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## Introduction

The State of Maine is planning for a 2-ft rise in sea level over the next 100-years for projects within the coastal sand dune system (Chapter 355, Coastal Sand Dune Rules). This is in response to documented and predicted rises in sea level for the global oceans and the Gulf of Maine, including data collected at the City of Portland tide gauge between1912 and 2002, which documents an approximate 0.2 m (0.6 ft) rise in sea level, in addition to Intergovernmental Panel on Climate Change (IPCC, 2001) projections of 0.5 m of global average sea level rise by 2100. An estimated 2-ft rise in sea level will have dramatic impacts along Maine's coastlines in terms of sensitive geographic areas including beaches and dunes, wetlands, and nearshore habitats.

The purpose of this demonstration project was to model a static 2-foot rise in sea level for an area of the Rachel Carson National Wildlife Refuge that is covered by Light Detection and Ranging (LIDAR) data flown in 2004 for the NOAA Coastal Services Center (NOAA, 2004). The study area utilized for this demonstration project is shown in Figure 1. This area was selected for multiple reasons. It is a nationally designated refuge, yet the surrounding area supports a multitude of development intensities (including the highly developed Drakes Island), reserves (Wells National Estuarine Research Reserve at Laudholm Farm), Coastal Barrier Resource Areas, species habitats (salt marshes, state-designated piping plover and least tern nesting habitat), various FEMA Flood Zone Designations, and landform types (beach and dune, salt marsh, scrub-shrub lowland, forested upland).

The Maine Geological Survey (MGS) also simulated a static 1-ft and 3-ft rise in sea level for the study area, and evaluated potential impacts on marsh habitat and flooding.

## Methodology

### *Compile required data coverages*

MGS acquired 2004 LIDAR topographic data from the NOAA Coastal Services Center. The data was received in gridded, bare-earth, 4-m averaged bin resolution. The LIDAR data has a vertical RMSE of 0.067 m. The flight was completed May 5-6, 2004. Gridded LIDAR data for the study area is shown in Figure 2.

MGS acquired high quality true color (24-bit) 1-foot resolution aerial orthophotographs of the study area from the Maine Office of GIS (MEGIS). The original aerial photographs were flown on May 19, 2003.

All data coverages were compiled within ESRI ArcMap® for data display and analysis.

### *Project a static 2-ft rise in sea level and its impacts on the study area.*

Water levels for the study area were determined using a simplified tide calculator created by MGS for converting between different datums (Dickson, 2005). Using this data, we then calculated the area ($m^2$) of different marsh types within the study area for existing conditions. This was then done for 1, 2, and 3-ft sea level rise scenarios.

It is important to point out the assumptions associated with this project, which include:

1. *Different marsh areas correspond with different water levels*. We assumed that low-marsh, dominated by *Spartina alterniflora*, existed between the limits of open water (0 m NAVD) and the mean high water (MHW) line (calculated to be 1.2 m NAVD). High marsh, dominated by *Spartina patens*, was assumed to exist within the area between MHW and the

highest annual tide (HAT, 1.8 m NAVD; see Table 1). In general, the determined elevations corresponded very well with aerial interpretation of marsh vegetation. Existing areas of open water, low marsh, high marsh, and upland (above highest annual tide) were determined (see Figure 2). Afterwards, we simulated a static 1, 2, and 3-ft rise in sea level using the LIDAR topography and subsequent changes in sea level, mean high water, and highest annual tide.

2. *Marshes are able to keep up with sea level rise.* We assumed that both high marsh and low marsh will be able to overtake and colonize existing land to the limits designated by the increases in tidal elevations after 1, 2, and 3 ft of sea level rise. This assumes that sedimentation rates will be able to keep up with sea level rise.
3. *Marsh transgression is not impeded by existing developed property.* We assumed that marsh transgression will continue even on currently developed properties.
4. *Sea level rise is static.* We assumed that existing topography (from the 2004 LIDAR) will not change in response to a rising sea level.

| Area | Elevation (m, NAVD) | | | |
|---|---|---|---|---|
| | Exist. Cond. | 1-ft SL | 2-ft SL | 3-ft SL |
| Open Water | 0.000 | 0.305 | 0.610 | 0.915 |
| Mean High Water | 1.200 | 1.505 | 1.810 | 2.114 |
| Highest Annual Tide | 1.790 | 2.095 | 2.400 | 2.704 |

**Table 1.** Elevations utilized to classify low marsh (open water - mean high water) and high marsh (mean high water – highest annual tide) in response to sea level rise.

## Results

Generalized results for the simulated changes in sea level are shown in Tables 2 and 3, and Figures 3 through 17. These results are described below for each scenario, including existing conditions.

### *Marsh Habitat Changes*

This section presents the results of the different sea level change scenarios and their impacts on the existing marsh habitat(s) within the study area.

Existing Conditions

Approximately 48% of the study area is considered upland (elevations above highest annual tide (HAT), 1.8 m). High marsh currently dominates the salt marsh, accounting for 24% of the study area (Table 2). Open water (14%) and low marsh (14%) account for the remainder of the study area (Figure 3).

1-ft Sea Level Rise

After a simulated static 1-ft rise in sea level, 44% of the study area is upland, 27% is low marsh, 17% is open water, and only 12% is high marsh (Table 2). Most notable is a dramatic 101% increase in low marsh area from existing conditions, and a substantial decrease of -49% in high marsh area (see Table 3, Figure 4). There also is a 15% increase in open water area, and a -8% decrease in the upland area. This indicates that, even after only a 1-ft rise in sea level, high marsh area will most likely be pinched out between the low marsh and the uplands since it is not able to convert enough upland to high marsh due to steeper slopes.

Low marsh areas expand dramatically along the main tributaries of the Webhannet River and marsh system, along the Little River, and east and south of the Drakes Island Road causeway. High marsh areas expand only slightly, mostly at relatively flat, low-lying areas (i.e., along Drakes Island Road), but is overtaken by low marsh along many areas. It appears that the high marsh area capacity within the study area is near its maximum.

| Area | Existing Area ($m^2$) | %Total | 1 ft Area ($m^2$) | %Total | %Δ* | 2 ft Area ($m^2$) | %Total | %Δ* | 3 ft Area ($m^2$) | %Total | %Δ* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Open Water | 1043585 | 14.4 | 1206107 | 16.6 | 2.2 | 1390305 | 19.2 | 4.8 | 1607104 | 22.2 | 7.8 |
| MHW (Low Marsh) | 967394 | 13.4 | 1949508 | 26.9 | 13.5 | 2365355 | 32.6 | 19.3 | 2452054 | 33.8 | 20.5 |
| HAT (High Marsh) | 1733834 | 23.9 | 882870 | 12.2 | -11.7 | 615678 | 8.5 | -15.4 | 576381 | 7.9 | -16.0 |
| Upland** | 3504731 | 48.3 | 3211059 | 44.3 | -4.1 | 2878206 | 39.7 | -8.6 | 2614005 | 36.1 | -12.3 |
| Total | 7249544 | 100.0 | 7249544 | 100.0 | | 7249544 | 100.0 | | 7249544 | 100.0 | |

* % overall change from existing conditions
** above HAT

**Table 2.** Overall changes in area and percentage of the study area for low marsh (OW-MHW), high marsh (MHW-HAT), and upland (HAT+).

<u>2-ft Sea Level Rise</u>
After a simulated static 2-ft rise in sea level, about 40% of the study area is upland, 33% is low marsh, 19% is open water, and less than 9% is high marsh (Table 2). The low marsh has expanded by over 144% (21% more from 1 ft conditions) from existing conditions, while open water areas have grown by over 33% since existing conditions. The high marsh area continues to decrease by an additional -30% (from +1 ft numbers), and uplands decrease by 10% (Table 3 and Figure 5). A total of 65% of the existing condition high marsh has been lost after 2-ft of sea level rise.

| Area | Existing Area ($m^2$) | 1 ft Area ($m^2$) | %ΔExisting* | 2 ft Area ($m^2$) | %ΔExisting | %Δ1' | 3 ft Area ($m^2$) | %ΔExisting | %Δ2' |
|---|---|---|---|---|---|---|---|---|---|
| Open Water | 1043585 | 1206107 | 15.6 | 1390305 | 33.2 | 15.3 | 1607104 | 54.0 | 15.6 |
| MHW (Low Marsh) | 967394 | 1949508 | 101.5 | 2365355 | 144.5 | 21.3 | 2452054 | 153.5 | 3.7 |
| HAT (High Marsh) | 1733834 | 882870 | -49.1 | 615678 | -64.5 | -30.3 | 576381 | -66.8 | -6.4 |
| Upland** | 3504731 | 3211059 | -8.4 | 2878206 | -17.9 | -10.4 | 2614005 | -25.4 | -9.2 |

* % change from existing areas
** above HAT

**Table 3.** Changes in area and percentage from existing area for low marsh (OW-MHW), high marsh (MHW-HAT), and upland (HAT+) after 1, 2, and 3-ft of sea level rise.

The majority of MHW (i.e., low marsh) expansion continues to encroach on previous high-marsh areas around the Webhannet and Little River main tributaries. High marsh, in general, continues to lose ground to low marsh. However, high marsh and highest annual tide expansion continues around Drakes Island and in the Little River tributaries.

<u>3-ft Sea Level Rise</u>
After a simulated static 3-ft rise in sea level, only about 36% of the study area remains upland. Low marsh areas account for 34% of the study area, while 22% is open water area. Only 8% of the study area remains as high marsh (Table 2). The low marsh area increased over 153% from existing conditions, and the open water area grew by 54%. The high marsh decreased by a total of about 67% from existing conditions, while the upland area lost about 25% of existing conditions total upland area (Table 3 and Figure 6). Low marsh only grew an additional 4% from 2-ft-to-3-ft conditions, indicating its expansion is reaching steeper slopes.

Figures 7 through 9 display overall changes for Open Water (OW), Mean High Water (MHW, assumed to be "Low Marsh"), and Highest Annual Tide (HAT, assumed to be "High Marsh") for the 1, 2, and 3-ft rises in sea level scenarios.

### *Flooding Implications*

Changes in sea level may also have major implications for developed areas (both private and public infrastructure) in terms of flooding. This section describes the results seen from 1, 2, and 3-ft sea level rise scenarios for the developed areas of Drakes Island and Wells Beach. Refer to Figures 10-16 as referenced below. Note that only figures for MHW and HAT conditions have been created for further investigation of each scenario, as no flooding results directly from changes to OW conditions.

<u>1-ft Sea Level Rise</u>

It does not appear that any developed areas on Drakes Island or Wells Beach would be threatened as a result of +1ft OW sea level conditions (no figure shown). +1 ft MHW conditions results in encroachment (but not inundation) on numerous properties along the marsh side (west side) of Island Beach Road on Drakes Island (Figure 10). There do not appear to be any impacts along Wells Beach.

Along Drakes Island, +1 ft HAT conditions will cause isolated flooding concentrated on the north side of Drakes Island Road, and southwest of the Eaton Ave/Drakes Island Road intersection towards Fern Street (Figure 11). In this area, close to 30 private properties may become flooded, as do substantial portions of Drakes Island Road, Eaton Avenue, and Grove Street. Additionally, portions of Island Beach Road leading southwest to the public parking lot, and a portion of Shady Lane would undergo flooding. North of the Drakes Island Road/Island Beach Road intersection, isolated lots on the northwest side of Island Beach Road would also incur flooding.

<u>2-ft Sea Level Rise</u>

+2ft OW conditions do not appear to result in any apparent flooding of Drakes Island or Wells Beach. +2 ft MHW brings the water level directly against all of the bulkheads along Wells Beach, though it does not appear that any are overtopped. Along Drakes Island, flooding appears at the unpaved public parking lot and adjoining properties northeast of the intersection of Eaton Ave and Drakes Island Road, and at isolated lots west of Island Beach Road. No public roadways appear to be compromised (Figure 12).

The areas of possible flooding along Drakes Island increase dramatically with 2-ft of sea level rise under HAT conditions (Figure 13). Flooding of Island Beach Road nearest the parking lot (that adjoins the Wells jetties) is more extensive, as is flooding along developed lots along Shady Lane, Eaton Ave, Grove and Fern Streets, and both sides of Drakes Island Road. Additionally, it appears that the causeway (Drakes Island Road) crossing the marsh may become flooded under +2 HAT conditions. Along Island Beach Road north of the intersection with Drakes Island Road, flooding of individual private lots becomes much more extensive. Only isolated pockets of minor flooding appear along the Webhannet River side of Wells Beach after +2 HAT conditions (Figure 14).

<u>3-ft Sea Level Rise</u>

+3ft OW conditions still do not appear to result in any apparent flooding of Wells Beach or Drakes Island private or public property. +3ft MHW results in possible minor flooding along Wells Beach at the southern end of the study area, and ponding of water at the northern end of Wells Beach, near the jetty. Along Drakes Island, +3ft MHW inundates portions of Shady Lane (due to an excavated canal running parallel to it), and flooding becomes more extensive along Eaton Ave, and Drakes Island Road. Several lots along the west side of Island Beach Road also become inundated (Figure 15).

As expected, +3ft HAT conditions are the most dramatic, especially along Drakes Island. The Drakes Island Road causeway (Figure 16) becomes completely flooded, and results in extensive flooding west, east, and north of Eaton Road. Numerous lots are flooded all the way along Drakes Island Road. Additionally, the majority of lots west of Island Beach Road undergo inundation. Along Wells Beach, flooding occurs along the marsh-side at several isolated spots within the study area, ponding just south of the northern jetty, and inundation of several low-lying areas towards the oceanfront (Figure 17).

## Discussion

### *Implications for Marsh Habitat*

Results of the sea level rise scenarios indicate that a 1-ft rise in sea level may have significant impacts on the existing marsh habitat by drastically increasing the area of low marsh (by over 100%), while substantially decreasing the area of high marsh by almost 50%. This is mainly due to pinching out of high marsh along steeper sloped upland areas. 2-ft of sea level rise would increase these percentages to144% and -65%, respectively. This would dramatically change the overall dominant marsh type and habitat within the study area. Additionally, uplands within the study area (i.e., areas above HAT) would undergo 18-25% losses under 2-3-ft rise in sea level scenarios. It appears that the existing high marsh within the study area is near its maximum area, and cannot expand much more due to the steeper slopes that remain (hence the pinching out of high marsh).

The assumption that marshes would be able to keep up with sea level rise through increased sedimentation rates may not be correct. It is quite possible that increasing open water areas (which increase by 33% under a 2-ft rise in sea level scenario) would substantially alter channel morphology of the Webhannet and Little Rivers and their tributaries, which could subsequently change flood-and-ebb tidal current patterns. In turn, this could lead to increased erosion of marsh surfaces and possible removal of eroded material from the marsh system, resulting in increased open water, and a decrease in projected marsh growth. It is not within the scope of this project to simulate these occurrences, but it is important to note these limitations and possibilities.

Also, areas of marsh transgression are assumed to occur even where development (i.e., developed lots) may impede the natural transgression of marsh surfaces. This would play a large factor in the ability of the high marsh to successfully transgress onto higher topography; thus, it could be expected that the projected reduction of high marsh area *may actually be lower than what would actually occur.*

### *Flooding Implications*

Results of the sea level rise scenarios raise some important issues regarding flooding along Wells Beach and Drakes Island.

The portion of Wells Beach within the study area appears, in general, to fair well under the different flooding scenarios of 1, 2, and 3-ft of sea level rise. The seawalls that line the Webhannet River side of Wells Beach appear to be of adequate elevation to prevent overtopping under 1 and 2-ft sea level rise scenarios. Minor inundation does occur in +2 ft HAT conditions, and is more widespread after 3 ft of sea level rise.

Even a 1-ft rise in sea level may have major implications regarding the future flooding of private property and public infrastructure, especially along the lower-lying Drakes Island Beach during times of MHW and HAT. With 2-ft of sea level rise, flooding becomes more pronounced and starts to inhibit emergency access to portions of the island. Should a coastal storm coincide with the HAT (or even MHW) and 1-2 ft of sea level rise, vehicular access to Drakes Island could be severely compromised, with possible flooding of the causeway completely cutting off Drakes Island from the mainland. Such information is vital to the preparation of future county and regional emergency management plans.

Although there does not appear to be any flooding impacts on the oceanfront properties under the sea level rise scenarios simulated, none of the scenarios take into account superimposed storm water levels and waves *on top of the water elevations simulated. One could expect 1-3 ft of additional water on top of these elevations during storm events.* This could have a major impact on oceanfront lots along both Wells and Drakes Island, where overwash and minor flooding already are known to occur during storm events.

We have identified several potential breach locations (which already exist) which will become more susceptible to overwash and erosion as sea level rises. Most notably are those identified in Figures 14 and 15 on Drakes Island, at the intersection of Drakes Island Road and Island Beach Road, and at the northeastern end of the seawalled properties along Island Beach Road. On Wells Beach, breach points are located at the stretch of shoreline near the northern jetty that is unprotected by natural dune vegetation, and just south of this location. Additionally, the inner-most portions of the jetties may be overtopped in scenarios of 2-ft sea level rise and HAT conditions (Figures 16 and 17).

**Findings and Recommendations**

Based on the results of this study, we are able to make the following findings:

- With a 1-2 ft rise in sea level, high marsh, which currently dominates the study area, will be be overtaken by a transgressing low marsh, steeper bank topography, and developed areas. The percentage of high marsh loss and low marsh gain is largest with a 1-ft rise in sea level.
- In general, the Wells Beach portion of the study area appears to be able to sustain 1-2 ft of sea level rise without major flooding. Some minor flooding on HAT would be expected on the Webhannet River (marsh) side after 2-ft of sea level rise.
- Drakes Island appears to be most susceptible to flooding after 1 or 2-ft rises in sea level due to its lower overall topography. Isolated flooding of private property can be expected during times of MHW and HAT after a 1 ft rise in sea level, especially along the low-lying areas adjacent to Drakes Island Road.
- Public infrastructure (roads) on Drakes Island appears to be threatened by flooding after a 2-ft rise in sea level, mostly under HAT conditions.
- The causeway leading to Drakes Island will be susceptible to flooding on +2 ft HAT conditions, and completely flooded under 3-ft sea level rise conditions.
- Breach areas will likely become more susceptible to overwash and erosion as sea level rises. Key breach areas include: on Drakes Island, at the intersection of Drakes Island Road and

Island Beach Road, and at the northeastern end of the seawalled properties along Island Beach Road; on Wells Beach, at the stretch of shoreline near the northern jetty that is unprotected by natural dune vegetation.

We also make the following recommendations:

- Areas of potential flooding should be evaluated within emergency management plans in order to determine 1) designated evacuation areas; 2) breach points susceptible to flooding and overwash during storm events; and 3) specific water elevations that may trigger flooding of emergency transportation corridors (most notably Drakes Island Road). We recommend giving consideration to methods available to make these areas less susceptible to flooding in the future.
- The existing bayside areas protected by seawalls should be evaluated in terms of their elevations in order to withstand future sea level rise, flooding, and storm events.
- The Wells/Drakes Island jetties should be evaluated in order to determine appropriate future elevations of the jetties to withstand overtopping after sea level rises.
- Communities should evaluate existing developed and open space areas in order designate natural areas to allow for the natural transgression of marsh surfaces.
- Upland areas identified as being vulnerable to marsh transgression could be targeted as prime areas for restoration, conservation and/or land-use planning.
- Communities should evaluate the existing dune and beach areas in order to determine the best management techniques to help protect these natural resources (and habitat areas) from loss due to future sea level rise and the presence of sea walls.
- Similar sea-level rise studies should be completed for other highly-developed and resource-valuable areas of the Maine coastline.
- Future studies should be conducted to determine existing sedimentation rates of the marshes, and the rates that would be required to allow the marshes to keep up with sea level rise.
- Future studies should be conducted to simulate *non-static* responses of the marshes and topography to sea level rise.
- FEMA Flood Insurance Rate Maps may need to be updated in the near future as changes in sea level become more dramatic, causing the 100-year floodplain to migrate upwards and inland.

**Conclusions**

MGS developed GIS coverages and datasets that identify and quantify the impacts of a projected 2-ft rise in sea level within the defined study area. In addition, we inspected the impacts of 1-ft and 3-ft rises in sea level on existing marsh habitat and flooding implications.

Results of this demonstration project could be utilized for various land-use planning, conservation, and restoration considerations. Areas of upland (both developed and undeveloped) and mapped back-dune identified as being vulnerable to marsh transgression could be targeted as prime areas for restoration, conservation and/or land-use planning. Back-dune areas could help identify areas for improved Dune Rule regulation on bulkheads, building elevations, impervious surfaces, and possible limits to riprap. Changes in floodplains and identification of potential hazard areas (overwash, breach zones) resulting from sea level rise could be useful for the Maine Emergency Management Agency (MEMA) and for State and County emergency management plans.

MGS also expects that results from this demonstration project could be used as leverage for expanded LIDAR surveys in Maine for wetlands protection and efforts to adapt to higher sea levels induced by climate change.

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**Figure 1.** Color aerial orthophotograph (1-ft resolution) of the study area from Maine OGIS (2003). The study area includes salt marsh, areas of dredge spoils, 2 tidal inlets, and developed (Wells Beach and Drakes Island Beach), and undeveloped (Laudholm Beach) beaches.

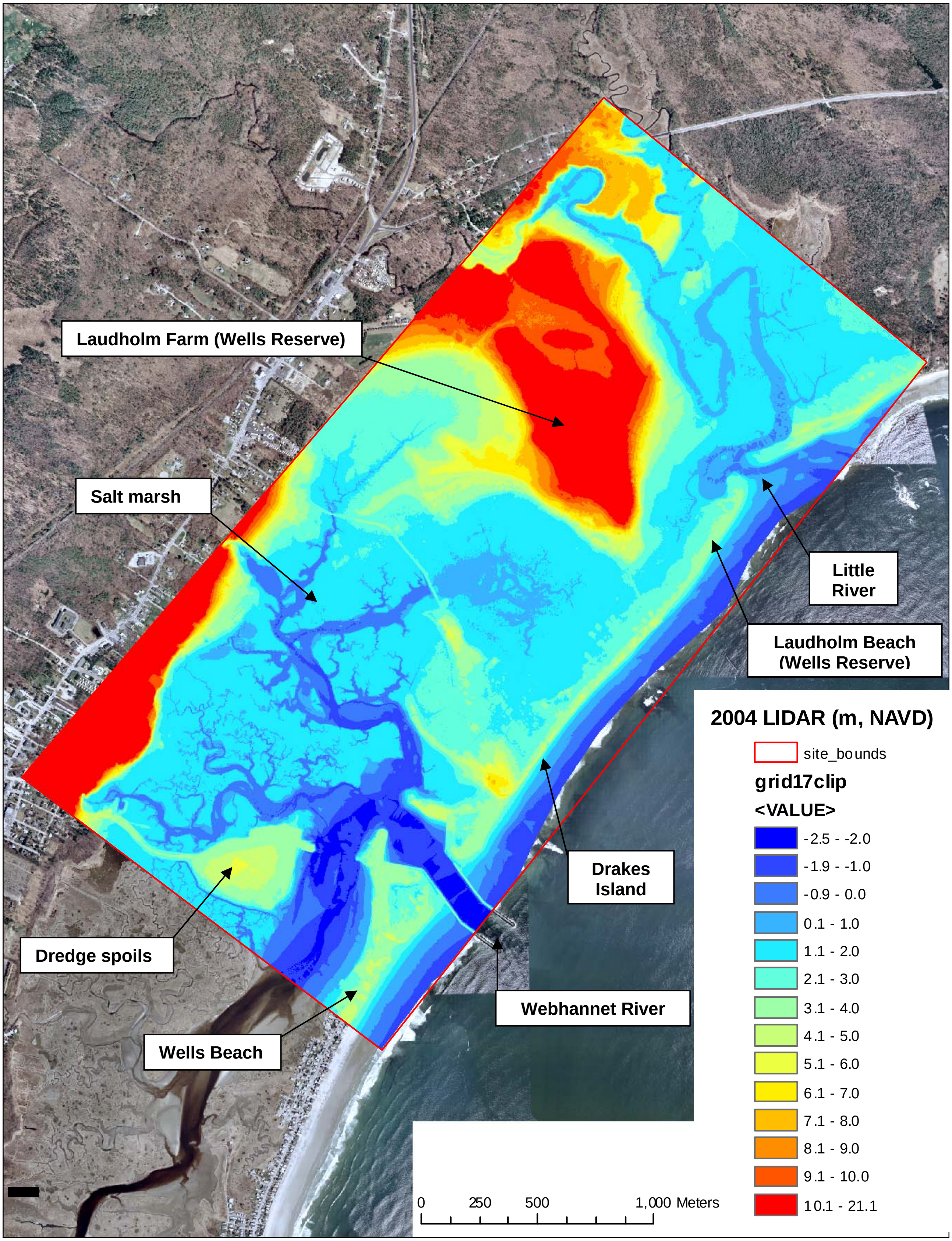


**Figure 2.** Color interpolated gridded topography of the study area from 2004 LIDAR data. The majority of the study area is below 5 m NAVD, dominated by high and low salt marsh and low-lying barrier beach (LIDAR provided by the NOAA Coastal Services Center).


**Figure 3.** Existing conditions within the study area. Marsh areas (below HAT) are dominated by high marsh (area between MHW-HAT), which accounts for 24% of the study area, while upland areas (no colors) account for approximately 48% of the study area. Low marsh (between OW-MHW) and open water areas account evenly for the remaining 28%.


**Figure 4.** Conditions after a simulated 1-ft static rise in sea level. Most notable are a substantial increase in low marsh area (between OW-MHW) of +14%, and a subsequent decrease in high marsh (between MHW-HAT) of -12% of the study area. There is also a loss of -4% of the upland areas from existing conditions. There is only a minimal increase (2%) in open water areas (below 0 m).

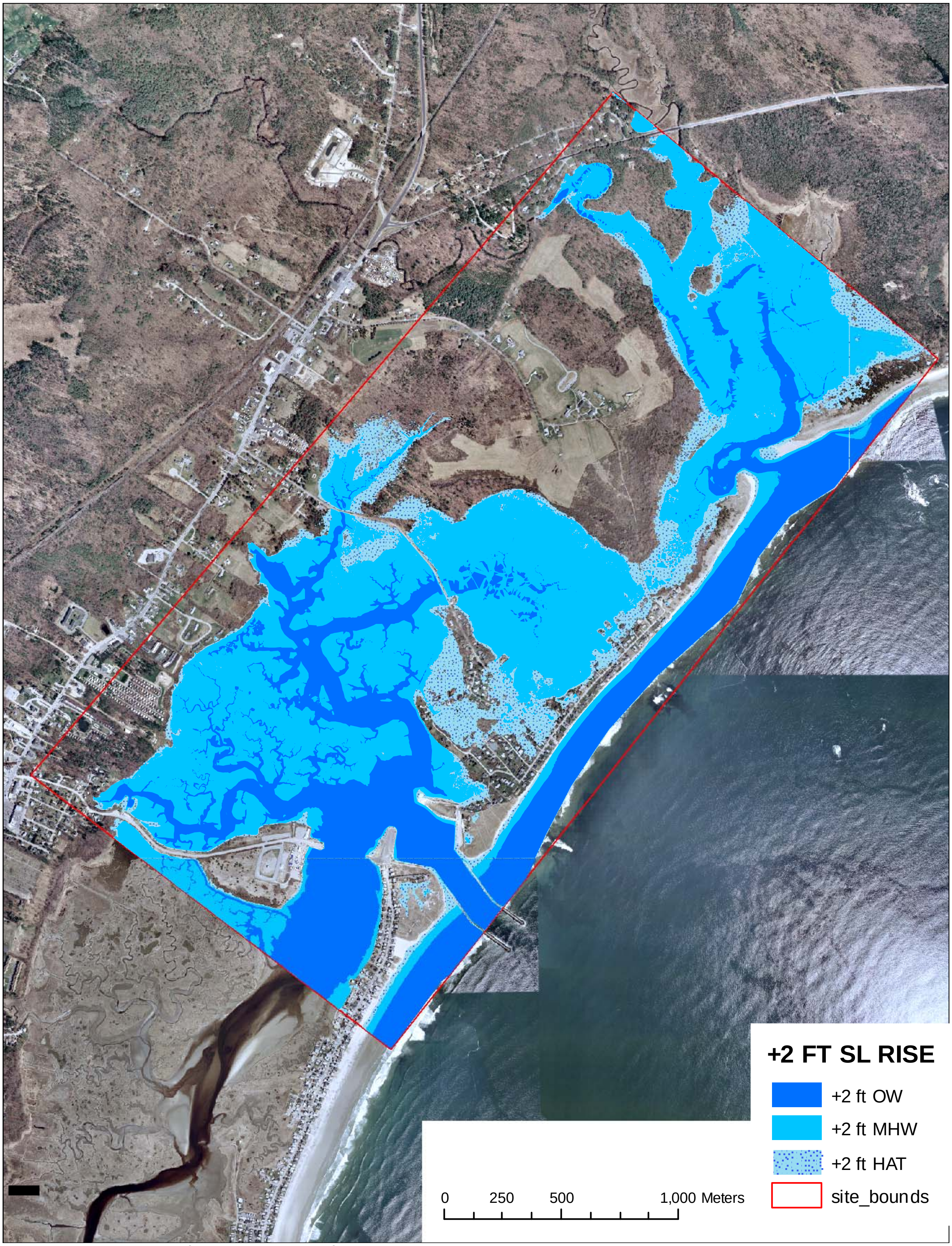


**Figure 5.** Conditions after a simulated 2-ft static rise in sea level. The low marsh (MHW) continues to overtake the high marsh areas, which is beginning to pinch out along steeper topography. Open water is now 19% of the study area, while low marsh comprises over 33%. Uplands have decreased to about 39% of the study area.

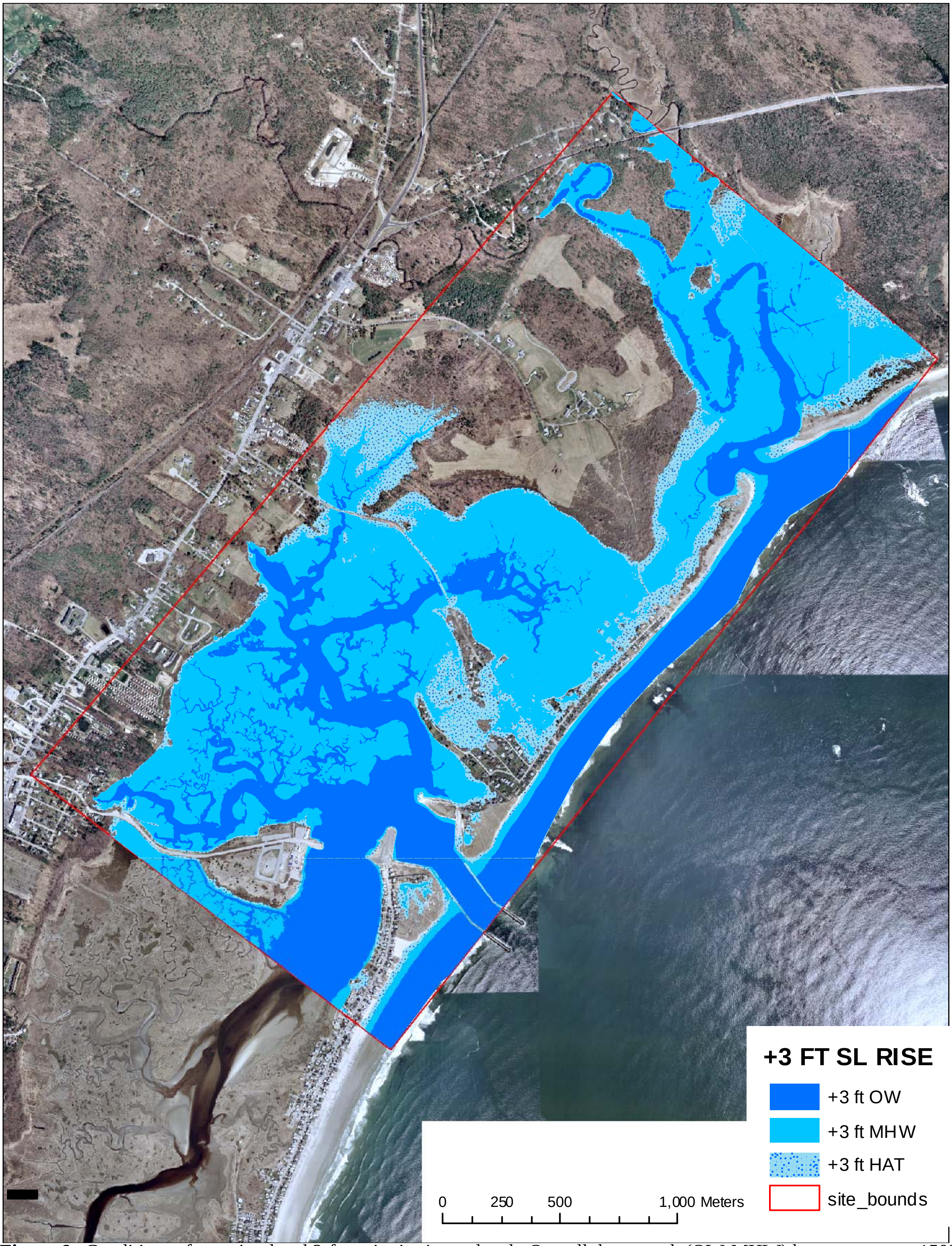


**Figure 6.** Conditions after a simulated 3-ft static rise in sea level. Overall, low marsh (OW-MHW) has grown over 150% from existing conditions, while the area of high marsh has decreased by 67%. Open water has grown by about 54% from existing conditions, and uplands have lost 25% of their existing conditions area.


**Figure 7.** Figure showing spatial growth of open water areas from existing conditions to 3-ft rise in sea level.

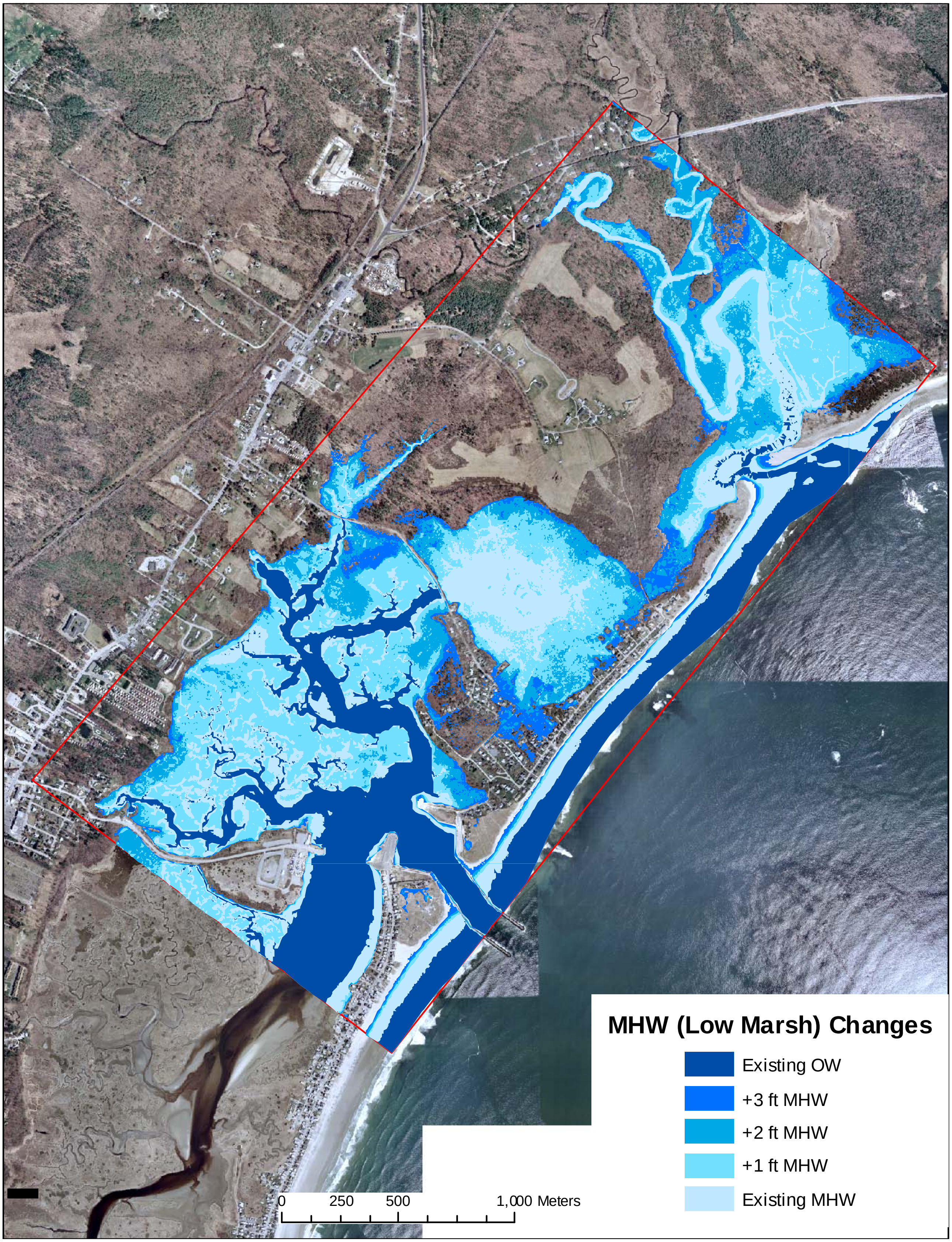


**Figure 8.** Figure showing spatial growth of the MHW (defining the low marsh in this study) from existing conditions. The largest growth occurs after 1-ft rise in sea level, where low marsh area increases by approximately 100% from existing conditions.

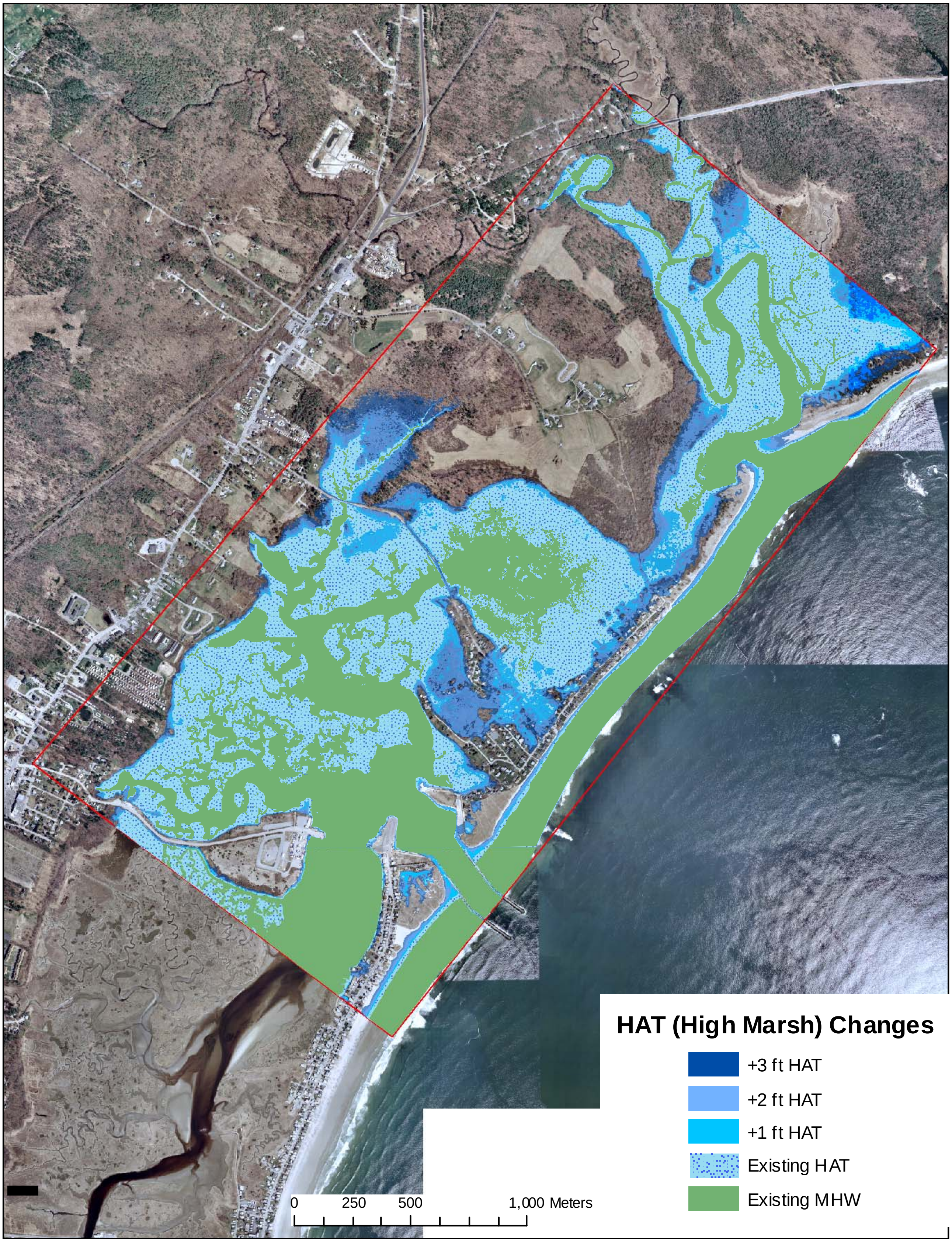


**Figure 9.** Figures showing spatial growth of the HAT (assumed to mark the limit of the high marsh) after sea level rise. High marsh currently dominates the study area. It appears that the room for growth of the high marsh is limited by steep banks and developed areas.


**Figure 10.** Simulated flooding of Drakes Island after 1-ft of sea level rise under MHW conditions. Note the encroachment of flood waters near private property (and a public parking lot) northeast of Drakes Island Road and northwest of Island Beach Road.


**Figure 11.** Simulated flooding of Drakes Island after 2-ft of sea level rise and MHW conditions.


**Figure 12.** Simulated flooding of Drakes Island under +3 ft of sea level rise at MHW conditions. Note extensive flooding along both sides of Drakes Island Road, and at properties along Island Beach Road.


**Figure 13.** Simulated flooding of Drakes Island for 1-ft of sea level rise at HAT conditions. Note that Drakes Island Road, Shady Lane, and Eaton Avenue would all undergo flooding under these conditions.


**Figure 14.** Simulated flooding of Drakes Island under 2-ft sea level rise at HAT conditions. Note that the causeway (Drakes Island Road) is now flooded. More extensive flooding occurs along the central portion of Drakes Island Road, Shady Lane, Eaton Ave, and down Grove St. Isolated lots along Island Beach Road also undergo flooding.


**Figure 15.** Simulated flooding of Drakes Island with 3-ft of sea level rise at HAT conditions. Extensive flooding of the Island occurs, including full submersion of the causeway. Flooding extends to the lots on the west side of Island Beach Road.


**Figure 16.** Simulated flooding for Wells Beach with 2-ft rise in sea level at HAT conditions. Only minor flooding is apparent on the marsh (Webhannet River) side of the island, where several low-lying areas are flooded. Portions of the existing jetties are also overtopped.


**Figure 17.** Simulated flooding of Wells Beach for 3-ft sea level rise at HAT conditions. More extensive overtopping of the seawalls would occur, resulting in more flooding along the Webhannet River side of the island. More extensive ponding adjacent to the jetties occurs, and several breach points become more apparent.