SOUTHERN PALM BEACH ISLAND COMPREHENSIVE SHORELINE STABILIZATION PROJECT ENVIRONMENTAL IMPACT STATEMENT (EIS) SBEACH ANALYSIS REPORT

Prepared for:

U.S. Army Corps of Engineers (USACE)
Engineering Division

Prepared by:

Coastal Planning & Engineering, Inc.
a CB&I Company (CB&I)

January 2014

SOUTHERN PALM BEACH ISLAND COMPREHENSIVE SHORELINE STABILIZATION PROJECT ENVIRONMENTAL IMPACT STATEMENT (EIS) SBEACH ANALYSIS REPORT

Table of Contents

List of Figures

List of Tables

Table No.

SOUTHERN PALM BEACH ISLAND COMPREHENSIVE SHORELINE STABILIZATION PROJECT ENVIRONMENTAL IMPACT STATEMENT (EIS) SBEACH ANALYSIS REPORT

Table of Contents

List of Appendices

SOUTHERN PALM BEACH ISLAND COMPREHENSIVE SHORELINE STABILIZATION PROJECT ENVIRONMENTAL IMPACT STATEMENT (EIS) SBEACH ANALYSIS REPORT

1 INTRODUCTION

The project area for the Southern Palm Beach Island Comprehensive Shoreline Stabilization Project comprises approximately 2.07 miles of shoreline and nearshore environment. The north and south limits are Florida Department of Environmental Protection (FDEP) range monuments (R-monuments) R-129-210 (south end of Lake Worth Municipal Beach) and R-138+551 (south of the Eau Palm Beach Resort and Spa in Manalapan), respectively (Figure 2-1). The project area's beaches provide storm protection to residential and public infrastructure and serve as nesting areas for marine turtles. A portion of the project area has been designated as "critically eroded" (R-133.5 to R138.4) and the active hurricane tropical storm activity that occurred between 2004 and 2008 has resulted in a narrow, low profile beach along the majority of its shoreline. Over the past 8 years, the annual shoreline change has averaged a loss of 2.25 feet per year (CPE, 2013). Previous attempts to rebuild dunes in the project area have not resulted in a stable dune system or a stable beach. The applicant's proposed project under evaluation in the Environmental Impact Statement (EIS) intends to address the current erosion rates by stabilizing and widening the shoreline, thereby extending the construction interval between projects.

2 OBJECTIVE OF SBEACH MODEL STUDY

The objectives of this beach profile storm response study using the SBEACH model are as follows:

- To verify the need for a project along all sections of the project area
- Determine the level of storm protection provided by the existing conditions
- Preliminarily evaluate the storm protection benefits of two proposed fill alternatives

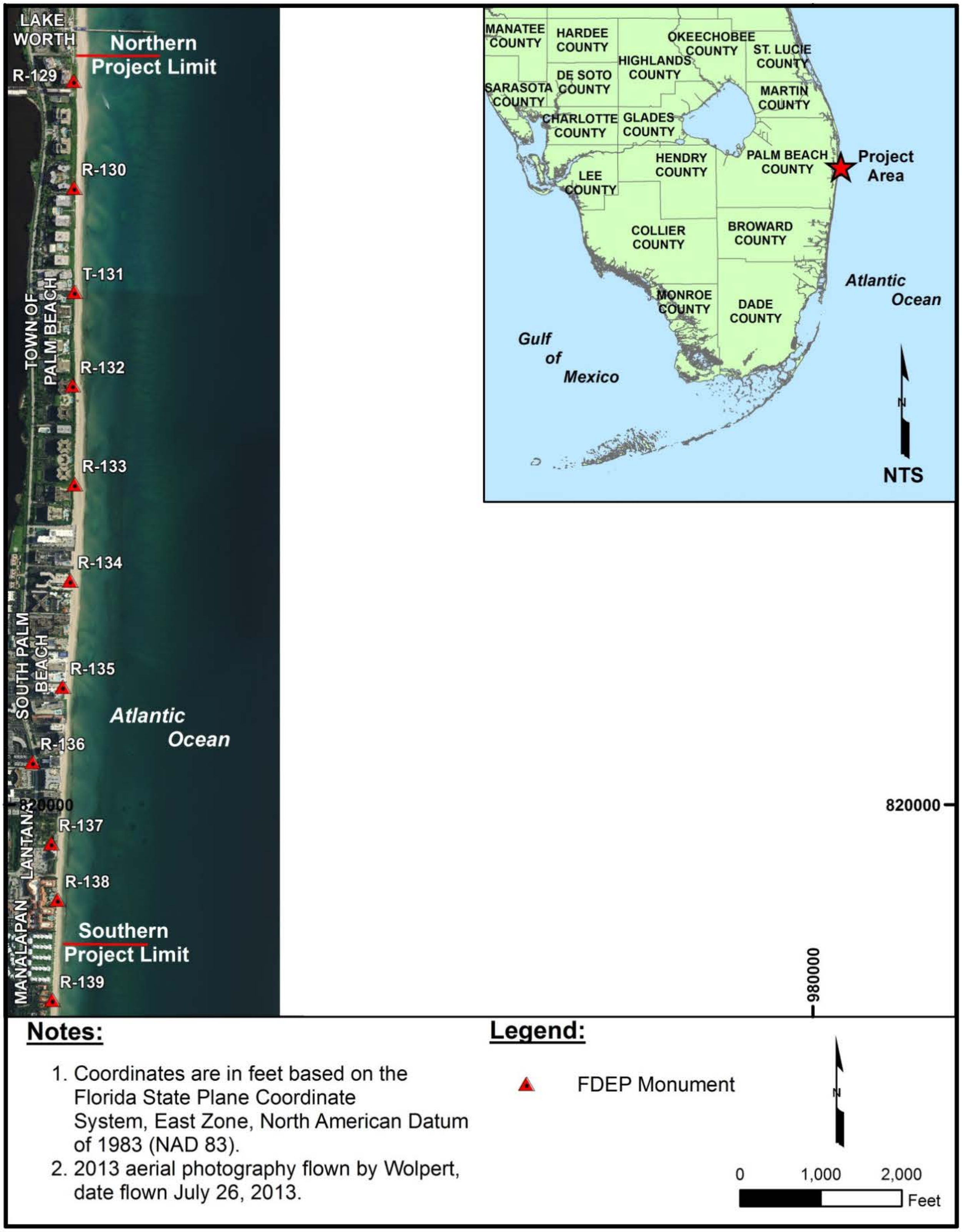


Figure 2-1 Southern Palm Beach Island Comprehensive Shoreline Stabilization Project Location.

3 METHODOLOGY

Cross-shore storm impact evaluations for the project area were conducted using the Storm Induced Beach Change Model (SBEACH) (Larson and Kraus, 1989). SBEACH is a numerical model that simulates changes to beach and dune profiles due to storm-driven erosion. Inputs to the SBEACH model include the initial profile, the time histories of the waves and water levels during each storm, and a set of model calibration parameters. Changes to the beach and dune profiles were simulated for storms return periods of 5, 15, 25, 50, and 100 years. The level of storm protection afforded by the existing beach and by the design beach fill and dune is defined by the return period of the storm event that causes a 0.5 foot vertical loss at the landward limit of the beach.

4 SBEACH MODEL SETUP

4.1 Model Background

SBEACH Version 4.03 (Larson et al., 2004) was used to model the cross-shore response of the design cross-section to the 5, 15, 25, 50 and 100 year storms. SBEACH is a one-dimensional model that simulates beach profile changes resulting from varying storm waves and water levels. These profile changes include the formation and movement of morphological features such as longshore bars, troughs, berms, and dunes. SBEACH evaluates storm impacts through simulated profile changes produced by cross-shore processes.

SBEACH is an empirically based numerical model, formulated using both field data and the results of large-scale physical model tests. Input data required by SBEACH includes the beach cross-section, the median sediment grain size, several calibration parameters, and the waves, wind velocities, and water surface elevations over the duration of the storm. SBEACH calculates the cross-shore variation in wave height and wave setup at discrete points along the profile from the offshore zone to the landward survey limit.

The following basic assumptions underlie the SBEACH model:

- Breaking waves and variations in water level are the major causes of sand transport and profile change.
- The influence of structures blocking longshore transport is small, and the shoreline is straight (i.e., longshore effects are negligible during the term of simulation).
- Linear wave theory is applicable everywhere along the beach profile.

4.2 Model Calibration

The model calibration was conducted using Hurricanes Frances (Category 2) and Jeanne (Category 3) because of the availability of beach profile survey data before and after the storms. These storms made landfall approximately 54 miles north of the project area near Hutchinson Island between August 25, 2004 and September 30, 2004.

The following wave, water level, and wind data collected during Hurricanes Frances and Jeanne was used in the SBEACH model setup:

- Waves were primarily based on the NOAA WAVEWATCH hindcast for the Western North Atlantic for the period from August 25, 2004 through September 30, 2004. Wave heights, wave periods, and wave directions at 3 hour intervals were taken from an observation point 12 miles northeast from the project site (Palm Beach Country Club, 26°45'N, 80°W) at a depth of -126.76 feet NGVD.
- Water levels were based on hourly measurements collected during the storms at the Lake Worth Pier tide gauge (NOAA Station ID LKWF1- 8722670), located immediately north of the project site.
- Wind data from NOAA Buoy LKWF1, Lake Worth was also used for calibration. Wind speed and direction was recorded hourly throughout the storm. There were two instances in the record when the station went offline for 3 to 9 hours. The wind statistics were linearly interpolated during these periods to generate a continuous record.

The following beach profile surveys were used for the SBEACH model setup and calibration:

- Pre-storm beach profile survey conducted by Morgan & Ecklund dated August 20, 2004.
- Post-storm LIDAR survey conducted by the NOAA Coastal Services Center Coastal Remote Sensing Program between November 22, 2004 and December 3, 2004.
- Post-storm beach profile survey including R-137 conducted by Palm Beach County dated October 4, 2004

The following LIDAR surveys were used to extend the SBEACH profiles landward where necessary:

- US Army Corps of Engineers (USACE) Joint Airborne Lidar Bathymetry Technical Center of Expertise (JALBTCX) survey data collected by the Compact Hydrographic Airborne Rapid Total Survey (CHARTS) system along the coast of Florida from August 31 - October 3, 2009.
- Airborne Topographic Mapper LIDAR data collected in partnership with the National Oceanic and Atmospheric Administration (NOAA) Coastal Services Center along the coast of Florida in 1990.

4.3 Model Parameters

The observed changes due to Hurricane Frances and Jeanne were used as the basis for determining the calibration settings. The initial calibration run utilized the default parameters. In the following runs, a range of values for each calibration parameter were considered until the settings with the best agreement between observed and simulated conditions were identified. Varying calibration parameters to correct the agreement at a specific profile resulted in greater discrepancies at other profiles; therefore, the final calibration parameters were selected based on the agreement across the project area as a whole.

The final calibration parameters used in the production runs were as follows:

- The transport rate coefficient, which was equal to the ratio between the cross-shore transport rate and the wave energy dissipation rate was set to K = 2.5 x 10^{-7} m^4/N.

- The slope dependent coefficient, which governed the influence of the profile slope on the cross-shore transport, was set to $\varepsilon = 0.001$ m^2/s.

- The transport rate decay coefficient, which governed the reduction in the wave height over the beach profile due to wave breaking, was set to $\lambda = 0.5$.

- The assumed depth at landward end of the surf zone was set to Dfs = 1 foot.

In addition to the parameters above, the following assumptions were made for parameters required in the most recent version of SBEACH (4.03):

- A median grain size of 0.3 mm for the existing conditions. Samples collected in 2006 confirm the native grain size to be 0.3 mm (CPE, 2007). As an additional note, dune nourishments constructed in 2011 placed a small amount of coarser sand along the dune measuring 0.45 mm from an upland sand source (ATM, 2012).

- A grain size of 0.3 mm for the beach and dune fill. The grain size of sand in the borrow areas included in the Beach Management Agreement range from 0.25 to 0.29 mm with a compliance range of 0.25 mm to 0.6 mm for the region containing the project area (FDEP, 2013). Additionally, using the same grain size sediment for the various alternatives during production runs as was used in calibration allows the results to be comparable and eliminates a potential source of error.

- Average water temperature of 28.5°C (83°F) (NOAA, 2013).

- A default avalanche slope of 45°.

- The beach profiles were represented in the model with grid cell spacing of 6 feet.

- The time step used in simulations was 1 minute.

- An overwash coefficient of 0.008. The overwash coefficient is a relatively recent addition to the SBEACH model (see Larson, et al, 2004). The default value of this parameter is 0.005 for an unreinforced dune. No significant difference is noticed between simulations with varying overwash parameters for the 5, 15, 25, and 50 year storms. During the 100 year storm, the profiles are sensitive to the overwash coefficient and the magnitude of overwash increases as the coefficient increases (Figure 4-1).

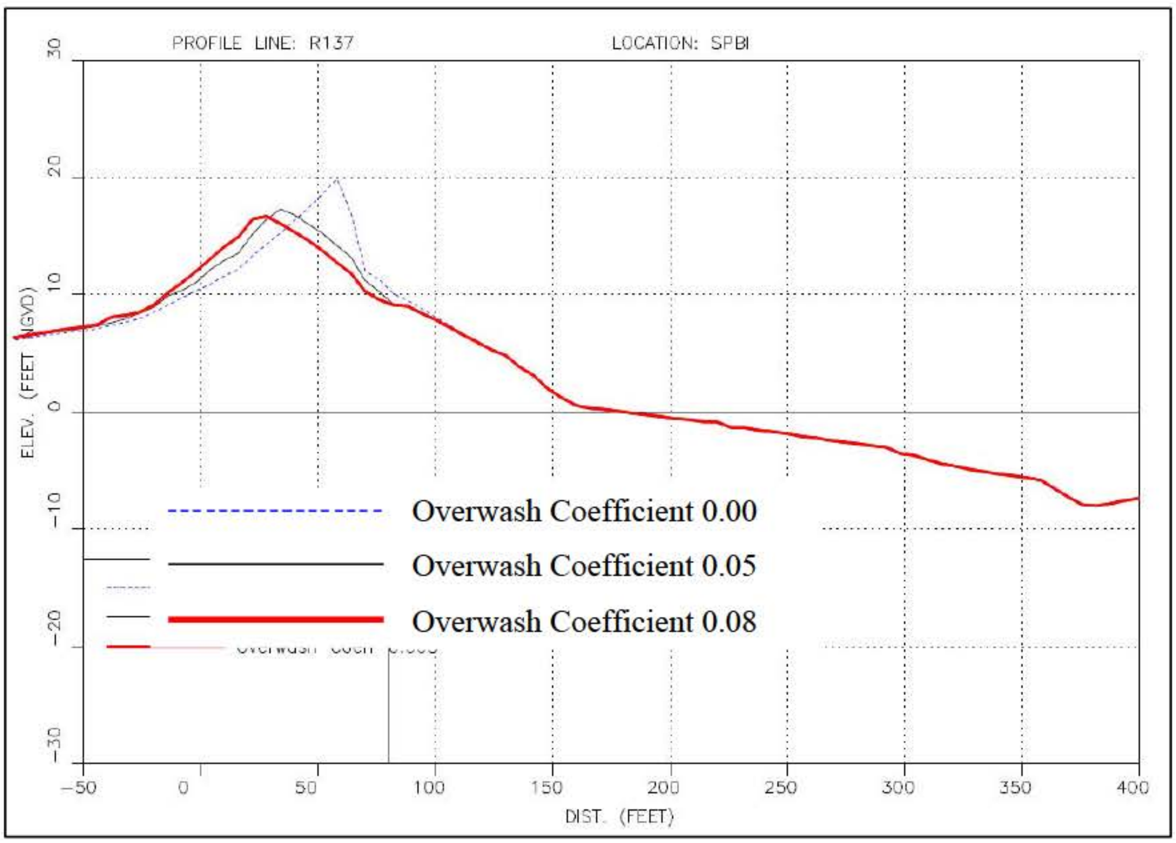


Figure 4-1 Sensitivity of overwash coefficient for R-137 profile, 100 year storm.

4.3.1 Final Calibration Results

The simulated beach profile responses with the final calibration settings agree well with the observed conditions within the project area. A comparison of the observed and calibrated shoreline changes, volume changes and landward limits of erosion is presented in Table 4-4-1. The average difference between the observed and calibrated shoreline changes was 6 feet. The average difference between the observed and calibrated volume change above mean low water (MLW) was 4 cubic yards per foot (cy/ft). The average difference between the observed and calibrated landward limit of storm recession, where at least 0.5 feet of elevation was lost, was 5 feet. On average, the calibration slightly overpredicted the erosion resulting from Hurricanes Frances and Jeanne along most profiles. This overprediction rather than underprediction of erosion is expected to positively affect the reliability of the results of the production runs. Unlike the calibration storms, the storms used in the production runs will be assumed to make landfall at the project area. As a result, the erosion simulated in production during an equivalent return period storm as Hurricanes Frances is expected to be more severe than what was observed in calibration.

TABLE 4-1 OBSERVED vs CALIBRATION RUN RESULTS FOR VOLUME AND SHORELINE CHANGES

Profile[1]	Shoreline Change (feet)		Volume Change above Mean Low Water (-0.73 feet NGVD) (cy/ft)		Landward Limit of Storm Erosion[2] (feet from R-monument)	
	Observed	Calibrated	Observed	Calibrated	Observed	Calibrated
R-129	-49	-53	-13	-15	60	60
R-130	-50	-45	-16	-15	37	53
R-131	-71	-46	-22	-14	27	35
R-132	-16	-21	-8	-13	33	N/A
R-133	9	-21	-5	-13	3	11
R-134	-19	-6	-13	-13	0	0
R-135	-13	-35	-8	-19	15	N/A
R-136	-20	-32	-7	-17	11	N/A
R-137	-27	-48	-4	-19	80	80
Average[3]	-28	-34	-11	-15	35	40
Difference		-6		-4		-5

[1]Survey data was not available at R-138

[2] Survey data near the landward limit of the active profile was not available at profiles R-132, R-135 and R-136.

[3]Averages only include profiles where data was available.

4.4 Seawalls

Seawalls are present along 78% of the project area (CPE, 2007) and serve as an important component of storm protection for upland properties. The seawalls are non-homogeneous in that the quality and age of construction materials used and design criteria utilized varies by property. The information available about these seawalls is limited to the elevation of the top of the wall. Despite the limited information available, including seawalls in SBEACH is critical for simulating the beach profile response to storms.

In SBEACH, location and seawall failure criteria can be included in the model setup. The locations of the seawalls as included in the model are shown on the figures in Appendix A. The SBEACH model has three modes of failure 1) scour at the toe of the structure, 2) direct wave attack and 3) inundation. The seawall is assumed to fail and erosion occurs landward of the seawall if one or more of these criteria are met during a time step. Detailed information about the construction and stability of each seawall within the project area was not available. The following assumptions were made to incorporate seawalls into the SBEACH model setup. These assumptions were intended to conservatively represent the conditions of the seawalls.

- Toe scour failure was assumed to occur when the beach profile elevation at the seawall lowered to -3 feet NGVD. Based on an average seawall height of +17 feet NGVD, the depths of the seawalls were anticipated to extend to at least -3 feet NGVD.

- The wave height at the seawall which causes failure was computed for each design storm based on the maximum water level that occurred during each storm and the overtopping failure criteria of 0.015 cubic meters per second per meter (Allsop et al, 2005; USACE, 2000).

- The water level at the seawall which was expected to cause inundation failure was assumed to be equal to the top elevation of the seawall.

Recent storms have provided evidence of the likelihood of seawall failure along the project area. Along the southern portion of the project area, many of the seawalls are exposed directly to wave action during storms (Figure 4-2 and Figure 4-3). The seawalls along the project area vary in age, stability and degree of exposure, leaving them more or less vulnerable to the modes of failure discussed previously. As an example, wave impacts and scouring that occurred during Hurricane Sandy led to failure and undermining of walls less than one mile south of the project site resulting in significant property damage and loss (Figure 4-4). Examining the likelihood and magnitude of toe scour using SBEACH will assist in understanding the risk of seawall failure along the project area and determining the overall need for the project.

Figure 4-2. Impacts of Hurricane Sandy near R-136, Town of South Palm Beach (October 26, 2012).

Figure 4-3. Impacts of Hurricane Sandy near R-137, Town of South Palm Beach (October 26, 2012).

Figure 4-4 Failure of seawall in Manalapan after Hurricane Sandy (1 mile south of the project area, R-143.5) (Coastal Star, 2013)

4.4.1 Seawall Replacement Cost

The estimated cost per mile to replace a seawall in Palm Beach County is approximately $30.6 million based on the 2009 seawall construction that occurred near R136. Therefore, the cost to replace all of the seawalls (78% of shoreline) along the 2.07-mile long project area after catastrophic failure would be approximately $49.4 million.

4.5 Representative Profiles

Ten beach profiles were modeled using SBEACH (R129 to R138). To represent the most recent conditions, profile survey data collected between 2011 and 2012 was utilized. The datum used during the surveys were the Florida State Plane Coordinate System, North American Datum of 1983. The surveys were converted to the National Geodetic Vertical Datum using Corpscon (ver. 6.x) for consistency of datums throughout the calibration and production runs. The beach profile cross sections were extended landward for modeling purposes using the 1990 Survey for R-129 to R-137 and the 2009 Light Detection and Ranging (LIDAR) Survey for R-138.

The most recent survey of the project area which is being used for analysis and model setup was collected in November 2011 along the Town of Palm Beach (R129-R134) and in January 2012 for the County shoreline (R135-R138). Table 4-2 lists the most recent dune nourishments within the project area. The dune nourishments occurred approximately 9 months to 3 years prior to the survey dates for the Town of Palm Beach and County, respectively. Based on the information reviewed, neither of the surveys was an as-built survey. No major hurricanes have made a direct impact to the project area since the nourishments; however, storms have occurred and likely contributed to the background erosion rate.

TABLE 4-2 MOST RECENT DUNE NOURISHMENTS

Date	Project	Project Extents	Volume (cy)	Sand Source
2009	South Palm Beach/Lantana Dune Restoration	R-135+460 to R-137+410	10,000	Upland
December 2010 – February 2011	Phipps Ocean Park Beach and Dune Restoration	Dune R-129 to R-133	56,000	Upland

4.5.1 Design Cross-Sections

The Southern Palm Beach Island Comprehensive Shoreline Stabilization Project currently evaluates seven alternatives:

1) No Action
1a) No Action Status Quo (includes dune nourishment)
2) Applicant's preferred with groins
3) Applicant's preferred without groins
4) Town preferred alternative and larger County project (3 years fill, no groins)
5) Town larger project (modified Erickson alternative) and County preferred alternative
6) Town larger project and County larger project.

SBEACH modeling was conducted for Alternatives 1, 3 and 6 (Table 4-3). Alternative 2 was not modeled since the fill design is the same as Alternative 3. SBEACH is a cross-shore transport model and does not include the option of including groins as present in Alternative 2.

- Alternative 1 utilized the 2011/2012 surveys without modification to represent the existing conditions or No Action Status Quo alternative. No Action Status Quo includes dune nourishments with fill volume placements of approximately 11 cubic yards per foot from R-129 to R-133 and 5 cubic yards per foot from R-135_460 to R-137+410 every 1 to 5 years.

- Alternative 2 was not simulated in SBEACH. The results from Alternative 3 are applicable to Alternative 2. Alternative 2 has 7 low-profile pile and panel groins as part of the design. SBEACH cannot consider the effects of groins in simulating the cross-shore storm response of beach profiles.

- Alternative 3 utilized the Applicant's Preferred fill design which consisted of dune fill only from R-129-210 to R-129+150, dune and beach fill from R-129+150 to R-131, dune fill only from R-131 to R-134+113 (Town of Palm Beach southern limit), and beach fill from R-134+113 to R-138+551 (Towns of South Palm Beach, Lantana and Manalapan).

This alternative was originally designed to require approximately 150,000 cubic yards of fill for the entire project based on 2009 surveyed profiles along the Town of Palm Beach and 2011 surveyed profiles for the remainder of the project area. The design of the Town of Palm Beach section (R-129-R-134) was updated based on the available 2012 profiles for use in the SBEACH model setup. The seaward crests of the dune and berm from the original design remained at the same range and elevation in the updated design with two exceptions 1) if the 2012 dune was located seaward of the original design, no fill was added to the dune and 2) no fill was placed landward of the edge of vegetation as shown in the 2011/2012 aerials.

- Alternative 4 utilized the same Applicant's Preferred design as Alternative 2 for the Town of Palm Beach portion of the project area (R-129 to R-134) and a larger design along the County portion (R-135 to R-138). The fill volume from R-134 to R-138+551 was increased from 75,000 cubic yards to 160,600 cubic yards.
- Alternative 5 utilized a modified design for the Town of Palm Beach portion (R-129 to R-134) and the Applicant's Preferred design along the County portion of the project area (R-135 to R-138). The modified design consisted of placing additional fill on the dry beach (R-129-R-134) where feasible, totaling 96,000 cubic yards.
- Alternative 6 utilized the same design as Alternative 5 which placed more fill along the dry beach of Town of Palm Beach (R-129 to R-134; 96,000 cubic yards) and the same larger design used in Alternative 4 (~160,000 cy) along the County portion (R-135 to R-138).

TABLE 4-3 CROSS-SECTIONS SIMULATED IN THE SBEACH MODEL

Profile	Dune/Berm Width (feet)	Dune/Berm Slope	Seawall Included
Alternatives 2 & 3			
R129	No fill added		No
R130	17	1V:10H	Yes
R131	18	1V:3H	No
R132	10	1V:3H	Yes
R133	No Fill added		No
R134	35.2	1V:3H	Yes
R135	22.2	1V:10H	No
R136	75.6	1V:10H	Yes
R137	52.7	1V:10H	Yes
R138	18.5	1V:10H	Yes
Alternative 4			
R129	No fill added		No
R130	17	1V:10H	Yes
R131	18	1V:3H	No
R132	10	1V:3H	Yes
R133	No Fill added		No
R134	35.2	1V:3H	Yes
R135	66.2	1V:10H	No
R136	130.2	1V:10H	Yes
R137	98.4	1V:10H	Yes
R138	58.5	1V:10H	Yes
	Alternative 5		
R129	65.2	1V:5H	No
R130	17	1V:10H	Yes
R131	18	1V:3H	No
R132	0	1V:3H	Yes
R133	46.9	1V:3H	No
R134	72.8	1V:3H	Yes
R135	22.2	1V:10H	No
R136	75.6	1V:10H	Yes
R137	52.7	1V:10H	Yes
R138	18.5	1V:10H	Yes

TABLE 4-4 CROSS-SECTIONS SIMULATED IN THE SBEACH MODEL CONTINUED

Profile	Dune/Berm Width (feet)	Dune/Berm Slope	Seawall Included
Alternative 6			
R129	65.2	1V:5H	No
R130	17	1V:10H	Yes
R131	18	1V:3H	No
R132	10	1V:3H	Yes
R133	46.9	1V:3H	No
R134	72.8	1V:3H	Yes
R135	66.2	1V:10H	No
R136	130.2	1V:10H	Yes
R137	98.4	1V:10H	Yes
R138	58.5	1V:10H	Yes

4.6 Storm Data

Five specific return interval storm events were used in the SBEACH cross-shore analyses, 5 year, 15 year, 25 year, 50 year and 100 year. Wind, water level and wave data from Hurricane Frances observed during the time period from August 25, 2004 to September 9, 2004 was used as the basis for the design of the return interval storms. The Hurricane Frances data was scaled accordingly to match the maximum values listed in Table 4-5 for each storm. Maximum wave heights, wave periods, and water levels during each storm appear in Table 4-5. Plots of the wave height, wave period, and water level versus time appear in Appendix B.

TABLE 4-5 DESIGN STORM SUMMARY

Return Period	Maximum Values			
Return Period (years)	**Offshore Significant Wave Height[1] (feet)**	**Peak Wave Period (seconds)**	**Water Level[2] (feet NGVD)**	**Wind Speed[3] (mph)**
5	20.8	9.7	*3.7*	*69*
15	26.4	11.0	*5.0*	*85*
25	29.1	11.5	*5.5*	93
50	32.6	12.2	6.3	103
100	36.2	12.8	7.0	111

NOTES: 1. Wave heights are given at a depth of 356 meters (USACE, 2012).

3. Values in italics are interpolated or extrapolated from FEMA (1982). These values do not include wave setup as it is calculated and included by SBEACH during the simulations.

4. Values in italics are interpolated or extrapolated from USACE (1985).

FEMA return period water level accounts for tidal effects. FEMA used a numerical hydrodynamic model of the region to simulate the coastal surge generated by different return period storms. The astronomical tide for the region was statistically combined with the computed storm tide to yield recurrence intervals of total water level shown in the published water levels (FEMA, 1982).

5 MODEL RESULTS

5.1 General

SBEACH model results appear in Appendices C and D and include the post-storm profiles for all design storms in TABLE 4-5.

5.2 Existing Conditions (2011/2012 Beach Profiles) / No Action Status Quo Scenario

The existing conditions along the project area shoreline consist of eroded dunes, exposed seawalls and steep gradient berms. Along the Town of Palm Beach, there is a continuous dune feature and line of vegetation separating the beach from the residential infrastructure. There are several buried seawalls along this section of shoreline (R-129- R-134). Along the Towns of South Palm Beach, Lantana and Manalapan, there is no dune feature and the majority of the beach profiles consist of partially exposed seawalls.

The degree of erosion during a storm will vary spatially due to the characteristics of the beach profiles (Table 5-1; Appendix C). Profiles R-131 through R-134 will experience the most erosion. Profile R-131 is not protected by seawalls. This profile also has the steepest existing beach face which leads to higher breaking waves in the surf zone and increases the potential for runup and erosion. Profiles R-132, R-134 and R-137 will experience similar erosion. The exposed seawalls present on these profiles leads to scouring and volume loss at the base of the wall. The other profiles have similar but slightly lower erosion rates. The average volume change above mean low water during a 5, 10, 25, 50 and 100-year return interval storm along the project area was -6.0 cy/ft, -7.3 cy/ft, -7.7 cy/ft, -8.4 cy/ft and -9.1 cy/ft, respectively (Table 5-2).

Under existing conditions, the seawalls and revetments at monuments R-130, R-132, R-136 are exposed. Scouring at the toe of the seawalls occurs at these locations in all of the simulated return interval storms (Appendix C). Scouring increases incrementally with magnitude of storm. No seawall failures were observed during the simulations.

The landward limit of erosion was quantified to determine the potential impacts to infrastructure and property landward of the project area (**Error! Reference source not found.**). The landward limit of erosion was defined as the landward position where at least 0.5 feet of elevation was lost as a result of the storm. The values in Table 5-3 are referenced to the FDEP R-monuments since the monuments are at a fixed location. As the profiles erodes landward towards the R-monuments, the values in the table decrease until they retreat landward of the monument and then the values are negative. The table values in red signify that recession landward of the improved or maintained property has occurred. Maintained property refers to landscaped areas or paved/ gravel areas. While a seawall is operational, the landward limit of recession is the same for different return interval storms because the seawalls prevent further landward recession as shown in the table at R-130 for the 15, 25, 50, 100-year storms. In general, profiles without seawalls, R-131 and R-135 are certainly at risk of damage during the occurrence of a 25-year return interval storm or stronger storm. Damage is possible adjacent to profile R-133 as a result of a 50-year return interval or stronger storm. The critical storm return interval for damage to property to occur is between a 15-year and 25-year storm.

TABLE 5-1 SBEACH SHORELINE RETREAT & EROSION UNDER EXISTING CONDITIONS (2011/2012) AND A 15 YEAR STORM

Profile	**MLW Change (feet)**	**Volume Change above MLW (cy/foot)**
R-129	-17	-5.6
R-130	0	-6.4
R-131	2	-8.1
R-132	4	-8.1
R-133	-23	-9.2
R-134	-22	-8.7
R-135	-17	-7.1
R-136	-22	-5.8
R-137	-24	-7.4
R-138	-40	-6.1

NOTE: Mean Low Water (MLW) = -0.73' NGVD.

TABLE 5-2 SBEACH SHORELINE RETREAT & EROSION, EXISTING CONDITIONS (2011/2012)

	5 Year Storm	15 Year Storm	25 Year Storm	50 Year Storm	100 Year Storm
Profile	**Volume Change above MLW (cy/ft)**	**Volume Change above MLW (cy/ft)**	**Volume Change above MLW (cy/ft)**	**Volume Change above MLW (cy/ft)**	**Volume Change above MLW (cy/ft)**
R-129	-4.6	-5.6	-6.0	-6.6	-7.1
R-130	-5	-6.4	-6.8	-7.4	-8
R-131	-6.5	-8.1	-8.8	-9.9	-10.7
R-132	-6.3	-8.1	-8.8	-9.8	-10.6
R-133	-7.6	-9.2	-9.9	-10.7	-11.4
R-134	-7.4	-8.7	-9.3	-10	-10.5
R-135	-5.9	-7.1	-7.6	-8.2	-8.7
R-136	-5.0	-5.8	-6.0	-6.5	-6.7
R-137	-6.5	-7.4	-7.5	-8	-10.3
R-138	-5.3	-6.1	-6.3	-6.7	-7.2

TABLE 5-3 SBEACH LANDWARD LIMIT OF STORM EROSION

FDEP R-Monument[1]	Simulation ID	Landward Limit of Storm Erosion[3] (feet from seaward edge of maintained property) Given Return Period in Years:				
		5	15	25	50	100
R-129	Existing Conditions	97	66	52	33	31
	Alternative 3	97	66	52	36	31
	Alternative 6	111	93	85	50	31
R-130	Existing Conditions	55	37	32	-2	-7
	Seawall Failure[3]	55	37	32	-14	-24
	Alternative 3	80	49	47	40	-6
	Alternative 6	88	61	59	56	49
R-131	Existing Conditions	19	9	-1	-13	-42
	Alternative 3	21	13	-2	-12	-56
	Alternative 6	21	13	-2	-11	-56
R-132	Existing Conditions	24	18	16	11	10
	Seawall Failure[3]	24	18	8	-20	-38
	Alternative 3	45	34	23	18	16
	Alternative 6	48	34	23	18	16
R-133	Existing Conditions	30	12	10	-6	-8
	Alternative 3	29	12	10	-4	-8
	Alternative 6	55	39	35	26	13
R-134	Existing Conditions	54	30	23	11	0
	Seawall Failure[3]	-17	-17	-17	-17	-17
	Alternative 3	59	43	34	28	18
	Alternative 6	68	59	55	44	40
R-135	Existing Conditions	48	-1	-71	-96	-133
	Alternative 3	81	50	-55	-88	-119
	Alternative 6	81	14	12	2	-93

TABLE 5-4 SBEACH LANDWARD LIMIT OF STORM EROSION CONTINUED

FDEP R-Monument[1]	Simulation ID	Landward Limit of Storm Erosion[2] (feet from seaward edge of maintained property) Given Return Period in Years:				
		5	15	25	50	100
R-136	Existing Conditions	8	2	0	0	0
	Seawall Failure[3]	**-14**	**-19**	**-20**	**-30**	**-42**
	Alternative 3	54	36	31	26	24
	Alternative 6	110	71	66	54	50
R-137	Existing Conditions	**-15**	**-27**	**-29**	**-29**	**-29**
	Seawall Failure[3]	**-15**	**-27**	**-29**	**-54**	**-77**
	Alternative 3	13	22	**-10**	**-16**	**-22**
	Alternative 6	73	61	47	43	**-16**
R-138	Existing Conditions	0	0	0	0	0
	Seawall Failure[3]	**-21**	**-51**	**-88**	**-144**	**-142**
	Alternative 3	3	0	0	0	0
	Alternative 6	28	18	13	8	1

[1]Profiles R-129, R-131 and R-135 do not have a seawall.

[2]Values bolded in red represent erosion landward of the edge of maintained or improved property or infrastructure. Cells shaded yellow represent exposed seawalls.

[4]Simulations run assuming seawall had failed.

5.3 Future scenario without project conditions

Evaluating the existing conditions alone does not provide a complete perspective of the beach response to storms without a project. Based on the erosional trend along the project area, the beach profile is likely to continue recessing and lowering in elevation. To represent future scenarios without a project, 10-year and 50-year projections of beach profiles were developed and simulated with SBEACH. The existing condition profiles were translated landward based on the background erosion rate of 2.25 feet per year (CPE, 2013). Seawalls were included in the future scenarios as they were in the existing conditions simulations.

The landward limits of erosion for the future scenarios are presented in Table 5-5. Based on the future scenario simulations, all storm protection provided by the dune between R-130 and R-134 is lost. Seawalls that were buried within the dune have become exposed and are subject to wave action. The seawalls along the shoreline between R-136 and R-138 fail due to toe scour, allowing erosion of upland property and damage to infrastructure (Figure 5-1).

Table 5-5 SBEACH LANDWARD LIMIT OF STORM EROSION FUTURE SCENARIO

FDEP R-Monument[1]	Future Scenario	Landward Limit of Storm Erosion[2] (feet from seaward edge of maintained property) Given Return Period in Years: 5	15	25	50	100
R-129	10 years into future	91	59	39	29	**-9**
	50 years into future	1	**-31**	**-51**	**-61**	**-99**
R-130	10 years into future	13	5	**-2**	**-11**	**-16**
	50 years into future	**-21**	**-32**	**-36**	**-43**	**-43**
R-131	10 years into future	**-11**	**-34**	**-40**	**-67**	**-83**
	50 years into future	**-101**	**-124**	**-130**	**-180**	**-188**
R-132	10 years into future	29	16	**-7**	**-15**	**-34**
	50 years into future	**-25**	**-26**	**-26**	**-26**	**-26**
R-133[3]	10 years into future	0	**-19.5**	**-25**	**-56**	**-72**
	50 years into future	**-37**	**-37**	**-37**	**-37**	**-37**
R-134	10 years into future	21	1	**-5**	**-5**	**-5**
	50 years into future	**-5**	**-5**	**-5**	**-5**	**-5**
R-135	10 years into future	**-246**	**-246**	**-246**	**-246**	**-246**
	50 years into future	**-236**	**-236**	**-236**	**-236**	**-236**
R-136	10 years into future	354	354	353	353	353
	50 years into future	354	354	354	354	355
R-137	10 years into future	95	95	95	24	**-8**
	50 years into future	77	77	77	77	**-51**
R-138	10 years into future	**-11**	**-11**	**-11**	**-11**	**-11**
	50 years into future	**-11**	**-11**	**-11**	**-11**	**-11**

[1]Profiles R-129, R-131 and R-135 do not have a seawall.

[2]Values bolded in red represent erosion landward of the edge of maintained or improved property or infrastructure.

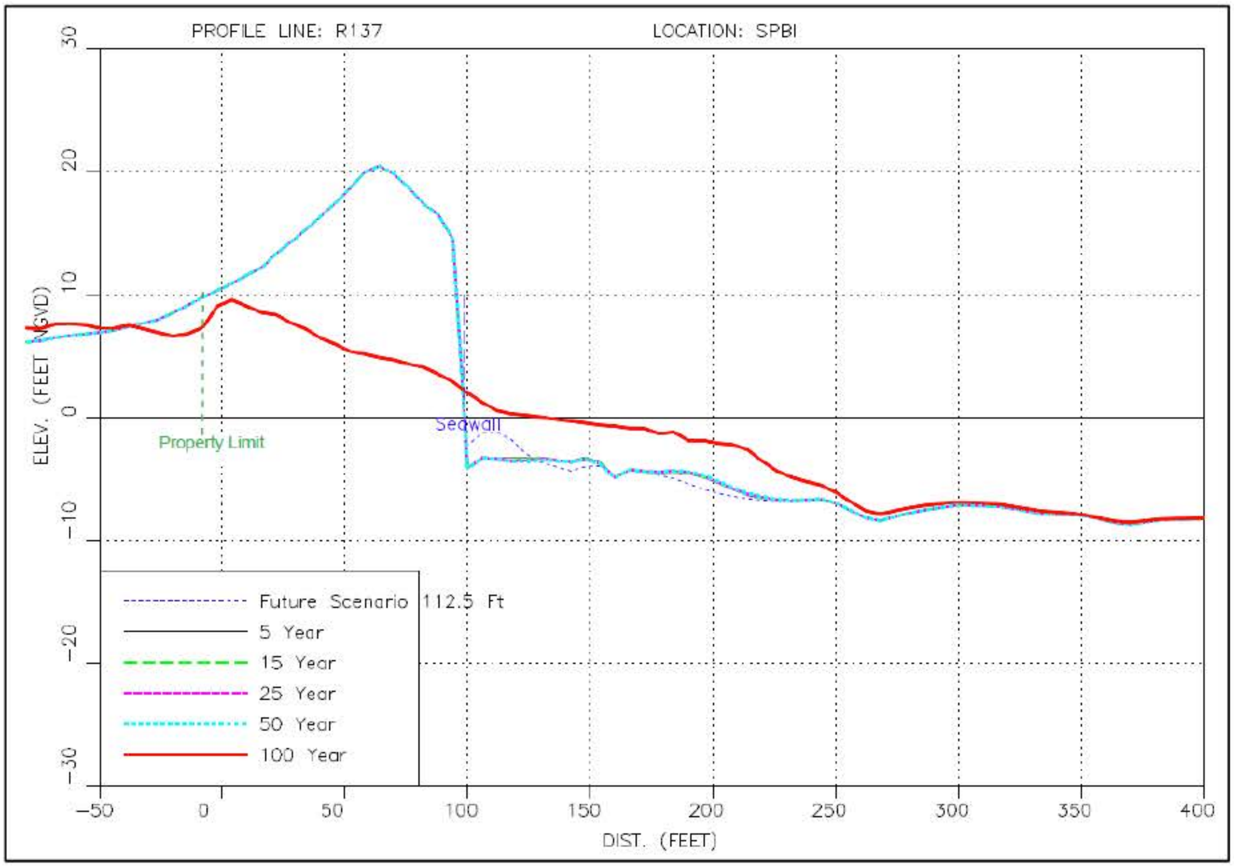


Figure 5-1 Seawall failure profile R-137 Future Scenario (50 years into the future)

5.4 Alternative 3: Applicant's Preferred Alternative Without Structures

The applicant's preferred alternative fill design consists of dune only and dune and berm fill from R-129 to R-134 (75,000 cy) and berm fill only from R-135 through R-138 (75,000 cy). No fill was simulated at R-129 since the existing conditions met the design criteria for the seaward dune extent. The placement of berm fill only from R-135 to R-138 allows the seawalls to remain partially exposed.

The project prevents scouring at the toe of the seawalls at all locations simulated except R-136 and R-138 (Appendix C). At these two locations, scouring increases incrementally with magnitude of storm. Furthermore, none of the buried seawalls were exposed as a result of the return interval storms. No seawall failures were observed during the simulations.

In general, the project provides storm protection against a 15-year storm with little to no impact to the pre-construction profile (**Error! Reference source not found.**). Under the occurrence of a 5, 15 and 25-year storm, the frontal dunes present at profiles R-129 through R-133 retained their shape but lost volume. Recession into the pre-construction profile increases with increasing magnitude of return interval storm. The berm profile remains at a 2 to 3-foot higher elevation than the pre-construction profile even after a 100-year storm.

5.5 Alternative 6: Larger Fill Design along Project Area (R-129- R-138)

Alternative 6 consists of a wider dune fill at profiles R-129 through R-134 (96,000 cubic yards) and a wider berm fill at profiles R-135 through R-138 than the applicant's preferred alternative (approximately 160,000 cubic yards). Berm widths range from approximately 17 to 130 feet from the pre-construction profile (Table 4-3).

The project prevents scouring at the toe of the seawalls at all locations (Appendix C). None of the buried seawalls were exposed as a result of the return interval storms. No seawall failures were observed during the simulations.

In general, the project provides storm protection against a 15-year storm with little to no impact to the pre-construction profile from profiles R-129 to R-134 and 50-year return interval storm protection to the pre-construction profiles from R-135 through R-138. Under the occurrence of a 5, 15 and 25-year storm, the frontal dunes present at profiles R-129 through R-133 retained their shape but receded and lost volume. Recession into the pre-construction profile increases with increasing magnitude of return interval storm. The berm profile remains at a 2 to 5-foot higher elevation than the pre-construction profile even after a 100-year storm.

Based on the landward limit of erosion calculation, damage to property is possible adjacent to profile R-131 as a result of a 25-year return interval or stronger storm (**Error! Reference source not found.**). Property along profiles R-135 and R-137 are at risk of damage during the occurrence of a 100-year return interval storm or stronger storm.

6 CONCLUSIONS AND RECOMMENDATIONS

To determine the level of storm protection provided by existing and potential dunes and berms along the project area, the SBEACH model was applied and storm erosion given the existing (Winter 2011/2012) conditions and two alternatives of beach and dune fill cross-sections was analyzed. The following conclusions were made based on the results of the model study:

- The critical return interval storm resulting in property damage under existing conditions is between a 15-year and 25-year storm. On average, 7.3 to 7.7 cubic yards per foot was simulated to erode from the beach above mean low water during a 15-year and 25-year storm, respectively. This volumetric loss coincides with a steepening of the dune face, shoreline retreat and lowering of the beach profile elevation. Based on 2011/2012 conditions, erosion and wave impacts were simulated to extend landward damaging infrastructure and maintained (landscaped) property areas at FDEP R-monuments R-130, R-133, R-135 and R-137. These locations lack seawalls or have seawalls located further landward on the property.

- Seawalls prevent erosion into the upland property until wall failure. Scouring at the toe of exposed seawalls increases their likelihood of failure. Based on the 2011/2012 conditions response to a storm event, the berm elevation adjacent to exposed seawalls will lower increasing the likelihood of seawall failure during storms. If seawall failure is assumed to occur along the project area, infrastructure would be impacted from R-130 through R-138. A detailed analysis of the structural stability of the individual seawalls along the project area would be necessary to truly assess the vulnerability of this critical component of storm protection infrastructure.

- Based on the SBEACH simulations and background erosion rates, the status quo dune nourishments alone are not sufficient to sustain the existing conditions. The No Action Status Quo conditions for the project area include dune nourishments of 5 to 11 cubic yards per foot of fill between R-135+460 to R-137+410 and R-129 to R-133, respectively, placed every 1 to 5 years. This conclusion is made based on the storm response simulation of the 2011/2012 conditions which are representative of the No

Action Status Quo Scenario. The 2011/2012 conditions represent the beach 9 months to 3 years after a dune nourishment and without the impacts of a major storm. The majority if not all of this placed volume would be lost during a 15-year storm or after 2 to 5 years of average wave climate period without major storms.

- Based on the simulation of two forecasted No Action scenarios 10 and 50 years from the present (not Status Quo, no dune nourishments included in simulation setup), all remaining storm protection provided by the dune between R-130 and R-134 would be lost after one major storm event. Seawalls that were buried within the dune would become exposed and subjected to wave action. The seawalls between R-136 and R-138 would possibly fail due to toe scour depending on the depth of the wall, allowing erosion of upland property and damage to infrastructure.

REFERENCES

Allsop, W., Bruce, T., Pearson, J., Besley, P. 2005. Wave overtopping at vertical and steep seawalls. Maritime Engineering. 158. pp. 103-114.

Applied Technology & Management. 2012. Town of Palm Beach Offshore Sand Search Investigations South Area Summary. Prepared for the Town of Palm Beach.

Coastal Planning & Engineering. 2013. Central Palm Beach County Comprehensive Erosion Control Project Reformulated Shore Protection Alternatives. Prepared for Palm Beach County. 109 p.

Coastal Planning & Engineering. 2007. Town of Palm Beach Reach 8 Beach Nourishment Project Response to RAI #3 JCP File Number 0250572-001-JC; July 2007; CPE02829-03802.

Federal Emergency Management Agency. 1982. Flood Insurance Study, Wave Height Analysis, Town of South Palm Beach, Florida, Palm Beach County. 15 p.

Florida Department of Environmental Protection. 2013. Palm Beach Island Beach Management Agreement. http://www.dep.state.fl.us/BEACHES/pb-bma/index.htm

Larson M., and Kraus, N.C., 1989. SBEACH: Numerical Model for Simulating Storm-Induced Beach Change, 2 Vols., Technical Report CERC 89-9, U.S. Army Corps of Engineers, Washington.

Larson, M., Wise, R.A., Kraus, NC., 2004. Modeling Dune Response by Overwash Transport, Proceedings of the International Conference on Coastal Engineering 2004, American Society of Civil Engineers, Reston, VA, pp. 2133-2145.

National Oceanographic and Atmospheric Administration, 2013. WAVEWATCH III Model

Data Access, http://polar.ncep.noaa.gov/waves/download.shtml?.

National Oceanographic and Atmospheric Administration, 2003. Bench Mark Data Sheets, Lake Worth Pier, FL, Station ID: 8722670, http://tidesandcurrents.noaa.gov/.

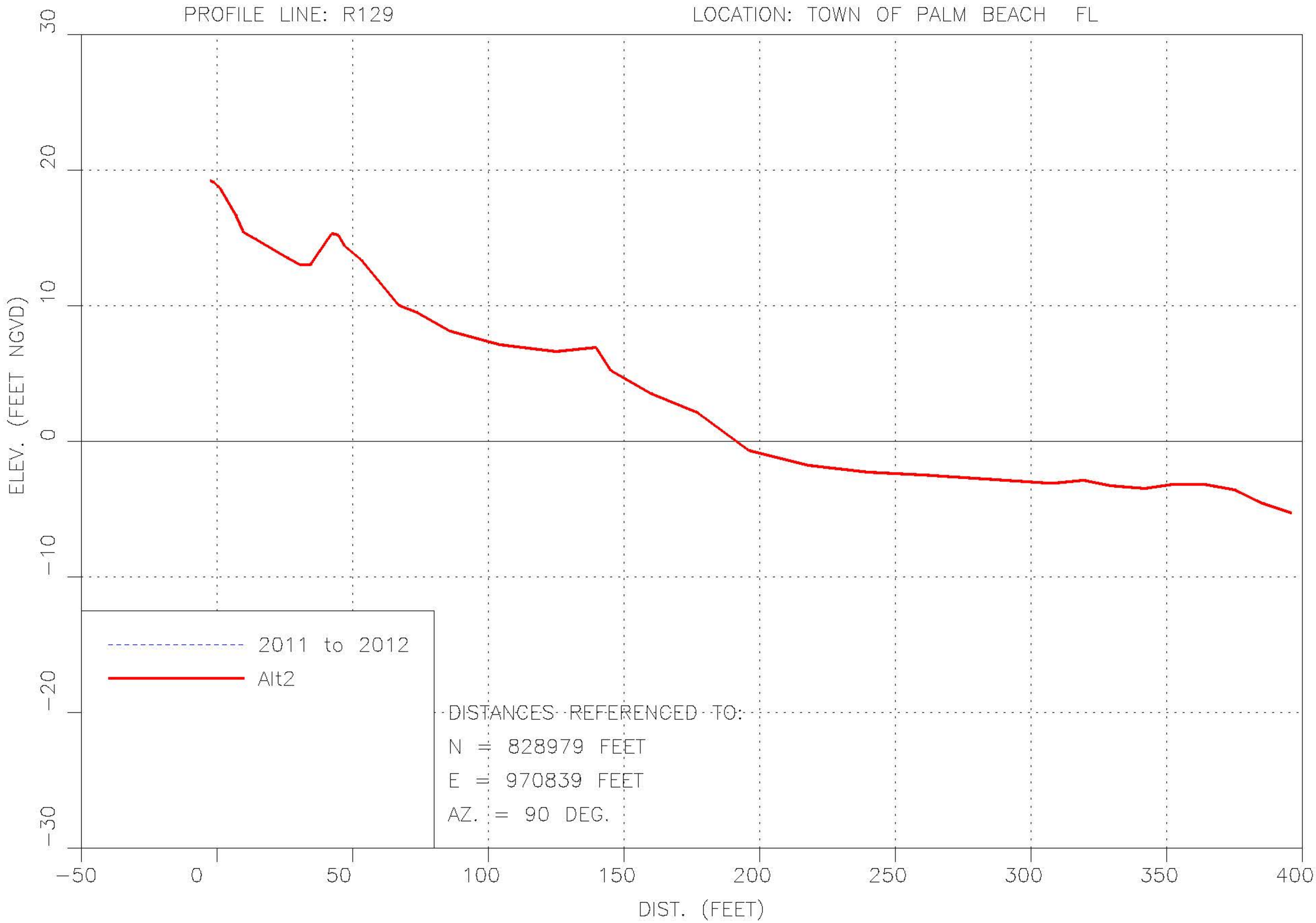
U.S. Army Corps of Engineers, 2000. Coastal Engineering Manual, Engineer Manual 1110-2-1100, U.S. Army Corps of Engineers, Washington, D.C. (in 6 volumes).

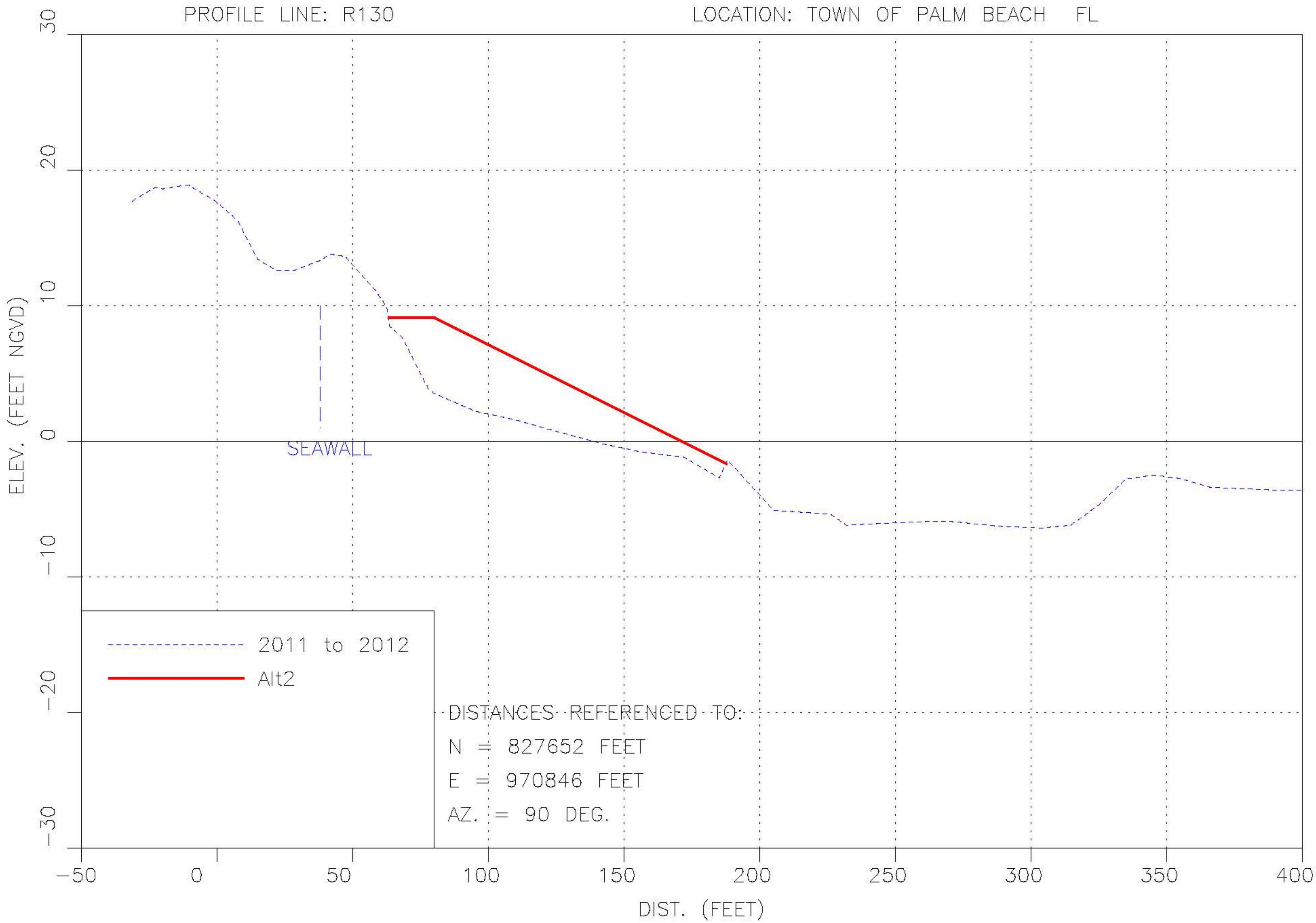
U.S. Army Corps of Engineers, 1991. Measurements for Lake Worth, FL, http://sandbar.wes.army.mil/public_html/pmab2web/htdocs/florida/lakeworth/lakeworth.html.

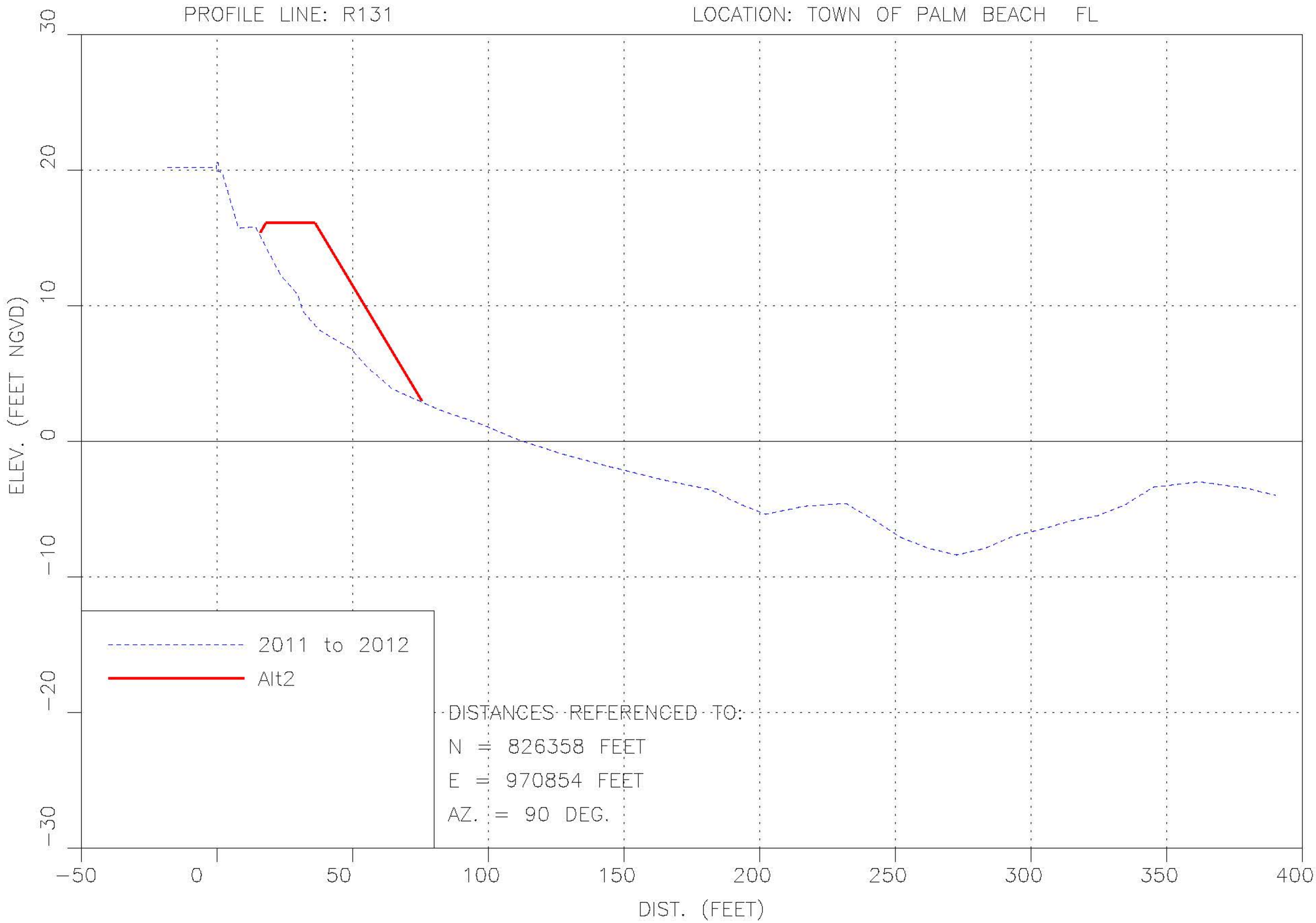
U. S. Army Engineer Waterways Experiment Station. 1985. Estimates of Hurricane Winds for the East and Gulf Coasts of the United States. CETN-I-36. 7 p.

APPENDIX A

PROSPECTIVE DESIGN PROFILES

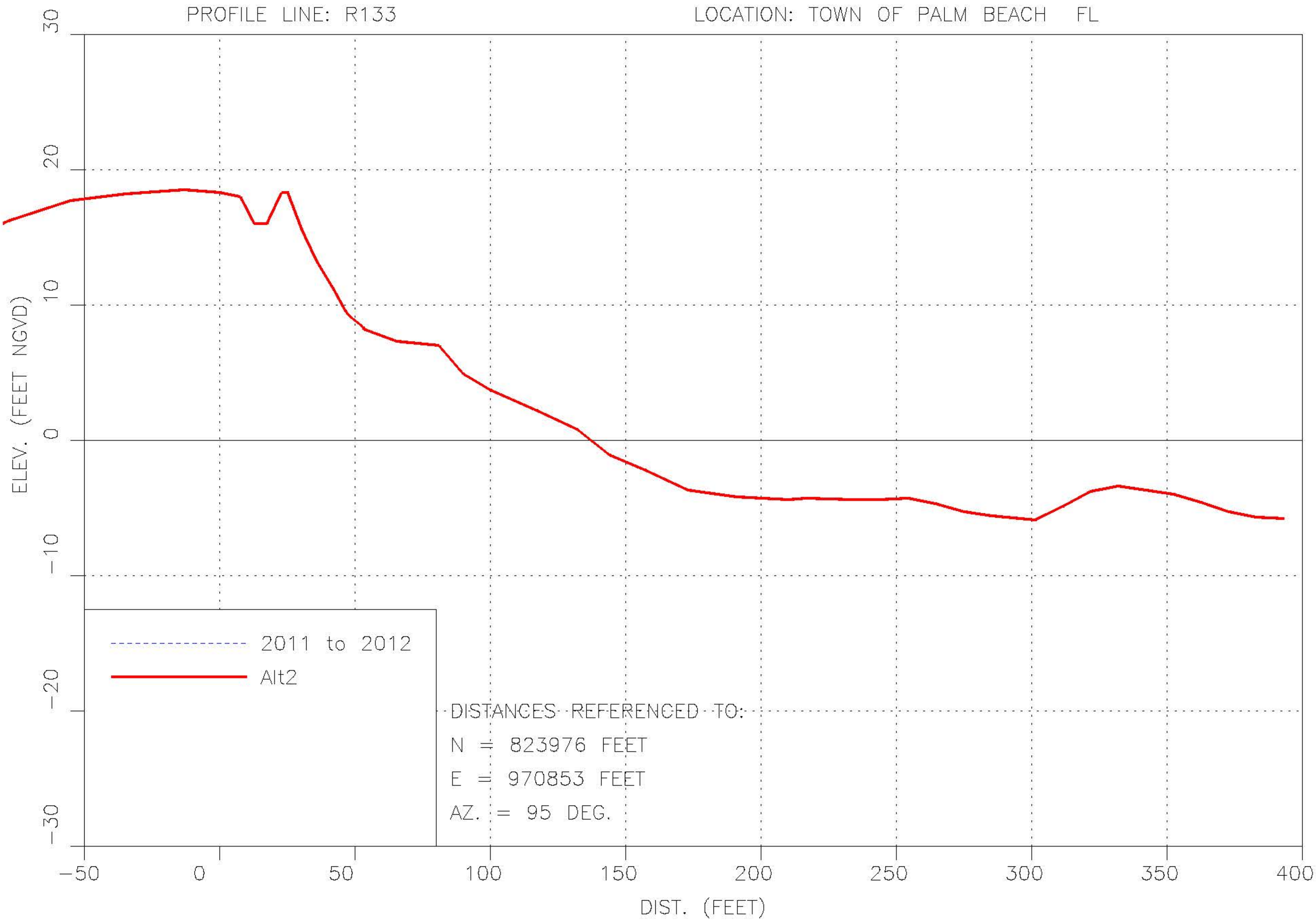

PROFILE LINE: R129
LOCATION: TOWN OF PALM BEACH FL
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
2011 to 2012
Alt2
DISTANCES REFERENCED TO:
N = 828979 FEET
E = 970839 FEET
AZ. = 90 DEG.

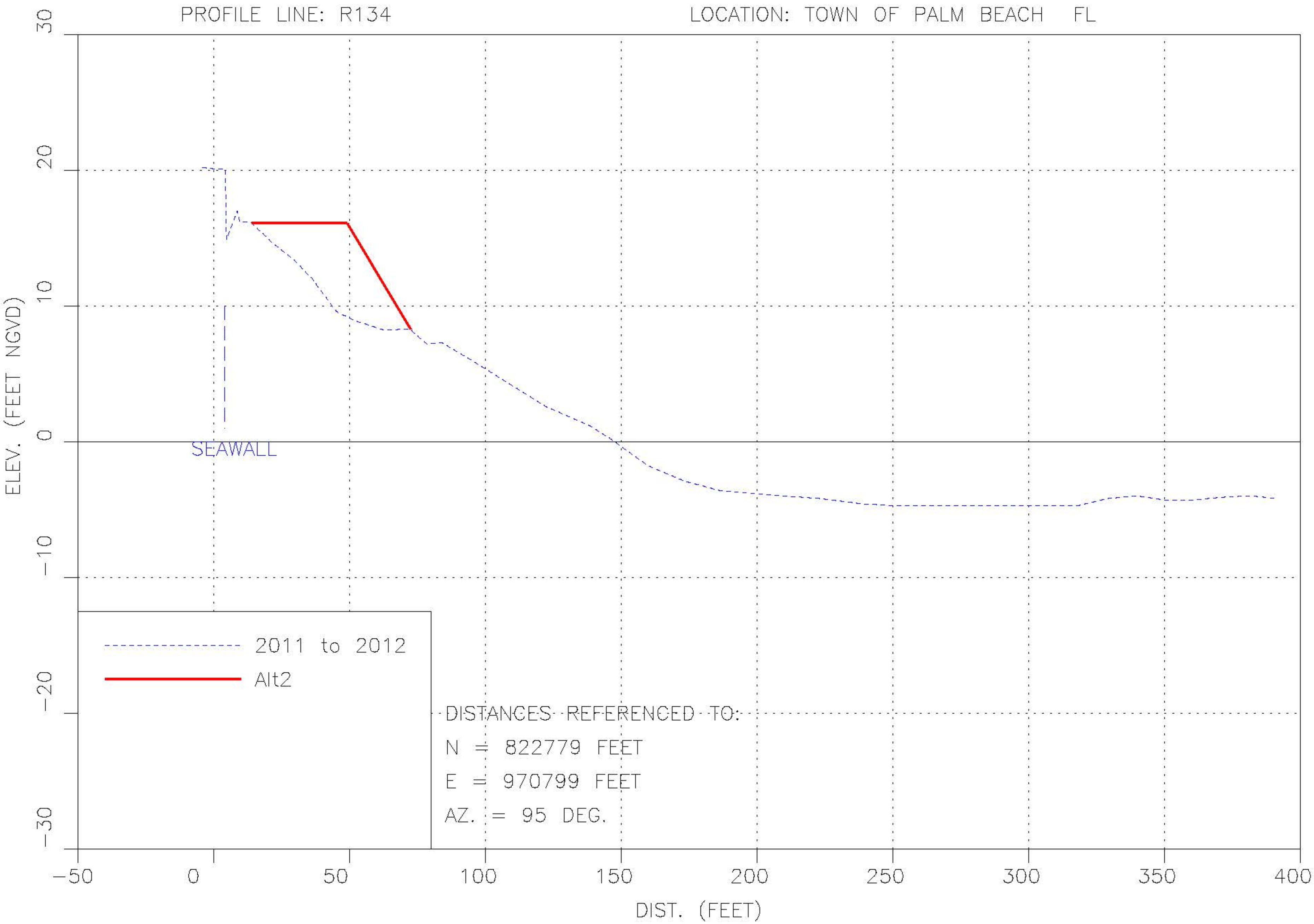

PROFILE LINE: R130
LOCATION: TOWN OF PALM BEACH FL
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
SEAWALL
2011 to 2012
Alt2
DISTANCES REFERENCED TO:
N = 827652 FEET
E = 970846 FEET
AZ. = 90 DEG.
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)

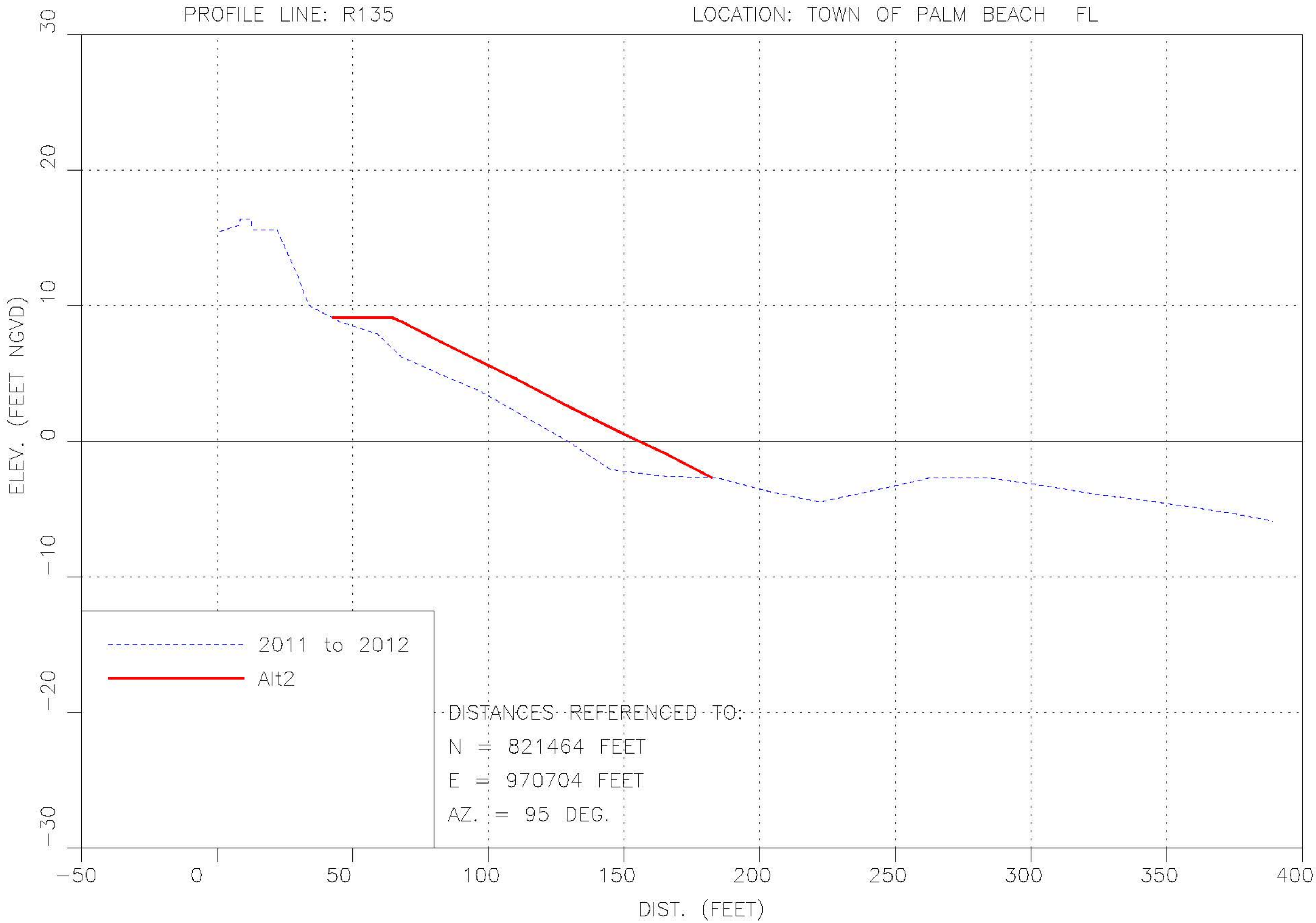


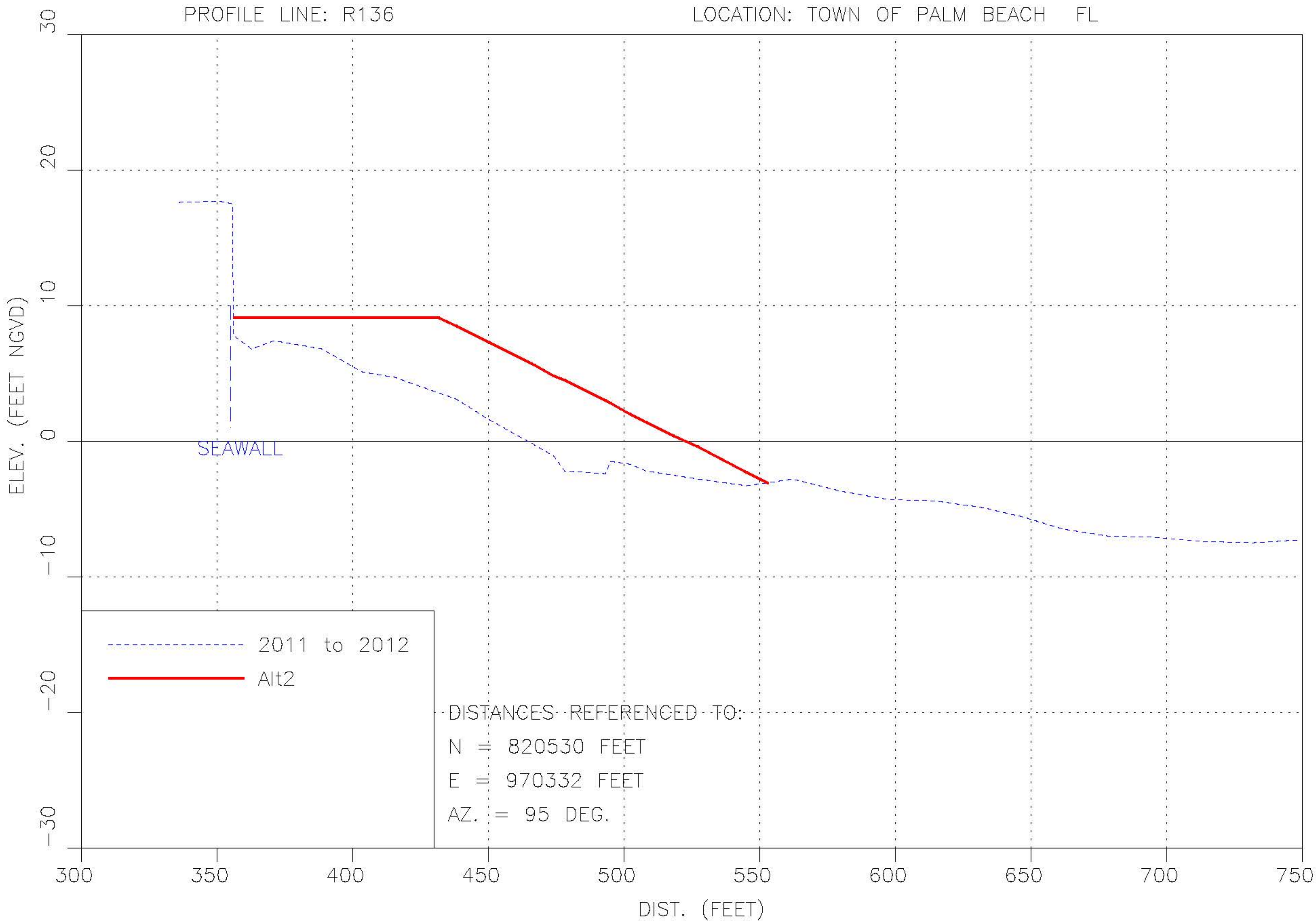
PROFILE LINE: R131
LOCATION: TOWN OF PALM BEACH FL
ELEV. (FEET NGVD)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
2011 to 2012
Alt2
DISTANCES REFERENCED TO:
N = 826358 FEET
E = 970854 FEET
AZ. = 90 DEG.

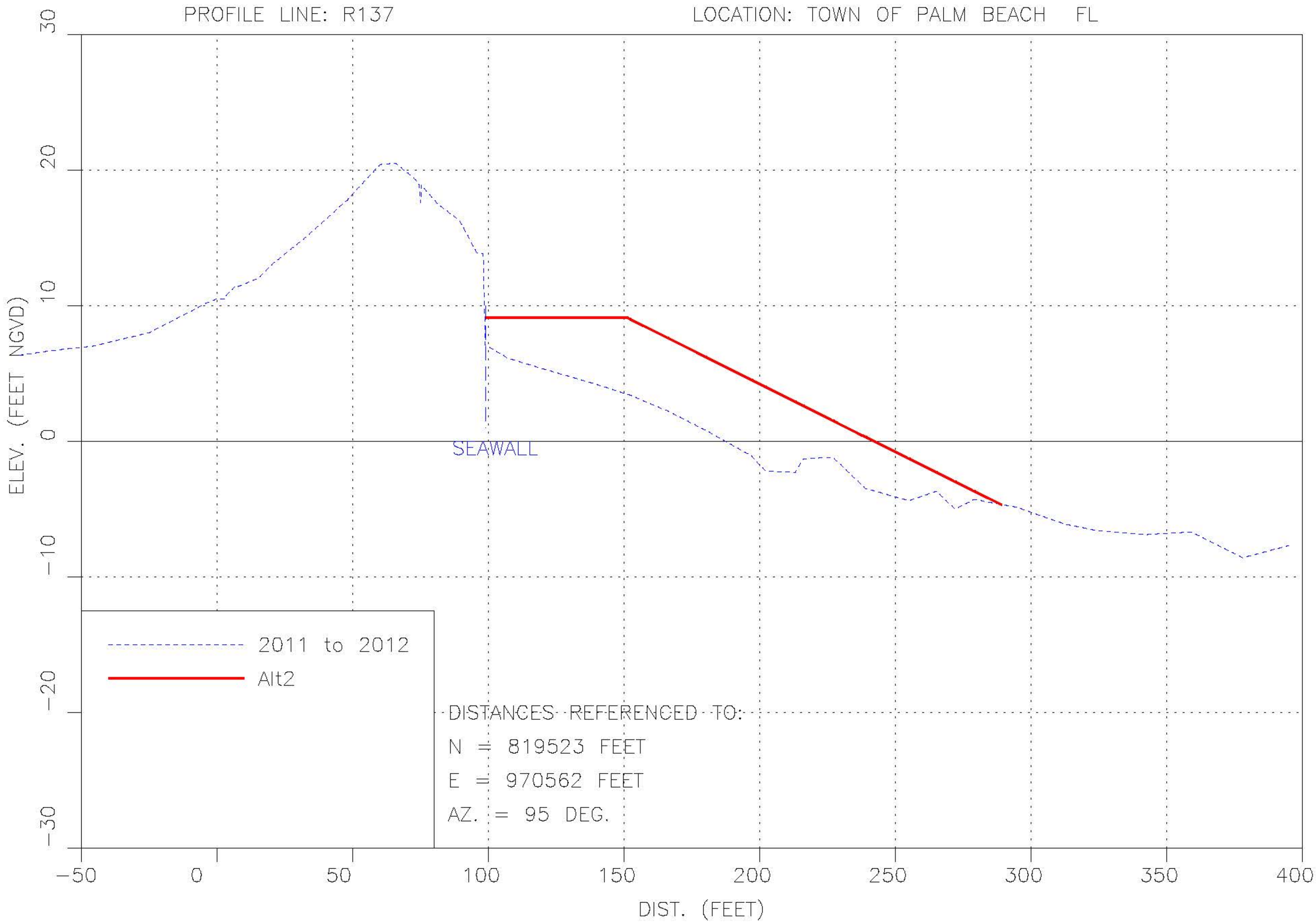

PROFILE LINE: R132
LOCATION: TOWN OF PALM BEACH FL
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
SEAWALL
2011 to 2012
Alt2
DISTANCES REFERENCED TO:
N = 825200 FEET
E = 970827 FEET
AZ. = 95 DEG.

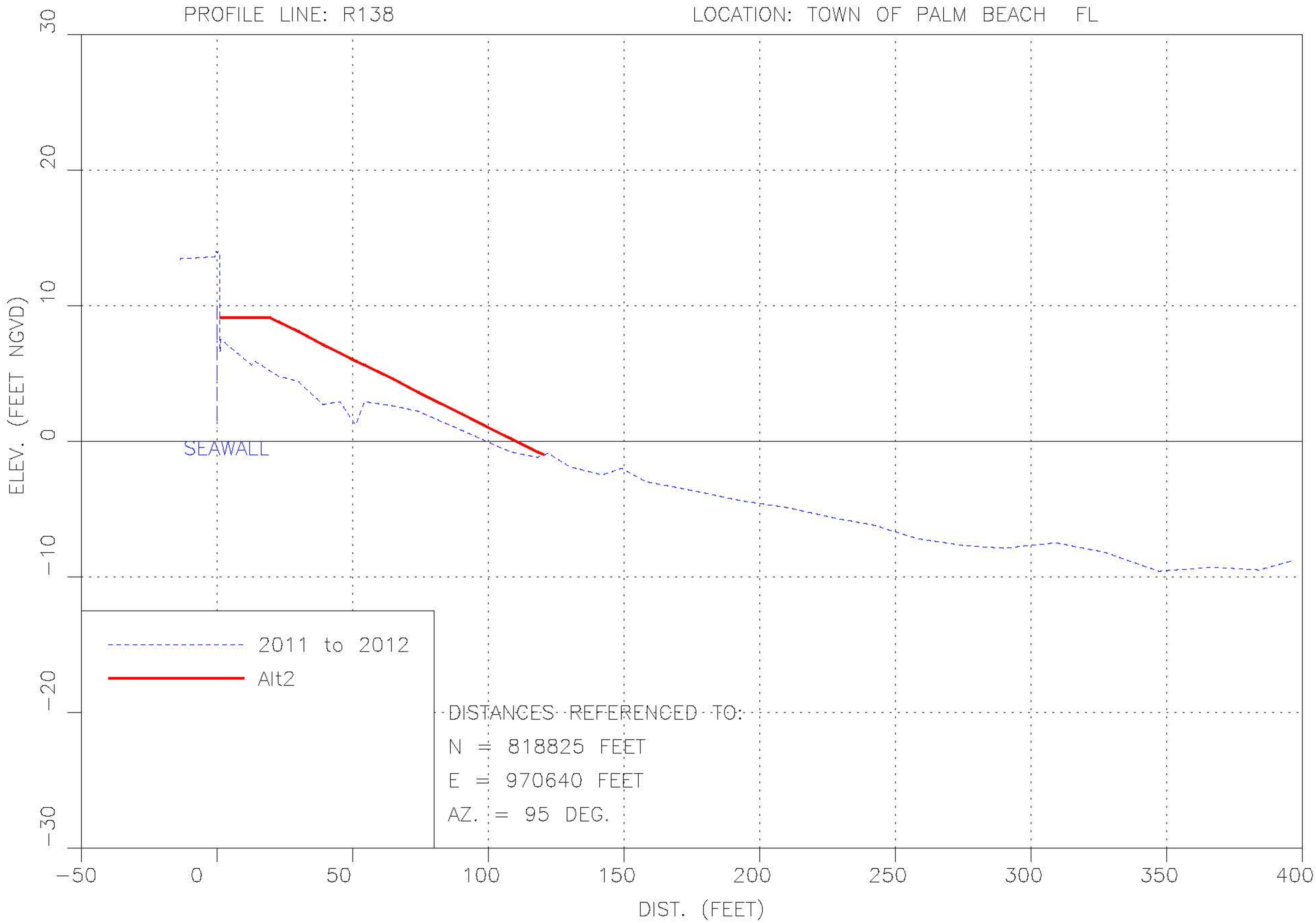

PROFILE LINE: R133
LOCATION: TOWN OF PALM BEACH FL
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
2011 to 2012
Alt2
DISTANCES REFERENCED TO:
N = 823976 FEET
E = 970853 FEET
AZ. = 95 DEG.

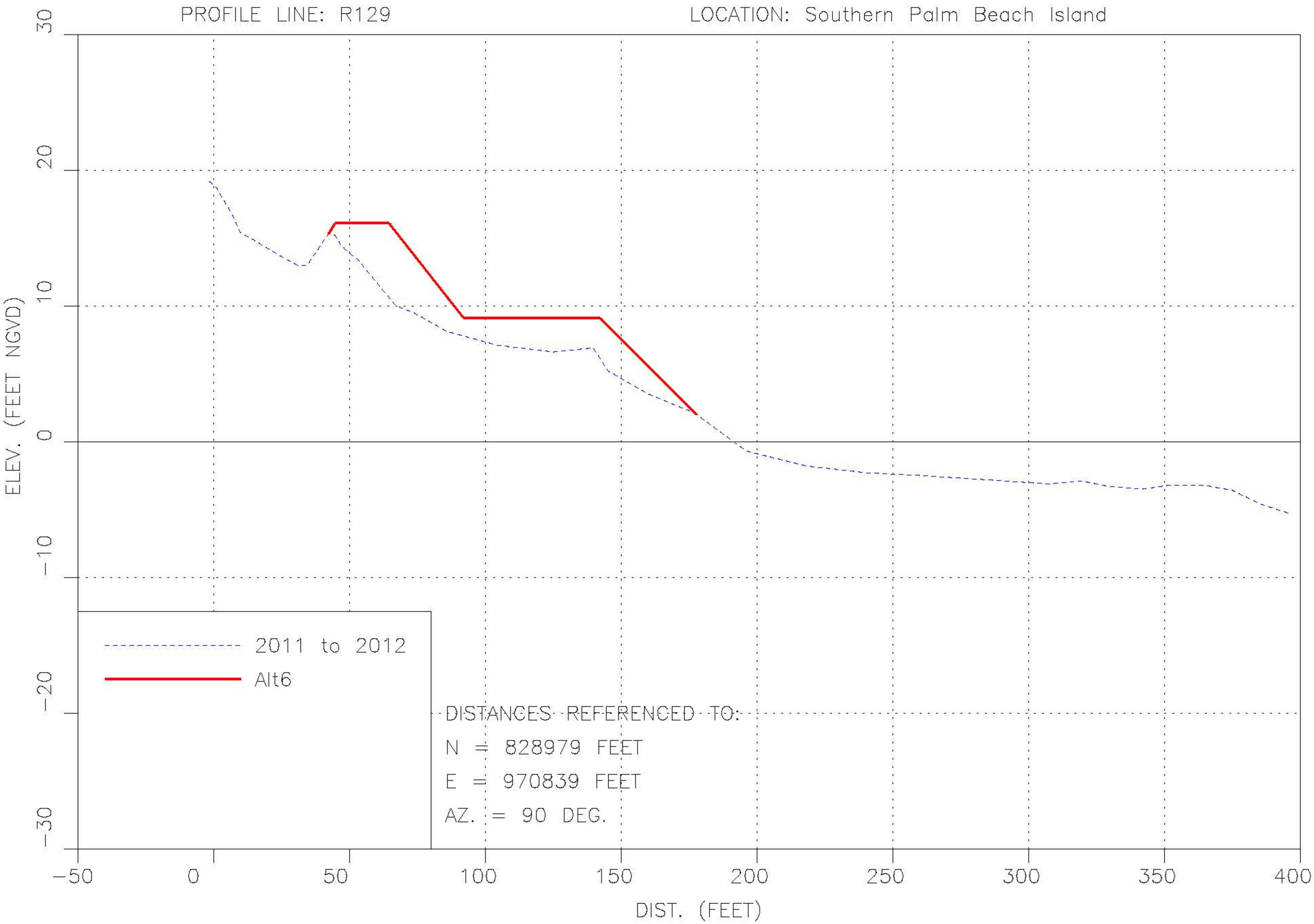

PROFILE LINE: R134
LOCATION: TOWN OF PALM BEACH FL
ELEV. (FEET NGVD)
DIST. (FEET)
SEAWALL
2011 to 2012
Alt2
DISTANCES REFERENCED TO:
N = 822779 FEET
E = 970799 FEET
AZ. = 95 DEG.
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400


PROFILE LINE: R135
LOCATION: TOWN OF PALM BEACH FL
ELEV. (FEET NGVD)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
2011 to 2012
Alt2
DISTANCES REFERENCED TO:
N = 821464 FEET
E = 970704 FEET
AZ. = 95 DEG.


PROFILE LINE: R136
LOCATION: TOWN OF PALM BEACH FL
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
SEAWALL
2011 to 2012
Alt2
DISTANCES REFERENCED TO:
N = 820530 FEET
E = 970332 FEET
AZ. = 95 DEG.
300
350
400
450
500
550
600
650
700
750
DIST. (FEET)

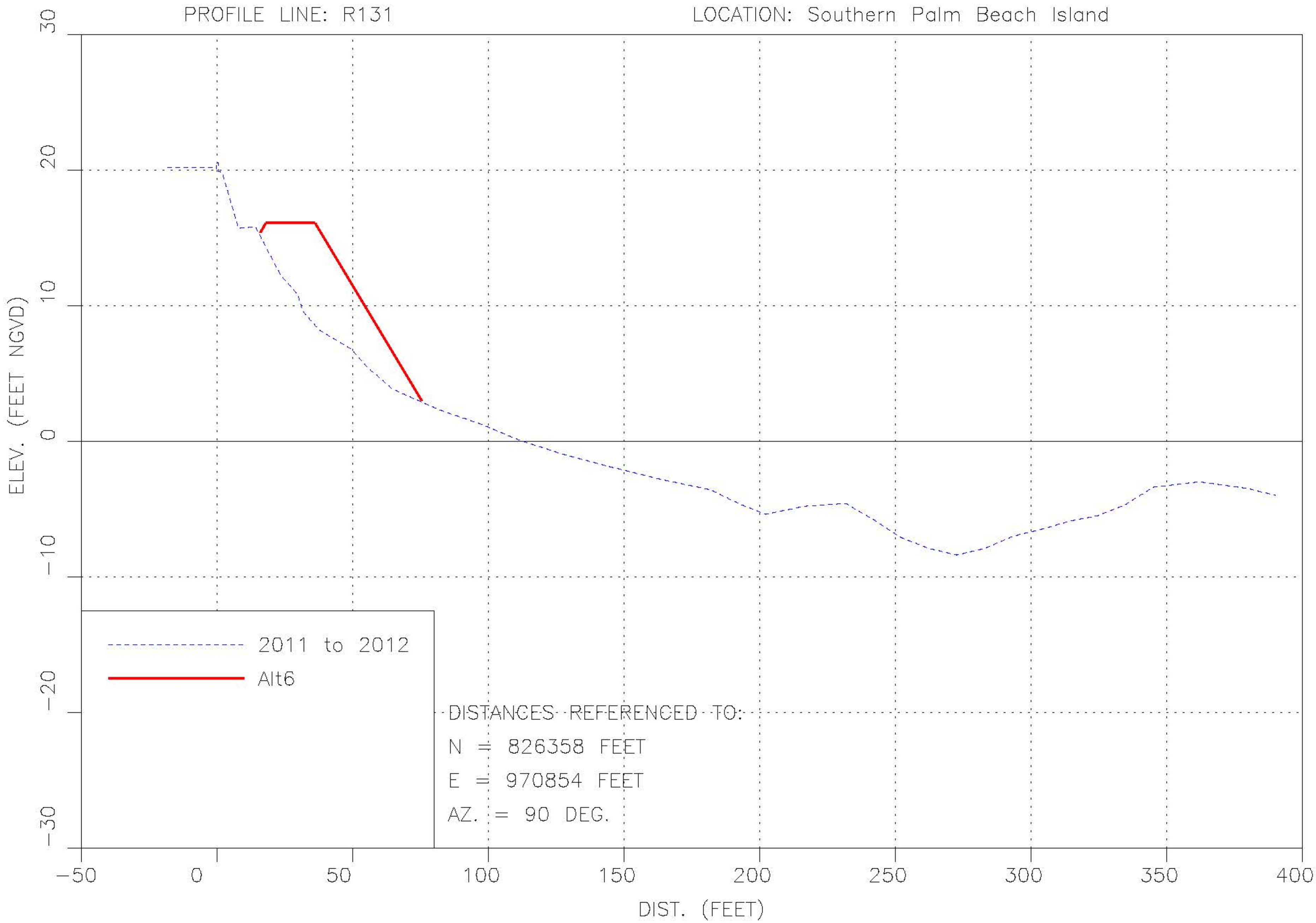

PROFILE LINE: R137
LOCATION: TOWN OF PALM BEACH FL
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
SEAWALL
2011 to 2012
Alt2
DISTANCES REFERENCED TO:
N = 819523 FEET
E = 970562 FEET
AZ. = 95 DEG.
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)


PROFILE LINE: R138
LOCATION: TOWN OF PALM BEACH FL
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
SEAWALL
2011 to 2012
Alt2
DISTANCES REFERENCED TO:
N = 818825 FEET
E = 970640 FEET
AZ. = 95 DEG.
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)



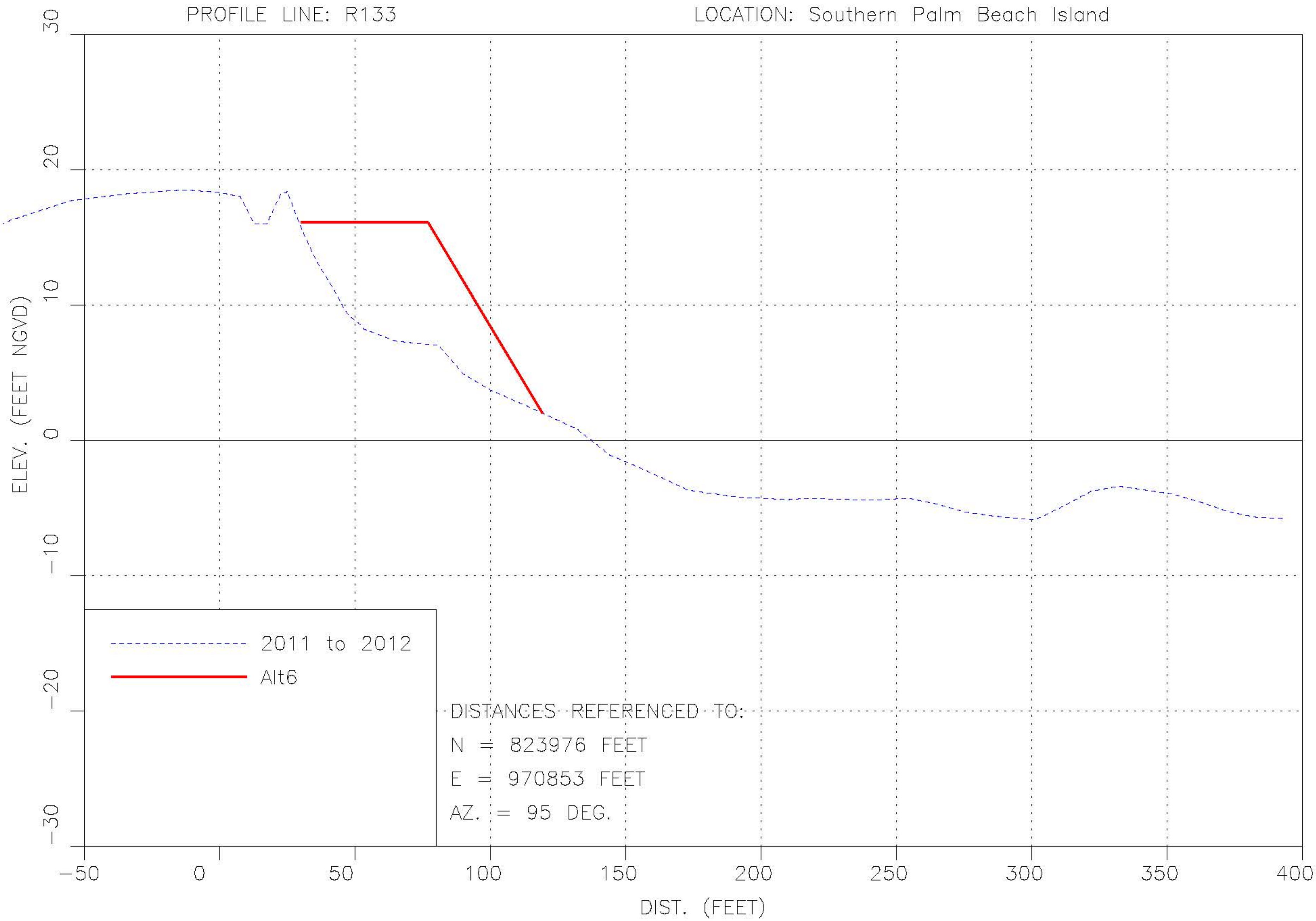
PROFILE LINE: R129
LOCATION: Southern Palm Beach Island
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
2011 to 2012
Alt6
DISTANCES REFERENCED TO:
N = 828979 FEET
E = 970839 FEET
AZ. = 90 DEG.

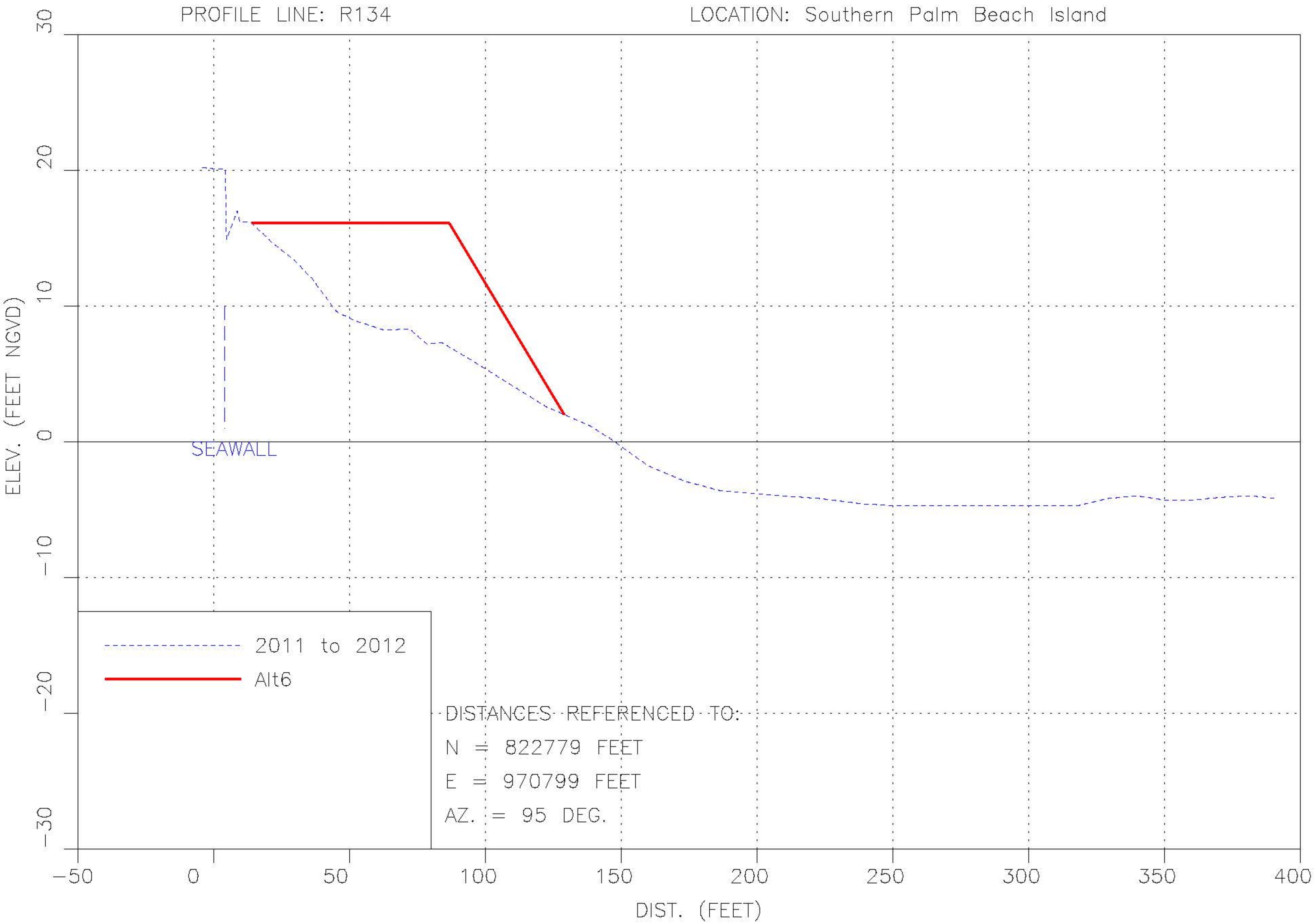

PROFILE LINE: R130
LOCATION: Southern Palm Beach Island
ELEV. (FEET NGVD)
30
20
10
0
−10
−20
−30
SEAWALL
2011 to 2012
Alt6
DISTANCES REFERENCED TO:
N = 827652 FEET
E = 970846 FEET
AZ. = 90 DEG.
−50
0
50
100
150
200
250
300
350
400
DIST. (FEET)



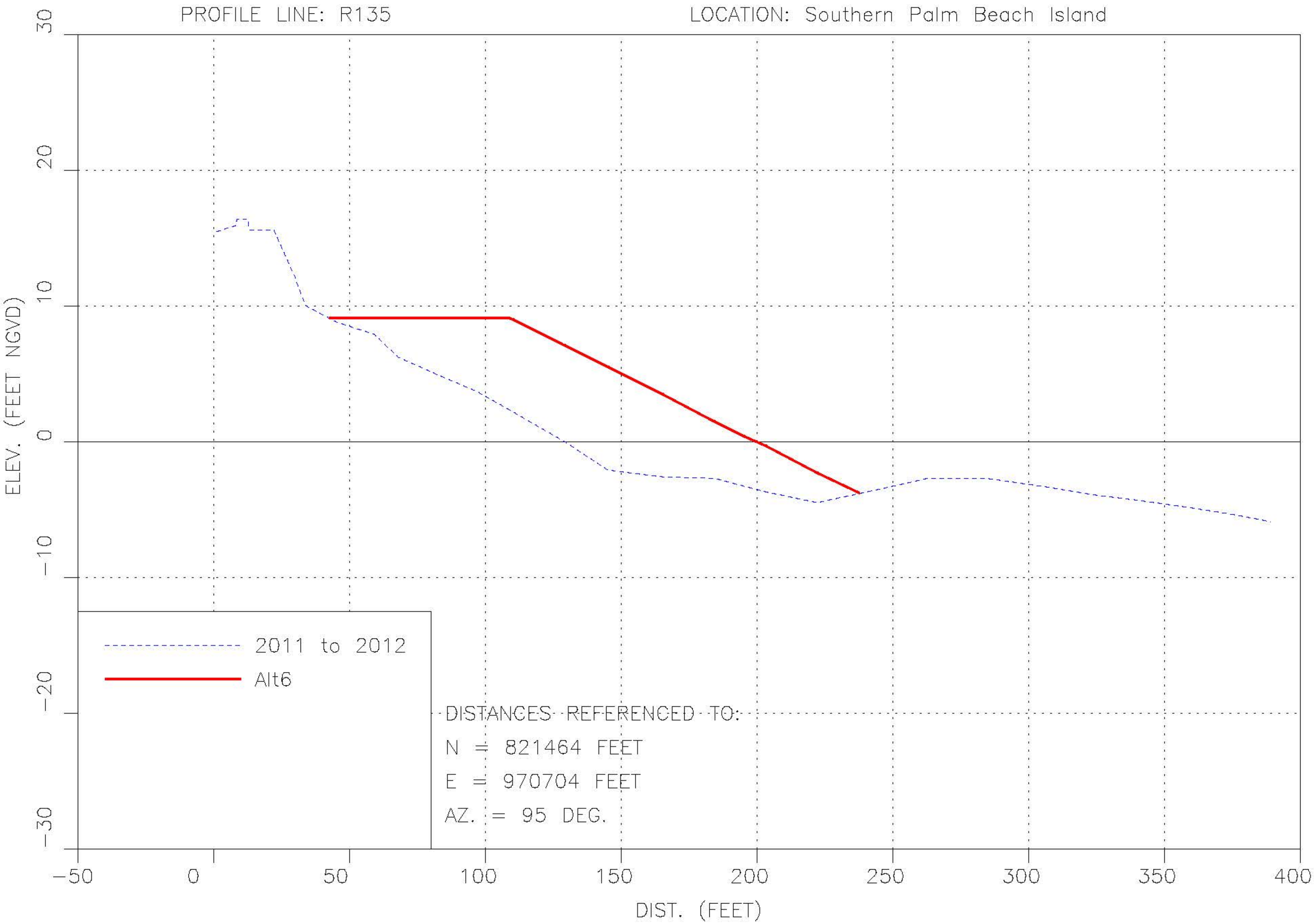
PROFILE LINE: R131
LOCATION: Southern Palm Beach Island
ELEV. (FEET NGVD)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
2011 to 2012
Alt6
DISTANCES REFERENCED TO:
N = 826358 FEET
E = 970854 FEET
AZ. = 90 DEG.

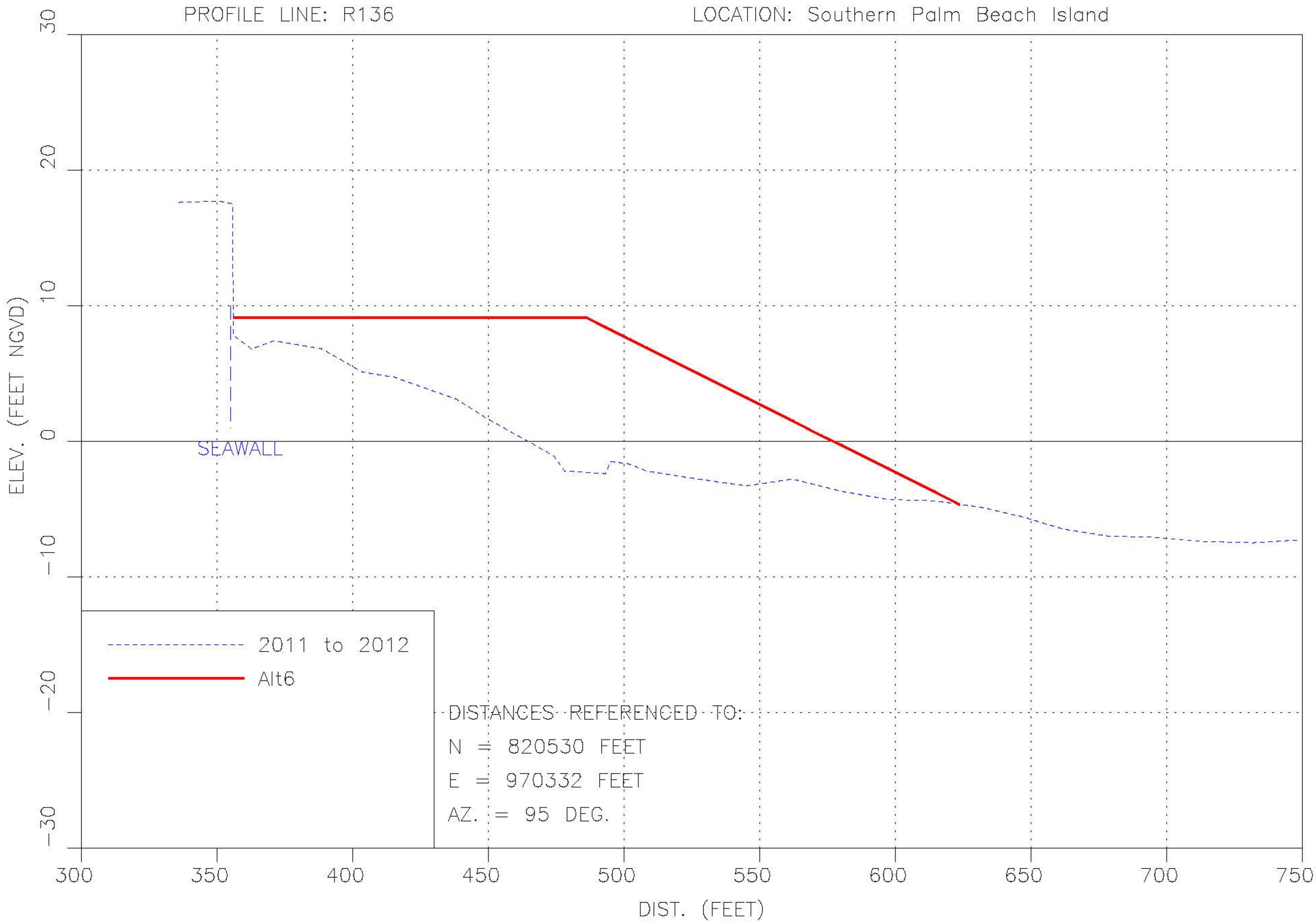

PROFILE LINE: R132
LOCATION: Southern Palm Beach Island
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
SEAWALL
2011 to 2012
Alt6
DISTANCES REFERENCED TO:
N = 825200 FEET
E = 970827 FEET
AZ. = 95 DEG.
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)


PROFILE LINE: R133
LOCATION: Southern Palm Beach Island
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
2011 to 2012
Alt6
DISTANCES REFERENCED TO:
N = 823976 FEET
E = 970853 FEET
AZ. = 95 DEG.

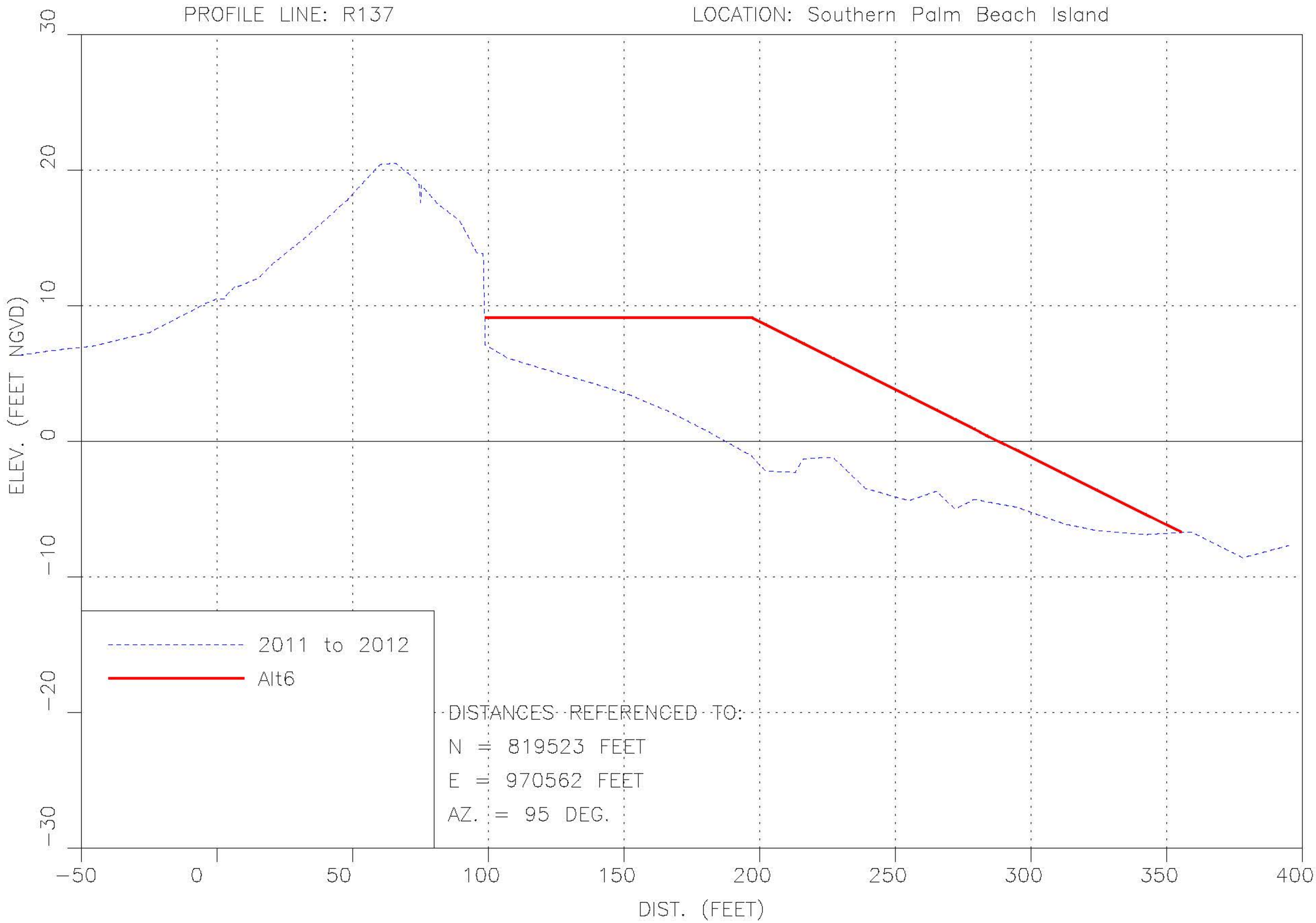


PROFILE LINE: R134
LOCATION: Southern Palm Beach Island
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
SEAWALL
2011 to 2012
Alt6
DISTANCES REFERENCED TO:
N = 822779 FEET
E = 970799 FEET
AZ. = 95 DEG.
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)

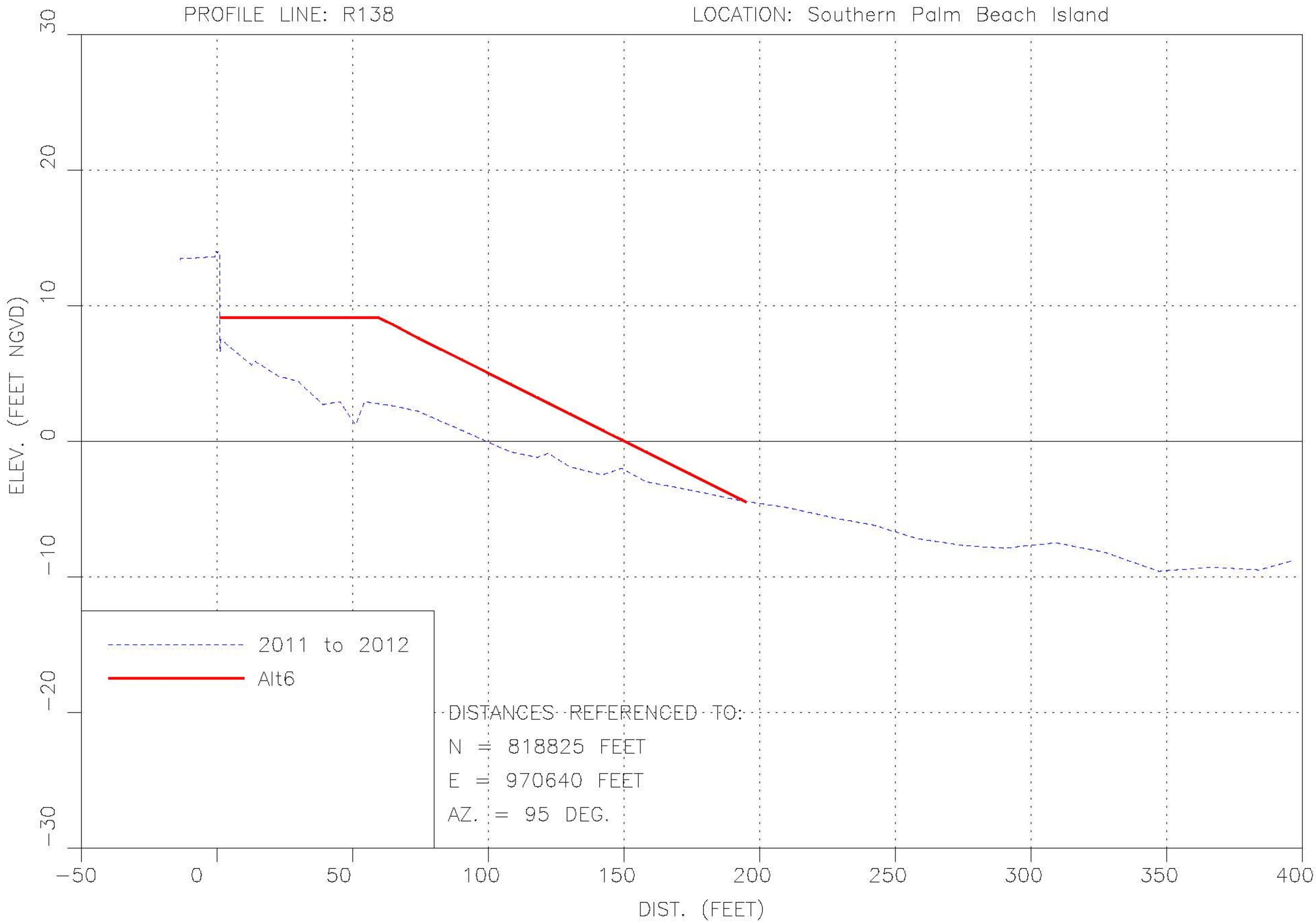

PROFILE LINE: R135
LOCATION: Southern Palm Beach Island
ELEV. (FEET NGVD)
30
20
10
0
−10
−20
−30
DIST. (FEET)
−50
0
50
100
150
200
250
300
350
400
2011 to 2012
Alt6
DISTANCES REFERENCED TO:
N = 821464 FEET
E = 970704 FEET
AZ. = 95 DEG.



PROFILE LINE: R136
LOCATION: Southern Palm Beach Island
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
SEAWALL
2011 to 2012
Alt6
DISTANCES REFERENCED TO:
N = 820530 FEET
E = 970332 FEET
AZ. = 95 DEG.
300
350
400
450
500
550
600
650
700
750
DIST. (FEET)

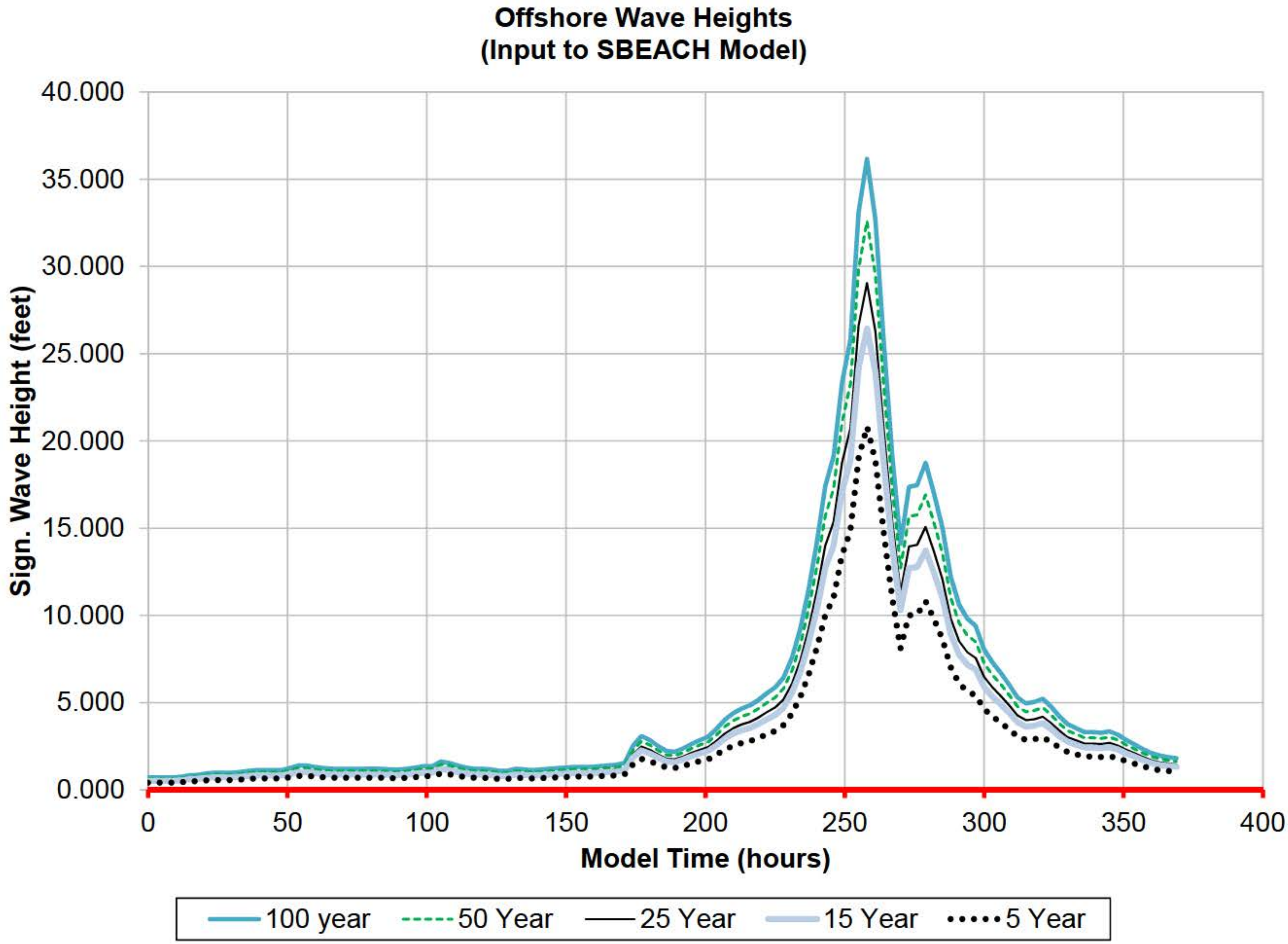


PROFILE LINE: R137
LOCATION: Southern Palm Beach Island
30
20
10
0
−10
−20
−30
ELEV. (FEET NGVD)
−50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
2011 to 2012
Alt6
DISTANCES REFERENCED TO:
N = 819523 FEET
E = 970562 FEET
AZ. = 95 DEG.

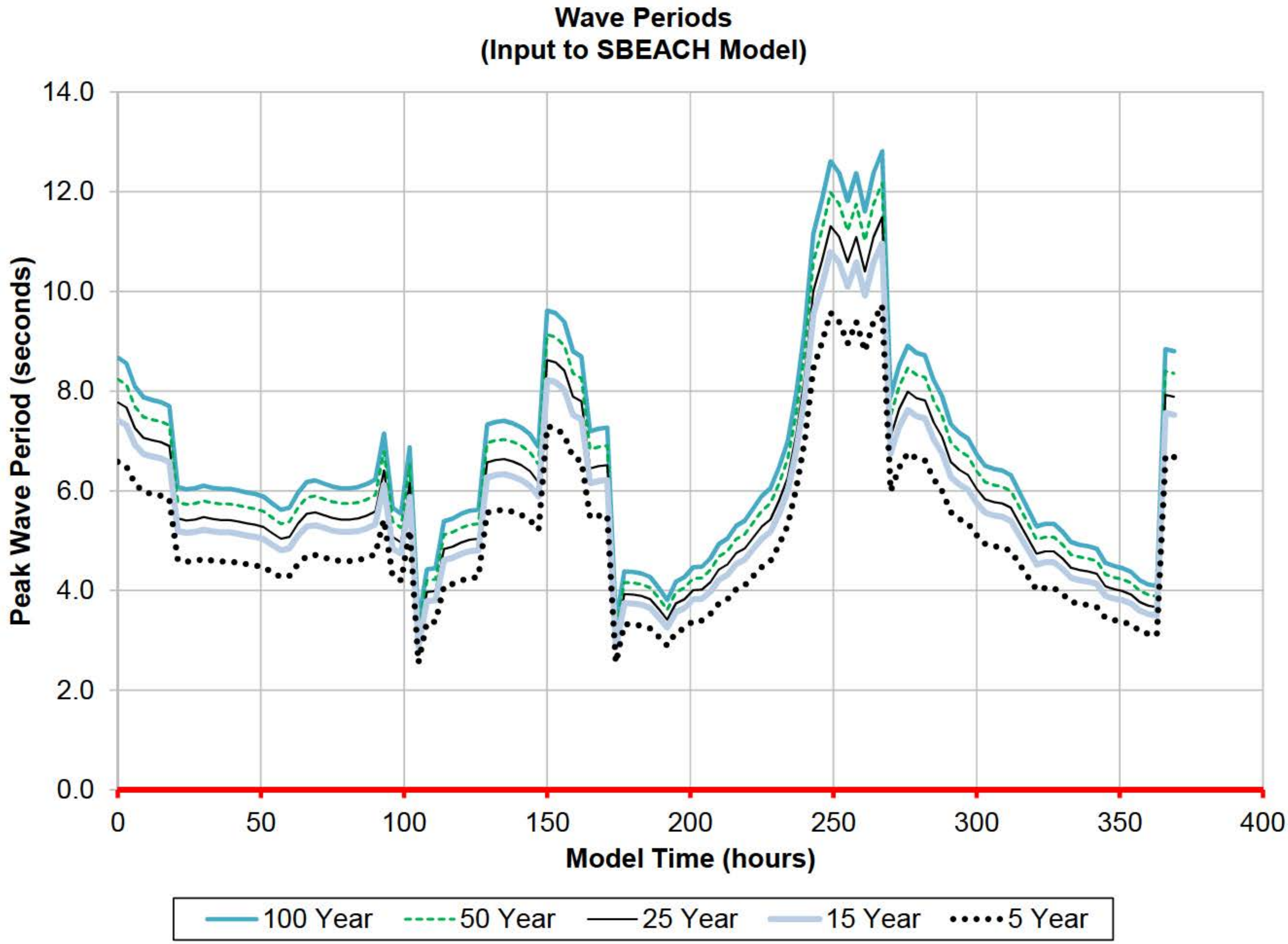

PROFILE LINE: R138
LOCATION: Southern Palm Beach Island
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
2011 to 2012
Alt6
DISTANCES REFERENCED TO:
N = 818825 FEET
E = 970640 FEET
AZ. = 95 DEG.

APPENDIX B

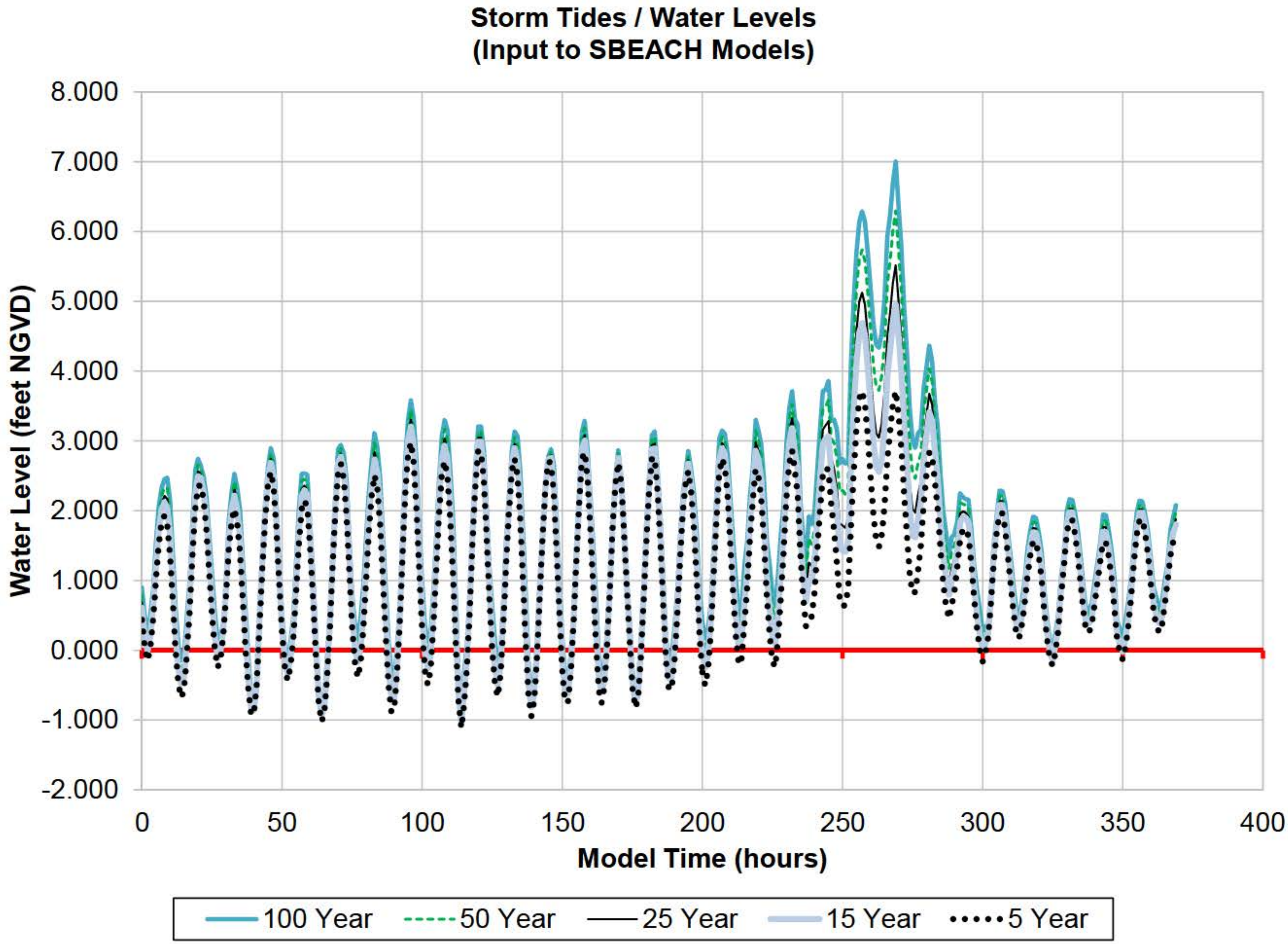
INPUT STORMS FOR SBEACH MODEL



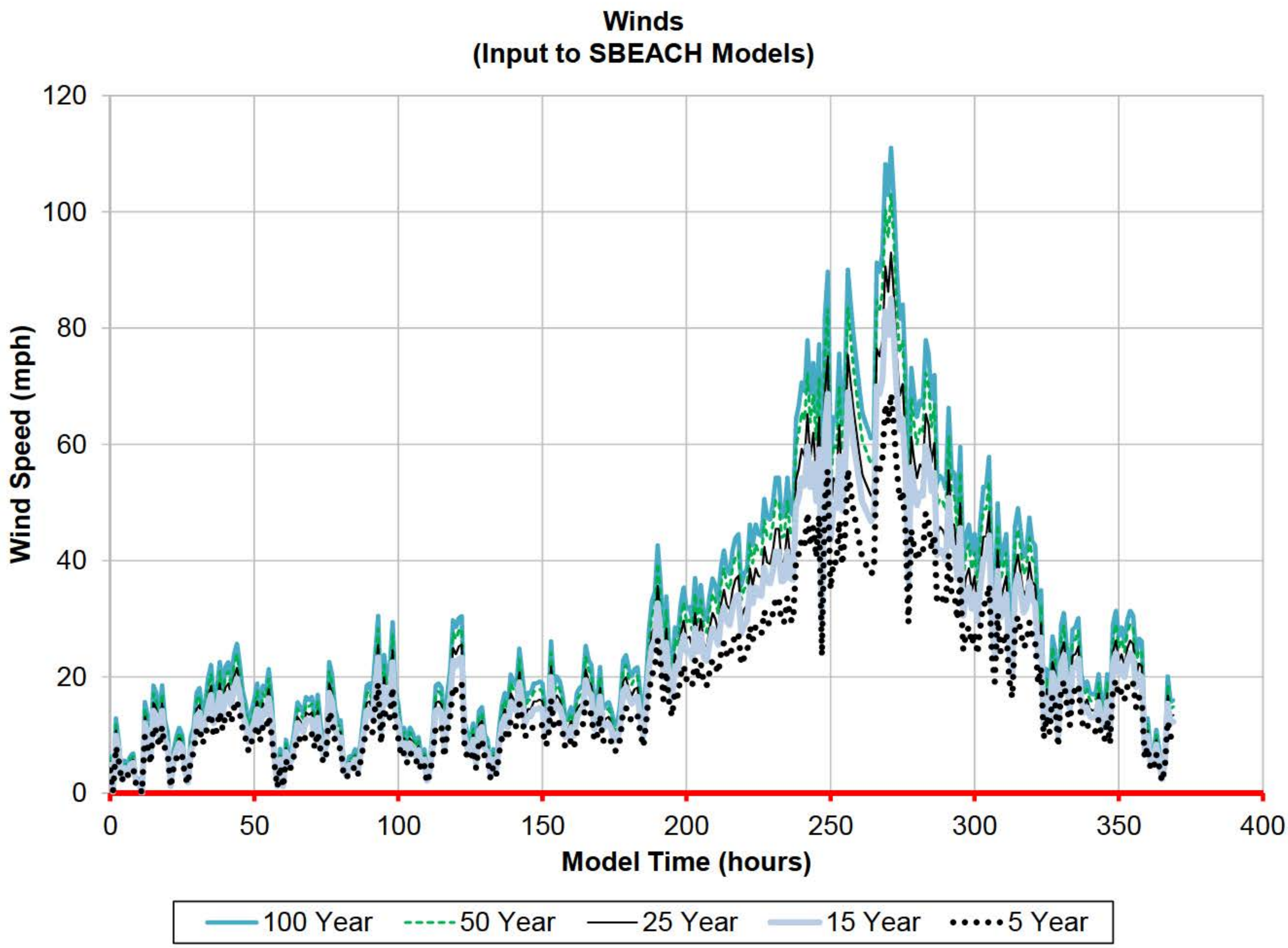
Offshore Wave Heights
(Input to SBEACH Model)
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.000
Sign. Wave Height (feet)
0
50
100
150
200
250
300
350
400
Model Time (hours)
100 year
50 Year
25 Year
15 Year
5 Year

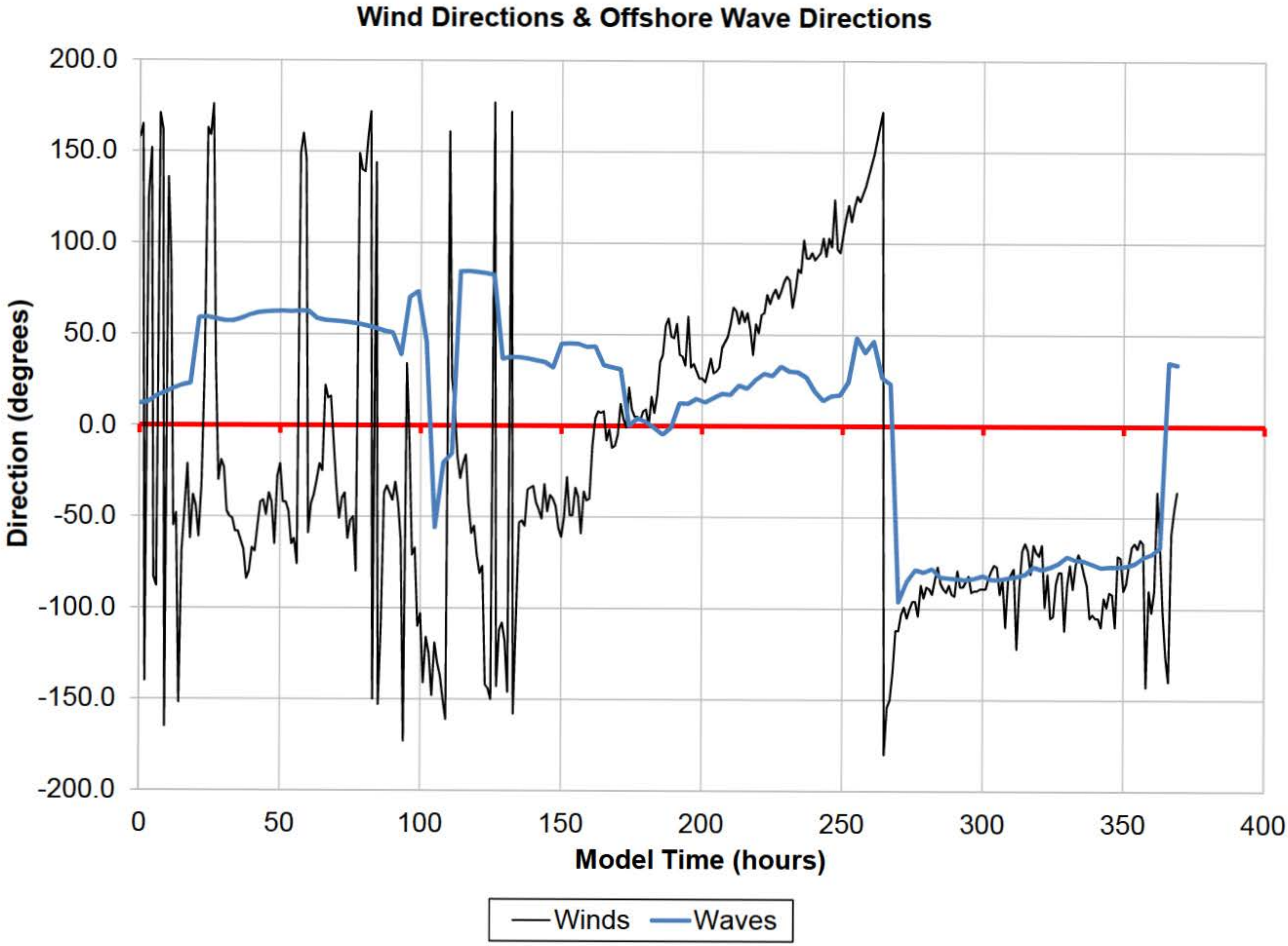


Wave Periods
(Input to SBEACH Model)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Peak Wave Period (seconds)
0
50
100
150
200
250
300
350
400
Model Time (hours)
100 Year
50 Year
25 Year
15 Year
5 Year



Storm Tides / Water Levels
(Input to SBEACH Models)
Water Level (feet NGVD)
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
-1.000
-2.000
0
50
100
150
200
250
300
350
400
Model Time (hours)
100 Year
50 Year
25 Year
15 Year
5 Year


Winds
(Input to SBEACH Models)
120
100
80
60
40
20
0
Wind Speed (mph)
0
50
100
150
200
250
300
350
400
Model Time (hours)
100 Year
50 Year
25 Year
15 Year
5 Year



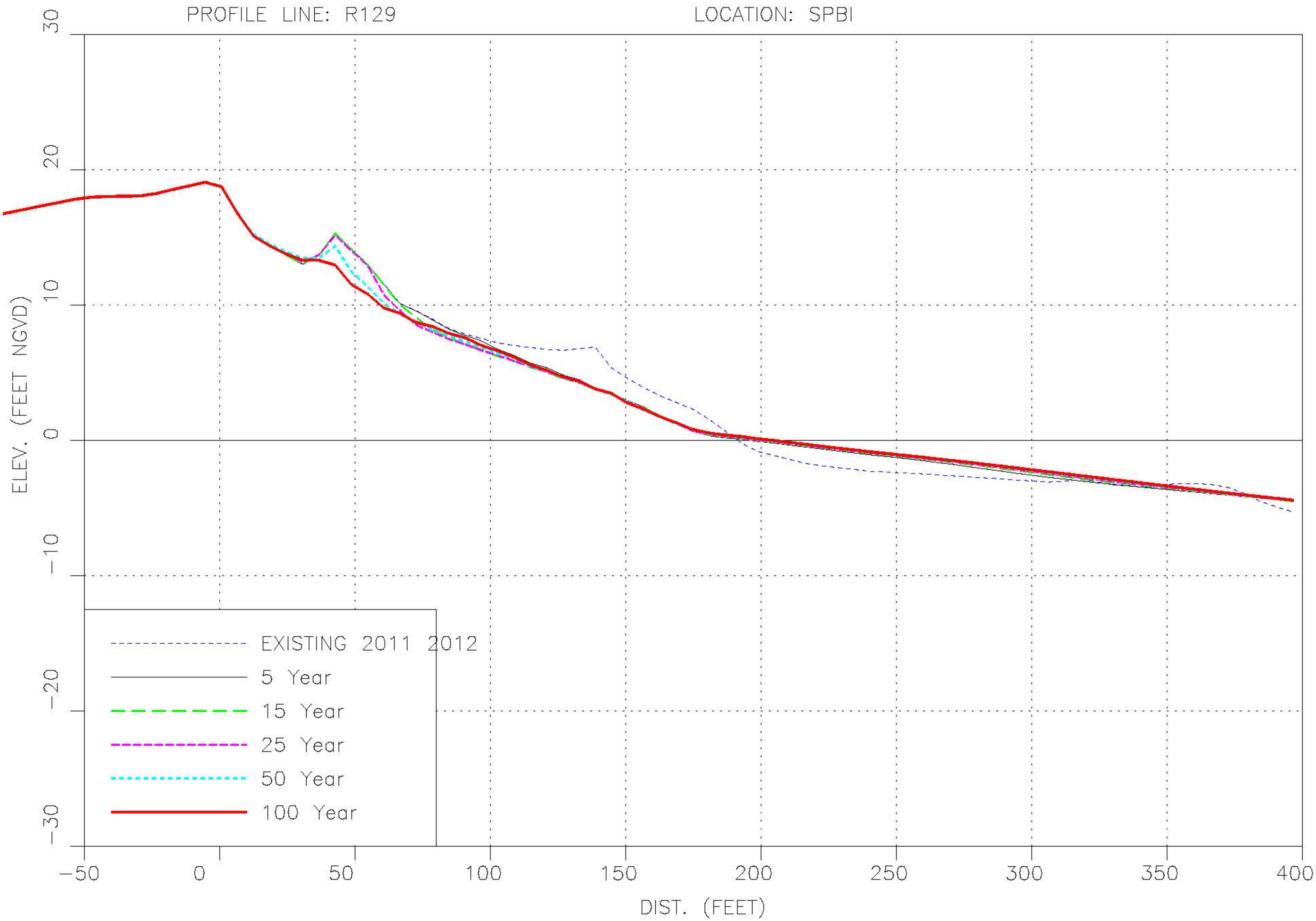
Wind Directions & Offshore Wave Directions
200.0
150.0
100.0
50.0
0.0
-50.0
-100.0
-150.0
-200.0
Direction (degrees)
0
50
100
150
200
250
300
350
400
Model Time (hours)
Winds
Waves

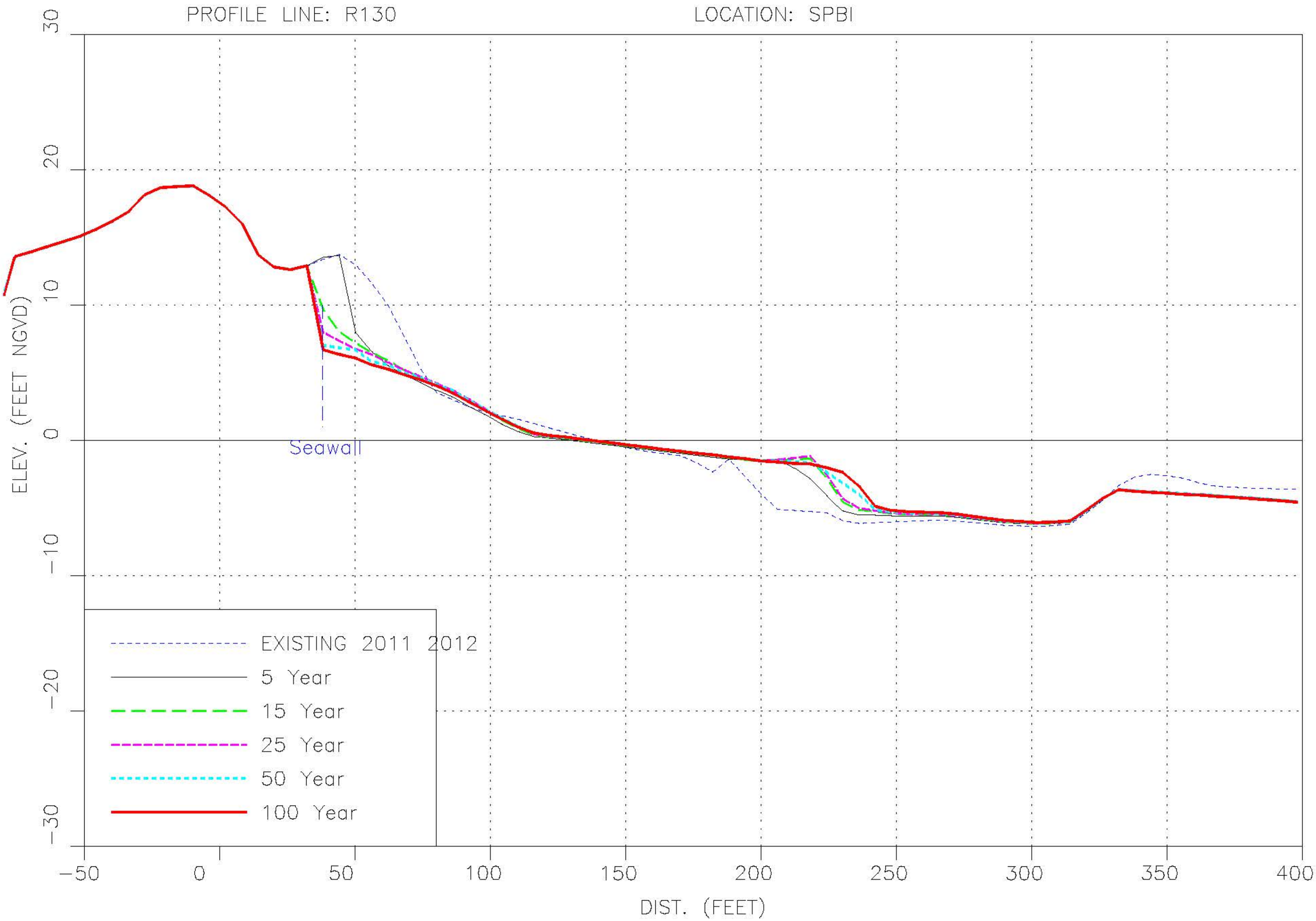
APPENDIX C

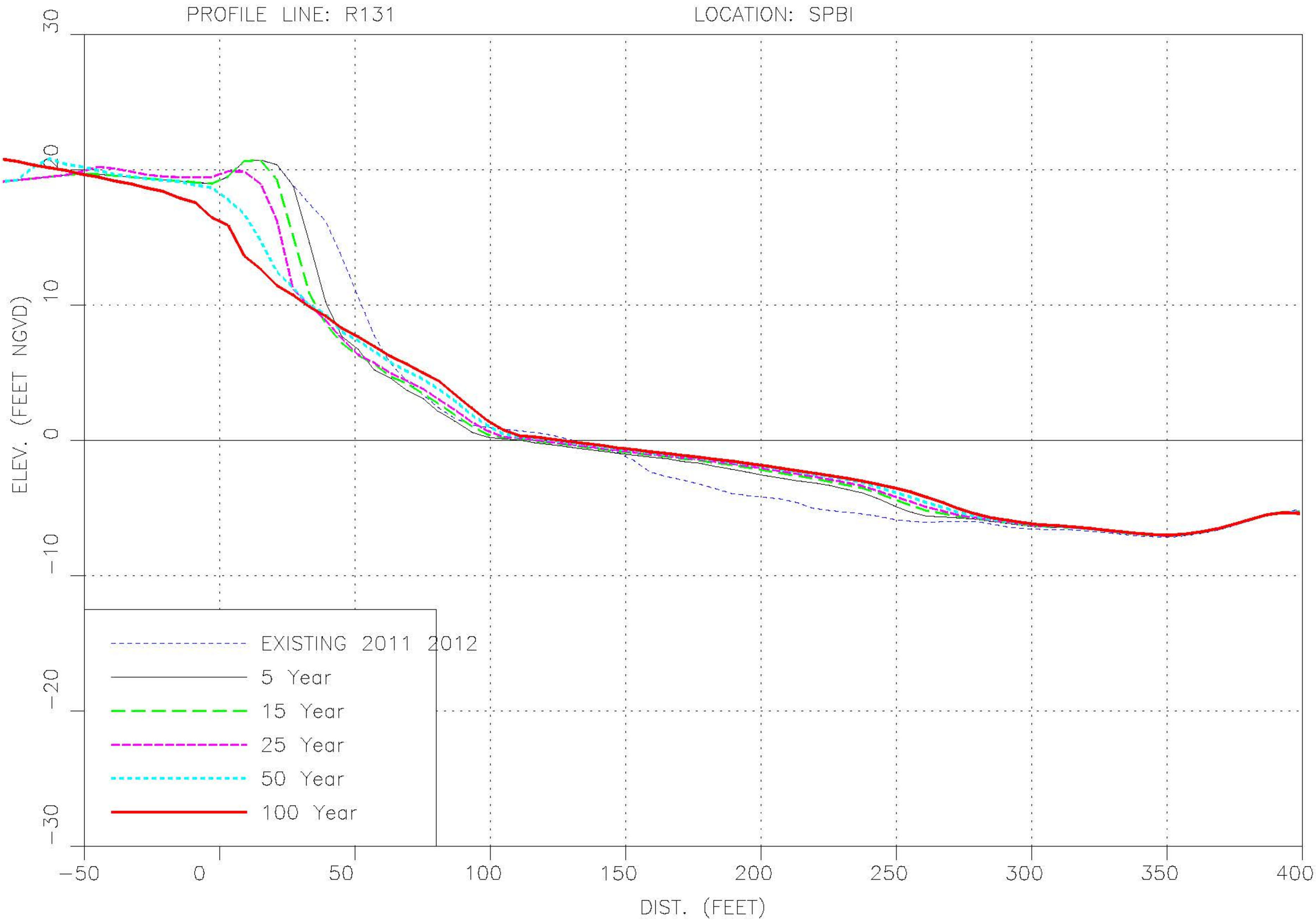
SBEACH MODEL RESULTS

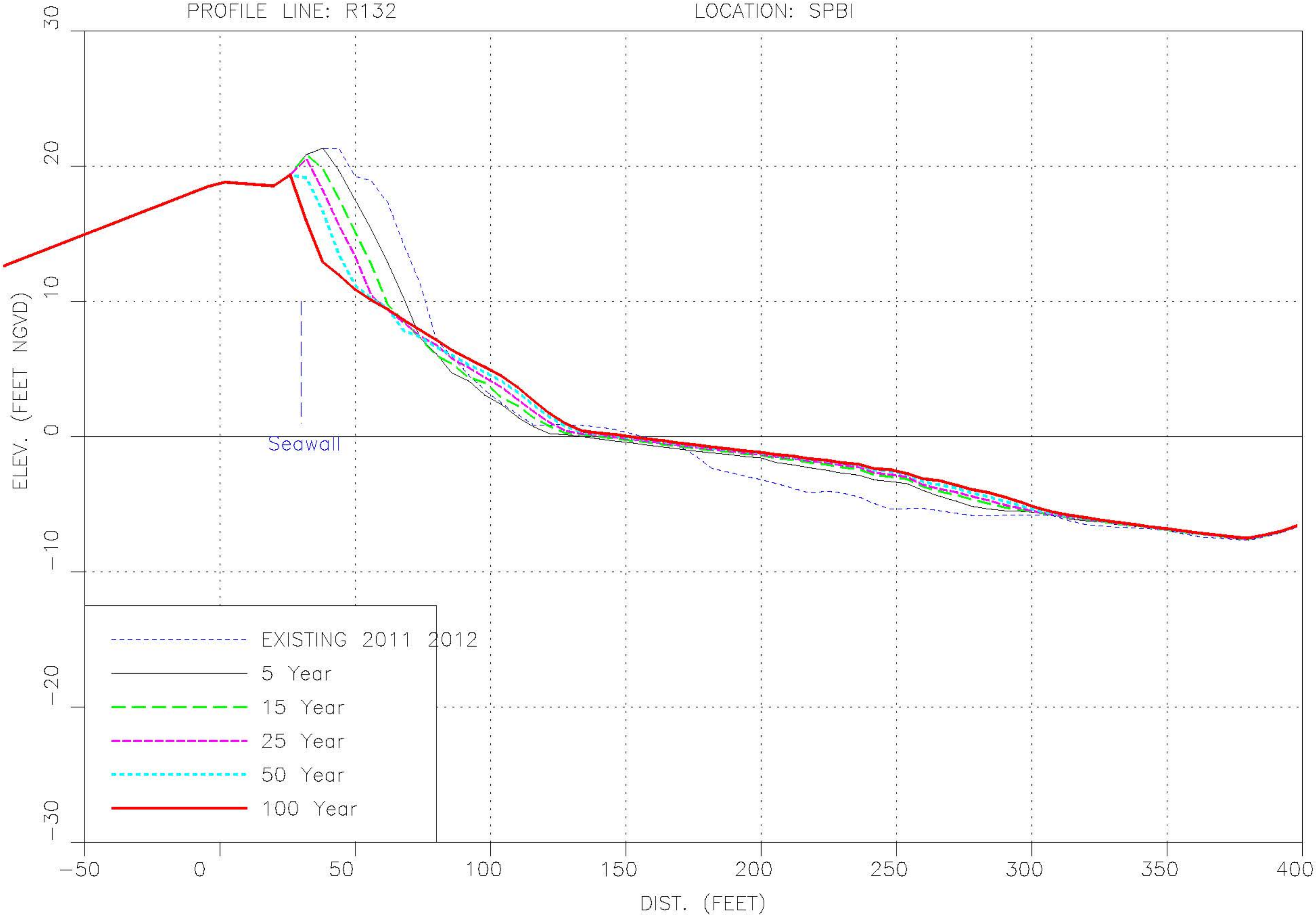
APPENDIX C-1

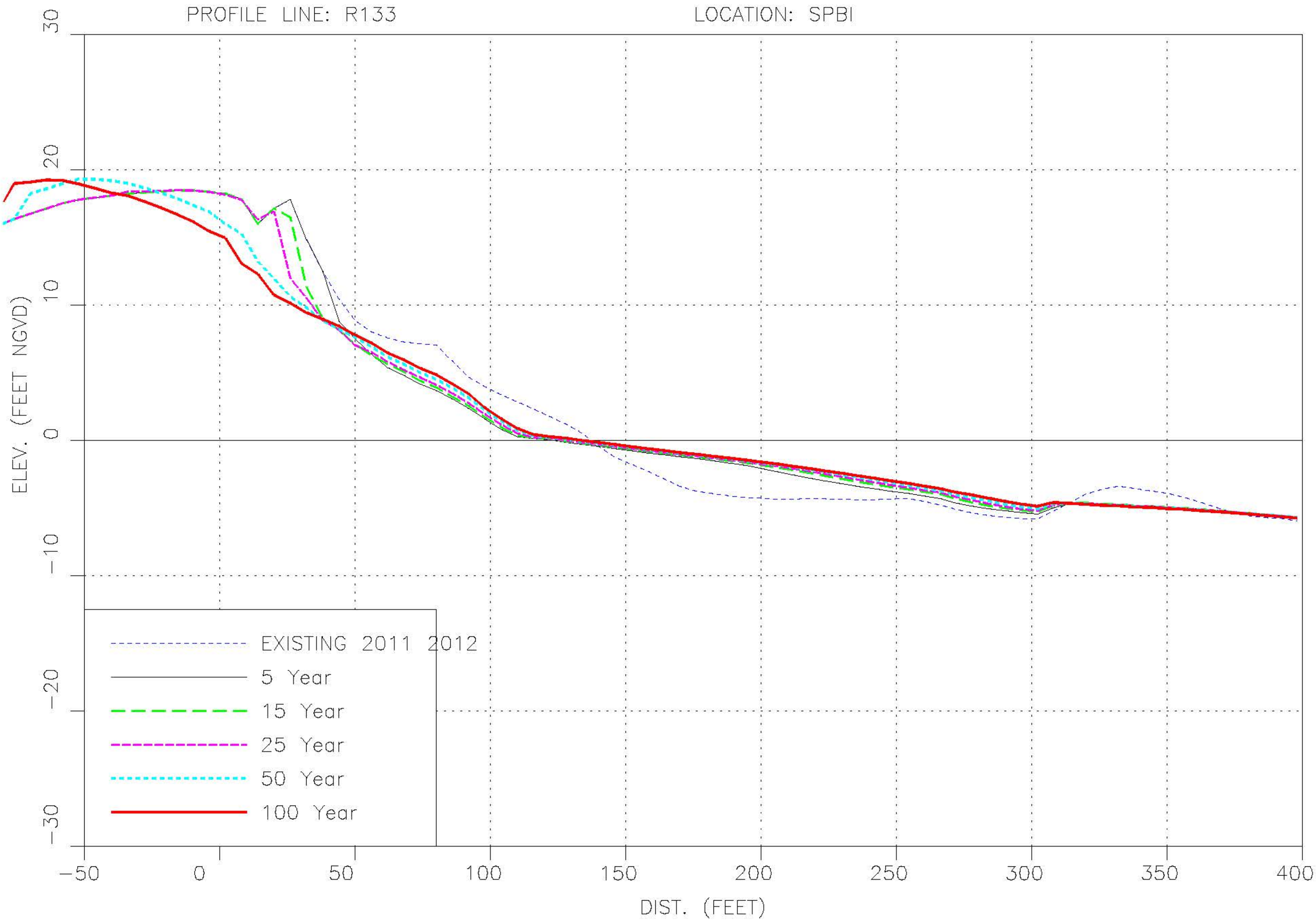
EXISTING CONDITIONS (2011/2012 SURVEY)

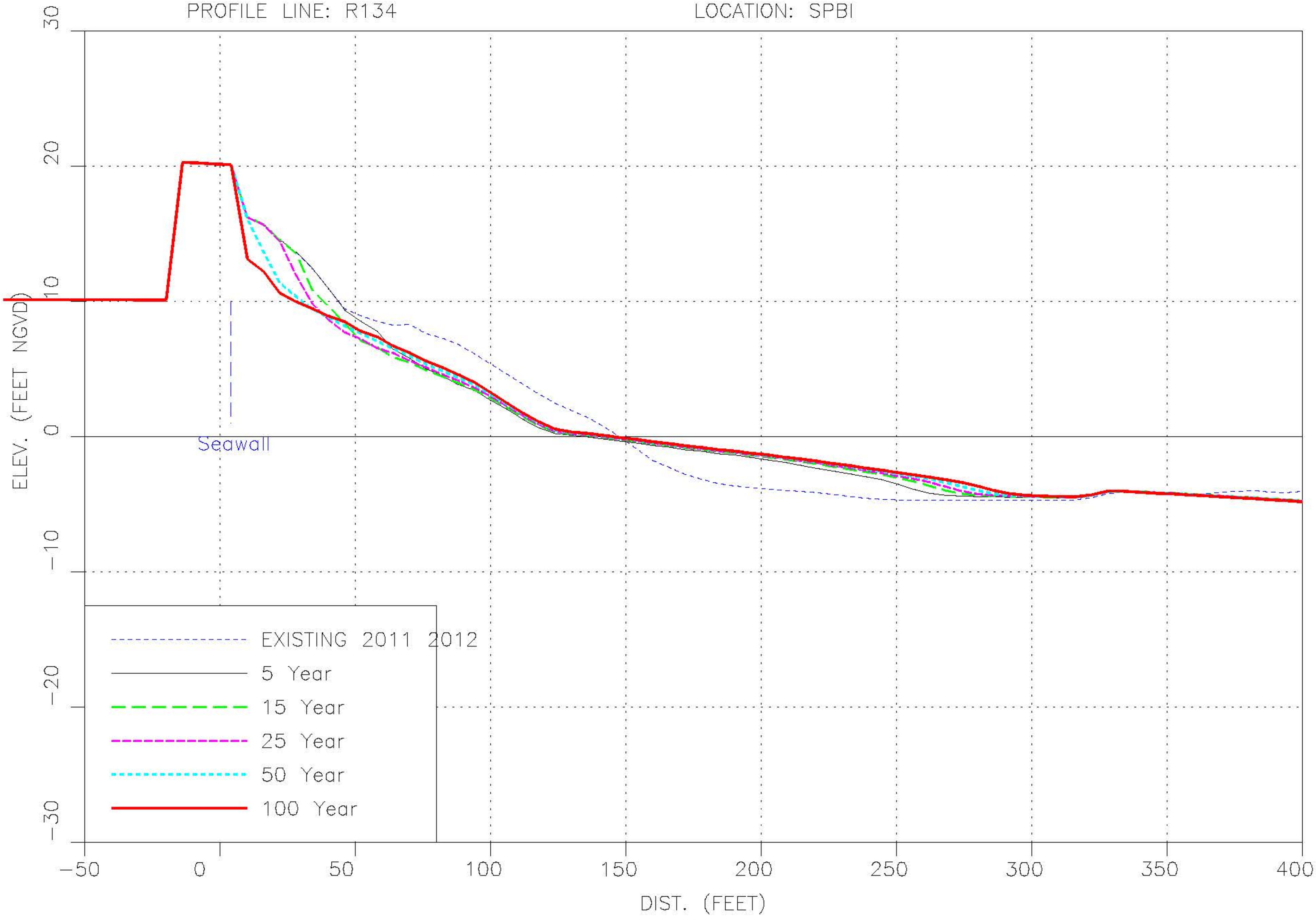

PROFILE LINE: R129
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year

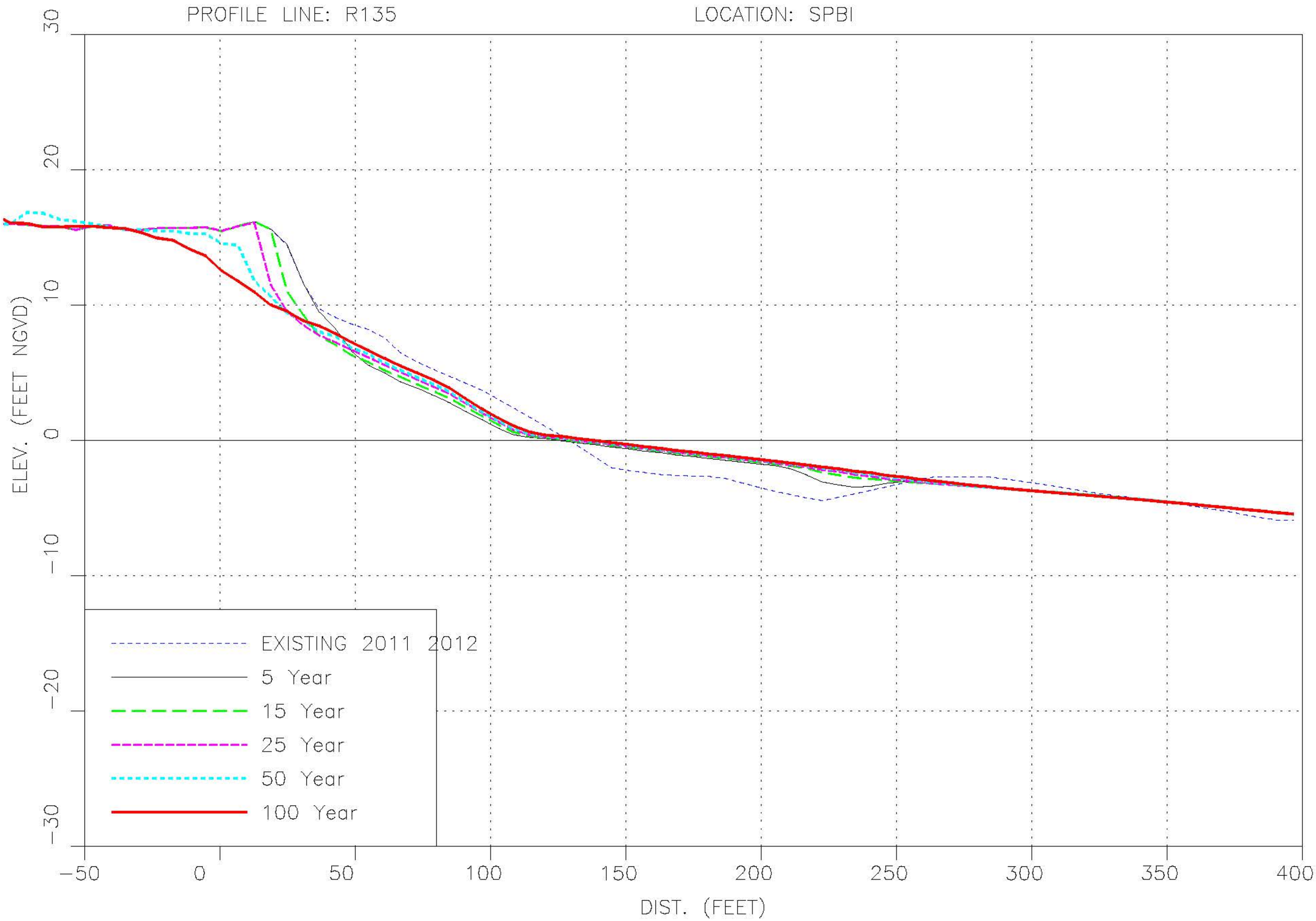

PROFILE LINE: R130
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400


PROFILE LINE: R131
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year

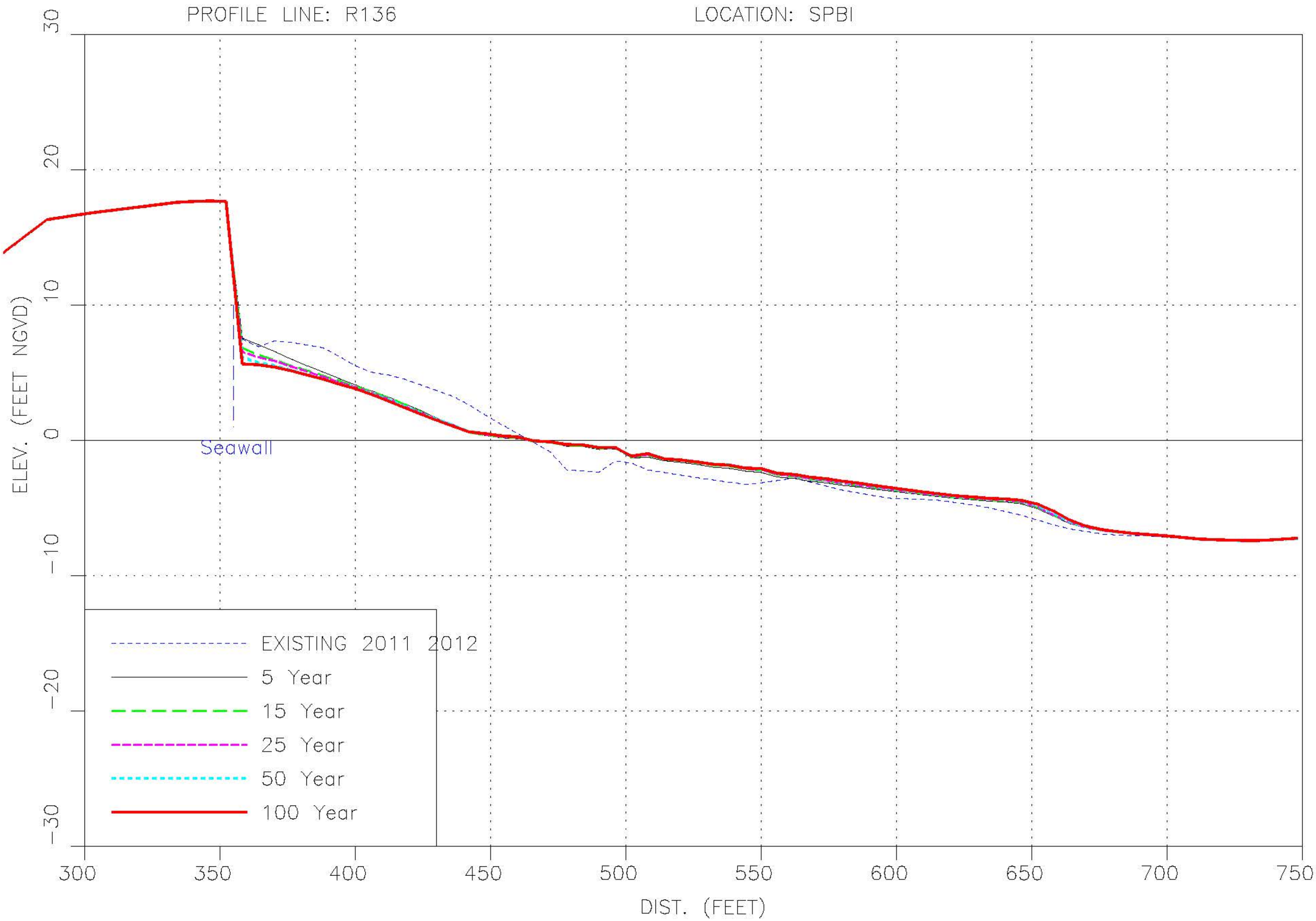

PROFILE LINE: R132
LOCATION: SPBI
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
Seawall
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year


PROFILE LINE: R133
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year

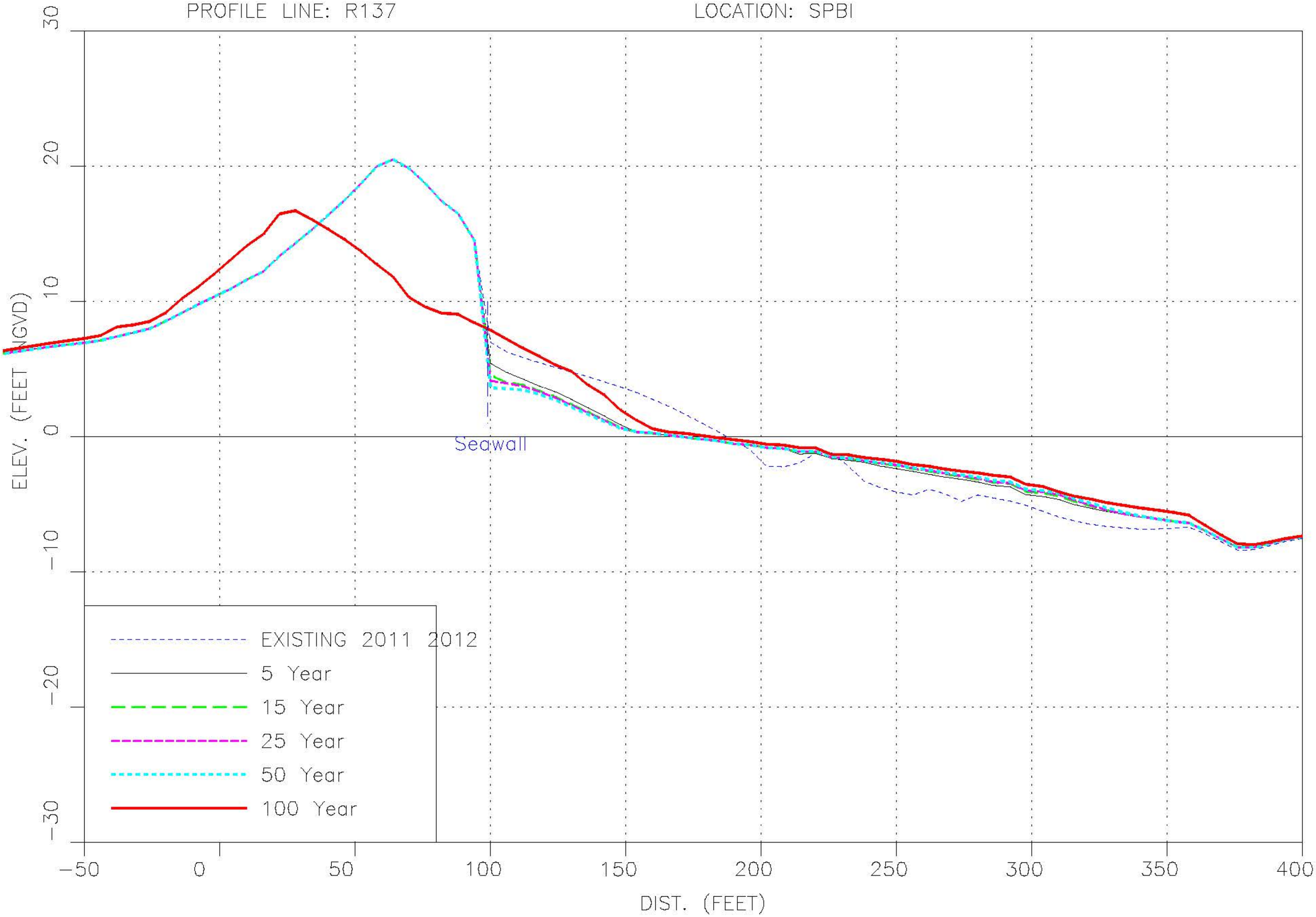

PROFILE LINE: R134
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year



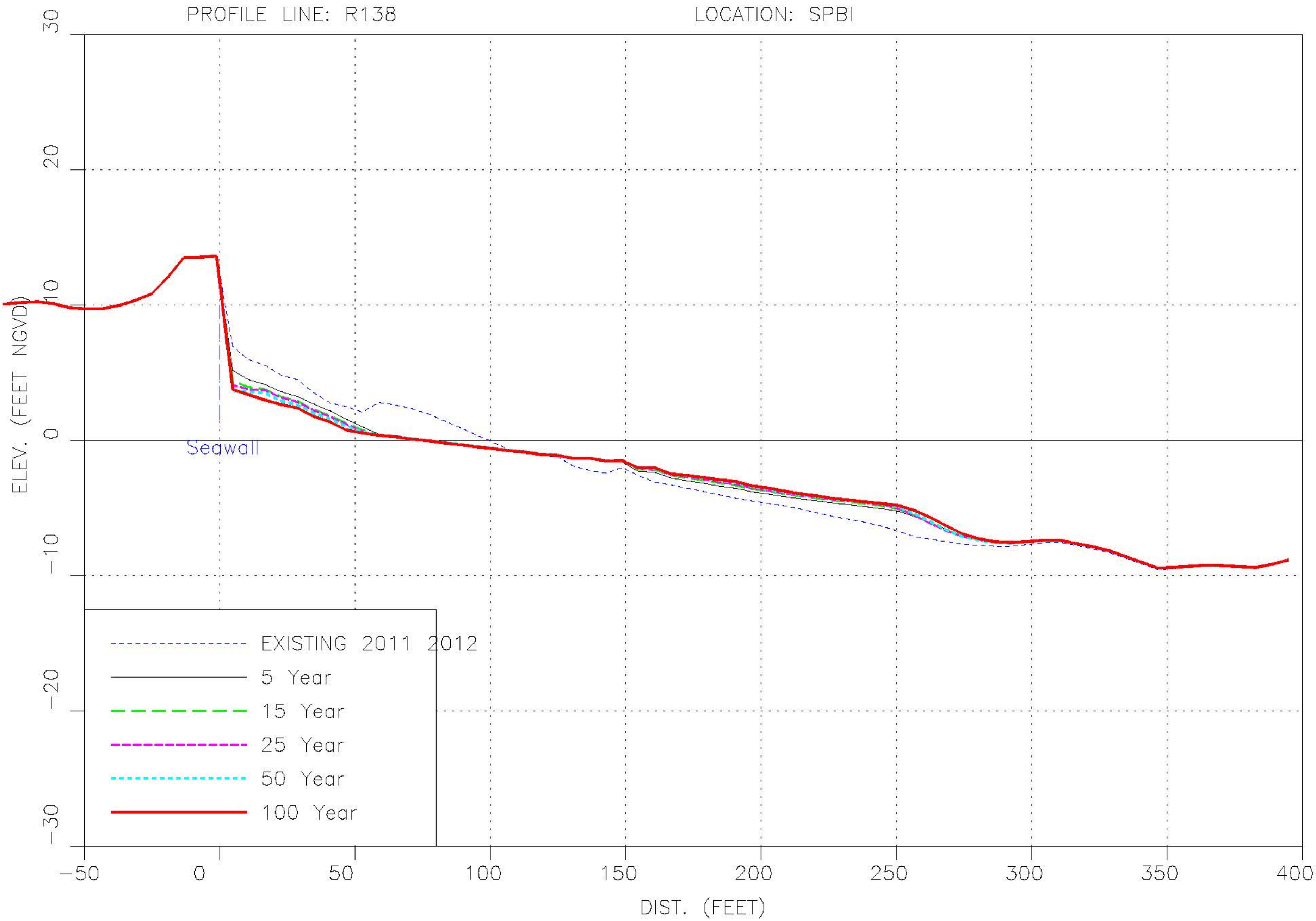
PROFILE LINE: R135
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year



PROFILE LINE: R136
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
−10
−20
−30
300
350
400
450
500
550
600
650
700
750



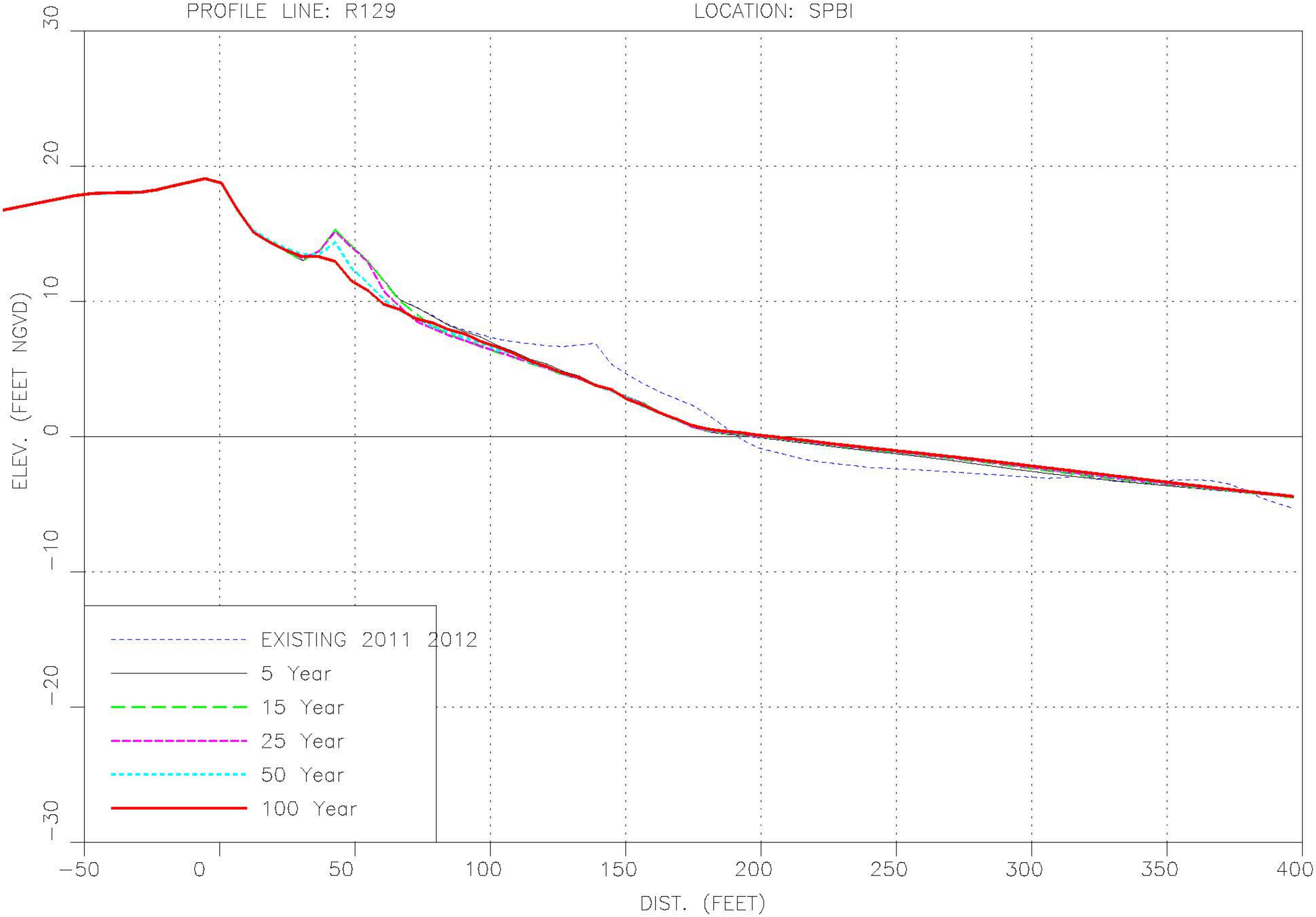
PROFILE LINE: R137
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year


PROFILE LINE: R138
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400

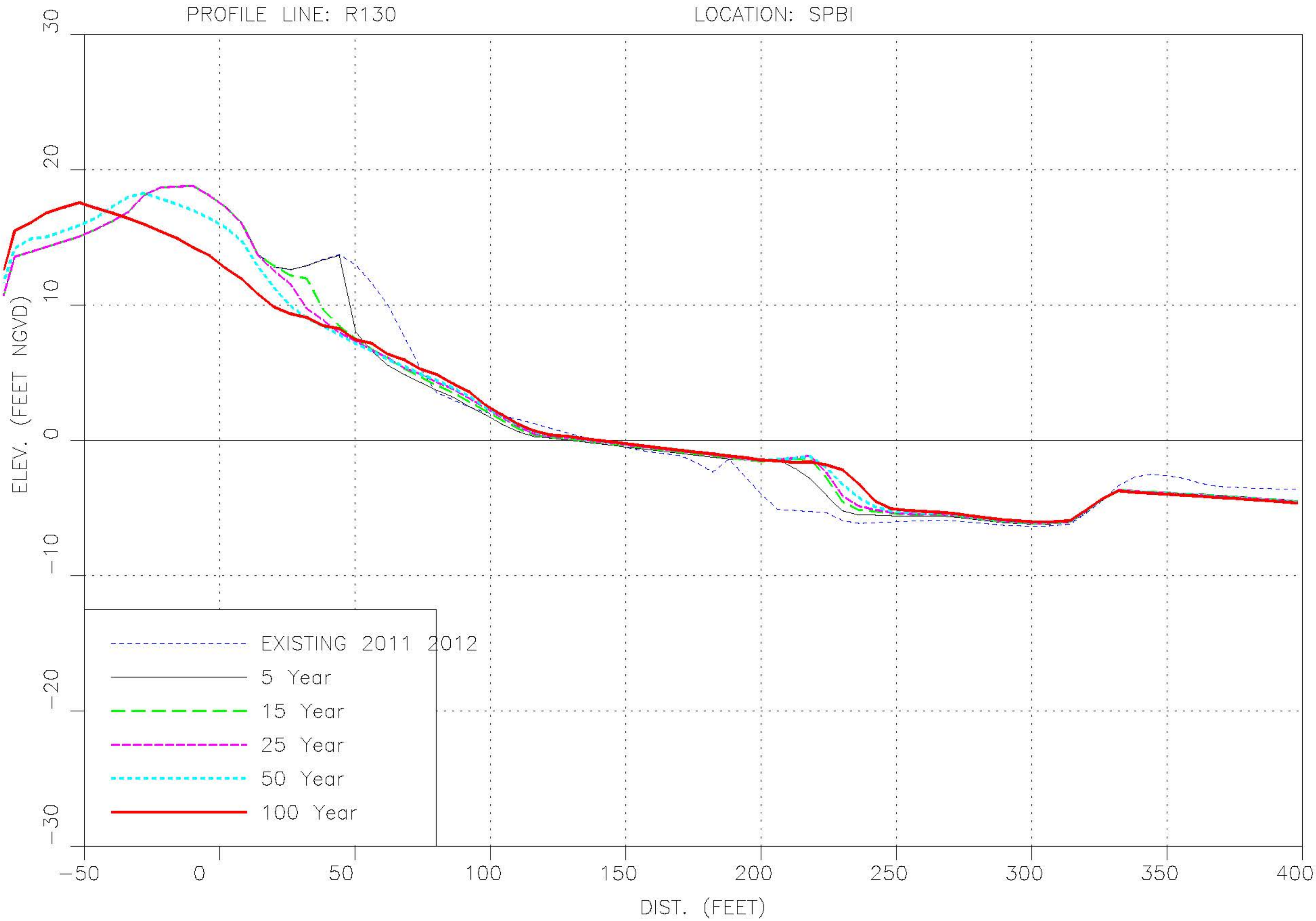
APPENDIX C-2

EXISTING CONDITIONS (2011/2012 SURVEY)

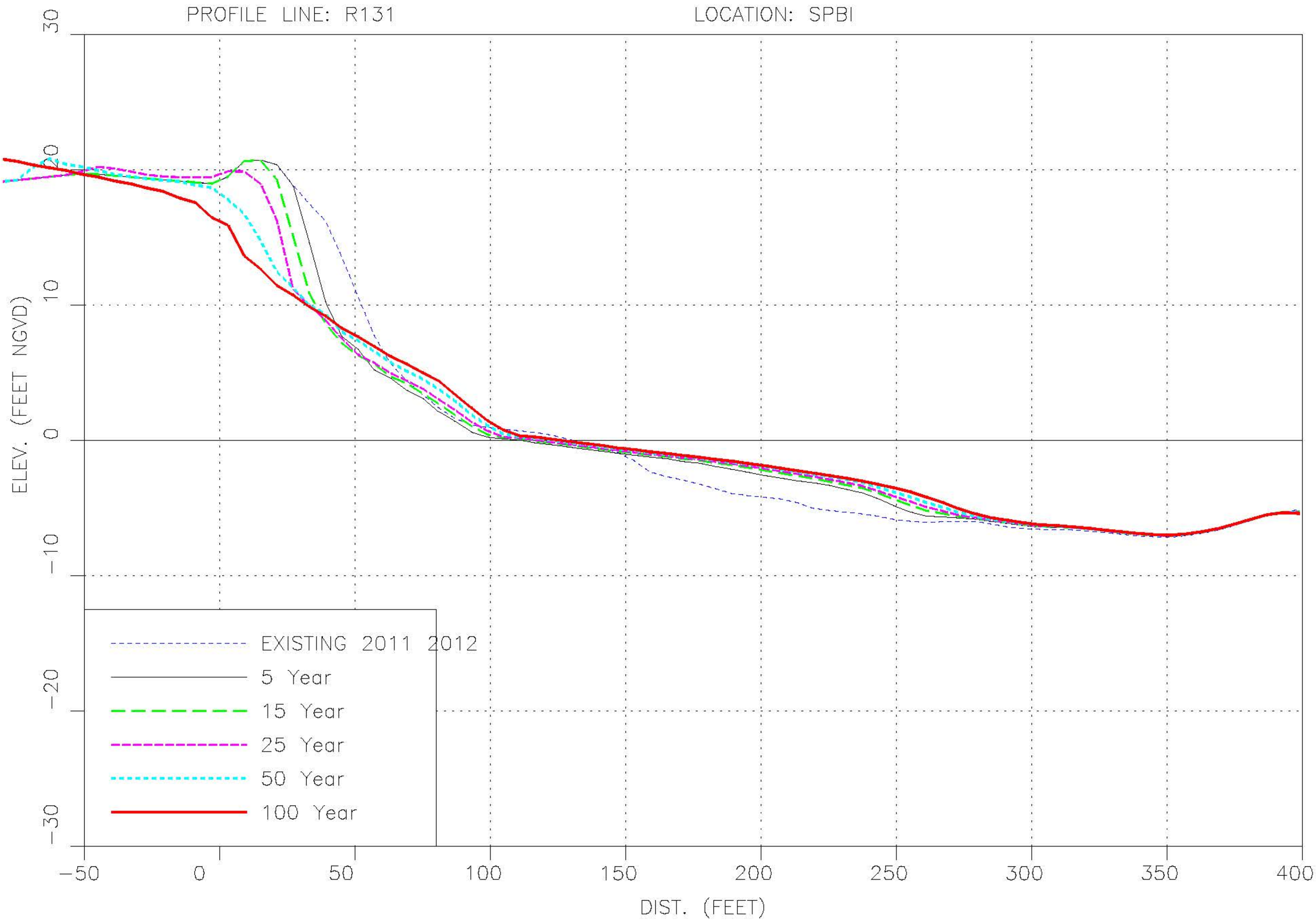
NO SEAWALL/SEAWALL FAILURE



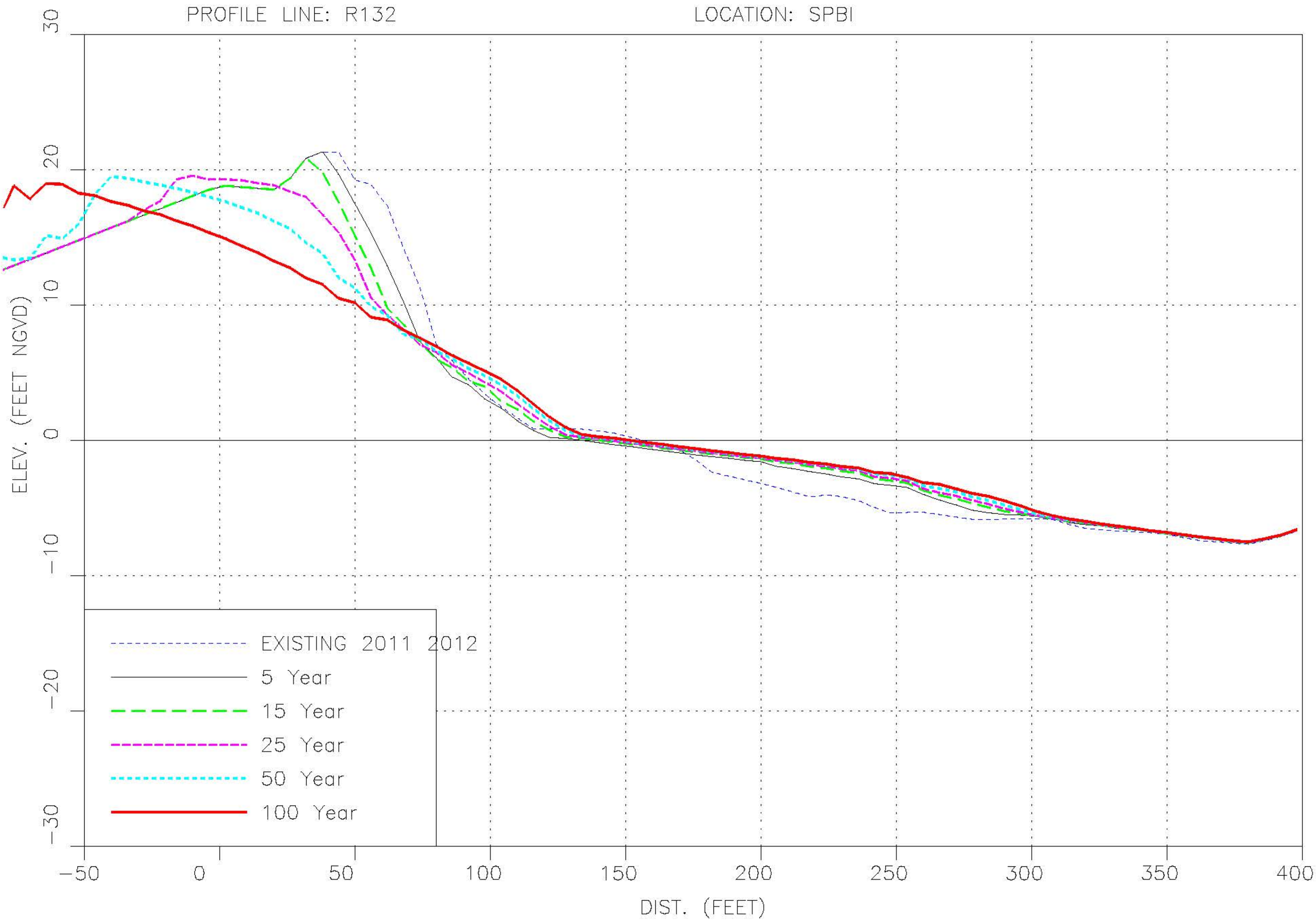
PROFILE LINE: R129
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year

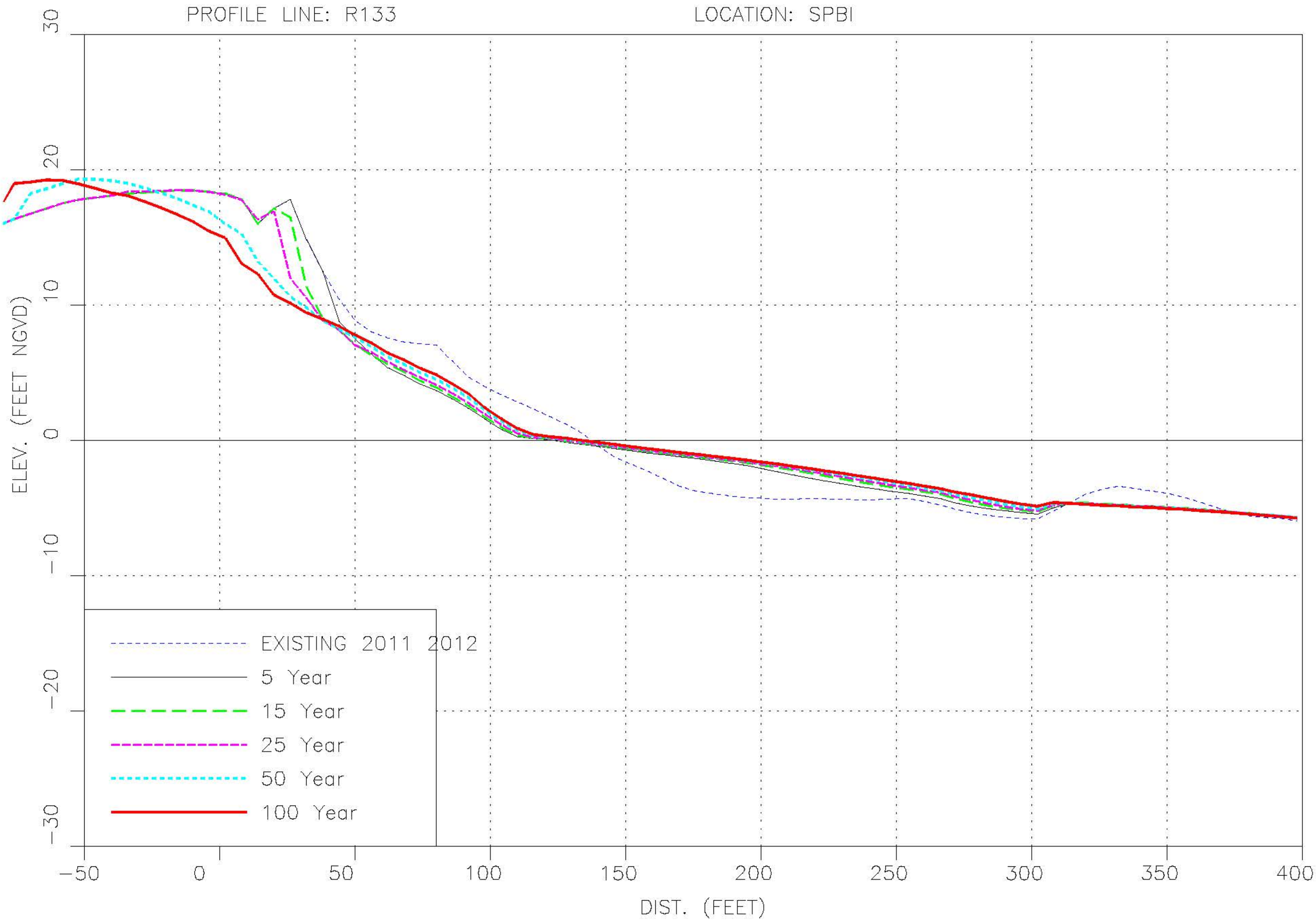


PROFILE LINE: R130
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year

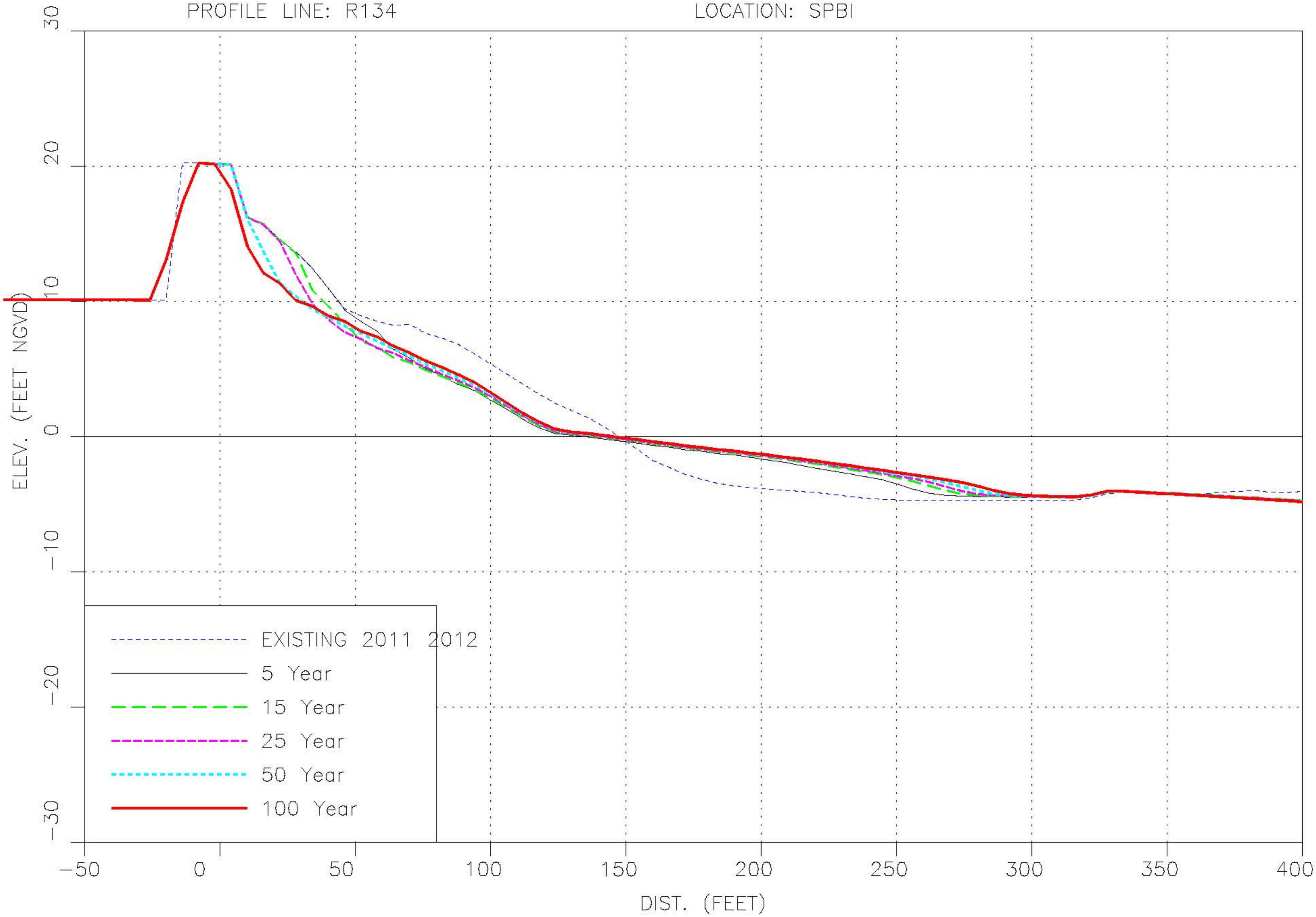


PROFILE LINE: R131
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year

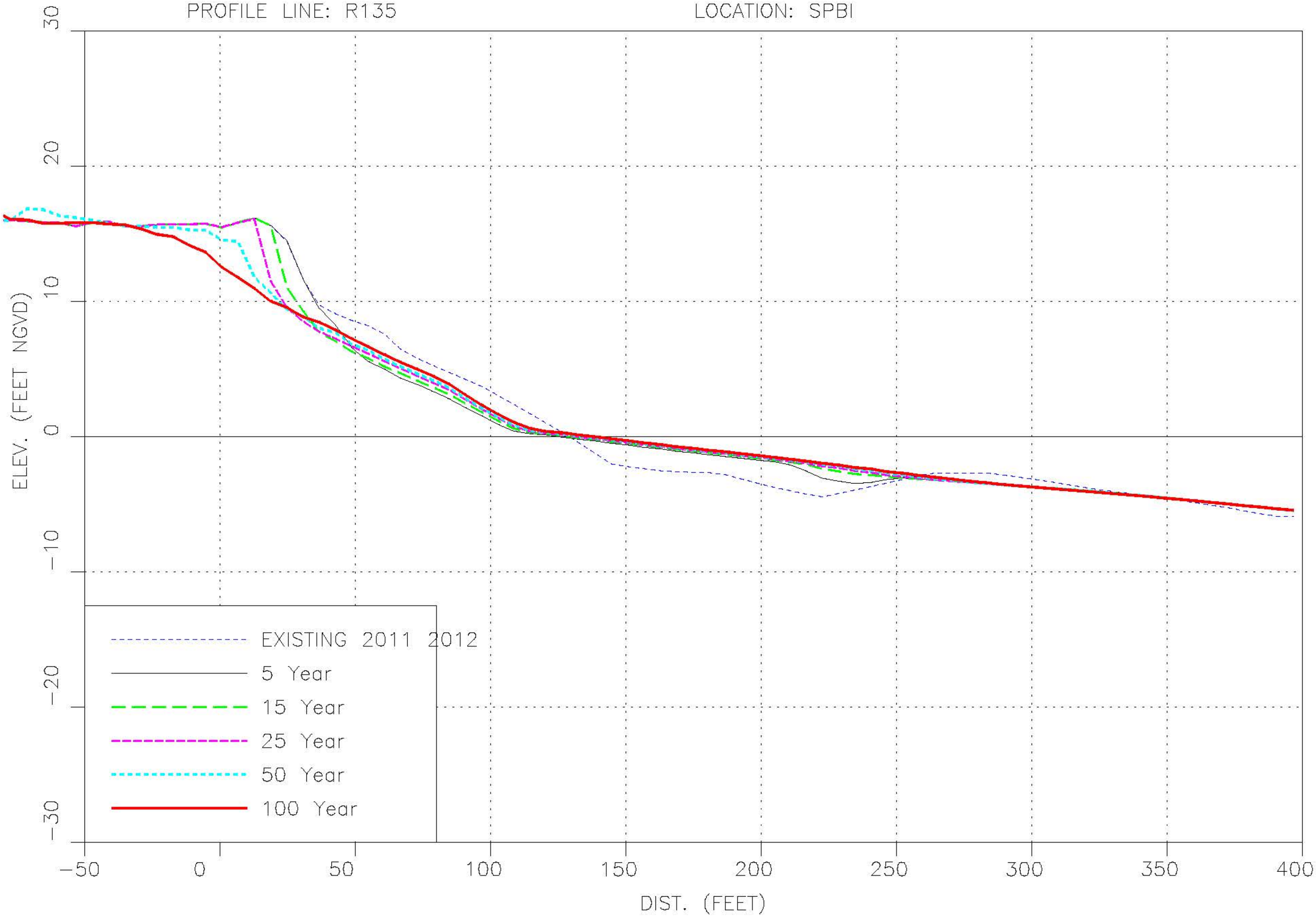

PROFILE LINE: R132
LOCATION: SPBI
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
DIST. (FEET)
-50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year



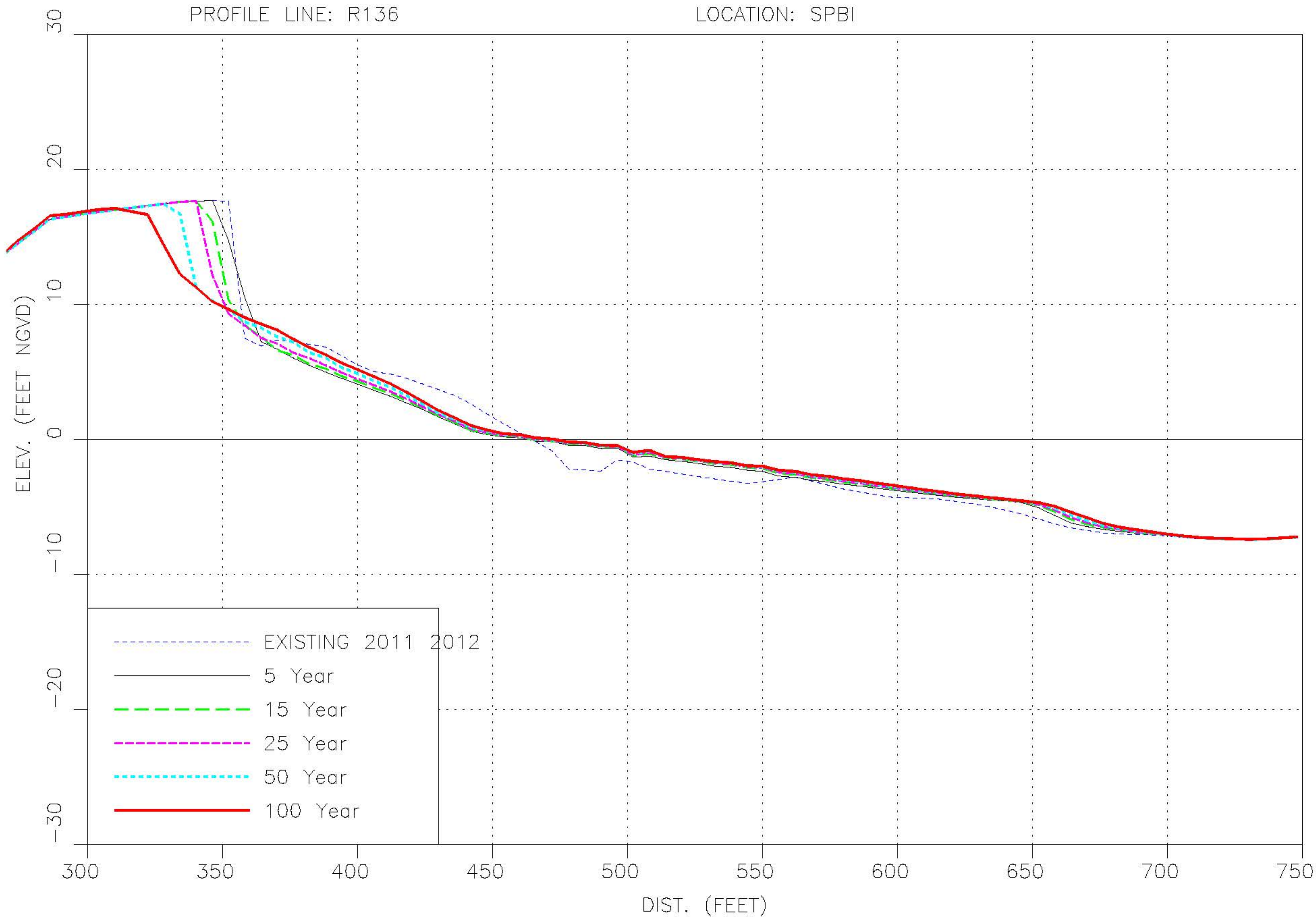
PROFILE LINE: R133
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year

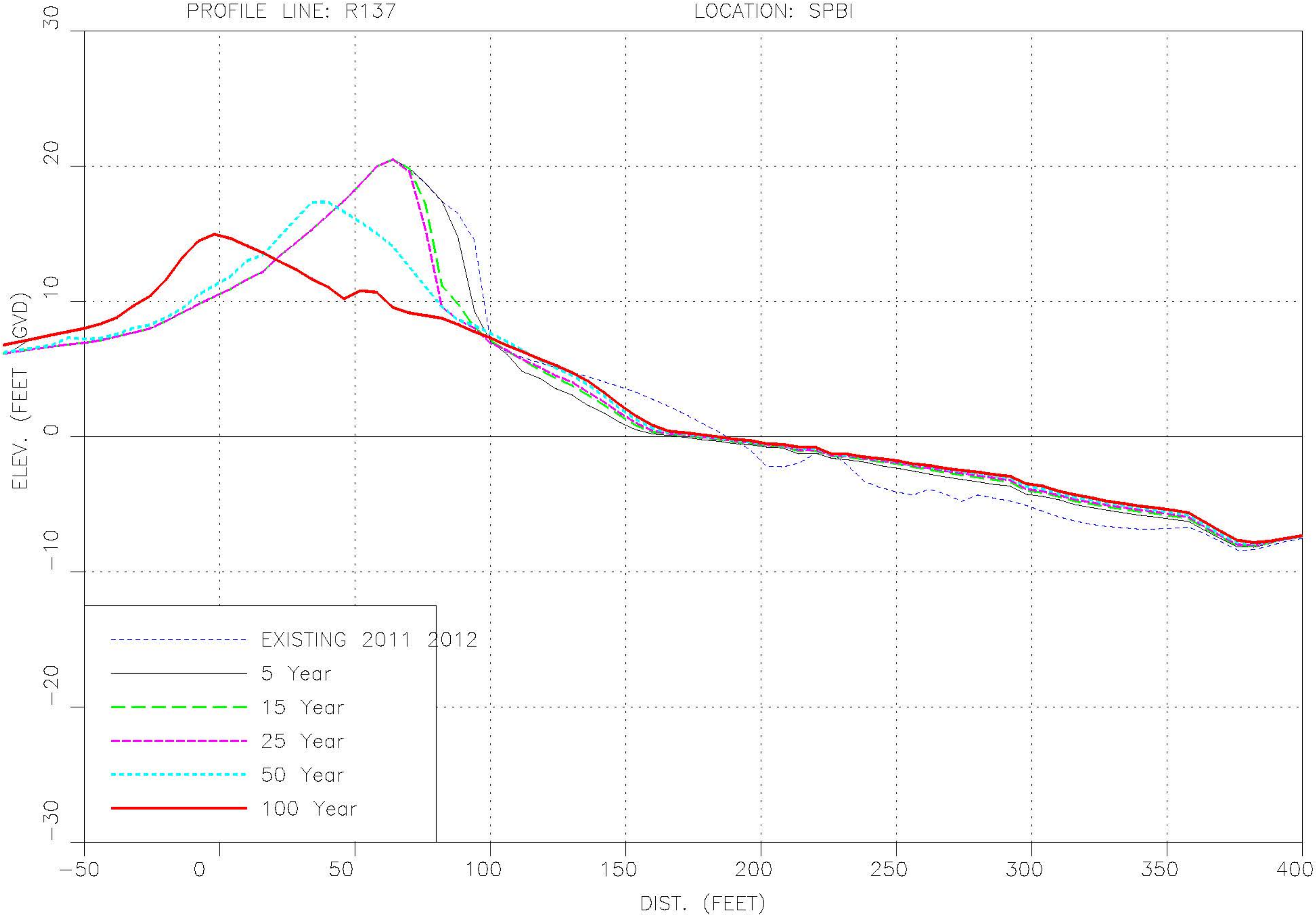


PROFILE LINE: R134
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year

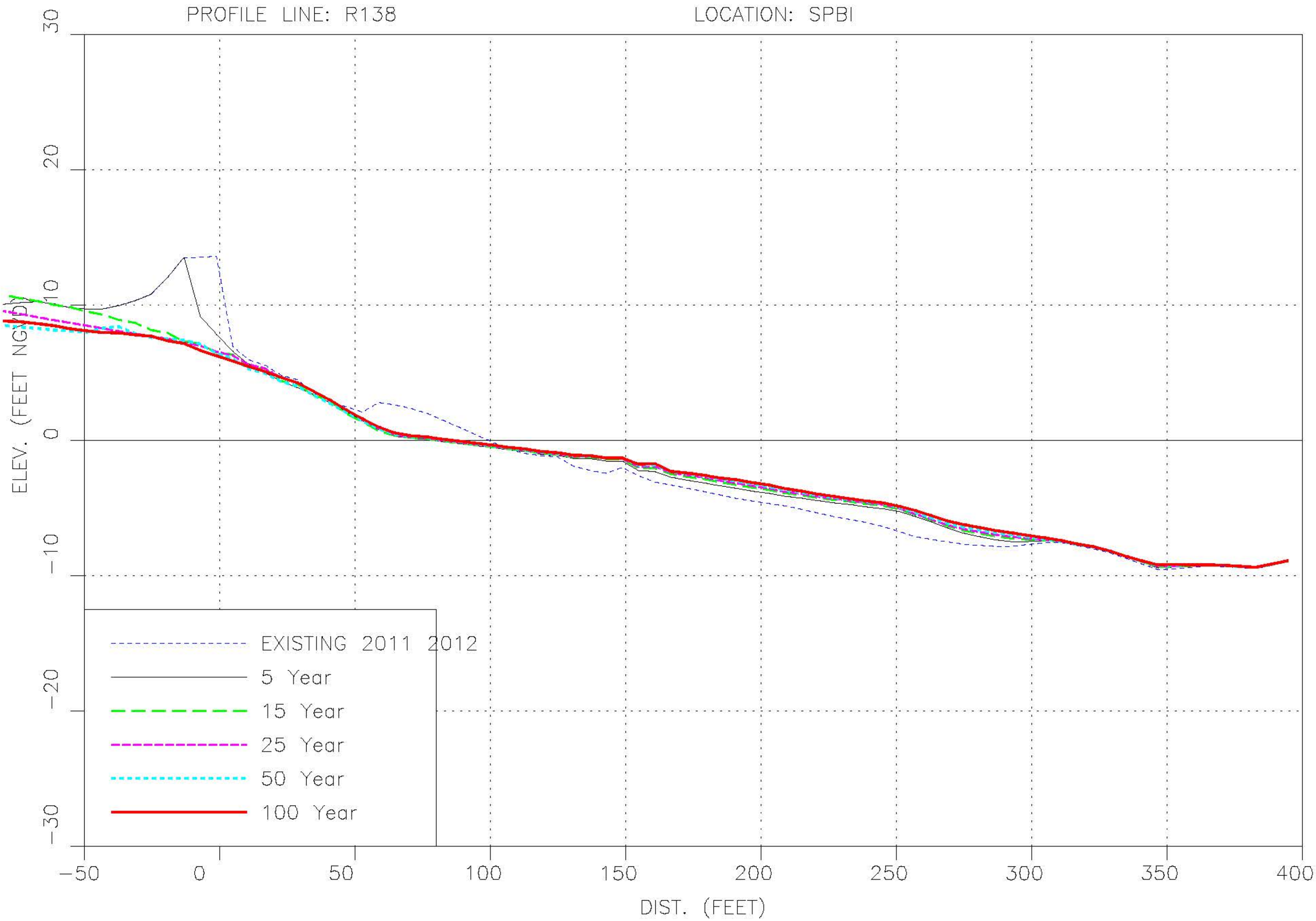


PROFILE LINE: R135
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year


PROFILE LINE: R136
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
300
350
400
450
500
550
600
650
700
750
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year

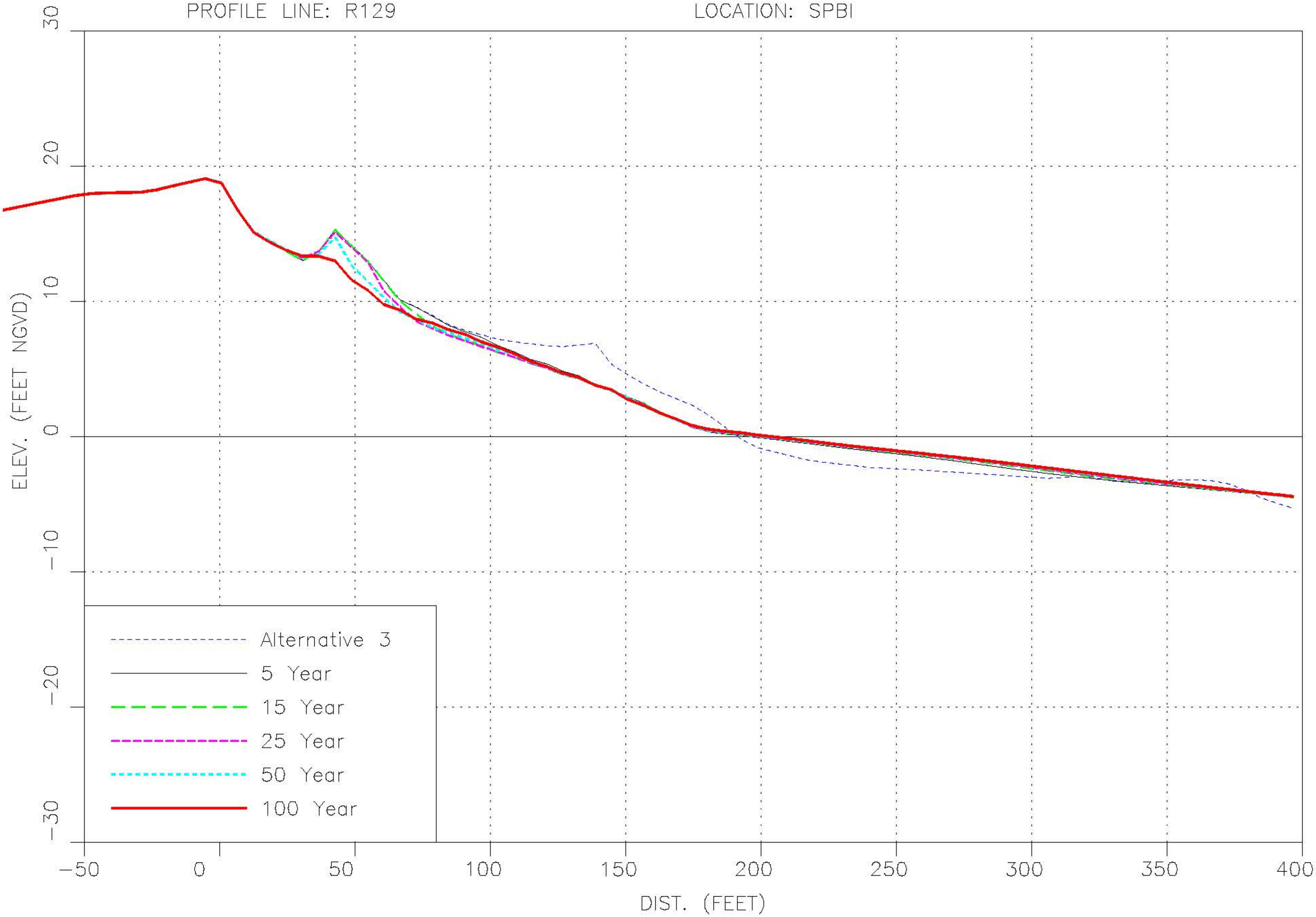


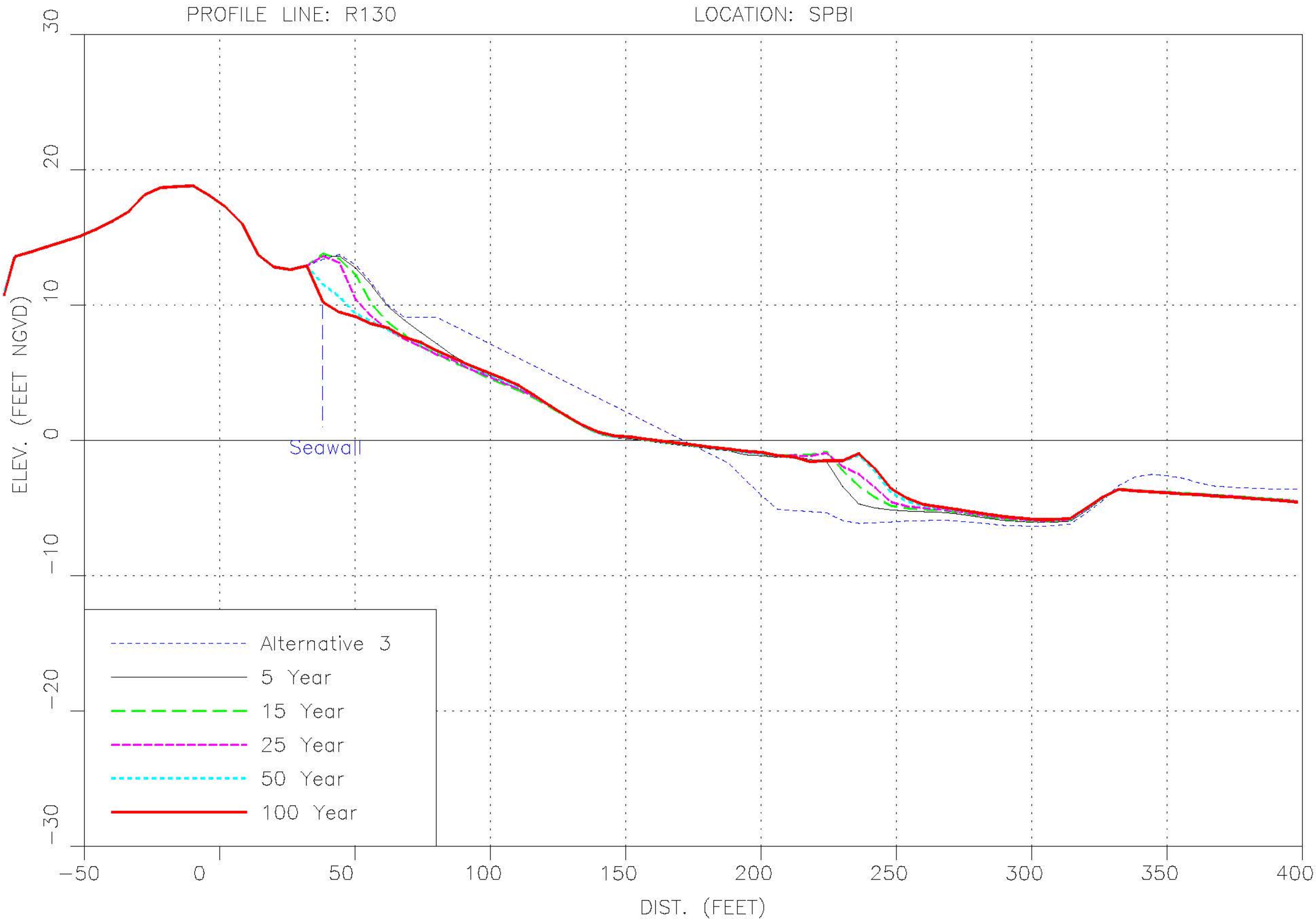
PROFILE LINE: R137
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year


PROFILE LINE: R138
LOCATION: SPBI
30
20
10
0
-10
-20
-30
ELEV. (FEET NGVD)
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
EXISTING 2011 2012
5 Year
15 Year
25 Year
50 Year
100 Year

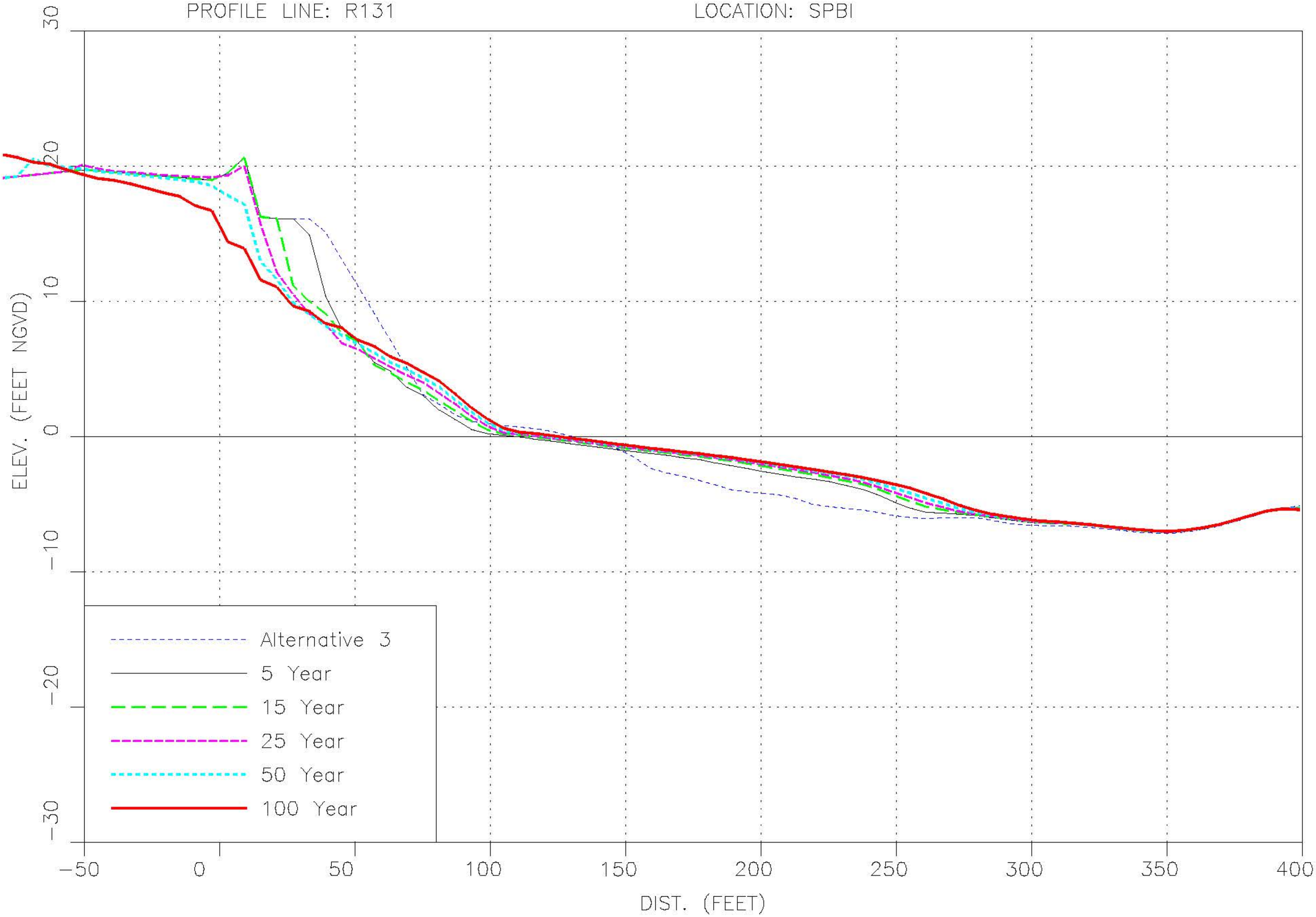
APPENDIX C-3

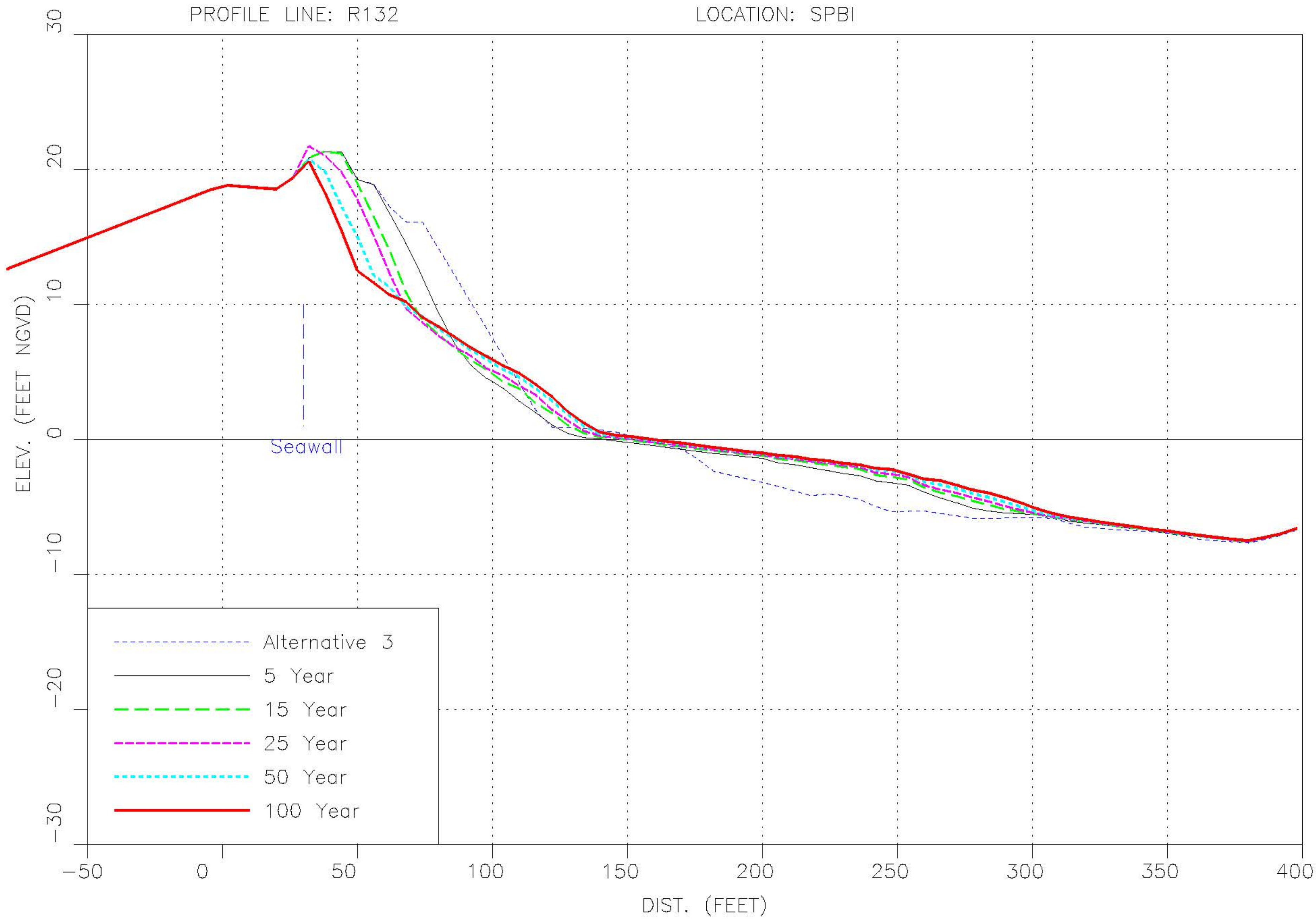
ALTERNATIVE 3 (APPLICANT'S PREFERRED)


PROFILE LINE: R129
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
Alternative 3
5 Year
15 Year
25 Year
50 Year
100 Year

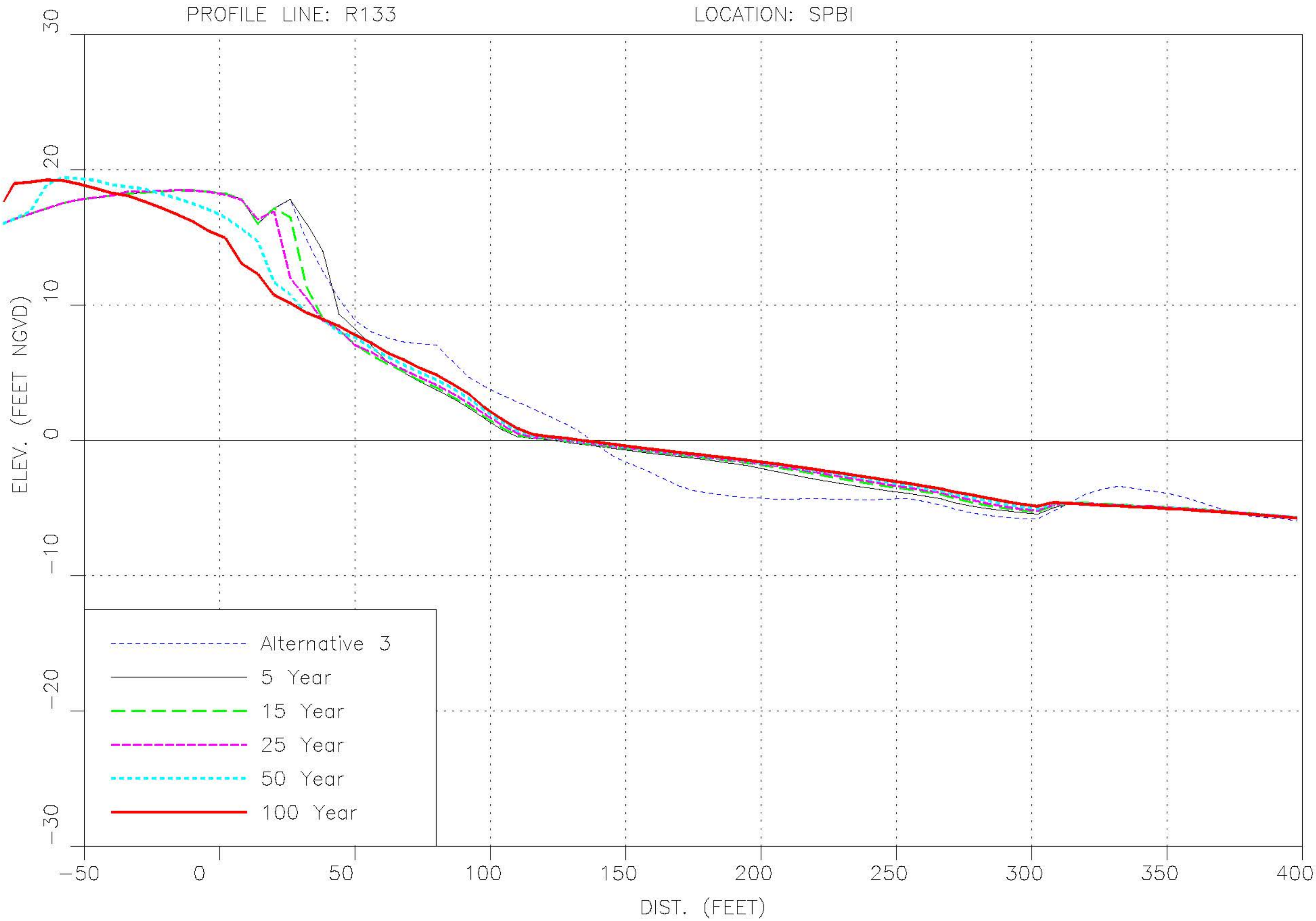


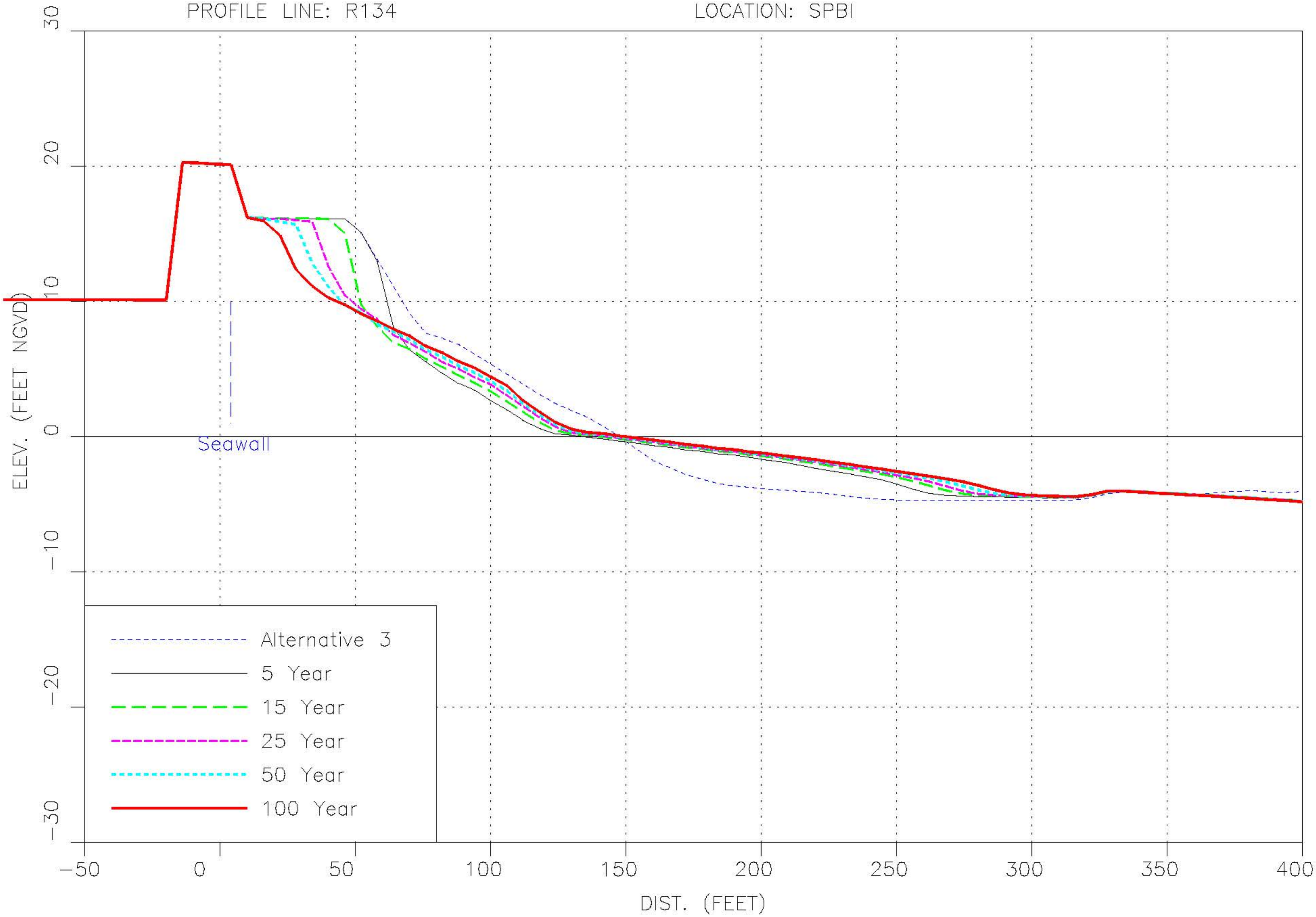
PROFILE LINE: R130
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Alternative 3
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400


PROFILE LINE: R131
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Alternative 3
5 Year
15 Year
25 Year
50 Year
100 Year

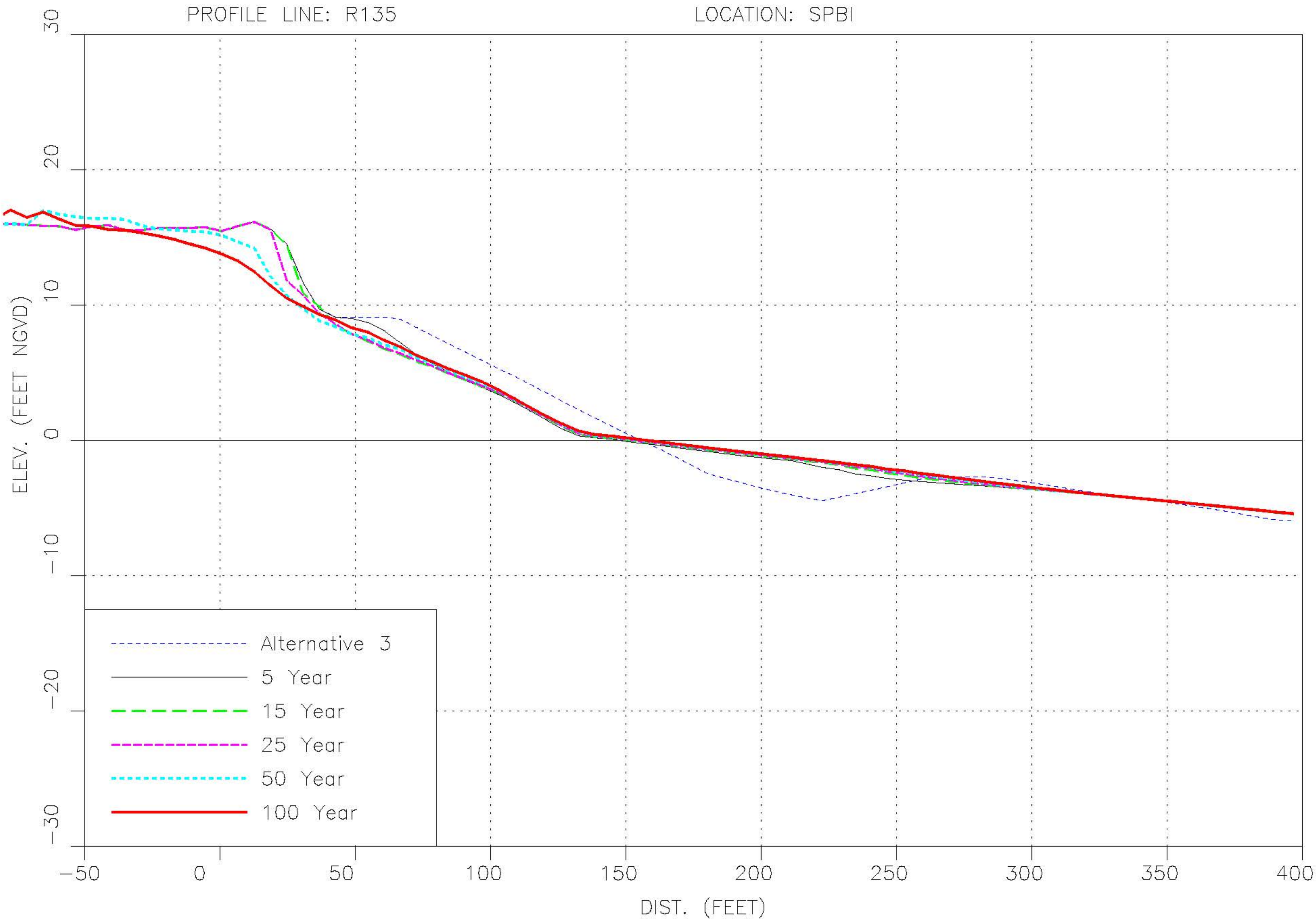


PROFILE LINE: R132
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Alternative 3
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400

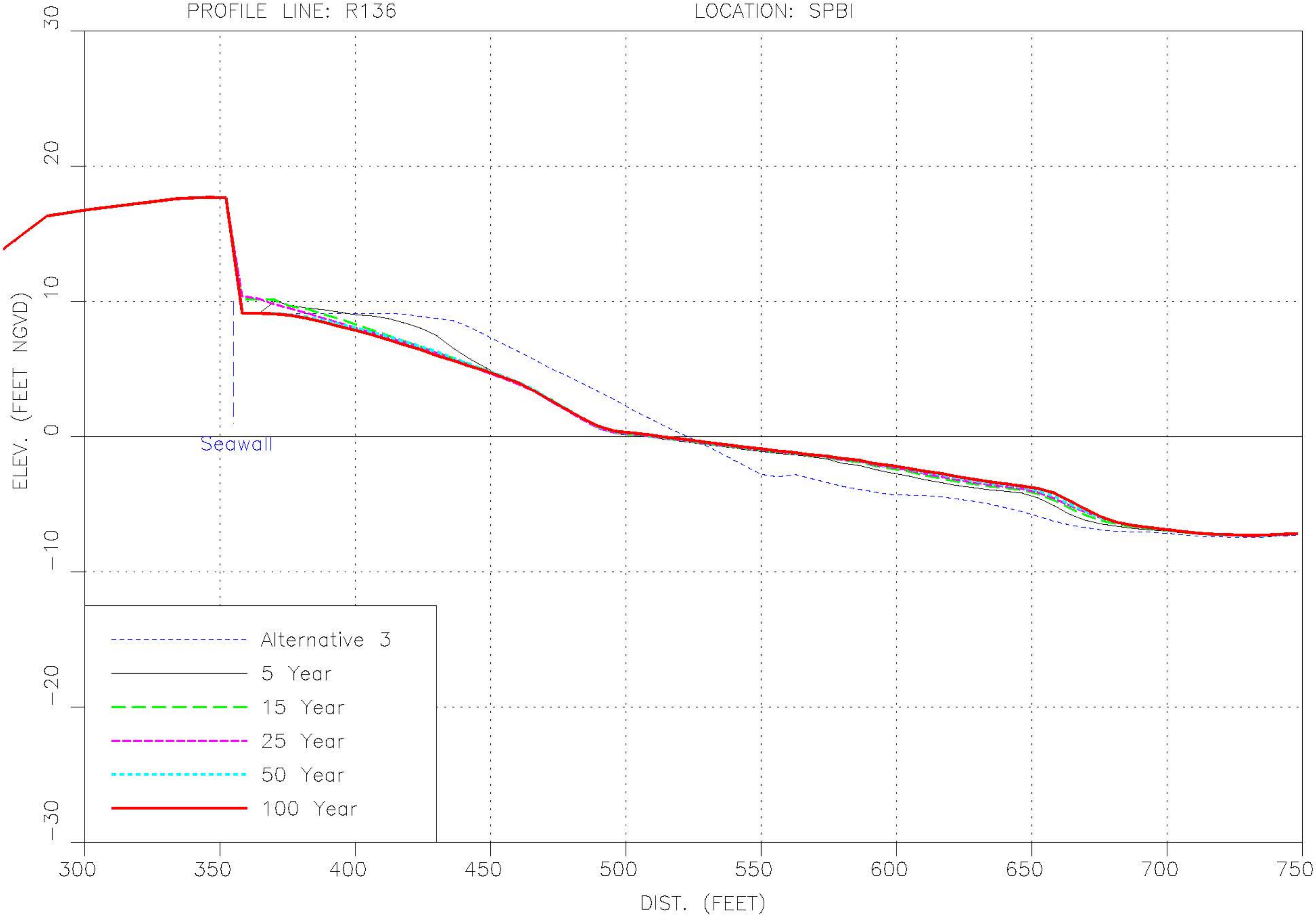

PROFILE LINE: R133
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Alternative 3
5 Year
15 Year
25 Year
50 Year
100 Year

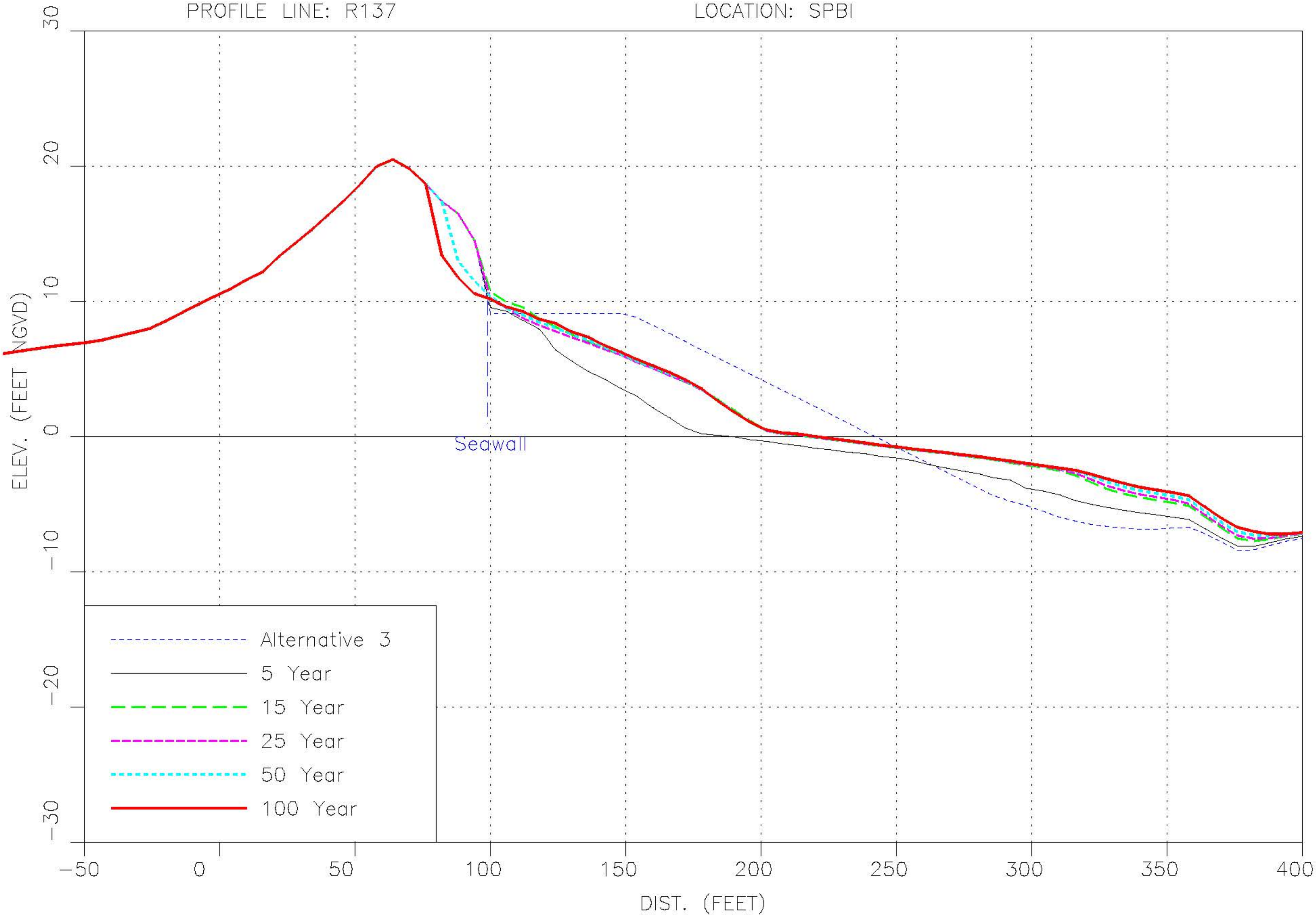


PROFILE LINE: R134
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Alternative 3
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400

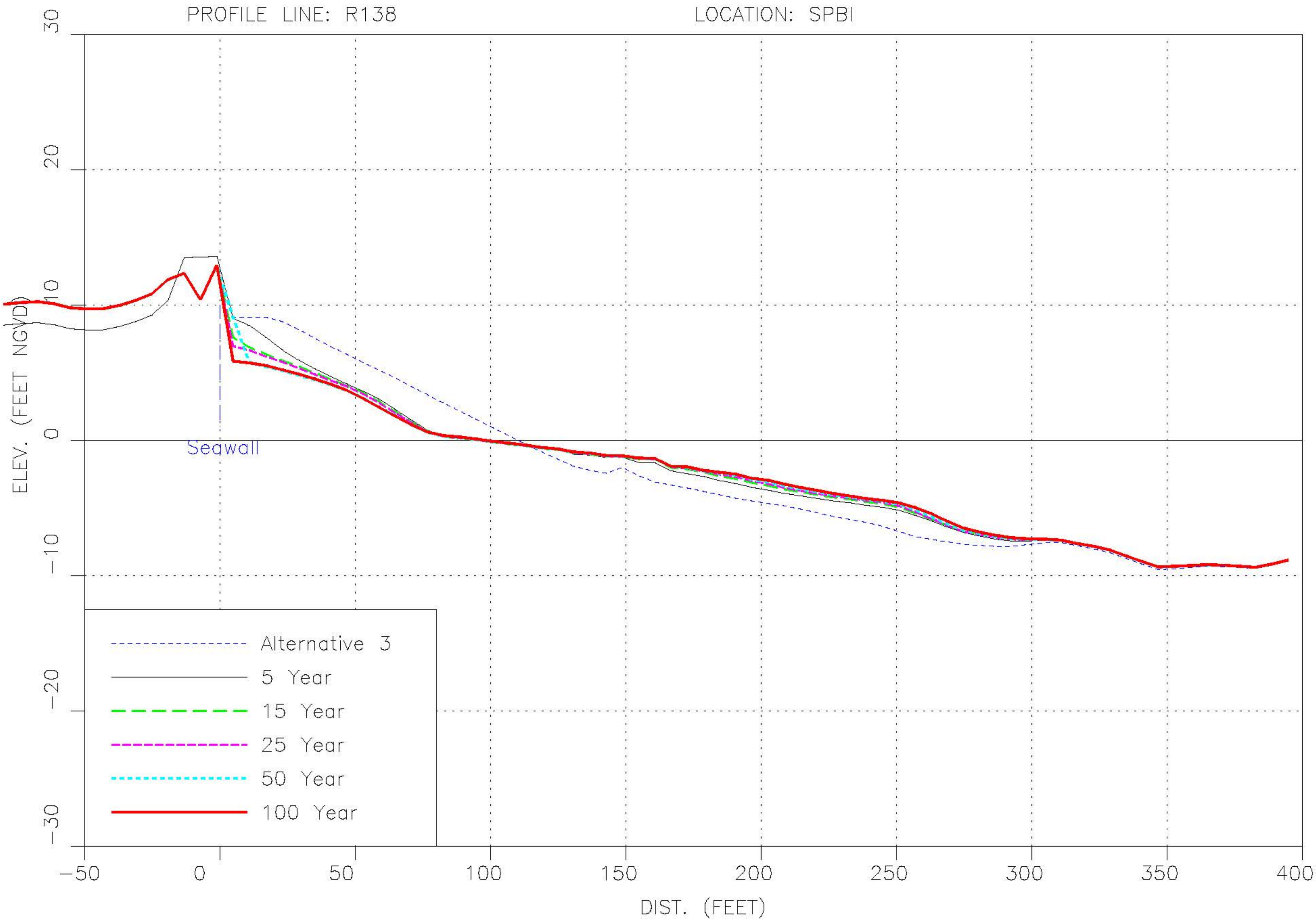


PROFILE LINE: R135
LOCATION: SPBI
30
20
10
0
−10
−20
−30
ELEV. (FEET NGVD)
−50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
Alternative 3
5 Year
15 Year
25 Year
50 Year
100 Year


PROFILE LINE: R136
LOCATION: SPBI
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
Seawall
300
350
400
450
500
550
600
650
700
750
DIST. (FEET)
Alternative 3
5 Year
15 Year
25 Year
50 Year
100 Year



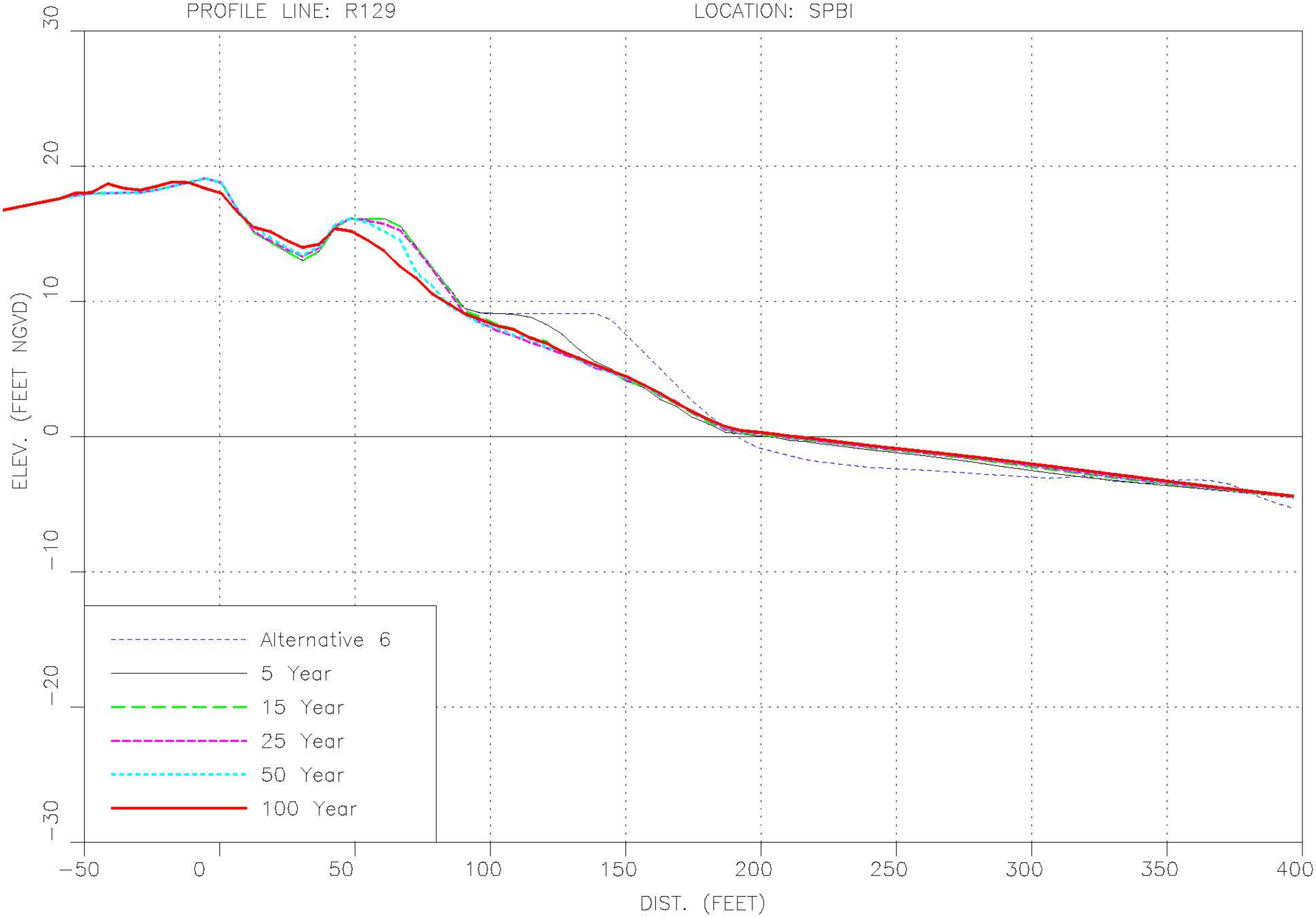
PROFILE LINE: R137
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Alternative 3
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400



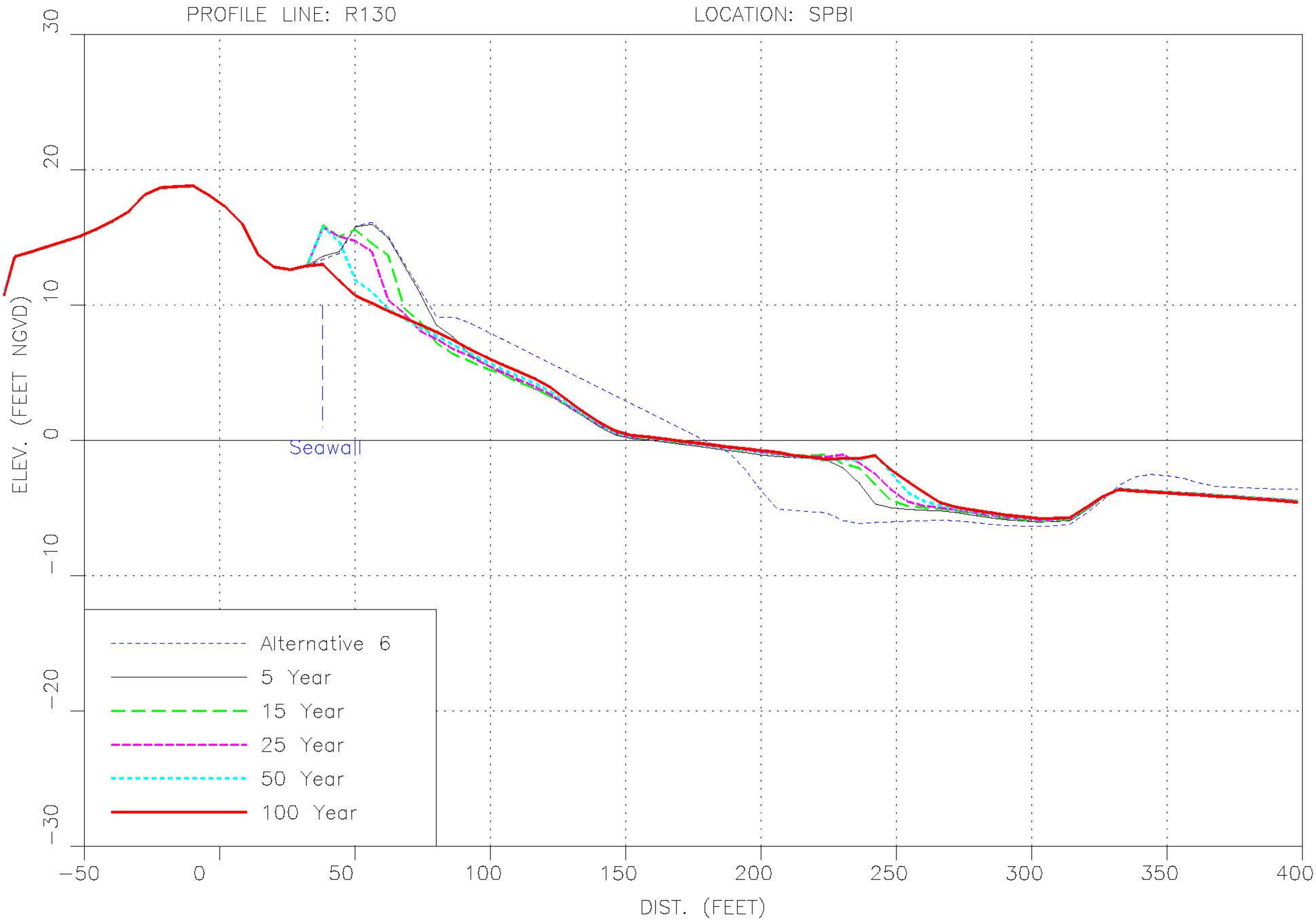
PROFILE LINE: R138
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
Alternative 3
5 Year
15 Year
25 Year
50 Year
100 Year

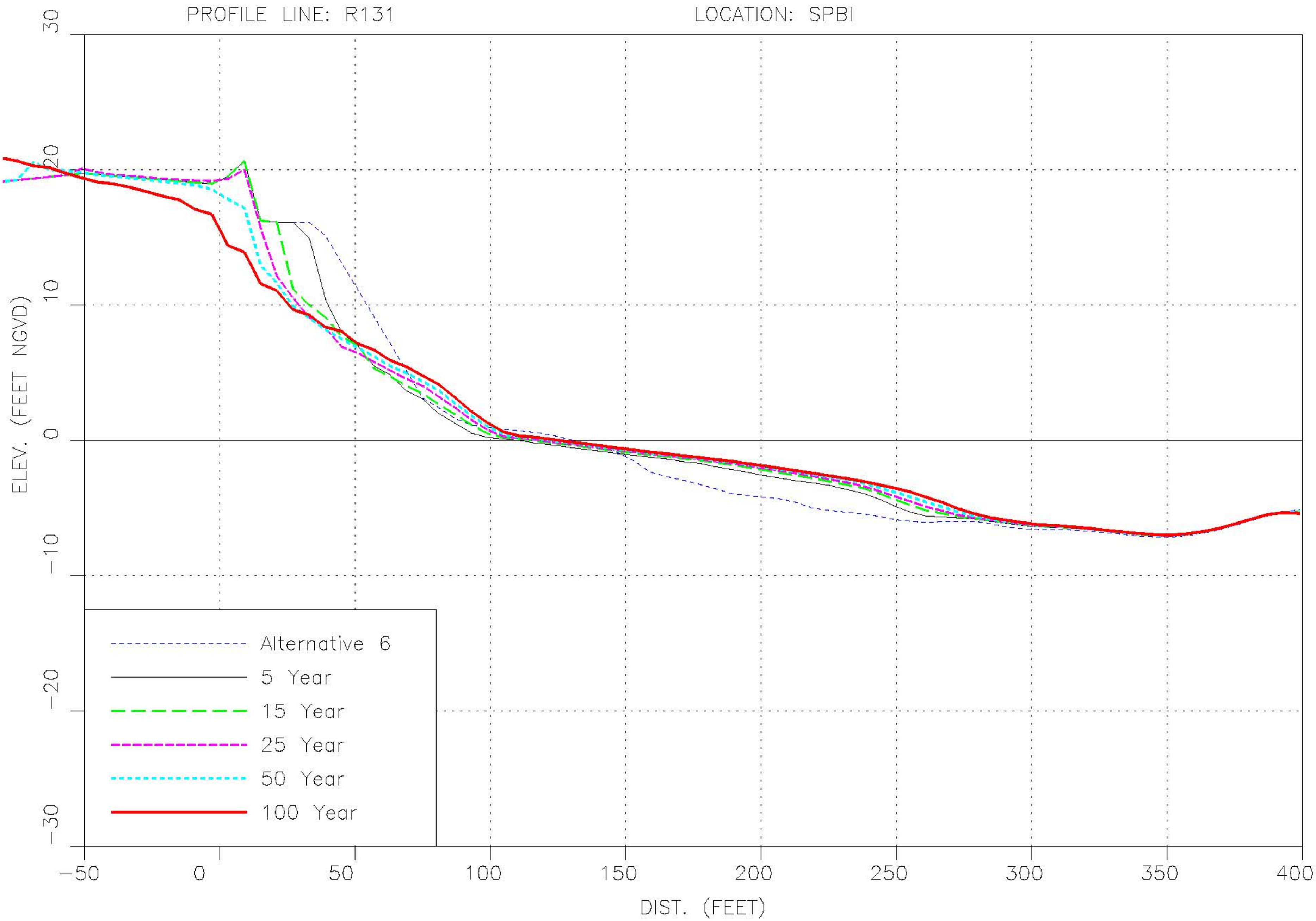
APPENDIX C-4

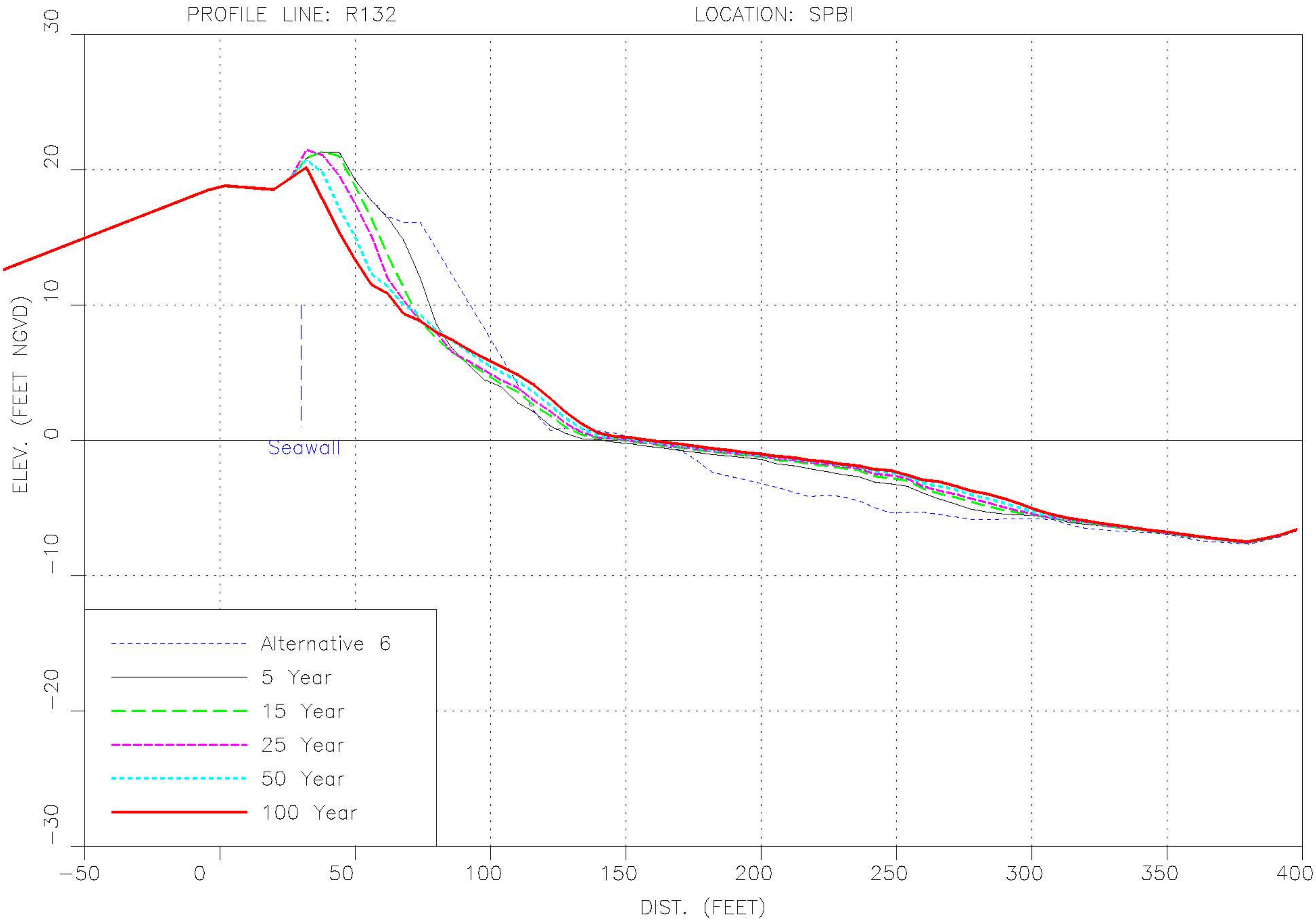
ALTERNATIVE 6 (LARGER FILL DESIGN)



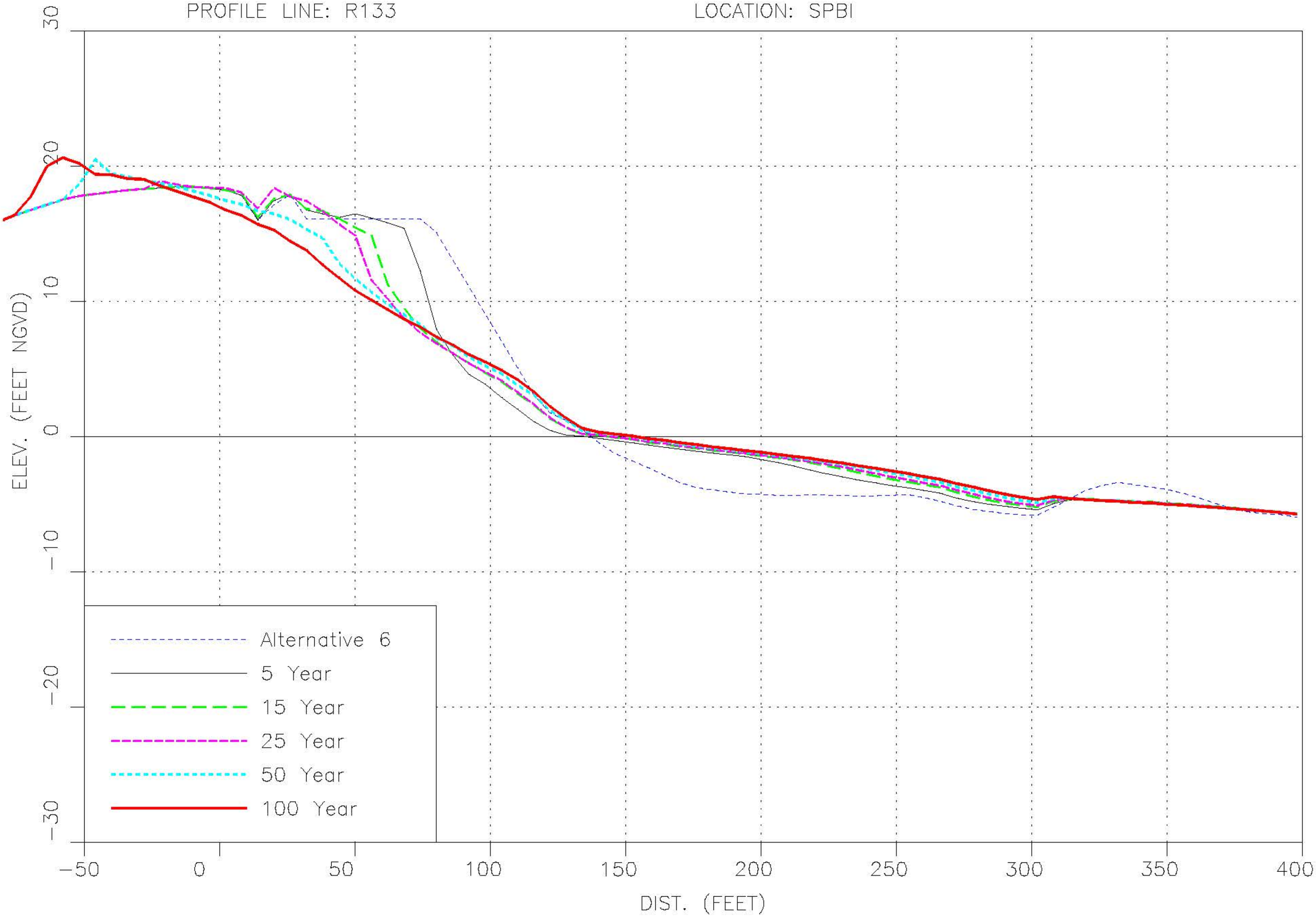
PROFILE LINE: R129
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Alternative 6
5 Year
15 Year
25 Year
50 Year
100 Year


PROFILE LINE: R130
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Seawall
Alternative 6
5 Year
15 Year
25 Year
50 Year
100 Year

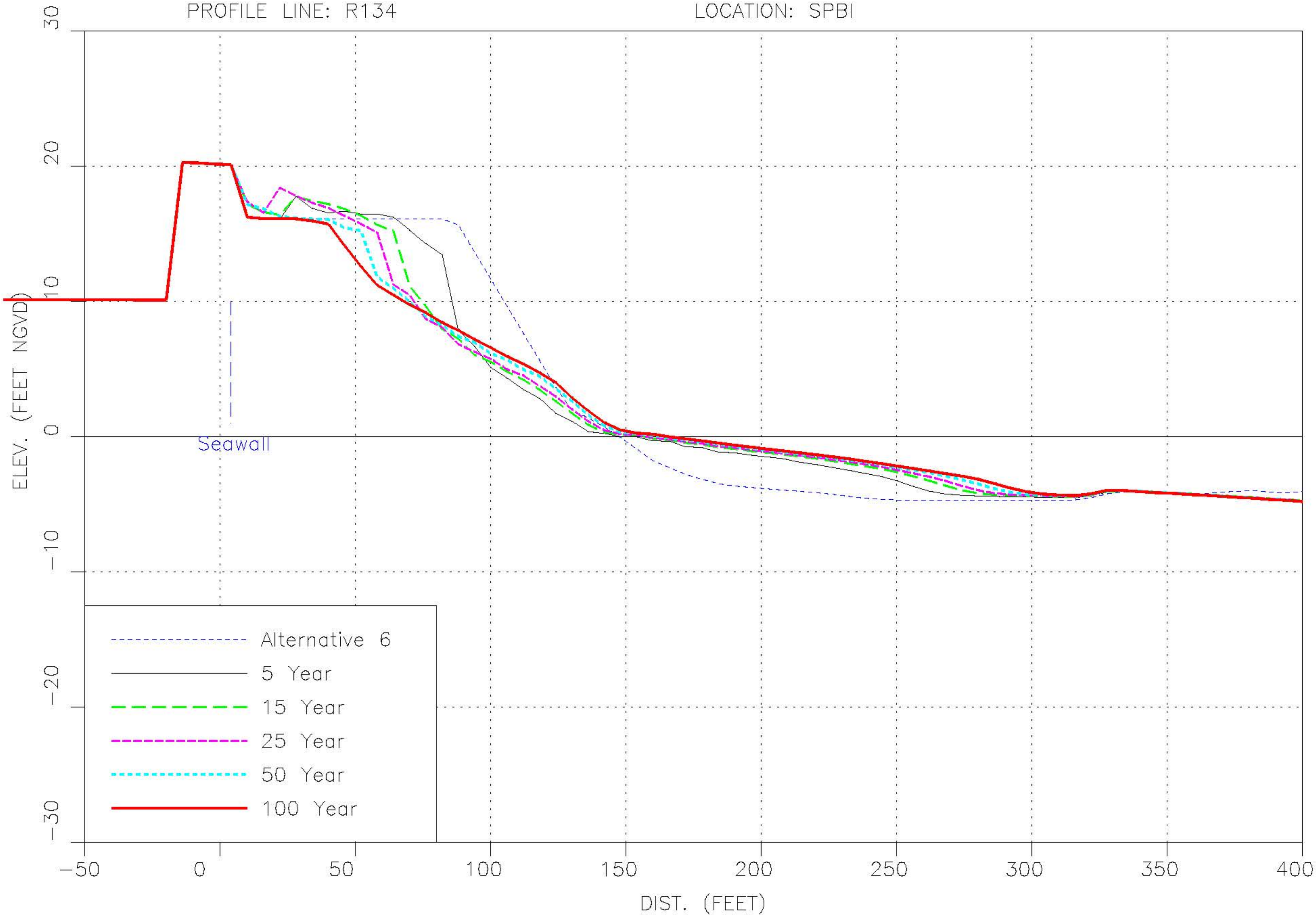

PROFILE LINE: R131
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Alternative 6
5 Year
15 Year
25 Year
50 Year
100 Year

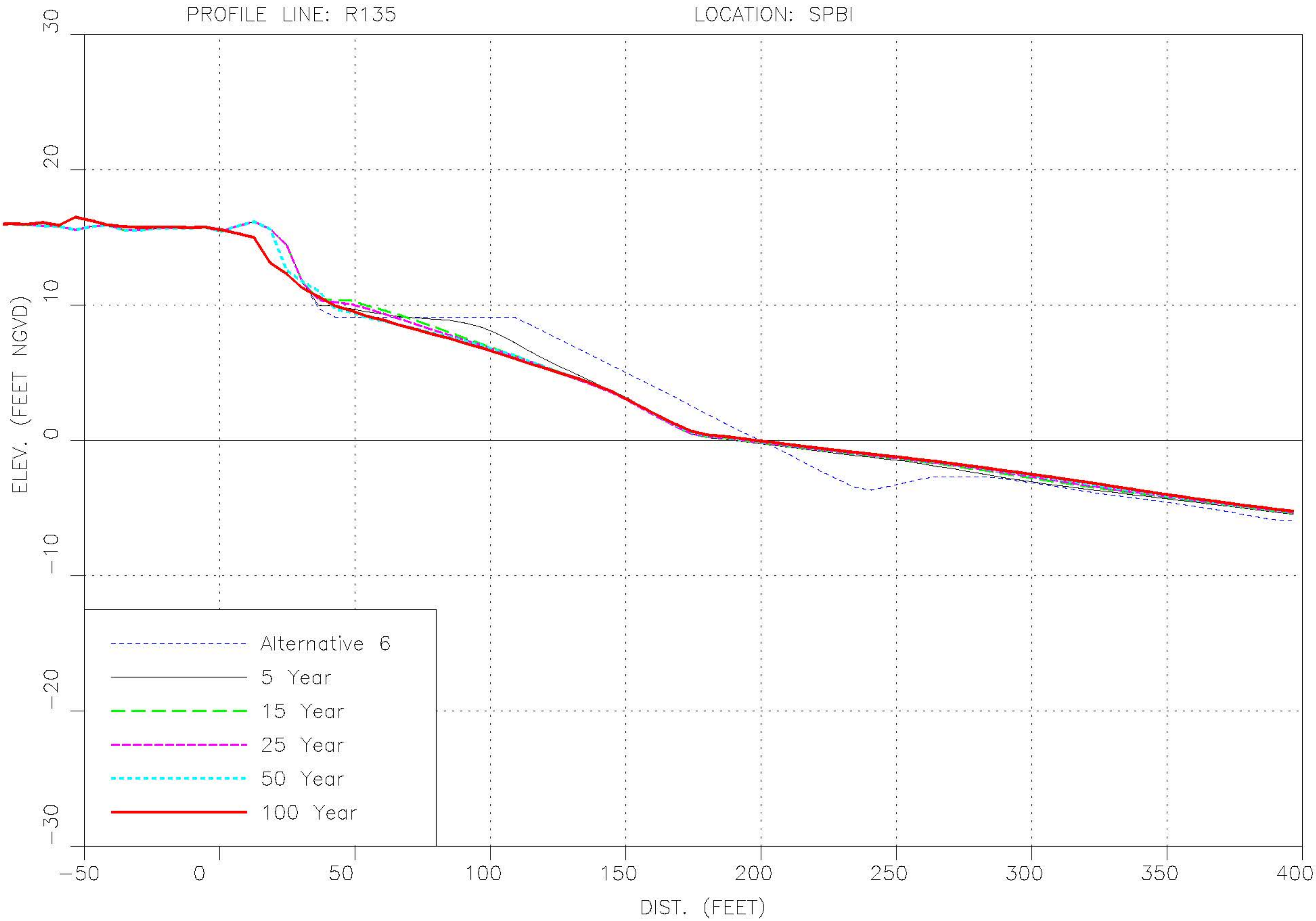


PROFILE LINE: R132
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Alternative 6
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400

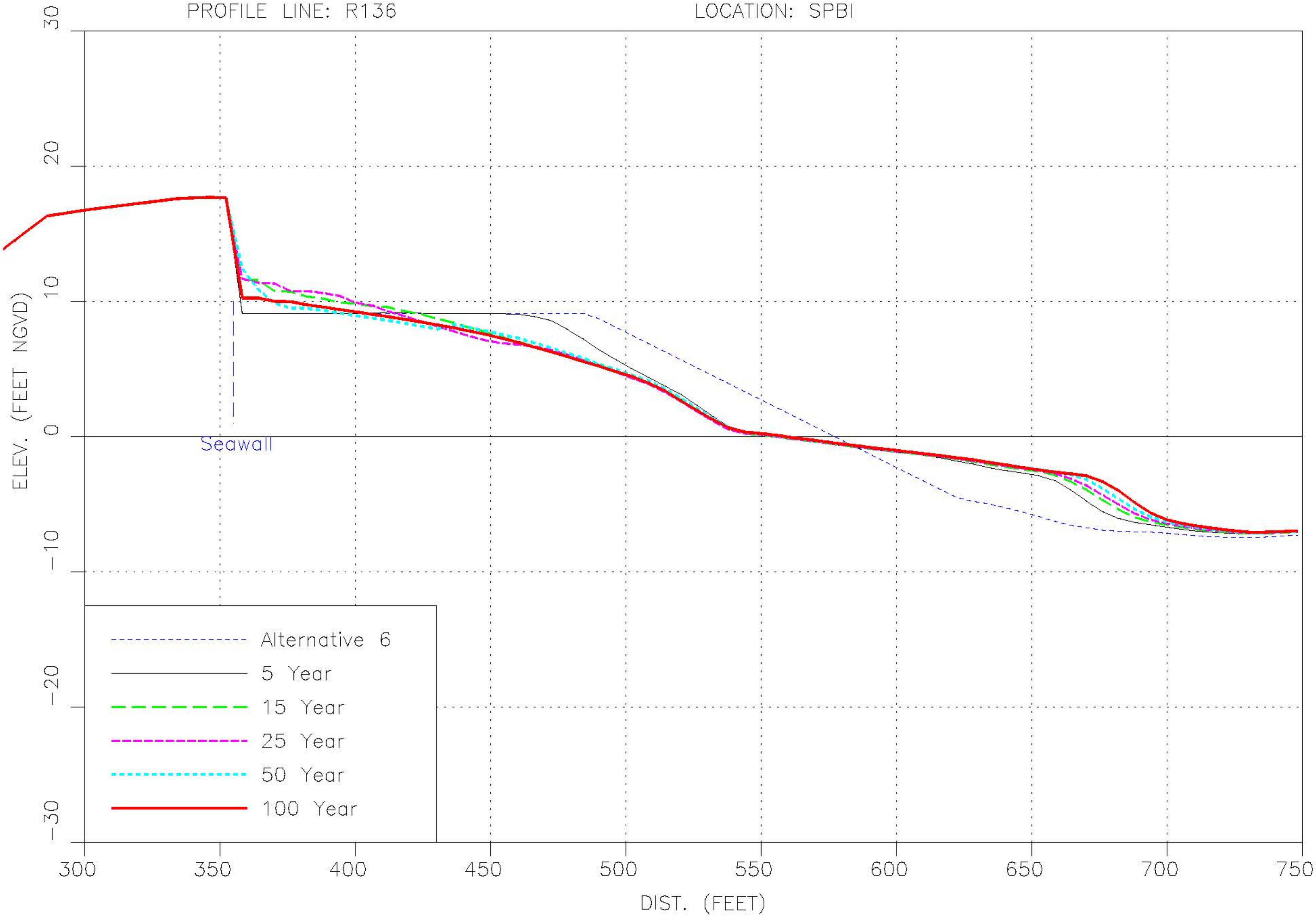


PROFILE LINE: R133
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Alternative 6
5 Year
15 Year
25 Year
50 Year
100 Year

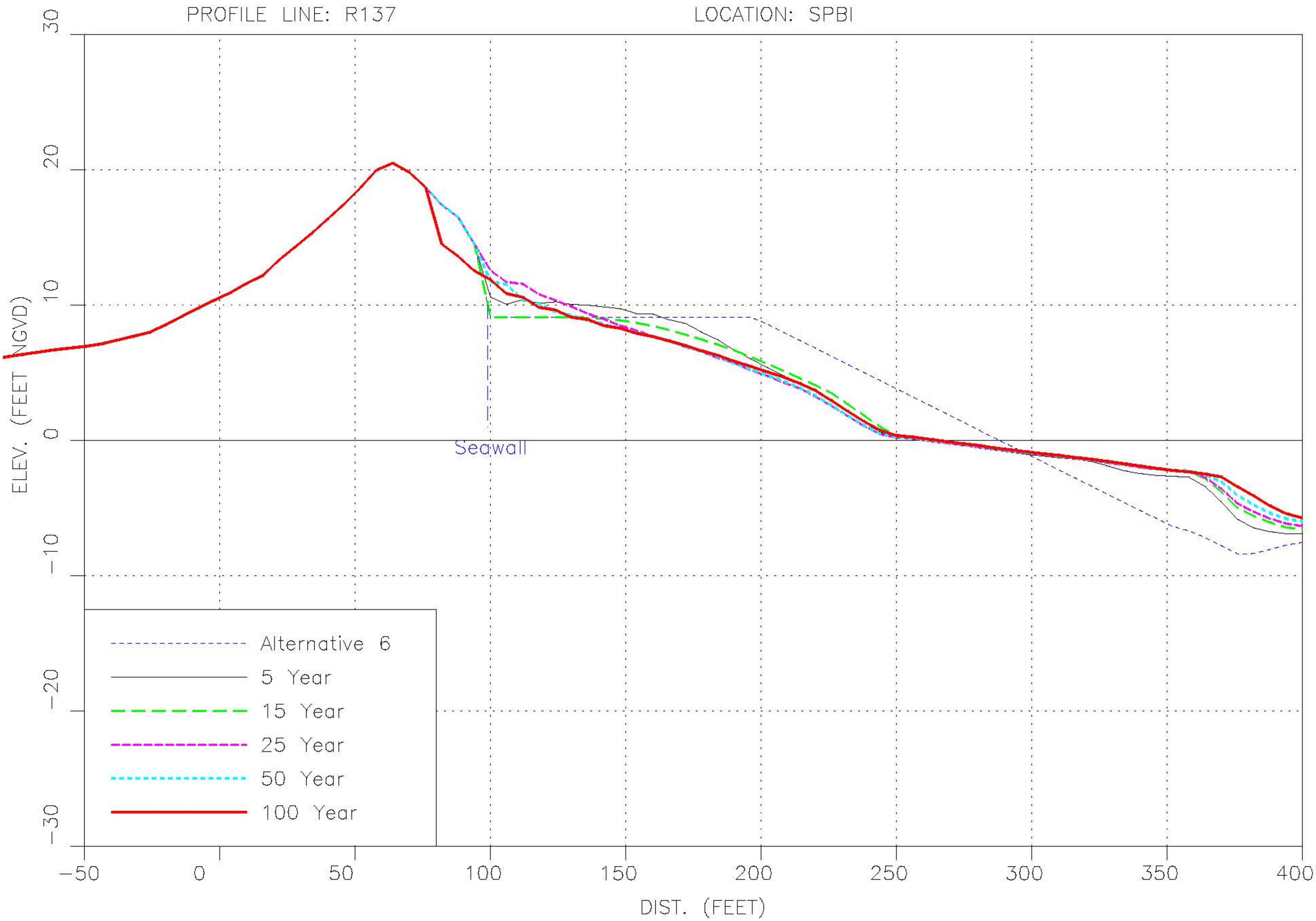

PROFILE LINE: R134
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
Alternative 6
5 Year
15 Year
25 Year
50 Year
100 Year



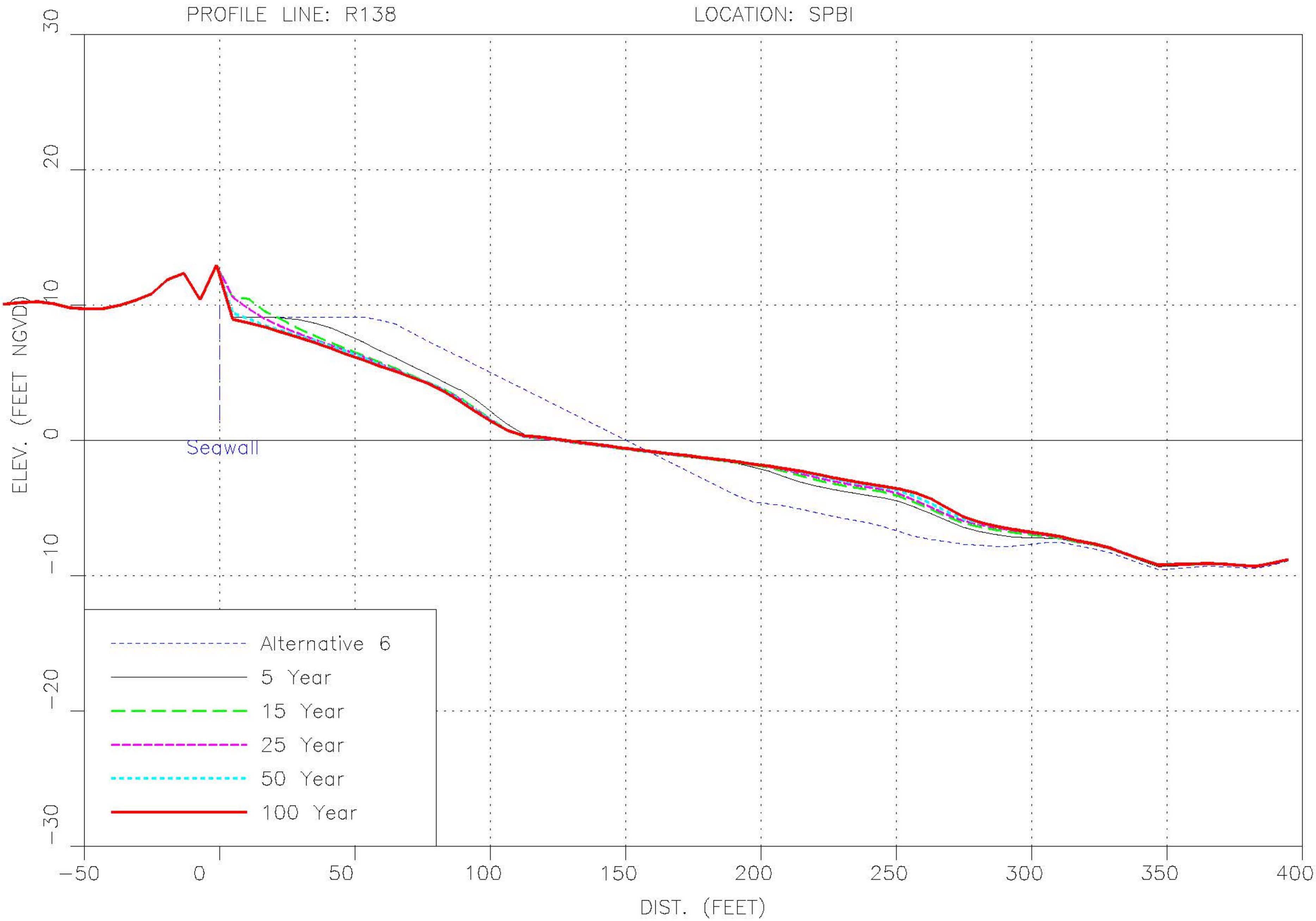
PROFILE LINE: R135
LOCATION: SPBI
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
Alternative 6
5 Year
15 Year
25 Year
50 Year
100 Year



PROFILE LINE: R136
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
300
350
400
450
500
550
600
650
700
750
Seawall
Alternative 6
5 Year
15 Year
25 Year
50 Year
100 Year

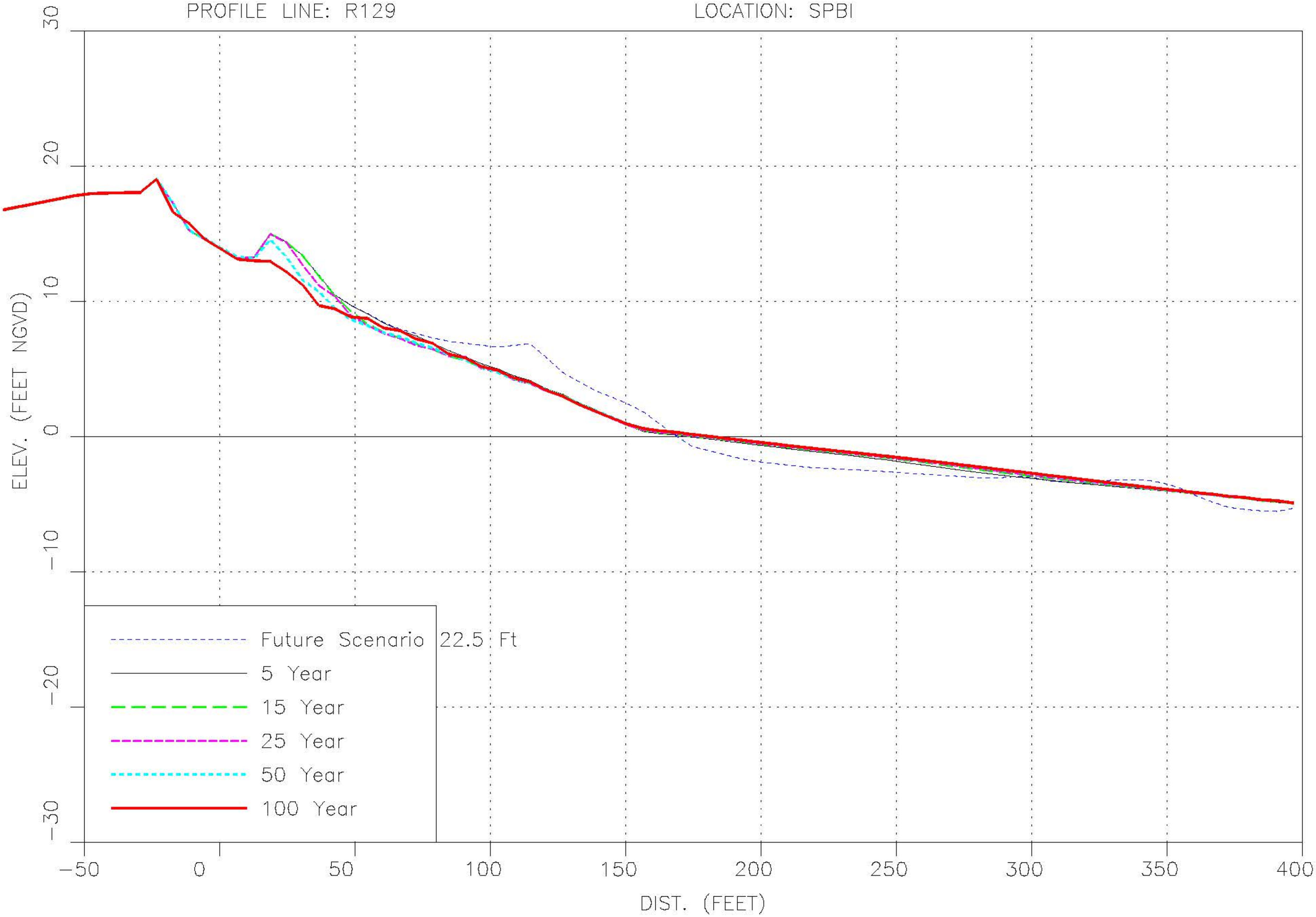


PROFILE LINE: R137
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Alternative 6
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400

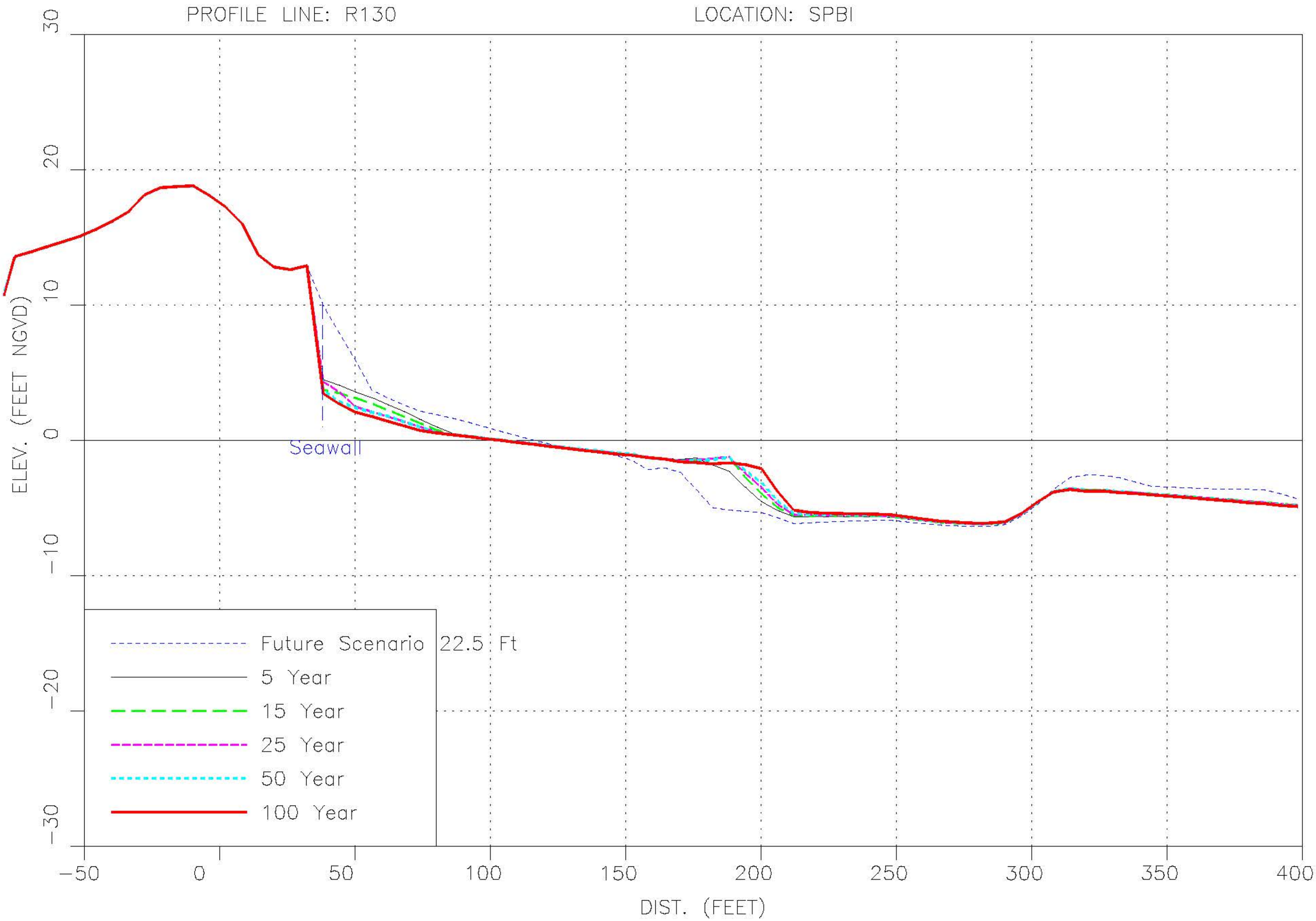

PROFILE LINE: R138
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Alternative 6
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400

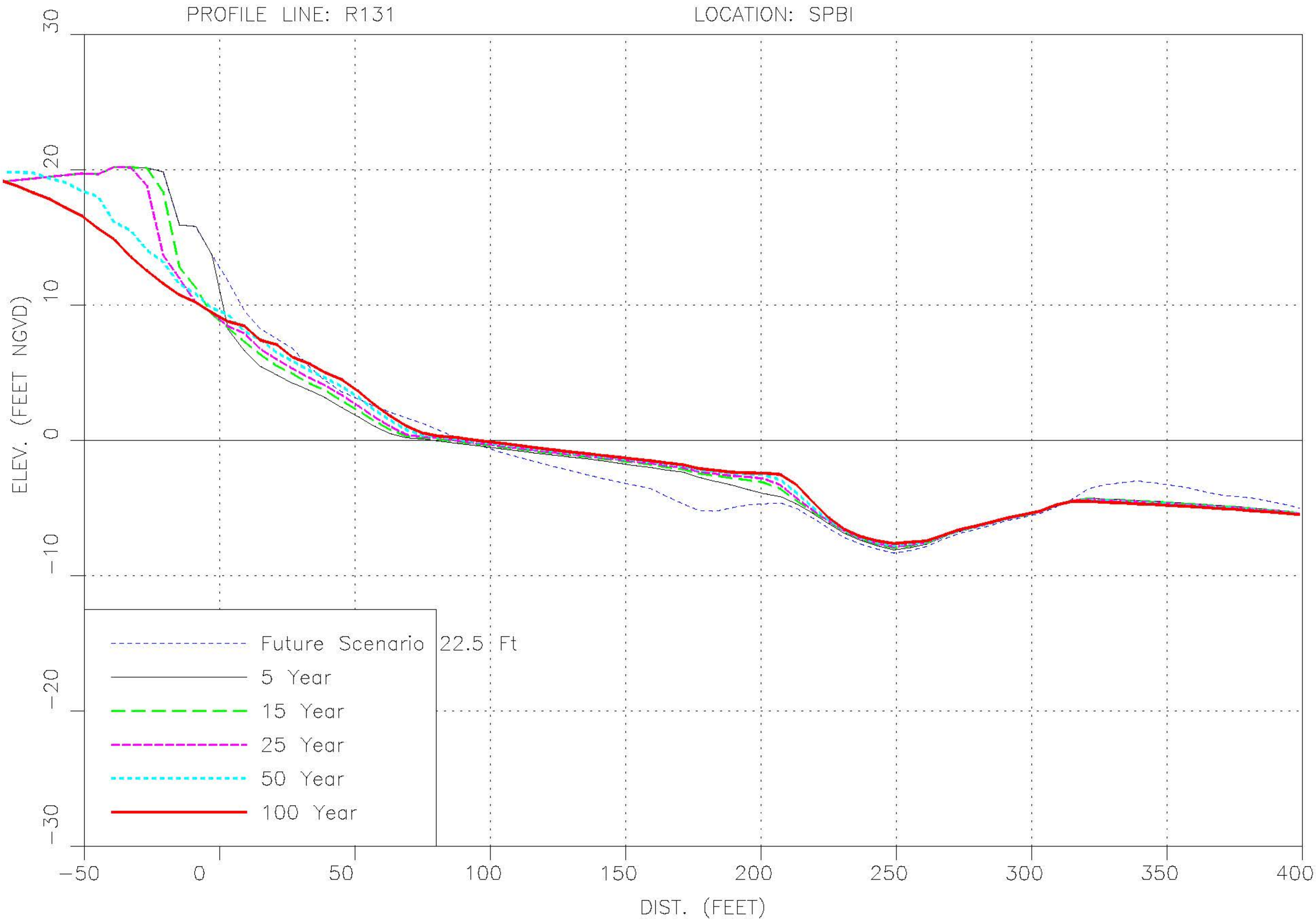
APPENDIX C-5

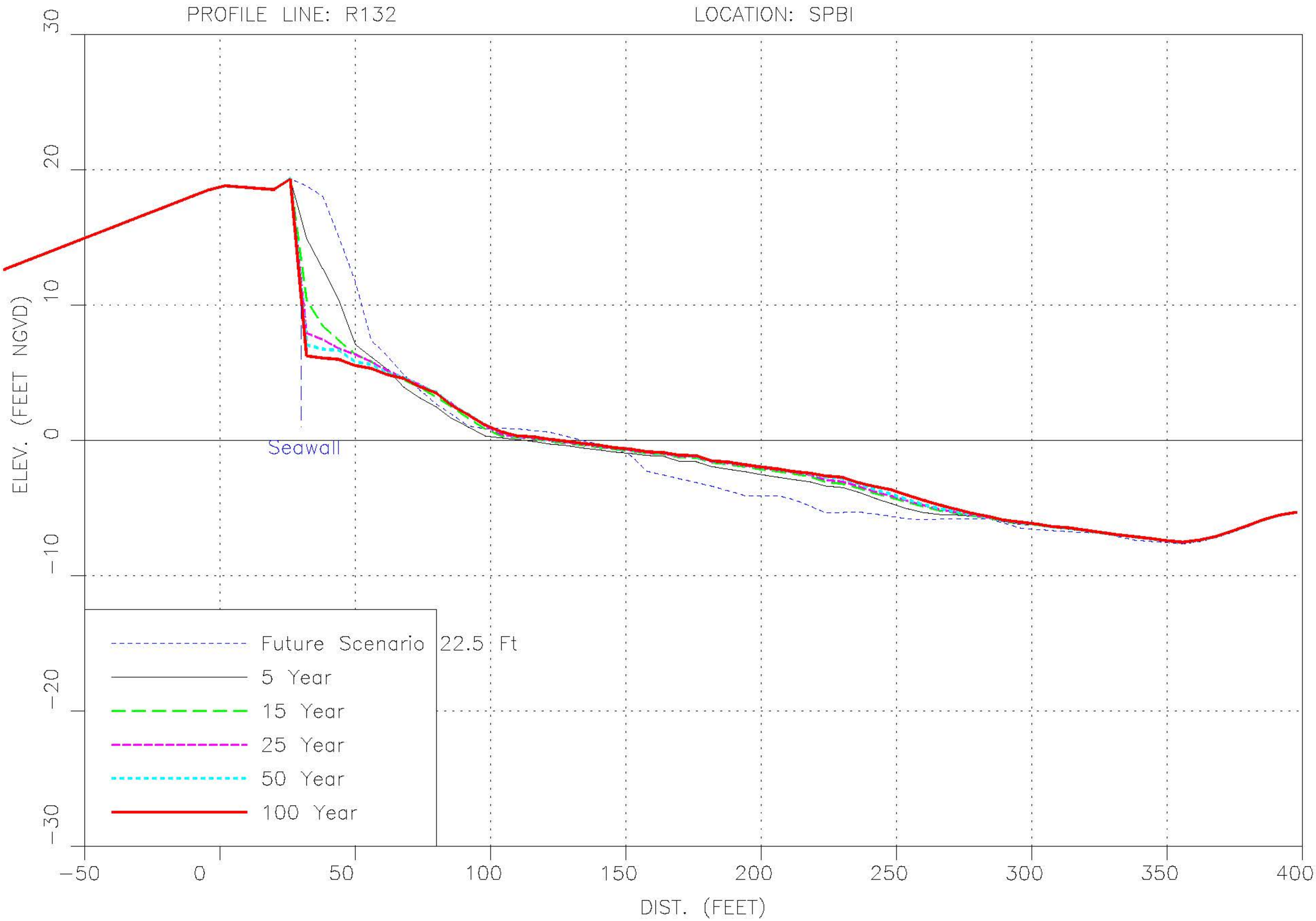
FUTURE SCENARIO (WITHOUT PROJECT CONDITIONS)

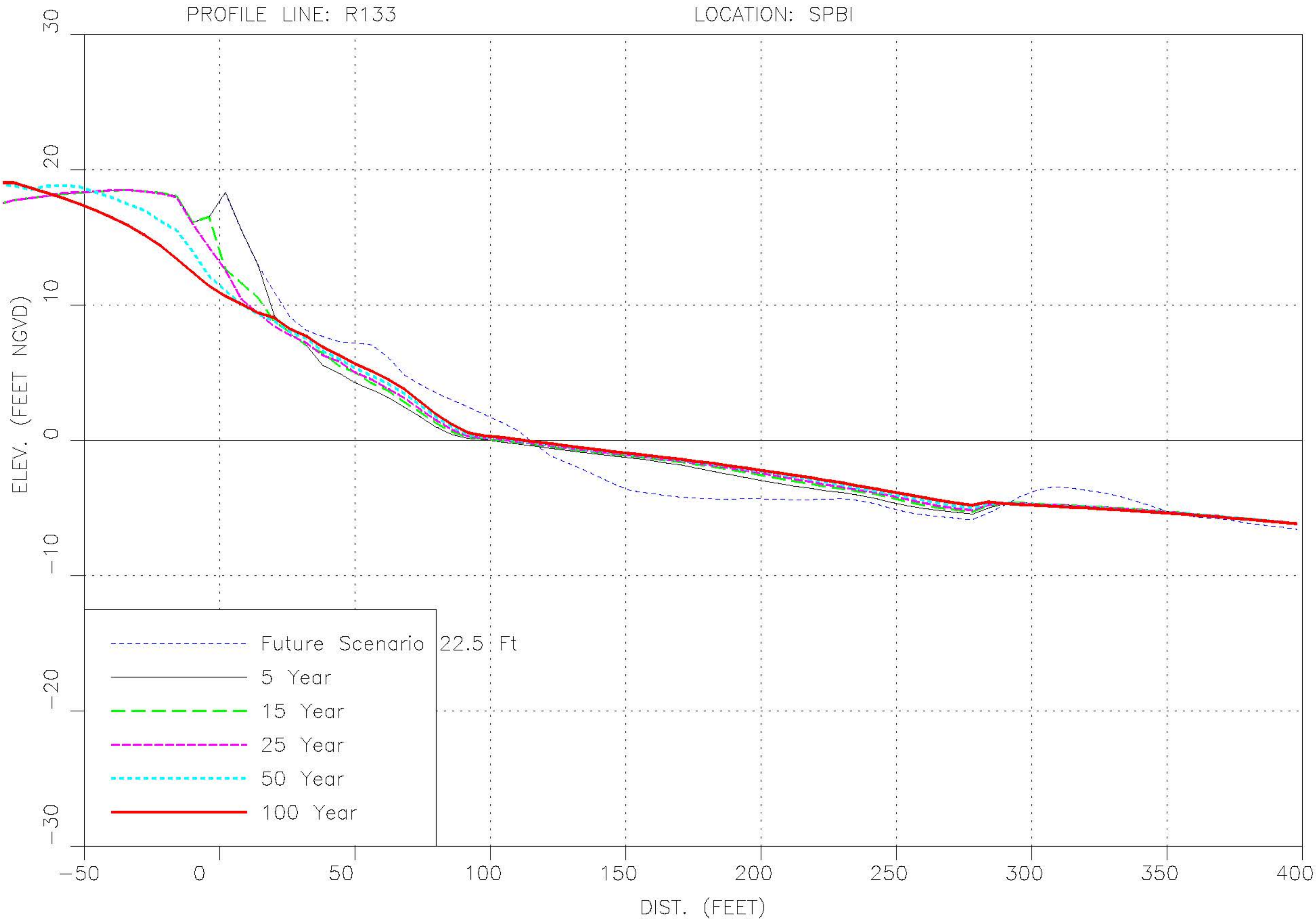


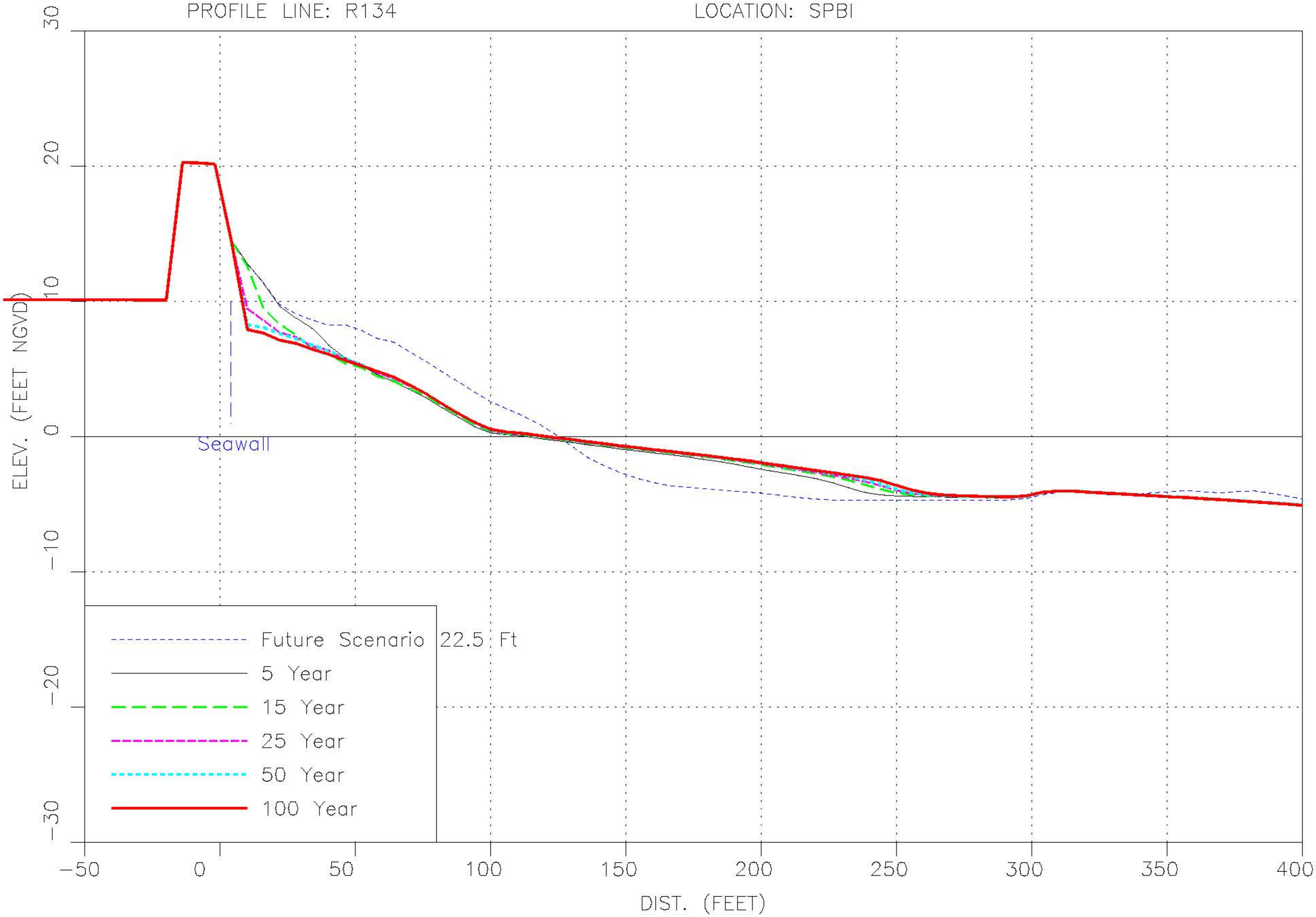
PROFILE LINE: R129
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Future Scenario 22.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year

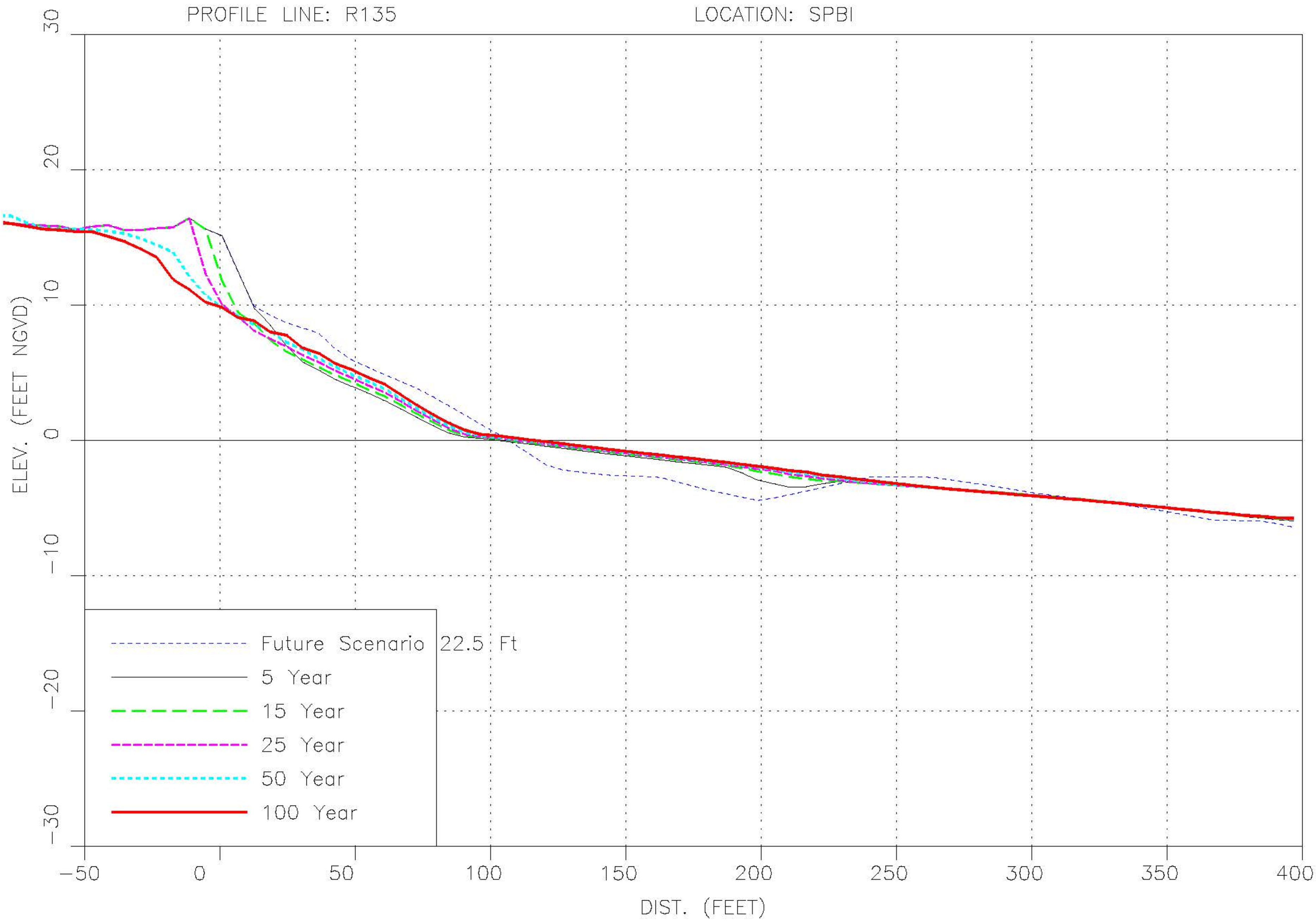

PROFILE LINE: R130
LOCATION: SPBI
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
Seawall
Future Scenario 22.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)


PROFILE LINE: R131
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Future Scenario 22.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year

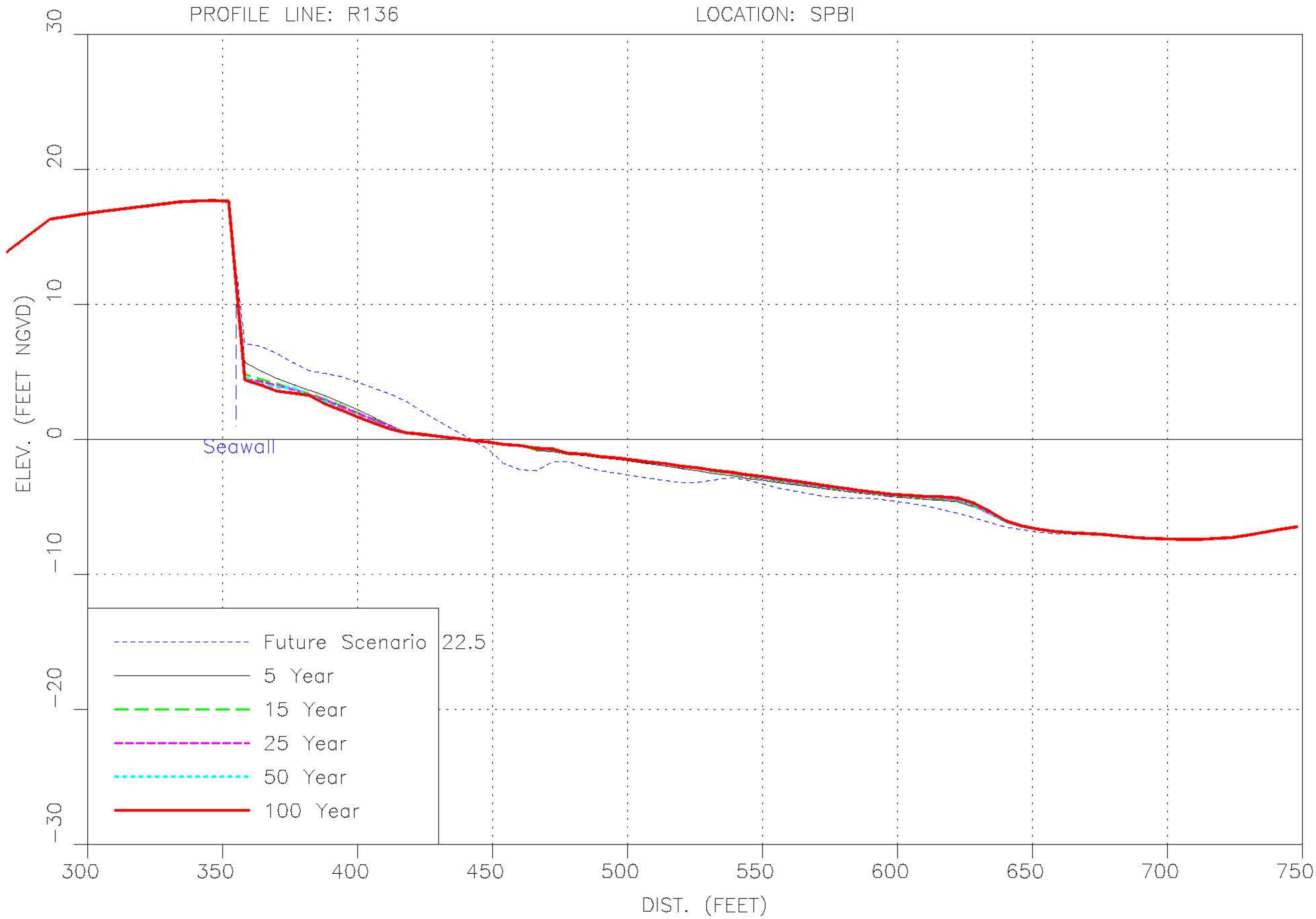

PROFILE LINE: R132
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Future Scenario 22.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year

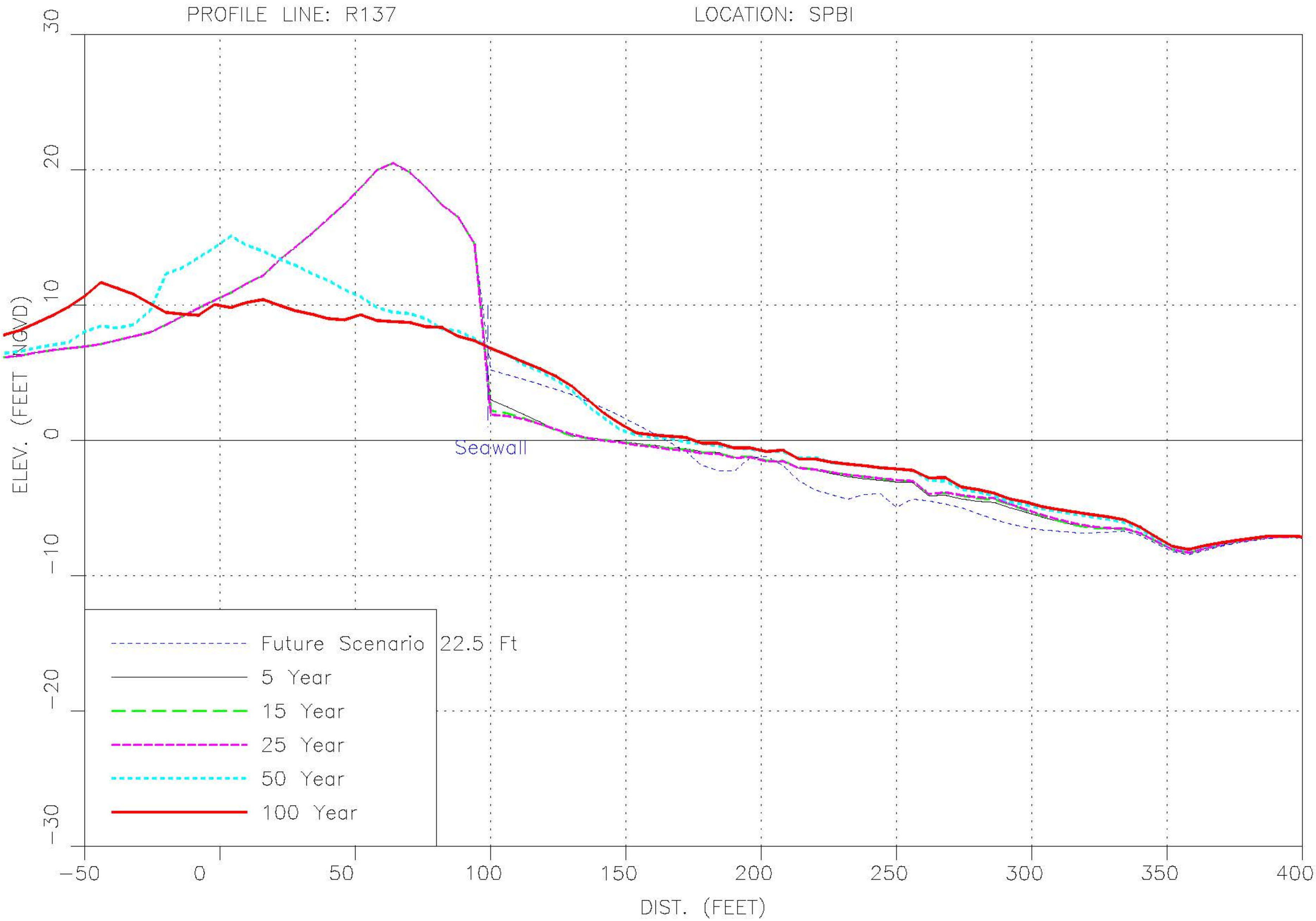

PROFILE LINE: R133
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Future Scenario 22.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year

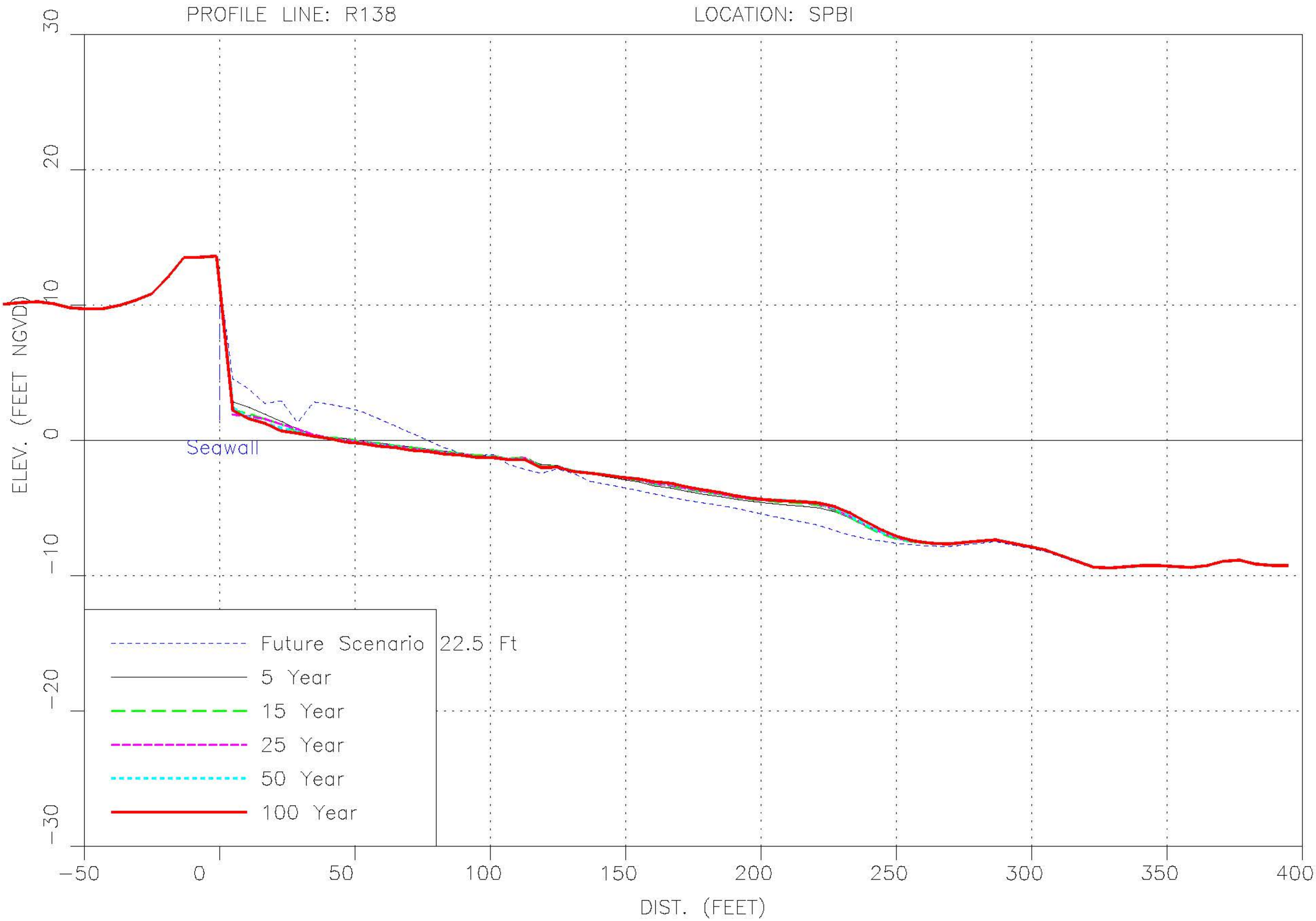

PROFILE LINE: R134
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Future Scenario 22.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year



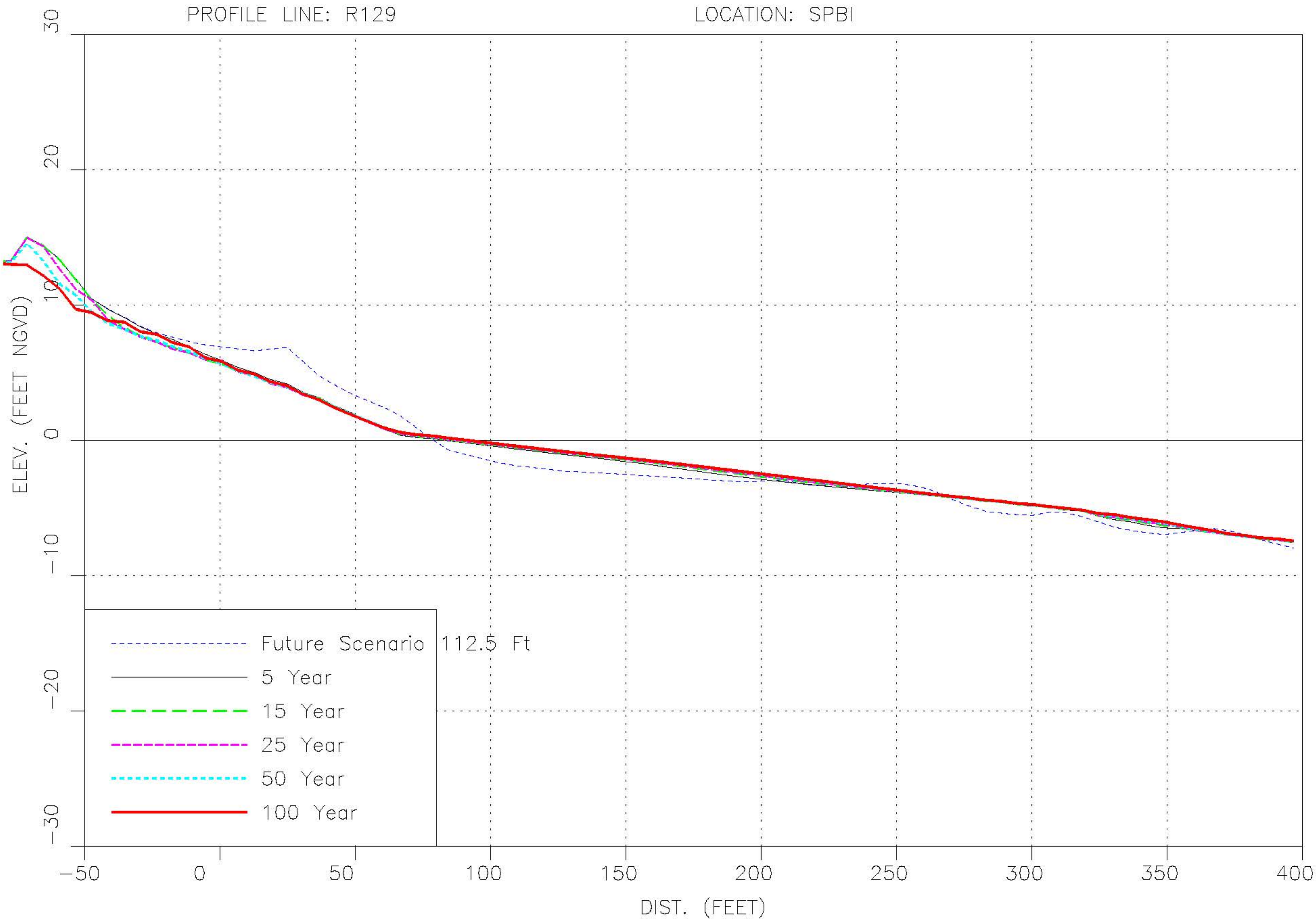
PROFILE LINE: R135
LOCATION: SPBI
ELEV. (FEET NGVD)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
DIST. (FEET)
Future Scenario 22.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year


PROFILE LINE: R136
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Future Scenario 22.5
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
-10
-20
-30
300
350
400
450
500
550
600
650
700
750

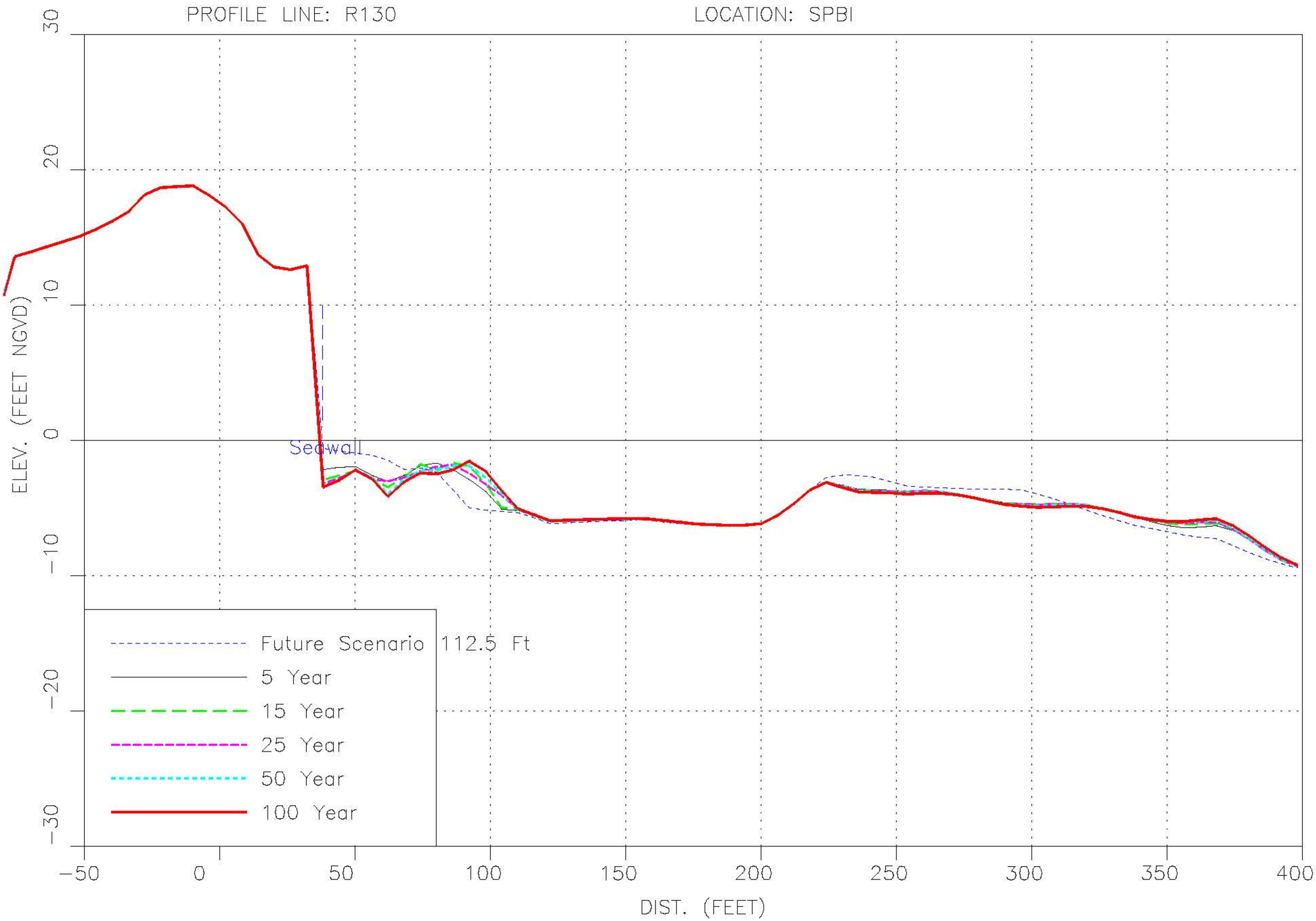

PROFILE LINE: R137
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Future Scenario 22.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year



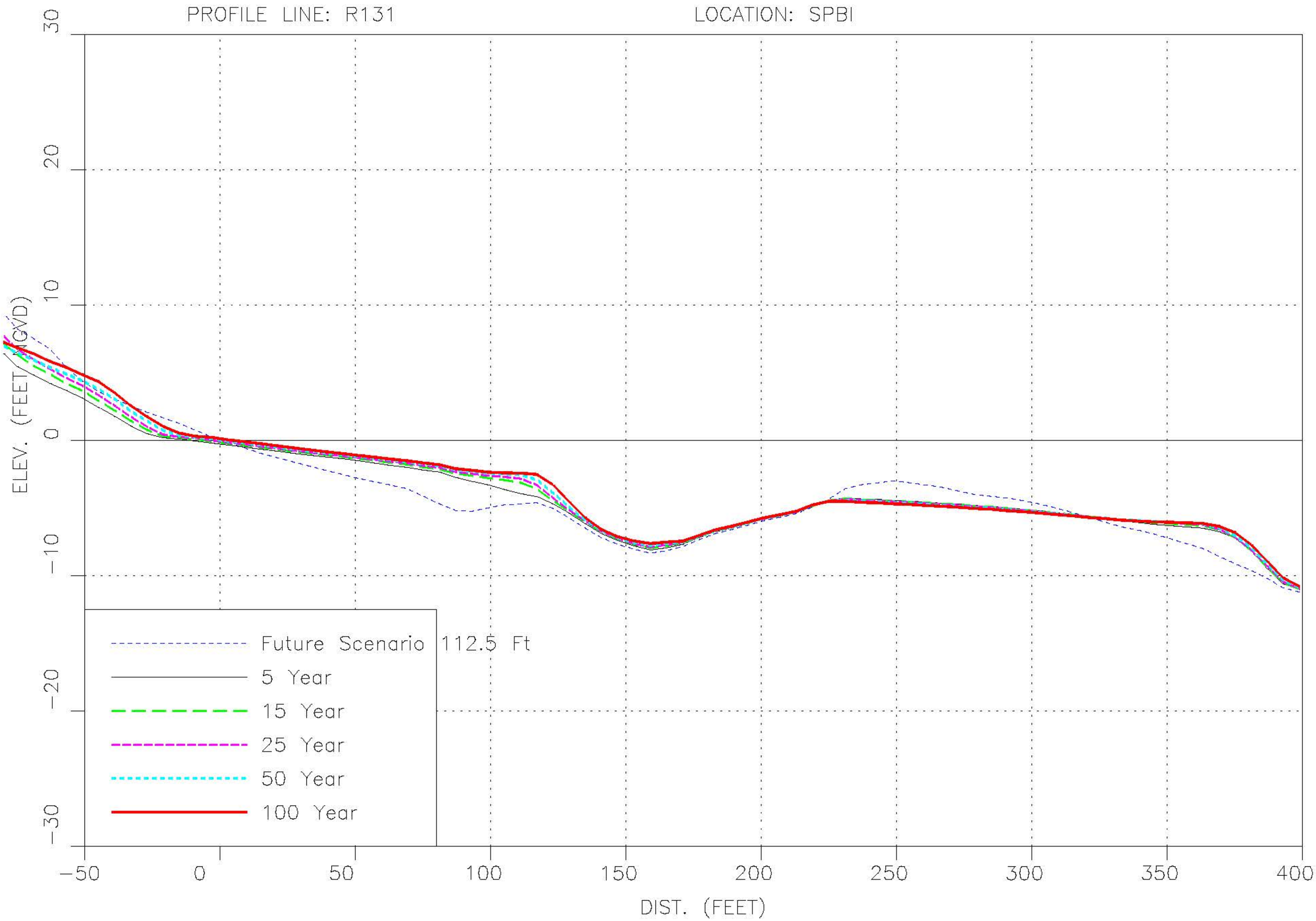
PROFILE LINE: R138
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Seawall
Future Scenario 22.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year



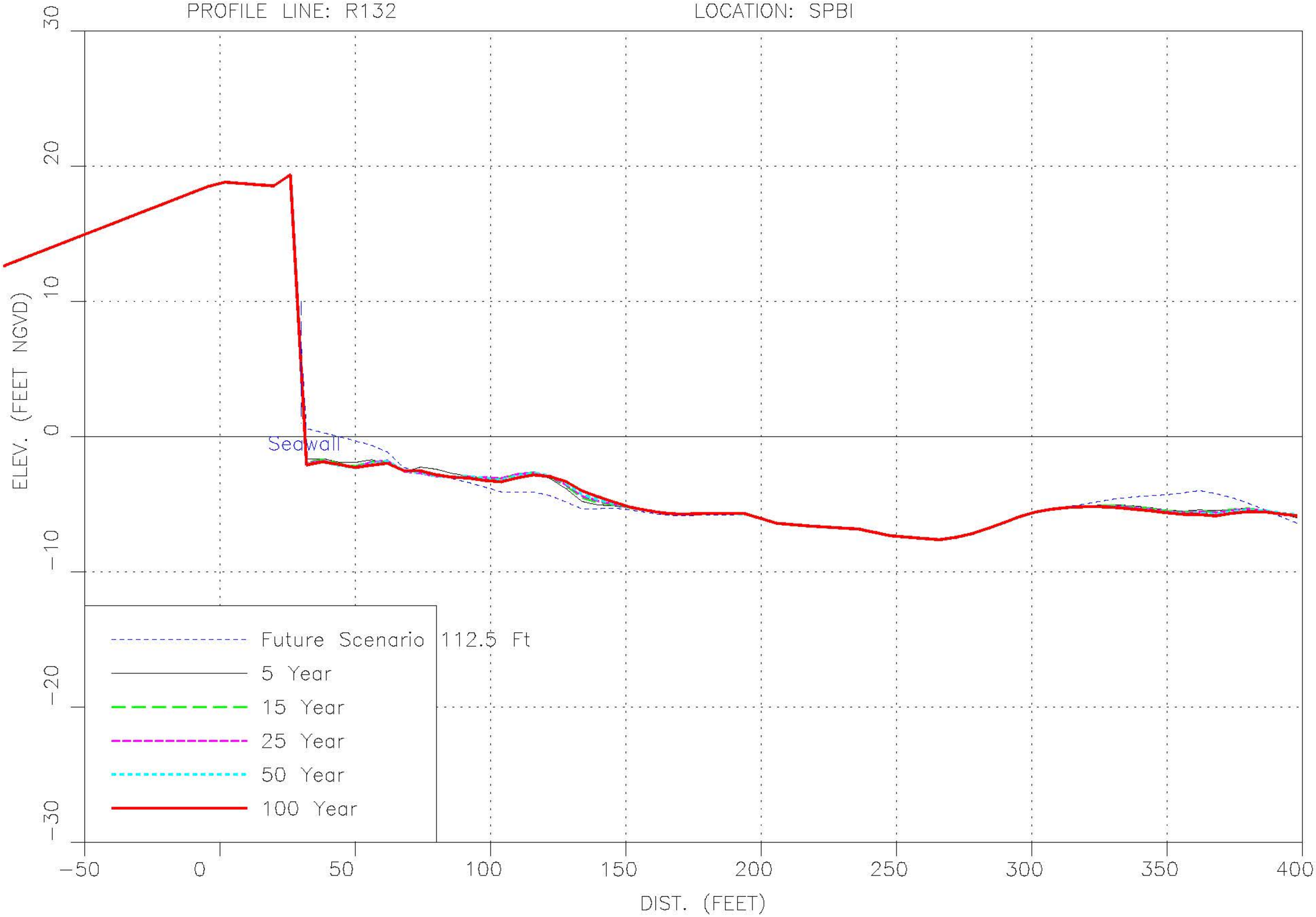
PROFILE LINE: R129
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
Future Scenario 112.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year

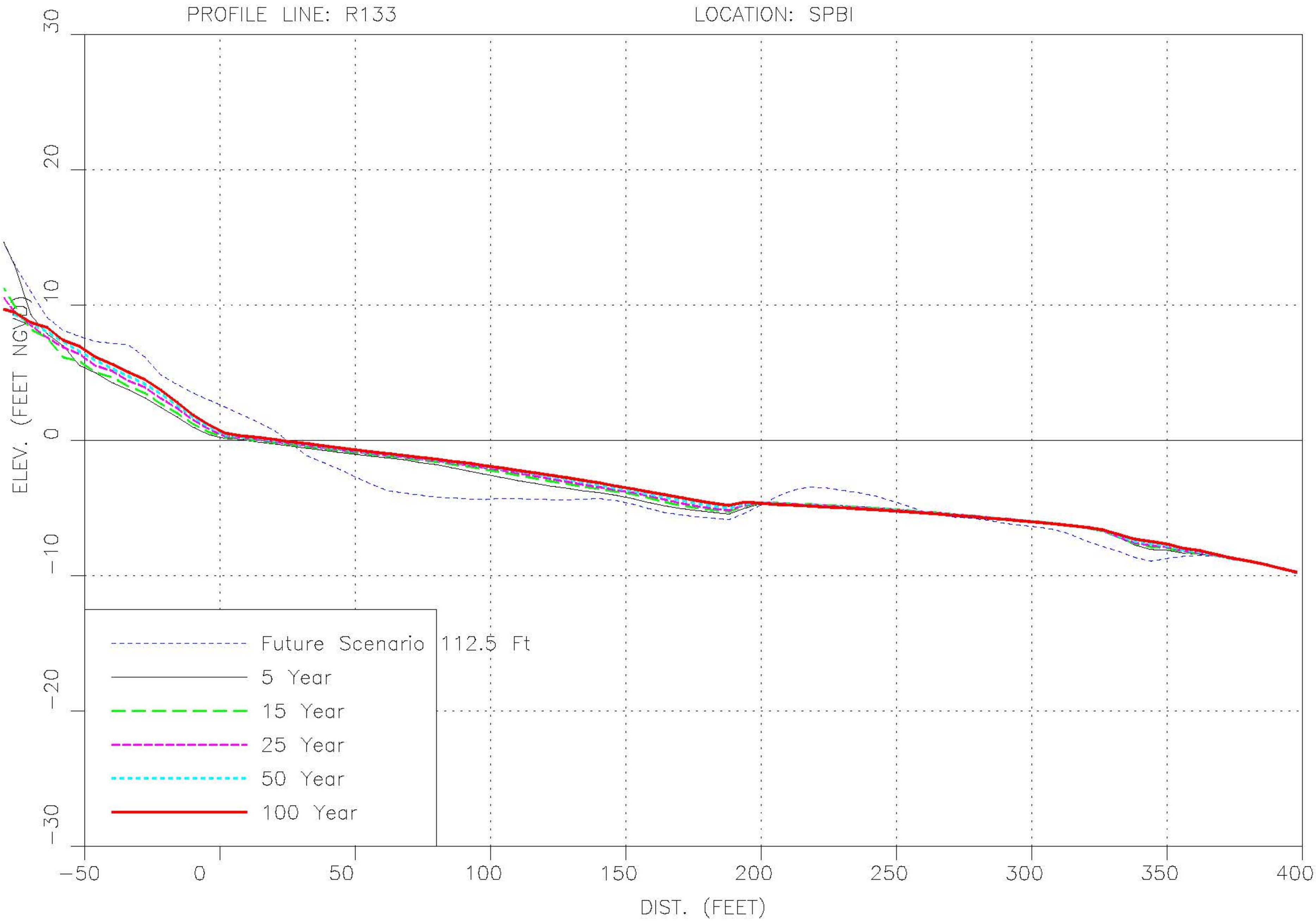


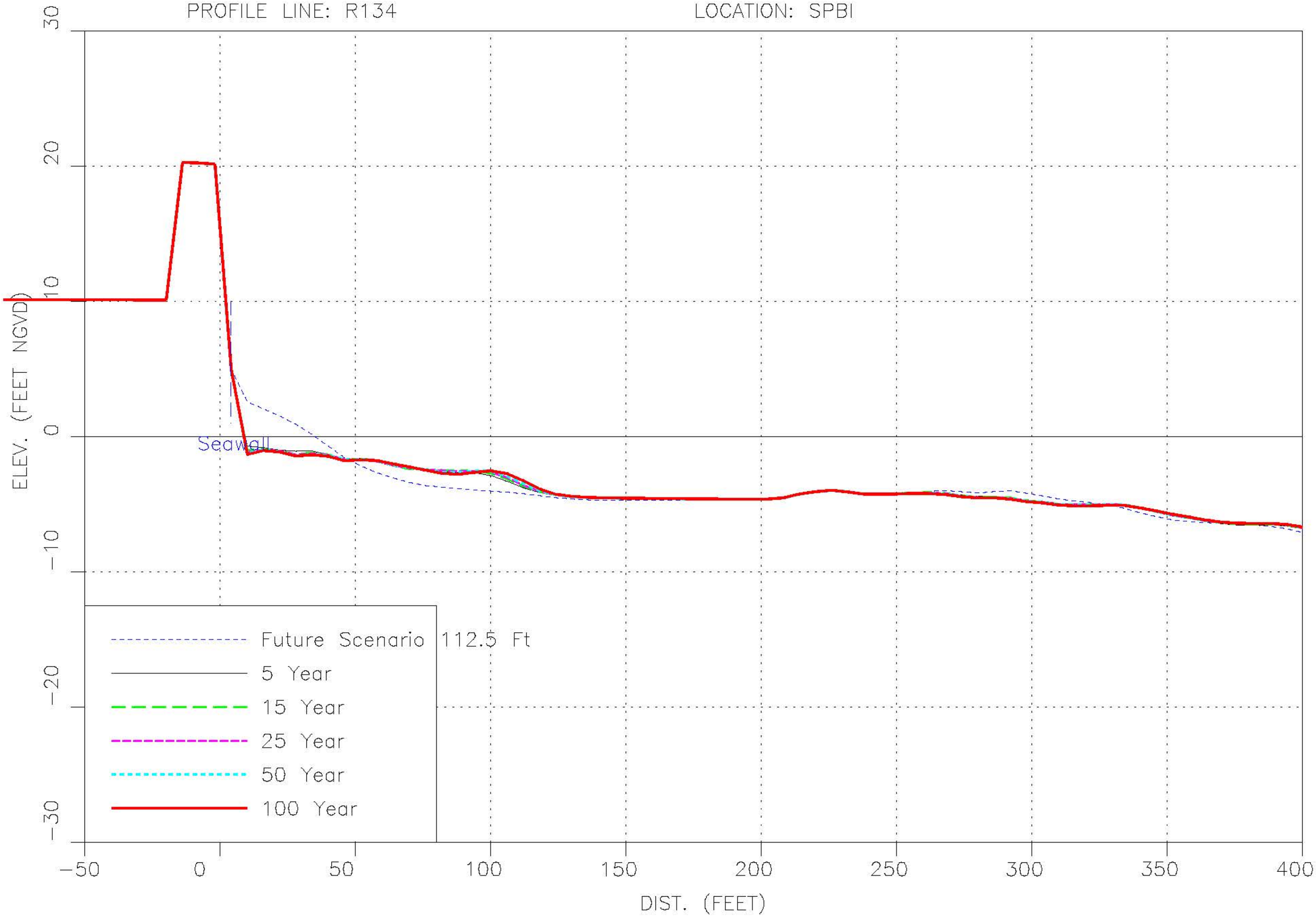
PROFILE LINE: R130
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Future Scenario 112.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400

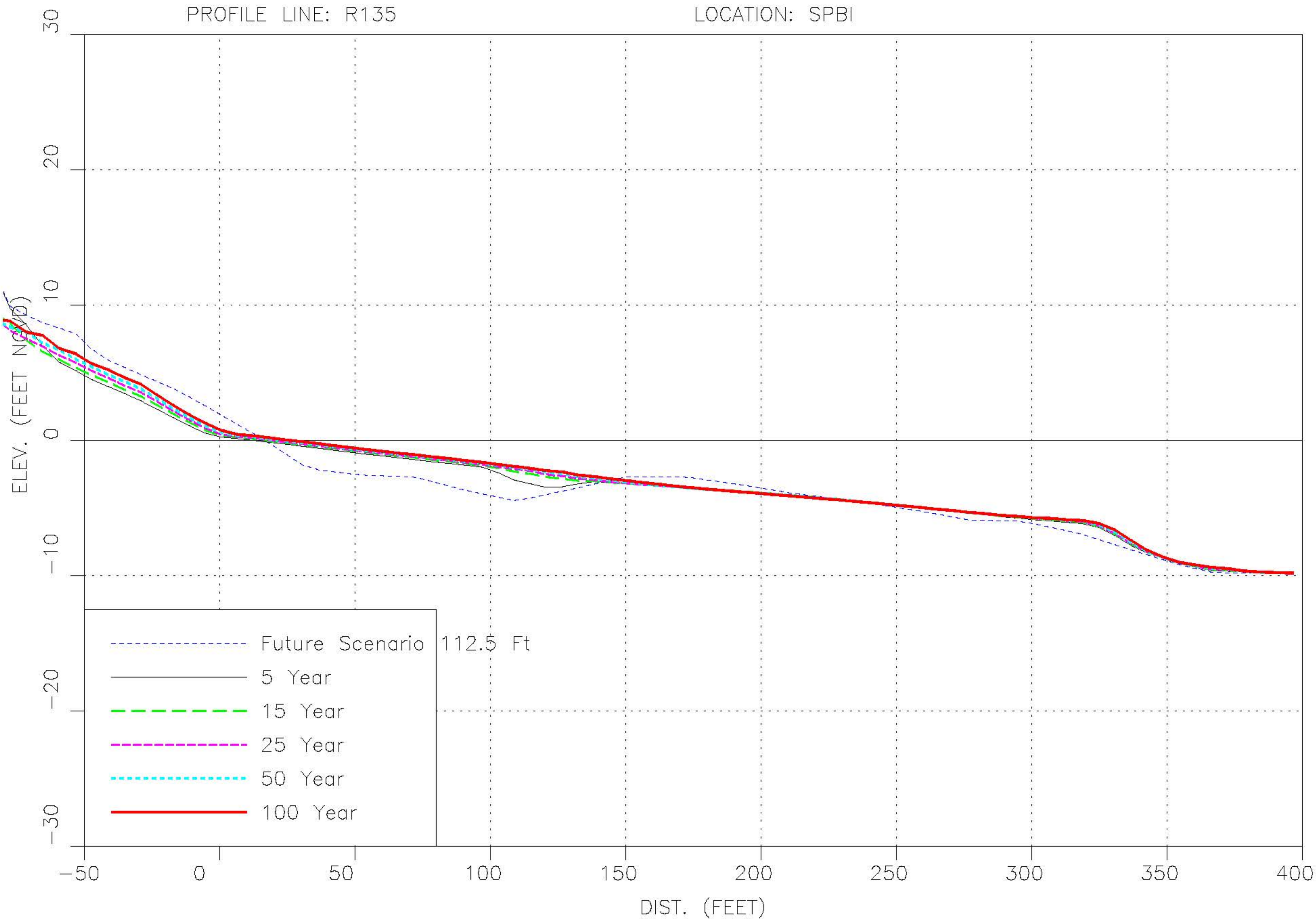


PROFILE LINE: R131
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
Future Scenario 112.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year

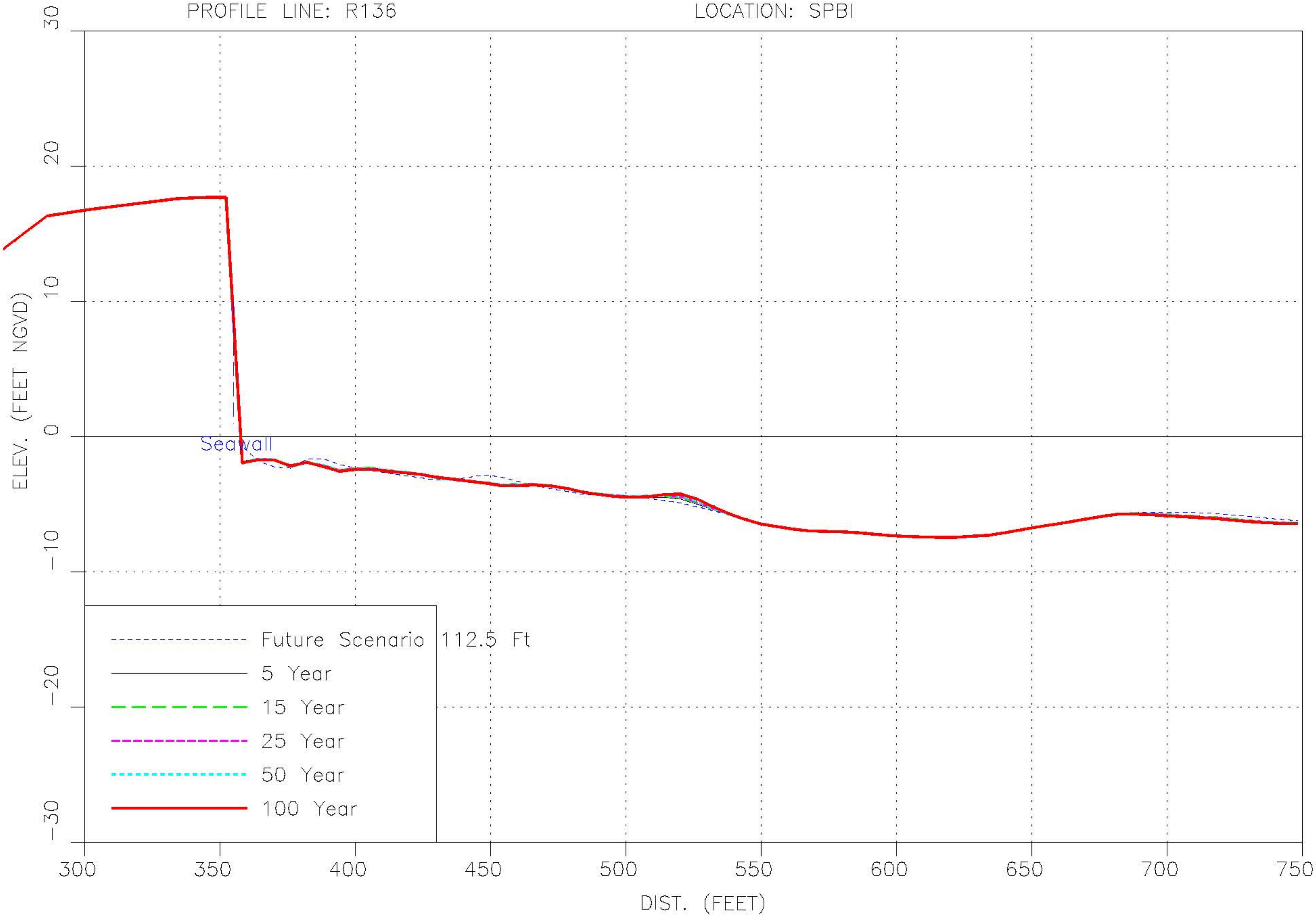

PROFILE LINE: R132
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Future Scenario 112.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400


PROFILE LINE: R133
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
−10
−20
−30
−50
0
50
100
150
200
250
300
350
400
Future Scenario 112.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year

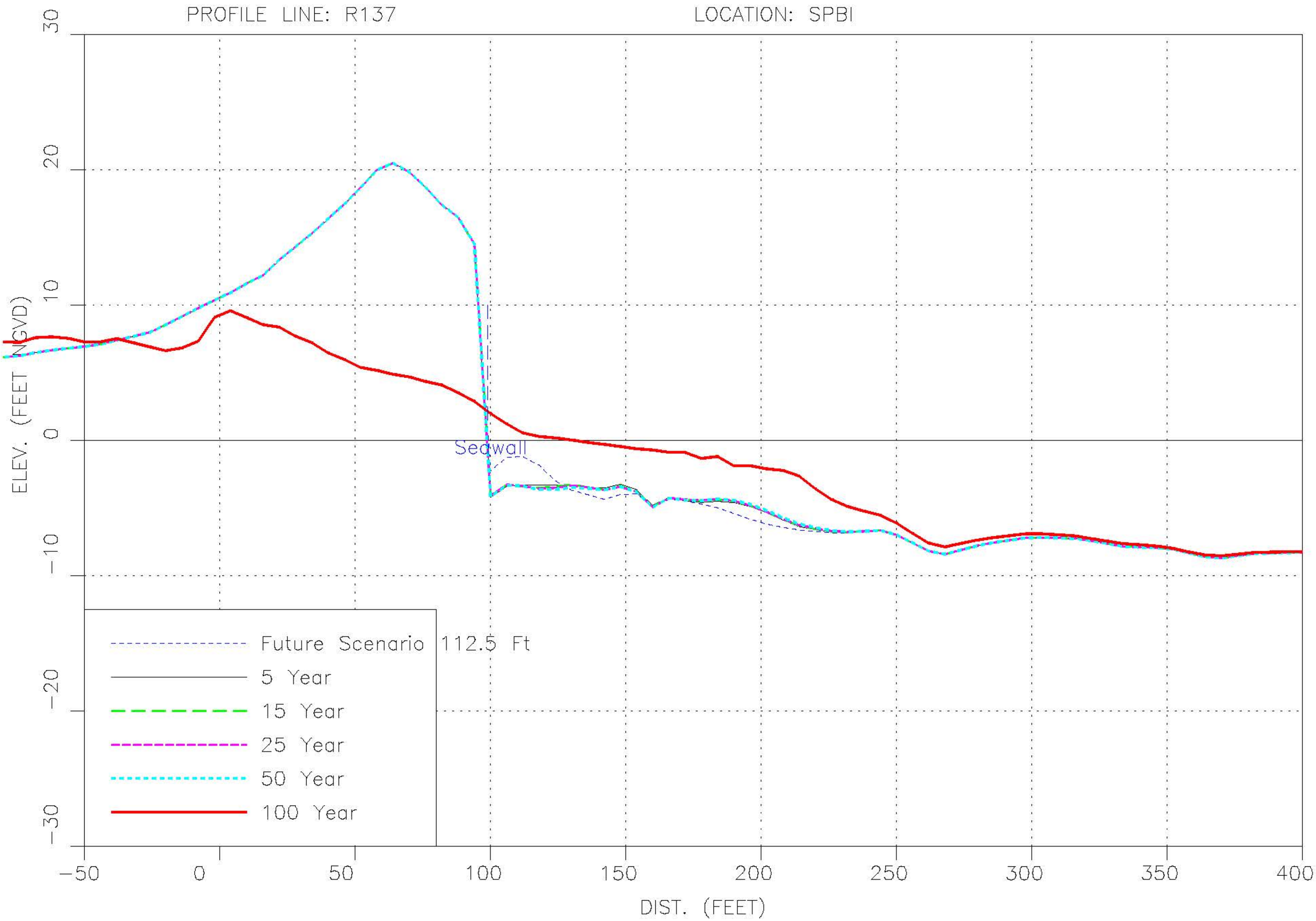

PROFILE LINE: R134
LOCATION: SPBI
ELEV. (FEET NGVD)
30
20
10
0
−10
−20
−30
Seawall
Future Scenario 112.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year
−50
0
50
100
150
200
250
300
350
400
DIST. (FEET)

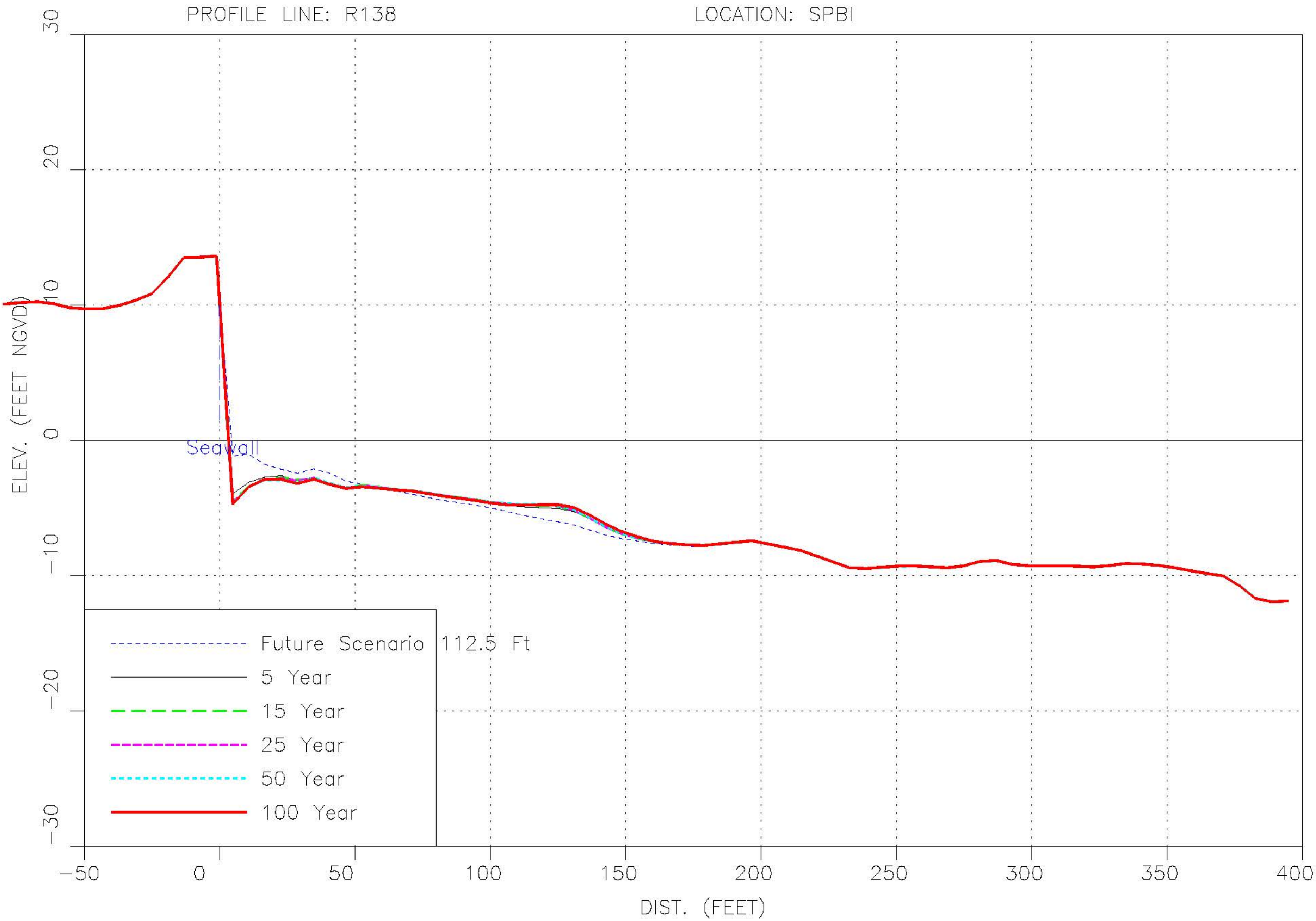


PROFILE LINE: R135
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400
Future Scenario 112.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year



PROFILE LINE: R136
LOCATION: SPBI
ELEV. (FEET NGVD)
30
20
10
0
−10
−20
−30
Seawall
Future Scenario 112.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year
300
350
400
450
500
550
600
650
700
750
DIST. (FEET)


PROFILE LINE: R137
LOCATION: SPBI
ELEV. (FEET NGVD)
DIST. (FEET)
Seawall
Future Scenario 112.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year
30
20
10
0
-10
-20
-30
-50
0
50
100
150
200
250
300
350
400



PROFILE LINE: R138
LOCATION: SPBI
30
20
10
0
−10
−20
−30
ELEV. (FEET NGVD)
Seawall
Future Scenario 112.5 Ft
5 Year
15 Year
25 Year
50 Year
100 Year
−50
0
50
100
150
200
250
300
350
400
DIST. (FEET)

APPENDIX D

LANDWARD LIMIT OF RECESSION BY RETURN PERIOD STORM BASED ON SBEACH RESULTS

Notes:

1. Coordinates are in feet based on the Florida State Plane Coordinate System, East Zone, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by theTown of Palm Beach, date flown March 30, 2012.

Legend:

- Year 5
- Year 15
- Year 25
- Year 50
- Year 100
- Monuments

EC - Existing Conditions (2011/2012 survey)
SF - Existing Conditions with Seawall Falilure
3- Alternative 3
6 - Alternative 6

N

0 75 150 Feet

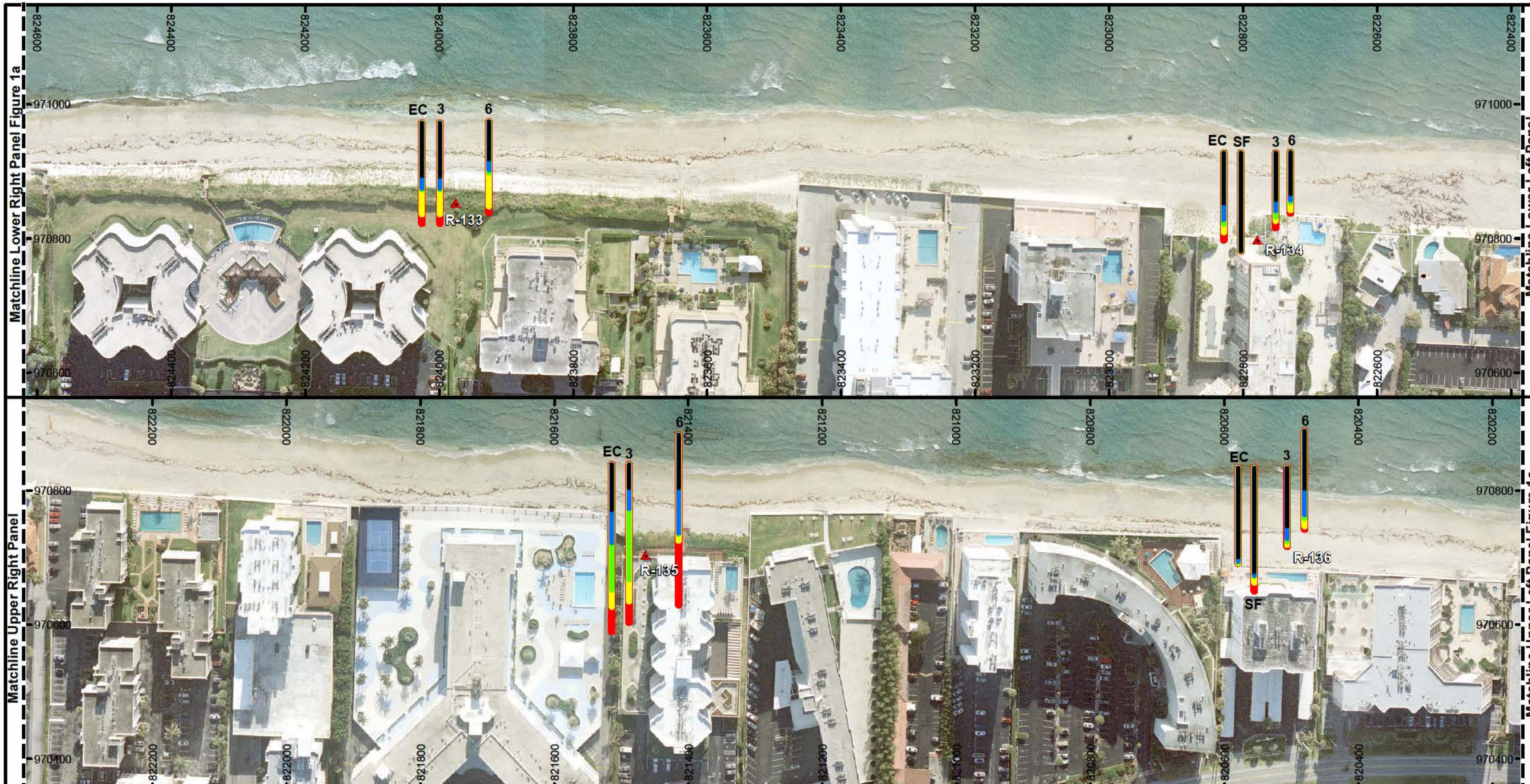
1 inch = 150 feet

TITLE: **Southern Palm Beach Island Shoreline Stabilization Project EIS Landward Limit of Recession by Return Period Storm Based on SBEACH Model Results**

COASTAL PLANNING & ENGINEERING, INC.
A CB&I COMPANY
2481 N. W. BOCA RATON BOULEVARD
BOCA RATON, FL 33431
PH. (561) 391-8102 FAX (561) 391-9116

Date: 01/22/14	By: HMV	Comm No. : 150814	**Figure No.: 1a**

G:\Enterprise\Palm_Beach\150814\Mxd\Alternatives.mxd



G:\Enterprise\Palm_Beach\150814\Mxd\Alternatives_2.mxd

Notes:

1. Coordinates are in feet based on the Florida State Plane Coordinate System, East Zone, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by theTown of Palm Beach, date flown March 30, 2012.

Legend:

- Year 5
- Year 15
- Year 25
- Year 50
- Year 100
- Monuments

EC - Existing Conditions (2011/2012 survey)
SF - Existing Conditions with Seawall Falilure
3- Alternative 3
6 - Alternative 6

N

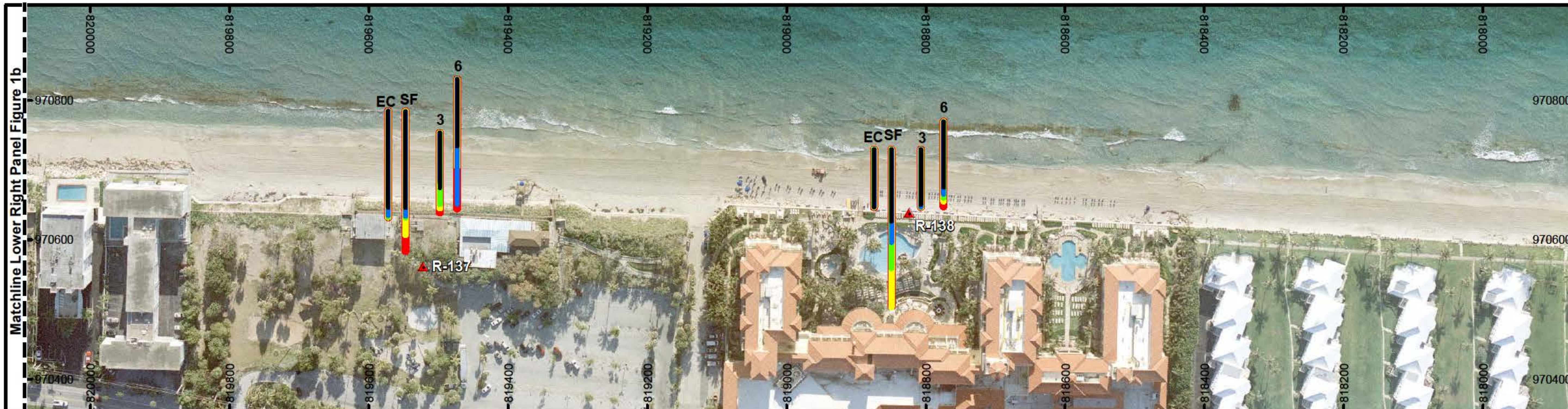
0 75 150 Feet

1 inch = 150 feet

TITLE:
Southern Palm Beach Island Shoreline Stabilization Project EIS Landward Limit of Recession by Return Period Storm Based on SBEACH Model Results

COASTAL PLANNING & ENGINEERING, INC.
A CB&I COMPANY
2481 N. W. BOCA RATON BOULEVARD
BOCA RATON, FL 33431
PH. (561) 391-8102 FAX (561) 391-9116

Date: 01/22/14	By: HMV	Comm No. : 150814	**Figure No.: 1b**



Notes:

1. Coordinates are in feet based on the Florida State Plane Coordinate System, East Zone, North American Datum of 1983 (NAD 83).
2. Aerial photography provided by theTown of Palm Beach, date flown March 30, 2012.

Legend:

- Year 5
- Year 15
- Year 25
- Year 50
- Year 100
- Monuments

EC - Existing Conditions (2011/2012 survey)
SF - Existing Conditions with Seawall Falilure
3- Alternative 3
6 - Alternative 6

N

Feet
0 75 150
1 inch = 150 feet

TITLE:

Southern Palm Beach Island
Shoreline Stabilization Project EIS
Landward Limit of Recession
by Return Period Storm
Based on SBEACH Model Results

COASTAL PLANNING & ENGINEERING, INC.
A CB&I COMPANY
2481 N. W. BOCA RATON BOULEVARD
BOCA RATON, FL 33431
PH. (561) 391-8102 FAX (561) 391-9116

Date: 01/22/14	By: HMV	Comm No. : 150814	Figure No.: 1c

G:\Enterprise\Palm_Beach\150814\Mxd\Alternatives_3.mxd