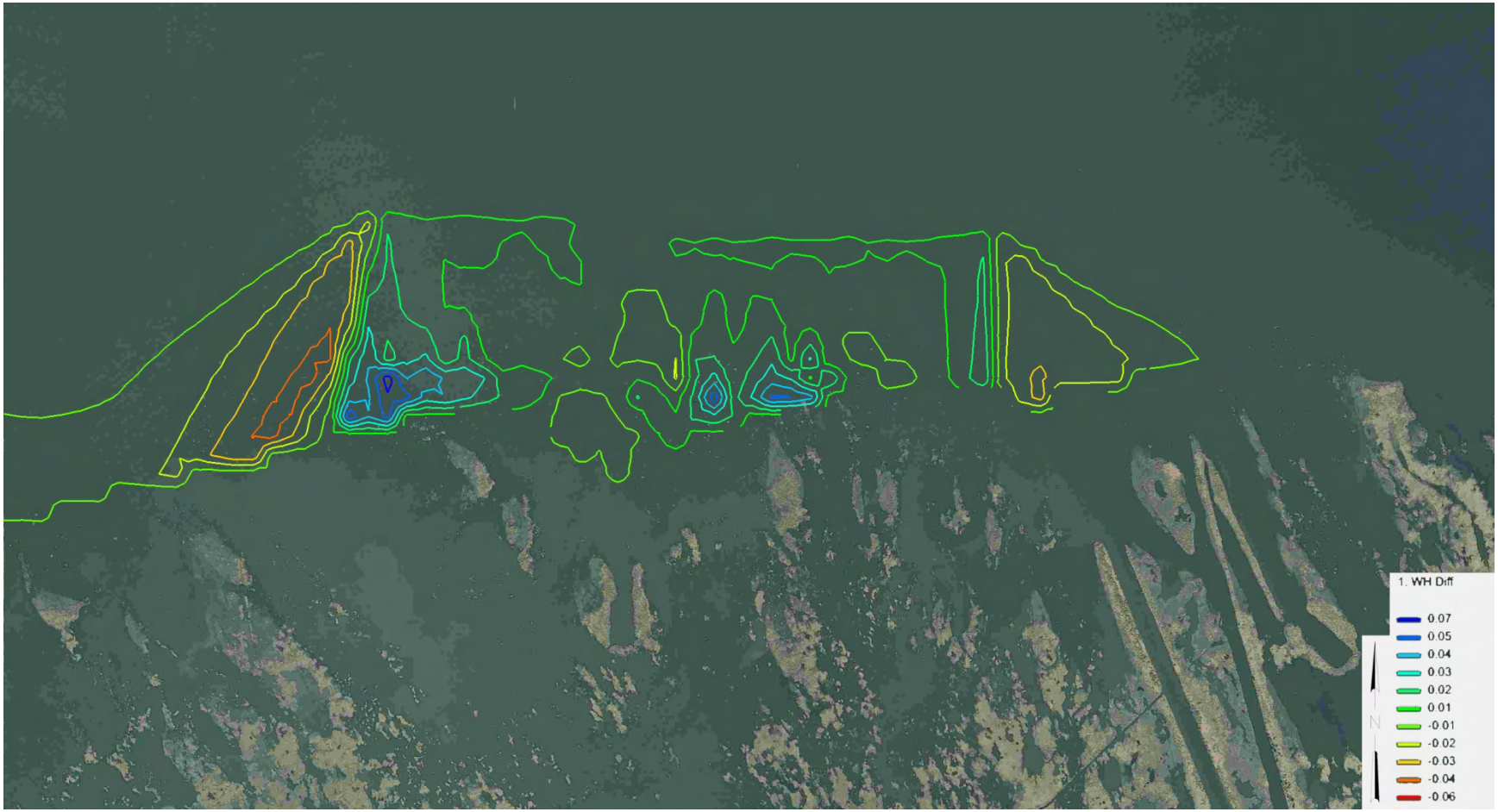

Figure A4. Borrow Area B Wave Height Difference – Case 1 (units = meters).

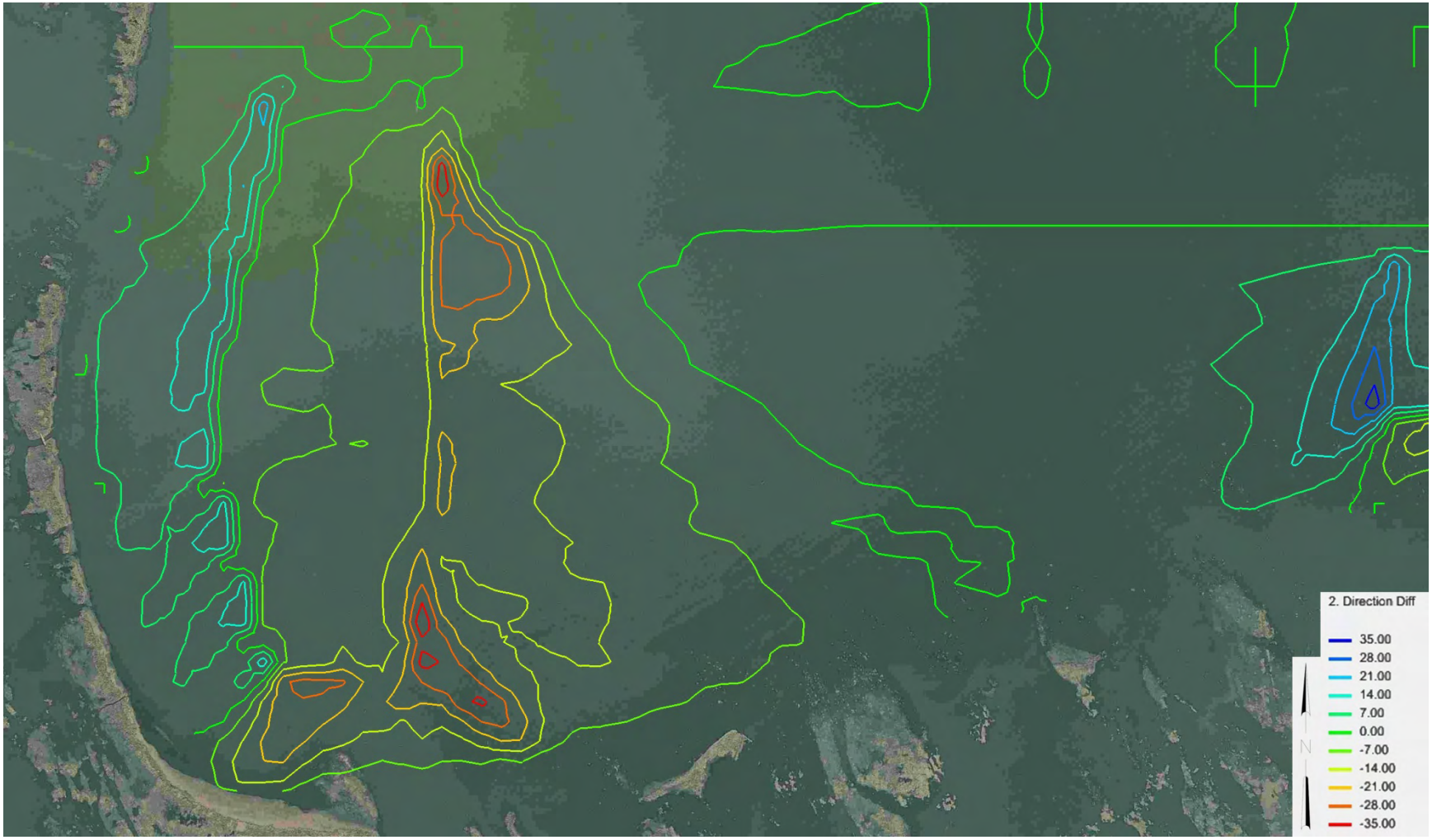

Figure A5. Borrow Area A Wave Direction Difference – Case 2 (units = meters).

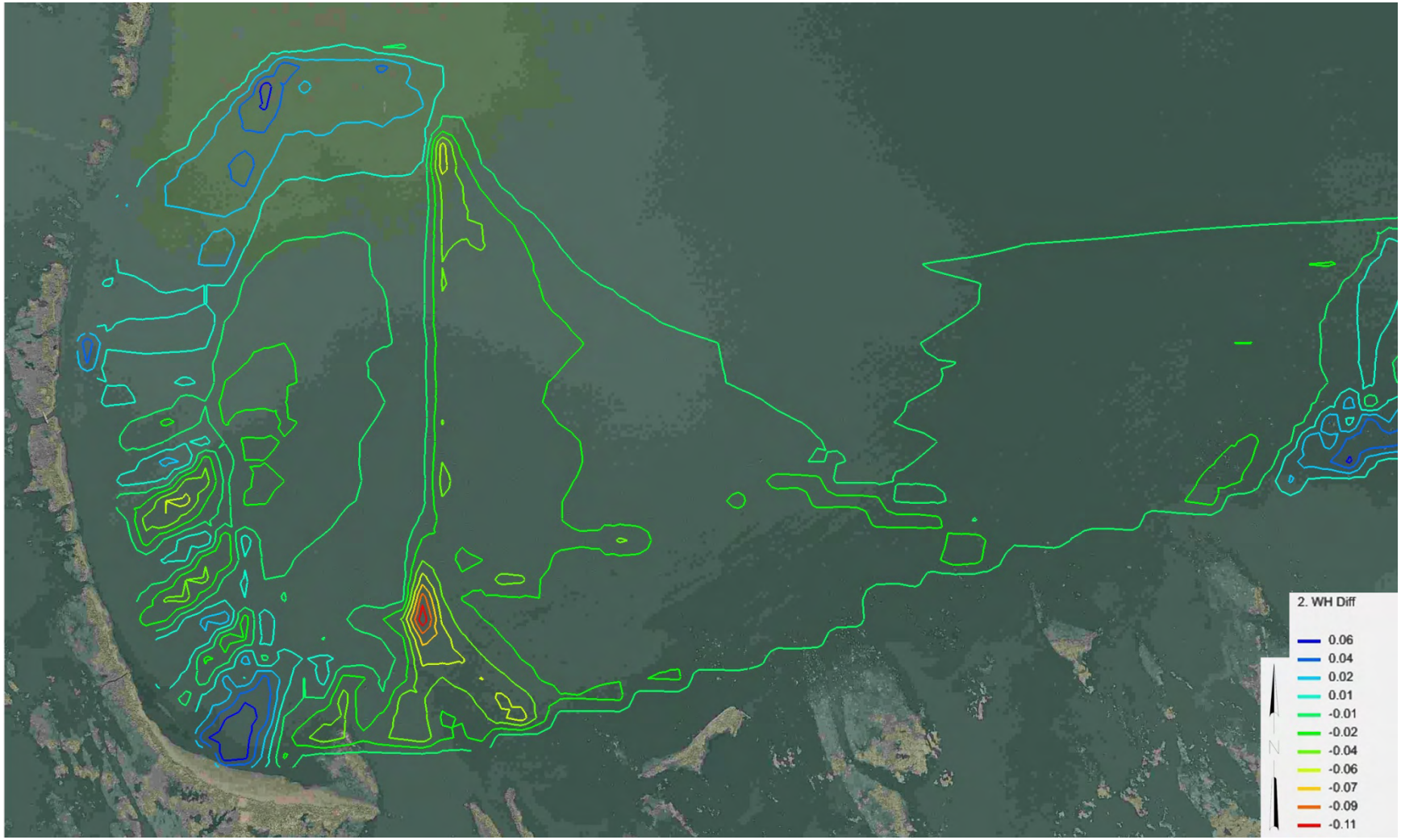

Figure A6. Borrow Area A Wave Height Difference – Case 2 (units = meters).

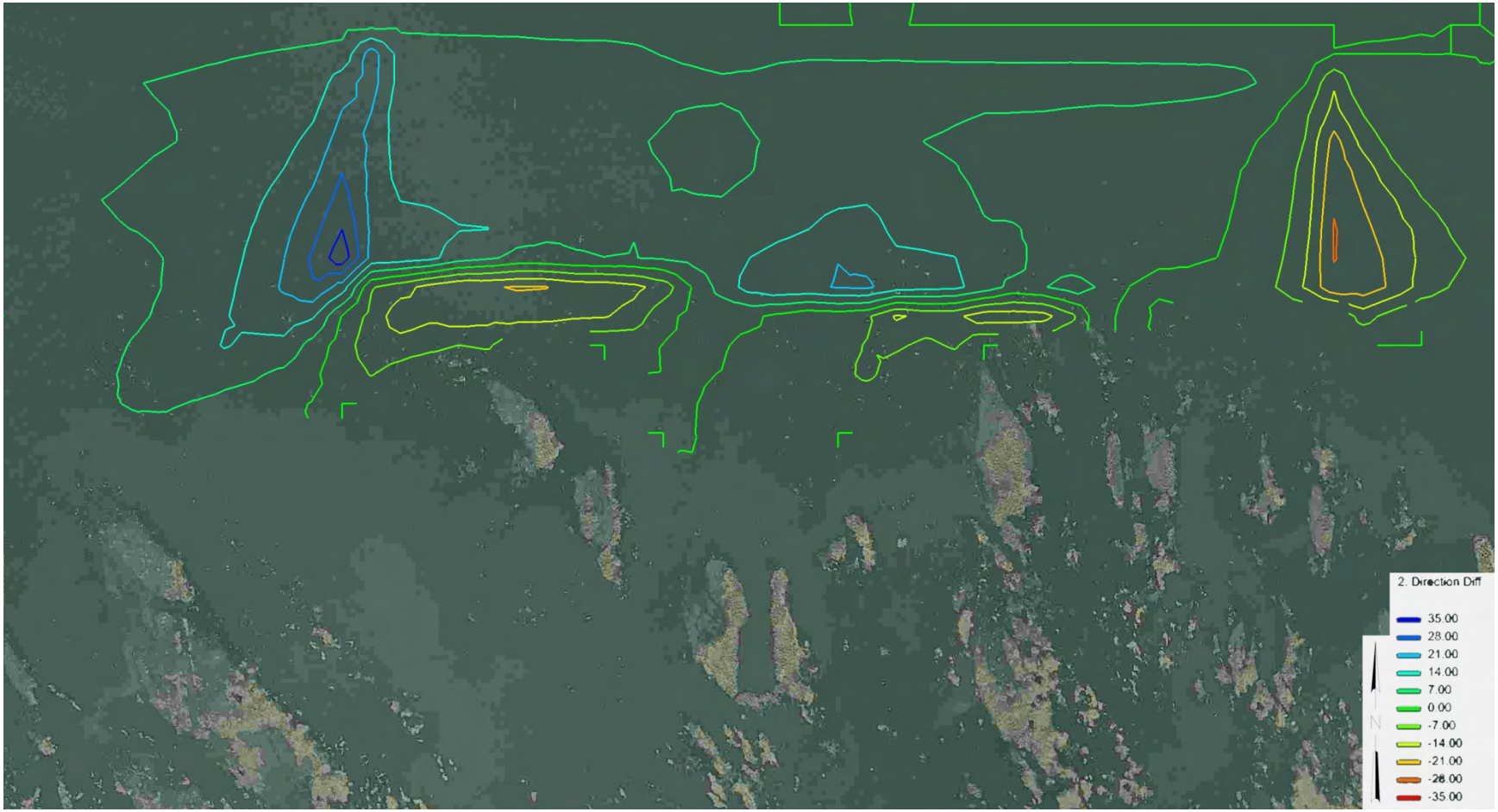

Figure A7. Borrow Area B Wave Direction Difference – Case 2 (units = meters).

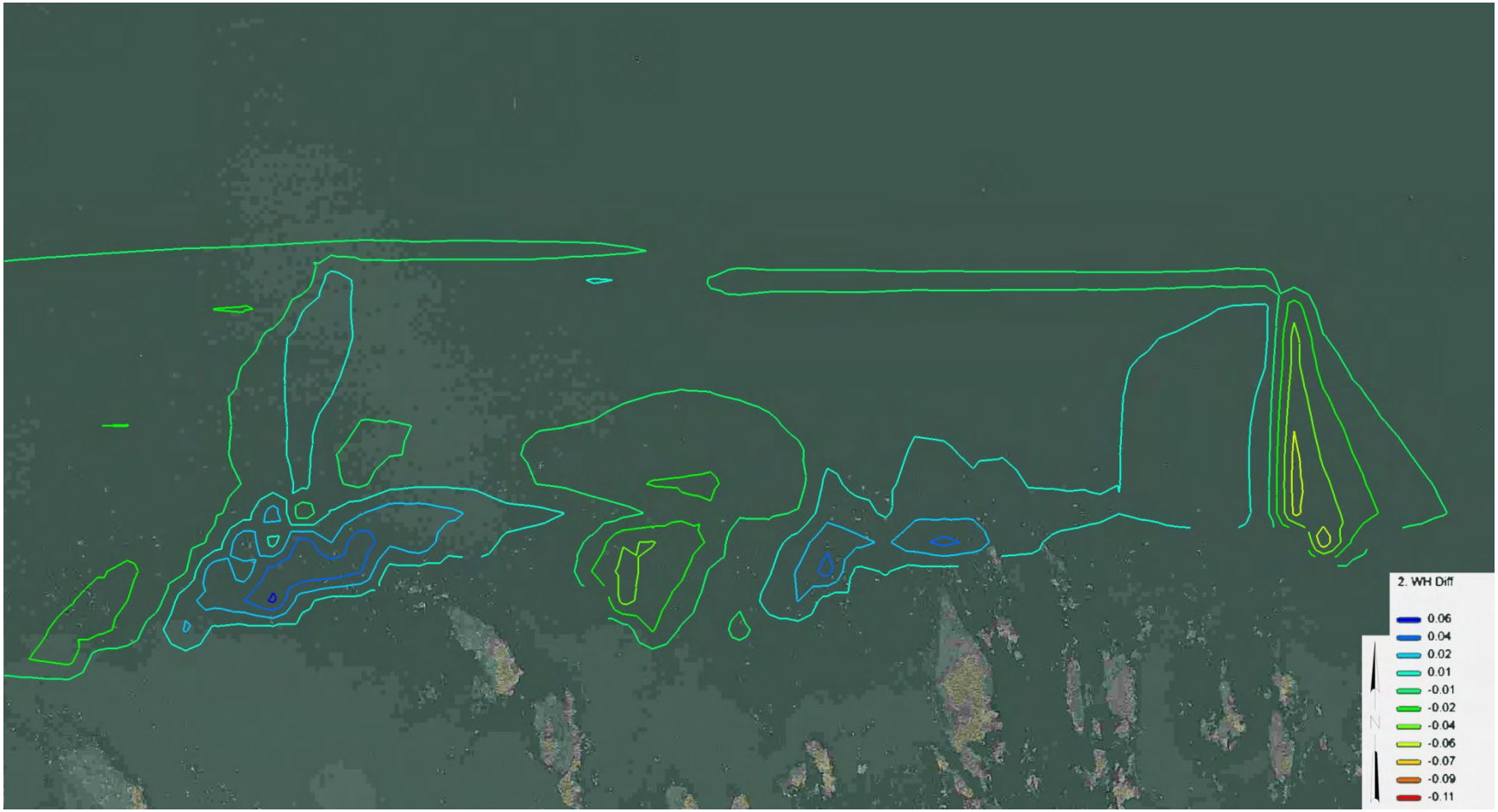

Figure A8. Borrow Area B Wave Height Difference – Case 2 (units = meters).

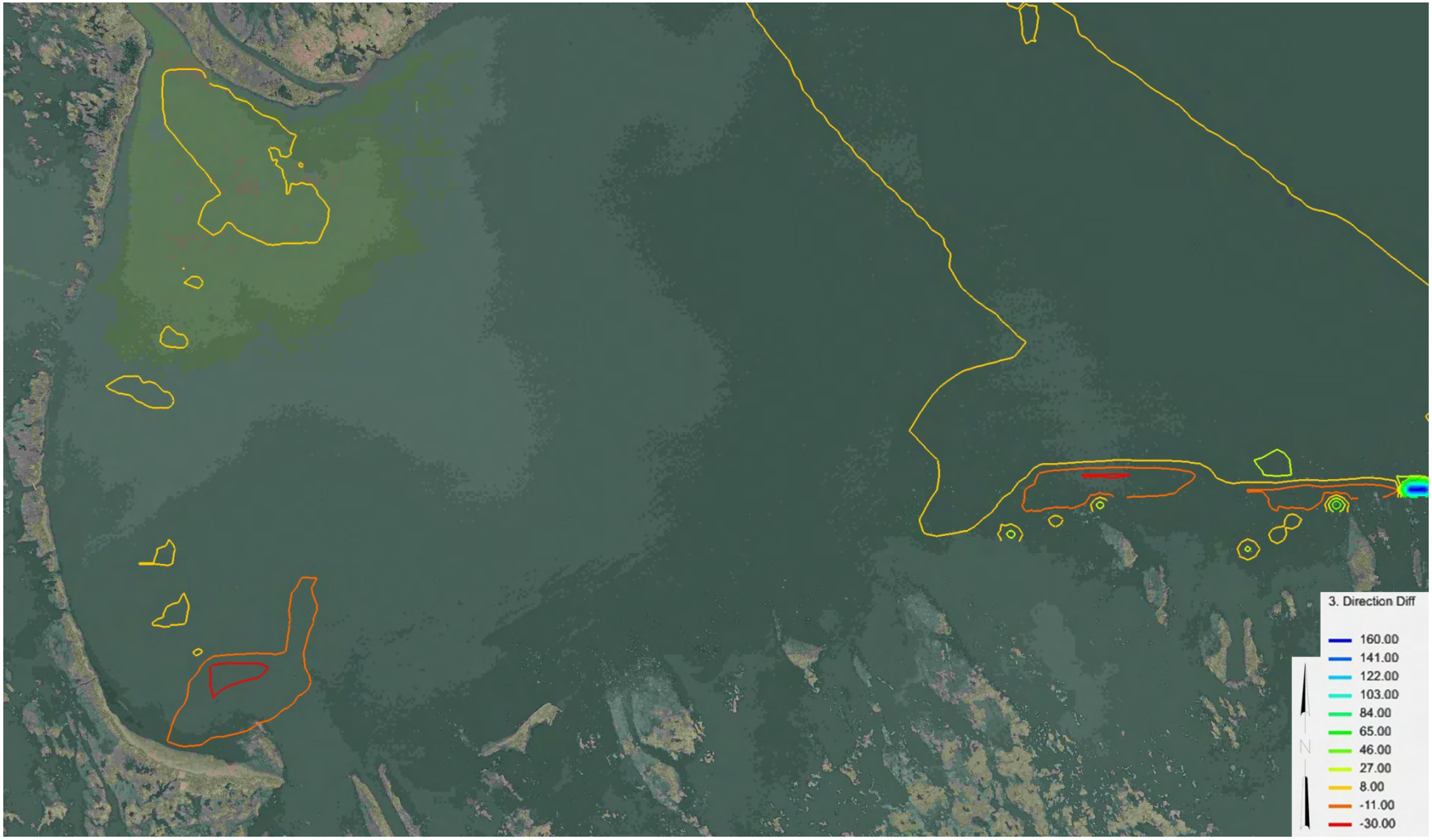

Figure A9. Borrow Area A Wave Direction Difference – Case 3 (units = meters).

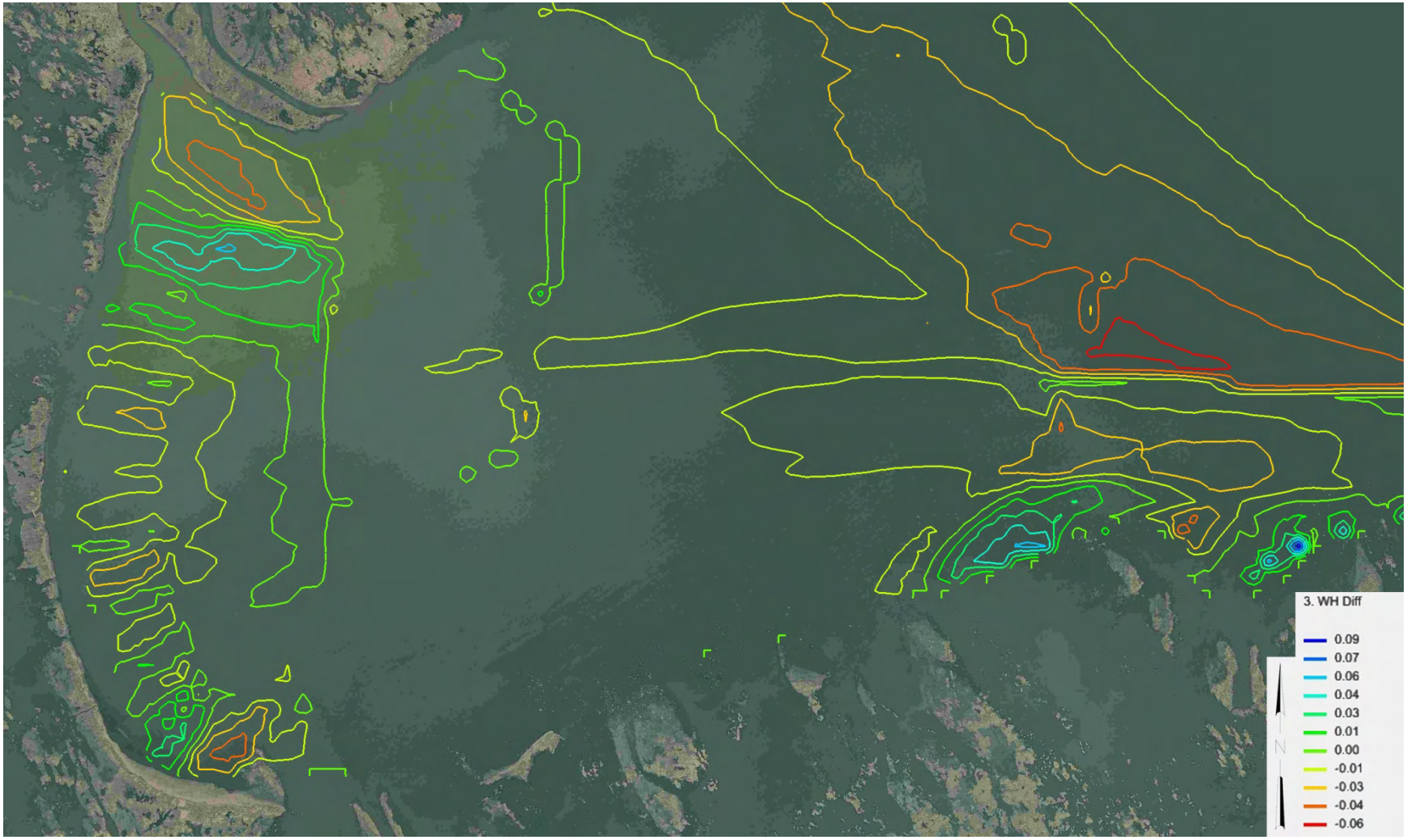

Figure A10. Borrow Area A Wave Height Difference – Case 3 (units = meters).

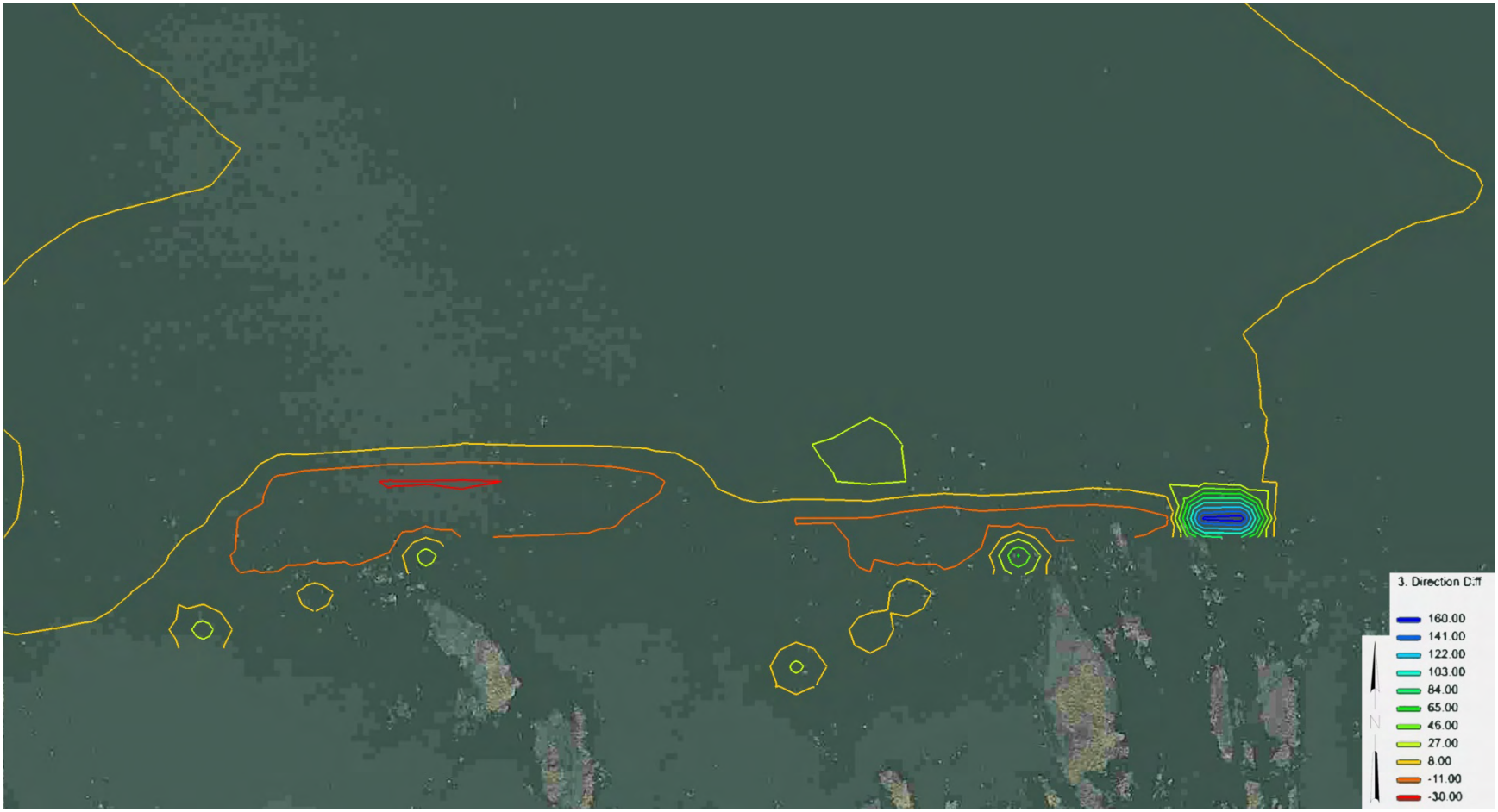

Figure A.11. Borrow Area B Wave Direction Difference – Case 3 (units = meters).

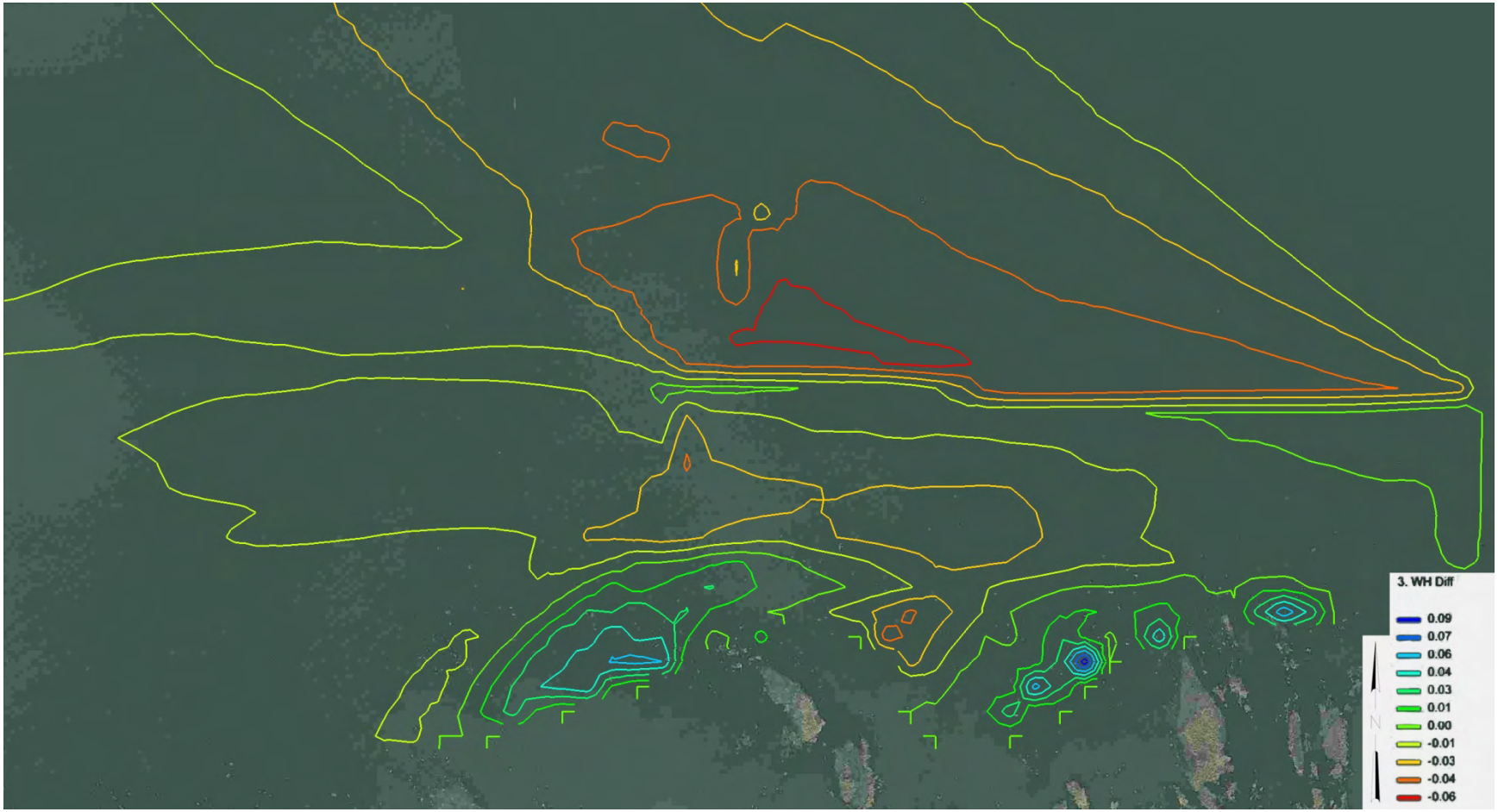

Figure A.12. Borrow Area B Wave Height Difference – Case 3 (units = meters).

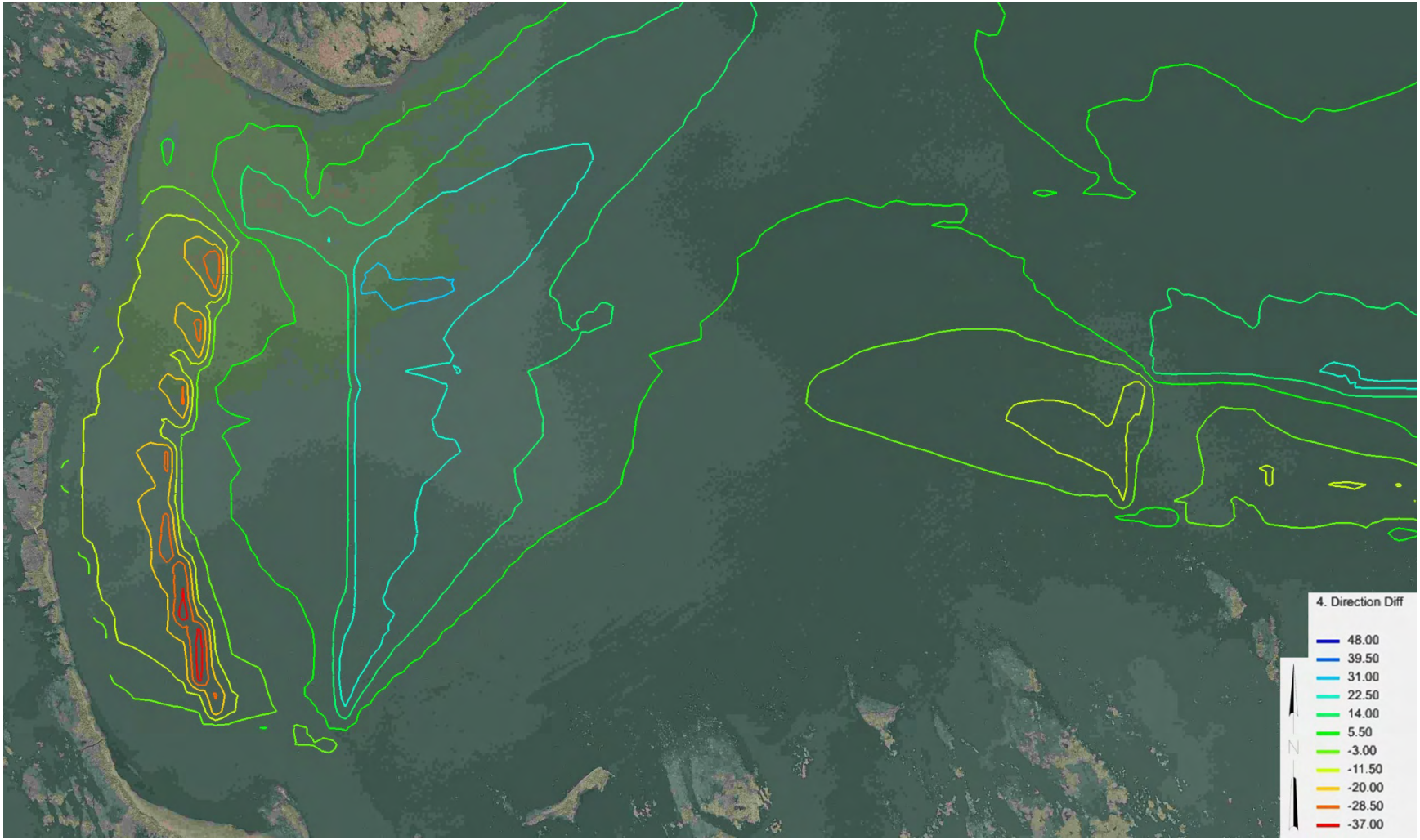

Figure A.13. Borrow Area A Wave Direction Difference – Case 4 (units = meters).

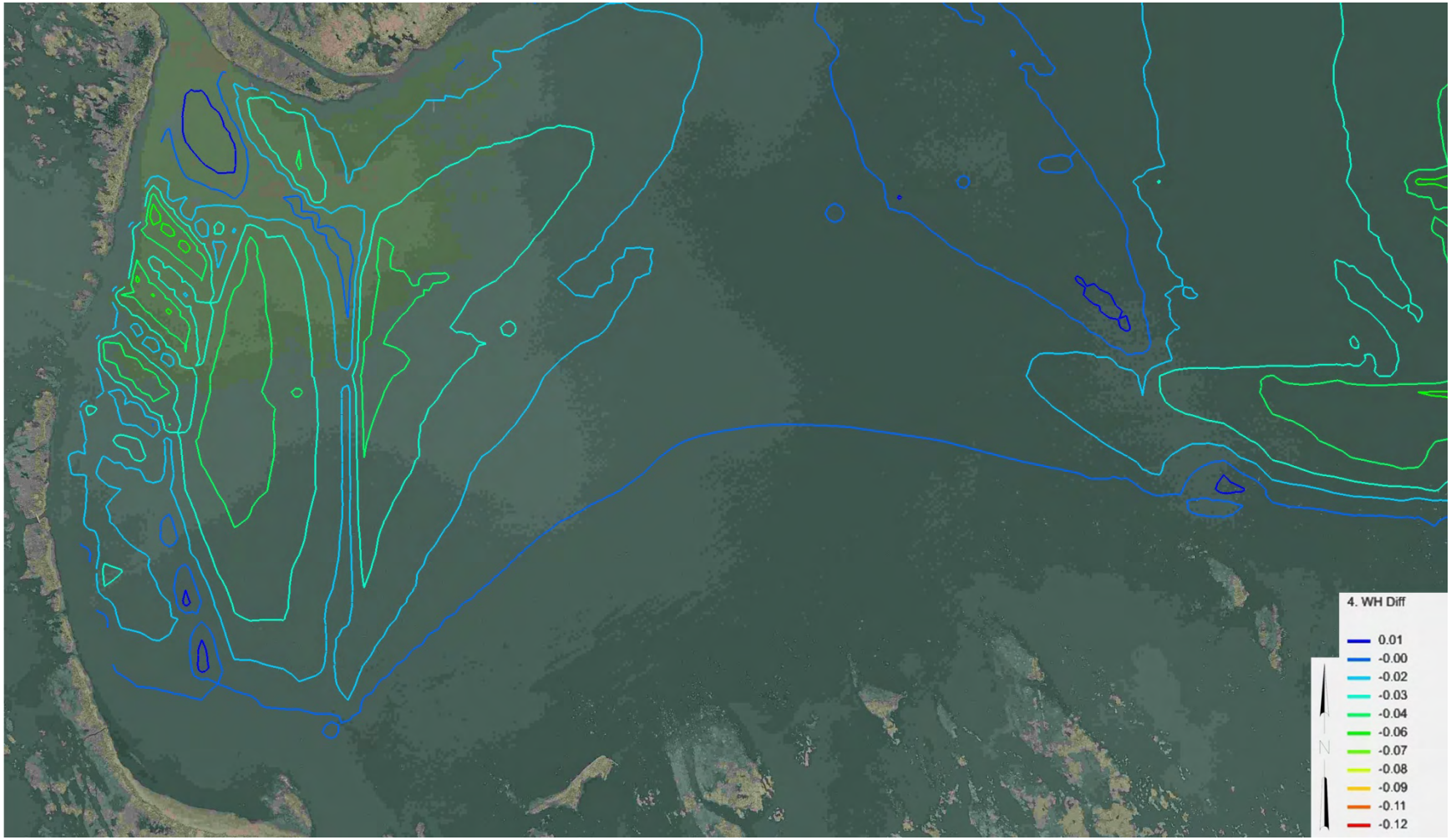

Figure A.14. Borrow Area A Wave Height Difference – Case 4 (units = meters).

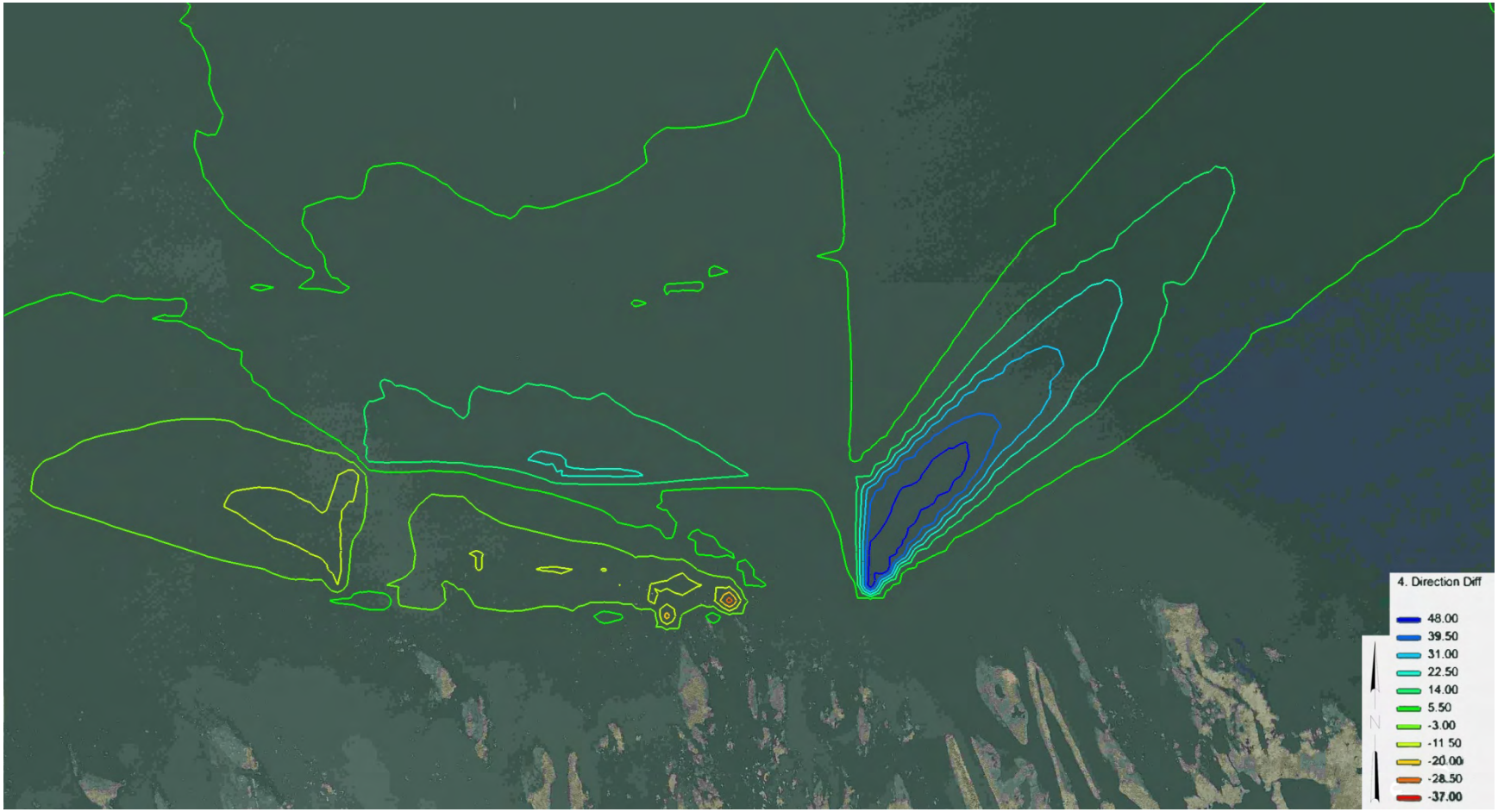

Figure A.15. Borrow Area B Wave Direction Difference – Case 4 (units = meters).

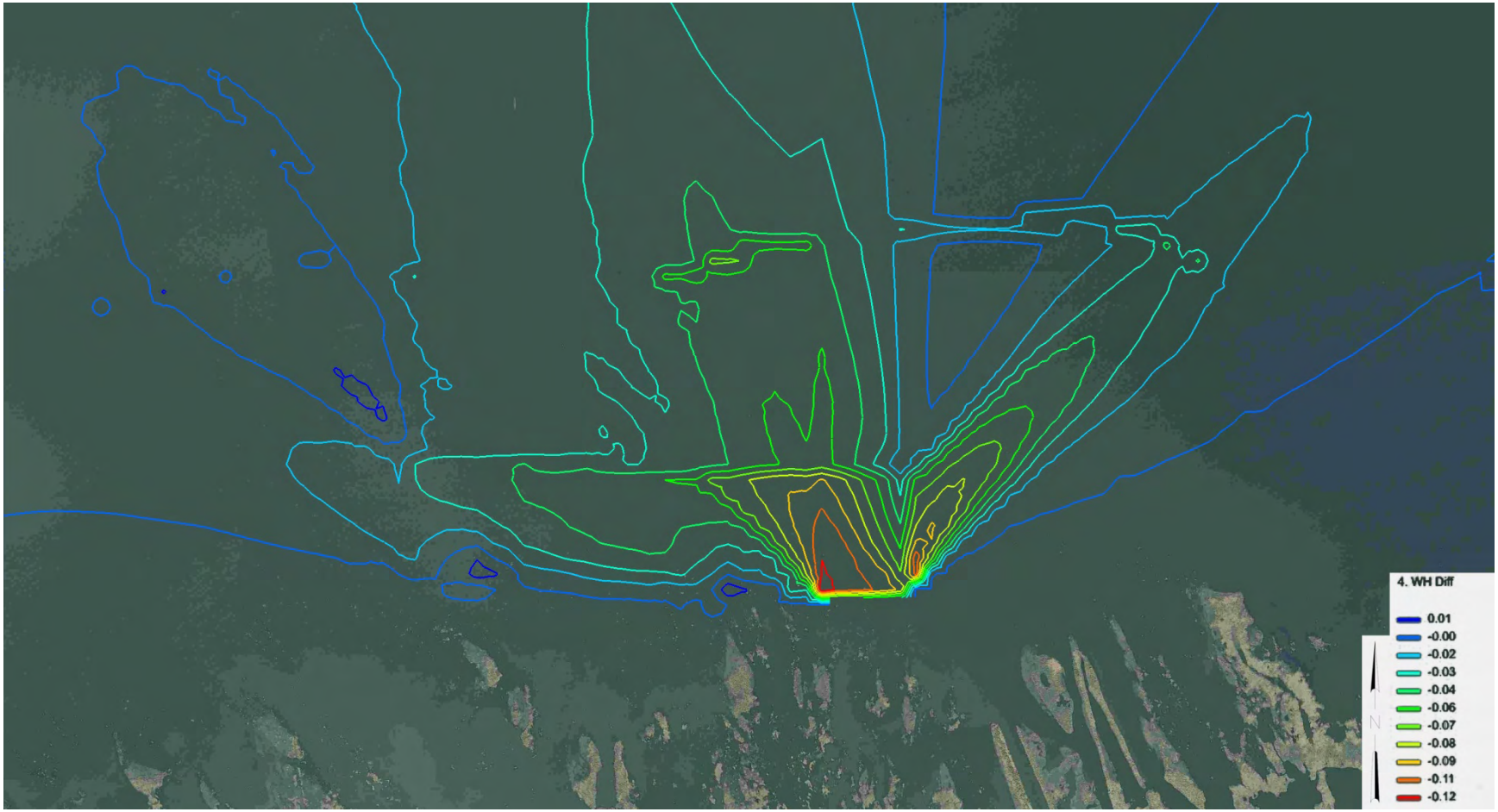

Figure A.16. Borrow Area B Wave Height Difference – Case 4 (units = meters).

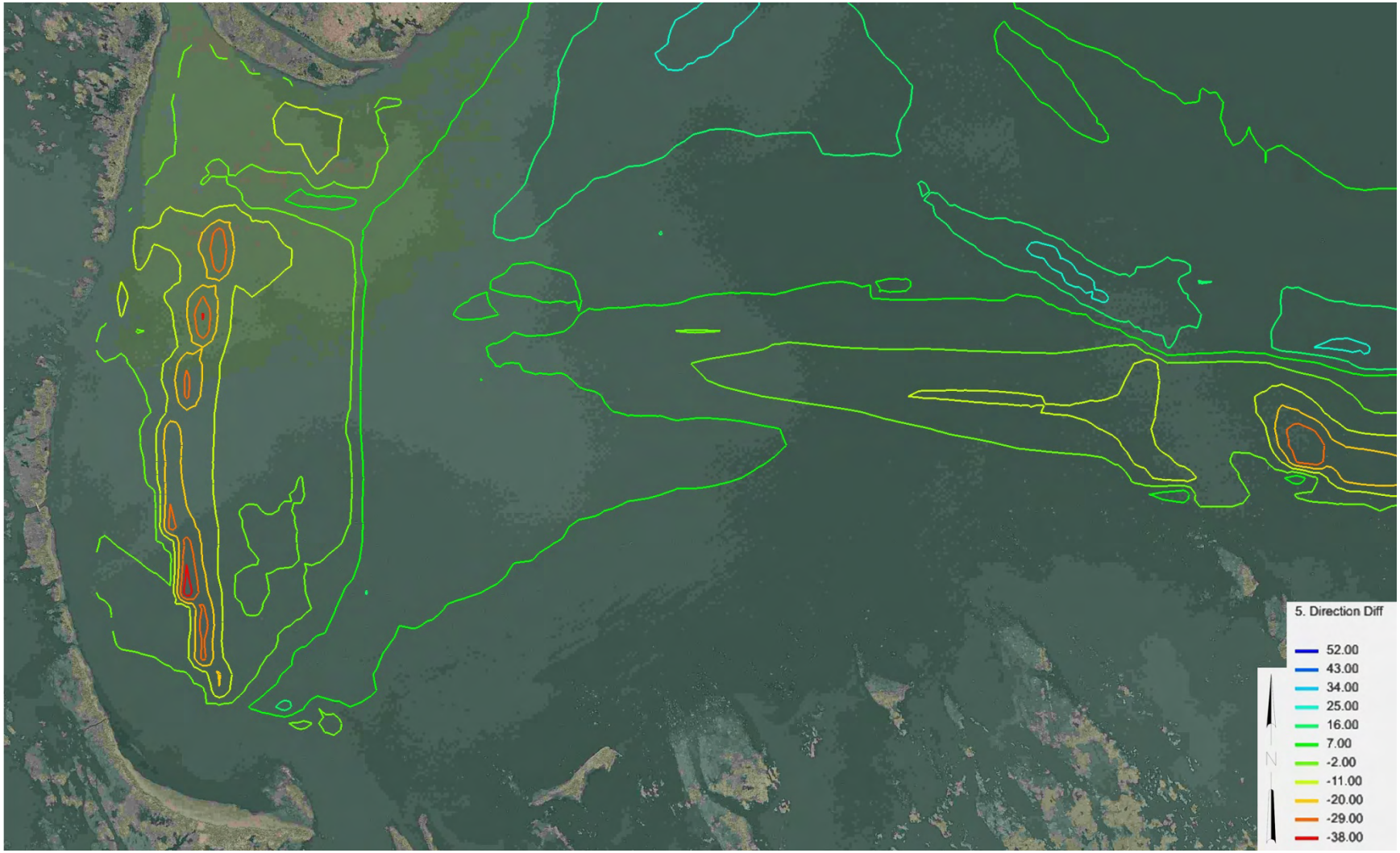

Figure A.17. Borrow Area A Wave Direction Difference – Case 4 (units = meters).

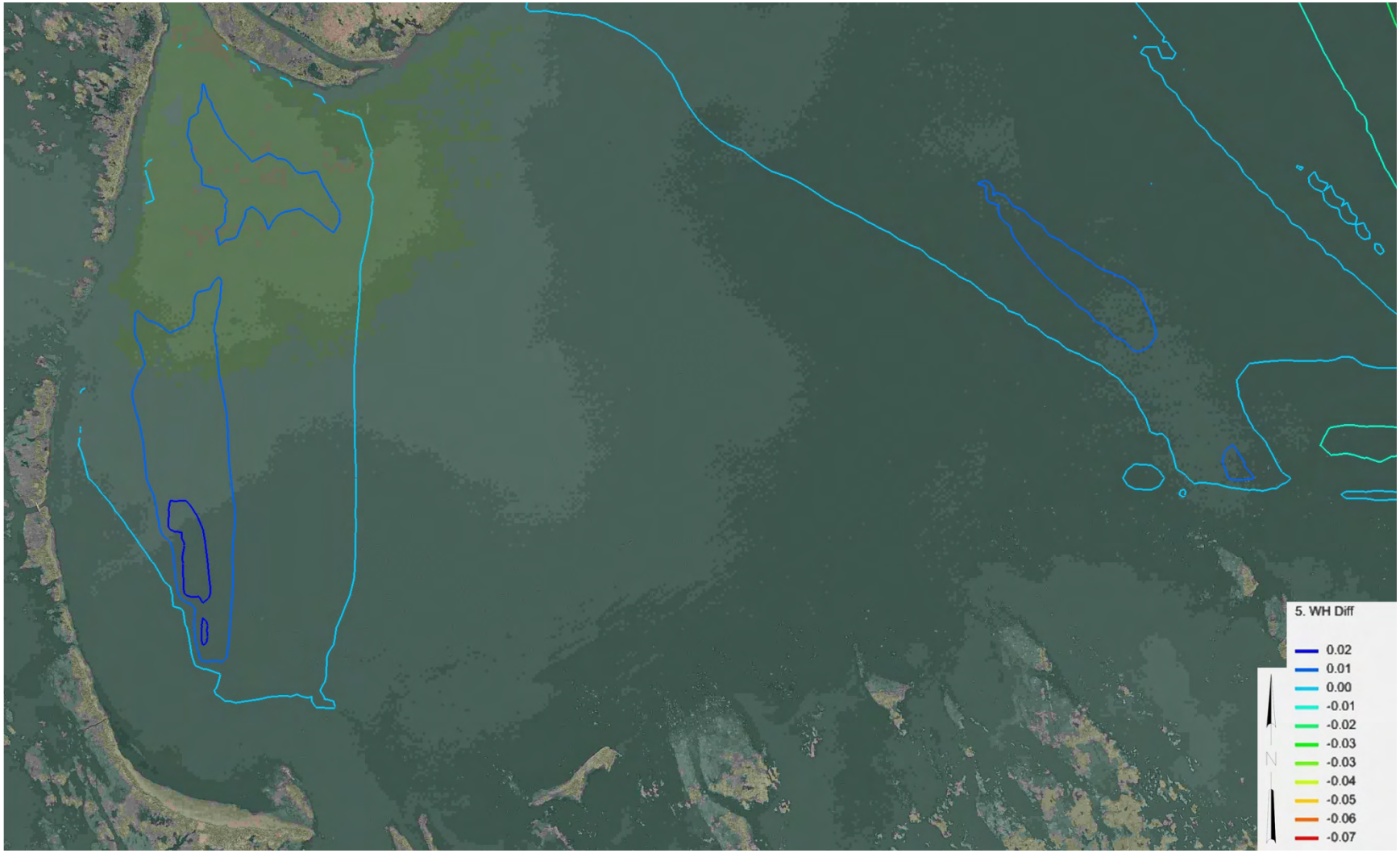

Figure A.18. Borrow Area A Wave Height Difference – Case 5 (units = meters).

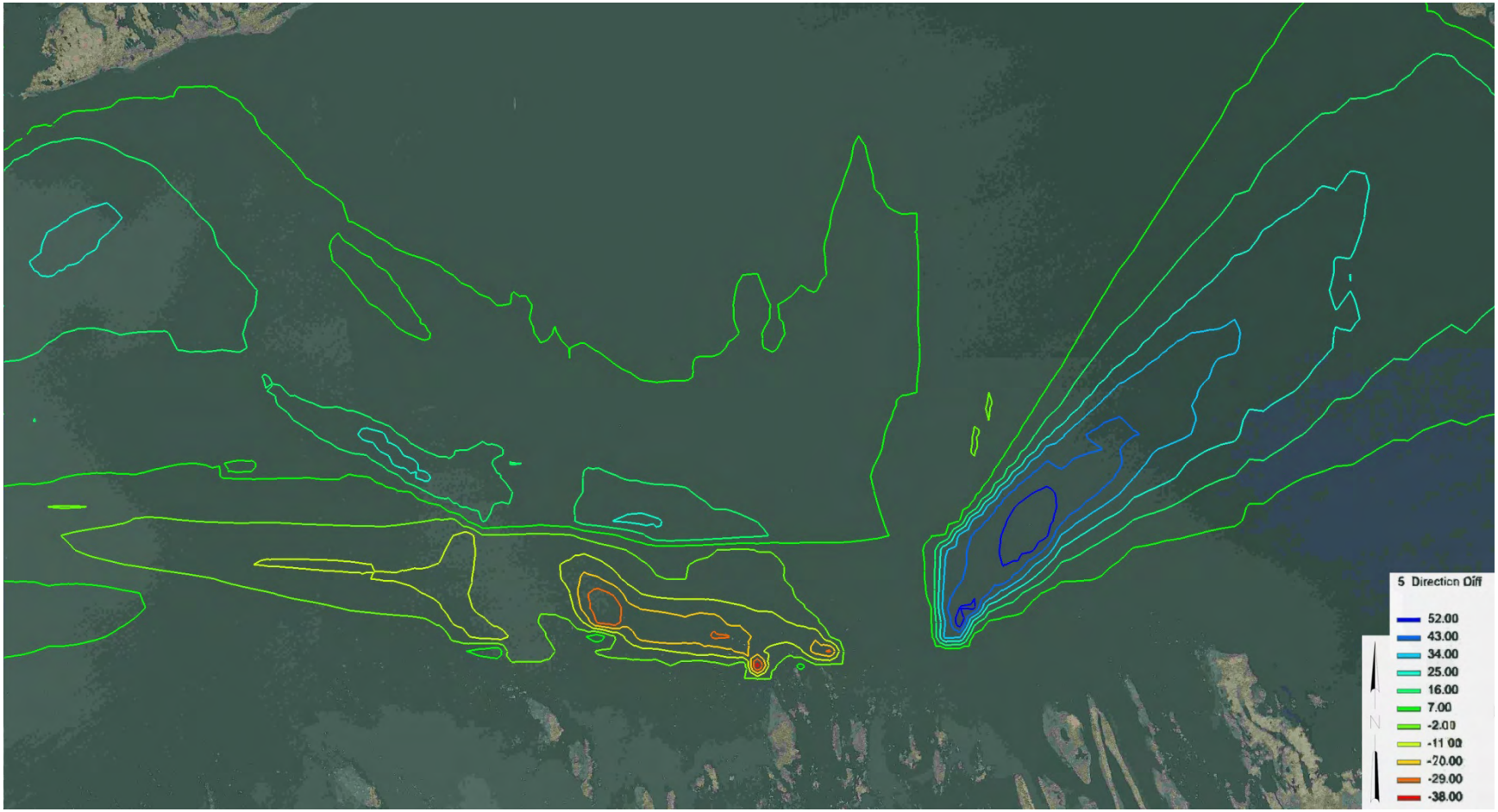

Figure A.19. Borrow Area B Wave Direction Difference – Case 5 (units = meters).

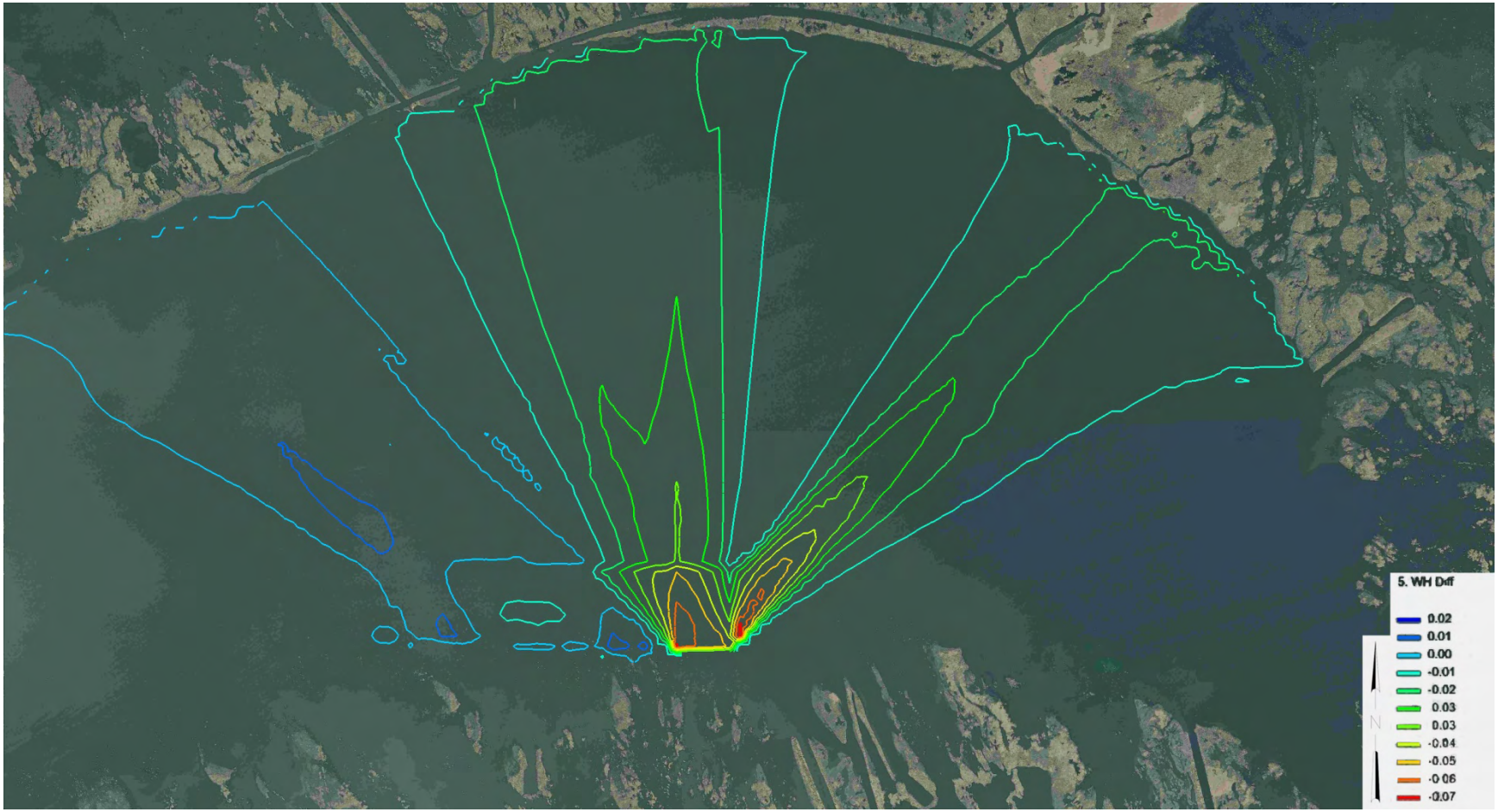

Figure A.20. Borrow Area B Wave Height Difference – Case 5 (units = meters).

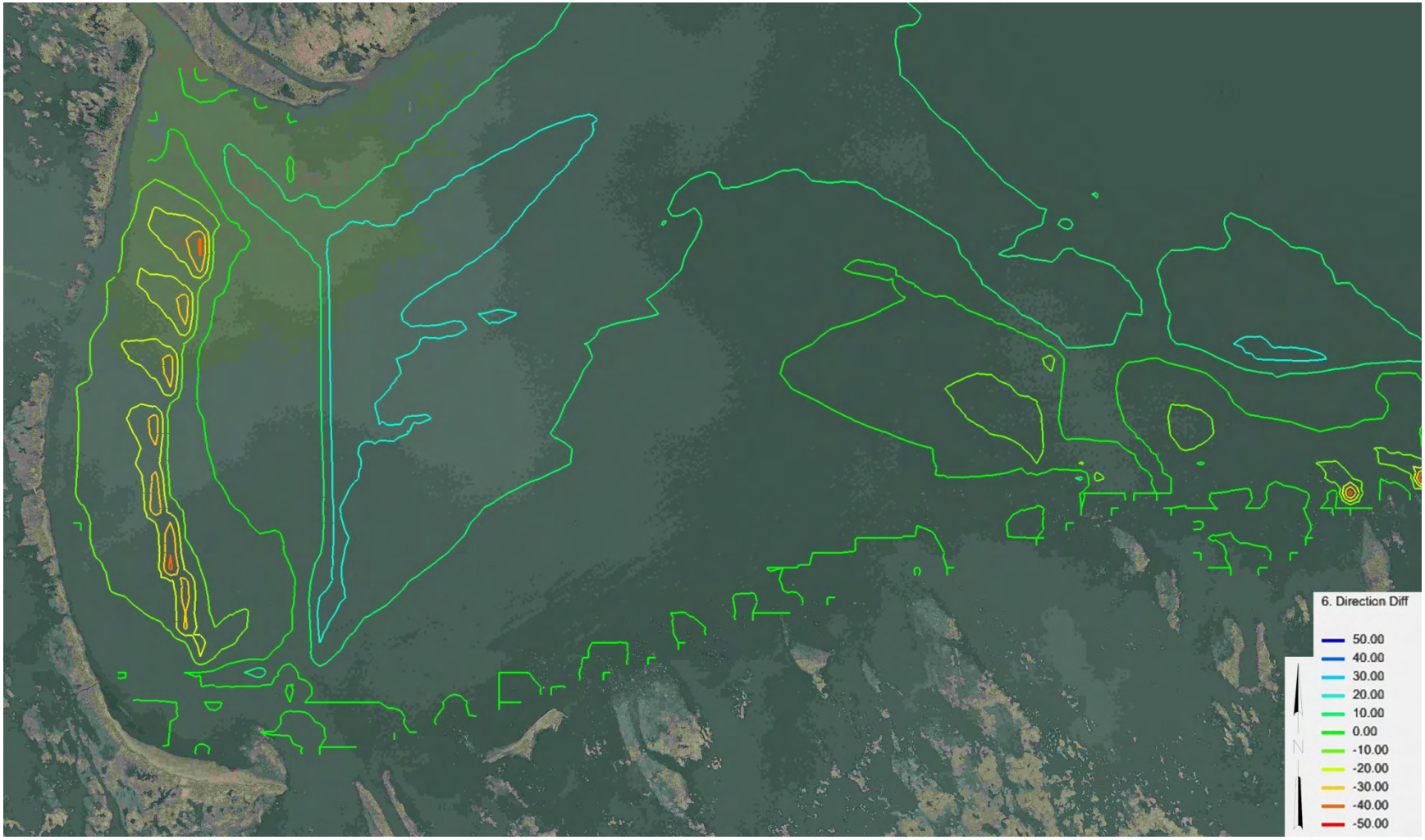

Figure A.21. Borrow Area A Wave Direction Difference – Case 6 (units = meters).

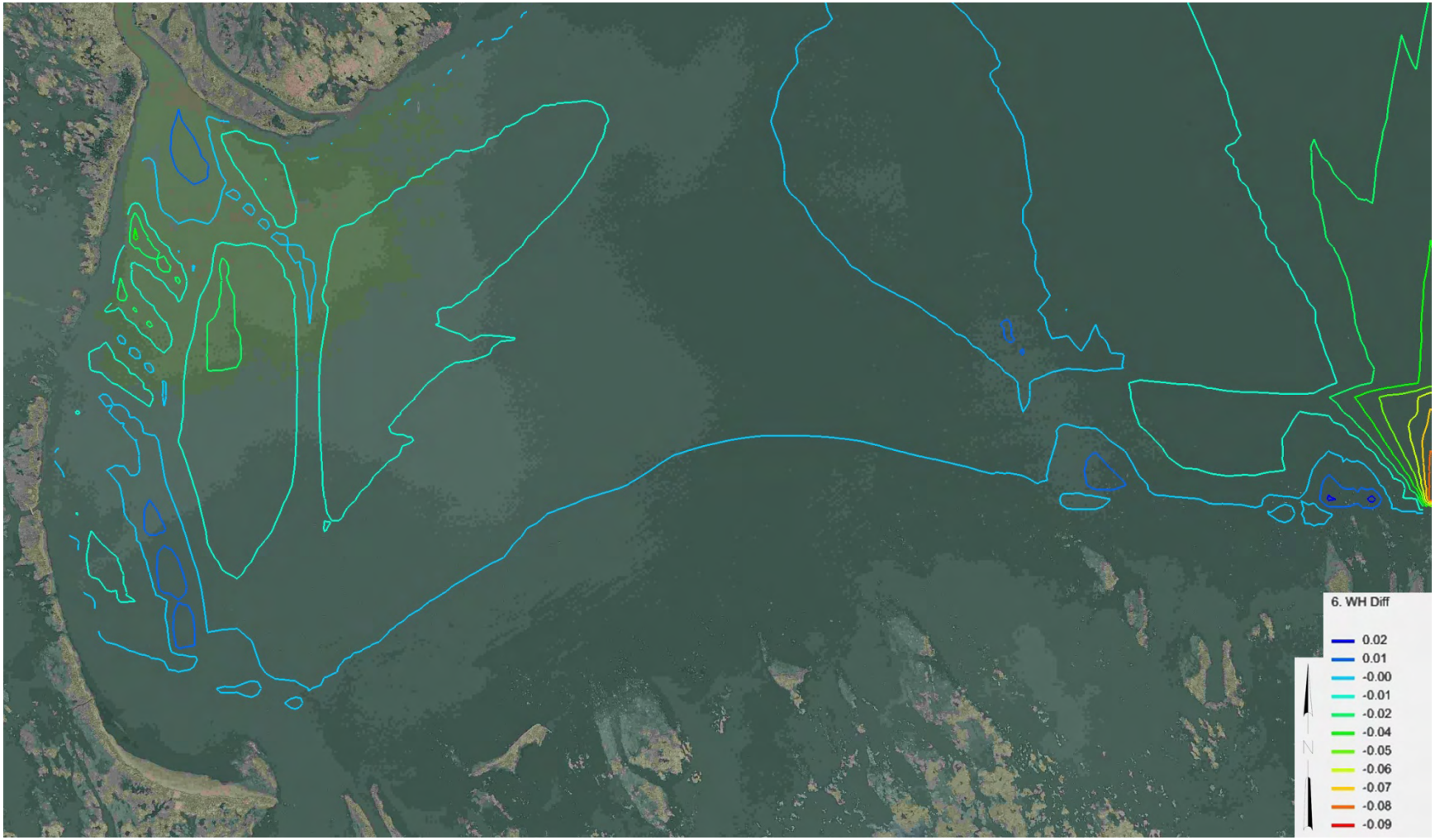

Figure A.22. Borrow Area A Wave Height Difference – Case 6 (units = meters).

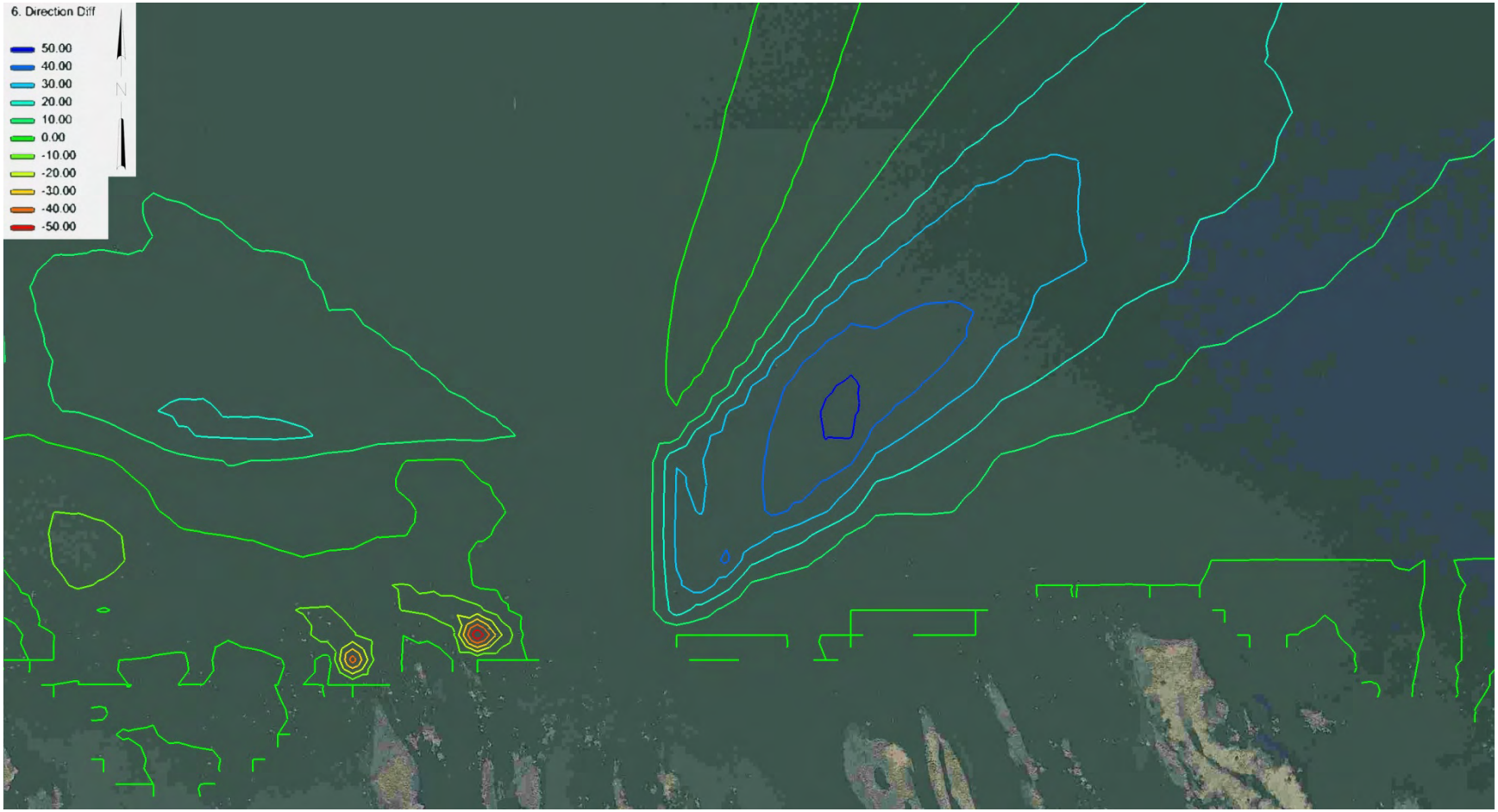

Figure A.23. Borrow Area B Wave Direction Difference – Case 6 (units = meters).

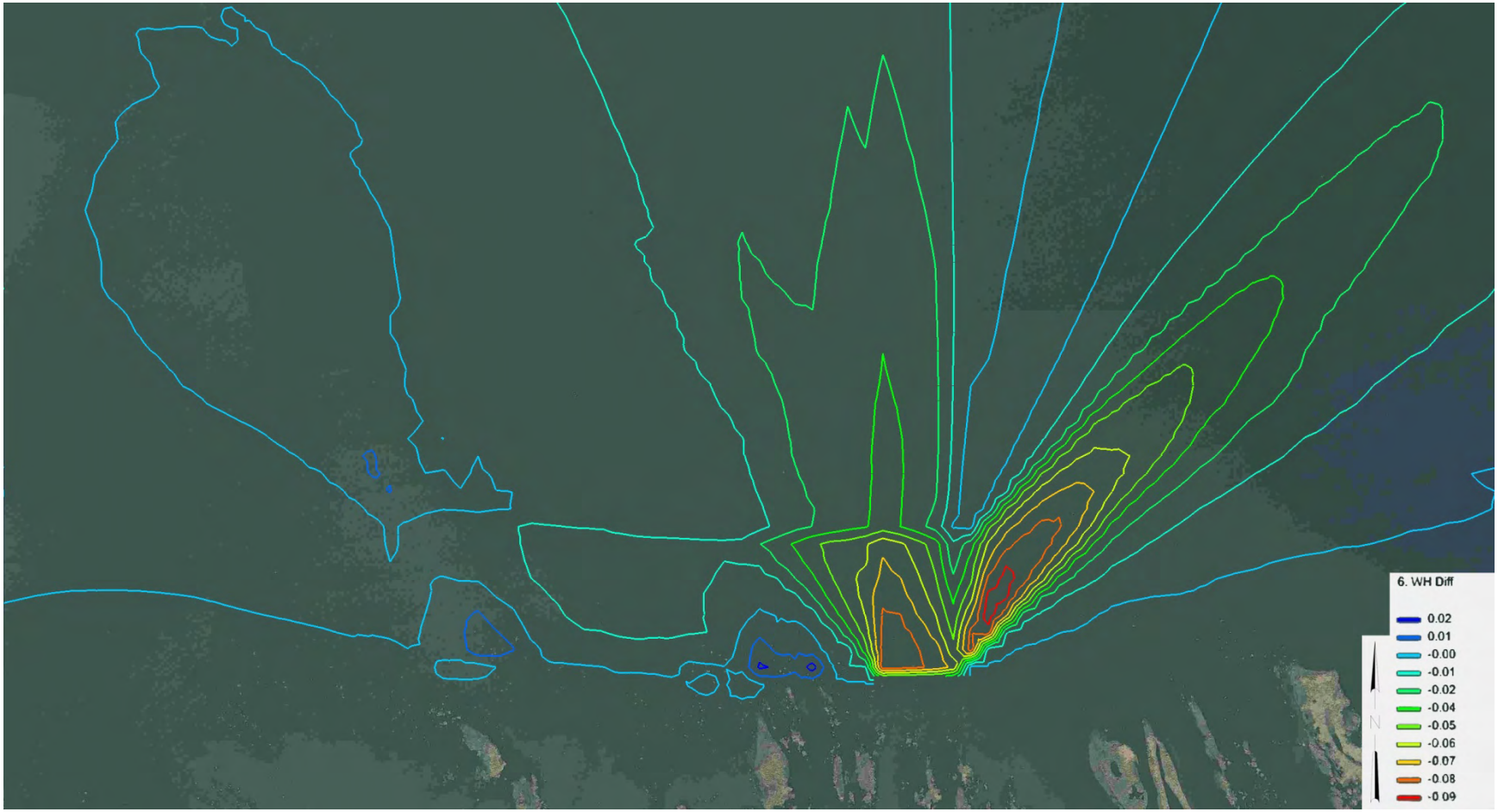

Figure A.24. Borrow Area B Wave Height Difference – Case 6 (units = meters).

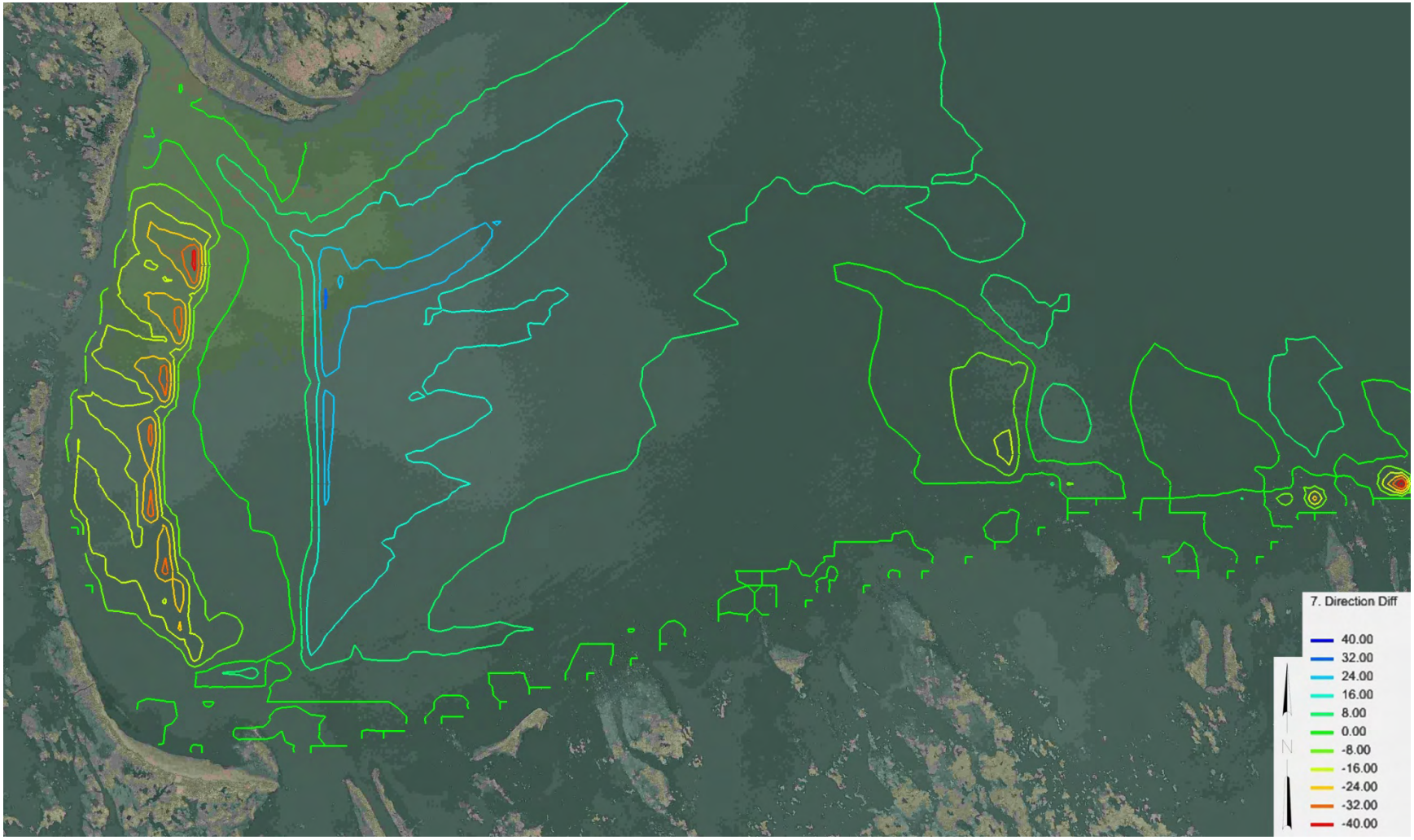

Figure A.25. Borrow Area A Wave Direction Difference – Case 7 (units = meters).

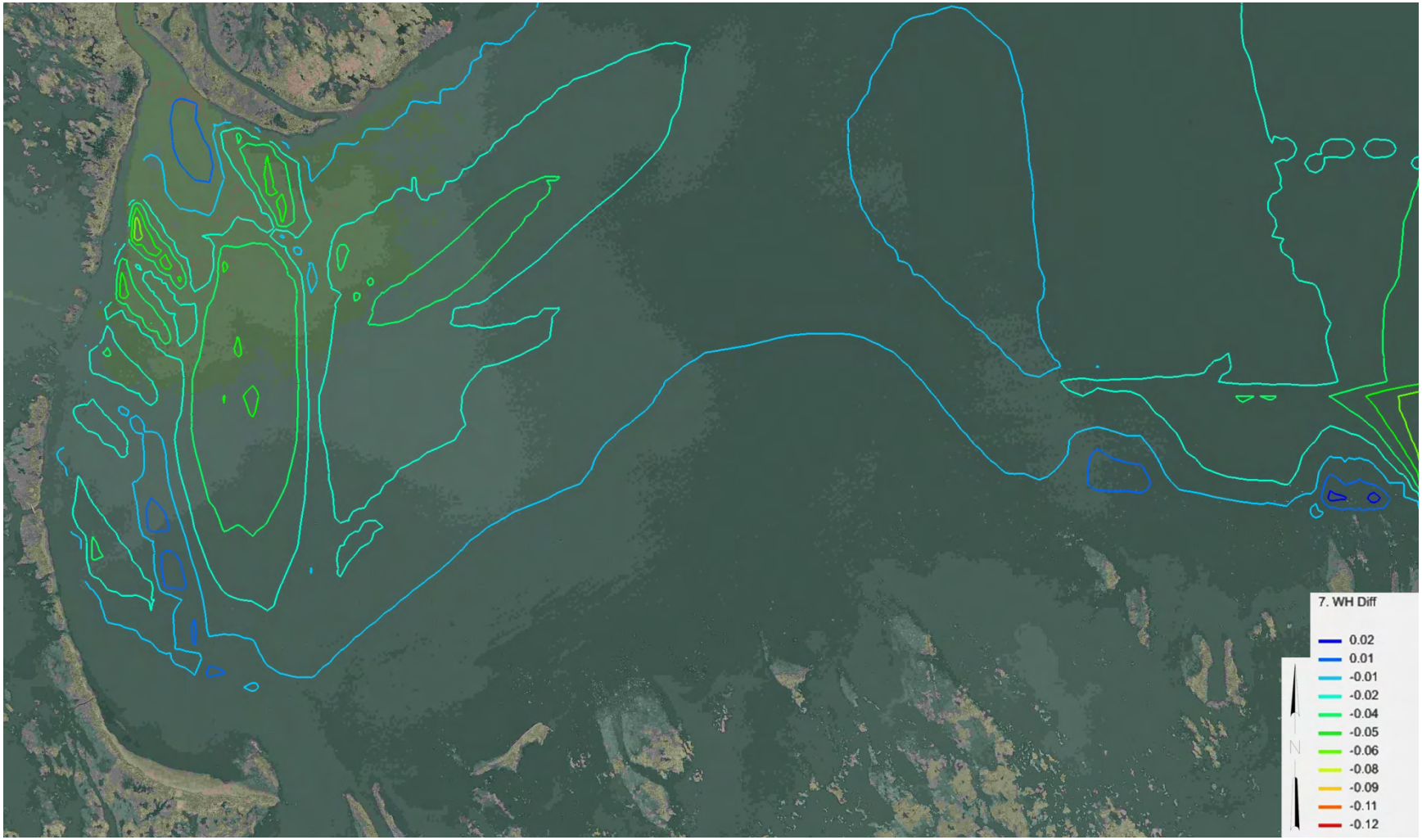

Figure A.26. Borrow Area A Wave Height Difference – Case 7 (units = meters).

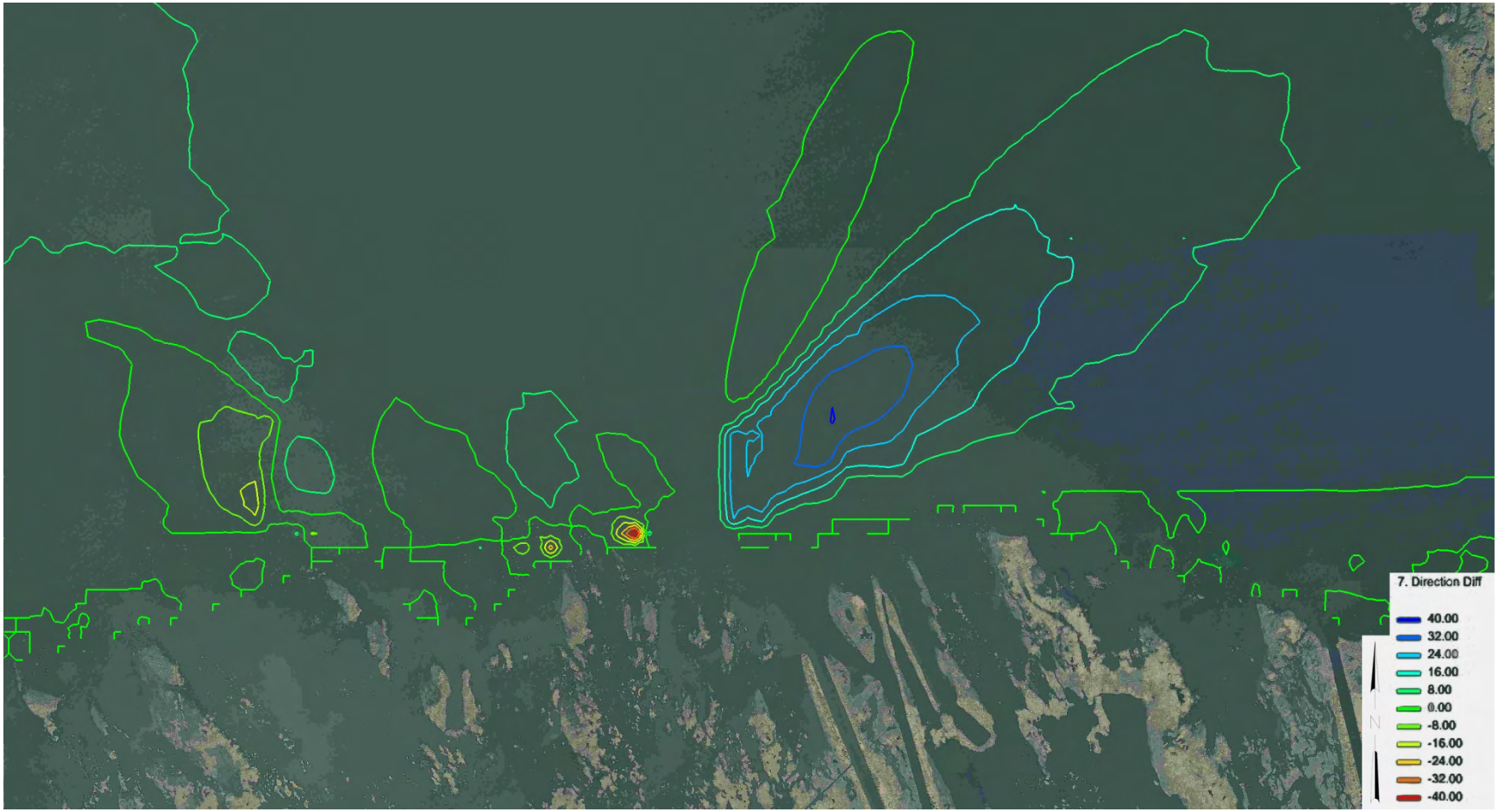

Figure A.27. Borrow Area B Wave Direction Difference – Case 7 (units = meters).

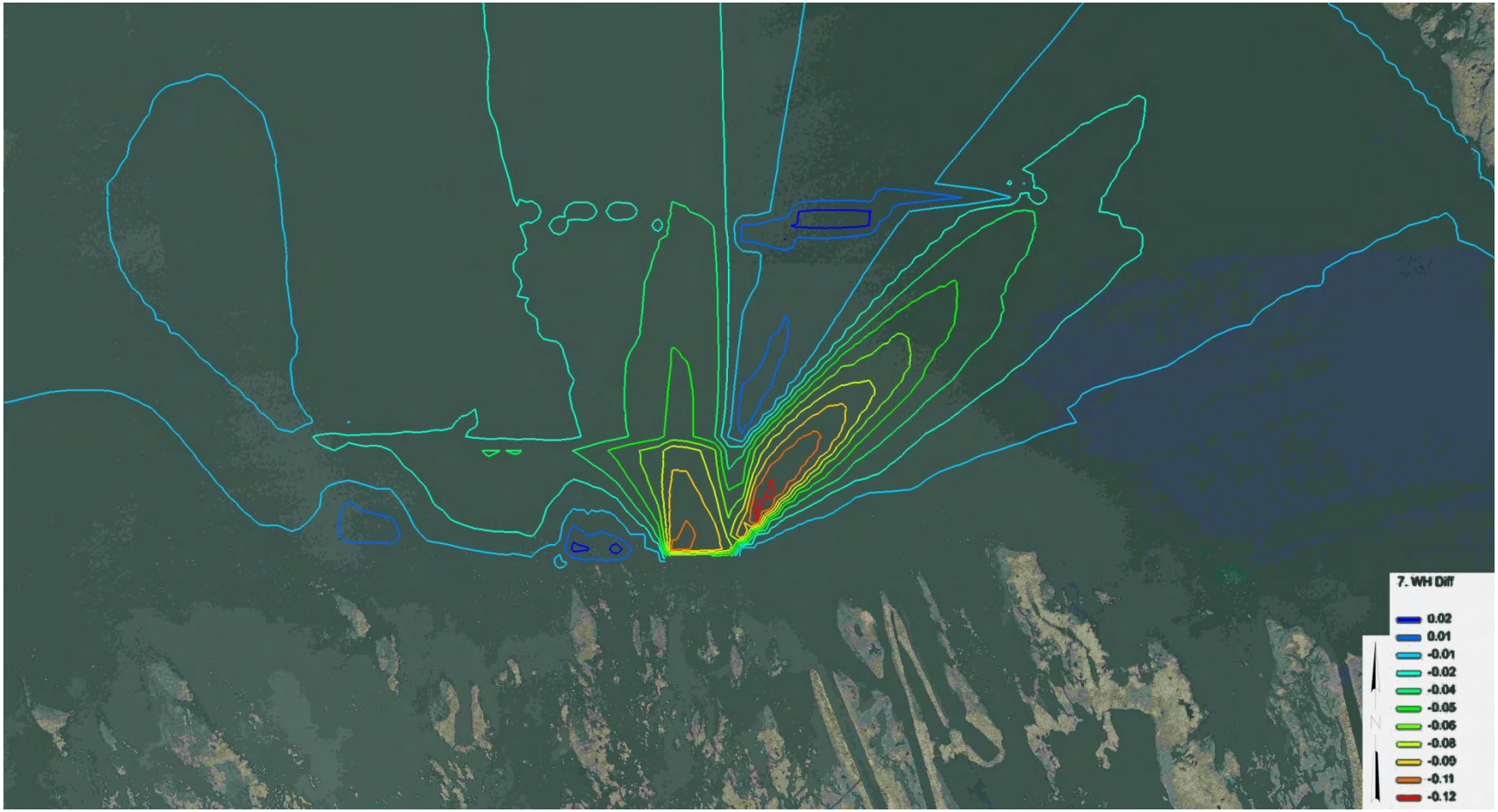

Figure A.28. Borrow Area B Wave Height Difference – Case 7 (units = meters).