BAYSHORE DUNE MANAGEMENT PLAN

BACKGROUND REPORT

Prepared for

Lincoln County

225 West Olive Street
Newport, Oregon

By

Terra Firma Geologic Services

27766 Hunter Creek Road
Gold Beach, OR 97444

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LIMITATIONS

This document was prepared for the Lincoln County Planning Department, Newport, Oregon following the DLCD document: *Dune Management Planning; A Guide to Preparing a Dune Management Plan as Provided for in Statewide Planning Goal 18* and methodologies used to prepare other foredune management plan background reports. The information contained in this document consists of published and unpublished data which we were able to locate and which was made available to us. Important data was also gleaned from interviews with residents, utility district managers, agency representatives and others with experience at Bayshore. Most of the fieldwork for this report was done on 5/9-12/2011. Bayshore was visited on 1/26/2011, two weeks after an inundation event, and on 1/18/2012 during an inundation event. It is possible that additional data exists that may allow alternative interpretations of dune dynamics and beach processes at Bayshore. However, regardless of what additional information becomes available it is undeniable that homes and infrastructure are impacted by sand inundation multiple times a year, and portions of the spit have an elevated level of risk to be eroded by ocean waves during natural, infrequent, reoccurring climatic events.

The ocean front residences in the southern part of Bayshore are located within a foredune on a sand spit adjacent to an uncontrolled outlet for Alsea River. Because of that setting the beach adjacent to many of the residences has an elevated risk to be eroded by ocean waves during large wave erosion events. The area has an abundance of sand available for transport and the location of the homes within the foredune makes them conducive to accumulation of wind transported sand during periods of accretion. Preparation of this document does not imply that we condone the location of the residences in the southern part of Bayshore. The document was prepared to enable the residents at Bayshore to proceed with implementation of a foredune management plan, as allowed under Statewide Planning Goal 18. No warranties, either expressed or implied are provided. This report is submitted with the limitation that damages related to ocean wave erosion, tsunamis or even deposition of wind transported sand is borne by the property owners and is an inherent risk of having property located in such a geologically active environment.

CERTIFIED
OREGON
RON SONNEVIL
E1233
ENGINEERING GEOLOGIST

Expires 6/30/2012
Ron Sonnevil, CEG

Erin Minster GIT 2164
Staff Geologist

TERRA FIRMA
Geologic Services

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TERRA FIRMA Geologic Services

INTRODUCTION

Statewide Planning Goal 18: Beaches and Dunes (OAR 660-015-0010(3)) establishes requirements for foredune grading and management through a dune management plan (DLCD, 2010). Those requirements include "consideration of factors affecting the stability of the shoreline to be managed including sources of sand, ocean flooding, and patterns of accretion and erosion and effects of beachfront protective structures and jetties." This report addresses those requirements and is intended to be used as a basis to prepare a dune management plan at Bayshore on Alsea Spit in Lincoln County, Oregon. Bayshore was "committed to development" in the 1960's and qualifies for foredune grading if other requirements of Goal 18 can be met. This report is organized into several sections including a general physical description of the area and its relationship to the littoral cell it is contained within, a discussion of physical factors influencing the site and a discussion of human factors.

SITE DESCRIPTION AND SETTING

The subject area is located in the northern part of the southern half of the Newport littoral cell, a 27 mile long stretch of coastline that runs from Cape Perpetua to Yaquina Head (Figure 1). The dune management planning area (Figure 2) extends from the southerly tip of Alsea Spit approximately 8,000 feet north to the northern edge of the Bayshore development, an unincorporated area of Lincoln County. The inland extent of the plan area is located at the seaward edge of the foundations for the residences from the north edge of the plan area to beach access # 5, then jogs east and follows the inland boundary of NW Oceania Drive and NW Alsea Bay Drive to the south end of the plan area. The planning area is divided into 8 management units (Figures 3A&B) that are referred to extensively in this report.

The southern edge of the planning area is located at the mouth of the Alsea River, which has the largest watershed (466 miles^2) within the Newport littoral cell. No published literature was found regarding the sediment budget of the Newport littoral cell. Obvious major sand sources within the littoral cell include the Alsea and Yaquina Rivers. Smaller streams such as the Yachats River, Beaver Creek, Theil Creek and others contribute sediment to the littoral cell. Seacliffs are another source of sand within the Newport littoral cell. Natural sand sinks include Alsea Bay, Yaquina Bay and areas offshore. Prior to development of Alsea Spit an obvious sand sink consisted of the large dunes that began in the northern part of what was to become the Bayshore development but since the area was developed in the 1960's sand has not been deposited in those dunes. The Newport littoral cell is bounded to the north and south by headlands composed of Tertiary age basalt. The seacliffs consist of Pleistocene age terrace sediments deposited over Tertiary age siltstone and sandstone. Inland areas are underlain predominately by Tertiary age siltstones and sandstones (Schlicker and others, 1973).

Relationship of Planning Area to the Foredune

The shape and position of the foredune varies significantly within the planning area. Throughout the entire planning area the foredune ranges from conditionally stable to active. In the northern part of the planning area (management units 1, 2, 3 and 4) the foredune is distinct and well seaward of the homes. A conditionally stable dune ridge that represents an older foredune exists to the east of the active foredune beginning in the middle of management unit 1 and extends to the clubhouse in management unit 4 where it is obscured by the clubhouse parking lot. This older dune ridge appears to be the active foredune in the late 1970's through the 1980's. In management unit 5 the foredune ceases to be a distinct ridge that is seaward and separate from the homes but becomes a feature that includes the homes. The homes in the northern part of management unit 5 are located on the eastern part of the foredune and in the southern part they are located within the crest of the foredune. The homes and NW Oceania Drive are essentially part of the foredune in management units 6 and 7. The foredune ends at the south end of management unit 7. Management unit 8 is adjacent to the mouth of the bay and although it lacks a foredune it is still subject to sand inundation.

Three main beach environments were identified including an open sand beach containing driftwood and occasional scattered small clumps of European beach grass. This area extends from the surf zone to an elevation of about 14 feet NAVD88 and, in the summer contains numerous small transverse dunes resulting from north winds. The second area identified includes an area of numerous scattered hummocks containing European beach grass. If accretion continues and the area is not subjected to another wave erosion event it appears that these hummock dunes will develop into another foredune, at least in management units 4-2 where they are best developed. The foredune has a variable cover of European beach grass, ranging from conditionally stable to active. Extensive portions of the foredune in the southern part of the area are bare sand due to grading or recent sand deposition. The dune ridge that represents an older foredune in management units 1-4 is vegetated in European beach grass with scattered shrubs, shorepines, and spruce trees. An oblique aerial photograph taken in May, 2011 is on the cover of this report and Appendix 1 is a series of oblique aerial photographs taken at the same time which show the individual management units.

PHYSICAL FACTORS AND PROCESSES

Wind

The wind climate of the Oregon coast is bimodal (Hunter and others,1983). In the summer the North Pacific High dominates the weather pattern resulting in dry conditions and north to northwest winds of moderate velocities commonly reaching 20 to 30 miles per hour. In the winter the Aleutian Low dominates the atmospheric circulation resulting in frontal storms that pass over the coast with associated heavy rains and strong (30 to 50+ miles per hour) south to southwesterly winds.

Both southerly and northerly winds influence sand movement and the dunes at Bayshore but the greatest changes and impacts are associated with the strong southerly winds in the winter. It is not uncommon in the southern part of the planning area for sand accumulations of several feet to occur during individual storms. Sand is deposited seaward of existing homes, against and on top of homes, in yards and driveways between homes and NW Oceania and NW Alsea Bay Drives, and on portions of NW Oceania Drive and NW Alsea Bay Drive. Inundation occurs after a prolong period of strong northwesterly winds during summer months but impacts are generally not as severe as during winter storms with strong southerly or southwesterly winds. It appears that an important function of the northerly winds is to transport sand along the open beach where it accumulates in the southern part of the spit and becomes accessible to the strong southerly winds which are more onshore in the southern most part of the planning area. Another source of sand is the beach between Alsea Bay and Yachats. Sand along that section of beach transported by southerly winds and swells ultimately makes it into Alsea Bay. At low tides the sand is exposed to strong southerly winds and deposited on the beach at Alsea Spit.

The orientation of the shoreline at Bayshore is not the same throughout the planning area. In management unit 5 the shoreline straightens out and has a uniform north to northeast trend that extends past the north edge of the planning area (Figure 2). Between management units 5 and 8 the shoreline curves becoming oriented southeast and finally nearly east-west. Where the beach faces southwest to south the strong southerly storm winds have a significant onshore component causing the sand to be deposited on and even inland of the structures. Where the beach faces west the sand blown off the spit is deposited on the outer part of the foredune and on the beach seaward of the foredune. North of management unit 4 the amount of sand deposited on the foredune is much less than farther to the south.

Waves and Ocean Levels

The beach is regularly shaped by ocean waves. Winter storm waves remove sand from the beach to offshore bars and summer waves return that sand (Komar, 1998a). Erosional changes associated with ocean waves are controlled by wave conditions, including wave height and wave period, and water level.

Wave data (wave heights and periods) have been measured in the North Pacific using wave buoys and sensor arrays since the 1970's. Prior to the late 1990's the 100-year extreme storm for the Pacific Northwest coast was projected to have a deep water significant wave height of 33 feet (Ruggiero and others, 1996). That height was exceeded once during the 1997-98 winter, four times during the 1998-99 winter and again in January, 2000. Analyses of these additional data for several wave buoys located offshore from the Pacific Northwest coast yield 100-year storm wave heights that ranged from 46 to 55 feet (Allan and Komar, 2001).

Ocean water levels are controlled by the state of the tide, storm surge and El Nino conditions. Water levels along the Oregon coast are consistently higher during the winter months due to storm surge, seasonal changes in ocean currents off the coast and water temperatures (Komar, 1997). The combination of high tides, higher ocean levels and high waves that occurs during the winter months causes most of the erosion along the Oregon coast.

Water levels and wave parameters for various conditions are typically incorporated into a geometric model (Figure 4) that calculates the erosional response of a beach with a specific geometry to sets of variables that represent various scenarios that may impact a given area. The results of those calculations are used to delineate areas with different levels of beach erosion hazard, including areas with high, moderate and low hazard with the scenario for the high hazard having the greatest likelihood of occurring. Witter and others (2007) calculated beach erosion hazard areas for the Bayshore area using the foredune erosion model of Komar and others (1999). The wave and water level values used for different scenarios that were calculated are listed in Table 1 and the resulting hazard areas are shown in Figures 5A&B. The high hazard scenario includes wave and water level conditions that approximate conditions which occurred in 1997-1999. The moderate hazard scenario includes a larger wave event analogous to the predicted "100-year event" combined with a sea level rise expected in a 100-year period. The low hazard scenario combines the moderate hazard scenario with predicted subsidence expected to occur during a Cascadia subduction zone earthquake. The beach geometry for the modeling was obtained from LIDAR data collected in 1998. Appendix 2 contains a brief explanation of LIDAR.

Hazard Zone Scenario	Significant Wave Height	Peak Spectral Wave Period	Mean Higher High Tide	Monthly Mean Water Level	Storm Surge	Sea Level Rise	Regional Subsidence*	Change in Water Elevation†
High	47.6 ft	17 s	7.5 ft	1.3 ft	3.3 ft	—	—	12.1 ft
moderate	52.5 ft	20 s	7.5 ft	1.3 ft	5.6 ft	1.3 ft	—	15.7 ft
Low	52.5 ft	20 s	7.5 ft	1.3 ft	5.6 ft	1.3 ft	3.3 ft	19.0 ft

*Due to a Cascadia subduction zone earthquake.
†Relative to NAVD88 datum.

Table 1. Parameters used to model maximum potential erosion distance on dune-backed shorelines in southern Lincoln County, Oregon. Source: Witter and others (2007).

Witter and others (2007) show that, in management units 1-4 at Bayshore, only the northernmost homes are in the high and moderate hazard areas and that only a few homes are within the low hazard area. However, most of the homes in management units 5-8 are located in the high and moderate hazard areas. It is noteworthy that erosion has historically threatened homes in those areas leading to installation of rip rap shore protection structures. Importantly, the beach erosion model does not consider the presence of a shoreline protective structure such as rip rap. The beach erosion hazard areas were defined using beach geometry obtained from LIDAR data collected in 1998 after the beach had adjusted to a major El Nino event. Much of the beach has accreted since 1998 and the same modeling using current beach geometry is expected to result in some seaward shift of the hazard zone boundaries where accretion has been significant.

However, when the beach erodes it will resume a profile configuration and elevation much more similar to the 1998 profile than the accreted profile that currently exists (Allan and Komar, 2005). Because of that the 1998 geometry should be used for determining hazard zone locations and, in our opinion, the hazard zones determined by Witter and others (2007) remain valid.

The amount of foredune retreat predicted by the geometric model is based on the assumption that the beach junction angle will retreat inland along the slope of the profile until it reaches the total water level of the design storm (Location B or C on Figure 4). This assumption has implications for the effectiveness of enlarging a foredune to protect inland properties from beach erosion. According to the model the beach will ultimately erode to the predicted location regardless of how much foredune exists. Thus, one can argue that for conditions associated with a predicted 50-100 year event, an enlarged foredune is not expected to provide long term protection to properties from erosion if a given beach completely erodes to the geometry predicted by the model.

A problem with applying the model for conditions associated with a multi-decade design event is that the assumed extreme water levels and storm wave conditions are not sufficiently sustained for a beach to reach the maximum eroded state during a single storm event. Thus, the modeled changes are expected to require a series of major storms and elevated water levels that repeat themselves throughout a season or even over multiple seasons. The existence of a wider foredune can help to retard the erosion rate and provide some additional level of protection to properties by absorbing wave energy and providing additional sand to the beach as the dune erodes.

Bay Outlet Migration

The outlet of Alsea Bay is not controlled by jetties and migration of the Alsea Bay outlet is a process that has caused significant change to the beach at Alsea Spit. Under normal conditions the outlet for Alsea Bay is located adjacent to the bedrock point on the south side of the bay. During El Nino conditions there is a stronger northward movement of sand along beaches in the Pacific Northwest (Komar, 1998b). Sand movement during the 1982-83 El Nino was sufficient to create a large offshore sand bar on the south side of Alsea Bay that migrated north. This diverted the outlet of the bay to the north which, in turn, eroded the offshore beach in front of the southern part of the spit. Erosion of the offshore bars exposed the beach to direct wave attack (Komar, 1997). These conditions resulted in erosion of the beach and dunes in front of the existing homes causing the loss of one home and threatening others. The outlet channel remained deflected but migrated south, exposing the beach to wave attack during that process. In fall of 1985 outlet flow from Alsea Bay eroded the sand at the tip of the spit threatening the homes near the end of the spit. This process will repeat itself and when it does the beach is expected to erode in a similar fashion, removing the accumulated sand and exposing the rip rap that was installed earlier.

El Nino

El Nino is a periodic atmospheric – oceanographic event that is initiated elsewhere in the Pacific Ocean but can affect the entire west coast of the United States and lead to heightened coastal erosion on the Oregon coastline. El Nino is caused by a breakdown in the equatorial trade winds of the central and western Pacific Ocean (Wyrtki, 1975). Normally the strong equatorial trade winds cause the sea level to be elevated in the western Pacific Ocean. However, when the trade winds stop blowing the elevated warm waters of the western Pacific surge back toward North and South America. Due to the rotation of the earth, currents are created that flow northerly and southerly away from the equator along the coasts of North and South America. This bulge of warm water has been detected on tide gages along the coast of Oregon. Tide gage measurements at Newport, Oregon indicate that during the El Nino event of 1982-83 the ocean surface was elevated 14 inches above the average winter sea level for several months (Komar, 1997).

El Nino is a major disturbance of the meteorological and oceanographic conditions throughout the Pacific Ocean causing dislocation of the jet stream to the south which causes winter storms to cross the coast further to the south in California rather than over Oregon and Washington. The passage of winter storms to the south of the normal track causes high winter waves to approach the Oregon coast from the southwest rather than from the west or northwest. The occurrence of the high winter storm waves from the southwest coincident with the bulge of high water created by the El Nino coastal currents results in a northward displacement of sand along Oregon's beaches, resulting in more beach erosion at the southern part of a littoral cell than in the northern part. Northward displacement of sand along Oregon's beaches during an El Nino can also result in northward migration of stream and bay outlets.

El Nino is a periodic phenomenon that has repeated itself many times. The Multivariate ENSO Index (MEI) is commonly used to measure the strength of El Nino and La Nina events (Wolter and Timlin 1993, 1998). Figure 6 shows a plot of the MEI from 1950 to June, 2011 (Wolter 2011). The two events that resulted in significant erosion at Alsea Spit were the strongest that have been measured since 1950, based on the MEI. This data suggests that there may be a MEI threshold for major El Nino related impacts to occur at Bayshore. The frequency of strong El Nino events has increased in the last few decades but recent research indicates that this occurrence is not anomalous when records are extended into the 1800's (Wolter and Timlin, 2011). Future strong El Nino events will occur and when they do the risk for associated erosion events at Bayshore will be elevated.

Ocean Flooding

The Federal Emergency Management Agency (FEMA) has calculated elevations for flooding related to ocean waves and water levels for events with various frequencies. These data are summarized in a county wide Flood Insurance Study (FIS) and shown in greater detail on Flood Insurance Rate Maps (FIRM) in a series of panels (FEMA, 2009 A-C). Areas interpreted to be at risk of being flooded by events with 1 percent and 0.2 percent annual chances of occurring (i.e. 100-year and 500-year flood events, respectively) are shown on the FIRM. Coastal beach areas have a special flood hazard area related to calculated ocean wave runup designated as the velocity zone that has a specific base flood elevation (BFE) assigned to it. Within the planning area the FEMA designated velocity zone elevation ranges between 24 and 34 feet (NAVD 88). Areas interpreted to be at risk of being impacted by shallow flooding by water with average depths of 1 to 3 feet are designated as being within the AO zone. Hydraulic analyses give an average depth of one foot to the AO zone within the planning area. The AE zone is used where the predicted flooding is just related to the water level in the bay. Figures 7a and 7b show the FEMA designated VE, AO and AE zones within the management area. Statewide Planning Goal 18 requires that foredunes be graded no lower than 4 feet above the FEMA 100-year BFE resulting in minimum graded dune heights for the VE zone between 28 and 38 feet (NAVD 88). FIRM maps in portions of coastal Oregon have recently been updated and Lincoln County is scheduled to be updated in 2014 (FEMA, 2011). Changes made to the BFE during the update will affect the minimum heights that dunes may be lowered to.

Tsunamis

Tsunamis periodically occur and represent a process that can cause change to the beach. Tsunamis with both distant and local sources are expected to impact the Oregon coast. Tsunamis with distant sources such as Alaska and Japan have a large range in sizes and subsequent inundation amounts. The 1964 tsunami generated from the great Alaska earthquake is the largest distant tsunami to historically impact this area. No published documentation was found regarding the amount of runup and impacts that occurred at Bayshore from that tsunami. An unverified hearsay account indicates that the 1964 tsunami washed over the foredune at Bayshore. Large distant tsunamis are capable of eroding the beach at Bayshore. The amount of erosion that occurs during a distant tsunami will depend on its source and when it occurs, but it is not likely to exceed the amount modeled for the high hazard scenario, particularly if a tsunami occurs when the beach is in an accreted state.

A local tsunami generated during a large Cascadia Subduction Zone (CSZ) earthquake is predicted to impact all of the dune management area. Modeling indicates that the maximum CSZ tsunami will inundate all of Alsea Spit including at least the southern half of the lower lying portions of the Bayshore Development (Priest, 1995). Large local tsunamis generated by a continuous rupture on the CSZ (from California through Washington) are interpreted to have a recurrence interval of about 500 years with the last event occurring in 1700. Recent research indicates that smaller tsunamis generated by CSZ events with shorter rupture lengths in southern Oregon and northern California are more frequent and have a recurrence interval closer to 250 years (Priest and others, 2009). Runup from a smaller CSZ tsunami in the Bayshore area has not been modeled.

Tsunami inundation modeling for distant and local tsunamis is in the process of being revised for the entire Oregon Coast. Where the new modeling has been done most of the inundation areas are significantly larger than earlier modeling indicated and this trend is likely to apply to the Bayshore area (Rob Witter, personal communication 2011). A local tsunami resulting from a large CSZ earthquake is likely to overwhelm much of the Bayshore development and cause extensive damage to the beach and dwellings within the dune management area.

A robust foredune can help provide protection from most distant tsunamis, similar to how it could provide protection during a large storm. However, an extremely large distant tsunami or even a moderate local tsunami appears to have the potential to erode the beach at Bayshore. A large local tsunami is expected to overwhelm the area resulting in major damage to properties and residences at Bayshore.

EROSION AND BEACH HISTORY

Stereo pairs of aerial photographs taken in 1939, 1967, 1972, 1985, 1986 and 1987 were studied with a stereoscope for this project to document changes. A single aerial photograph taken in 1952 was also studied as were digital ortho-photographs or ortho-images for the years 1977, 1994, 2000, 2005, 2007 and 2009. This section describes what is visible on the aerial photographs and what is available in the literature.

Aerial photographs taken in 1939 show much of Alsea Spit as being a low lying expanse of bare sand. There are scattered, isolated patches of vegetation consisting of either low trees or brush in the southern part of the spit but the majority of the spit consists of bare sand. In 1939 the southern part of the spit contained a broad, relatively low lying foredune that narrows to the north where it is bounded to the west by a distinct erosion scarp. Large dune ridges ramp up onto the forested slope to the north of the spit and it is obvious that those dunes were formed by wind from the south and southwest. Those dunes come nearly to the foredune near the northern extent of what was to become the Bayshore development.

A single aerial photograph taken in 1952 shows scattered low vegetation on the southern part of the spit and locally on the northwest part of the spit. The areas that appear vegetated in the 1939 photographs are larger and have more vegetation in 1952. However, the general morphology of the spit appears similar to the 1939 photography. A stereo pair was not available for the 1952 photography so it is not possible to discern foredune height or width. Cooper (1958) provides the first description of dune morphology on Alsea Spit and describes it as a "blunt spit bare of dunes".

Aerial photographs taken in 1967 show the project shortly after it was developed with only a few homes in place. In 1967 much of the foredune appears to have been graded and consists of a relatively narrow area seaward of NW Oceania Drive. The graded portion of the foredune appears to have been planted (in dune grass?) and other parts that were not apparently graded were covered with low vegetation. Most of the few homes that existed seaward of NW Oceania Drive in 1967 were essentially notched into the foredune and many of those were located on the seaward edge of the foredune adjacent to the edge of the bare sand beach. Lund (1972) describes Alsea spit as a low dune ridge near the beach with a low sandy grassy plain that slopes to Alsea Bay. Stembridge (1975) describes Alsea Spit and the Bayshore development in the mid-1970's and reports a significant amount of accretion occurring, mainly in the southern part of the development with the main foredune increasing in elevation at a rate of 0.5 foot/year.

Aerial photographs taken in 1977 and 1980 show a significant seaward enlargement of the foredune, particularly in the southern half of the project area. It is apparent on the aerial photographs that a small amount of seaward growth of the foredune occurred in the northern part of the development between 1967 and 1977.

The 1982-83 El Nino resulted in significant changes at Bayshore (Jackson and Rosenfield, 1987; Komar, 1997). Those changes, which are described in the previous section regarding outlet migration, resulted in placement of a large amount of rip rap to protect properties in the southern part of the Bayshore Development. Records at Oregon Parks and Recreation Department (OPRD) indicate that in 1984 permits were issued for installation of rock rip rap extending from the northern edge of the Beach Club property (beach access 4) south around the end of the spit (Tony Stein written communication, 2011).

Aerial photographs taken in 1984 and 1985 show a seaward enlargement of the vegetated dunes and an increase in vegetation on the dunes in management units 1-3, relative to 1977. In management unit 4 and the northern part of management unit 5 the vegetated dunes do not enlarge seaward but the amount of vegetation cover increases dramatically between 1977 and 1984-85. Obvious erosion and landward retreat of the dunes begins in the southern part of management unit 5 and extends into management unit 7. Rip rap is obvious in management units 5-8 on the photographs but not farther north. The seaward edge of the foredune in management units 1-4 is a very distinct feature on the 1985 photography and appears to have been recently eroded.

Aerial photographs taken in 1987 show a significant amount of recent sand deposition in the southern part of the planning area obscuring much of the rip rap. In the northern part of the planning area the width of the vegetated dunes is similar to 1985 but the seaward edge of the dunes is not nearly as distinct as it is on the 1985 photographs. In 1987 the beach has much more driftwood than in 1985 and there appears to be more sand, suggesting that the beach was accreting.

The late 1980's through the mid 1990's were a period of recovery and accretion for the beach and dunes along Alsea Spit. Komar (1998) reports that by 1997 the beach at Alsea Spit had fully recovered from the 1982-83 El Nino. In 1997-98 the area was subjected to another strong El Nino immediately followed by a strong La Nina in the 1998-99 winter resulting in another period of erosion that threatened homes in the southern part of the planning area, some of which had reportedly been constructed seaward of the rip rap installed a decade earlier (Komar, 1998). Records at Oregon Parks and Recreation Department (OPRD) indicate that in 1999 several permits were issued for installation of additional rip rap at several locations in management units 5, 6 and 7 (Tony Stein written communication, 2011).

Aerial photographs taken in 2000 show the beach in management units 5-7 to locally have major erosion with several obvious areas of rip rap apparent. The beach in front of management units 6 and 7 is very narrow and eroded nearly to the rip rap. The 2000 photography obviously records the erosion event that started during the 1997-98 El Nino. In 2000 the foredune location in management units 1-4 is seaward of its location on the 1987 photographs and covered with scattered vegetation (except at the very north end of management unit 1 where it is similar to how it appeared in 1987).

The ortho imagery from 2005-2009 lacks consistency and detail of the traditional aerial photography. In some places such as management unit 1 the images document an obvious increase in vegetation during those years and seaward enlargement of the vegetated area. In other areas the details are not obvious due to over exposure of the image and pixilation. Beginning in the late 1990's LIDAR surveys became available and our documentation of change is done using that methodology which is described below.

Changes in the Shoreline Location

Figures 8A-B show the location of historic shorelines and the position of the shoreline as captured in 2011. The shorelines were generated using various methods a description of which is contained in Appendix 4, however each can serve as a proxy for the location of the mean higher high water (MHHW) line. The MHHW line is generally the average height of the highest high tides over a given interval of time. The 1928 shoreline location is the eastern most and oldest of the available shorelines. In management units 1 and 2 it is located very near and locally inland of the current foredune location. The line then trends seaward through management units 3 and

4 before migrating landward again in units 5, 6, and 7. The next available shoreline is the 1967 line which is located on average 100-200 feet west of the 1928 line through the middle of management unit 4 where it then trends seaward through the tip of the spit suggesting that the tip was much wider in 1967 than in 1928. The 1997, 1998, and 2002 shorelines are derived from LIDAR data and bracket the El Nino erosion event that occurred during that time. The 1997 shoreline is generally west of the 1998 shoreline showing that indeed the beach underwent some amount of erosion during that time. The erosion appears to be greatest in management units 4 and 5 where the 1998 shoreline migrated to the east near and locally landward of the location of the shoreline in 1928. This coincides with where many of the shore protection permits were issued in 1999 for lots within management unit 5. The 2002 shoreline captures the subsequent accretion following the erosion event, especially in management units 5, 6, and 7. The shorelines from 2007, 2008, 2010, 2011 in general show minor erosion relative to the 2007 shoreline in the northern half of the planning area while the southern half including the tip shows general accretion.

Changes in Beach Profiles

Beach profiles are commonly used to compare and quantify changes over time on a section of beach. Beach profiles at Bayshore have been measured using two methods: 1) surveying with a Real Time Kinematic Differential Global Positioning System (RTK-DGPS) unit and, 2) using elevation data acquired from LIDAR. LIDAR data for the beach at Alsea Spit is available for the years 1997, 1998, 2002 and 2009. Appendix 3 describes how profiles were generated using both methods. For this report we show ten profiles to document change in the planning area. Figures 9A-B show the location of the profiles and Figures 10A-J show the profiles plotted. The location of the Oregon Statutory Vegetation Line is shown on Figure 9 and on the x-axis of the plotted profiles (Figure 10). The BFE and BFE + 4 feet is plotted on the Y-axis of the plots. For all ten locations we generated profiles from the 1998, 2002 and 2009 LIDAR data. Profiles 3, 5, 7,8 and 9 were surveyed in May, 2011 with the RTK-DGPS and we show that data as well. Profiles 3, 5 and 8 have been monitored by DOGAMI and include the 1997 beach profile. The 1997 configuration was purposefully omitted from the other profiles to simplify them.

The profiles show consistent trends. In viewing the profiles it is important to keep in mind the timing of profile measurement relative to storm history. The 1997 profiles were prepared from LIDAR data that was gathered before the 1997-98 El Nino event and the 1998 profiles were based on data collected after the 1997-98 El Nino. Profiles 3, 5 and 8 clearly show erosion between 1997 and 1998, changes that are inferred to be related to the 1997-98 El Nino. As previously discussed the Pacific Northwest was impacted by very large wave events several times in the winter of 1998-99 and once again in the winter of 2000. Most of the 2002 profiles show some amount of landward retreat of the seaward edge of the dune system or erosion of the beach near the beach junction angle. It is likely that most of the change between the 1998 and 2002 profiles are due to the large wave events that occurred during the two winters after the 1998

LIDAR data was collected. The 2009 profiles essentially all show seaward growth of the foredune face relative to 2002 and many of them show an elevation increase of the foredune crest. Profiles surveyed in 2011 show continued growth of the dune system both as a seaward migration of the foredune face and an elevation increase of the dune crest.

Not all of the changes apparent on the profiles are related to natural events, some of the change is related to grading. This apparently was the case on profile 7 where the dune was lowered about 10 feet between 1998 and 2002 and on profile 9 where the dune was lowered by 4 feet between 2002 and 2009.

CURRENT BEACH TOPOGRAPHY

Availability of Sand for Grading

The ability to grade the foredune is dependent on the elevation of the dune relative to the base flood elevation. Goal 18 requires maintaining a foredune height that is 4 feet above the 100-year BFE for the velocity zone. The most complete recent topographic data set for the foredune system at Bayshore is the 2009 LIDAR. Figures 11A-H show LIDAR-derived contour maps of the planning area for each management unit. On each figure there are up to three colors of contours. The contour matching the BFE is shown as blue, the contours with values that exceed the base flood elevation by 4 feet are shown in red and all other contours are shown as grey. The figures also show the footprints of the existing homes. Three of the figures do not have any red contours because the elevation of the foredune in 2009 did not exceed the base flood elevation by 4 feet in management units 1, 2 and 3. The elevation of the foredune decreases to the north and in management units 1and 2 the vast majority of the foredune in 2009 was below the base flood elevation.

The management units with the widest area of sand seaward of the homes that was available for grading, based on the 2009 topography, are management units 4 and 5. The reasons for this are twofold: 1) areas within several of the management units had been graded prior to collection of the LIDAR data, and 2) the way sand is transported and deposited on the beach as discussed earlier.

The 2011 survey of profile 3, located in management unit 3, shows the foredune crest to be 4 feet higher than it was in 2009 and essentially four feet above the base flood elevation (Figure 9C). The aerial photography taken in 2011 shows recent sand deposition along portions of the foredune along the entire management area and it is likely that the magnitude of change of the foredune crest in the northern management units between 2009 and 2011 is similar to the change at profile 3. The topographic data collected in 2011 shows an overall increase in elevation of the dune crest in management units 4-7 (except where grading had lowered it below the 2009 elevation).

Changes in Sand Dune Elevations Since 2009

A traverse made along the crest of the foredune from north to south using the RTK-DGPS beginning in the southern part of management unit 4 and ending in management unit 7. Elevation data was automatically collected every meter along the traverse. The traverse was incorporated into the GIS and the elevation data was compared with elevations taken from the LIDAR digital elevation model at the same locations. Figure 12 is plan view showing the location of the traverse and Figure 13 is a plot of the traverse showing elevations along it in 2009 and 2011. It is apparent from the traverse that elevations of portions of the traverse increased by 1 to 9 feet. Some areas remained the same or decreased in elevation and many of those are where grading had occurred. Dune elevations in 2011 were only measured in one area north of the traverse and that was on profile 3, in management unit 3. Profile 3 showed that the dune crest grew 4 feet in elevation between 2009 and 2011. We expect that elsewhere in the northern part of the management area the foredune crest has grown in height on the order of 1 to 4+ feet.

We also collected several hundred elevation points with the RTK-DGPS on the dune system in the southeast part of management unit 7. That data, which is cumbersome to show, indicates several feet of vertical change. Most of the change was positive indicating dune growth but some of the change was negative, indicating dune migration. The maximum negative change measured was -3.65 feet, the maximum positive change was +8.96 feet and the average change measured was +3.77 feet.

HUMAN FACTORS

Human factors that influence the beach include installation of beachfront protective structures, establishment of stabilizing vegetation, construction of homes and development of trails for beach access and use.

Beachfront Protective Structures

Beachfront protection structures (aka shore protection structures), in the form of rip rap, exist in the southern half of the planning area. Records at Oregon Parks and Recreation Department (OPRD) indicate permits were issued for installation of rock rip rap extending from the northern edge of the Beach Club property (approximate north edge of management unit 4) south around the end of the spit (Tony Stein written communication, 2011). Permits were issued for riprap in 1984 and 1999 with the 1999 permits being for repairs to the earlier rip rap that was damaged. The 1999 permits were issued for properties from the middle of management unit 5 into the northern part of management unit 7.

Information regarding the location and height of the rip rap is highly variable. There is very little documentation regarding much of the rip rap that was placed in 1984, especially in management unit 4. The information that is available indicates that riprap placed in 1984 had a height above the beach ranging between 13 and 30 feet. The 1999 permits state that riprap heights ranged from 18 to 30 feet. The exact location of the rip rap relative to the existing homes is not consistently documented in the permit file. A review of the permits indicates that the location of the rip rap varies from being 50 feet seaward of the homes to being directly beneath the seaward edge of the homes (Tony Stein, written communication, 2011). The permit file is large and materials within it are not consistent. Komar (1998) reports that some homes constructed between the mid 1980's and the mid 1990's were located seaward of the 1984 riprap.

Review of the 1999 permits indicates that the repairs were made because the 1984 riprap was inadequate and not well constructed (Tony Stein, written communication, 2011). Additional repairs are expected to be necessary when the area is once again subjected to ocean conditions that erode the foredune and expose or undermine the older rip.

The existing rip rap is obviously not adversely affecting recent sand deposition at Bayshore since it has been completely buried for many years. Sand accumulation rates at this site are so high that the riprap is not expected to be an adverse impact to future sand deposition when it ultimately becomes exposed in the next major erosion event.

Establishment of Vegetation and Home Construction
The establishment of European beach grass has led to major growth of the foredune system on Oregon's beaches. It is apparent on the older aerial photographs that, prior to development, blowing sand was not accumulating in significant amounts on Alsea Spit. Instead, the sand was blowing off of the beach across the bare sand area and accumulating in a system of inland dunes in the northern part of the spit. Establishment of European beach grass has helped retain much of the sand on the beach. Construction of homes on the southern part of the spit has also resulted in significant sand deposition and retention. Low lying areas on the leeward edges of homes are areas where sand is regularly deposited. The homes constructed in the southern part of Bayshore do not have consistent elevations. Many of the more recently constructed homes are at significantly higher elevations than homes which were constructed earlier because the dunes had grown in elevation in the period between when the older homes were constructed and when the newer homes were constructed. This difference in elevation results in more sand being deposited on several of the older homes which are lower. If sand was not removed by remedial grading many of the homes in management units 6 and 7 would, to a large extent, be buried by sand as a large dune develops.

Trails Across Beach
It is evident on the aerial photographs that an extensive informal social trail system exists at Bayshore. Nearly every home has a trail that accesses the beach and locally there is a myriad of interconnected social trails (Appendix 1). Although there are plenty of bare sand areas associated with the trails we did not identify areas where large erosion problems exist that are

related to trail use, primarily due to the large amount of accretion that is occurring. It is possible that vegetation damage related to trampling may be affecting colonization of the foredune where it is not completely vegetated.

Vacant Lots

Vacant lots exist in management units 1, 3, 4, 5 and 7. The LIDAR data indicates that vacant lots in management unit 7 and the southern half of management unit 5 increased in elevation by several feet between 2002 and 2009. The amount of change varies significantly, even on individual lots, ranging from no change to a gain of as much as 14 feet. The two northern lots in management unit 5 show no significant elevation gain between 2002 and 2009 but the dune seaward of them showed significant growth. This is inferred to be due to the orientation of the shoreline relative to the wind direction. The vacant lots in management units 1, 3 and 4 did not experience change.

The vacant lots which have accumulated significant sand in management units 5 and 7 are higher than surrounding areas and, during large wind events, wind transported sand is deposited on adjacent lower areas on their leeward sides. This process has resulted in the build-up of large deposits of sand on adjacent areas. Sand has also locally built up to a point where it can slough and fail onto adjacent lower lying portions of lots that have been cleared.

Beach Access Areas

There are 7 designated beach access locations in the planning area (Figure 3). According to the Lincoln County Tax Assessors Maps the access areas range between 10 and about 22 feet in width. Access 1, the northernmost, is shown to be about 22 feet wide, accesses 4, 6 and 7 are shown to be about 16 feet wide and the remainder have a width of about 10 feet. The beach accesses function as trails across the dunes to the beach. All of the accesses have been impacted by sand accumulations and growth of the foredune but the greatest impacts have been at the southern two accesses where sand has accumulated near NW Oceania Drive, particularly access 6 which is bounded to the south by a vacant lot. At least some of the access locations are likely routes for equipment for foredune grading.

Sand Inundation Impacts

Sand inundation has been an ongoing issue at Bayshore and it is referenced as far back as the mid-1970's (USDA 1975). However, discussions with residents and other individuals who have regularly visited or worked in the area indicate that the impacts have become more severe in the last few years. Discussions with people who visited the area in the 1980's report that sand inundation was an issue. A photograph included in a draft dune management plan prepared sometime between the late 1980-s and mid 1990's by Wilbur Ternyik shows a home partially buried by sand. We have taken similar photographs of that same structure.

Impacts include sand accumulation against structures (locally up to their roofs), burial of driveways, burial of front lawns and septic systems and burial of portions of Oceania Drive and Alsea Bay Drive. Home access has been blocked, windows and garage doors damaged and walls are threatened by the load of the accumulated sand. Accumulation of sand in the area between homes and Oceania Drive has buried water lines, water meters and fire hydrants. Sand has accumulated within walls and on ceilings through vents which has reportedly resulted in collapse of a ceiling and damaged electrical wiring. In many cases sand removed from driveways and the road surface of Oceania Drive has been piled along the shoulder of the road contributing to burial of the water system. Sand that buries the water system inhibits emergency response making it impossible to access water valves and buried hydrants. A dune management plan can help provide a mechanism to manage sand on the roads and improve emergency response capability.

Accumulated sand has been removed through the remedial grading process and permitted by Lincoln County. The Oregon Statutory Vegetation Line is located just seaward of the homes and Oregon State Parks and Recreation Department has issued numerous permits for disposal of sand on the beach seaward of the Vegetation Line. Areas of recent grading are evident on the recent photography (Appendix 1) and it obvious from the aerial photography and the LIDAR data that remedial grading has been occurring for many years.

CONCLUSIONS

1. The planning area was "developed" prior to 1977 thus it does qualify for foredune grading.

2. Inundation by wind blown sand at Bayshore has been a problem for many years and will continue. Aerial photographs taken in 1939 and 1952 prior to development show large active sand dunes downwind. The same processes that caused those dunes to develop exist today, the major difference is that sand is being deposited in the foredune rather than being transported across an open sand flat to inland dunes.

3. Beachfront protective structures exist at the site. These structures provide some level of protection to homes when the beach is subjected to a significant wave erosion event but they do not influence the deposition or erosion of sand by wind.

4. The area will be subjected to future wave erosion events most likely in association with a strong El Nino. Such erosion events will erode the foredune and likely expose the beachfront protective rip rap, possibly locally eroding it. The area at greatest risk of impacts is located within management units 5-7.

5. Northward outlet migration of Alsea Bay is likely to occur again during a very strong El Nino Event. When that occurs portions of the beach are expected to be severely eroded by ocean waves, exposing the rip rap and resulting in placement of additional rip rap.

6. A wider foredune has the potential to lower the risk for waves to erode all the way to the rip rap, depending on the severity of the wave event(s). A dune management plan can provide the ability to help accomplish a wider foredune that can lower the risk of impacts if a dune with a sufficient width can be developed.

7. Events that result in the erosion of the foredune will be followed by periods of accretion, foredune growth and, ultimately, future inundation problems. Management of the foredune through a dune management plan earlier in the recovery process is expected to be more effective at reducing inundation impacts than implementing a program when impacts are severe. However, a dune management plan will allow for a much more integrated approach to sand management to lessen impacts to the developments.

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Figure 1. Map showing location of Bayshore Dune Management Planning Area.

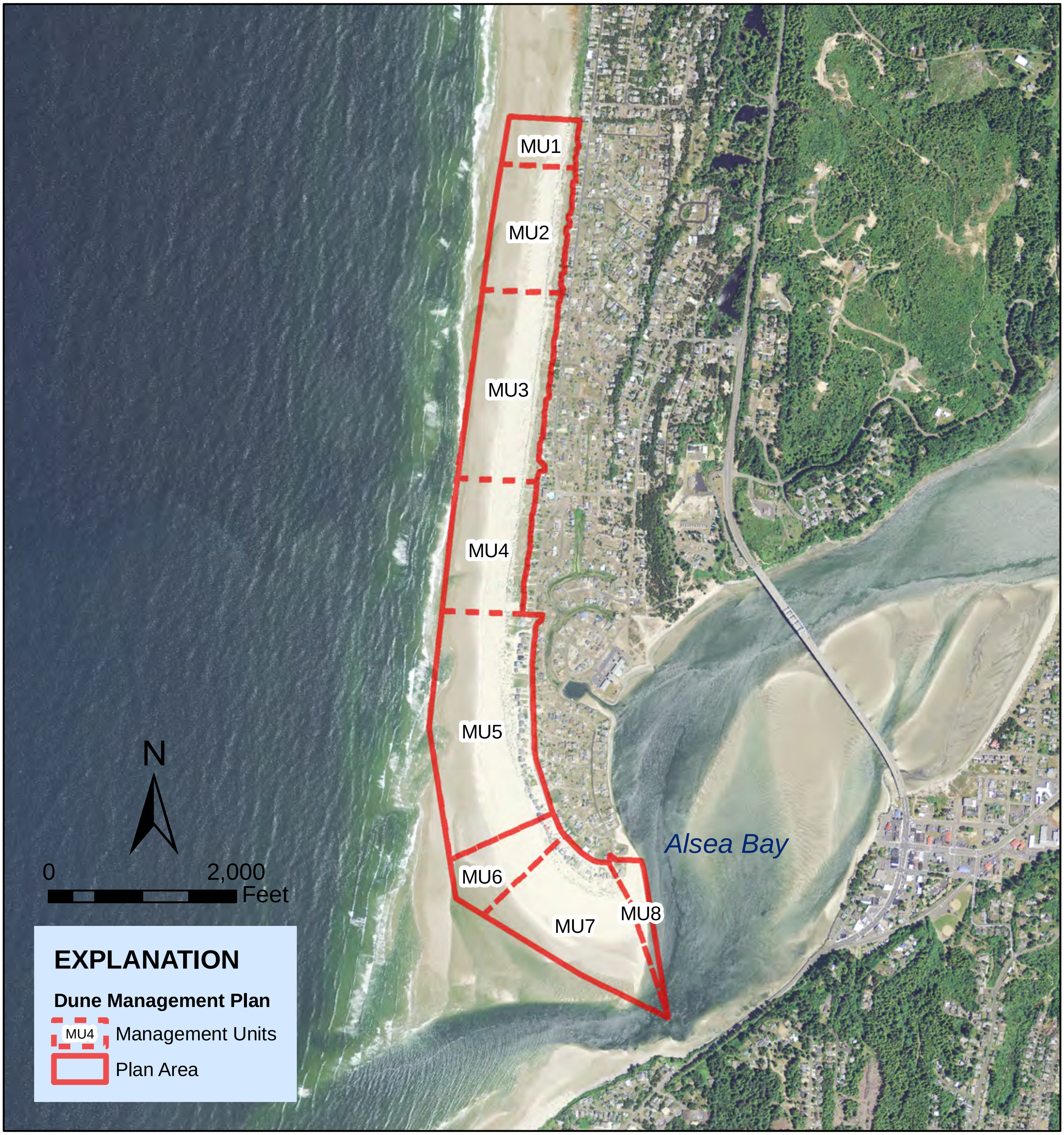

Figure 2. Overview showing setting of Bayshore Dune Management Planning Area and Management Units.

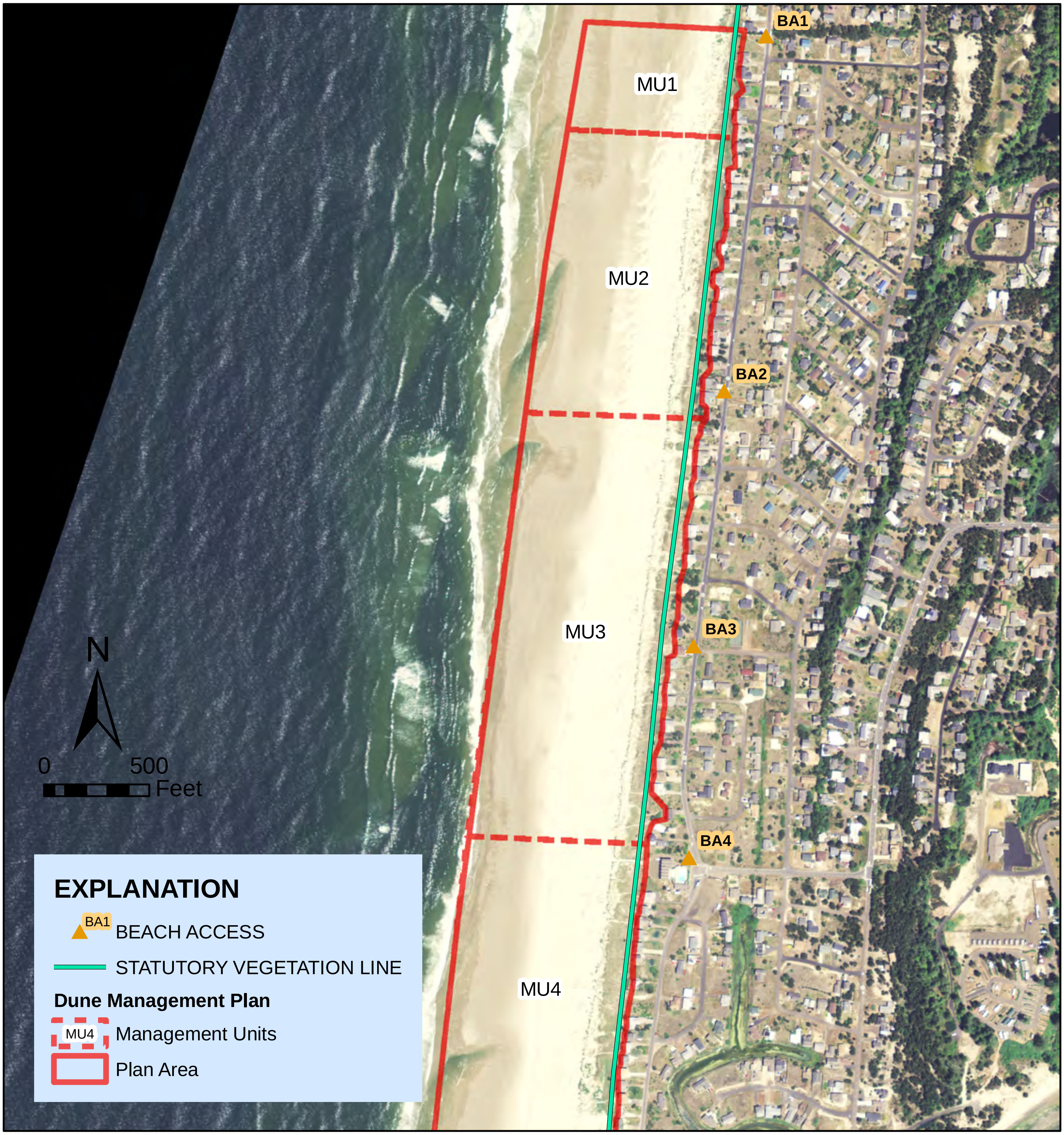

Figure 3A. Management units within northern half of Bayshore Dune Management Planning Area, 2009 imagery.

TERRA FIRMA Geologic Services

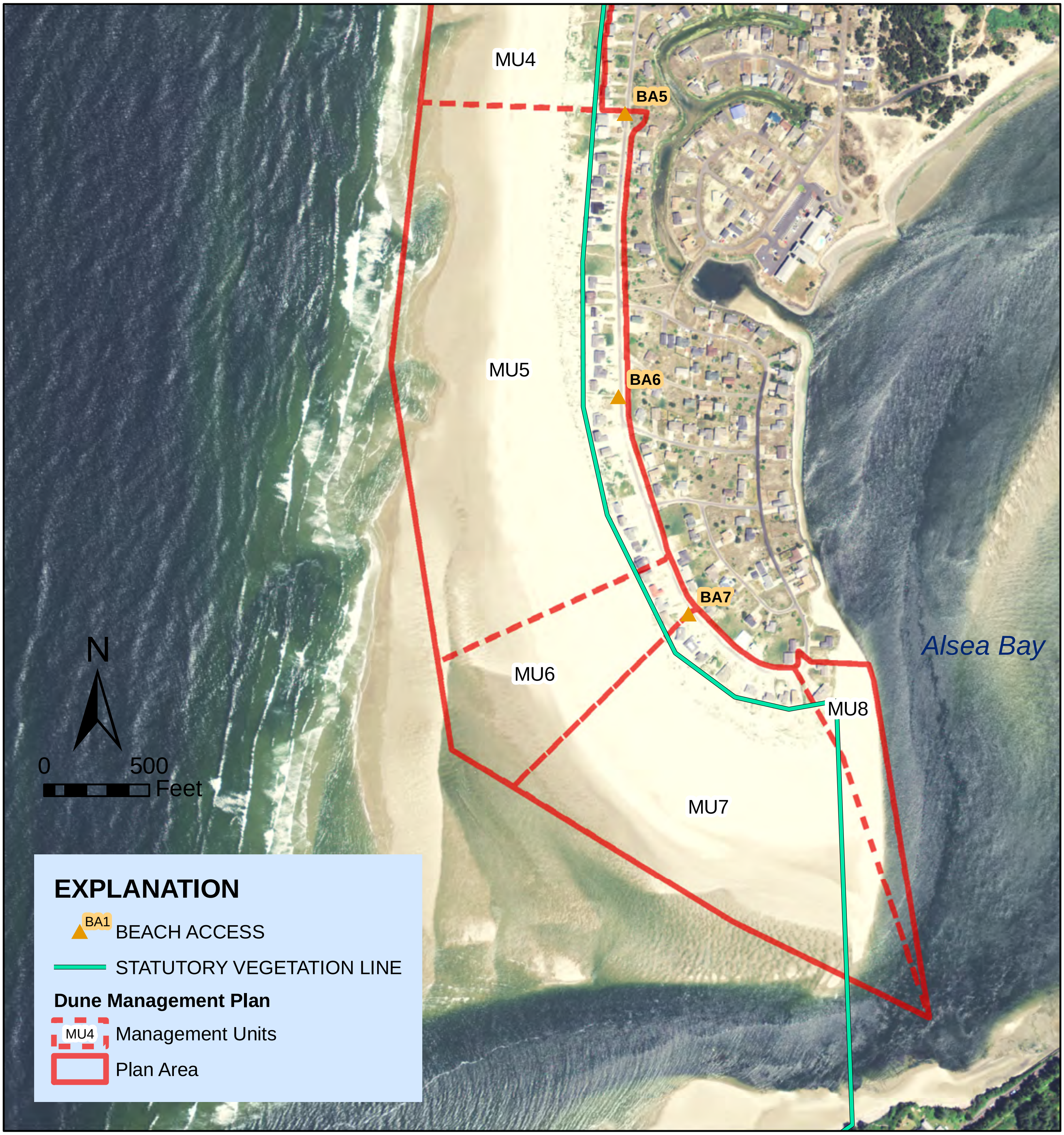

Figure 3B. Management units within southern half of Bayshore Dune Management Planning Area, 2009 imagery.

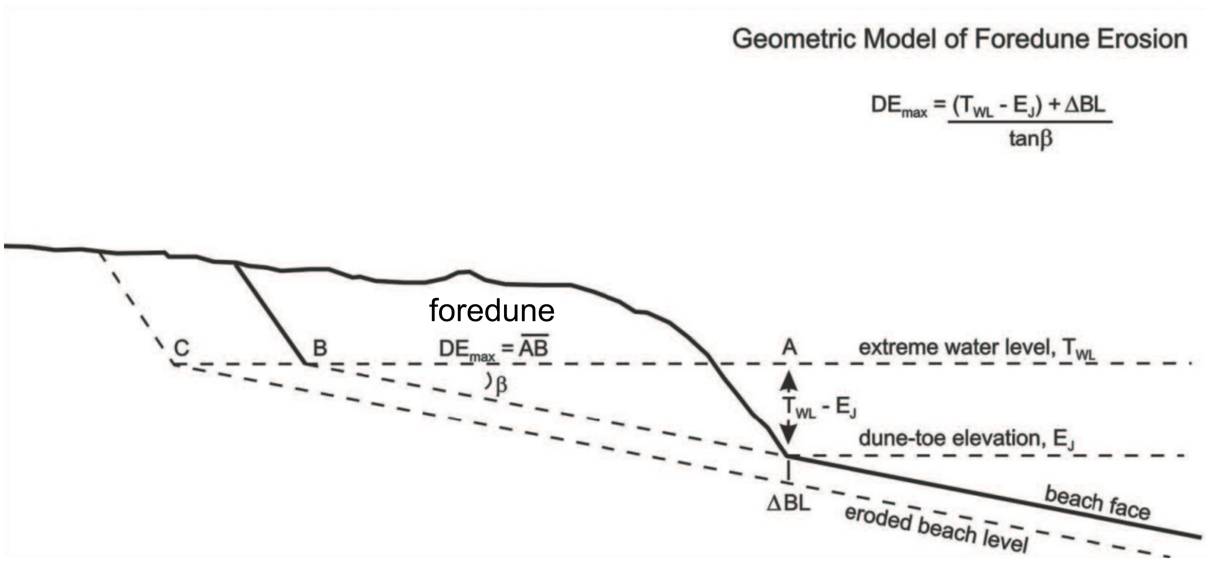

Figure 4. Geometric Foredune Erosion Model of Komar and others (1999) from Allan and Komar (2005). Dune-toe (Ej) elevation migrates inland along slope of beach face in response to extreme water levels, resulting in erosion of the foredune. Note that if beach face is lowered by erosion then Ej is predicted to migrate farther inland than if beach face is elevated.

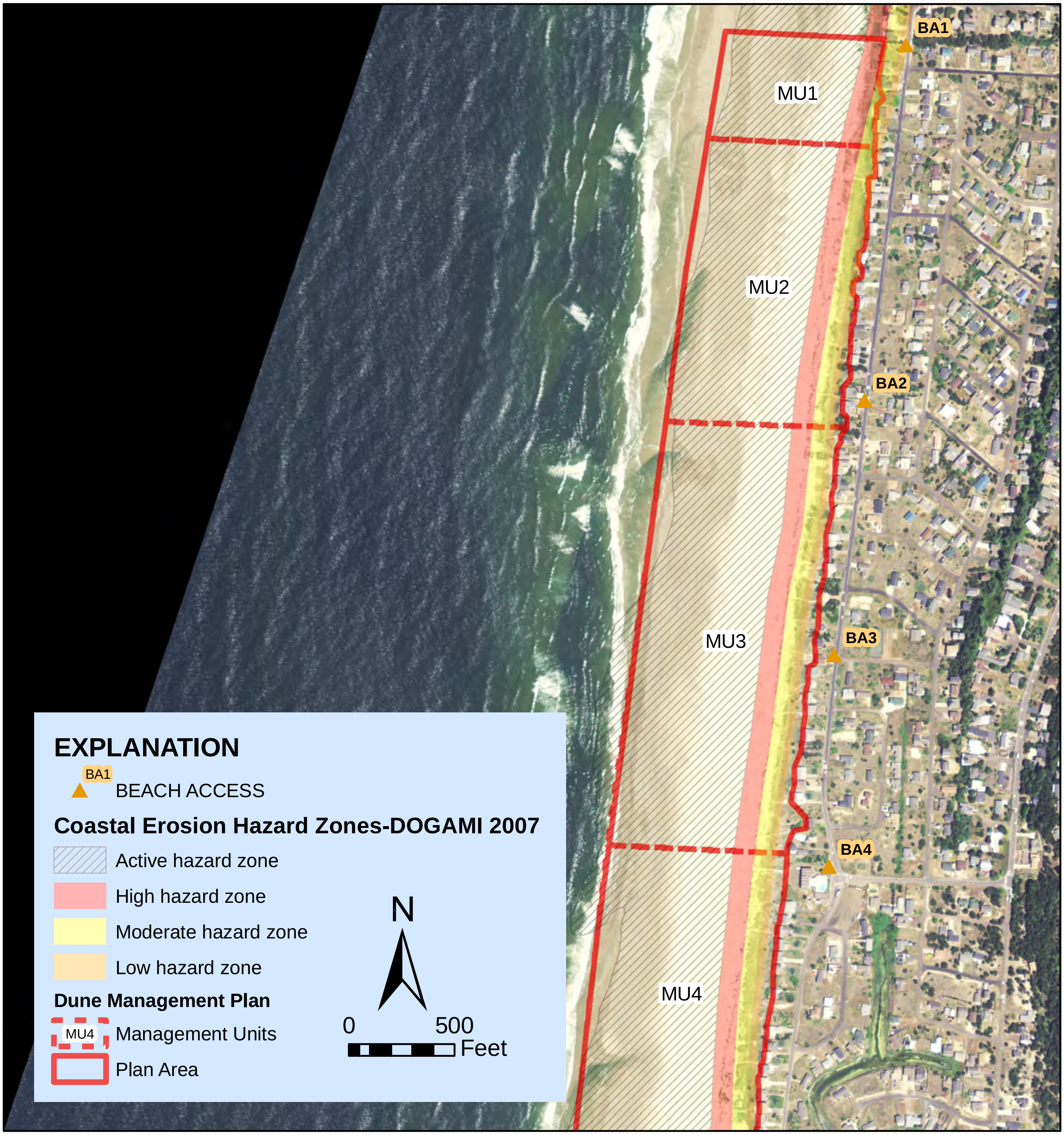

Figure 5A. Erosion hazard zones determined for various scenarios along the northern half of the Bayshore Dune Management area using geometric foredune erosion model. Source: Witter and others, 2007.

Figure 5B. Erosion hazard zones determined for various scenarios along the southern half of the Bayshore Dune Management area using geometric foredune erosion model. Source: Witter and others, 2007.

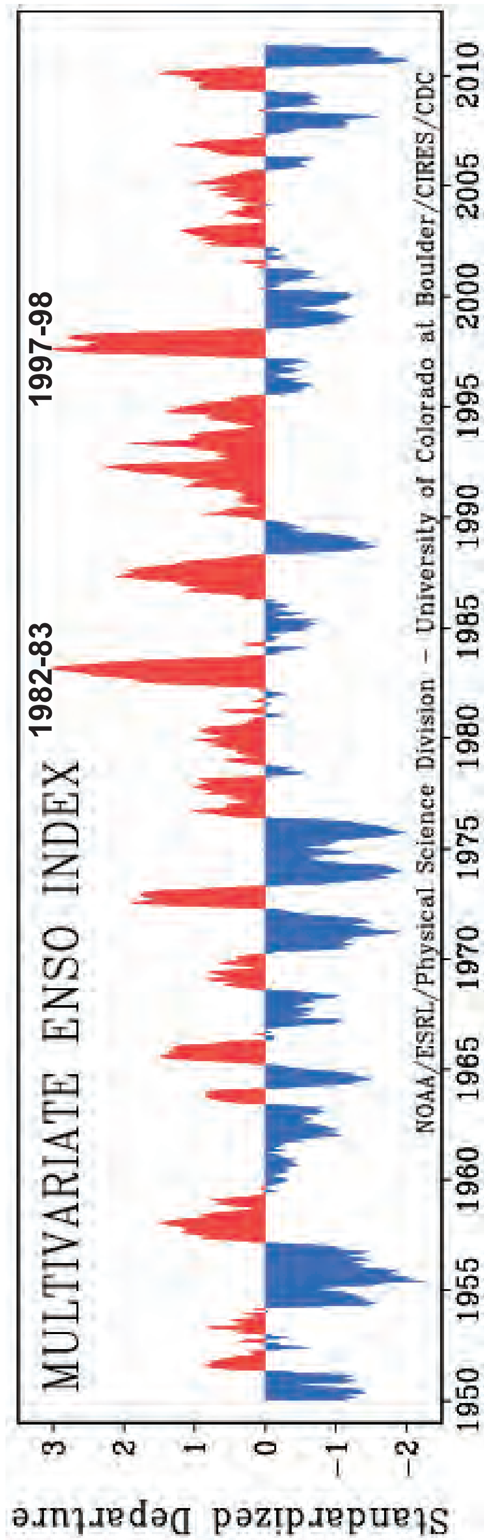

Figure 6. Multivariate ENSO Index (MEI) 1950-2011. Positive values (shown in red) represent El Nino events and negative values (shown in blue) represent La Nina events. Source: Wolter (2011).

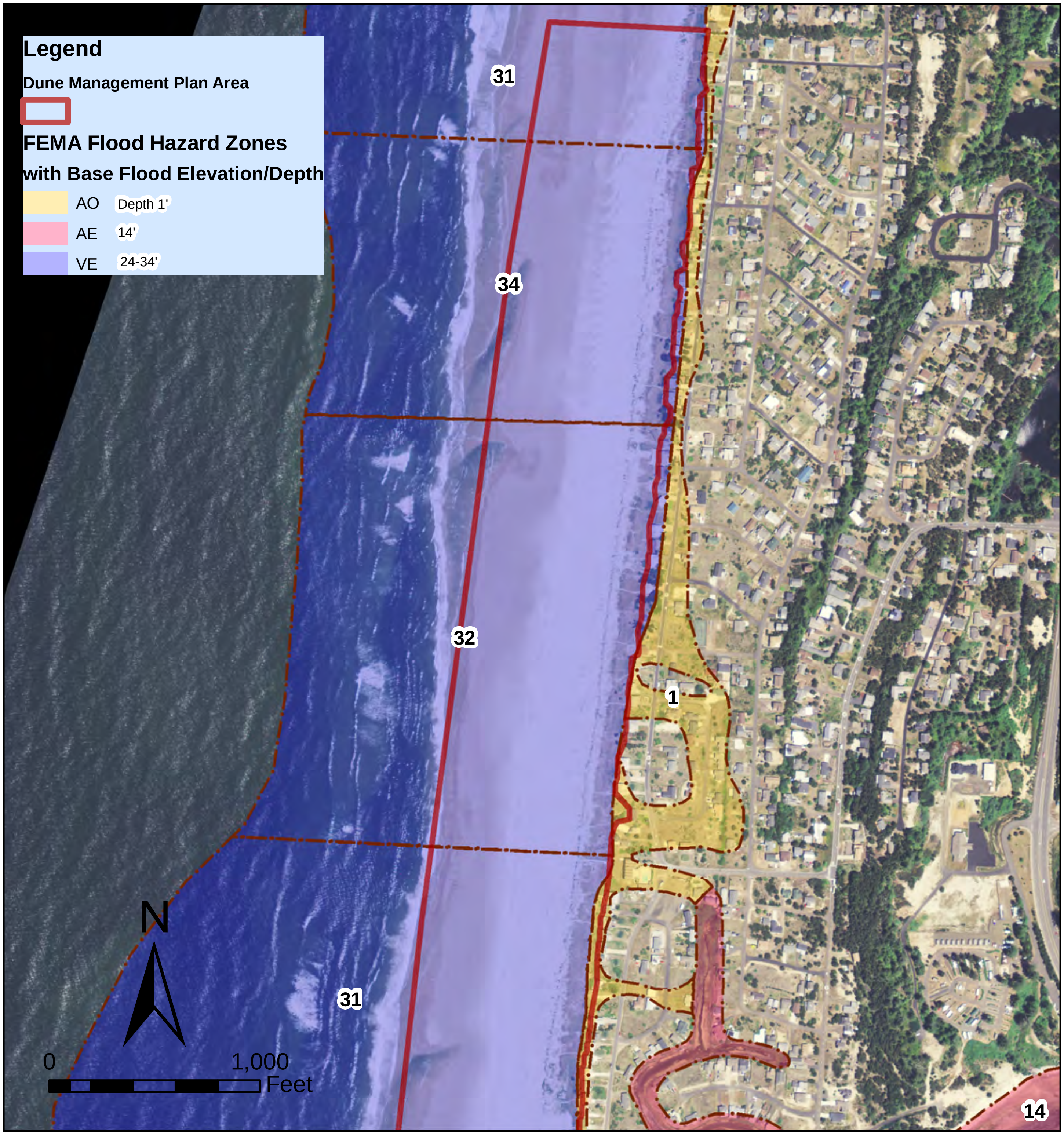

Figure 7A. FEMA Flood hazard zones for the northern half of the Bayshore Dune Management Plan Area overlaid on 2009 imagery. Source: FEMA, 2009 B, C.

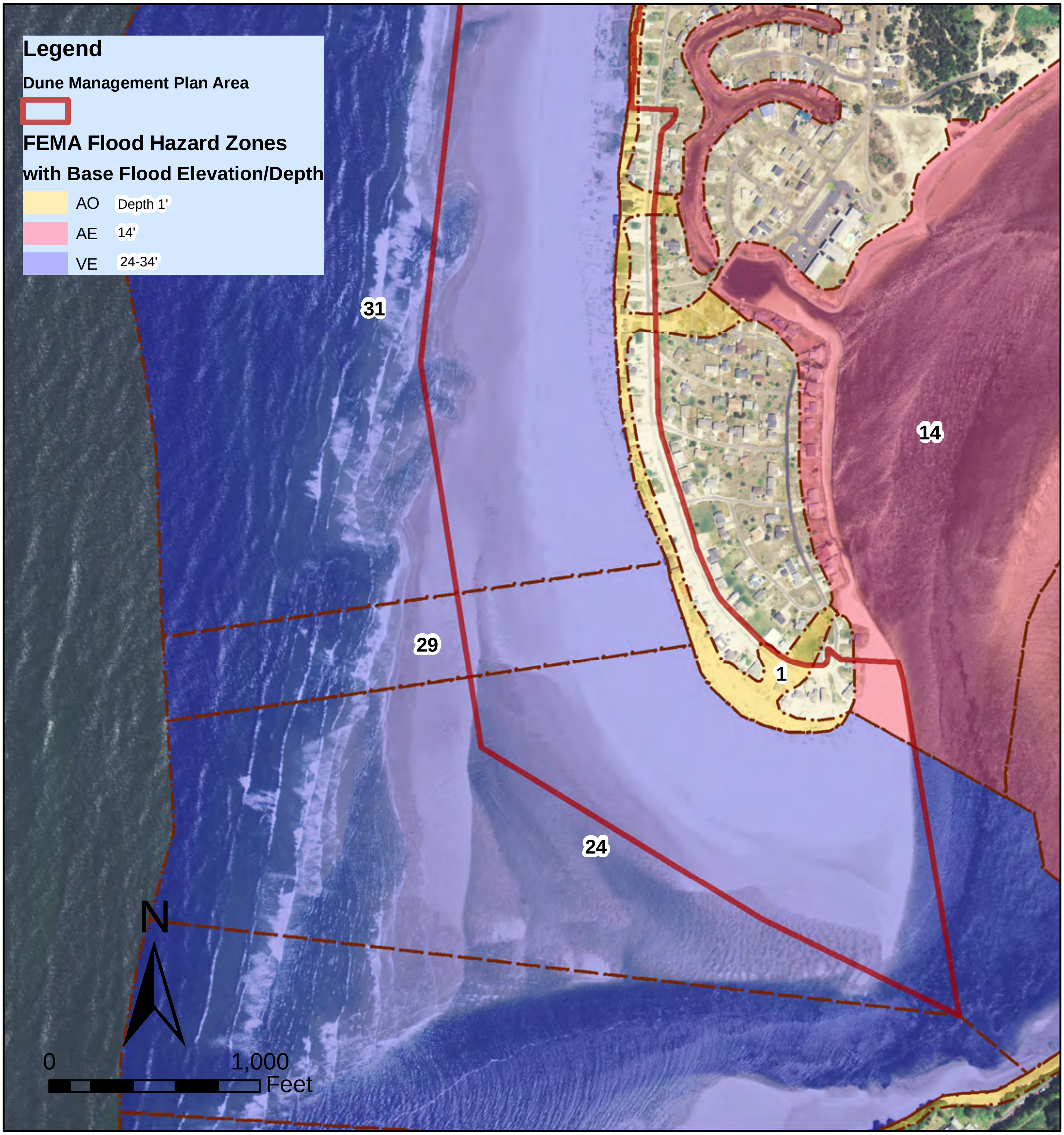

Figure 7B. FEMA Flood hazard zones for the northern half of the Bayshore Dune Management Plan Area overlaid on 2009 imagery. Source: FEMA, 2009 C.

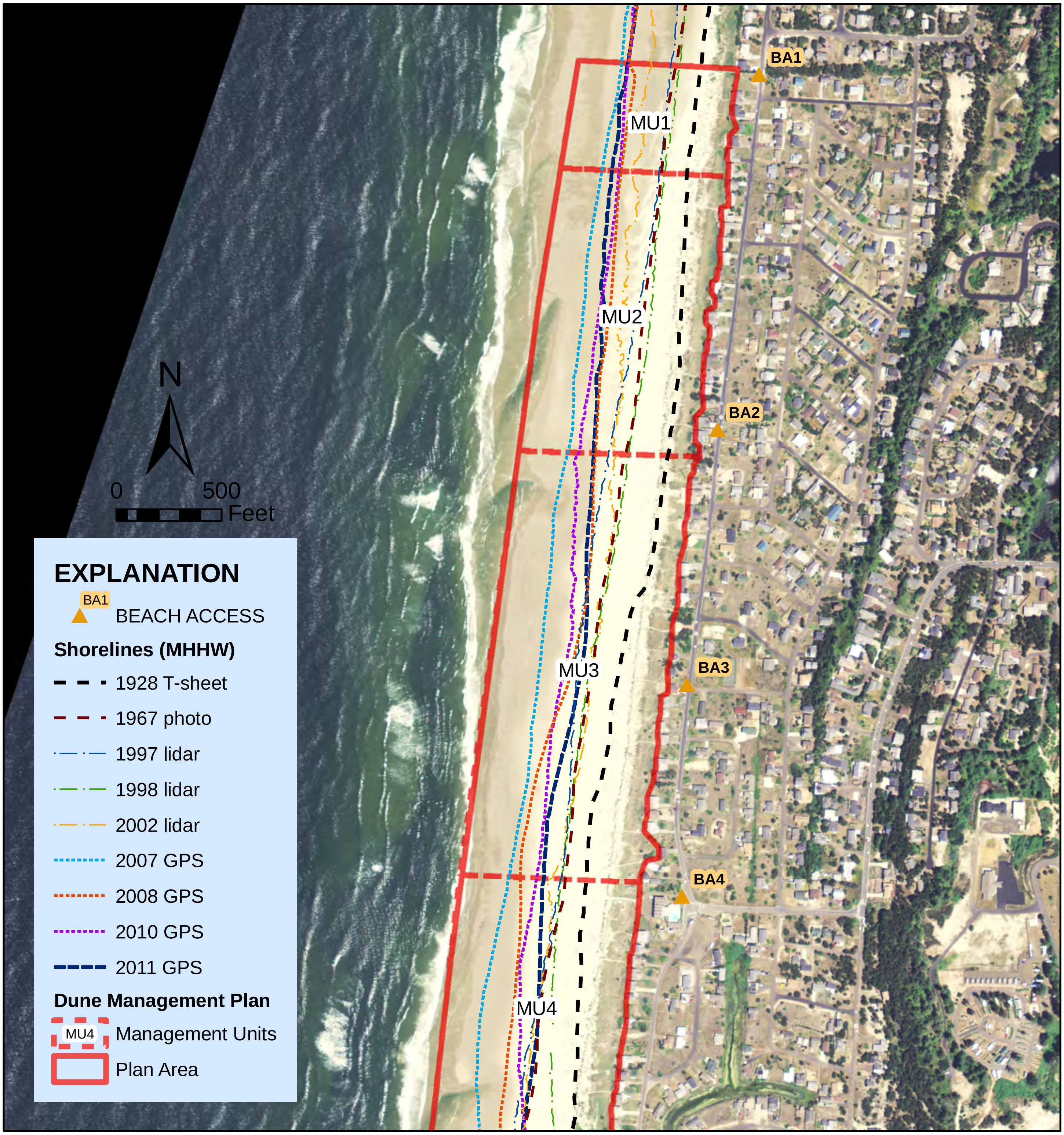

Figure 8A. Shoreline locations 1928-2011 in the northern half of the Bayshore Dune Management Plan Area overlaid on 2009 imagery. Sources of data: LeFever and Swainson (1928), Allan and Hart (2005), Allan (unpublished data 2011).

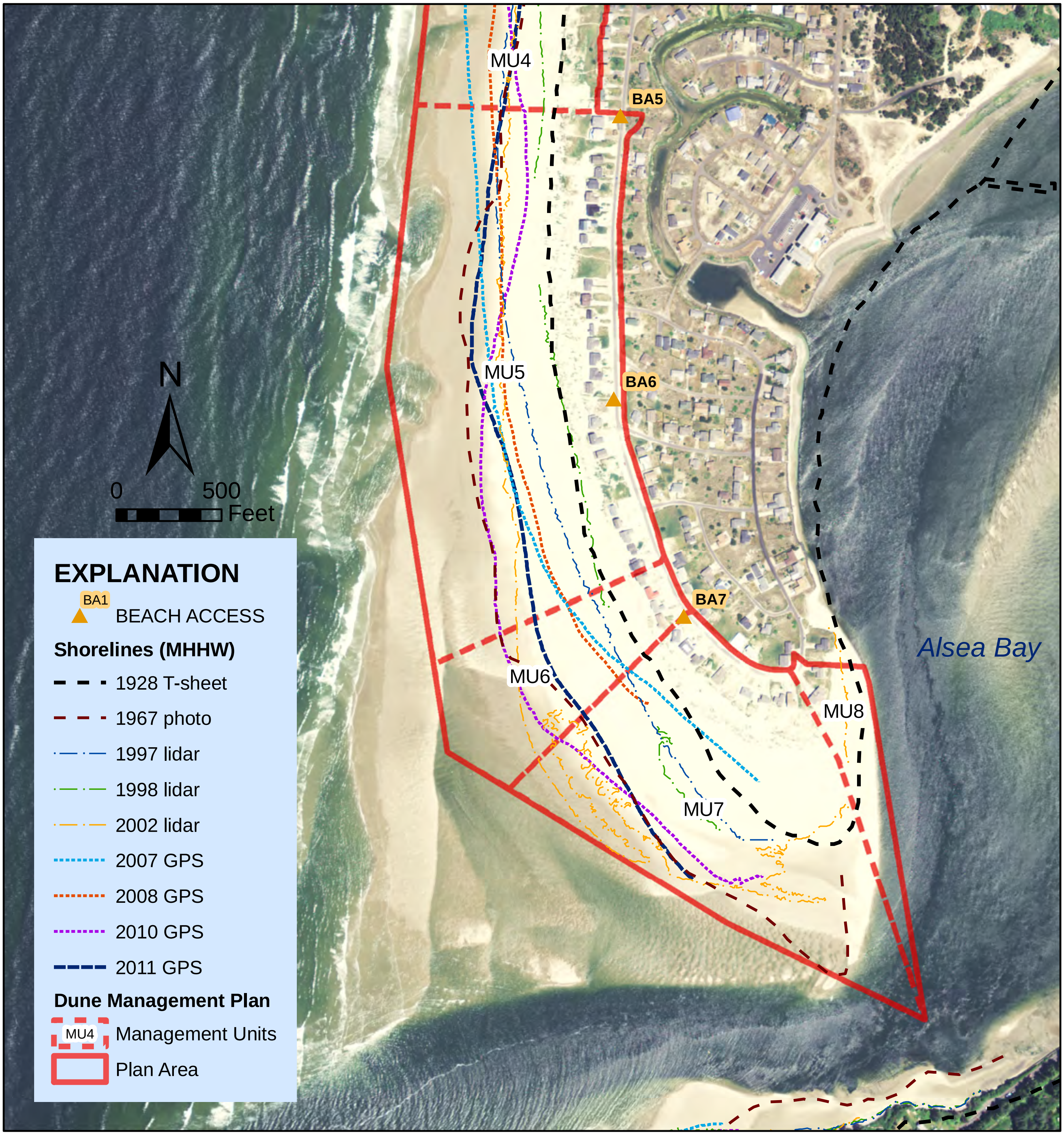

Figure 8B. Shoreline locations 1928-2011 in the southern half of the Bayshore Dune Management Plan Area overlaid on 2009 imagery. Sources of data: LeFever and Swainson (1928), Allan and Hart (2005), Allan (unpublished data 2011).

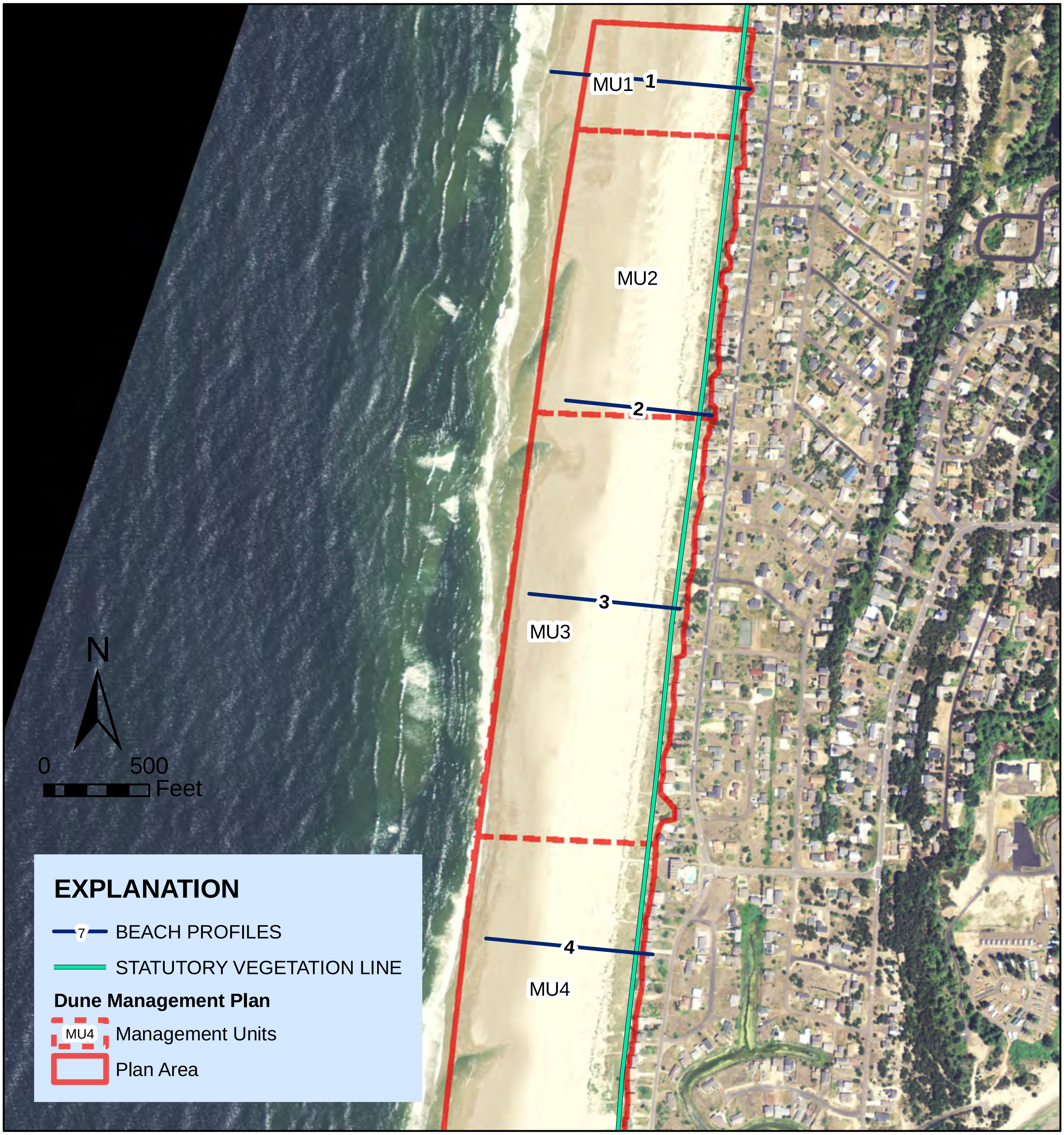

Figure 9A. Profile locations in the northern half of the Bayshore Dune Management Plan Area, 2009 imagery.

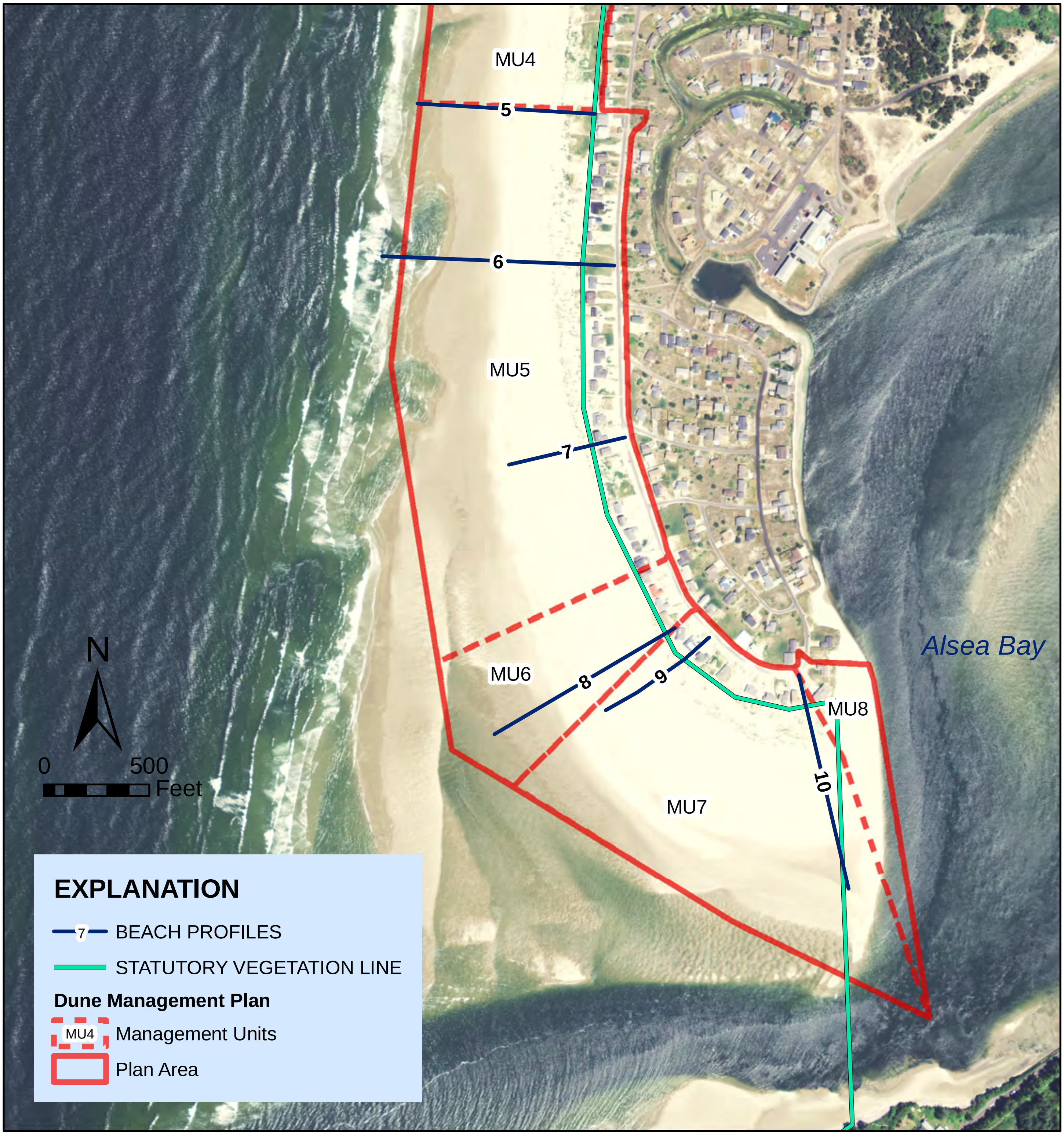

Figure 9B. Profile locations in the southern half of the Bayshore Dune Management Plan Area, 2009 imagery.

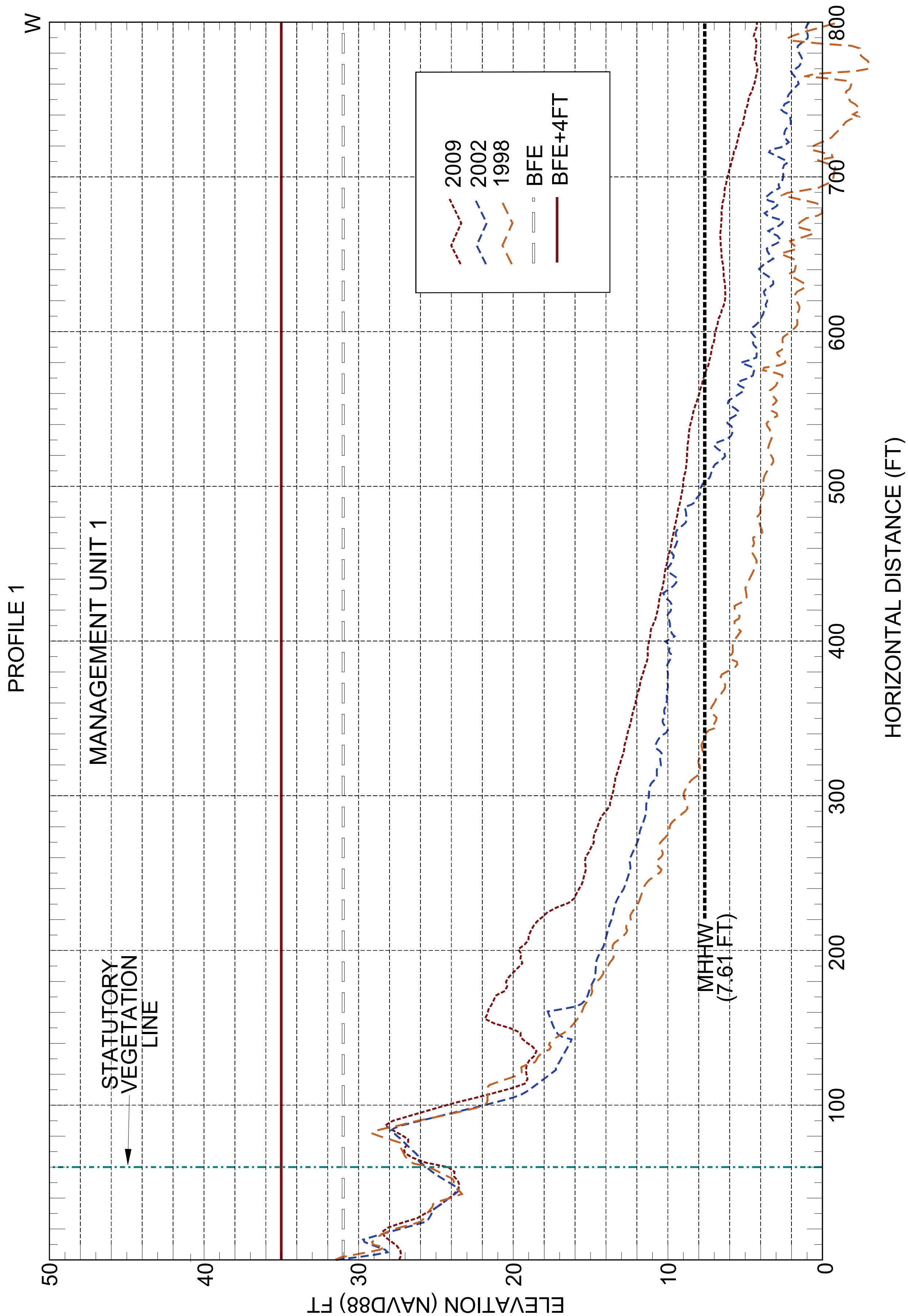

Figure 10A. Beach profile 1 showing changes from 1998-2009, also shown are 100-year BFE and BFE +4 feet. Statutory Vegetation Line shown for reference. 10X Vertical exaggeration.

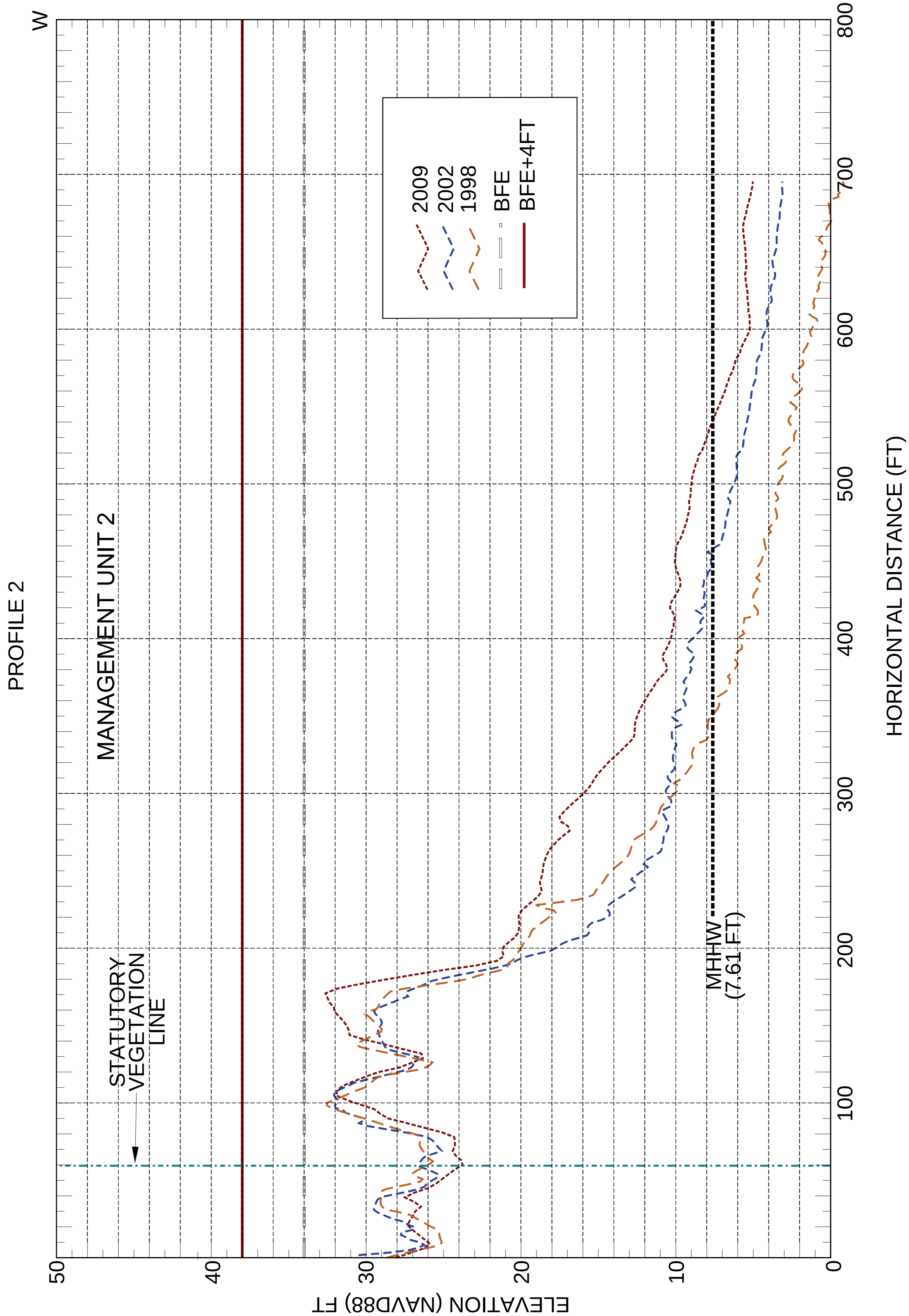

Figure 10B. Beach profile 2 showing changes from 1998-2009, also shown are 100-year BFE and BFE +4 feet. Statutory Vegetation Line shown for reference. 10X Vertical exaggeration.

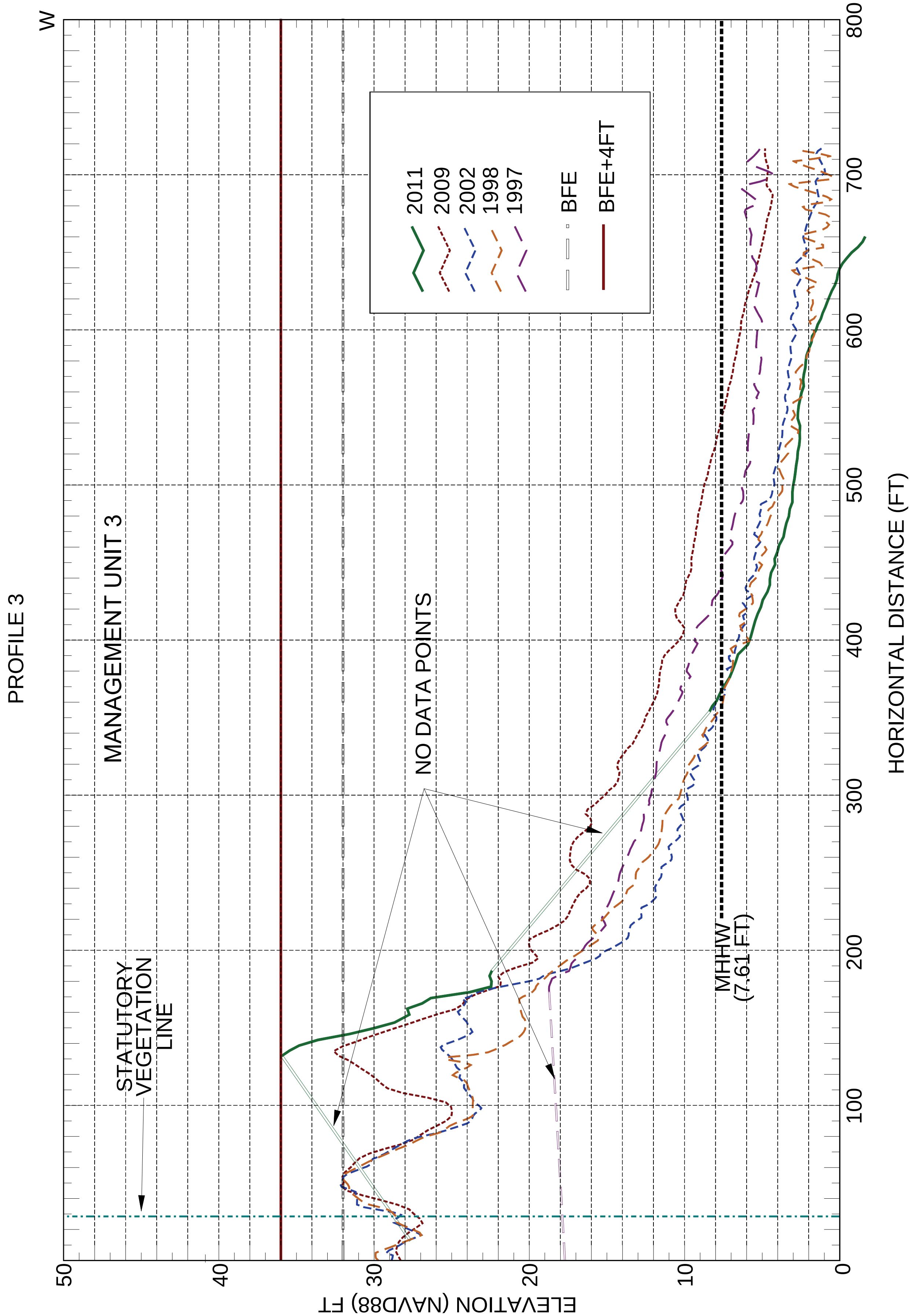

Figure 10C. Beach profile 3 showing changes from 1997-2011, also shown are100-year BFE and BFE +4 feet. Statutory Vegetation Line shown for reference. 10X Vertical exaggeration.

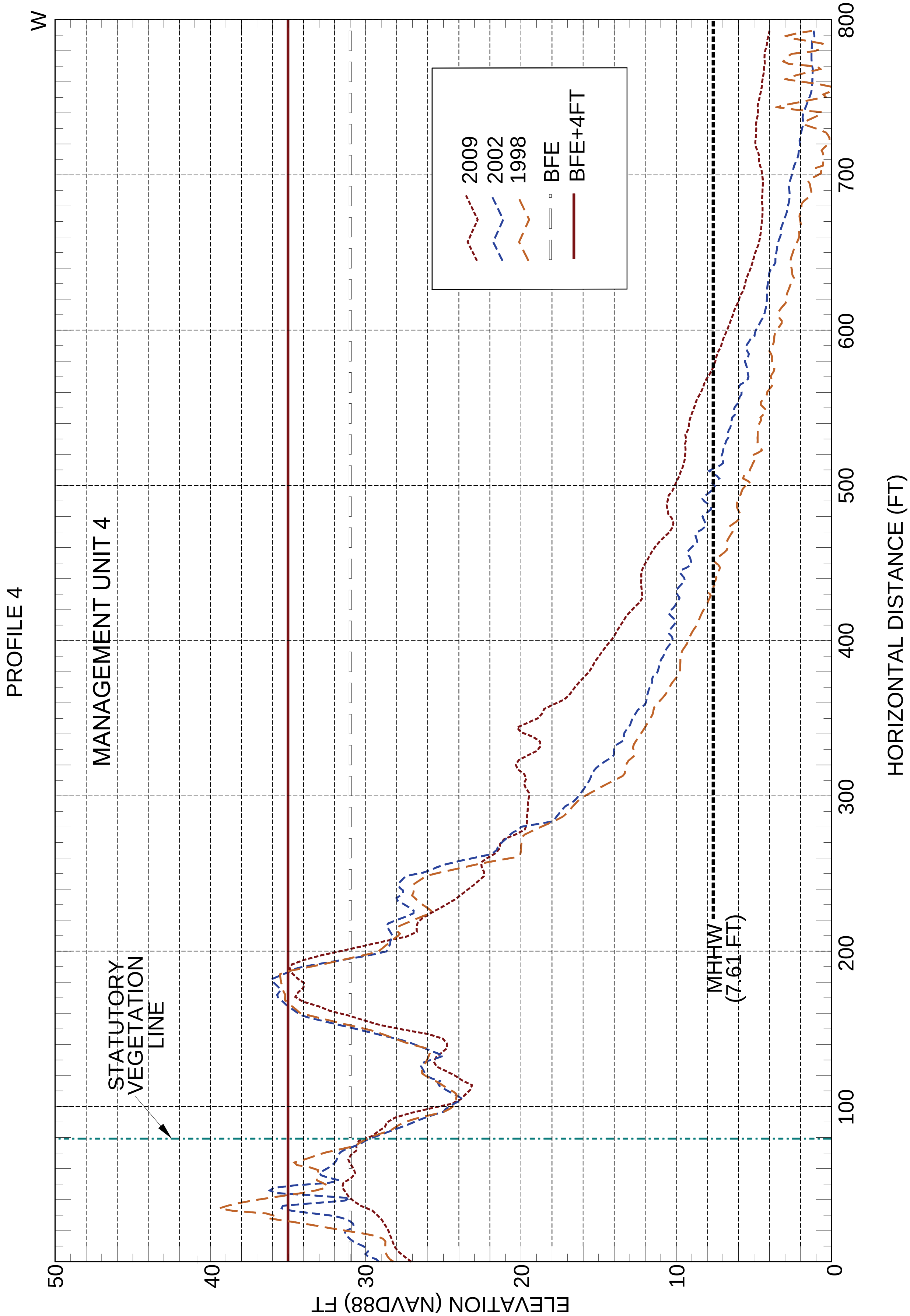

Figure 10D. Beach profile 4 showing changes from 1998-2009, also shown are 100-year BFE and BFE +4 feet. Statutory Vegetation Line shown for reference. 10X Vertical exaggeration.

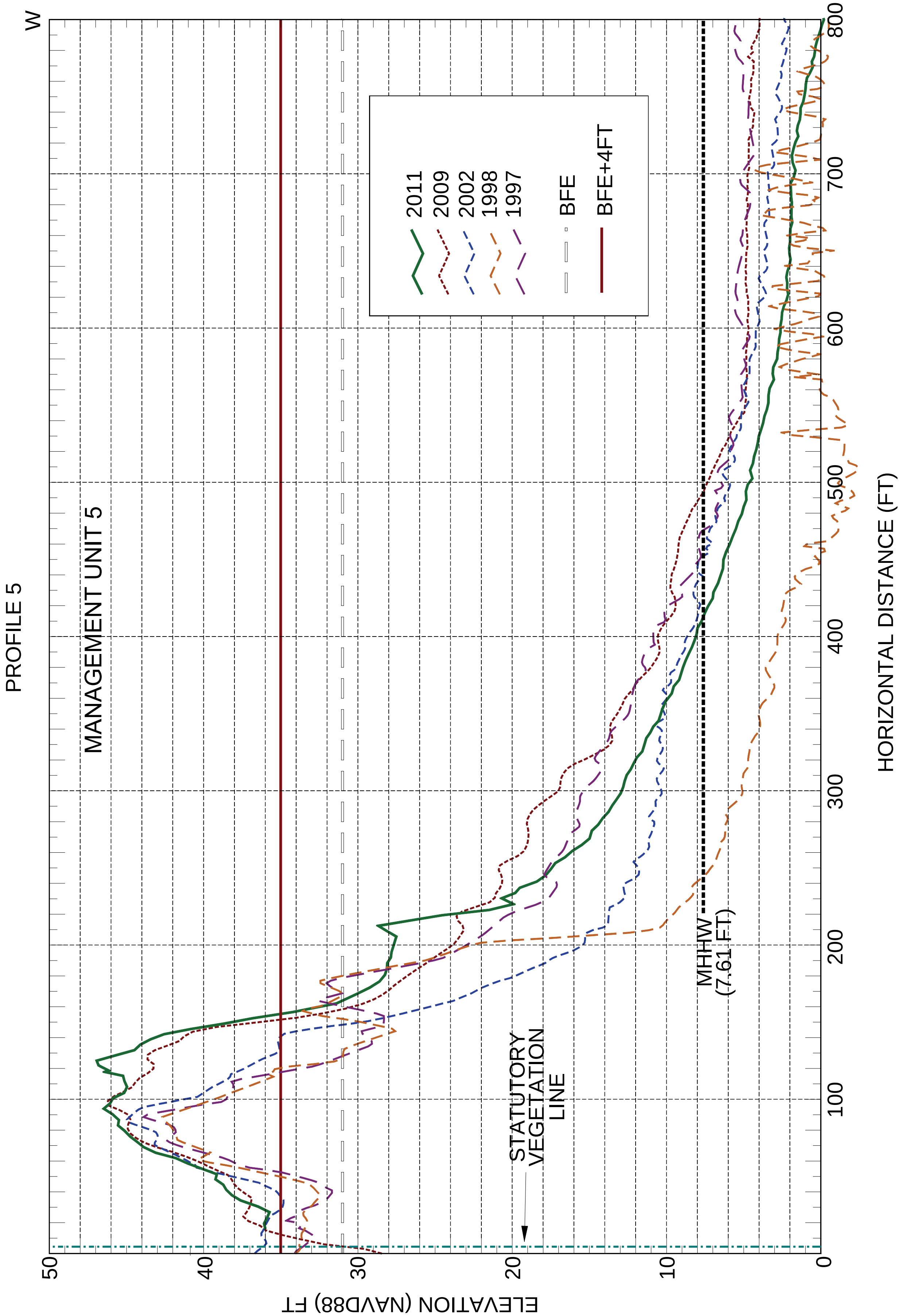

Figure 10E. Beach profile 5 showing changes from 1997-2011, also shown are 100-year BFE and BFE +4 feet. Statutory Vegetation Line shown for reference. 10X Vertical exaggeration.

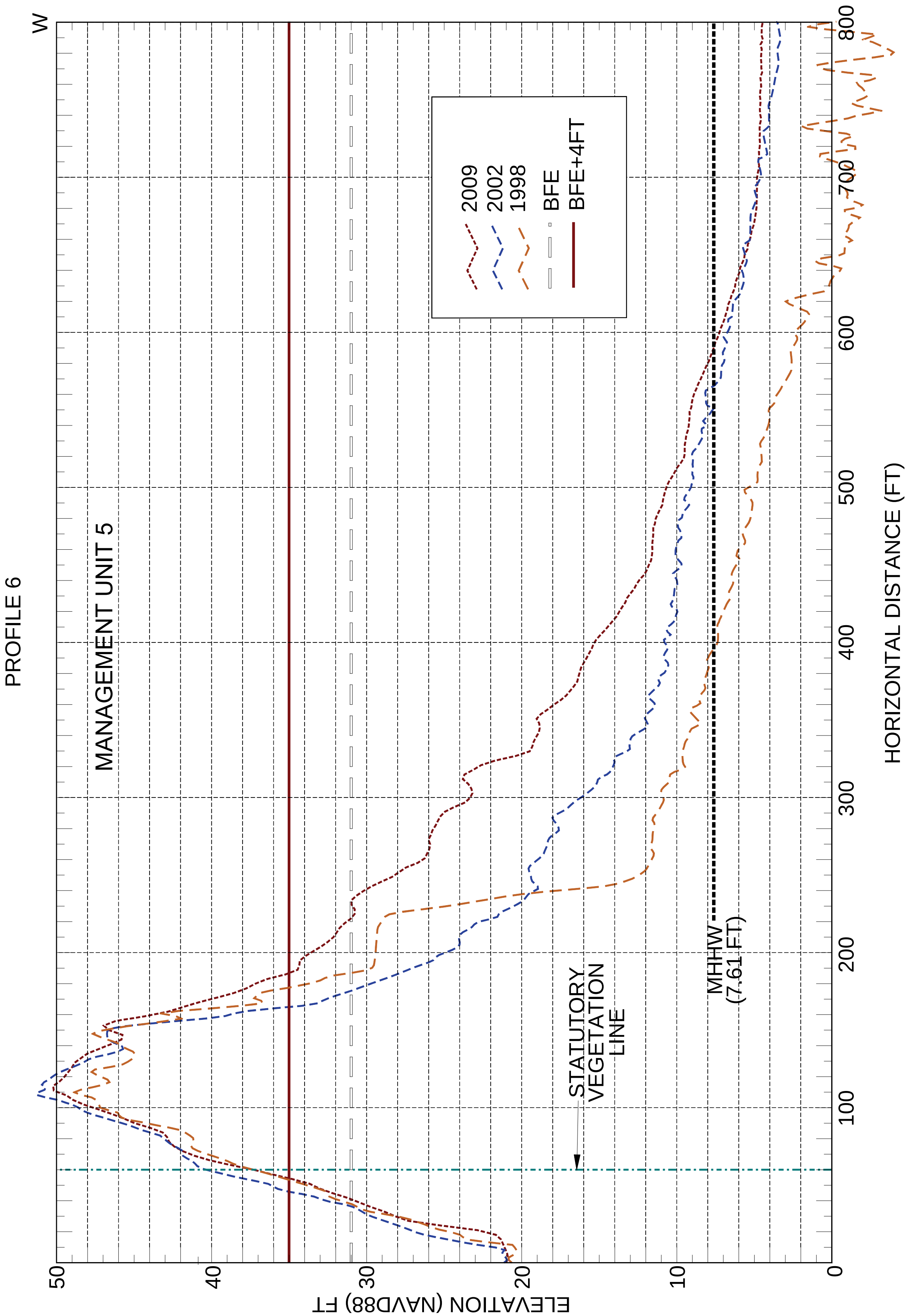

Figure 10F. Beach profile 6 showing changes from 1998-2009, also shown are 100-year BFE and BFE +4 feet. Statutory Vegetation Line shown for reference. 10X Vertical exaggeration.

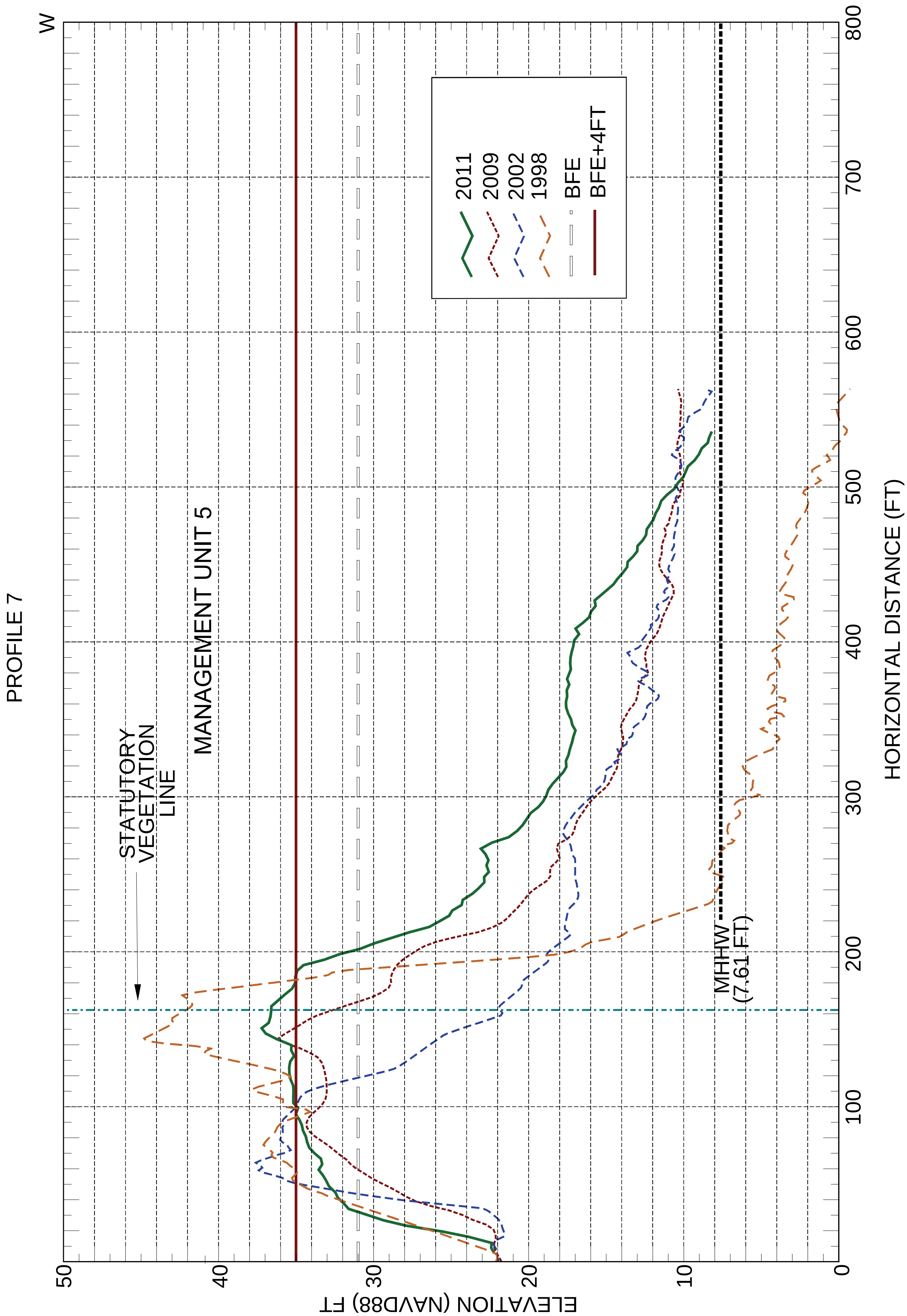

Figure 10G. Beach profile 7 showing changes from 1998-2011, also shown are 100-year BFE and BFE +4 feet. Statutory Vegetation Line shown for reference. 10X Vertical exaggeration.

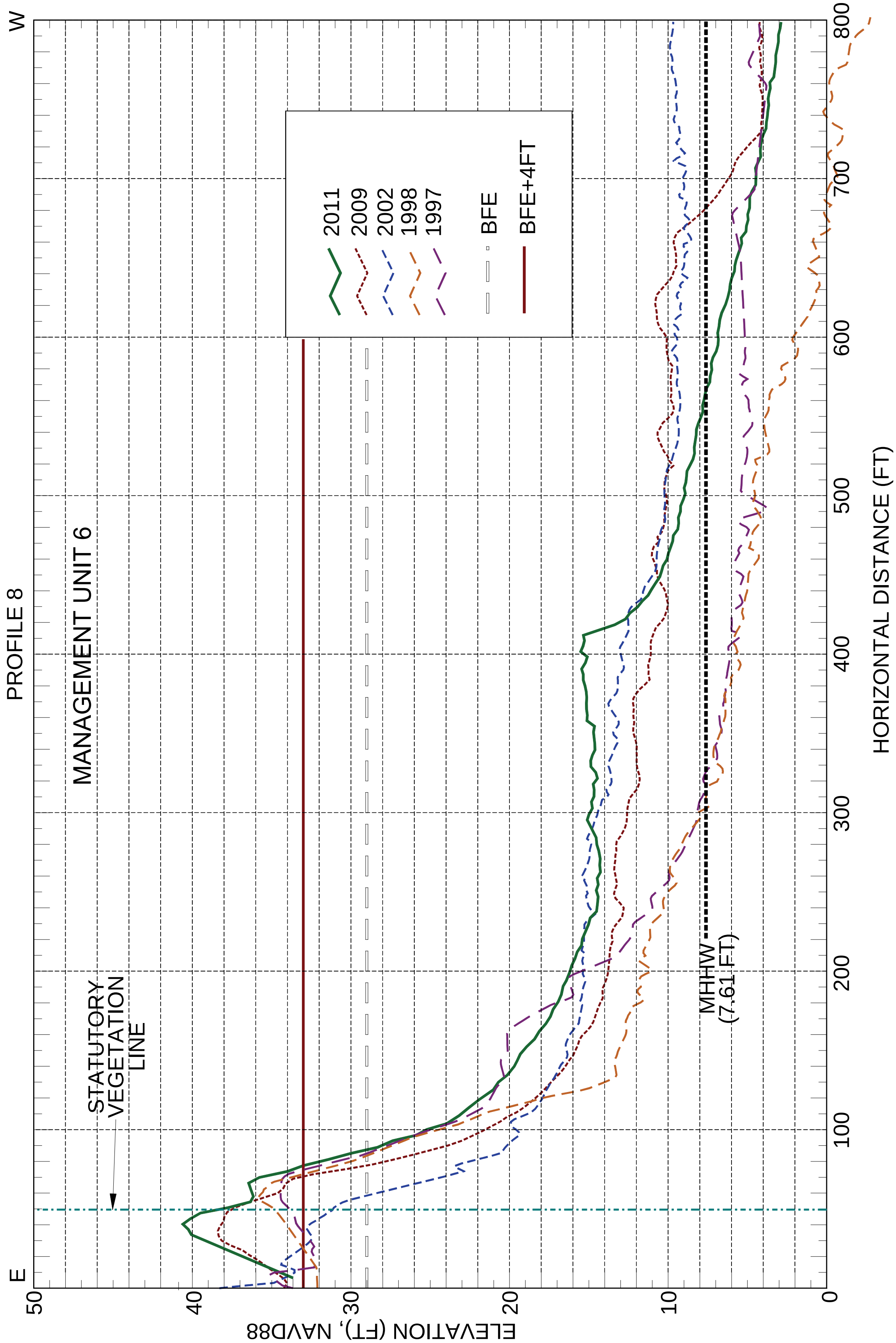

Figure 10H. Beach profile 8 showing changes from 1997-2011, also shown are 100-year BFE and BFE +4 feet. Statutory Vegetation Line shown for reference. 10X Vertical exaggeration.

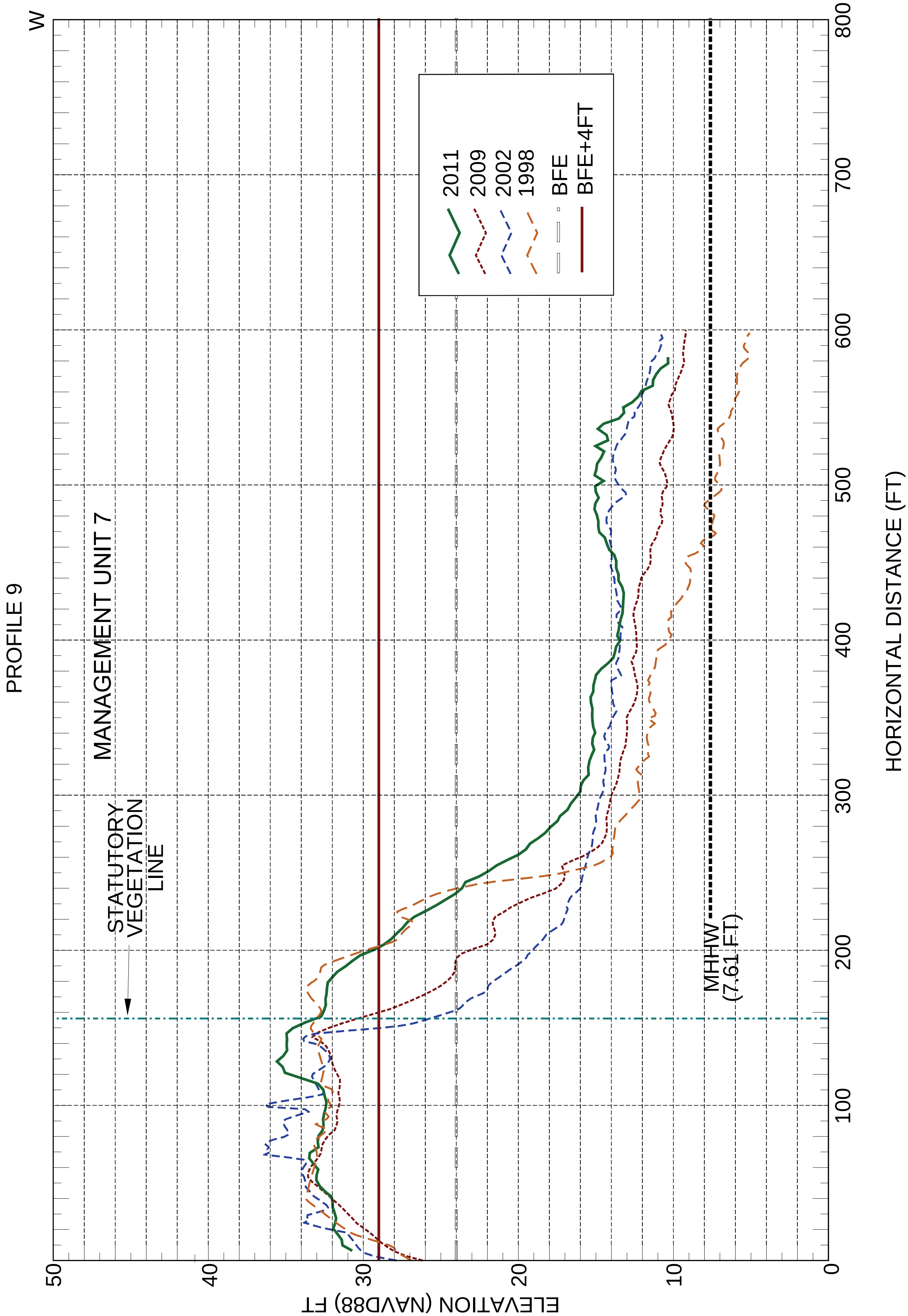

Figure 10I. Beach profile 9 showing changes from 1998-2011, also shown are 100-year BFE and BFE +4 feet. Statutory Vegetation Line shown for reference. 10X Vertical exaggeration.

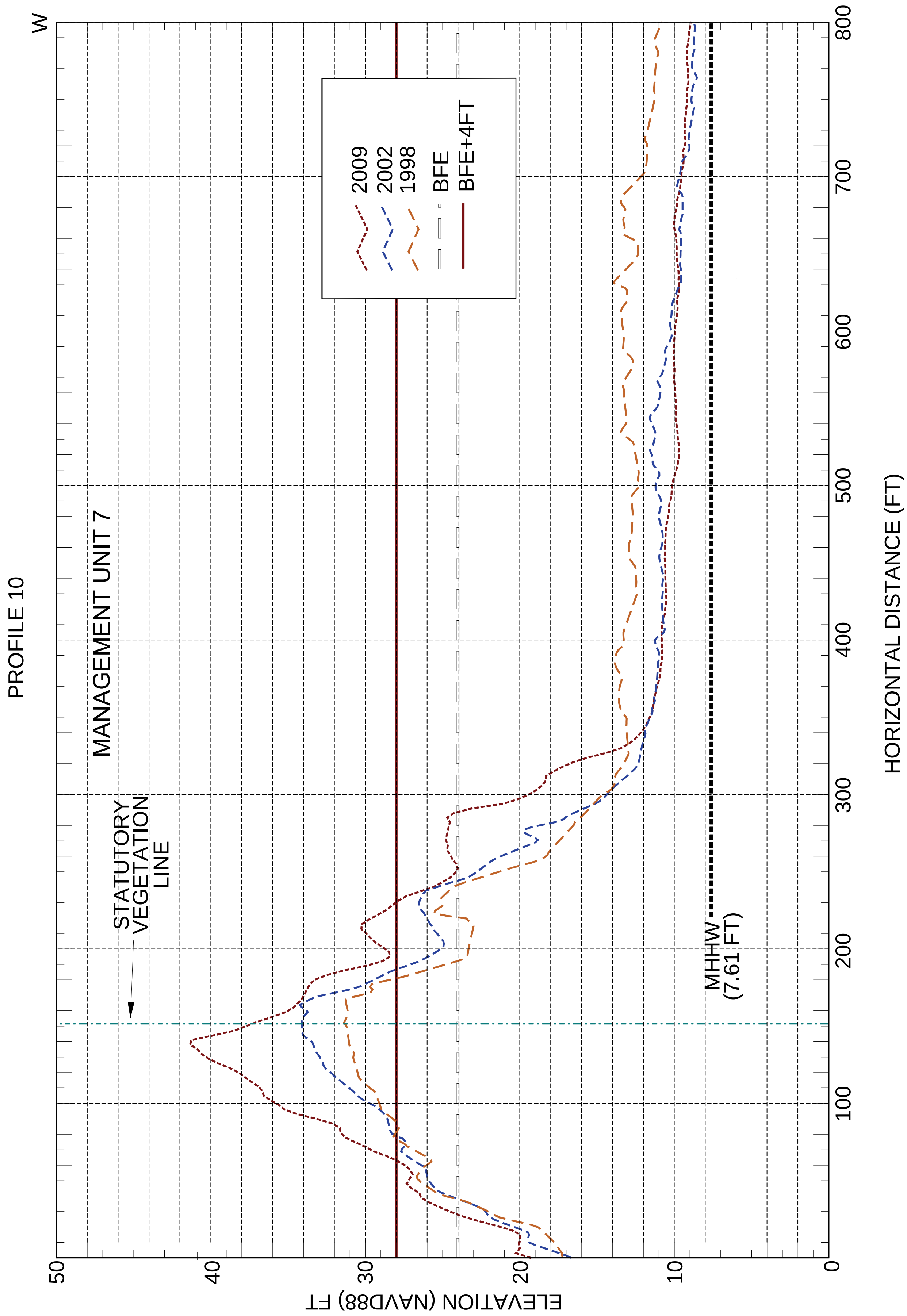

Figure 10J. Beach profile 10 showing changes from 1998-2009, also shown are 100-year BFE and BFE +4 feet. Statutory Vegetation Line shown for reference. 10X Vertical exaggeration.

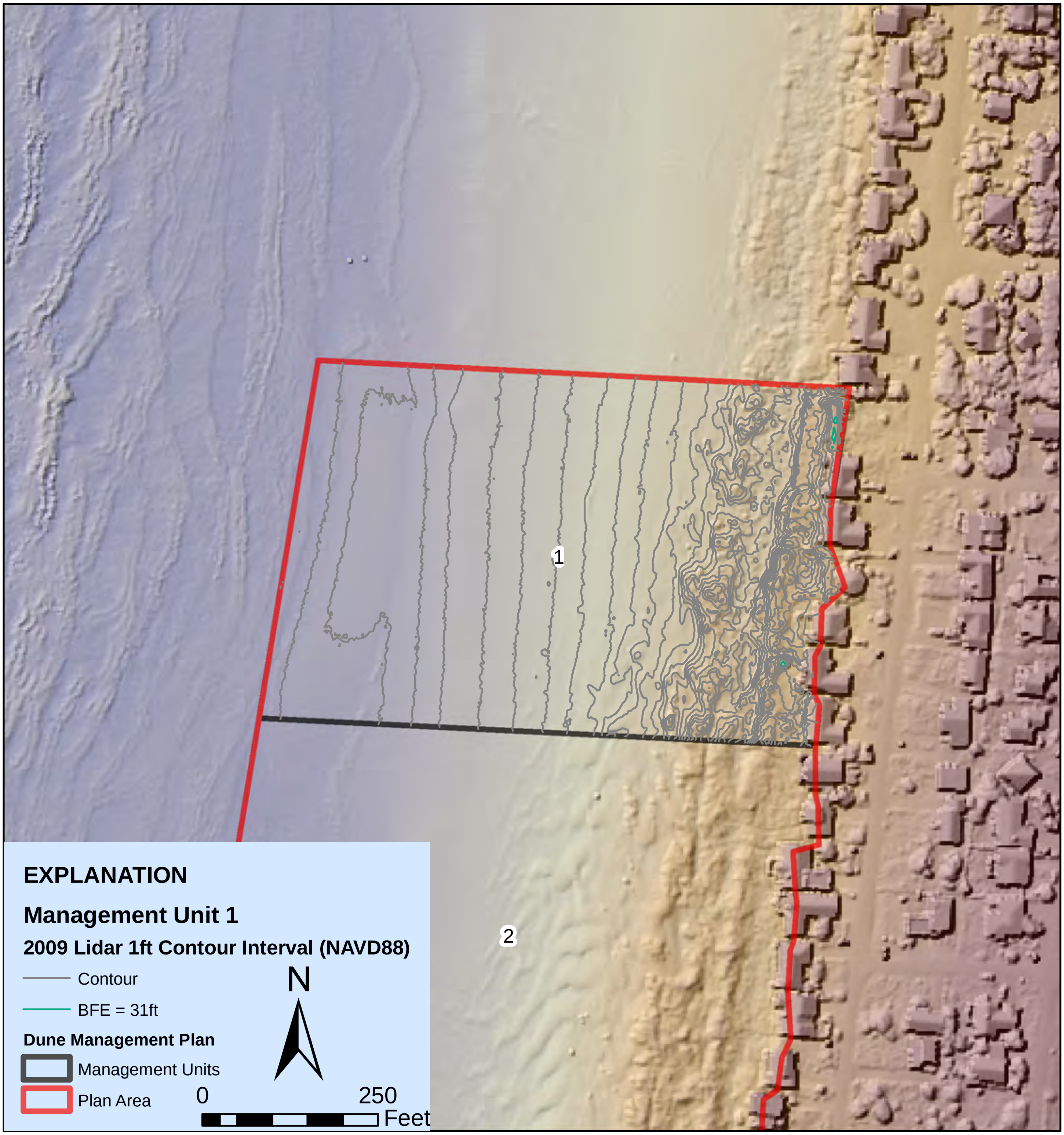

Figure 11A. Contours (1 foot interval) with hillshade view from 2009 LIDAR. Management unit 1 in Bayshore Dune Management Plan Area. FEMA 100 year BFE shown as green contour.

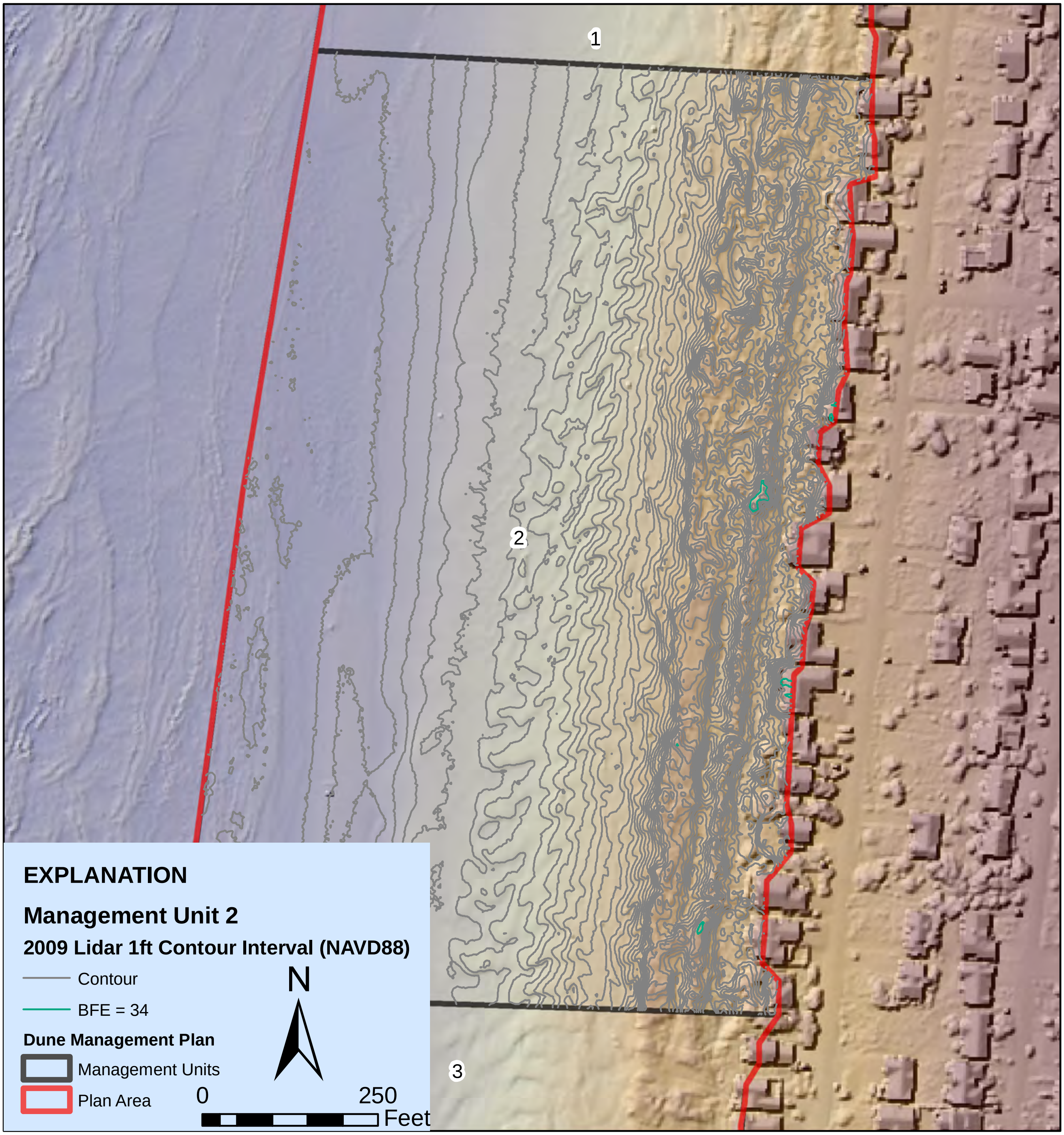

Figure 11B. Contours (1 foot interval) with hillshade view from 2009 LIDAR. Management unit 2 in Bayshore Dune Management Plan Area. FEMA 100 year BFE shown as green contour.

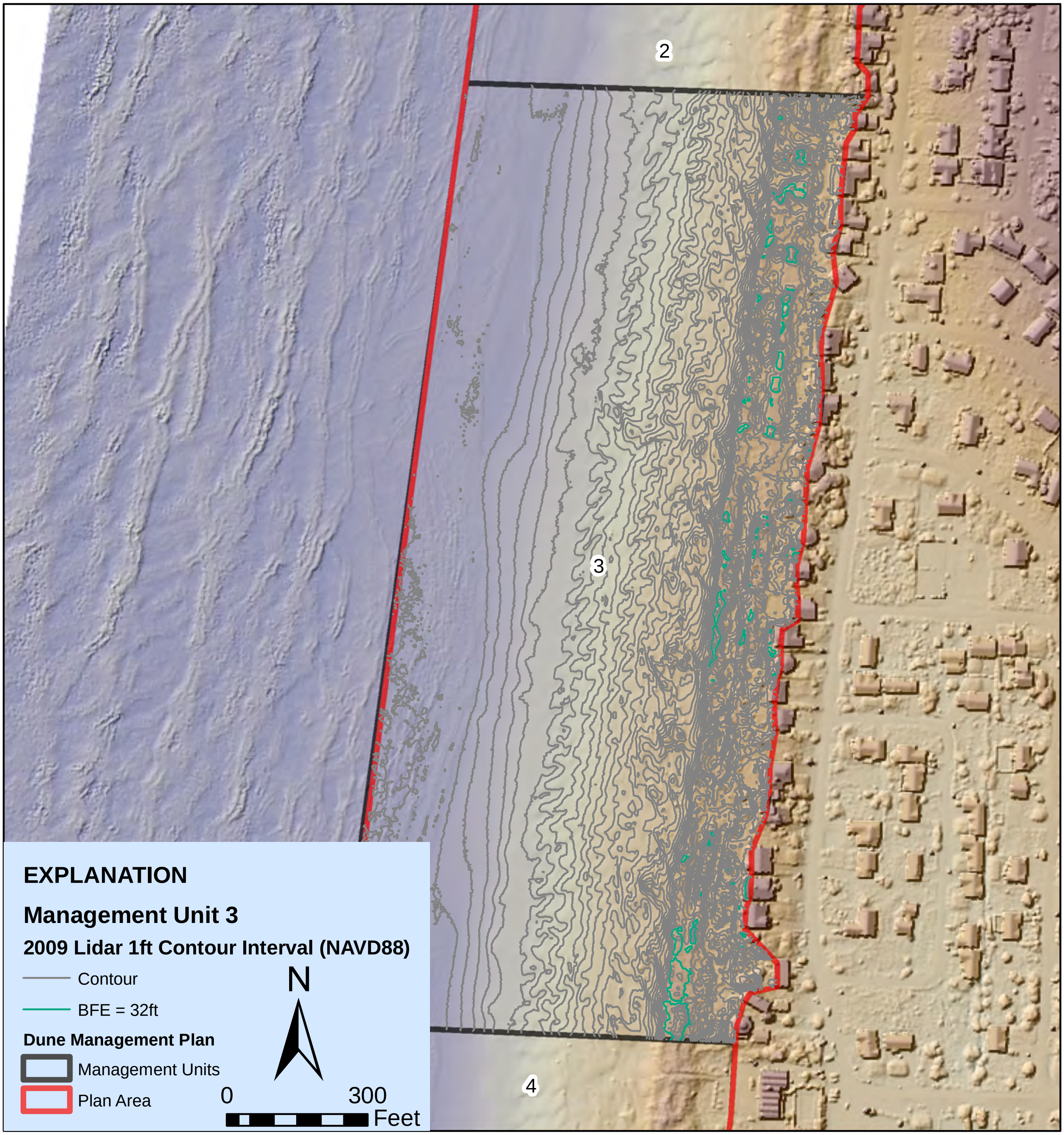

Figure 11C. Contours (1 foot interval) with hillshade view from 2009 LIDAR. Management unit 3 in Bayshore Dune Management Plan Area. FEMA 100 year BFE shown as green contour.

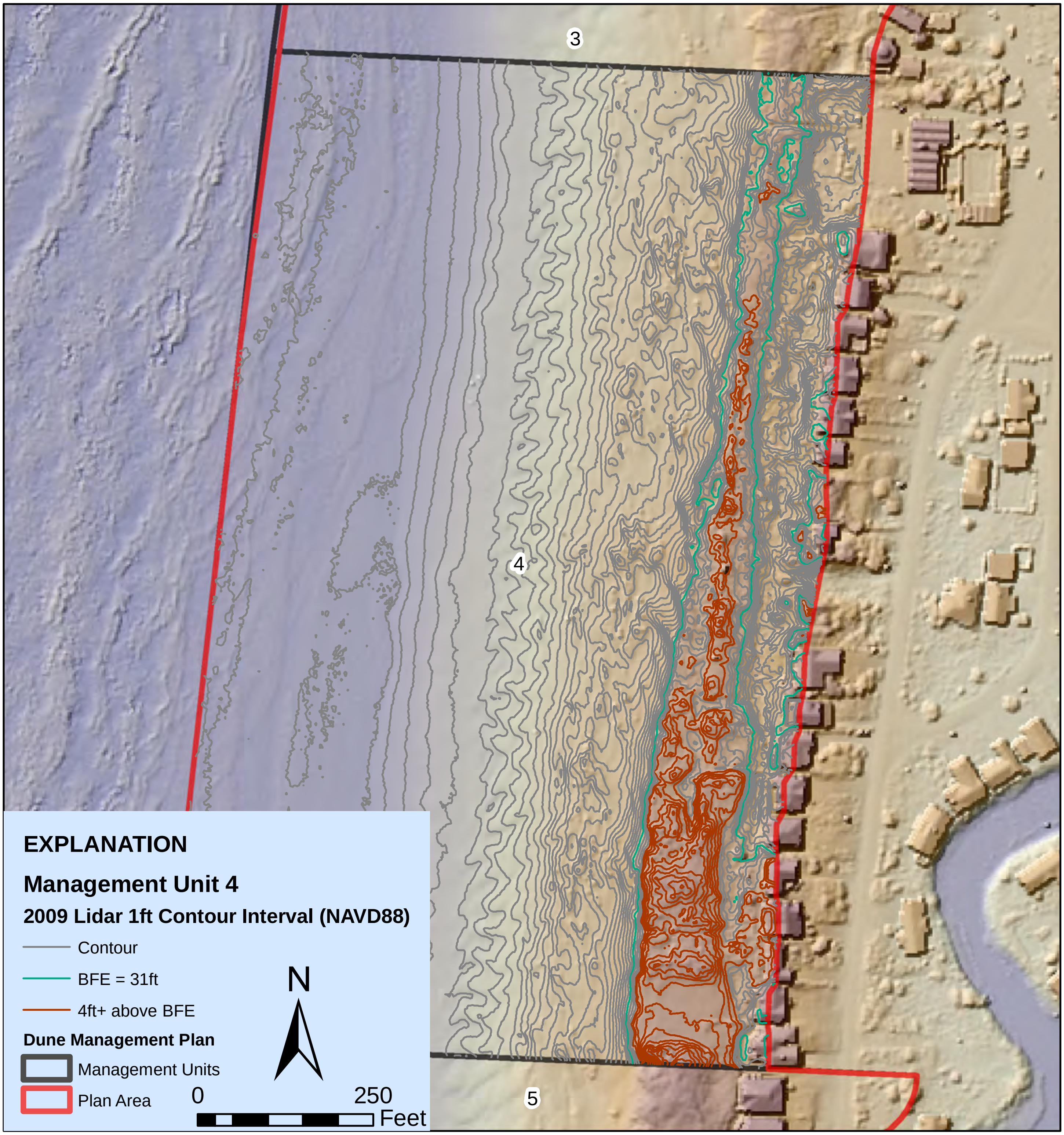

Figure 11D. Contours (1 foot interval) with hillshade view from 2009 LIDAR. Management unit 4 in Bayshore Dune Management Plan Area. FEMA 100 year BFE shown as green contour, red contours are 4 feet above BFE.

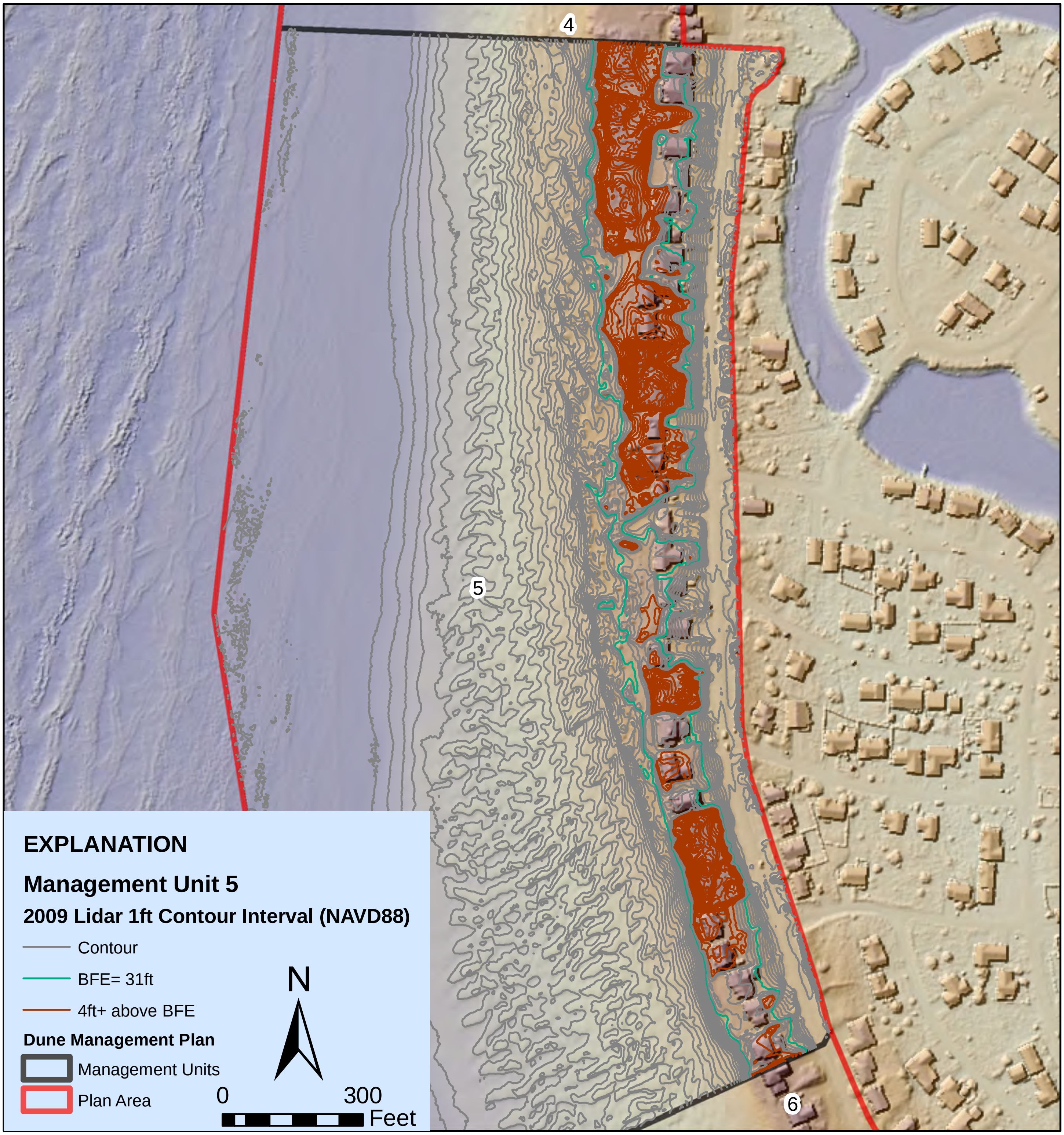

Figure 11E. Contours (1 foot interval) with hillshade view from 2009 LIDAR. Management unit 5 in Bayshore Dune Management Plan Area. FEMA 100 year BFE shown as green contour, red contours are 4 feet above BFE.

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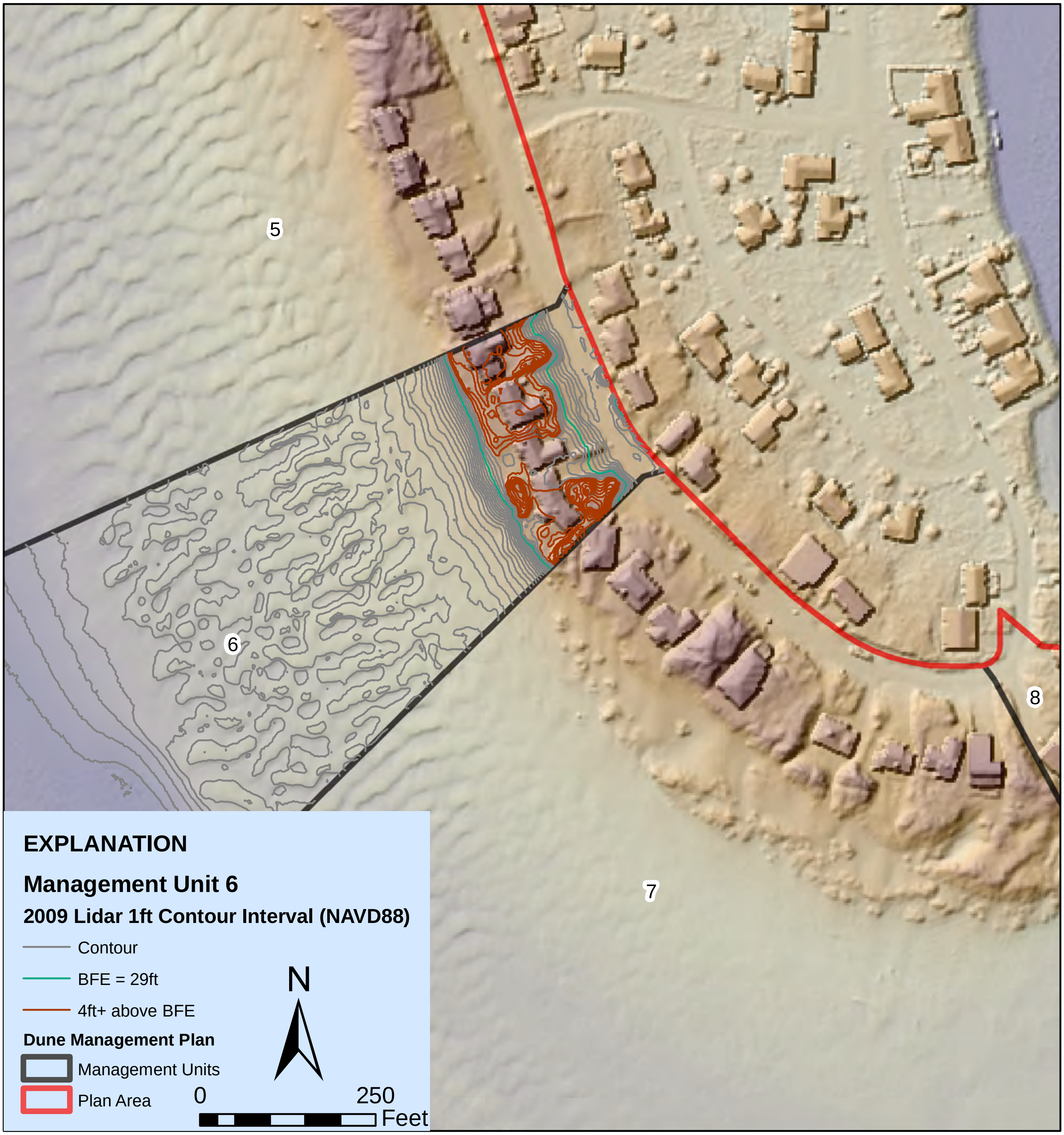

Figure 11F. Contours (1 foot interval) with hillshade view from 2009 LIDAR. Management unit 6 in Bayshore Dune Management Plan Area. FEMA 100 year BFE shown as green contour, red contours are 4 feet above BFE.

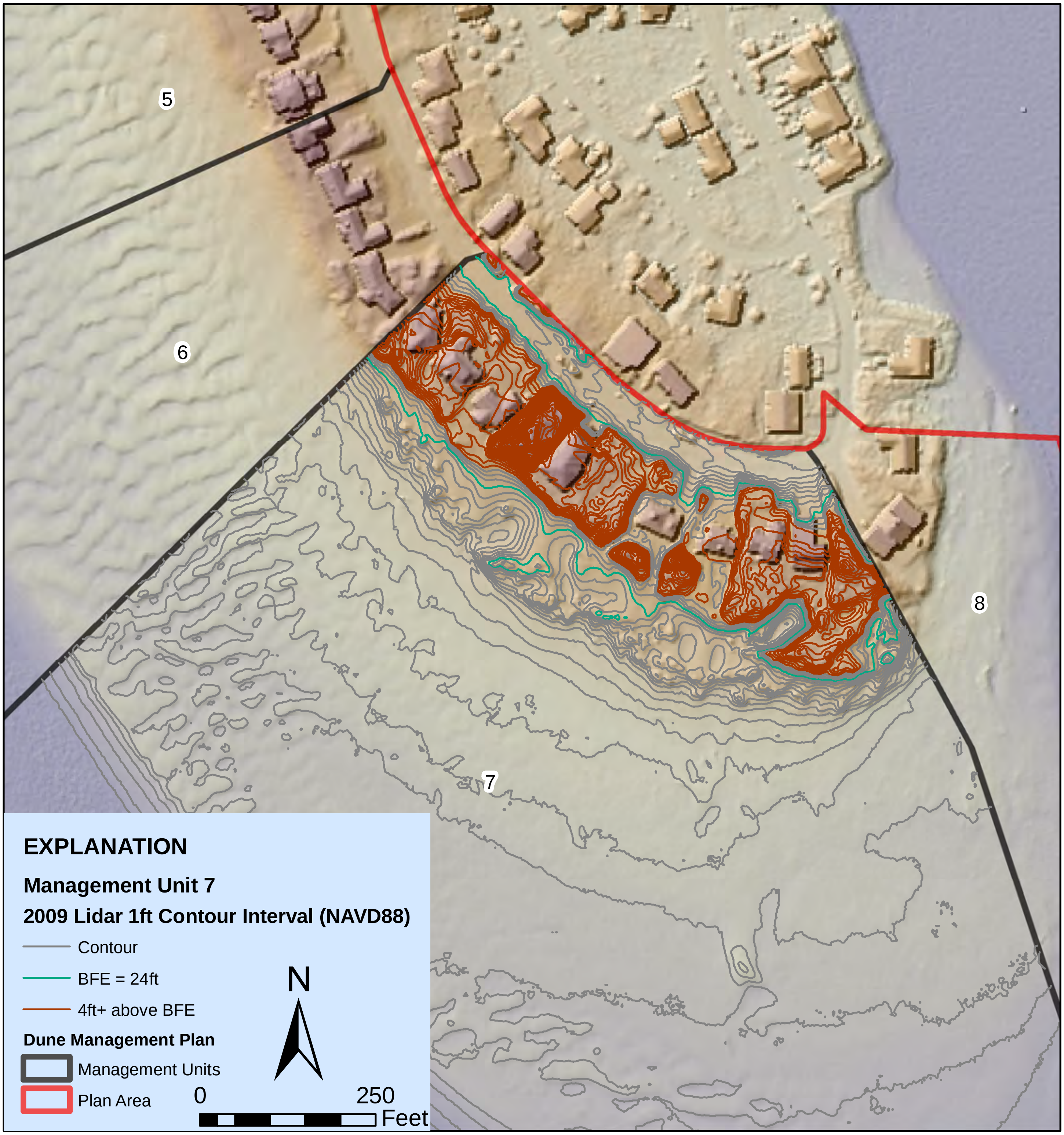

Figure 11G. Contours (1 foot interval) with hillshade view from 2009 LIDAR. Management unit 7 in Bayshore Dune Management Plan Area. FEMA 100 year BFE shown as green contour, red contours are 4 feet above BFE.

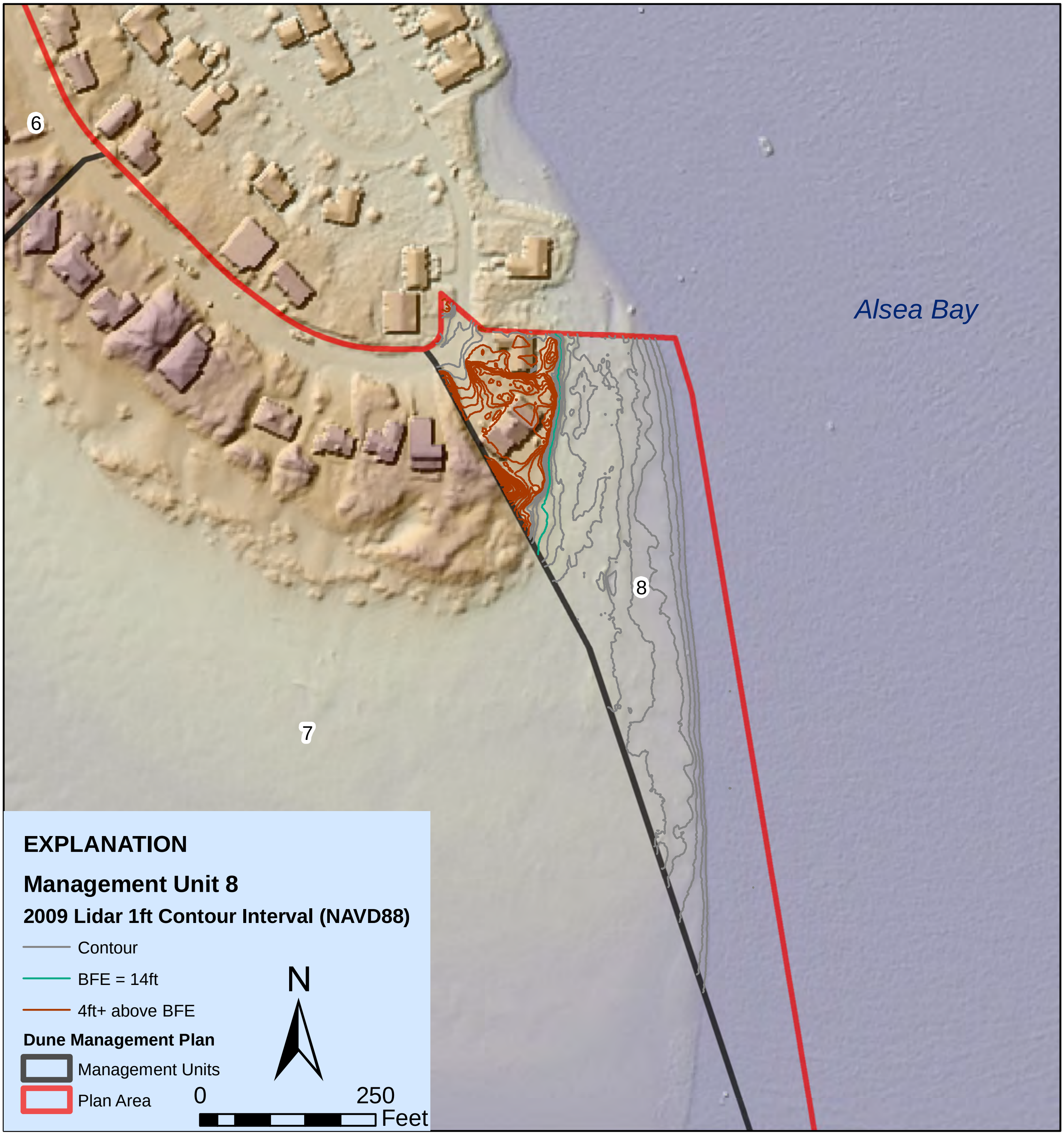

Figure 11H. Contours (1 foot interval) with hillshade view from 2009 LIDAR. Management unit 8 in Bayshore Dune Management Plan Area. FEMA 100 year BFE shown as green contour, red contours are 4 feet above BFE.

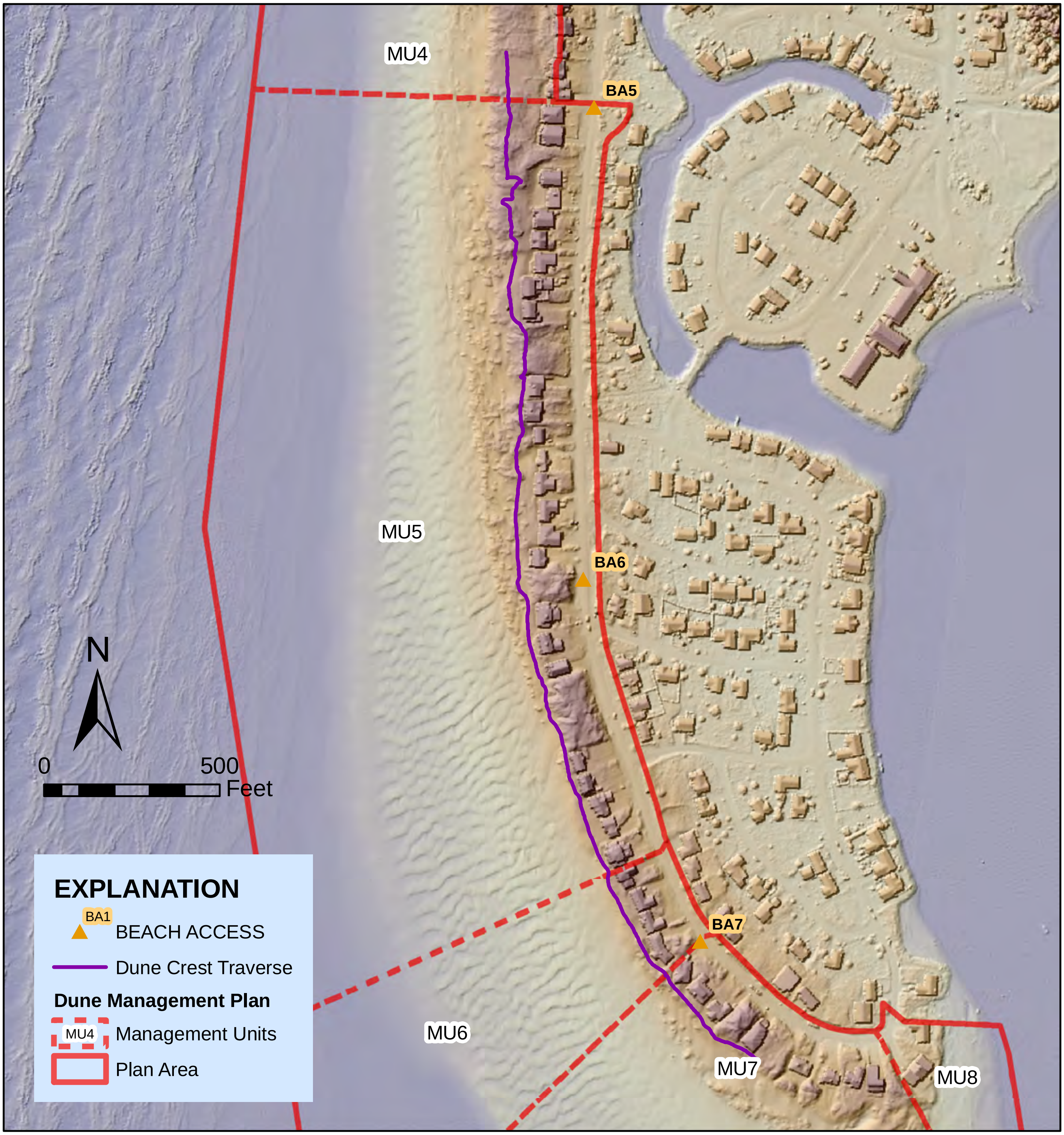

Figure 12. Location of traverse with RTK-DGPS in May, 2011 in management units 4-7 of Bayshore Dune Management Plan Area. Shown on hillshade view derived from 2009 LIDAR.

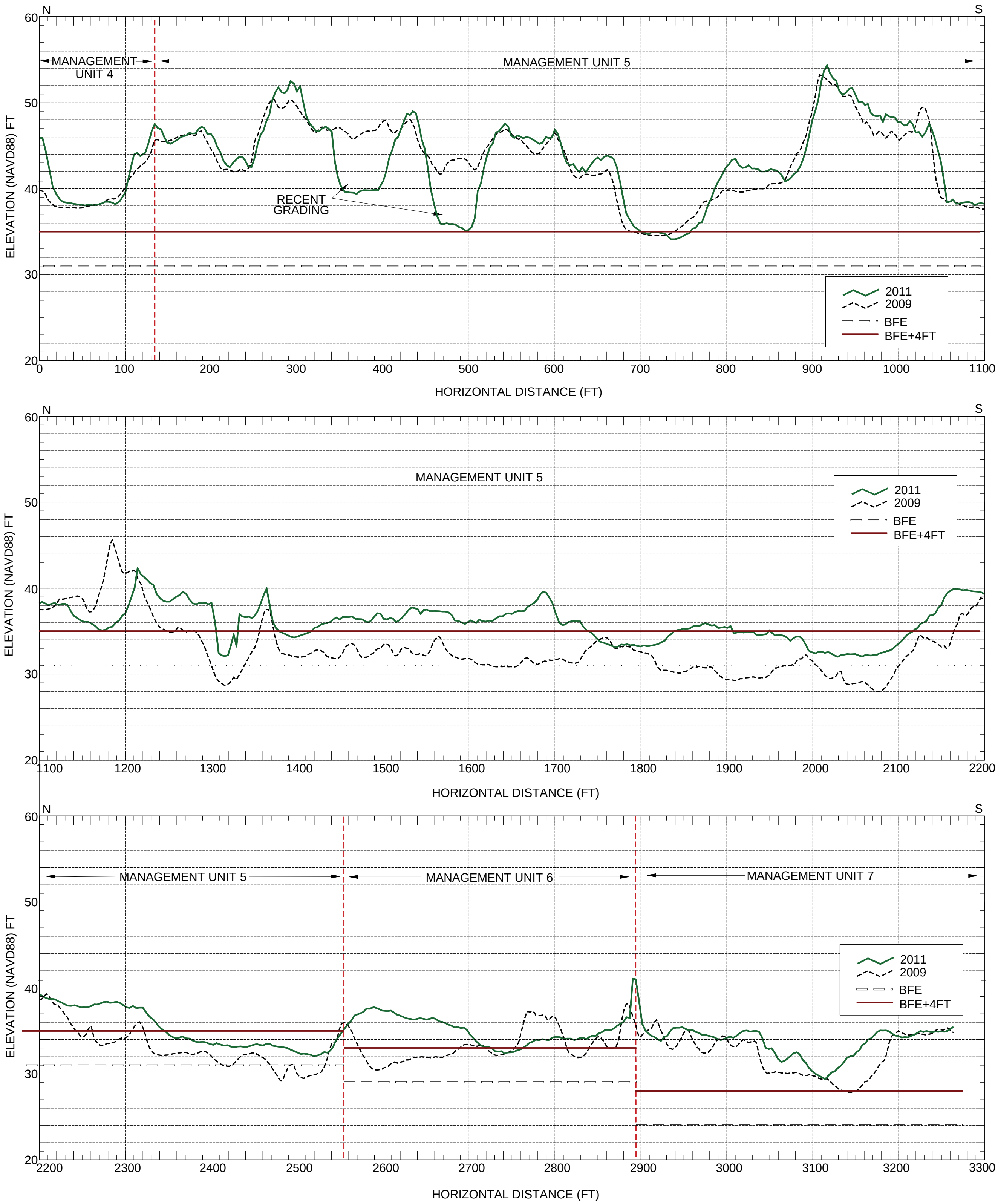

Figure 13. Elevation differences between 2009 and 2011 along traverse within management units 4-7 of Bayshore Dune Management Plan Area.

APPENDIX 1A

Appendix 1A. Oblique aerial photographs taken 5/10/11 of management units 1 & 2 Bayshore Management Plan. Photography by Don Best.

APPENDIX 1B

Appendix 1B. Oblique aerial photographs taken 5/10/11 of management unit 3 Bayshore Management Plan. Photography by Don Best.

APPENDIX 1C

Appendix 1C. Oblique aerial photographs taken 5/10/11 of management units 3 &4 Bayshore Management Plan. Photography by Don Best.

APPENDIX 1D

Appendix 1D. Oblique aerial photographs taken 5/10/11 of northern half of management unit 5 Bayshore Management Plan. Photography by Don Best.

APPENDIX 1E

Appendix 1E. Oblique aerial photographs taken 5/10/11 of southern half of management unit 5 and all of management unit 6 in Bayshore Management Plan. Photography by Don Best.

APPENDIX 1F

Appendix 1F. Oblique aerial photographs taken 5/10/11 of management units 6, 7 & 8, Bayshore Management Plan. Photography by Don Best.

APPENDIX 2

Lidar Description

LIDAR (Light Detection and Ranging) data consists of x, y, and z values of land topography that are derived using an airborne laser surveying system mounted on an aircraft at sufficient elevation and velocity to acquire a value of the surface elevation at spatial densities greater than one elevation measurement per square meter. The position of the aircraft is recorded by an onboard geodetic grade Global Positioning System (GPS) receiver, while an onboard inertial measuring unit provides three-dimensional aircraft orientation. The GPS data are then combined with signals collected concurrently by a nearby GPS base station, which allows for differential kinematic GPS post-processing to determine the aircraft's flight trajectory to within 5 cm. The collected data consists of a huge data set that is post-processed and reduced into a digital elevation model (DEM) that provides an elevation value for each m2 of area surveyed. This data can then be used by Geographic Information Systems (GIS) software to generate representations of the DEM including, but not limited to, hillshade views, contour maps and slope profiles. In some instances the LIDAR data is not processed to differentiate between the ground surface and the vegetation and in other cases it is.

LIDAR data from two different sources were used in this project. LIDAR data collected in 1997, 1998 and 2002 was collected jointly by NASA/USGS/NOAA as part of two separate Airborne LiDAR Assessment of Coastal Erosion (ALACE) Projects to monitor portions of the US coastline. The data is available from the NOAA Coastal Service Center. We were provided DEMs generated by Dr. Allan who had downloaded the data and processed it. The ALACE project data set does not differentiate between the ground surface and vegetation but because it is of the beach it essentially measures the ground surface. The 1997 and 1998 LIDAR elevation points are known to be horizontally accurate to +/- 0.8 meters at an aircraft altitude of 700 meters and raw elevation measurements have been determined to be vertically accurate to within 15 cm. Processing steps (datum conversion, projection, grid interpolation, etc.) can introduce additional error factors that are discussed by Allen and Hart (2005). The 2002 LIDAR elevation points are estimated to be horizontally accurate to +/- 0.8 meters at an aircraft altitude of 700 meters. Raw elevation measurements are estimated to be vertically accurate to within 15-20 cm.

The 2009 LIDAR data is from projects managed by the Oregon Department of Geology & Mineral Industries (DOGAMI), who contracted with Watershed Sciences, Inc. to collect high resolution topographic LiDAR data for multiple areas within the state of Oregon. The areas for LiDAR collection have been designed as part of a collaborative effort of state, federal, and local agencies in order to meet a wide range of project goals. The 2009 data set consists of bare earth and unclassified points. The average pulse density is 8.61 points per square meter over terrestrial surfaces. Project specifications required the LiDAR foot print to fall within 0.15 and 0.40 meters. The final vertical accuracy value for the entire project is 0.11 ft (0.03 m) RMSE. Additional information regarding this data can be obtained from the following report: ftp://ftp.csc.noaa.gov/pub/crs/beachmap/qa_docs/or/north_coast/NC_Data_Report_Delivery_Area_FINAL_compressed.pdf

APPENDIX 3

Profile Methods

On May 10, 2011 numerous field data were collected with technical assistance provided by DOGAMI. A backpack mounted Real Time Kinematic Differential Global Positioning System (RTK-DGPS) unit was used to survey 7 profiles on the beach within the Bayshore development. In addition to the profiles the area of major sand inundation on the southern tip of the spit and the area immediately seaward of the homes extending north approximately 3,200 feet were surveyed to quantify changes that have occurred since the 2009 LIDAR data set was collected. The mean higher high water (MHHW) line was also surveyed at this time. The RTK-DGPS system consists of a base station and radio transmitter setup at a known location that sends corrected GPS information to the backpack unit (NANOOS, 2011). The elevation data is collected in the North American Vertical Datum of 1988 (NAVD88). The data were downloaded and processed by DOGAMI and supplied to us as raw coordinates in a comma separated values (csv) file format. The raw data was imported into surveying software where the individual cross sections and other transects were split out and exported as CAD drawing files. The drawing files were imported into CAD software and were also converted to shapefiles for use in ArcMap GIS software.

Additional profiles were generated from LIDAR (Light Detection and Ranging) data sets from 1997, 1998, 2002, and 2009. Digitial elevation models (DEM) for the 1997, 1998, and 2002 LIDAR data sets were generated by DOGAMI for use in this project. The data was originally collected through a partnership of federal agencies for the Airborne LIDAR Assessment of Coastal Erosion (ALACE) Project (ALACE, 1998 and 2002). These data contain only first return data points and have not been further processed to remove returns from water or vegetation. The 2009 LIDAR data set was collected by DOGAMI as part of a collaborative effort of state, federal, and local agencies in order to meet a wide range of project goals. This data set includes bare earth and unclassified points. The bare earth DEM was used in the generation of profiles for this project.

All of the profiles were generated from the DEMs using ArcMap and its extensions and saved as shapefiles. The attributes of the shapefiles were exported to Excel which was used to generate a series of files that could then be imported into CAD and viewed over-lapping in order to visualize temporal changes along each profile. Figures 10A-J were then given a vertical exaggeration of 10-times in order to better see the morphological changes that have occurred.

APPENDIX 4

Shorelines

Shorelines for various years are shown in Figures 8A-B. The 1928 and 1967 shorelines are used as a proxy for the mean higher high water (MHHW) line which is the average of the higher high tides for each day observed over the National Tidal Datum Epoch. When determining the shoreline from tide gauge data the nearest gauge is used to account for local variability of the tides. The 1928 shoreline was digitized by NOAA from National Ocean Service (NOS) T-sheets where the surveyed shoreline represents the high water line as it existed at the time of the survey (LeFever and Swainson, 1928). This can then be used as an approximation of the MHHW line. The 1967 shoreline was digitized by the Washington State Department of Ecology for use by the United States Geological Survey in order to compare historical shorelines to modern-day shoreline data obtained by LIDAR. The approach used to generate the 1967 line was to scan, geo-reference, triangulate with ground points, ortho-rectify and mosaic individual aerial photos and to then digitize the wet-dry sand line that most closely corresponded to the MHHW given the tidal conditions at the time the photos were taken (McCandless, 2009). The shorelines for 1997, 1998, and 2002 were generated using LIDAR data, and local tide gauges were used to determine the elevation (NAVD88) of the MHHW line during those times (Allan and Hart, 2005). Recently, DOGAMI has begun mapping the MHHW line using a RTK-DGPS system. The 2007, 2008, 2010, and 2011 shorelines were generated using this system and provided to us by DOGAMI (Allan, unpublished data). These shorelines represent the MHHW for the spring season in Lincoln County.