# Elevating Roadway Improvements and Dune/Beach Nourishment along North Humarock for Improved Coastal Resiliency

**North Humarock, Scituate, Massachusetts**

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# 1.0 OVERVIEW

## 1.1 Introduction

The Town of Scituate, Massachusetts suffers extensive flood damage along many of its east-facing beaches and ongoing threats to public and private infrastructure continue to be a major concern for the Town, as both long-term coastal erosion and relative sea level rise in the coming decades will continue to exacerbate regional storm damage. Over the last several years, the Town of Scituate has made great strides providing public outreach regarding coastal hazards and the effects of future sea level rise. Work continues on upgrading existing seawalls (e.g. Minot Beach, Oceanside Drive and Edwards Foster Road) and moving forward on other needed shore protection improvements (e.g. large-scale beach re-nourishment along North Scituate Beach).

In 2016, the Town pursued a long-term planning effort to identify ongoing coastal erosion and the sediment transport pathways that govern this process, screen potential shore protection strategies to determine their applicability, assess both historical storm damage and needed shore improvement costs by shoreline reach, and prioritize shore protection and/or other management strategies based on potential costs and storm protection benefits. The proactive planning report *Coastal Erosion, Sediment Transport, and Prioritization Management Strategy Assessment for Shoreline Protection* was develop by Applied Coastal for the Town to provide a broader town-wide perspective relative to shore protection needs and prioritization of projects. The proposed project along the northern section of Humarock Beach represents one of the highest priority areas, both from long-term storm protection and emergency access perspectives. In the report, the recommended shore protection approaches were to elevate Central Avenue, construct mixed-sediment dunes along North Humarock, and to nourish the beach along the entire Humarock Beach shoreline.

The study area consists of the 4,800-foot section between 10 Cliff Road South and 130 Central Avenue in the Town of Scituate (Figure 1.1). This portion of Town suffers extensive flood damage across the entire width of developed barrier beach, with total FEMA (Federal Emergency Management Agency) claims in excess of $6.7 million from 1978 to March 2015 or approximately $1.5 million per 1,000 feet of shoreline. In addition, major post-storm efforts are required after every significant coastal storm to clear Central Avenue (critical evacuation route), which is rendered impassable by sand and cobble storm overwash. On-going threats to public and private infrastructure continue to be a major concern for the Town, as both long-term coastal erosion and relative sea-level rise in the coming decades will continue to exacerbate regional storm damage.

The study site consists of a low-lying public roadway (Cliff Road South and Central Avenue) fronted by numerous private dwellings both on solid fill and pile foundations. The barrier beach system consists of a mixed sediment beach and a cobble dune. Due to the insufficient volume of the dune system, typical nor'easters scour and overwash the dune, causing rapid landward migration of this feature that blocks vehicular access along this entire road, as well as areas to the north including the U.S. Air Force Fourth Cliff Family Recreation Area. This specific low-lying area of northern Humarock Beach also is susceptible to the formation of a breach that could lead to formation of a new tidal inlet. An impact of this type along a developed barrier beach system like Humarock would be catastrophic.


Figure 1.1 Study area extents along North Humarock, Scituate, MA.

## 1.2 Study Objective

The purpose of the study is to develop a conceptual plan for elevating a portion of Cliff Road South and Central Avenue along northern Humarock Beach and optimizing a dune or beach nourishment design to provide storm damage protection for repetitively damaged public and private infrastructure and to provide emergency egress during storm events. A critical aspect of the overall conceptual design plan for shore protection along the northern portion of Humarock Beach is public "buy-in" regarding both the process and the findings of this preliminary design effort. Two public meetings were held to provide details of how the conceptual design will provide improved shore protection for this stretch of Humarock Beach, with a focus on how these needed improvements will help ensure long-term coastal resiliency of the barrier beach system and help protect dwellings within the project footprint.

# 2.0 EXISTING CONDITIONS

## 2.1 Storm Damage History

Central Avenue provides the only emergency access route to the houses on Fourth Cliff and the U.S Air Force Fourth Cliff Family Recreation Area. Figure 2.1 and Figure 2.2 shows typical flooding and overwash conditions along North Humarock under relatively minor storm conditions. During significant storm events, the transported sand, gravel, and cobbles completely block Central Avenue, requiring emergency action by the Town to clear the roadway at a cost of $30,000 to $60,000 per storm (Figure 2.3).

FEMA defines a repetitive loss property as any insurable building for which two or more claims of more than $1,000 were paid by FEMA NFIP (National Flood Insurance Program) within any rolling ten-year period, since 1978. Repetitive loss property data was obtained from FEMA NFIP from 1978 to 2015; the information in the dataset included: the location/address of the properties, number of FEMA claims, the associated claim dates and claim amounts. It is acknowledged that the repetitive loss data does not include all claims to FEMA and does not take into account damages that property owners decided to not claim; however, the data gives an indication of the spatial distribution and the relative scale of damage costs. Figure 2.4 shows the spatial distribution of repetitive loss properties along Humarock Beach. To maintain confidentiality, the exact location of the repetitive loss properties are obscured. Table 2.2 summarizes the repetitive loss claims received for significant storms from 1979 to 2015. All claim values have been converted to 2015 dollars.

Figure 2.1 Overtopped and ponding water along Central Avenue prevents emergency access. (*Image source*: Jason Burtner on March 7, 2013)

Figure 2.2 Overwash between houses on Central Avenue. (*Image source*: William Schmid on January 24, 2016)

Figure 2.3 Road clearing efforts along Central Avenue. Overwashed sediment is piled along the sides of the road. (*Image source*: Jason Burtner on March 8, 2013)

Table 2.1 FEMA repetitive loss claims for significant storms from 1979 to 2015.

| Storm Date | Repetitive Loss Claims | Total Claims ($) | Return Period (years) |
|---|---|---|---|
| 1/24/1979 | 4 | $30,112 | 19 |
| 3/29/1984 | 2 | $7,927 | 1 |
| 1/2/1987 | 10 | $102,794 | 22 |
| 10/28/1991 | 38 | $3,197,631 | 30 |
| 12/10/1992 | 32 | $591,563 | 22 |
| 3/5/2001 | 11 | $338,139 | 3 |
| 1/1/2003 | 4 | $51,508 | 8 |
| 12/5/2003 | 2 | $29,598 | 1 |
| 1/22/2005 | 2 | $74,573 | 1 |
| 5/22/2005 | 3 | $20,535 | 11 |
| 4/15/2007 | 8 | $49,587 | 15 |
| 2/23/2010 | 1 | $36,204 | 2 |
| 12/16/2010 | 11 | $236,165 | 13 |
| 2/7/2013 | 13 | $445,427 | 4 |
| 3/4/2013 | 5 | $154,052 | 3 |
| 1/2/2014 | 4 | $90,609 | 17 |
| 1/26/2015 | 7 | $509,160 | 11 |


Figure 2.4 Spatial distribution of FEMA repetitive loss properties along Humarock Beach.

## 2.2 Wave Climate

Wave conditions were generated using the data available from the WIS hindcast database from station 63053. The WIS data were used to develop offshore wave boundary conditions. The WIS station is located 15 miles northeast of Humarock Beach and has a record that spans the 33-year period between January 1980 and December 2012. Each hourly WIS time step includes parameters that describe the wave conditions (i.e., wave period, wave height, and direction) and wind (direction and speed) at the station. The entire wave record from WIS hindcast is presented in Figure 2.5 as compass rose plots which show magnitude and percent occurrence as a function of direction. Direction indicates from where waves were traveling, relative to true north. Radial length of gray tone segments indicates percent occurrence for each range of wave heights and periods. Combined length of segments in each sector indicate percent occurrence of all waves from that direction.

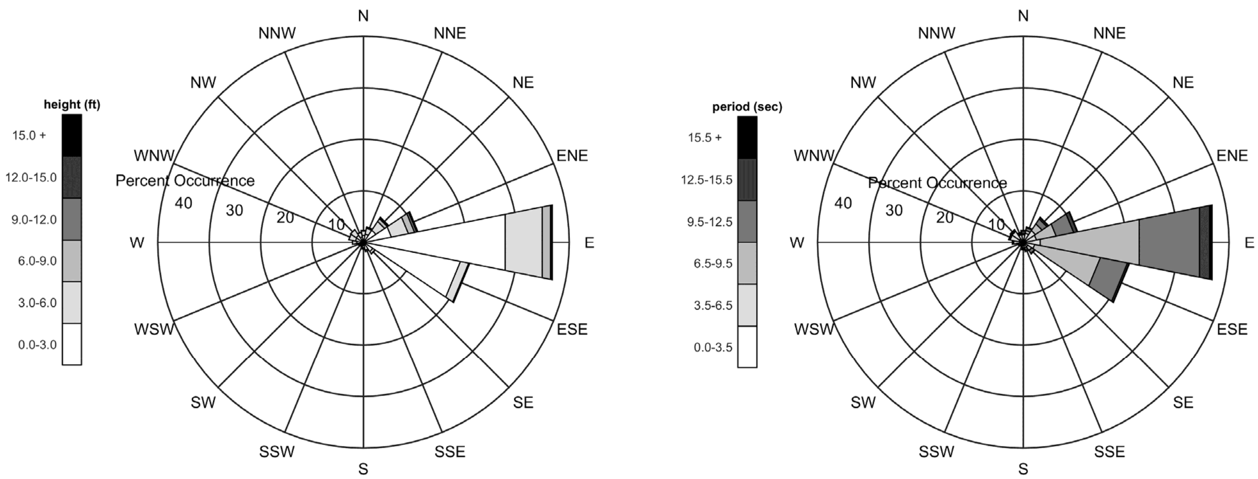



Figure 2.5 Wave height and period for hindcast data from WIS station 63053 (15 miles offshore of Humarock Beach) for the 33-year period between January 1980 and December 2012.

For the wave data of the WIS hindcast, east is the predominant sector. Waves propagate from this direction 37.5% of the time. 75.0% of waves from this sector have a height less than 3 feet. Wave heights between 6 and 3 feet occur 19.6% of the time from the south sector. The second-most frequently occurring sector at this station is east-southeast, which occurs 21.1% of the time. From this sector, 91.2% of the waves have a height that is less than 3 feet, and 7.8% have a height between 6 and 3 feet.

## 2.3 Extreme Water Levels

Storm surge is the rising water level caused by changes in atmospheric pressure and wind associated with a storm. The 10-, 50-, and 10-year still water elevations (SWEL) as defined by the Plymouth Country Flood Insurance Study (FEMA, 2012) are summarized in Table 2.2. Central Avenue is as low as 6.7 feet NAVD88 at some locations and is prone to flooding during minor storms from the west (river) side. Figure 2.6 shows the susceptibility of the road to flooding on a particularly high tide with water levels of 6.5 feet NAVD88.

Table 2.2 FEMA still water elevation (SWEL) for 10-, 50- and 100-year return period events.

| Return Period | FEMA SWEL (feet, NAVD88) |
|---|---|
| 10-year | 8.3 |
| 50-year | 9.1 |
| 100-year | 9.5 |

Figure 2.6 Near-flooding conditions at Central Avenue on where the water level is approximately 6.5 feet NAVD88. (*Image source*: Jason Burtner on March 31, 2014)

## 2.4 Topographic Surveys

Two sources of topographic data were used to estimate beach/dune nourishment volumes, road elevation, and location of buildings. The topographic data used to measure the existing road and driveways elevations was obtained from LiDAR (Light Detection and Ranging) datasets available from NOAA (National Oceanic and Atmospheric Administration). LiDAR is a system for collecting ultra-dense-coverage bathymetry and topography data using a laser system mounted to an airplane. A sample of the 2013/2014 LiDAR dataset is shown in Figure 2.7. CLE Engineering conducted topographic surveys on August 12, 2016 and June 20, 2017 from approximately 16 Cliff Road South to Barratt Street (see drawing in Appendix A). This survey was used as the primary source of topographic data for estimating the existing beach and dune volumes in order to determine the volume of additional sediment required to provide adequate storm protection. All elevation data was transformed to the NAVD88 (North American Vertical Datum of 1988) datum.

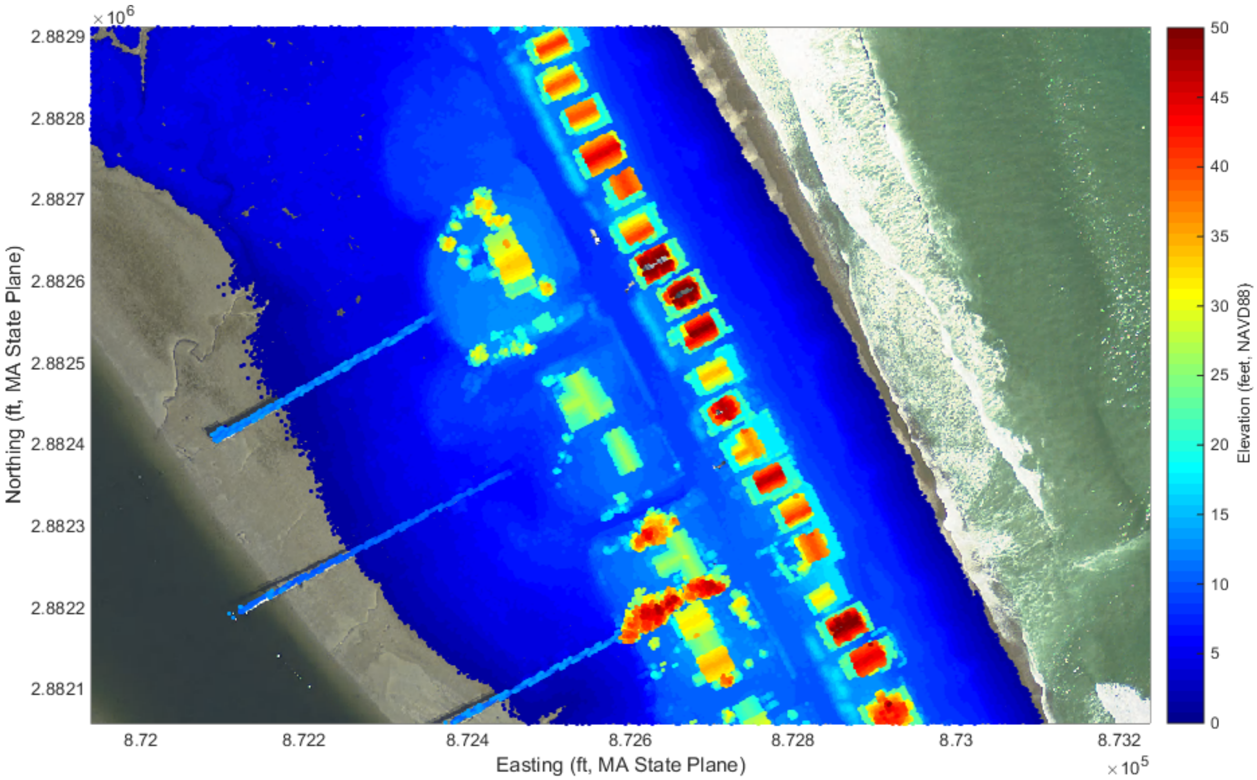



Figure 2.7 Sample area of the 2013/2014 LiDAR data coverage.

## 2.5 Shoreline Change Analysis

High water shorelines were obtained from 1950/1952 National Oceanic and Atmospheric Administration (NOAA) T-Sheets and by delineating the high water line from 2008 United States Geological Survey (USGS) aerial photographs. The high water shoreline position change rates were calculated by casting perpendicular transects to the later input shoreline at each analysis point (every 32.8 feet) along the line to the earlier shoreline. The result is a table of shoreline change magnitudes and rates for each transect where shoreline change denoted with a minus sign represents erosion. It should be noted that the change rates represent the horizontal shoreline migration only and do not include changes in the beach elevation (i.e. beach lowering) over time.

All shoreline position data contain inherent errors and/or uncertainties associated with field and laboratory compilation procedures. The potential measurement and analysis uncertainty between the data sets is additive when shoreline positions are compared. Because the individual uncertainties are considered to represent standard deviations, a root-mean-square (RMS) method was used to estimate the combined potential uncertainties in the data sets. The positional uncertainty estimates for each shoreline were calculated using the information in Table 2.3. These calculations estimated the total RMS uncertainty to be ±30.5 feet or ±0.5 feet per year from 1950/1952 to 2008.

Humarock Beach has generally experienced shoreline erosion from the 1950's to 2008, as shown in Figure 2.8. Long-term erosion is higher at the south end of Humarock Beach, near the Julian Street Bridge, where a landward shoreline migration rate of nearly 4 feet per year has been observed. Near the north end of the beach, the 2008 high water line is located approximately 50 feet seaward of the periodic public and private coastal engineering structures and this distance increases up to 100 feet at the south end of the beach.

Table 2.3 Estimates of potential error/uncertainty associated with shoreline position surveys (Byrnes *et al.*, 2010).

| | |
|---|---|
| **Traditional Engineering Field Surveys** | |
| Position of rodded points<br>Location of plane table<br>Interpretation of high-water shoreline position at rodded points<br>Error due to sketching between rodded points | ±3 feet<br>±7 to 10 feet<br>±10 to 13 feet<br>up to ±16 feet |
| **Cartographic Errors (1950/1952)** | Map Scale 1:10,000 |
| Inaccurate location of control points on map relative to true field location<br>Placement of shoreline on map<br>Line width representing shoreline<br>Digitizer error<br>Operator error | Up to ±10 feet<br>±16 feet<br>±10 feet<br>±3 feet<br>±3 feet |
| **Historical Aerial Surveys (1950/1952)** | Map Scale 1:10,000 |
| Delineating high-water shoreline position | ±16 feet |
| **Orthophotography (2008)** | |
| Delineating high-water shoreline position<br>Position of measured points | ±10 feet<br>±10 feet |
| **GPS Surveys** | |
| Delineating high-water shoreline position<br>Position of measured points | ±3 to ±10 feet<br>±3 to ±10 feet |

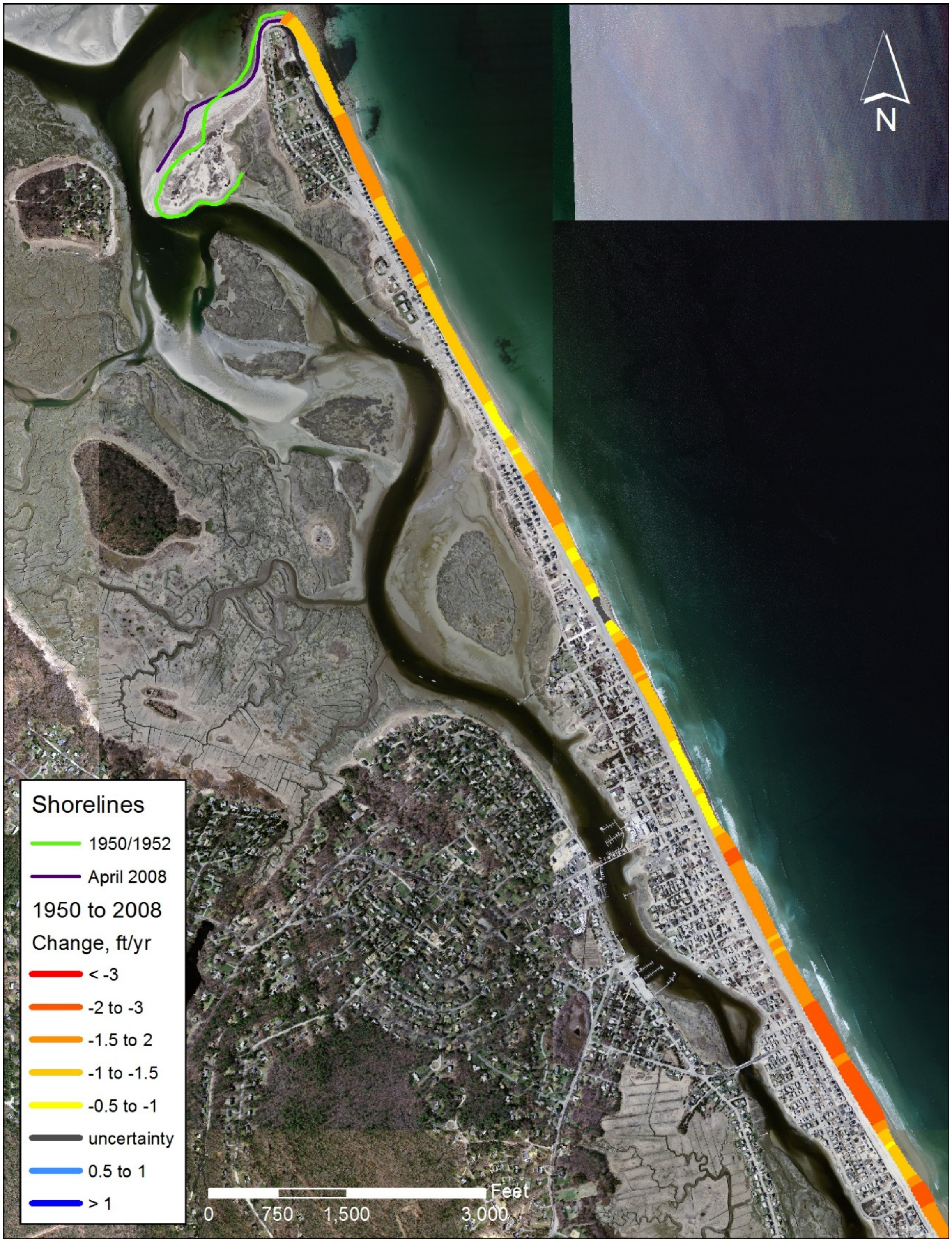



Figure 2.8 Historical shoreline change for Humarock Beach from 1950/1952 to 2008. Transects with calculated shoreline change rates within the RMS uncertainty are shown in gray.

## 2.6 Sediment Sampling

Sediment sampling was conducted on February 2, 2017 during low tide. Two samples were collected from the dunes at the north end of the beach near Fourth Cliff and at the south end of the study area near Seaview Avenue. The grain size distribution is shown in Figure 2.9. The median grain size, $D_{50}$, for the north and samples were 36.5 and 25.8 mm, respectively. The percentage of gravel and cobble (sediment larger than 4.75 mm or the #4 sieve) is 78 to 98% for the north and south samples, respectively. The grain size distributions illustrate that the native dunes is comprised of a sand-gravel-cobble mix. Test results are available in Appendix C.

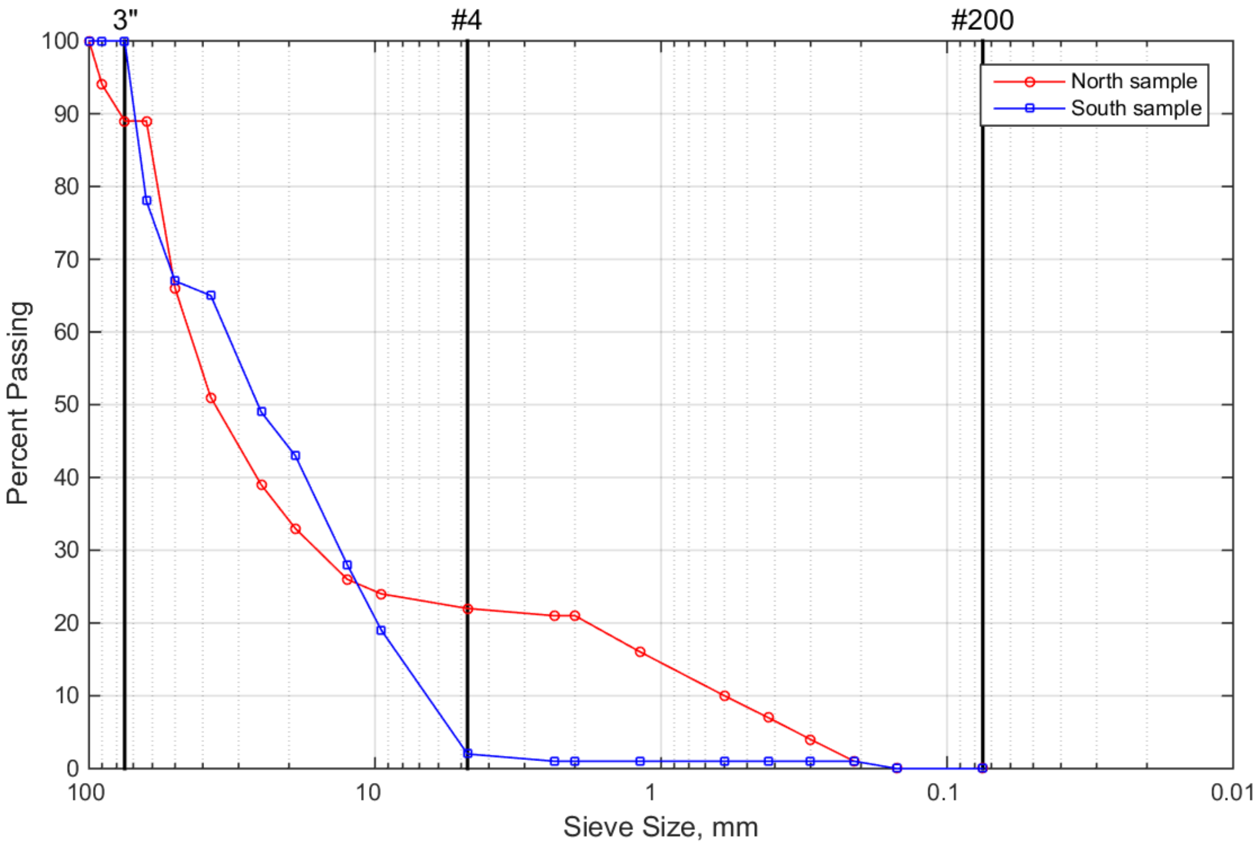



Figure 2.9 Sediment grain size distribution for the north and south samples on northern Humarock Beach. Samples were collected on February 2, 2017.

## 3.0 ALTERNATIVES ANALYSIS

A number of other alternatives were considered to provide storm damage protection for North Humarock: seawalls and revetments, managed retreat, and other innovative alternatives such as artificial reefs and wave attenuation devices. The preliminary alternatives analysis can be found in the 2016 report *Coastal Erosion, Sediment Transport, and Prioritization Management Strategy Assessment for Shoreline Protection* by Applied Coastal. Based on the results of the preliminary alternatives analysis, the recommended shore protection approaches were to elevate Central Avenue, construct mixed-sediment dunes along North Humarock, and to nourish the beach along the entire Humarock Beach shoreline.

### 3.1 Beach Nourishment

Beach nourishment refers to an engineered beach that is designed to withstand storm conditions including the effects of storm surge and wave action. Addition of this large volume of beach compatible sediment is designed to last several years, where the design life is dependent on the local sediment transport dynamics and berm overtopping potential. It should be noted that the engineered beach nourishment projects for shore protection purposes are substantially larger than the Humarock Beach sacrificial dune project in 1994. In this study, the beach nourishment alternatives are engineered to withstand a 50-year storm event.

A beach nourishment template for North Humarock was proposed consisting of a 75 foot berm at an elevation of 14 feet NAVD88 (Figure 3.1). The elevation of the beach berm is sufficient to prevent wave overtopping during a 50-year storm. From the berm, the beach slopes seaward at a slope of 1V:10H until it intersects the ocean bottom. The proposed design would increase the high water beach width by approximately 100 feet.

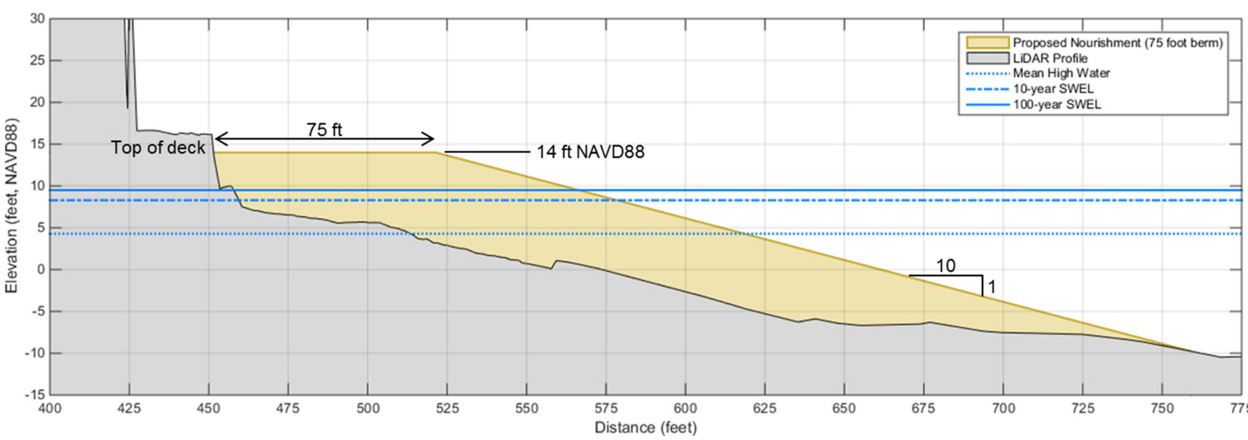



Figure 3.1 Proposed beach nourishment template featuring a 75-foot berm at an elevation of 14 feet NAVD88 and a beach slope of 1V:10H.

Due to the ongoing migration of sediment to adjacent shorelines as well as offshore, a maintenance plan for re-nourishment will be necessary for this alternative to be effective as a long-term management strategy. Maintenance should also be anticipated after significant storm events to replenish eroded sections of the beach to ensure stability and provide wave dissipation during future storm events. Repairs and maintenance funds may be provided by

FEMA through the Stafford Act after federally declared disasters if nourishment is consistently monitored and maintained (i.e. a maintenance plan with financial commitments is in place).

The nourishment length was varied and the re-nourishment interval was plotted in Figure 3.2 along with the approximate construction cost. Details of the wave and sediment transport model associated with determining nourishment design life are described in detail in Applied Coastal (2016). Generally, the longer the nourishment length, the greater the nourishment interval and a renourishment interval of approximately 10 years is desired. Based on model results, a 10-year re-nourishment interval corresponds to an 8,000-foot nourishment that extends from 10 Cliff Road South to the Marshfield Avenue Bridge (Figure 3.3). Figure 3.2 shows that a 4,800-foot (project limits) nourishment provides a nourishment interval of 6 years.

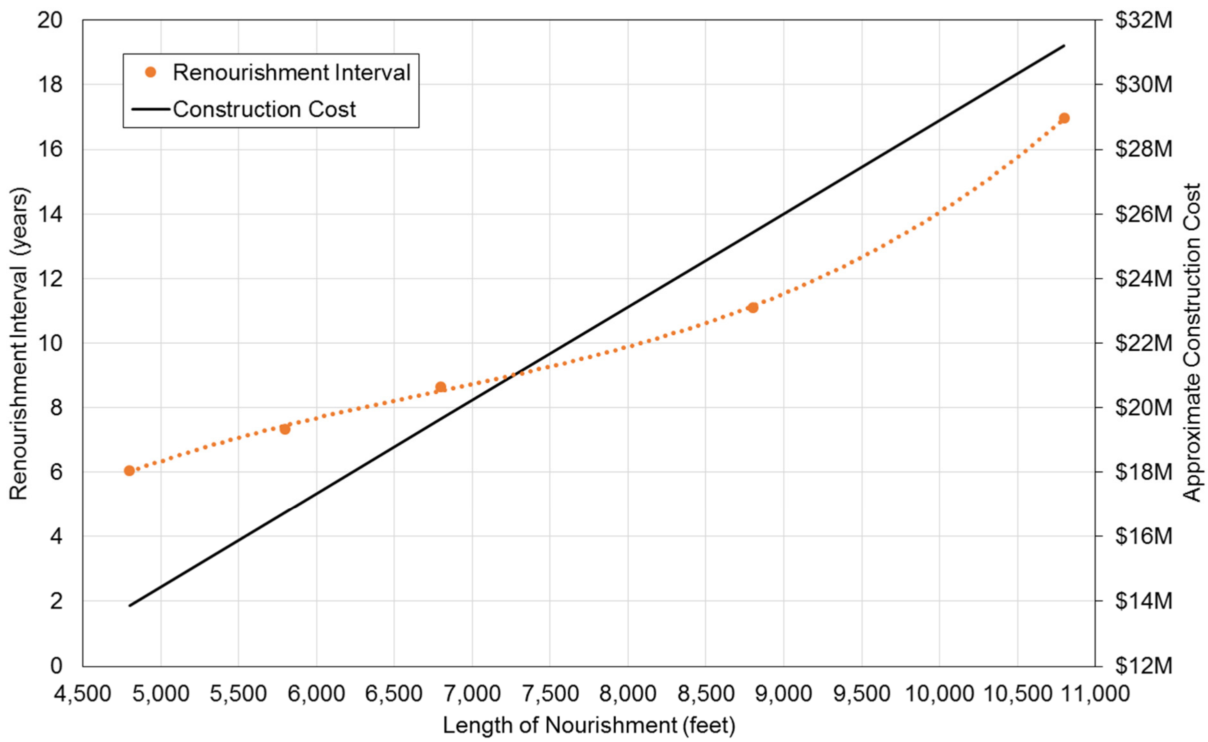



Figure 3.2 Renourishment interval and approximate construction cost as a function of nourishment length along Humarock Beach starting at 10 Cliff Road South.

For a 4,800 foot nourishment project, 425,000 cubic yards of cobble-gravel-sand mix (compatible with the existing beach material) is required. A construction cost estimate for beach nourishment is provided in Table 3.1 along with lifecycle costs over 50 years. The initial construction cost is based on a required sediment volume of 425,000 cubic yards at a cost of $34 per cubic yards. The lifecycle costs are depicted purely for comparison purposes with the other alternatives and are deliberately conservative. Over 50 years, it is estimated that approximately $209 million dollars will be required to construct and maintain the beach nourishment.


Figure 3.3 Modeled nourishment lengths along Humarock Beach starting at 10 Cliff Road South.

| Table 3.1 50-year lifecycle cost estimate for a 4,800-foot long beach nourishment along North Humarock. | |
|---|---|
| Construction Cost | $14,450,000 |
| Renourishment Cost | $10,115,000 |
| Renourishment Interval | 6 years |
| Life Cycle | 50 years |
| Inflation Rate | 3% |
| Money Spent over 50 Years | $209,401,745 |

In addition to cost, another obstacle in constructing a lengthier nourishment are the number of easements required from homeowners. If the project is publically funded, beach access easements are required from a contiguous segment of homeowners along the extents of the proposed nourishment which can be difficult. However, a longer project length can help justify the cost of beach nourishment as the area of storm protection is extended. Therefore, beach nourishment is not recommended unless the nourishment length can be extended further south to increase the re-nourishment interval and area of storm protection.

### 3.2 Constructed Mixed-Sediment Dunes

A Notice of Intent (NOI) was filed by Vautrinot & Webby Co. on March 31, 1994 on behalf on the Town of Scituate in response to the erosion along Humarock Beach experienced during the 1991 No-Name Storm (October 1991) and December 1992 nor'easter. The NOI proposed that a sacrificial dune, designed to withstand a 5-year storm, be constructed from the south end of Fourth Cliff to the Marshfield town line (approximate length of 2.4 miles). The dune was designed to have a 10-foot crest at an elevation of 15.1 feet NAVD88 and the seaward slope would be 1V:5H, intersect the existing beach above the extreme high water elevation (Figure 3.4). The NOI estimated that 60,590 cubic yards of material would be required with a nourishment volume of approximately 8 to 10 cubic yards per linear feet along North Humarock.

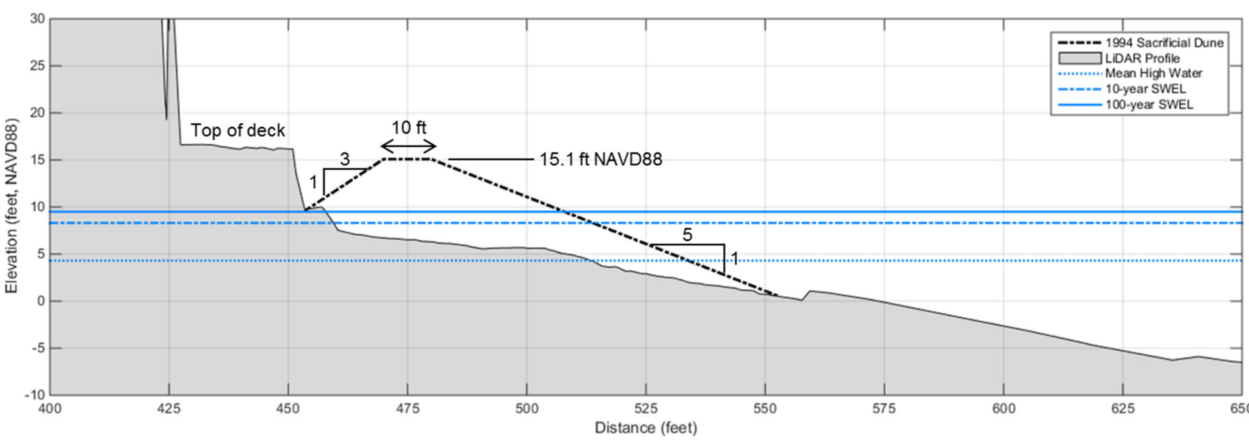



Figure 3.4 Proposed dune nourishment template for the 1994 sacrificial dune project along Humarock Beach.

Notes from MCZM (Massachusetts Office of Coastal Zone Management) state that the nourishment plan was revised to place 49,000 cubic yards instead of 60,590 cubic yards and an article in the Boston Globe notes that the constructed nourishment was 7,000 feet in length but the precise limits of the project are unknown. Figure 3.5 and Figure 3.6 shows the dune before and after construction. As constructed, the proposed design specified that 8 to 10 cubic yards of sediment per linear foot be placed along North Humarock, however visual inspection of the photos suggests that approximately 5 cubic yards per linear foot was placed during construction. It should be noted that the placed sediment appears to be much finer than the native beach sediment. During the September 5, 1994 Labor Day Storm, the dunes were eroded and the placed sediment redistributed into the littoral system, likely transported south towards South Humarock. The peak water level measured in Boston during the storm was 5.7 feet, less than a 1-year storm.

Figure 3.5 Placement of dune nourishment material along Humarock Beach in 1994 for the sacrificial dune project. (*Image source*: CZM)

Figure 3.6 Constructed dunes along Humarock Beach in 1994 for the sacrificial dune project. (*Image source*: CZM)

FEMA (2007) provides guidance on designing dunes to withstand major coastal storms; the minimum dune volume required to prevent dune overtopping during a storm is estimated using FEMA's "540 rule" (Figure 3.7). The "540 rule" states that dune volume is sufficient to protect against a 100-year storm when the volume seaward of the dune crest and above the 100-year still water elevation is greater than 540 square feet per linear foot of dune. More recently, FEMA's Coastal Construction Manual (2000) recommended that the target dune reservoir volume be increased to 1,100 square feet per linear foot of dune based on more recent post-storm surveys.

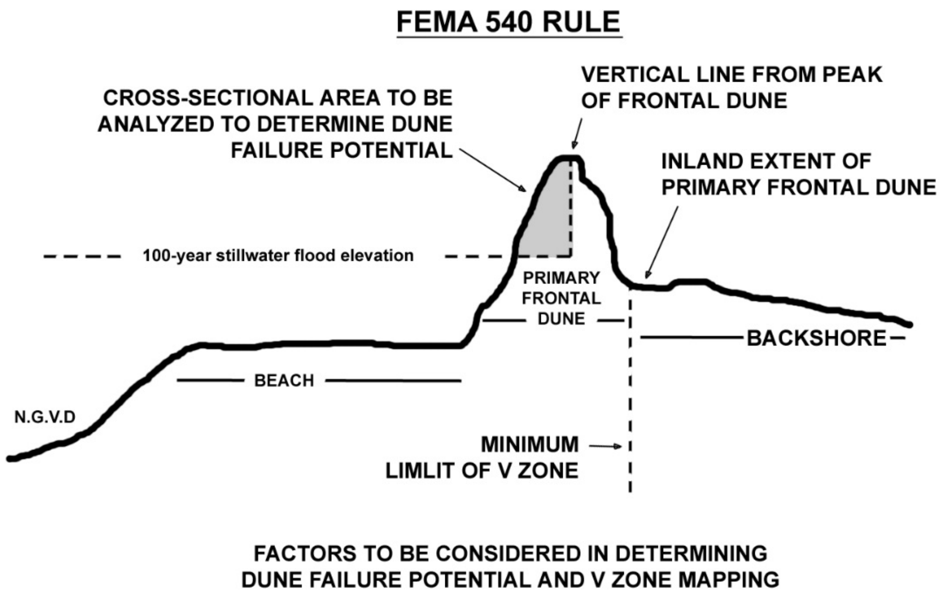



Figure 3.7 FEMA "540 rule" for determining dune failure potential. (*Image source:* FEMA, 2007)

Using the "540 rule" and the recent 1,100 square foot guideline, two mixed-sediment dune templates for North Humarock were designed (Figure 3.8). Both designs feature a steeper back slope of 1V:3H and a milder front slope of 1V:5H. The 540-square foot dune includes a crest width of 30 feet and crest elevation of 19.5 feet NAVD88 while the 1,100 square foot dune has a crest width of 50 feet and crest elevation of 23 feet NAVD88. Taking into consideration that the proposed mixed-sediment dune material (cobble, gravel, and sand) is less mobile than the sandy dunes surveyed in developing the "540 rule" and 1,100 square feet guideline, the lower volume dune design (540 square foot) was determined to provide adequate overtopping protection. In contrast, the 1994 sacrificial dune project had a dune volume (as defined by the "540 rule") of approximately 134 square feet per linear foot. Another benefit of the 540-square foot dune design is that the crest elevation allows for uninterrupted sightlines from the first floor decks from a standing position while the larger dune would block the ocean view from most houses.

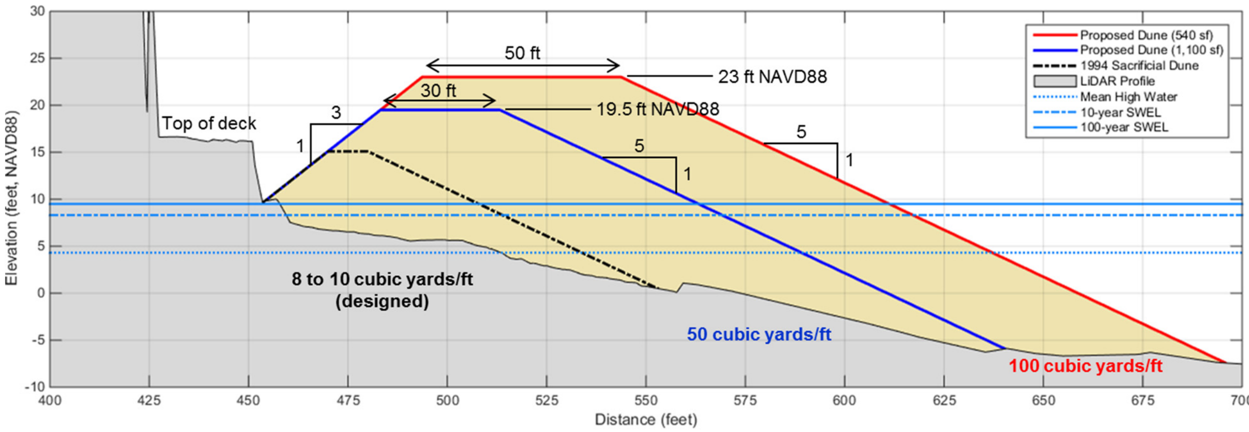



Figure 3.8 Two proposed dune nourishment templates for North Humarock that satisfy the “540 rule” (blue) and the 1,100 square foot standard (red). The 1994 sacrificial dune (dashed-black) is shown for comparative purposes.

To determine the reshaped profile of the proposed dune, a parametric profile model for shingle beaches by Powell (1990) was used. “Shingle beach” is a term used to describe sand/gravel/cobble mixed-sediment beaches in the United Kingdom. The model requires the significant wave height, mean wave period, offshore wave length, and median grain size as inputs. A median grain size of 30 mm was used based on the sediment sampling results. It is anticipated that the profile adjustment would occur in a few hours during the first significant northeast storm experienced by the nourishment project. The reshaped profile shown in Figure 3.9 estimates the profile after a 10-year storm. The dune crest is “kicked-up” to approximately 22 feet NAVD88 from the wave runup on the seaward face of the dune. After a significant storm, the crest may be regraded back to the designed 19.5 feet NAVD88 elevation to restore the ocean view from the houses.

The daily tidal fluctuations and waves will begin the adjustment and sorting process as soon as the nourishment is in place and form the lower berm profiles along the beach face. The existing sediment in the dunes is approximately 20% sand and 80% gravel and cobble with an average grain size of 1.2 inches and the sediment proposed for the dunes will be compatible. Similar to the existing beach, natural wave conditions will re-sort the sediments and it is anticipated that the higher elevation dunes will be comprised of mostly cobbles while the beach closer to the water will be sandier with a transition at the toe of the dune.

A construction cost estimate for the mixed-sediment dunes is provided in Table 3.2 along with lifecycle costs over 50 years. The initial construction cost is based on a required sediment volume of 250,000 cubic yards at a cost of $34 per cubic yards. The lifecycle costs are depicted purely for comparison purposes with the other alternatives and are deliberately conservative. Over 50 years, it is estimated that approximately $69 million dollars will be required to construct and maintain the dunes. Compared to the 50-year lifecycle cost of beach nourishment presented in Section 3.1, dunes are nearly three-times less expensive to maintain while providing a comparable level of storm damage protection.

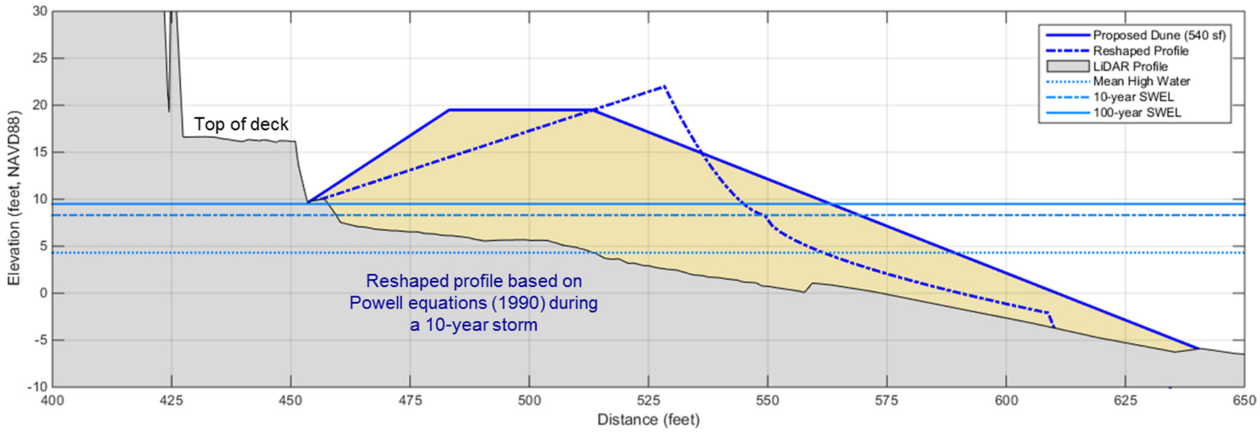



Figure 3.9 Proposed dune template profile (solid blue) and the reshaped dune profile (dashed blue) after a 10-year storm.

| Table 3.2 50-year lifecycle cost estimate for a 4,800-foot long mixed-sediment dune along North Humarock. | |
|---|---|
| Construction Cost | $8,500,000 |
| Maintenance Cost | $425,000 |
| Maintenance Cost Reoccurrence | 2 years |
| Reconstruction Cost | $4,250,000 |
| Reconstruction Cost Reoccurrence | 10 years |
| Life Cycle | 50 years |
| Inflation Rate | 3% |
| Money Spent over 50 Years | $69,257,251 |

### 3.3 Increase Elevation of Central Avenue

While beach and/or dune nourishment prevents flooding and wave overtopping from the east (ocean) side of Central Avenue, a separate approach is required to prevent still-water flooding from the west (river) side. High water levels may flood the road, preventing emergency access along Central Avenue and to/from Fourth Cliff. It is recommended that dunes and elevated road be constructed together to provide effective storm damage protection and maintain emergency egress.

In Figure 3.10, the existing elevation of the road was plotted using 2013/2014 LiDAR data and confirmed on site using an RTK-GPS (Real Time Kinematic Global Positioning System). The extreme low section along the road was identified as the 200-foot segment near the Central Avenue and Cliff Road South split (6 Cliff Road South to 298 Central Avenue). This area poses a high breaching potential as it may be submerged during even a minor (~1 year) storm. Two relatively high points in the road were identied where the elevation is above the 100-year water level, at approximately 254 Central Avenue and at 212 Central Avenue. However, the “dip” in the road between these two areas falls to the 1-year still water flood elevation, again posing a potential for a breach.

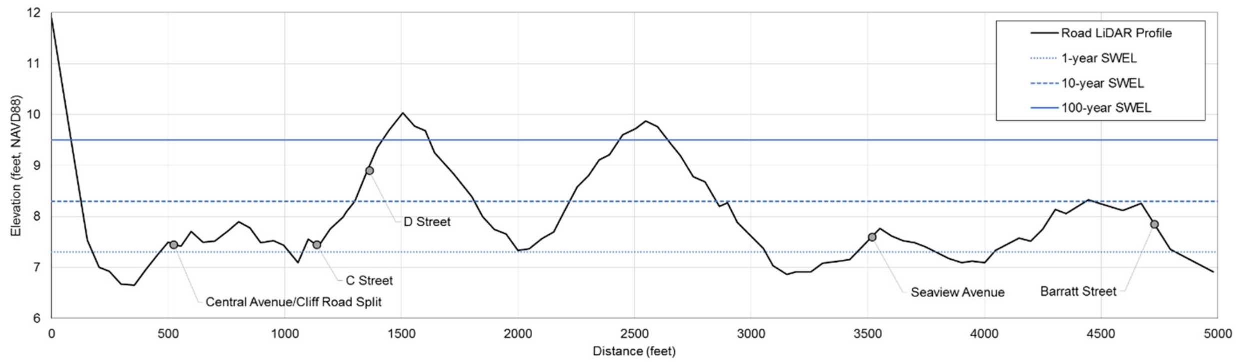



Figure 3.10 Existing road elevation along Cliff Road South and Central Avenue.

A site visit was conducted on February 2, 2017 to visually survey each house along the study limits to note any apparent obstacles with increasing the road elevation and issues with connecting the existing driveways to the raised roads (see Appendix B for survey notes). The survey was purely visual and more issues may be identified and resolved during the detailed design phase of the project.

In general, there are two main issues that are encountered when increasing the road elevation: (1) paved and/or landscaped driveways may need to be regraded and (2) some non-elevated houses with solid foundations are located in close proximity to the road and joining the road to the existing driveway may be difficult without utilizing a steep slope. Preliminary assessment of the houses examined raising the entire road to an elevation of 8.5 to 11 feet NAVD88 in half-foot increments while noting houses that may be affected by the issues above. Figure 3.11 shows the driveways affected when the road is raised to 10 feet NAVD88 throughout. The green points indicate that the driveway is paved or landscaped and may require regrading to meet the new roadway elevation. The red points identify houses that are not elevated and may need steep driveways. This preliminary analysis assisted in determining the extent of impacts associated with different roadway elevations.

From the preliminary assessment, it was determined that the road should be raised to the 10-year still water elevation (8.5 feet NAVD88) at a minimum to allow to emergency access during major storms. During the conceptual design phase, the driveway profile of each house in the study extents was analyzed individually to determine the impact of raising the road (see example in Figure 3.12). It was determined that the road may be raised to at least 9.5 feet NAVD88 (100-year storm) with a 1,500-foot section at the north end raised to 10 feet NAVD88. Figure 3.13 shows the proposed elevated road profile.

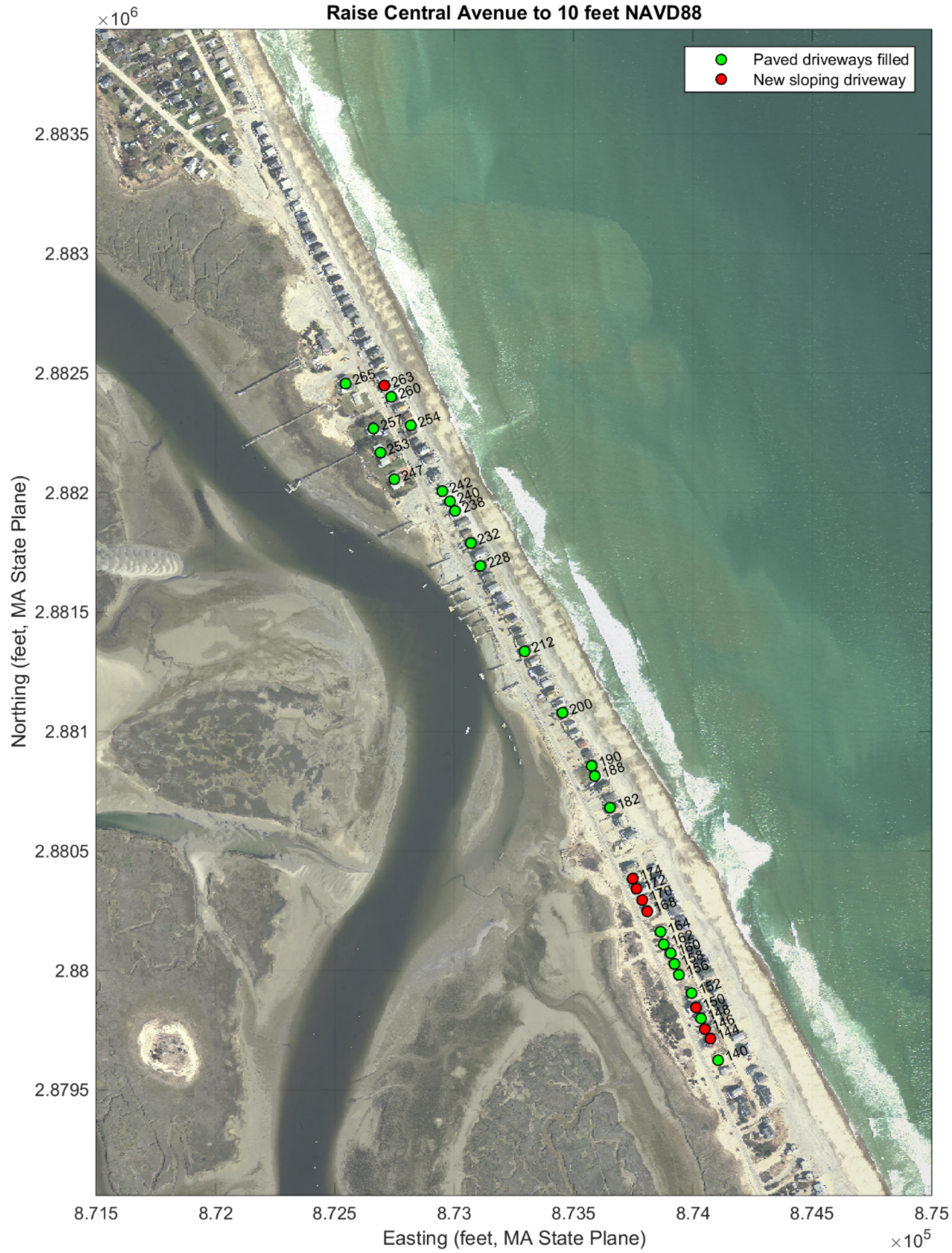



Figure 3.11 Potential issues identified during preliminary assessment of elevating Central Avenue where the road is raised to 10 feet NAVD88 throughout.

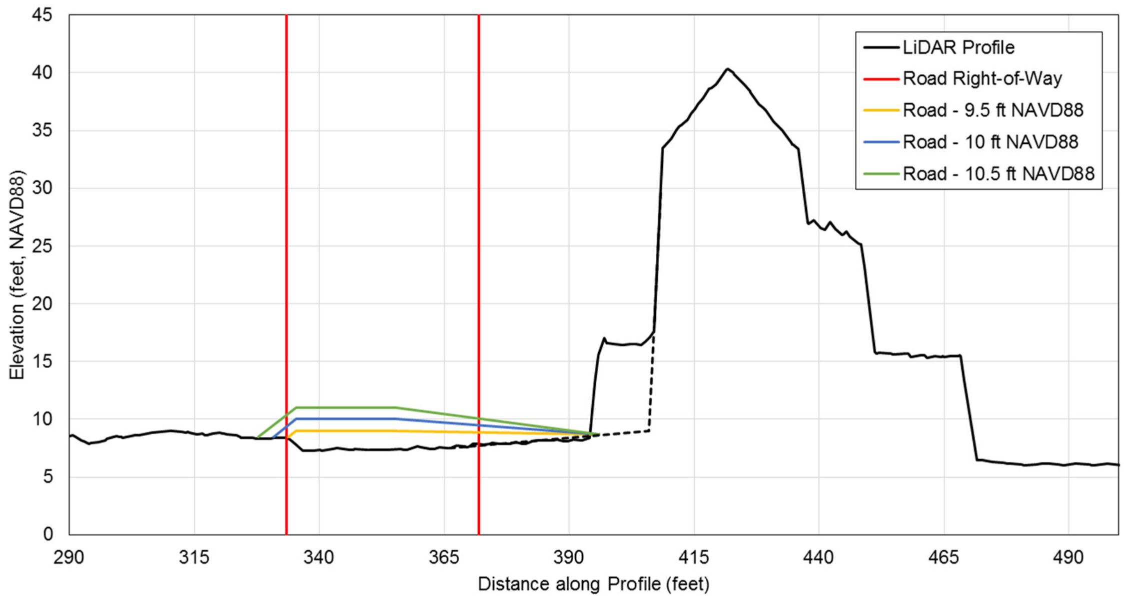



Figure 3.12 Example of roadway elevation impact examination that was completed for each house along the study extents.

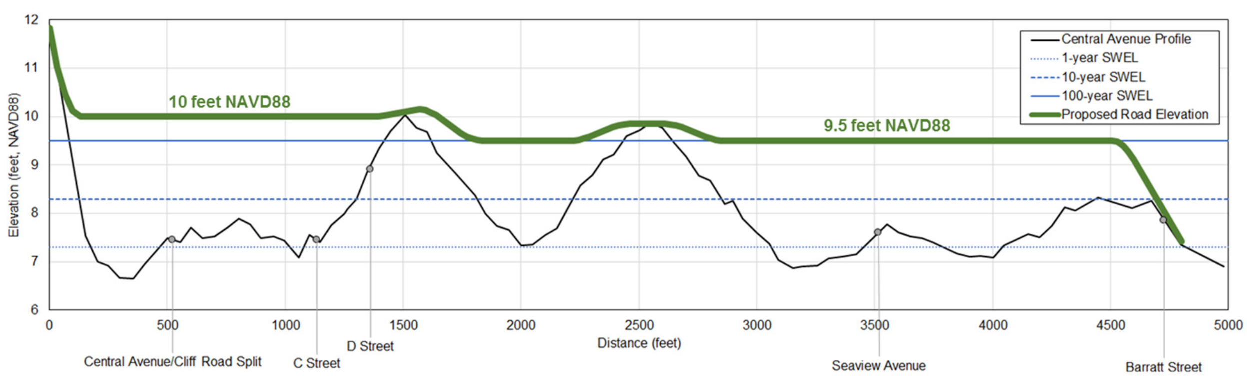



Figure 3.13 Existing road elevation (black) and proposed road elevation (green) along Cliff Road South and Central Avenue.

Five typical scenarios were identified for tying-in driveways to the proposed elevated road. The most straight-forward scenario is Section "A", where the house is elevated on piles (Figure 3.14) allowing for regrading to extend under the house, if necessary, and the resultant driveway is the same elevation as the newly elevated road. Section "B" shows a non-elevated house on the east side of the road that sits on a lot that is high enough above the existing road enough that the driveway can be tied in with the new road with a flat driveway (Figure 3.15). Section "C" depicts a non-elevated house on the east side of the road that requires a sloping driveway to meet the new road elevation, however the house is set back far enough from the road and the driveway slope is mild (<6% grade) (Figure 3.16). For houses on the west side of the road, Section "D" shows that the new driveway will be flat to prevent acceleration of overwash into the house (Figure 3.17). The last typical scenario is Section "E", where a non-elevated house located on the east side of the road has a relatively short distance from house to road, resulting in a relatively steep driveway slope (>6% grade) (Figure 3.18). These properties will be revisited during the detailed design phase to determine if the driveway slope is excessive and if there may be solutions to construct a less steep driveway. These solutions may range from altering the driveway placement, shifting the road to the west for additional driveway length, narrowing the roadway, or raising the house on piles. The detailed design would consists of working with the homeowners and the Town to determine solutions that are feasible. The type of tie-in for each house along the study extents is summarized in Appendix D.

The estimated construction cost for elevating 4,800 feet of the road is approximately $1.071 million. The estimate does not include for allowances such as relocating utilities, driveway repaving, adding risers for septic systems, etc. The cost of the allowances will be determined during the next project phase in detailed design.

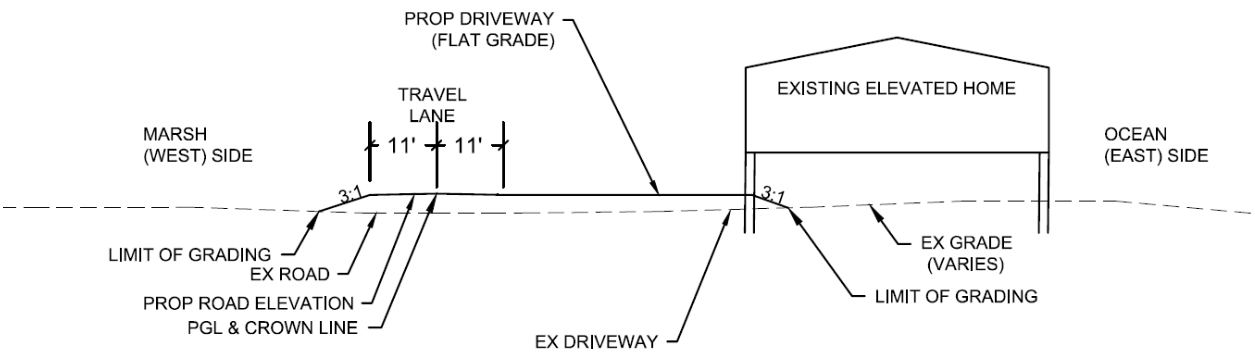



Figure 3.14 Typical driveway tie-in section “A”: elevated house on east side of road.

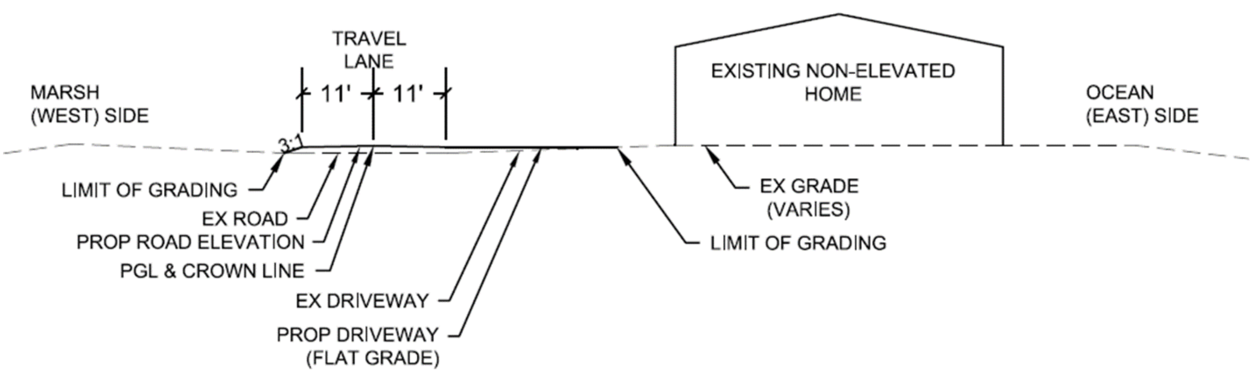



Figure 3.15 Typical driveway tie-in section “B”: non-elevated house on east side of road with proposed flat driveway.

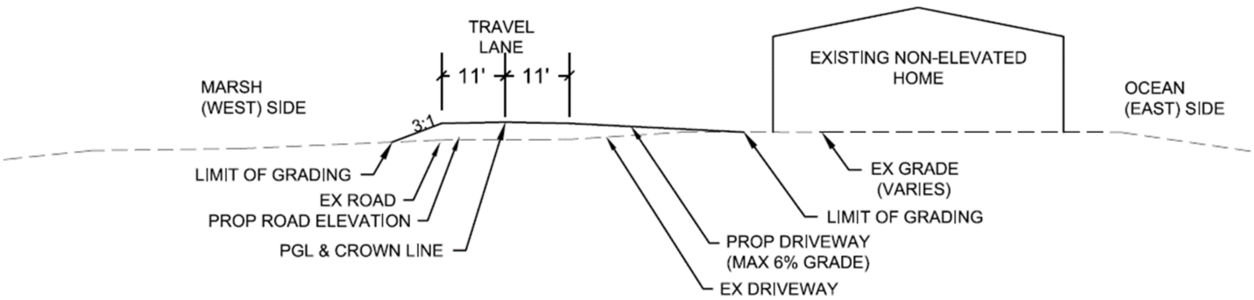



Figure 3.16 Typical driveway tie-in section “C”: non-elevated house on east side of road with proposed sloped driveway.

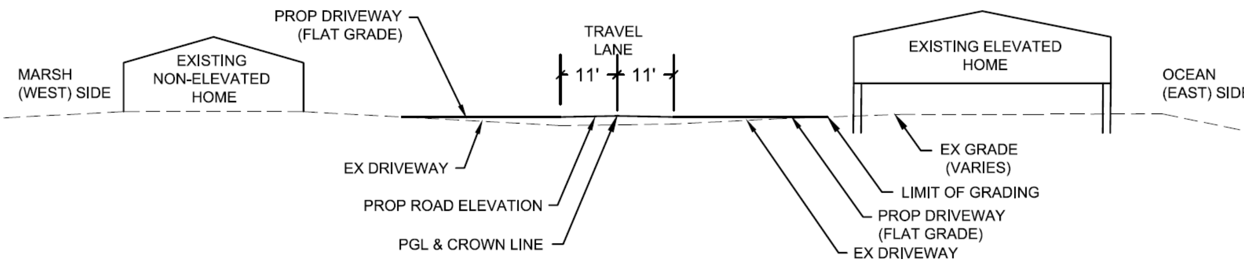



Figure 3.17 Typical driveway tie-in section “D”: non-elevated house on west side of road.

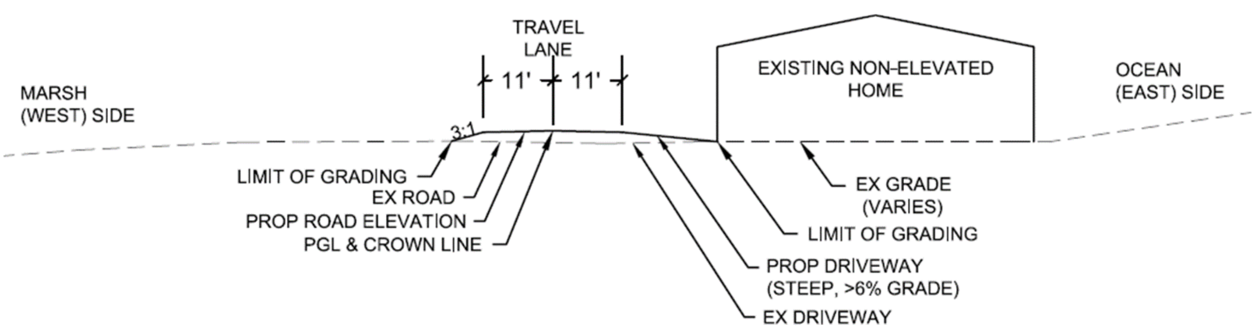



Figure 3.18 Typical driveway tie-in section “E”: non-elevated house on east side of road with insufficient driveway length.

## 4.0 RECOMMENDED PROJECT DESIGN

The recommended project is to construct mixed-sediment (cobble, gravel, and sand) dunes along the North Humarock from 10 Cliff Road South to 130 Central Avenue. The dunes will have a crest elevation of 19.5 feet NAVD88, which is sufficient to provide flooding and overwash protection for major storms while maintaining sightlines from the first-floor decks of the east-side houses. After a storm event, the crest of the dune may “kick-up” into peaks that may be regraded to the designed crest elevation.

In conjunction with the dunes, it is proposed that the road along the study extents be elevated to prevent still-water flooding from the west (river) side and also to maintain emergency access along Central Avenue and to/from Fourth Cliff. From 10 Cliff Road South to approximately 247 Central Avenue, the road will be elevated to 10 feet NAVD88 and the remainder of the road will be at 9.5 feet NAVD88 (elevation of the 100-year storm surge). Conceptual plans of the project are available in Appendix E.

### 4.1 Estimated Project Cost

The full project will cost approximately $9.6 million to construct plus additional allowances to relocate utilities, repave driveways, and add risers to septic systems. The cost of the allowances will be determined in the final design. Maintenance costs include costs to repair and re-nourish the dune after storm events to maintain their volume and/or height for adequate storm protection.

### 4.2 Project Phasing

The proposed project may be constructed in phases based on limitation in funds and/or attainment of easements. The first potential phase of the project is the 1,800-foot northern section from 10 Cliff Road South to approximately 242 Central Avenue (Figure 4.1). This segment of road is relatively straight-forward to elevate and the northern “bump” is a natural place to end the first phase as it is simpler to transition from the 10 feet NAVD88 elevation (Figure 4.2). This section is also most vulnerable to a breach as the barrier beach is lowest in this area, particularly from 6 Cliff Road South to 298 Central Avenue where the existing road elevation is below 7 feet NAVD88. The cost of the potential first phase of the project is approximately $3.6 million plus the cost of additonal allowances.

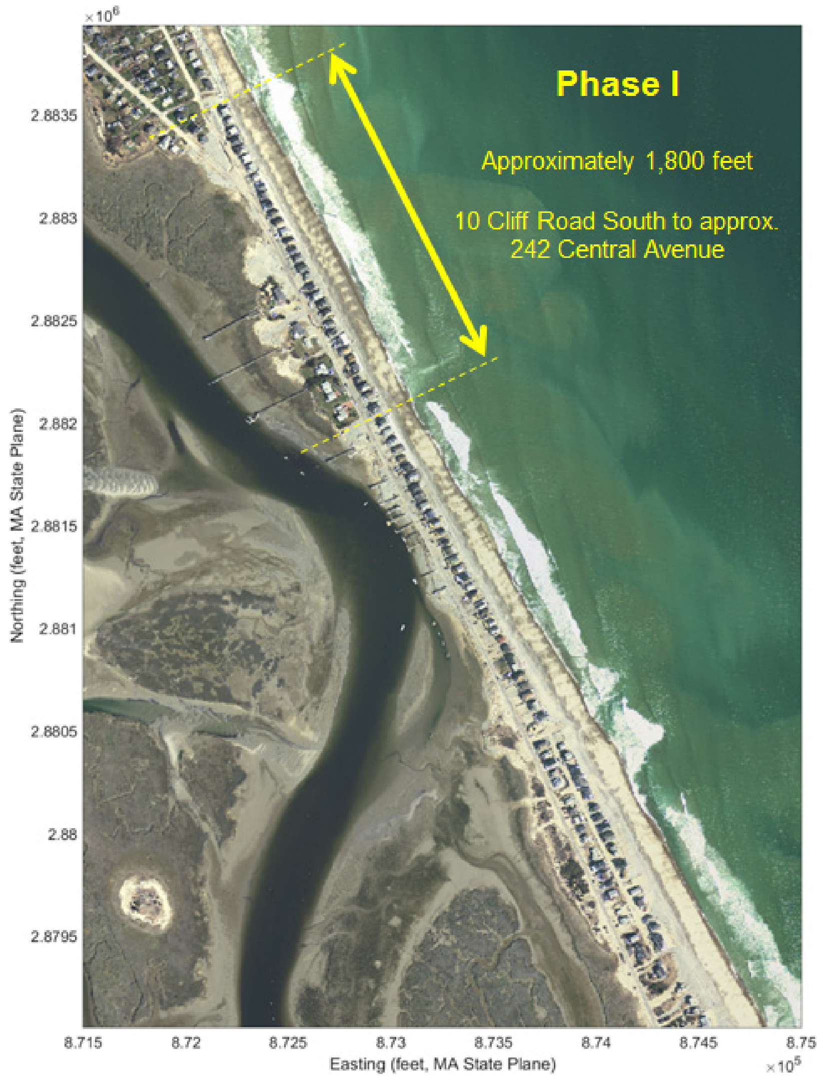



Figure 4.1 Potential first phase of the road elevation and dune construction project from 10 Cliff Road South to approximately 242 Central Avenue.

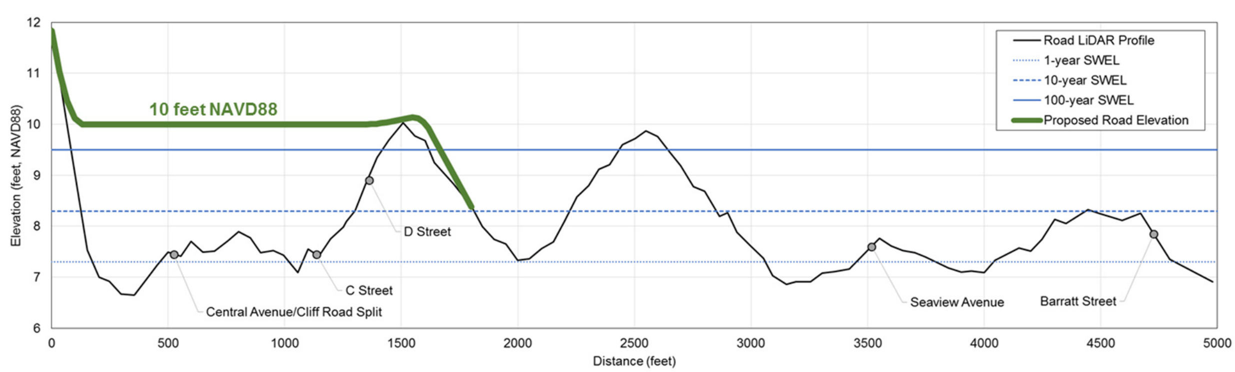



Figure 4.2 Existing road elevation (black) and potential first phase of road construction (green) along Cliff Road South and Central Avenue.

### 4.3 Sea Level Rise

Separate from the daily rise and fall of the tide, the average elevation of the ocean changes over time with respect to the land. This average position is called relative sea level and different geologic and atmospheric processes contribute to changes in the relative sea level. Some of the causes include glacial ice melt, thermal expansion of the ocean as the global temperature increases, and the rising or sinking of the earth's crust itself. While the specific causes of relative sea level change are the topic of much scientific and political debate, historical evidence indicates that over the past 90+ years, the relative sea-level in Boston, Massachusetts has been rising generally in a linear fashion, shown in Figure 4.3. Depending on the time period of the analysis and/or the tidal datum selected (e.g. monthly mean sea level or annual mean sea level), the long-term range varies from 2.63 mm per year or 0.86 feet per century (NOAA, 2013) to 2.97 mm per year (0.97 feet per century).

The Massachusetts Office of Coastal Zone Management (MCZM) also published their own report in 2013 regarding future sea level rise projections along the Massachusetts coast based upon much of the information developed by NOAA. These projections utilized estimates for the historical linear trend, an "intermediate low" scenario, an "intermediate high" scenario, and a "high" scenario as shown in Figure 4.4. For the evaluation of shore protection measures in this report, it is anticipated that a 50-year design life for new and/or reconstructed coastal engineering structures is appropriate. Utilizing the relatively conservative values associated with the "intermediate high" relative sea level rise projection for the region, the evaluation for future conditions assumed a 2-foot increase in relative sea level over the next 50 years.

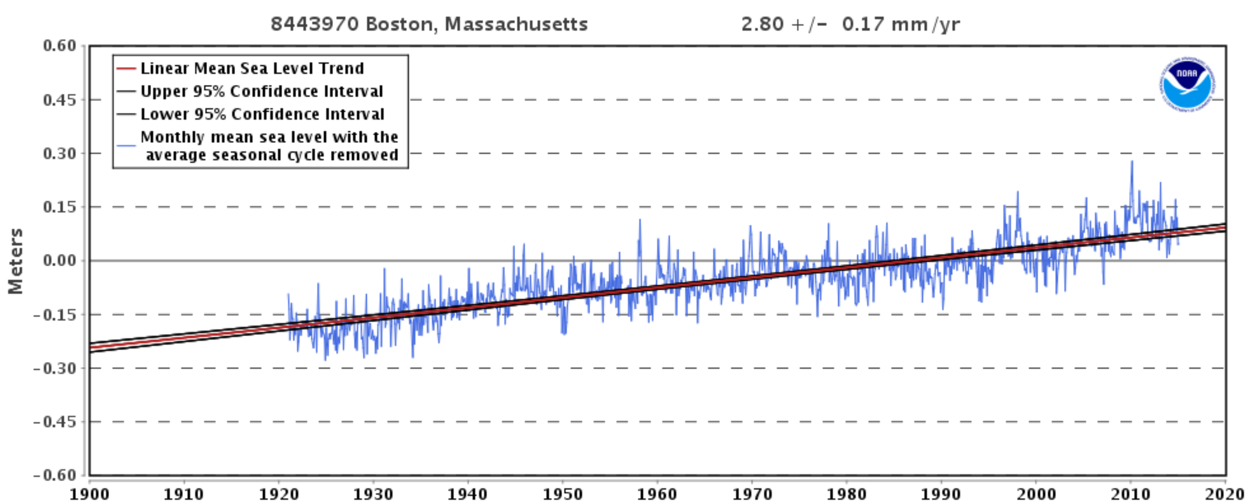



Figure 4.3. Monthly mean water levels recorded in Boston, Massachusetts between 1921 and 2013 indicate a linear trend in sea-level rise over the past 90+ years of approximately 2.80 mm per year. (*Image source*: NOAA, 2013)

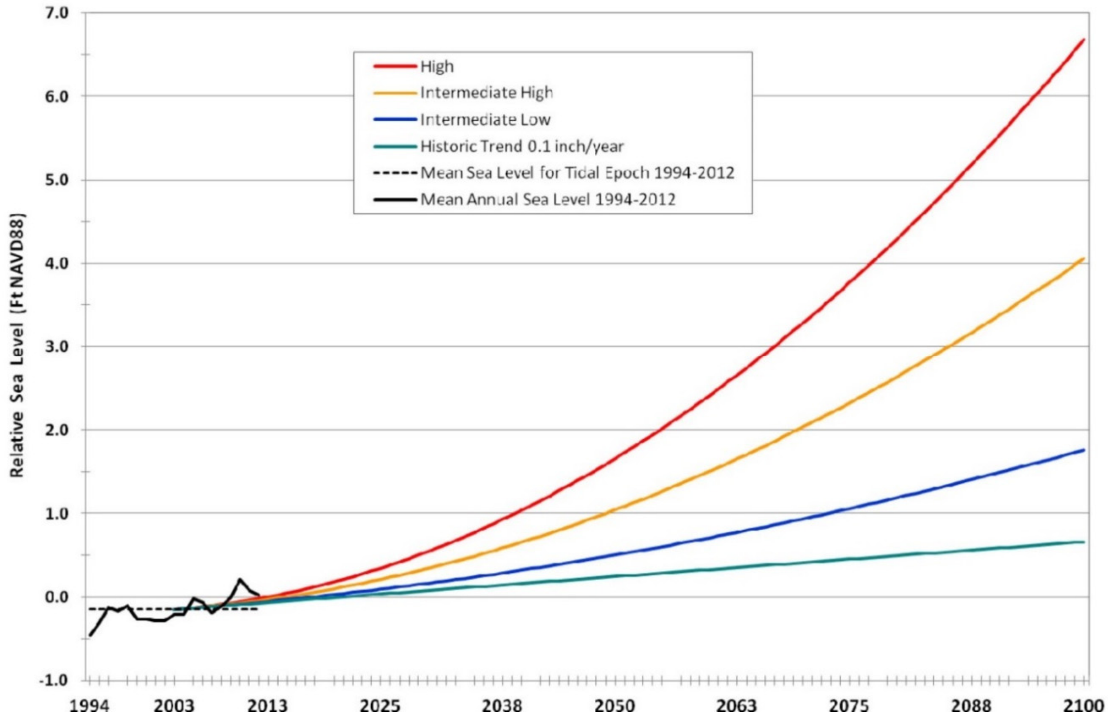



Figure 4.4 Relative sea level rise scenarios estimates (in feet NAVD88) for Boston, MA. Global scenarios from were adjusted to account for local vertical land movement with 2003 as the beginning year of analysis. (*Image source:* MCZM, 2013)

Sea level rise is not explicitly incorporated into the design of the mixed-sediment dunes, however monitoring of sea level rise trends and design modifications would become part of the ongoing maintenance requirement for the project. Under existing road elevations, a 2-foot rise in sea level would nearly flood the road's low sections during every high tide and the majority of the road would be submerged during even minor annual storm. The proposed elevation of the road is better prepared to prevent still-water flooding under sea level rise conditions.

## 4.4 Permitting and Next Steps

The following federal, state, and local permits and reviews are required for the project:

- MA Environmental Policy Act Environmental Notification Form
- MA Department of Environmental Protection Chapter 91 Permit
- MA Wetlands Protection Act Order of Conditions from the Town of Scituate Conservation Commission
- MA Coastal Zone Consistency Certification
- U.S. Army Corps of Engineers Section 10 and 404 Permits

The next steps for the Town are to secure funding for detailed design and permitting of the project. The Town must also obtain the appropriate easements prior to construction of the project if public funds are used. Project funding, public buy-in, and signing of public access easements are challenges that are anticipated in moving the project forward.

## 5.0 REFERENCES


Applied Coastal Research and Engineering (2016). Coastal Erosion, Sediment Transport, and Prioritization Management Strategy Assessment for Shoreline Protection. Prepared for the Town of Scituate. Mashpee, MA.

Byrnes, M.R., J.D. Rosati, and S.F. Griffee (2010). Littoral Sediment Budget for the Mississippi Sound Barrier Islands. Prepared for the Mississippi Coastal Improvements Program, USACE District Mobile, Mobile, AL.

FEMA (2007). Atlantic Ocean and Gulf of Mexico Coastal Guidelines Update. Michael Baker, Jr., Inc., Denton, TX.

FEMA (2012). "Flood Insurance Study, Plymouth County, Massachusetts, All Jurisdictions, Volume 1".

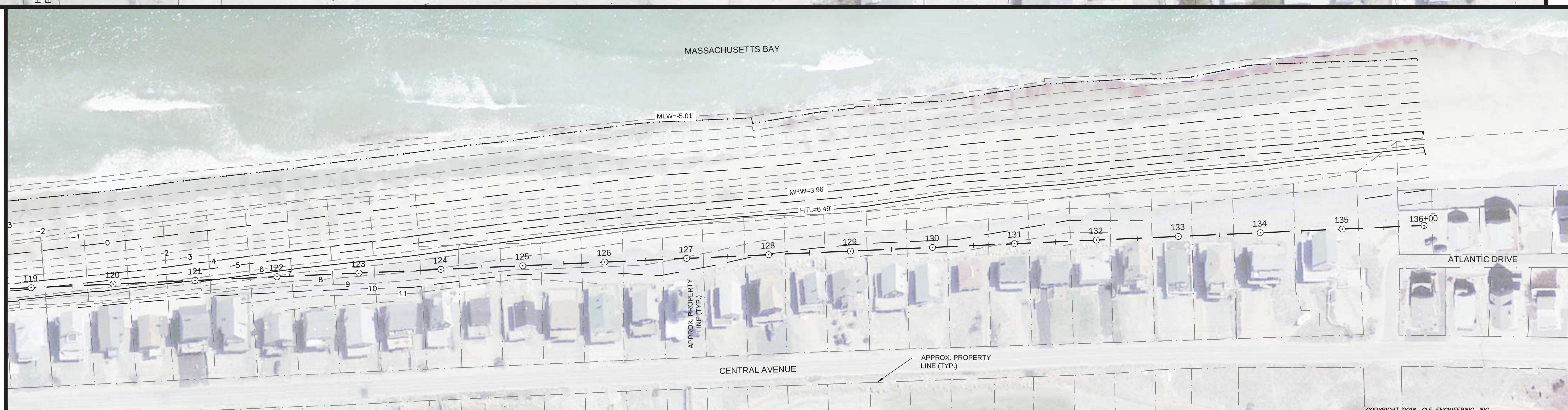
Massachusetts Coastal Zone Management Office (2013). Sea Level Rise: Understanding and Applying Trends and Future Scenarios for Analysis and Planning. Boston, MA.

Powell, K.A. 1990. Predicting short term profile response for shingle beaches, Hydraulics Research Report SR219, Wallingford, UK

## APPENDIX A – TOPOGRAPHIC BEACH SURVEY BY CLE ENGINEERING

MATCH LINE- SEE BELOW


MATCH LINE- SEE ABOVE

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# EXISTING SITE CONDITIONS

GRAPHIC SCALE

0 30 60 120

(IN FEET)
1 INCH = 60 FEET

DATUM OFFSETS

| MLW | NAVD88 | |
|---|---|---|
| 11.50 | 6.49 | HTL |
| 8.97 | 3.96 | MHW |
| 5.01 | 0 | |
| 0 | -5.01 | MLW |

NOTES:
1. RESULTS OF TOPOGRAPHIC SURVEY BY CLE ENGINEERING, INC. (CLE) ON 08/12/16.
2. ELEVATIONS ARE IN FEET AND TENTHS, AND REFER TO THE NAVD88 MLW= -5.01'; MHW= +3.93; HTL= +6.49'.
3. SITE BENCHMARK IS A MONUMENT (DISK) SET IN A RETAINING WALL PROVIDED BY THE NATIONAL OCEAN SERVICE. DESIGNATION: 844 5138 A. LONGITUDE -70°43'34.77776", LATITUDE 42°12'4.24353".
4. APPROXIMATE PROPERTY LINES SHOWN ARE BASED UPON MOST RECENT AVAILABLE MASS GIS DATA AND ARE NOT INDEPENDENTLY CONFIRMED.
5. POSSESSION AND USE OF THE MATERIAL CONTAINED ON THESE DRAWINGS IS GRANTED ONLY IN CONNECTION WITH ITS USE AS IT RELATES TO THE TITLED PROJECT, ANY OTHER USE, REPRODUCTION OR DISCLOSURE OF THE INFORMATION CONTAINED HEREON IS EXPRESSLY PROHIBITED WITHOUT THE WRITTEN CONSENT OF CLE ENGINEERING INC.

PROJECT: HUMAROCK BEACH NOURISHMENT PROJECT
SCITUATE–MARSHFIELD, MA

CLIENT: TOWN OF SCITUATE
600 CHIEF JUSTICE CUSHING HIGHWAY
SCITUATE, MA 02066

cleengineering
15 Creek Road | Marion, Massachusetts 02738
t: 508.748.0937 | www.cleengineering.com

EXISTING CONDITIONS SURVEY
SURVEY DATE 8-12-16

SHEET 1 OF 1

| SCALE: AS NOTED | CHECKED | DATE: AUGUST 2016 | JOB No. 13067.100 |
|---|---|---|---|
| DRAWN BY: CFF | BY: JMP | | |
| REVISION No. | DATE | COMMENT | |

## APPENDIX B – VISUAL SURVEY OF HOUSES

Survey completed on February 2, 2017 by Applied Coastal.

| | | |
|---|---|---|
| **Address** | 10 Cliff Road South |  |
| **Road Elevation** | 9.2 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway | |
| **Address** | 8 Cliff Road South |  |
| **Road Elevation** | 7.54 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway | |
| **Address** | 6 Cliff Road South |  |
| **Road Elevation** | 6.99 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway | |
| **Address** | 4 Cliff Road South |  |
| **Road Elevation** | 6.74 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway | |
| **Address** | 2 Cliff Road South |  |
| **Road Elevation** | 6.66 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~9’ above road<br>Unpaved driveway | |

| | | |
|---|---|---|
| **Address** | 300 Central Avenue |  |
| **Road Elevation** | 6.63 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~8' above road<br>Unpaved driveway | |
| **Address** | 298 Central Avenue |  |
| **Road Elevation** | 6.94 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Older homes rasied on concrete piles ~8' above road<br>Unpaved driveway | |
| **Address** | 296 Central Avenue |  |
| **Road Elevation** | 7.15 feet NAVD88 | |
| **Ease of Construction** | Challenge, but could be okay because of distance from road | |
| **Notes** | Older home on solid concrete foundation<br>Door and window in basement<br>~8' deck overhand<br>Slab looks to be ~1' above road | |
| **Address** | 294 Central Avenue |  |
| **Road Elevation** | 7.49 feet NAVD88 | |
| **Ease of Construction** | Challenge, but could be okay because of distance from road | |
| **Notes** | Older home on solid concrete foundation with garage and side door<br>~6' deck overhand<br>Slab looks to be ~0.5' above road | |
| **Address** | 292 Central Avenue |  |
| **Road Elevation** | 7.23 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~8' above road<br>Unpaved driveway | |

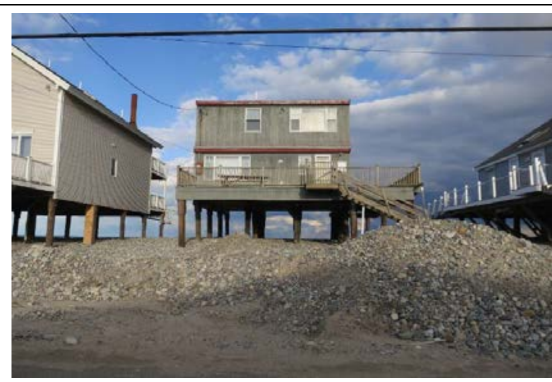
| | | |
|---|---|---|
| **Address** | 290 Central Avenue |  |
| **Road Elevation** | 7.42 feet NAVD88F | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~8' above road<br>Unpaved driveway | |
| **Address** | 288 Central Avenue |  |
| **Road Elevation** | 7.47 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~8' above road<br>Unpaved driveway | |
| **Address** | 286 Central Avenue |  |
| **Road Elevation** | 7.54 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~8' above road<br>Unpaved driveway | |
| **Address** | 284 Central Avenue |  |
| **Road Elevation** | 7.57 feet NAVD88 | |
| **Ease of Construction** | Challenge | |
| **Notes** | Home rehabbed on solid foundation<br>Slab at roadway elevation<br>Living space in basement<br>Brick chimney | |
| **Address** | 282 Central Avenue |  |
| **Road Elevation** | 7.79 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house raised on piles ~8' above road<br>Unpaved driveway | |

| | |
|---|---|
| **Address** | 280 Central Avenue |
| **Road Elevation** | 7.76 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 278 Central Avenue |
| **Road Elevation** | 7.52 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway<br>Across from town-dug overwash channel |

| | |
|---|---|
| **Address** | 276 Central Avenue |
| **Road Elevation** | 7.55 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 274 Central Avenue |
| **Road Elevation** | 7.24 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway |



| | |
|---|---|
| **Address** | 272 Central Avenue |
| **Road Elevation** | 7.12 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 271 Central Avenue |
| **Road Elevation** | 7.24 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | House on solid foundation on filled lot |

| | |
|---|---|
| **Address** | 270 Central Avenue |
| **Road Elevation** | 7.48 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 268 Central Avenue |
| **Road Elevation** | 7.34 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 266 Central Avenue |
| **Road Elevation** | 7.65 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern house raised on piles ~8’ above road<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 265 Central Avenue |
| **Road Elevation** | 7.65 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | House on solid foundation ~1.5’ above road |

| | |
|---|---|
| **Address** | 264 Central Avenue |
| **Road Elevation** | 7.98 feet NAVD88 |
| **Ease of Construction** | Challenge |
| **Notes** | House on solid concrete foundation with garage<br>Slab elevation ~1’ above road |

| | |
|---|---|
| **Address** | 262 Central Avenue |
| **Road Elevation** | 8.33 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern house on piles ~8’ above road<br>Unpaved driveway |

| | |
|---|---|
| **Address** | **261 Central Avenue** |
| **Road Elevation** | **7.98 feet NAVD88** |
| **Ease of Construction** | **Challenge/Acceptable** |
| **Notes** | **Concrete driveway ~6” above road** |

| | |
|---|---|
| **Address** | 260 Central Avenue |
| **Road Elevation** | 8.84 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Solid foundation with living space underneath<br>Paved driveway<br>Slab at road elevation<br>~8’ deck overhang |

| | |
|---|---|
| **Address** | 258 Central Avenue |
| **Road Elevation** | 9.37 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Newer home on piles ~8’ above road<br>10’ deck overhang<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 257 Central Avenue |
| **Road Elevation** | 9.69 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Solid foundation ~1’ above road<br>Paved driveway |

| | |
|---|---|
| **Address** | 256 Central Avenue |
| **Road Elevation** | 9.69 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Rehab on solid concrete foundation with brick fireplace<br>Slab ~6” above road<br>Garage<br>~8’ deck overhang<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 254 Central Avenue |
| **Road Elevation** | 9.88 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Newer rehab home on cinder block foundation<br>Living quarters underneath home<br>Paved driveway<br>Slab at roadway elevation |

| | |
|---|---|
| **Address** | 253 Central Avenue |
| **Road Elevation** | 9.78 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Brick house ~2’ above road<br>Lawn<br>Paved driveway |

| | |
|---|---|
| **Address** | 252 Central Avenue |
| **Road Elevation** | 9.78 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Older home on solid foundation with storage doors underneath<br>~6’ deck overhang<br>Unpaved driveway |

| | | |
|---|---|---|
| **Address** | 250 Central Avenue |  |
| **Road Elevation** | 9.65 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Newer house on piles<br>~10’ deck overhang<br>Unpaved driveway | |
| **Address** | 248 Central Avenue |  |
| **Road Elevation** | 9.28 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Newer house on piles ~10’ above road<br>Brick chimney on slab with concrete piles(?)<br>Unpaved driveway | |
| **Address** | 247 Central Avenue |  |
| **Road Elevation** | 9.28 feet NAVD88 | |
| **Ease of Construction** | Problem | |
| **Notes** | Brick driveway could be costly<br>Solid foundation<br>Road slope could redirect flood into house | |
| **Address** | 244/246 Central Avenue |  |
| **Road Elevation** | 8.78 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Newer house on piles<br>Fire hydrant adjacent to deck<br>Unpaved driveway | |
| **Address** | 242 Central Avenue |  |
| **Road Elevation** | 8.42 feet NAVD88 | |
| **Ease of Construction** | Acceptable(?) | |
| **Notes** | Newer or rehabbed home on solid foundation<br>Living space in basement ~1’ above road<br>Paved driveway<br>Large concrete slab around front and north side of home | |

| | | |
|---|---|---|
| **Address** | 240 Central Avenue |  |
| **Road Elevation** | 7.90 feet NAVD88 | |
| **Ease of Construction** | Acceptable, slab at road elevation | |
| **Notes** | Newer or rehabbed home on solid foundation<br>Garage door and living space in basement<br>Paved driveway<br>~8' deck overhand<br>Concrete side yard to north<br>Significant overwash | |
| **Address** | 238 Central Avenue |  |
| **Road Elevation** | 7.72 feet NAVD88 | |
| **Ease of Construction** | Acceptable | |
| **Notes** | Newer home on solid concrete foundation<br>~20' porch and deck overhang<br>Slab ~2' above road<br>Paved driveway | |
| **Address** | 236 Central Avenue |  |
| **Road Elevation** | 7.56 feet NAVD88 | |
| **Ease of Construction** | Problem | |
| **Notes** | Older home on solid concrete foundation<br>Door to basement – unclear whether this is only storage<br>Brick chimney<br>Significant overwash<br>Unpaved driveway | |
| **Address** | 234 Central Avenue |  |
| **Road Elevation** | 7.26 feet NAVD88 | |
| **Ease of Construction** | Problem | |
| **Notes** | Older home with solid foundation<br>Significant signs of overwash<br>Living space downstairs<br>Concrete slab under deck | |
| **Address** | 232 Central Avenue |  |
| **Road Elevation** | 7.35 feet NAVD88 | |
| **Ease of Construction** | Acceptable | |
| **Notes** | Modern house on concrete foundation<br>Slab at road level<br>Paved driveway<br>Door in basement with window but looks like storage<br>~12' deck overhang | |

| | |
|---|---|
| **Address** | 230 Central Avenue |
| **Road Elevation** | 7.54 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern house on piles<br>Floor ~8’ above road<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 228 Central Avenue |
| **Road Elevation** | 7.64 feet NAVD88 |
| **Ease of Construction** | Challenge |
| **Notes** | Newer home on solid foundation<br>Garage and living space in basement<br>~10’ deck overhang<br>Paved driveway<br>Slab ~1’ above road<br>Brick chimney |

| | |
|---|---|
| **Address** | 226 Central Avenue |
| **Road Elevation** | 8.14 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Modern home on piles<br>Floor ~8’ above road<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 224 Central Avenue |
| **Road Elevation** | 8.39 feet NAVD88 |
| **Ease of Construction** | Problem |
| **Notes** | Newer home with solid foundation<br>~12’ deck overhang<br>House is ~23-25’ from road<br>Living space in basement with door<br>Unpaved driveway<br>Slab at roadway elevation |

| | |
|---|---|
| **Address** | 222 Central Avenue |
| **Road Elevation** | 8.82 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Newer home on solid foundation<br>Garage door<br>~18’ deck overhang<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 220 Central Avenue |
| **Road Elevation** | 9.05 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Newer home on solid foundation<br>Garage door and side door<br>~20’ deck overhang<br>Basement floor ~1’ above road<br>Concrete slab under deck<br>Driveway unpaved |

| | |
|---|---|
| **Address** | 218 Central Avenue |
| **Road Elevation** | 9.17 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Newer home on old cinder block foundation<br>Foundation extends to within 4’ of deck overhang<br>Looks like storage underneath<br>Basement elevation ~1’ above road |

| | |
|---|---|
| **Address** | 216 Central Avenue |
| **Road Elevation** | 9.64 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | White older home on solid foundation<br>~10’ deck overhang<br>Unpaved driveway<br>Looks like door to storage in basement<br>Basement floor near elevation of road |

| | |
|---|---|
| **Address** | 214 Central Avenue |
| **Road Elevation** | 9.66 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Cape style home on open piles<br>~15’ deck overhang<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 212 Central Avenue |
| **Road Elevation** | 9.80 feet NAVD88 |
| **Ease of Construction** | Problem, but road elevation is high |
| **Notes** | Yellow/blue house on solid foundation<br>Concrete driveway<br>Living space in basement<br>~10’ deck overhang<br>Garage ~1’ above road |

| | | |
|---|---|---|
| **Address** | 210 Central Avenue |  |
| **Road Elevation** | 9.77 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | House on piles ~8’ above road | |
| **Address** | 208 Central Avenue |  |
| **Road Elevation** | 9.45 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house on piles ~7’ above road<br>~20’ deck overhang<br>Unpaved driveway | |
| **Address** | 206 Central Avenue |  |
| **Road Elevation** | 9.19 feet NAVD88 | |
| **Ease of Construction** | Acceptable | |
| **Notes** | Older home on solid foundation<br>Storage with door underneath at road elevation<br>Revetment ends, overwash to north | |
| **Address** | 204 Central Avenue |  |
| **Road Elevation** | 8.81 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | House on piles ~8’ above road<br>Unpaved driveway | |
| **Address** | 202 Central Avenue |  |
| **Road Elevation** | 8.64 feet NAVD88 | |
| **Ease of Construction** | Acceptable | |
| **Notes** | Gray/blue older home on solid foundation<br>Living space with sliders in basement ~1’ above road<br>Unpaved driveway | |

| | |
|---|---|
| **Address** | 200 Central Avenue |
| **Road Elevation** | 8.28 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Modernized solid foundation with living space in basement<br>Basement ~1' above road<br>Shell driveway |

| | |
|---|---|
| **Address** | 198 Central Avenue |
| **Road Elevation** | 8.18 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Older home with surrounding deck on piles<br>Solid foundation with living space underneath at road level<br>Concrete walls around house to direct flooding<br>Also concrete walkway to north<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 196 Central Avenue |
| **Road Elevation** | 8.18 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Older home on solid foundation<br>Concrete patio on south side<br>Doors to storage in basement<br>Basement ~2' above road<br>Main floor ~10' above road |

| | |
|---|---|
| **Address** | 194 Central Avenue |
| **Road Elevation** | 7.56 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Older home on concrete piers<br>House ~8' above road<br>Unpaved driveway |

| | |
|---|---|
| **Address** | 192 Central Avenue |
| **Road Elevation** | 7.22 feet NAVD88 |
| **Ease of Construction** | Acceptable |
| **Notes** | Older condemned-looking home<br>2 garages half-buried in cobble<br>Basement door<br>~10' deck overhang<br>Unsupported piles broken off<br>Pile of cobble along road |

| | | |
|---|---|---|
| **Address** | 190 Central Avenue |  |
| **Road Elevation** | 7.03 feet NAVD88 | |
| **Ease of Construction** | Acceptable | |
| **Notes** | Older home on solid foundation<br>Paved driveway with lawn to south<br>Garage ~1.5' above road | |
| **Address** | 188 Central Avenue |  |
| **Road Elevation** | 6.62 feet NAVD88 | |
| **Ease of Construction** | Acceptable | |
| **Notes** | Modern or rehabbed home with solid foundation<br>Garage underneath with ~10' deck overhang<br>Garage on north side<br>Garage level about ~1' above road | |
| **Address** | 186 Central Avenue |  |
| **Road Elevation** | 6.83 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house on piles<br>House ~9' above road<br>Overwash to north<br>Unpaved driveway | |
| **Address** | 184 Central Avenue |  |
| **Road Elevation** | 6.93 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Older single story home on piles<br>Unpaved driveway<br>Signs of overwash to the north<br>House ~9' above road | |
| **Address** | 182 Central Avenue |  |
| **Road Elevation** | 7.06 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house on piles with wood grating underneath<br>House ~10' above road<br>Paved driveway | |

| | | |
|---|---|---|
| **Address** | 180 Central Avenue |  |
| **Road Elevation** | 7.10 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | House on piles ~10’ above road<br>Signs of overwash south of house<br>Unpaved driveway | |
| **Address** | 178 Central Avenue |  |
| **Road Elevation** | 7.21 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house on piles ~10’ above road<br>Driveway off of Seaview Avenue | |
| **Address** | 176 Central Avenue |  |
| **Road Elevation** | 7.68 feet NAVD88 | |
| **Ease of Construction** | Challenge | |
| **Notes** | House on solid concrete foundation<br>Full height basement above ground with door, likely storage space<br>~10’ deck overhang<br>Unpaved driveway | |
| **Address** | 174 Central Avenue |  |
| **Road Elevation** | 7.63 feet NAVD88 | |
| **Ease of Construction** | Acceptable | |
| **Notes** | Solid foundation under main house<br>Crawlspace door in solid foundation<br>Approximate 18’ of extended deck is on block “piles”<br>Unpaved driveway<br>Floor ~6’ above road<br>Yellow fire hydrant in front | |
| **Address** | 172 Central Avenue |  |
| **Road Elevation** | 7.51 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Pile foundation approximately 10-20 years old<br>~12’ deck overhang<br>Paver tile driveway<br>House floor ~8’ above road | |

| | | |
|---|---|---|
| **Address** | 170 Central Avenue |  |
| **Road Elevation** | 7.46 feet NAVD88 | |
| **Ease of Construction** | Challenge | |
| **Notes** | Older home on solid foundation<br>Small door in foundation, likely for storage<br>~10’ deck overhang<br>House ~25’ back from road<br>Paved driveway | |
| **Address** | 168 Central Avenue |  |
| **Road Elevation** | 7.30 feet NAVD88 | |
| **Ease of Construction** | Challenge | |
| **Notes** | Updated older home with solid foundation and garage<br>Garage floor ~1’ above road<br>Other door and living space under home<br>~10’ deck overhang<br>Main floor ~8’ above road | |
| **Address** | 164 Central Avenue |  |
| **Road Elevation** | 7.09 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Older home with solid block foundation<br>~8’ covered porch<br>Floor ~3’ above road<br>Crawl space under house<br>Overwash channel across street between #164 and #168 | |
| **Address** | 162 Central Avenue |  |
| **Road Elevation** | 7.02 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | House on cinder block piles<br>Floor ~5’ above road<br>~4.5’ deck overhang<br>Paved driveway<br>Signs of flow-induced erosion on concrete driveway | |
| **Address** | 160 Central Avenue |  |
| **Road Elevation** | 7.00 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Older house raised on series of shore-perpendicular block strips<br>Signs of overwash from ocean<br>House ~3-4’ above road<br>Paved driveway | |

| | | |
|---|---|---|
| **Address** | 158 Central Avenue |  |
| **Road Elevation** | 7.10 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Older home with solid block and concrete foundation<br>Crawl space under house<br>Paved driveway<br>Lots of wrack from high tide in driveway | |
| **Address** | 156 Central Avenue |  |
| **Road Elevation** | 7.23 feet NAVD88 | |
| **Ease of Construction** | Challenge | |
| **Notes** | Older home with solid concrete foundation<br>Living space in basement<br>~10’ deck overhang<br>Paved driveway<br>Side door on southwest corner | |
| **Address** | 152 Central Avenue |  |
| **Road Elevation** | 7.42 feet NAVD88 | |
| **Ease of Construction** | Challenge | |
| **Notes** | Older home on solid block foundation<br>Looks like basement windows<br>Paved driveway<br>House flood ~2-3’ above street | |
| **Address** | 150 Central Avenue |  |
| **Road Elevation** | 7.56 feet NAVD88 | |
| **Ease of Construction** | Challenge/Acceptable | |
| **Notes** | Modern house with solid foundation<br>Stairs up from carport<br>Large overhanging carport/deck ~18-20’<br>Challenge due to carport posts but appears okay for fill<br>Floor is ~3’ above road | |
| **Address** | 148 Central Avenue |  |
| **Road Elevation** | 7.79 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Modern house on good piles with bracing<br>No problem with fill but bush landscaping will be affected | |

| | |
|---|---|
| **Address** | 146 Central Avenue |
| **Road Elevation** | 8.07 feet NAVD88 |
| **Ease of Construction** | Challenge |
| **Notes** | House on solid foundation<br>No garage<br>~8’ deck overhang<br>Paved driveway at same elevation as road<br>Should be able to bring fill up ~2 ft against house<br>Side access door could be a challenge |

| | |
|---|---|
| **Address** | 144 Central Avenue |
| **Road Elevation** | 8.10 feet NAVD88 |
| **Ease of Construction** | Challenge |
| **Notes** | House on solid foundation with garage and basement living space<br>~10’ deck overhang<br>Paved driveway<br>Garage ~1’ above road |

| | |
|---|---|
| **Address** | 140 Central Avenue |
| **Road Elevation** | 8.14 feet NAVD88 |
| **Ease of Construction** | Problem |
| **Notes** | Small house on block foundation<br>Floor ~2’ above road<br>Stone chimney<br>Paved driveway<br>Difficult to raise road more than 2 feet |

| | |
|---|---|
| **Address** | 138 Central Avenue |
| **Road Elevation** | 8.22 feet NAVD88 |
| **Ease of Construction** | Good |
| **Notes** | Small house with block foundation<br>Floor ~2.5’ above road<br>Paved driveway south of house |

| | |
|---|---|
| **Address** | 134 Central Avenue |
| **Road Elevation** | 7.94 feet NAVD88 |
| **Ease of Construction** | Challenge |
| **Notes** | House on solid foundation<br>Garage ~0.5-1’ above road<br>~12’ deck overhang |

| | | |
|---|---|---|
| **Address** | 130 Central Avenue |  |
| **Road Elevation** | 8.11 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | Driveway ~8’ above road | |
| **Address** | 128 Central Avenue |  |
| **Road Elevation** | 7.29 feet NAVD88 | |
| **Ease of Construction** | Good | |
| **Notes** | No problems | |

## APPENDIX C – SEDIMENT SAMPLING RESULTS

Sediment samples collected on February 2, 2017 by Applied Coastal.

Briggs Engineering & Testing
A Division of PK Associates, Inc.

Applied Coastal Research & Eng.
766 Falmouth Road
Suite A-1
Mashpee, MA 02649
Attn: Mr. Trey Ruthven

Report Date: 3/8/17

Project: **Humarock Beach, Scituate**
Briggs #: 23618

Tested: 3/7/17
Received: 3/3/17

| 1 | Sample No. | Description | Source of Material |
|---|---|---|---|
| | M-28218 | Existing Material | Humarock Beach North |

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

| Sieve Size Standard | Sieve Size Alternate | Results {% Passing by Wt.} | Specifications |
|---|---|---|---|
| 100 mm | 4" | 100 | |
| 90 mm | 3-1/2" | 94 | |
| 75 mm | 3" | 89 | |
| 63 mm | 2-1/2" | 89 | |
| 50 mm | 2" | 66 | |
| 37.5 mm | 1-1/2" | 51 | |
| 25 mm | 1" | 39 | |
| 19 mm | 3/4" | 33 | |
| 12.5 mm | 1/2" | 26 | |
| 9.5 mm | 3/8" | 24 | |
| 4.75 mm | #4 | 22 | |
| 2.36 mm | #8 | 21 | |
| 2.00 mm | #10 | 21 | |
| 1.18 mm | #16 | 16 | |
| 0.600 mm | #30 | 10 | |
| 0.422 mm | #40 | 7 | |
| 0.300 mm | #50 | 4 | |
| 0.211 mm | #70 | 1 | |
| 0.150 mm | #100 | 0 | |
| 0.075 mm | #200 | 0.0 | |

BRIGGS ENGINEERING & TESTING
*A Division of PK Associates, Inc.*

Sean Skorohod

Sean Skorohod
Director of Testing Services
Construction Technology Division



100 Weymouth Street - Unit C-2
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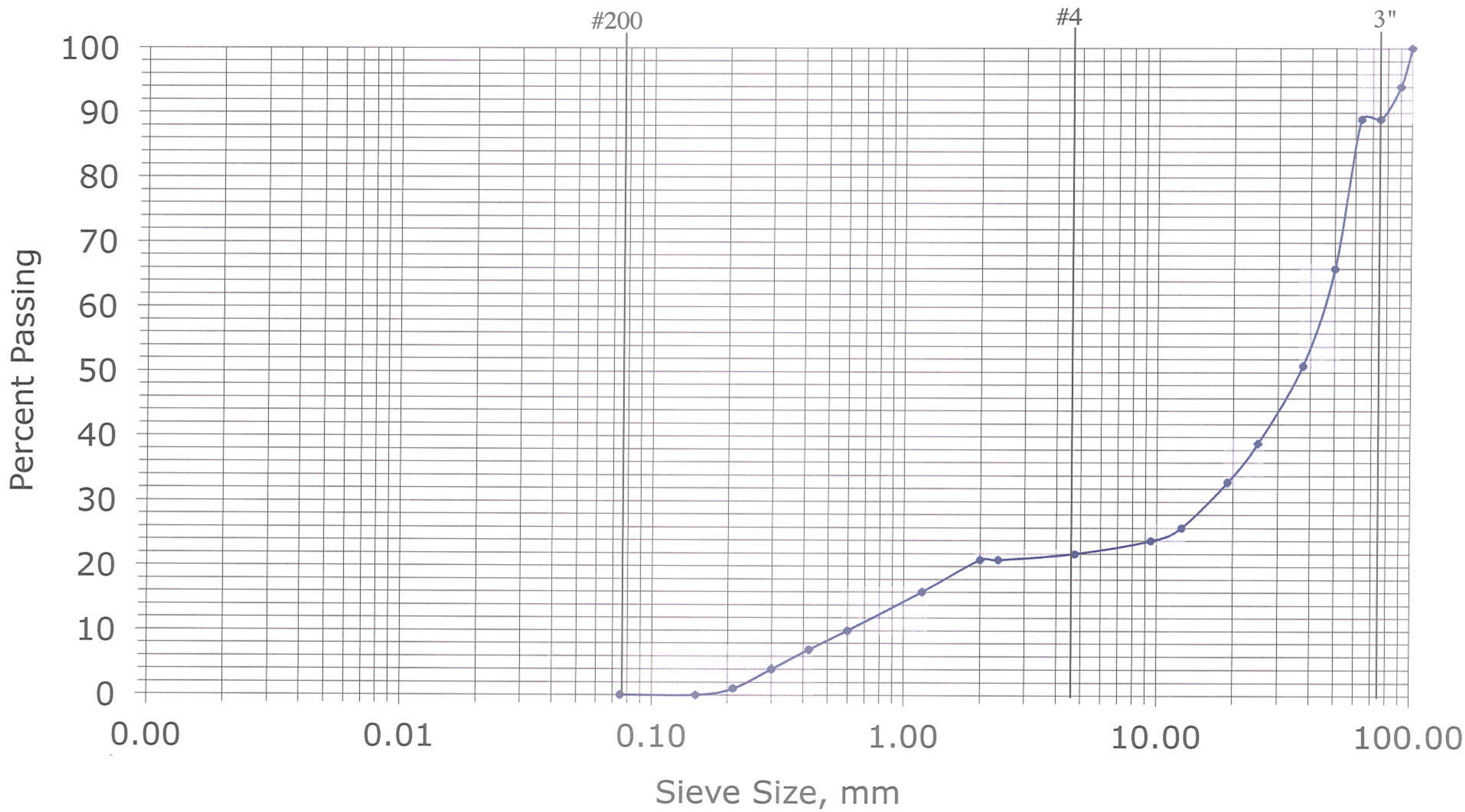
100 Pound Road
Cumberland, RI 02864
Phone (401) 658-2990 • Fax (401) 658-2977

Briggs Engineering & Testing
A Division of PK Associates, Inc.

| | |
|---|---|
| Project: | Humarock Beach, Scituate |
| Date Tested: | 3/7/17 |
| Lab Ref. No.: | M-28218 |

## Sieve Analysis



Briggs Engineering & Testing
*A Division of PK Associates, Inc.*

Applied Coastal Research & Eng.
766 Falmouth Road
Suite A-1
Mashpee, MA 02649
Attn: Mr. Trey Ruthven

Report Date: 3/8/17

Project: **Humarock Beach, Scituate**
Briggs #: 23618

Tested: 3/7/17
Received: 3/3/17

1

| Sample No. | Description | Source of Material |
|---|---|---|
| M-28219 | Existing Material | Humarock Beach South |

2. Sieve Analysis {ASTM C 136, and ASTM C 117}

| Sieve Size | | Results | Specifications |
|---|---|---|---|
| Standard | Alternate | {% Passing by Wt.} | |
| 100 mm | 4" | 100 | |
| 90 mm | 3-1/2" | 100 | |
| 75 mm | 3" | 100 | |
| 63 mm | 2-1/2" | 78 | |
| 50 mm | 2" | 67 | |
| 37.5 mm | 1-1/2" | 65 | |
| 25 mm | 1" | 49 | |
| 19 mm | 3/4" | 43 | |
| 12.5 mm | 1/2" | 28 | |
| 9.5 mm | 3/8" | 19 | |
| 4.75 mm | #4 | 2 | |
| 2.36 mm | #8 | 1 | |
| 2.00 mm | #10 | 1 | |
| 1.18 mm | #16 | 1 | |
| 0.600 mm | #30 | 1 | |
| 0.422 mm | #40 | 1 | |
| 0.300 mm | #50 | 1 | |
| 0.211 mm | #70 | 1 | |
| 0.150 mm | #100 | 0 | |
| 0.075 mm | #200 | 0.0 | |

BRIGGS ENGINEERING & TESTING
*A Division of PK Associates, Inc.*

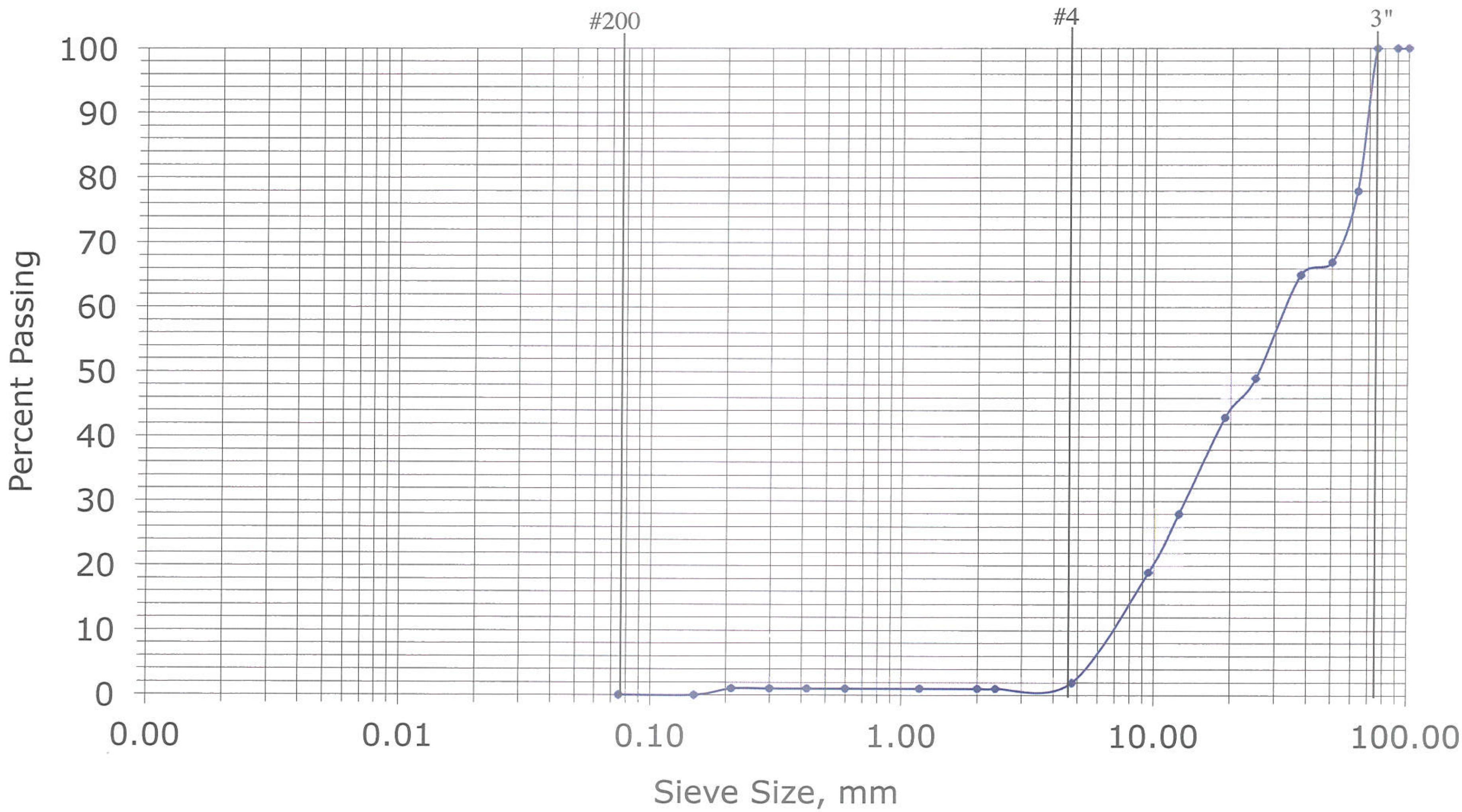
Sean Skorohod

Sean Skorohod
Director of Testing Services
Construction Technology Division

Briggs Engineering & Testing
A Division of PK Associates, Inc.

| | |
|---|---|
| Project: | Humarock Beach, Scituate |
| Date Tested: | 3/7/17 |
| Lab Ref. No.: | M-28219 |

## Sieve Analysis



# APPENDIX D – TYPICAL DRIVEWAY TIE-IN SECTIONS – BY HOUSE

| Address | Existing Road Elevation (ft, NAVD88) | Proposed Road Elevation (ft, NAVD88) | Elevation Increase (feet) | Typical Driveway Section | Address | Existing Road Elevation (ft, NAVD88) | Proposed Road Elevation (ft, NAVD88) | Elevation Increase (feet) | Typical Driveway Section |
|---|---|---|---|---|---|---|---|---|---|
| 10 Cliff Rd South | 9.2 | 10.2 | 1.0 | A | 228 Central Ave | 7.7 | 9.5 | 1.8 | B |
| 8 Cliff Rd South | 7.5 | 10.0 | 2.5 | A | 226 Central Ave | 8.1 | 9.5 | 1.4 | A |
| 6 Cliff Rd South | 7.0 | 10.0 | 3.0 | A | 224 Central Ave | 8.6 | 9.5 | 1.0 | C |
| 4 Cliff Rd South | 6.9 | 10.0 | 3.1 | A | 222 Central Ave | 8.8 | 9.6 | 0.8 | B |
| 2 Cliff Rd South | 6.7 | 10.0 | 3.3 | A | 220 Central Ave | 9.1 | 9.7 | 0.6 | B |
| 300 Central Ave | 6.6 | 10.0 | 3.4 | A | 218 Central Ave | 9.2 | 9.8 | 0.6 | B |
| 298 Central Ave | 7.0 | 10.0 | 3.0 | A | 216 Central Ave | 9.6 | 9.9 | 0.3 | B |
| 296 Central Ave | 7.2 | 10.0 | 2.8 | C | 214 Central Ave | 9.7 | 9.9 | 0.1 | A |
| 294 Central Ave | 7.5 | 10.0 | 2.5 | C | 212 Central Ave | 9.9 | 9.9 | 0.0 | B |
| 292 Central Ave | 7.4 | 10.0 | 2.6 | A | 210 Central Ave | 9.8 | 9.9 | 0.1 | A |
| 290 Central Ave | 7.7 | 10.0 | 2.3 | A | 208 Central Ave | 9.4 | 9.8 | 0.4 | A |
| 288 Central Ave | 7.5 | 10.0 | 2.5 | A | 206 Central Ave | 9.2 | 9.7 | 0.6 | B |
| 286 Central Ave | 7.5 | 10.0 | 2.5 | A | 204 Central Ave | 8.8 | 9.6 | 0.9 | A |
| 284 Central Ave | 7.7 | 10.0 | 2.3 | C | 202 Central Ave | 8.7 | 9.6 | 0.9 | B |
| 282 Central Ave | 7.9 | 10.0 | 2.1 | A | 200 Central Ave | 8.2 | 9.5 | 1.3 | B |
| 280 Central Ave | 7.8 | 10.0 | 2.2 | A | 198 Central Ave | 8.3 | 9.5 | 1.2 | B |
| 278 Central Ave | 7.5 | 10.0 | 2.5 | A | 196 Central Ave | 7.9 | 9.5 | 1.6 | B |
| 276 Central Ave | 7.5 | 10.0 | 2.5 | A | 194 Central Ave | 7.6 | 9.5 | 1.9 | A |
| 274 Central Ave | 7.4 | 10.0 | 2.6 | A | 192 Central Ave | 7.4 | 9.5 | 2.1 | B |
| 272 Central Ave | 7.1 | 10.0 | 2.9 | A | 190 Central Ave | 7.0 | 9.5 | 2.5 | B |
| 271 Central Ave | 7.1 | 10.0 | 2.9 | D | 188 Central Ave | 6.9 | 9.5 | 2.6 | B |
| 270 Central Ave | 7.6 | 10.0 | 2.4 | A | 186 Central Ave | 6.9 | 9.5 | 2.6 | A |
| 268 Central Ave | 7.4 | 10.0 | 2.6 | A | 184 Central Ave | 6.9 | 9.5 | 2.6 | A |
| 266 Central Ave | 7.8 | 10.0 | 2.2 | A | 182 Central Ave | 7.1 | 9.5 | 2.4 | A |
| 265 Central Ave | 8.0 | 10.0 | 2.0 | D | 180 Central Ave | 7.1 | 9.5 | 2.4 | A |
| 264 Central Ave | 8.0 | 10.0 | 2.0 | B | 178 Central Ave | 7.2 | 9.5 | 2.3 | A |
| 262 Central Ave | 8.3 | 10.0 | 1.7 | A | 176 Central Ave | 7.8 | 9.5 | 1.7 | C |
| 261 Central Ave | 8.1 | 10.0 | 1.9 | D | 174 Central Ave | 7.6 | 9.5 | 1.9 | E |
| 260 Central Ave | 8.8 | 10.0 | 1.2 | B | 172 Central Ave | 7.5 | 9.5 | 2.0 | A |
| 258 Central Ave | 9.3 | 10.0 | 0.7 | A | 170 Central Ave | 7.5 | 9.5 | 2.0 | C |
| 257 Central Ave | 9.7 | 10.0 | 0.4 | D | 168 Central Ave | 7.4 | 9.5 | 2.1 | E |
| 256 Central Ave | 9.7 | 10.0 | 0.4 | B | 164 Central Ave | 7.2 | 9.5 | 2.3 | C |
| 254 Central Ave | 10.0 | 10.1 | 0.1 | B | 162 Central Ave | 7.1 | 9.5 | 2.4 | A |
| 253 Central Ave | 9.8 | 10.1 | 0.4 | D | 160 Central Ave | 7.1 | 9.5 | 2.4 | A |
| 252 Central Ave | 9.8 | 10.1 | 0.4 | B | 158 Central Ave | 7.1 | 9.5 | 2.4 | C |
| 250 Central Ave | 9.7 | 10.1 | 0.4 | A | 156 Central Ave | 7.3 | 9.5 | 2.2 | C |
| 248 Central Ave | 9.3 | 10.0 | 0.8 | A | 152 Central Ave | 7.6 | 9.5 | 1.9 | C |
| 247 Central Ave | 9.3 | 10.0 | 0.8 | D | 150 Central Ave | 7.5 | 9.5 | 2.0 | E |
| 244/246 Central Ave | 8.8 | 9.7 | 0.9 | A | 148 Central Ave | 7.7 | 9.5 | 1.8 | A |
| 242 Central Ave | 8.4 | 9.5 | 1.1 | B | 146 Central Ave | 8.1 | 9.5 | 1.4 | C |
| 240 Central Ave | 8.0 | 9.5 | 1.5 | B | 144 Central Ave | 8.1 | 9.5 | 1.4 | C |
| 238 Central Ave | 7.7 | 9.5 | 1.8 | B | 140 Central Ave | 8.3 | 9.5 | 1.2 | C |
| 236 Central Ave | 7.7 | 9.5 | 1.8 | C | 138 Central Ave | 8.3 | 9.5 | 1.2 | C |
| 234 Central Ave | 7.3 | 9.5 | 2.2 | C | 134 Central Ave | 8.1 | 9.2 | 1.0 | C |
| 232 Central Ave | 7.4 | 9.5 | 2.1 | C | 130 Central Ave | 8.3 | 8.5 | 0.2 | C |
| 230 Central Ave | 7.6 | 9.5 | 1.9 | A | | | | | |

## APPENDIX E – CONCEPTUAL PLANS


## KEY SITE PLAN

0 160 320 640

SCALE: 1" = 160'

NOTES:

1. RESULTS OF TOPOGRAPHIC SURVEY BY CLE ENGINEERING, INC. (CLE) ON 08/12/16.
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3. EXISTING ROADWAY LIDAR PROVIDED BY APPLIED COASTAL RESEARCH AND ENGINEERING, INC.
4. ELEVATIONS ARE IN FEET AND TENTHS, AND REFER TO THE NAVD88 MLW= -5.01'; MHW= +3.93; HTL= +6.49'.
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SCITUATE, MA

CLIENT: TOWN OF SCITUATE
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SCITUATE, MA 02066

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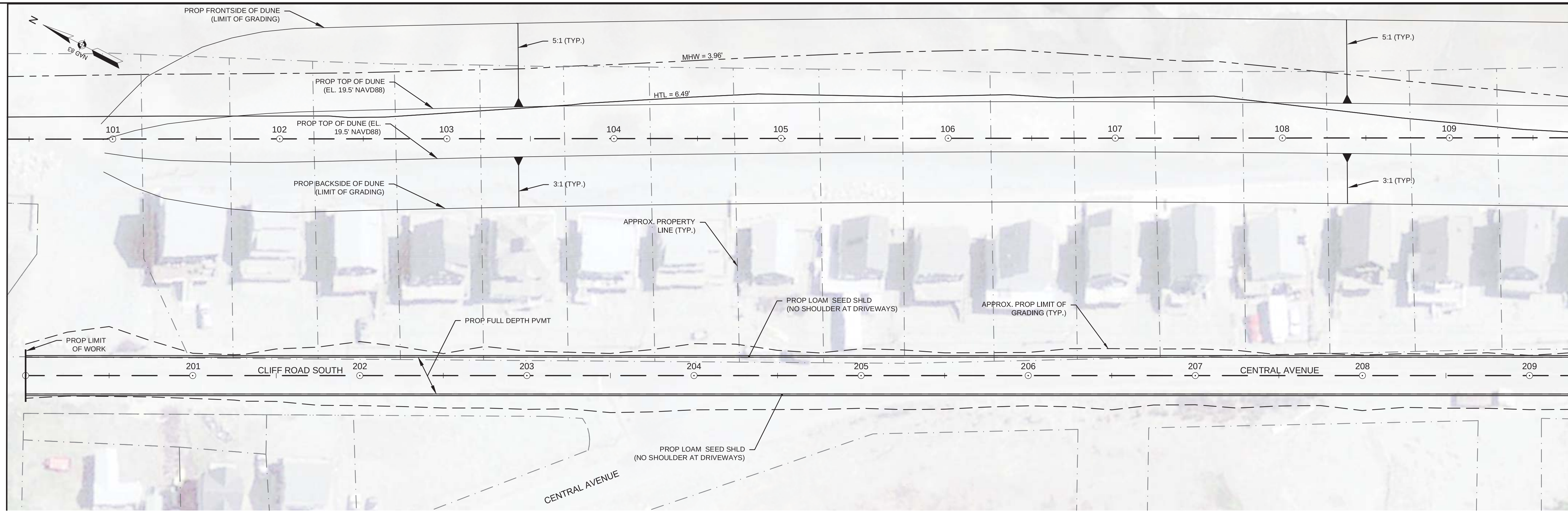
CENTRAL AVENUE RECONSTRUCTION & BEACH NOURISHMENT KEY PLAN

SHEET 1 OF 8

| SCALE: AS NOTED | CHECKED | DATE: JUNE 2017 | JOB No. 16266.100 |
|---|---|---|---|
| DRAWN BY: CJP | BY: JMP | | |
| REVISION No. | DATE | COMMENT | |

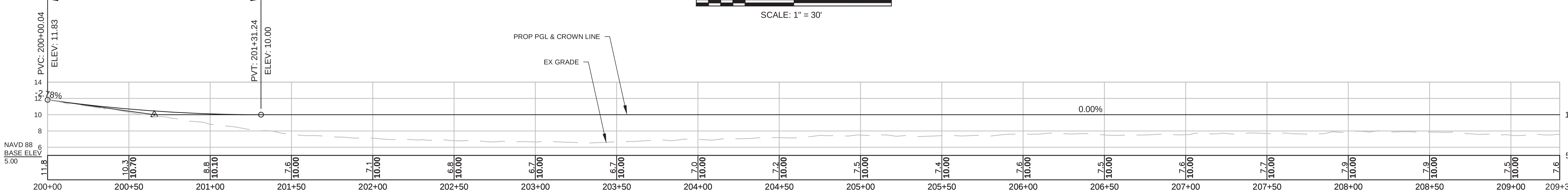



CONTINUED ON
SHEET NO 3

## CONCEPTUAL SITE PLAN

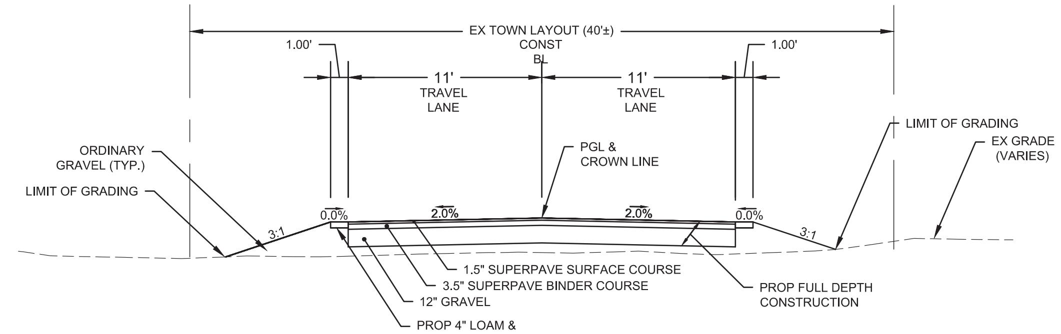
0 30 60 120

SCALE: 1" = 30'




HOR. SCALE IN FEET
30 0 30 60
6 0 6 12
VER. SCALE IN FEET

## ROADWAY PROFILE




HOR. SCALE IN FEET
5 0 5 10
5 0 5 10
VER. SCALE IN FEET

## TYPICAL SECTION

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CLIENT: TOWN OF SCITUATE
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CENTRAL AVENUE RECONSTRUCTION &
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SHEET 2 OF 8

| SCALE: AS NOTED | CHECKED | DATE: JUNE 2017 | JOB No. 16266.100 |
|---|---|---|---|
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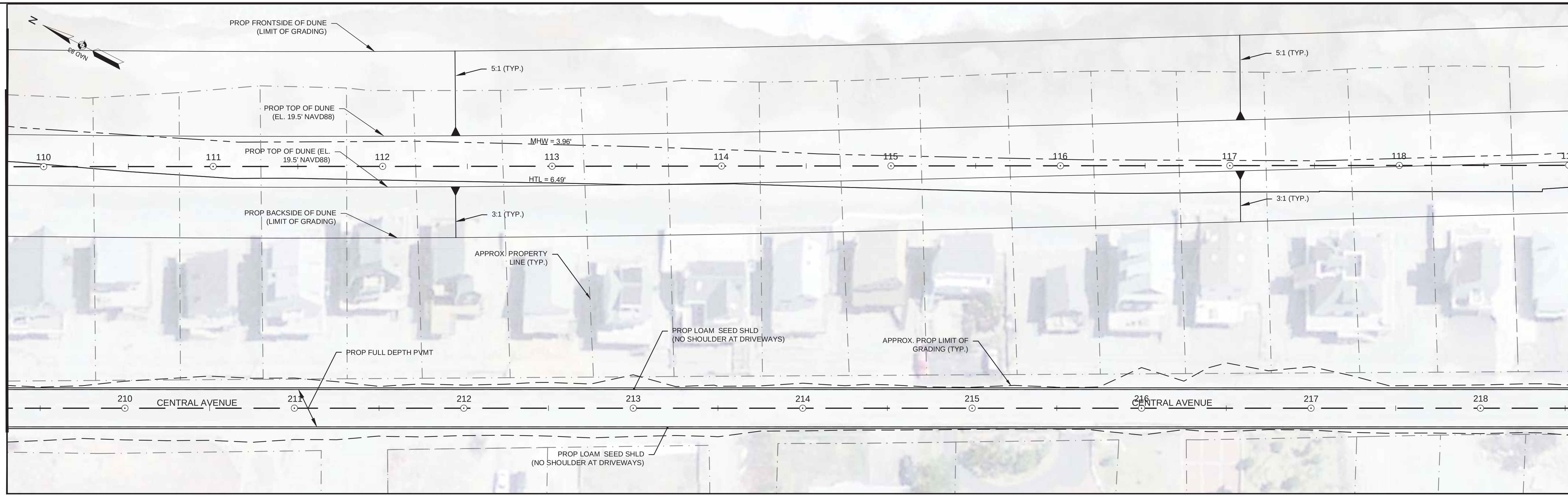
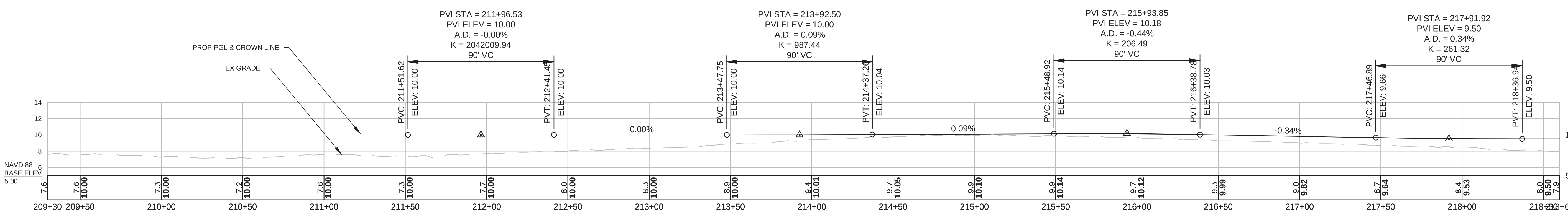



CONTINUED ON SHEET NO 4

## CONCEPTUAL SITE PLAN

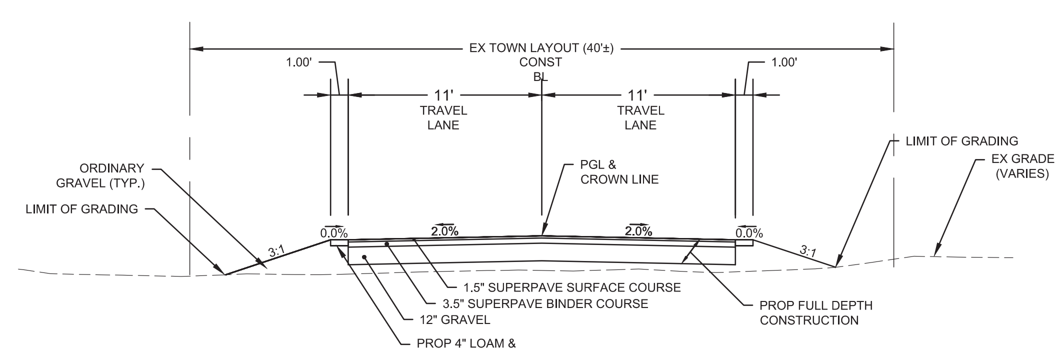
0 30 60 120

SCALE: 1" = 30'




## ROADWAY PROFILE

HOR. SCALE IN FEET
30 0 30 60
6 0 6 12
VER. SCALE IN FEET




## TYPICAL SECTION

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5 0 5 10
5 0 5 10
VER. SCALE IN FEET

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CENTRAL AVENUE RECONSTRUCTION & BEACH NOURISHMENT CONCEPT PLAN

SHEET 3 OF 8

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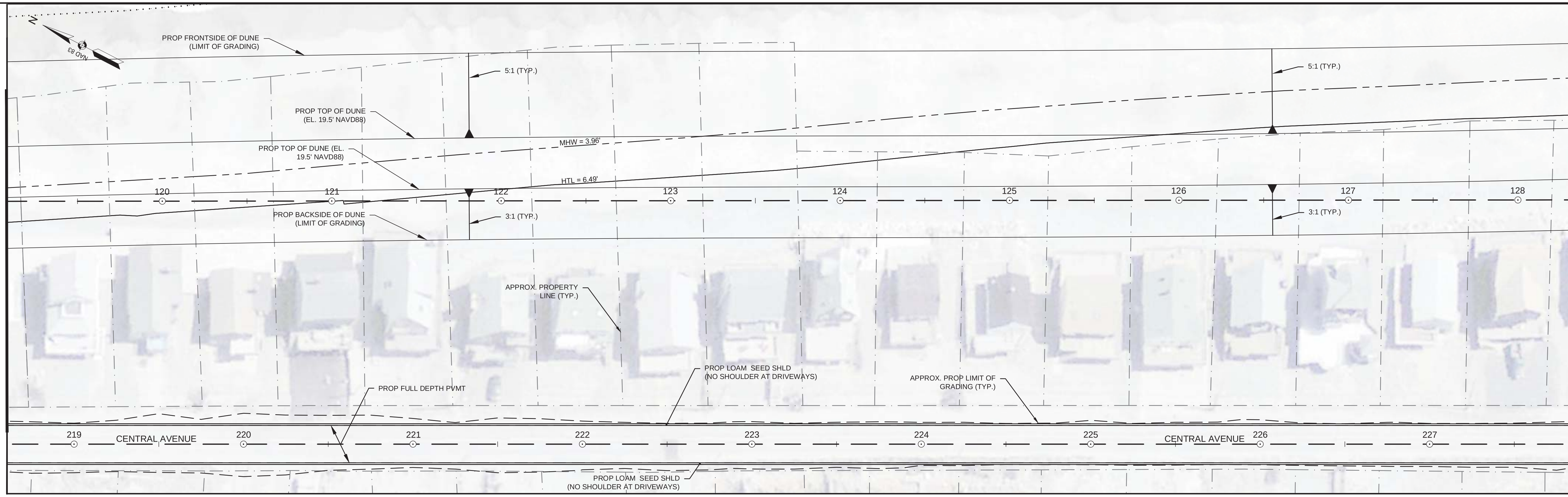
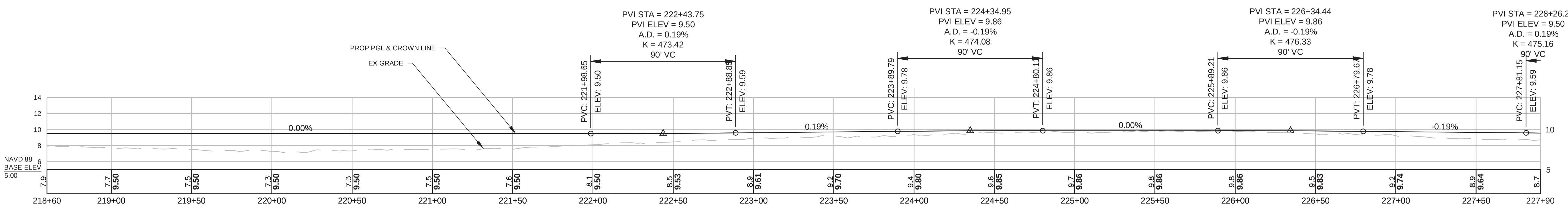
CONTINUED ON SHEET NO 3

CONTINUED ON SHEET NO 5



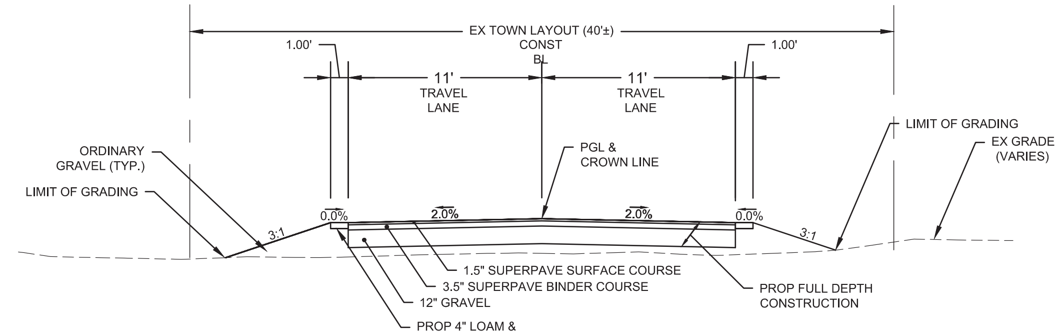

## CONCEPTUAL SITE PLAN

0 30 60 120
SCALE: 1" = 30'




## ROADWAY PROFILE

30 0 30 60
6 0 6 12
VER. SCALE IN FEET




## TYPICAL SECTION

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5 0 5 10
5 0 5 10
VER. SCALE IN FEET

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CLIENT: TOWN OF SCITUATE
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CENTRAL AVENUE RECONSTRUCTION &
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SHEET 4 OF 8

| SCALE: AS NOTED | CHECKED | DATE: JUNE 2017 | JOB No. 16266.100 |
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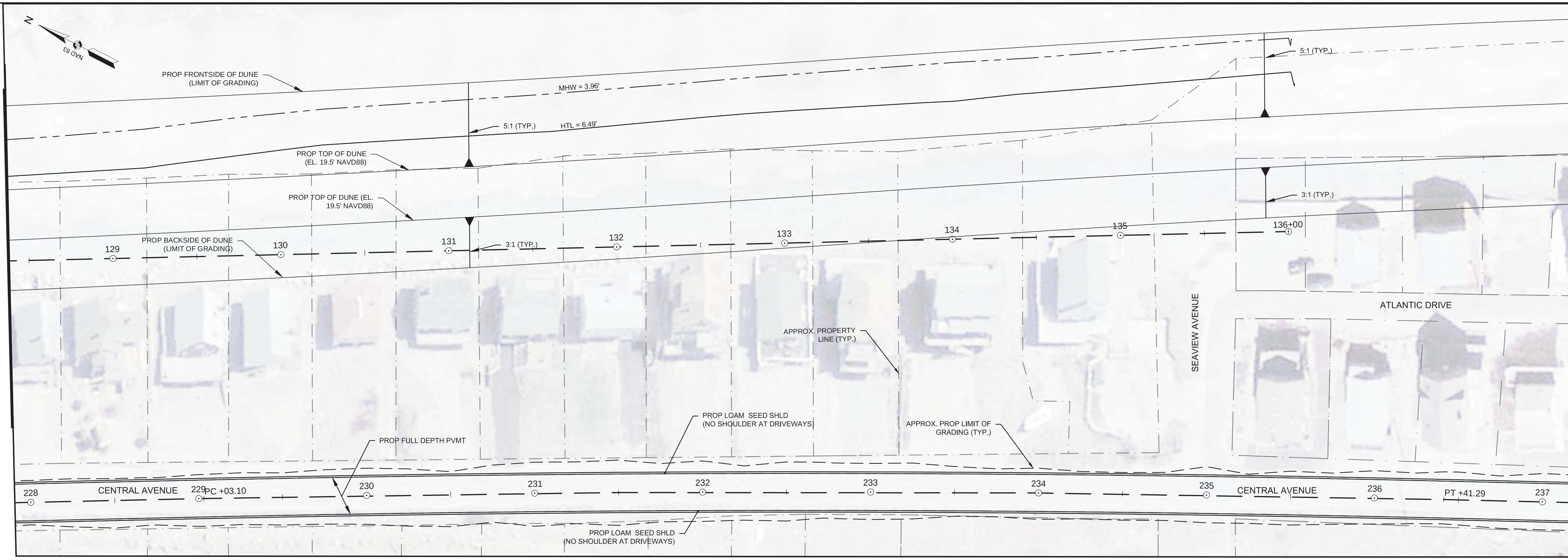
| REVISION No. | DATE | | COMMENT |

CONTINUED ON SHEET NO 4

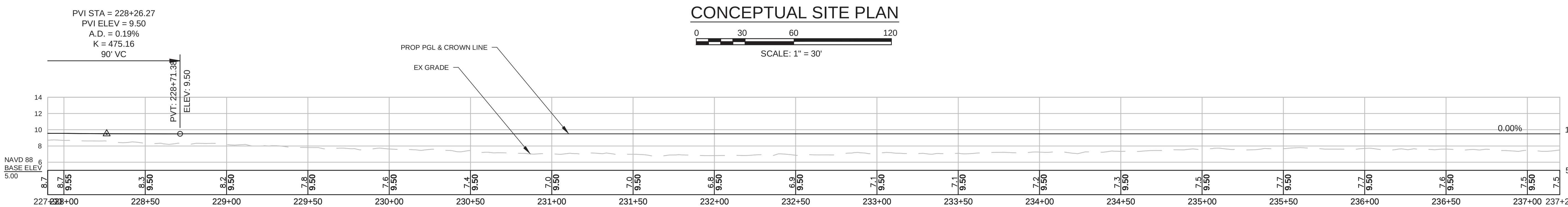
CONTINUED ON SHEET NO 6




## CONCEPTUAL SITE PLAN

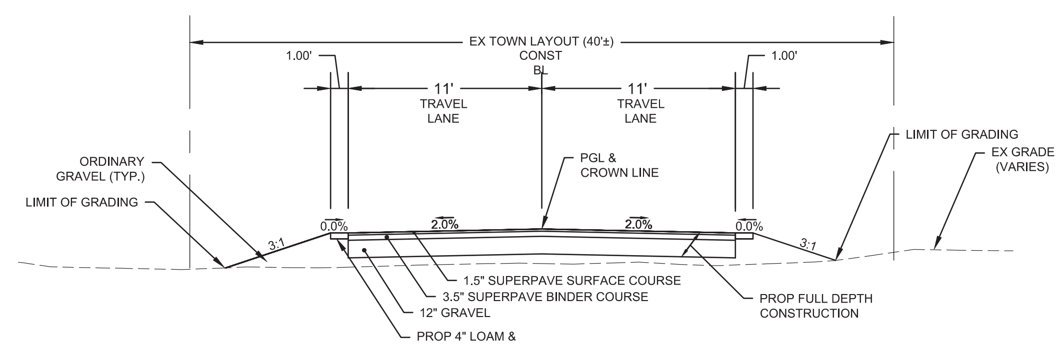
0 30 60 120

SCALE: 1" = 30'




## ROADWAY PROFILE

30 0 30 60
6 0 6 12
VER. SCALE IN FEET




## TYPICAL SECTION

HOR. SCALE IN FEET
5 0 5 10
5 0 5 10
VER. SCALE IN FEET

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SCITUATE, MA

CLIENT: TOWN OF SCITUATE
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CENTRAL AVENUE RECONSTRUCTION & BEACH NOURISHMENT CONCEPT PLAN

SHEET 5 OF 8

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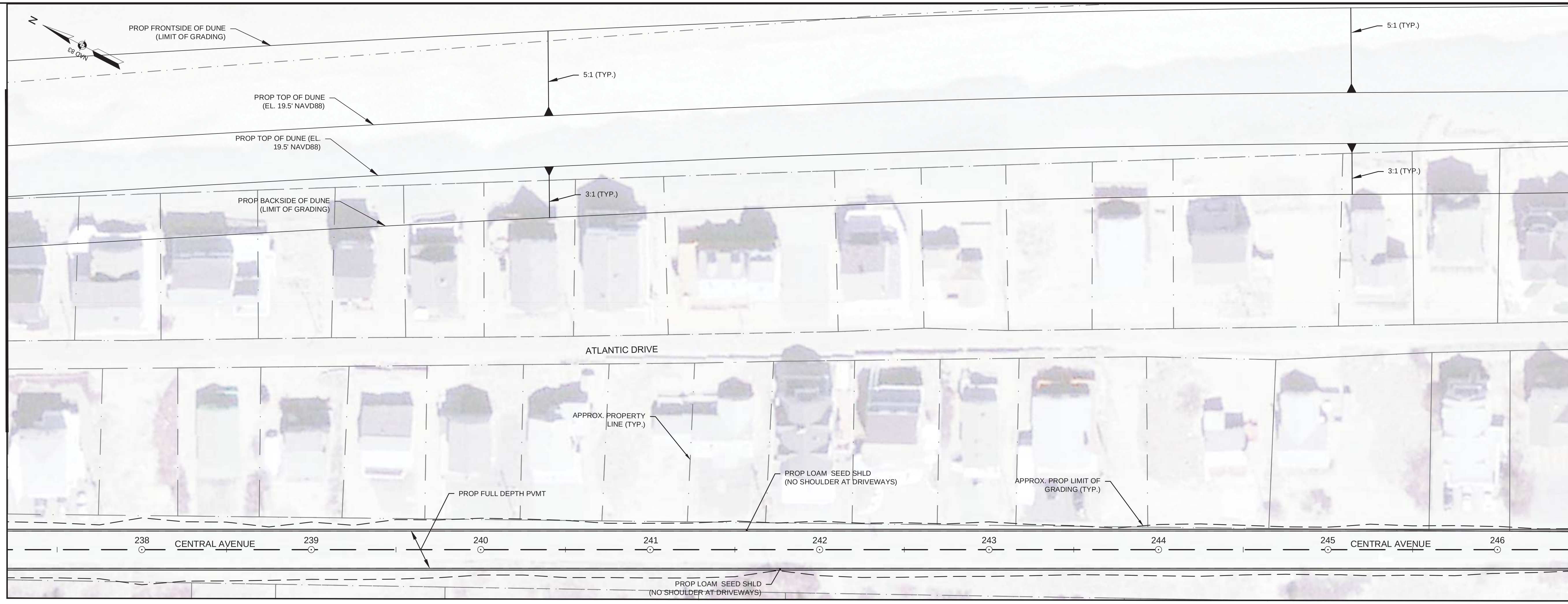
CONTINUED ON SHEET NO 5

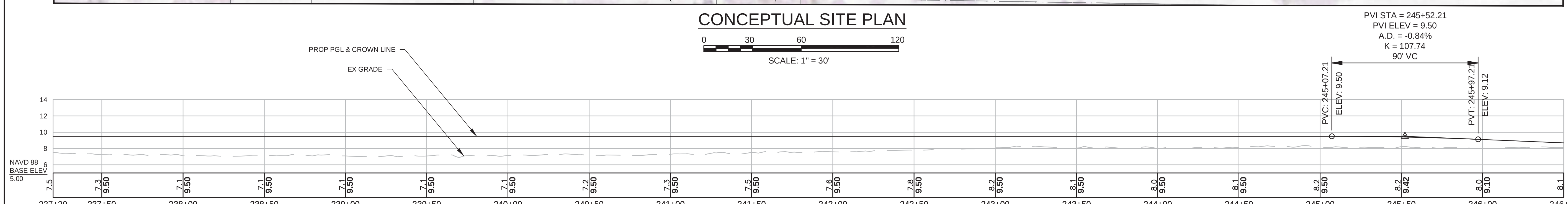
CONTINUED ON SHEET NO 7




## CONCEPTUAL SITE PLAN

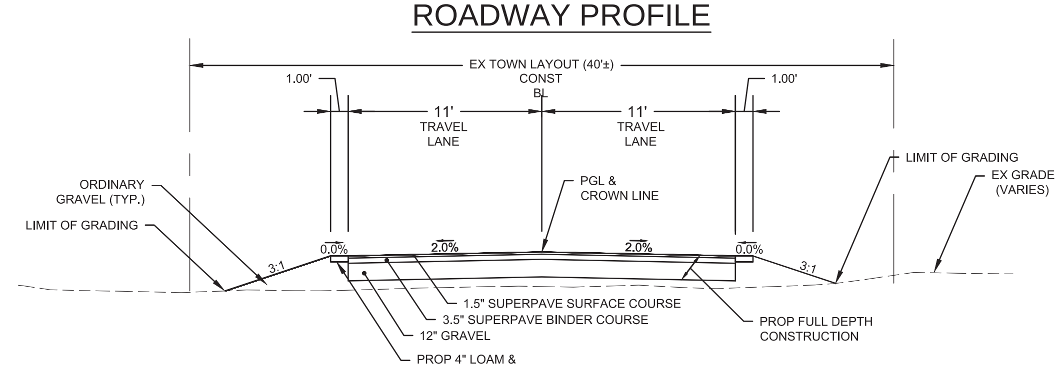
0 30 60 120

SCALE: 1" = 30'




## ROADWAY PROFILE

30 0 30 60
6 0 6 12
VER. SCALE IN FEET




## TYPICAL SECTION

HOR. SCALE IN FEET
5 0 5 10
5 0 5 10
VER. SCALE IN FEET

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CLIENT: TOWN OF SCITUATE
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CENTRAL AVENUE RECONSTRUCTION & BEACH NOURISHMENT CONCEPT PLAN

SHEET 6 OF 8

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|---|---|---|---|
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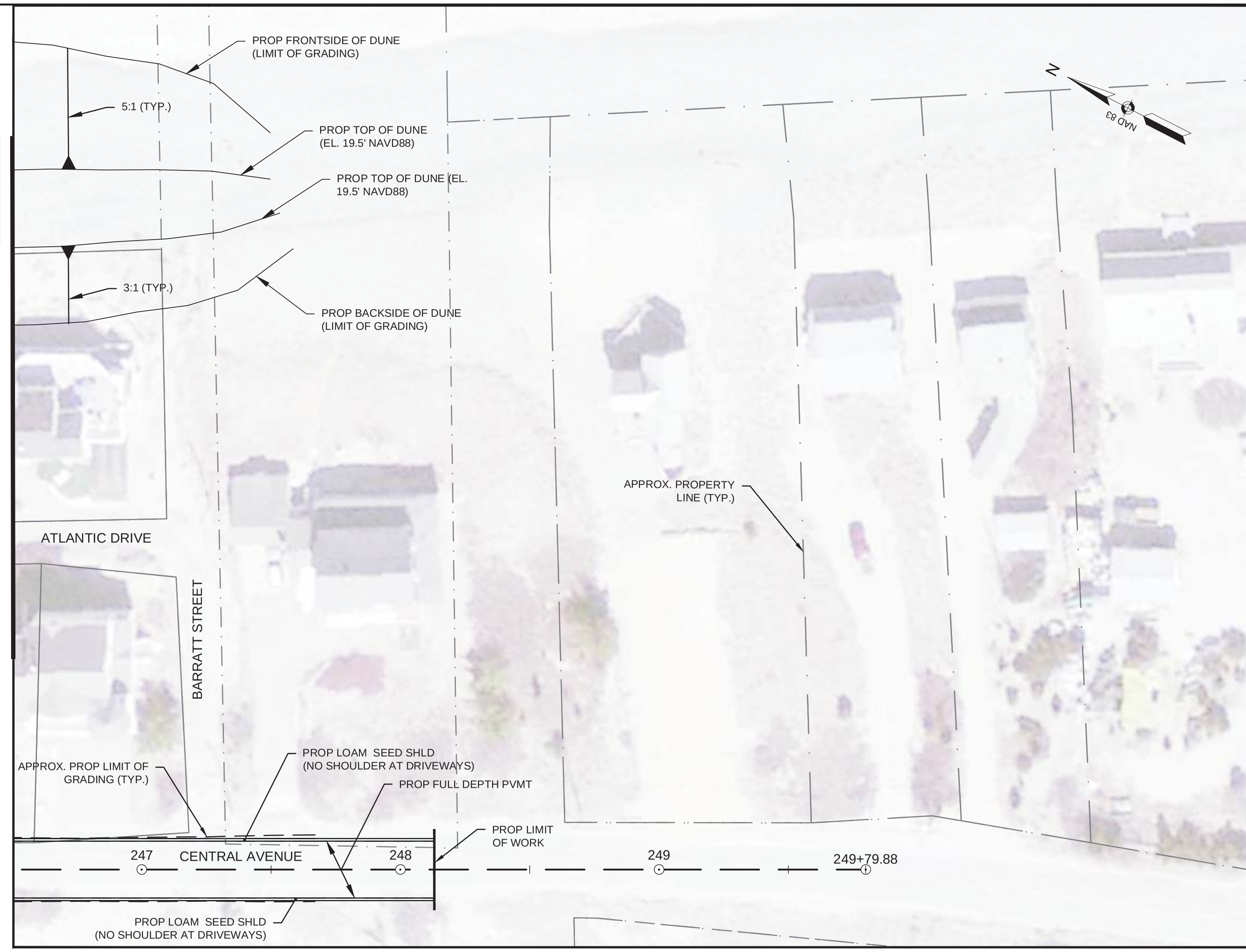
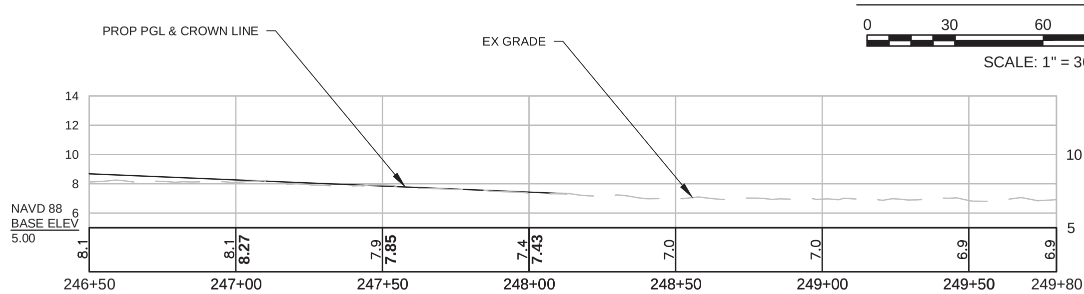


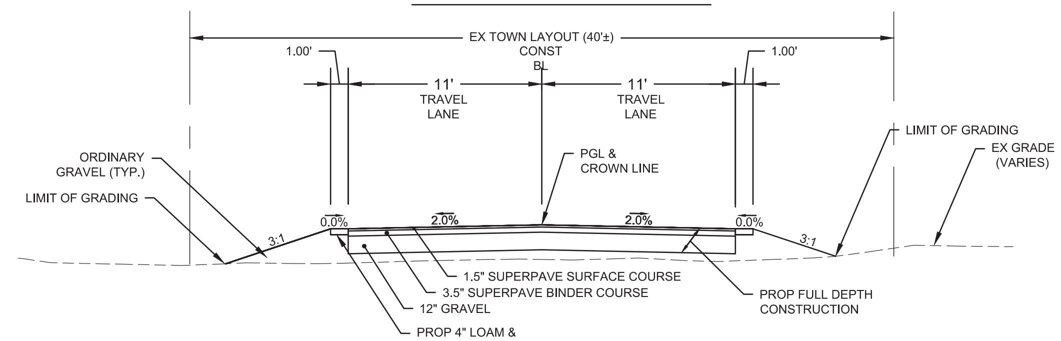

## CONCEPTUAL SITE PLAN

0 30 60 120

SCALE: 1" = 30'




## ROADWAY PROFILE




HOR. SCALE IN FEET
5 0 5 10

5 0 5 10
VER. SCALE IN FEET

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CENTRAL AVENUE RECONSTRUCTION &
BEACH NOURISHMENT CONCEPT PLAN

SHEET 7 OF 8

| SCALE: AS NOTED | CHECKED | DATE: JUNE 2017 | JOB No. 16266.100 |
|---|---|---|---|
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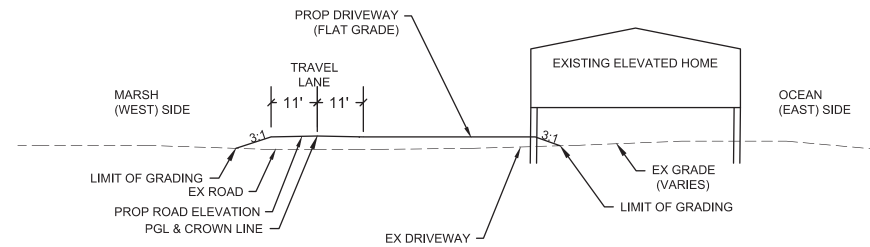
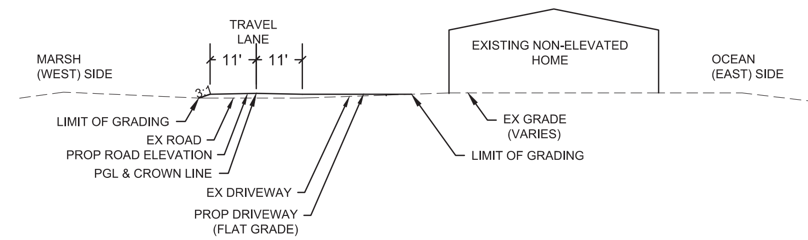
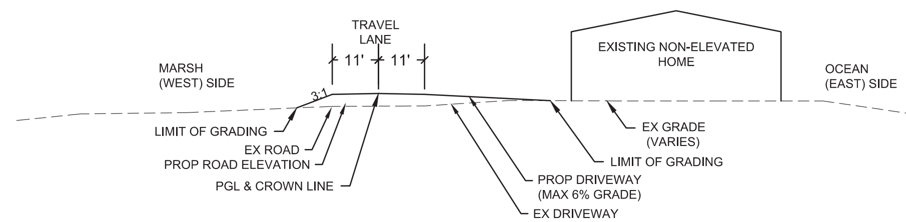


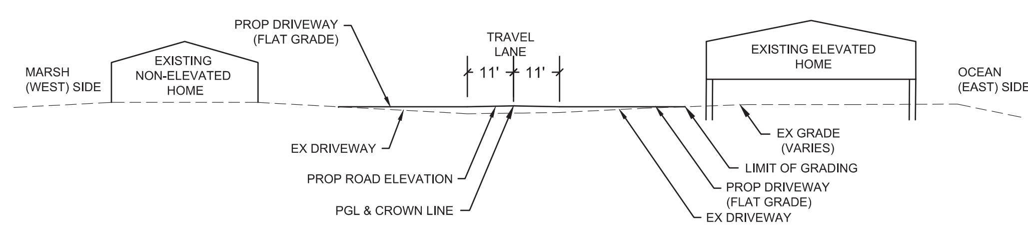

## TYPICAL DRIVEWAY TIE-IN "A"
## ELEVATED HOME ON EAST SIDE OF ROAD
SCALE = NTS



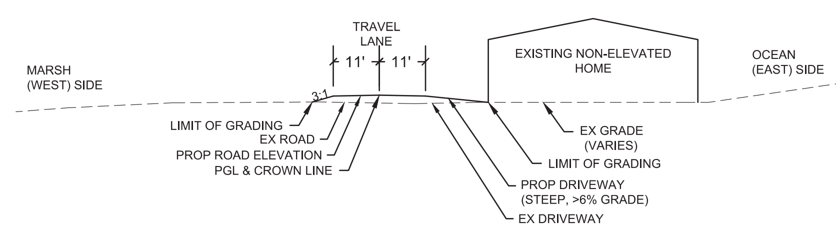

## TYPICAL DRIVEWAY TIE-IN "B"
## NON-ELEVATED HOME ON EAST SIDE OF ROAD WITH PROPOSED FLAT DRIVEWAY
SCALE = NTS




## TYPICAL DRIVEWAY TIE-IN "C"
## NON-ELEVATED HOME ON EAST SIDE OF ROAD WITH PROPOSED SLOPED DRIVEWAY
SCALE = NTS




## TYPICAL DRIVEWAY TIE-IN "D"
## NON-ELEVATED HOME ON WEST SIDE OF ROAD
SCALE = NTS




## TYPICAL DRIVEWAY TIE-IN "E"
## NON-ELEVATED HOME ON EAST SIDE OF ROAD WITH INSUFFICIENT DRIVEWAY LENGTH
SCALE = NTS

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CENTRAL AVENUE RECONSTRUCTION
TYPICAL DRIVEWAY TIE-INS

SHEET 8 OF 8

| SCALE: AS NOTED | CHECKED | DATE: JUNE 2017 | JOB No. 16266.100 |
|---|---|---|---|
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