

9.2 NUMERICAL MODELING OF SHORELINE EVOLUTION

Numerical modeling was used to simulate changes in shoreline morphology resulting from the proposed beach nourishment and dune restoration at Broad Beach. Numerical models are commonly used to quantify sand movement over time to evaluate potential downcoast impacts, impacts to resources, and project benefits. The primary function of the modeling will be to predict relative alongshore sand transport rates and shoreline change after placement of beach fill at Broad Beach.

Along with findings from the Everts Coastal historic shoreline assessment studies and estimates for cross shore evolution, the shoreline evolution modeling results were used to approximate the life expectancy of the initial beach nourishment.

9.2.1 Model Selection and Description

The effectiveness of the beach restoration project was evaluated using the Generalized Model for Simulating Shoreline Change (GENESIS), a numerical model developed for the US Army Corps of Engineers (USACE) to estimate long-term trends of shoreline change for coastal engineering projects.

GENESIS underwent extensive testing and verification before public release. The model is regularly updated by the Coastal and Hydraulics Lab (CHL) of the U.S. Army Engineer Research and Development Center (ERDC) based on recent applications and scientific research. GENESIS has been successfully applied at many artificial beach nourishment projects and was recently used to analyze a large-scale coastal development project in Southern California at Bolsa Chica in Orange County. The Bolsa Chica Steering Committee (including representatives of USACE) has demonstrated that GENESIS results are suitably accurate for these analyses (M&N, 1999). The model was also used by the San Diego Association of Governments (SANDAG) for the 2001 Regional Beach Sand Project to quantify potential project impacts. Modeling results were verified by post-project monitoring as being relatively accurate in predicting trends of beach fill fate. GENESIS has been previously used to simulate shoreline changes anticipated from proposed projects in Southern California by Gravens (1990 and 1991) and M&N (1994 and 1999).

Numerical modeling of shoreline morphology is inherently imprecise because of the complexity of coastal processes. Although coastal processes are becoming increasingly better understood, no comprehensive numerical model exists that accounts for the natural processes of coupled longshore and cross-shore sediment transport. GENESIS models only longshore sediment transport and assumes that cross-shore sediment movement is mainly seasonal and averages out over the long-term. GENESIS is intended to provide a generalized long-term trend in shoreline response from a specific action or actions. The results can be relied upon for anticipating general areas of accretion or erosion at orders of magnitude over large-scales and

relative differences between proposed nourishment volumes and shapes, rather than in predicting very precise, site-specific increments of shoreline movement over very small scales. It generally indicates whether erosion, accretion, or no effect will occur from an action. The GENESIS modeling results is one of many tools used to evaluate changes in shoreline morphology as a result of the proposed beach nourishment and restoration alternatives.

9.2.2 Model Study Area

The GENESIS model domain extends from Point Dume to La Piedra State Beach within the ZLC. The limits of the GENESIS model are shown in Figure 9-7. The eastward limit of the model domain was set at Point Dume because it represents the eastern limit of the ZLC and because the shoreline orientation changes dramatically east of the Point Dume headland. All previous studies indicate a predominant sand transport direction from west to east. The westward model boundary was positioned far enough from the reach of interest (Broad and Zuma Beaches) to avoid boundary effects as the modeled shoreline adjusts to the predicted sand transport rates. The westward limit of the model was set about a mile west of Point Lechuza near La Piedra State Beach.



Figure 9-7. GENESIS Model Study Area

9.2.3 Model Configuration

9.2.3.1 Shorelines

The shorelines used for calibration and verification models were generated from the same data set gathered for the Everts Coastal studies (Table 6-2). For the purposes of calibrating a shoreline change model such as GENESIS, the aerial photographs provide the best available information in regards to historic shoreline position and are assumed to capture the general trends of shoreline change over each time period.

9.2.3.2 Sediment Grain Size

The sediment grain size for modeling existing conditions along Broad Beach was based on grain size analysis done by CFC (2011). Grain size sampling was performed at two representative sections and throughout the active beach profile between +6 ft and -30 ft relative to MSL. The typical range of median grain size varied from 0.40 mm close to shore and 0.15 mm near the depth of closure. For calibration and verification modeling a grain size of 0.25 mm was applied to represent the existing median grain size. For simulations of beach nourishment, a range of median sediment diameters were applied to evaluate the sensitivity of modeling results to grain size.

9.2.3.3 Berm Elevation & Depth of Closure

The values applied in this analysis were determined by inspection of beach profiles measured by CFC (2009) as part of this investigation and historic beach profiles available from the USACE. As discussed in Section 6.1.2, the average berm height along Broad Beach is about 12 feet above MSL and the depth of closure boundary is about 27 feet below MSL. For shoreline modeling purposes, a berm height of 12 feet and a depth of closure of 27 feet were used.

9.2.3.4 Sand Sources and Sinks

Potential sediment sources along the model study area include bluff erosion and fluvial discharges from coastal watersheds of the Santa Monica Mountains. The sediment contributions from these sources within the modeling domain include some sea-cliff erosion west of Point Lechuza and fluvial discharges from Trancas Creek and Zuma Creek. The contributions from these sources are difficult to quantify and relatively insignificant in terms of predicting generalized trends of long-term shoreline change; therefore these sources were not included in the calibration and verification model simulations.

The Point Dume Submarine Canyon is not considered a significant sediment sink. Sediment budget evidence indicates most of the material that reaches Point Dume ends up at Santa Monica and Venice beaches (Everts, 2012). Further evidence that Dume Submarine Canyon is not a significant sink for littoral sand is based on the large separation distance between the

canyon and Point Dume, the water depth at the canyon rim, the characteristics of the infill deposit in the head of the canyon, the usually smooth sediment transport surface between the canyon rim and Point Dume, and the small offset between Westward Beach and Point Dume (Everts, 2012). Since the submarine canyon has an insignificant impact on littoral sand movement, it was not included in the GENESIS shoreline model.

9.2.4 Wave Transformation

Both internal and external wave transformation methods were applied in the GENESIS modeling effort. The first GENESIS simulations used nearshore wave data previously transformed to shallow water as part of the CCSTWS (USACE, 2009 Draft). The data was available at two nearshore stations within the model domain; therefore, the internal GENESIS wave transformation model was used to transform the waves to the breaking point. One limitation of the current version of GENESIS is the inability to apply different wave characteristics along the model domain without an external wave transformation program. This limitation is problematic for the application since the hook-shaped coastline between Point Dume and Point Lechuza results in varied wave characteristics from one end of the beach to the other. Despite good quality nearshore wave data, limitations of the GENESIS internal wave transformation model resulted in predicted shoreline trends that were not consistent with actual shoreline trends.

The results were acceptable in the vicinity of the selected nearshore wave data station, but upcoast and downcoast of this location the model was unable to simulate the measured shoreline trends. The internal wave transformation model in GENESIS is most applicable to a sea bottom with straight and parallel contours for which an entire model can be represented by a single wave climate. Between Point Dume and Point Lechuza, the shoreline orientation changes by about 30 degrees, so the wave climate along the model domain needs to account for this variability to best predict shoreline response.

Since the offshore contours between Point Dume and Point Lechuza are not straight and parallel, the calculation of nearshore wave characteristics must be based on the actual bathymetry in order to accurately model shoreline changes. RCPWAVE, an external wave transformation model included in the Coastal Engineering Design & Analysis Software (CEDAS) version 4.03 software package, was used to transform offshore (deepwater) wave data to the boundary of the GENESIS shoreline morphology model grid. This model is relatively efficient for transforming waves from deep to shallow water while accounting for shoaling, refraction, and diffraction caused by the actual offshore bathymetry. RCPWAVE transformation output is provided to GENESIS at stations spaced evenly along a nearshore reference line and simulates the refracted wave angles due to the hook-shaped coastline between Point Dume and Point Lechuza. By capturing the variable wave characteristics due to the actual offshore bathymetry, the RCPWAVE external wave transformation provided the most realistic estimate of wave data for shoreline modeling purposes (see Figure 9-8).

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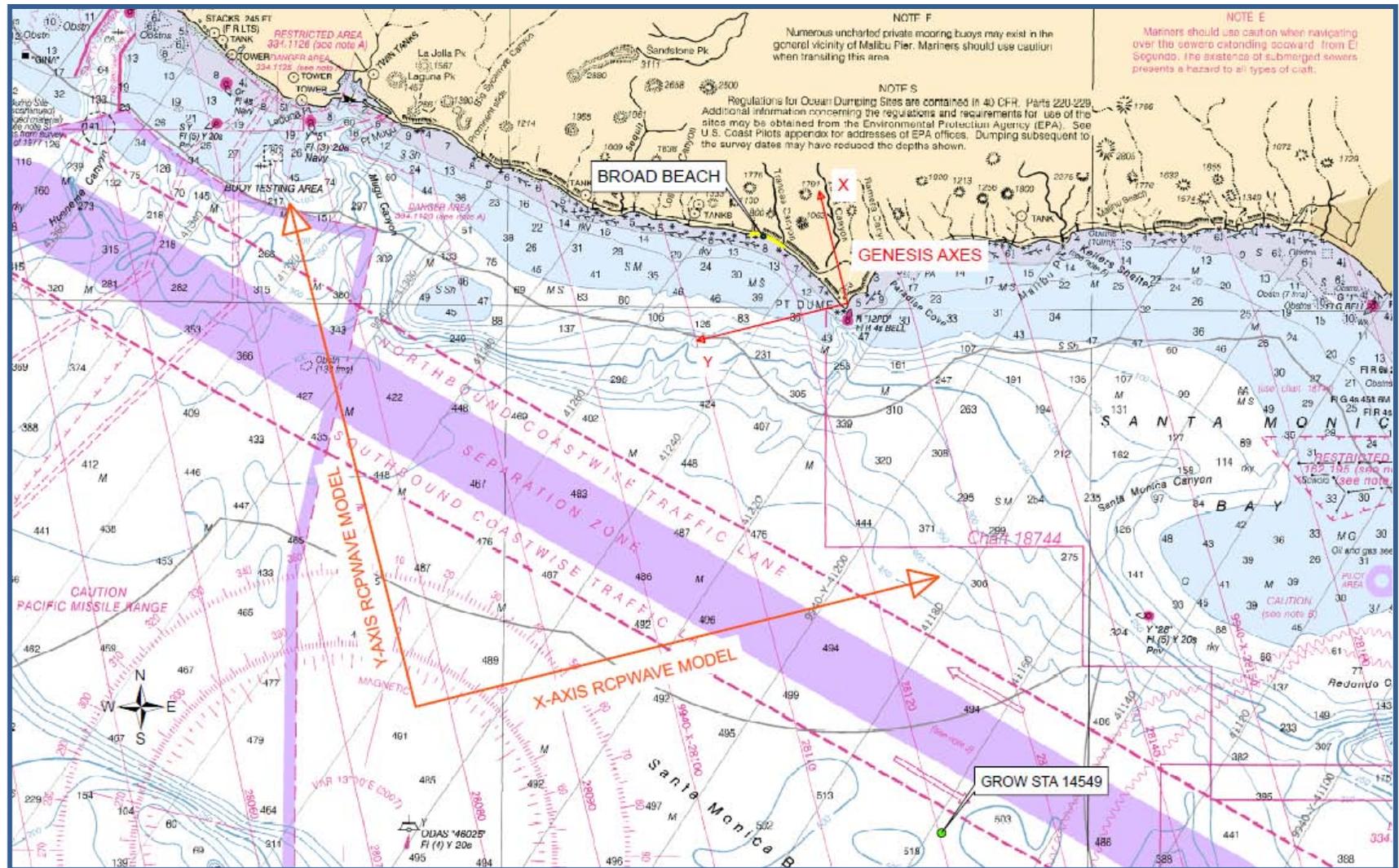


Figure 9-8. RCPWAVE Model Study Area

9.2.5 Model Calibration and Verification

Calibration is the process of adjusting the model's input variables and coefficients to reproduce known shoreline changes over a time period with known wave conditions. Verification is the application of the calibrated model to a different time period with known physical parameters to assess the reproducibility of the model. Sensitivity studies are then performed to determine the influence of various parameters on the results. The time period for calibration was from 1984 to 1990, and the period for model verification was 2003 to 2006. These periods were selected because the measured shoreline change over this period was typical of what has occurred along Broad Beach and Zuma Beach over the last several decades in that the shoreline receded along Broad Beach and advanced along portions of Zuma Beach.

9.2.5.1 Calibration

The overall objective for model calibration was to build a model that simulates long-term trends of shoreline change reasonably well. The model was calibrated to reproduce the shoreline change from 1984 – 1990.

To aid in the calibration process, the historic shoreline adjustments and net sediment transport rates of the study area have been well documented by several independent studies that more or less reach the same conclusion: the shoreline along Broad Beach has retreated at a rate of 4 to 7 ft/yr since the 1970s. Estimates for net alongshore transport rate along this part of the coast range from 20,000 to 100,000 cyy toward the east.

Previous GENESIS modeling of the ZLC was performed for the CCSTWS (USACE, 2009 Draft) to estimate sediment transport rates. The CCSTWS modeling effort was focused on predicting the direction and magnitude of alongshore sediment transport; therefore, shoreline change predicted by GENESIS was not reported. Their GENESIS simulations were simplified by assuming a straight shoreline according to a primary orientation of the subreach. Crescent shaped beaches, such as Zuma Beach, that could not be represented by a primary orientation were sub-divided and considered multiple orientations to assess a range in expected alongshore sediment transport. The Zuma Beach reach was divided into two reaches for this analysis. A western reach termed "Zuma Beach" was modeled separately from an eastern reach termed "Point Dume Beach."

The GENESIS modeling predicted an alongshore transport rate of 58,000 cyy towards the southeast for "Zuma Beach" and 133,000 cyy towards the northwest for Point Dume Beach. These results were unexpected in that predicted alongshore transport rates were opposite in direction for adjacent beaches. If these results were realized, there would be a vast accumulation of sand between Zuma Beach and Point Dume since the net transport for the adjacent beaches are directed toward one another. In reality, this accumulation of sand is non-

existent and the results help illustrate the limitations of numerically modeling shoreline change and sediment transport rates, especially on curved shorelines.

The GENESIS modeling approach for this analysis used a single model from Point Dume to west of Point Lechuza in an effort to predict shoreline change along Zuma and Point Dume Beaches as a result of nourishment at Broad Beach. The calibration results of the single model approach predicted net sediment transport in one direction along the entire beach. However, the direction and magnitude of net sediment transport was very sensitive to changes in approaching wave angles. If the model was adjusted to match to the shoreline orientation of the CCSTWS Point Dume model, the predicted net transport rates were similar in direction and magnitude to that model. If the model was adjusted to match the shoreline orientation of the CCSTWS Zuma Beach model, the predicted net transport rates were similar to that model. In other words, the single model approach was not able to resolve the limitations identified above.

These findings suggest the RCPWAVE transformation and GENESIS models may be limited in their ability to accurately predict shoreline change along this hook-shaped stretch of coast between Point Lechuza and Point Dume. For purposes of this study, the model was calibrated to produce net transport rates and shoreline change consistent with previous studies along the western portion of Zuma Beach and Broad Beach.

The calibration results are shown in Figure 9-9. The predicted net alongshore transport rate of the calibrated GENESIS model varies from 70,000 cyy to 117,000 cyy on average toward the east. This pattern results in erosion downdrift of Point Lechuza gradually trending toward accretion near Point Dume. The model predicts shoreline change reasonably well along Broad Beach but not very well at Zuma and Point Dume Beaches.

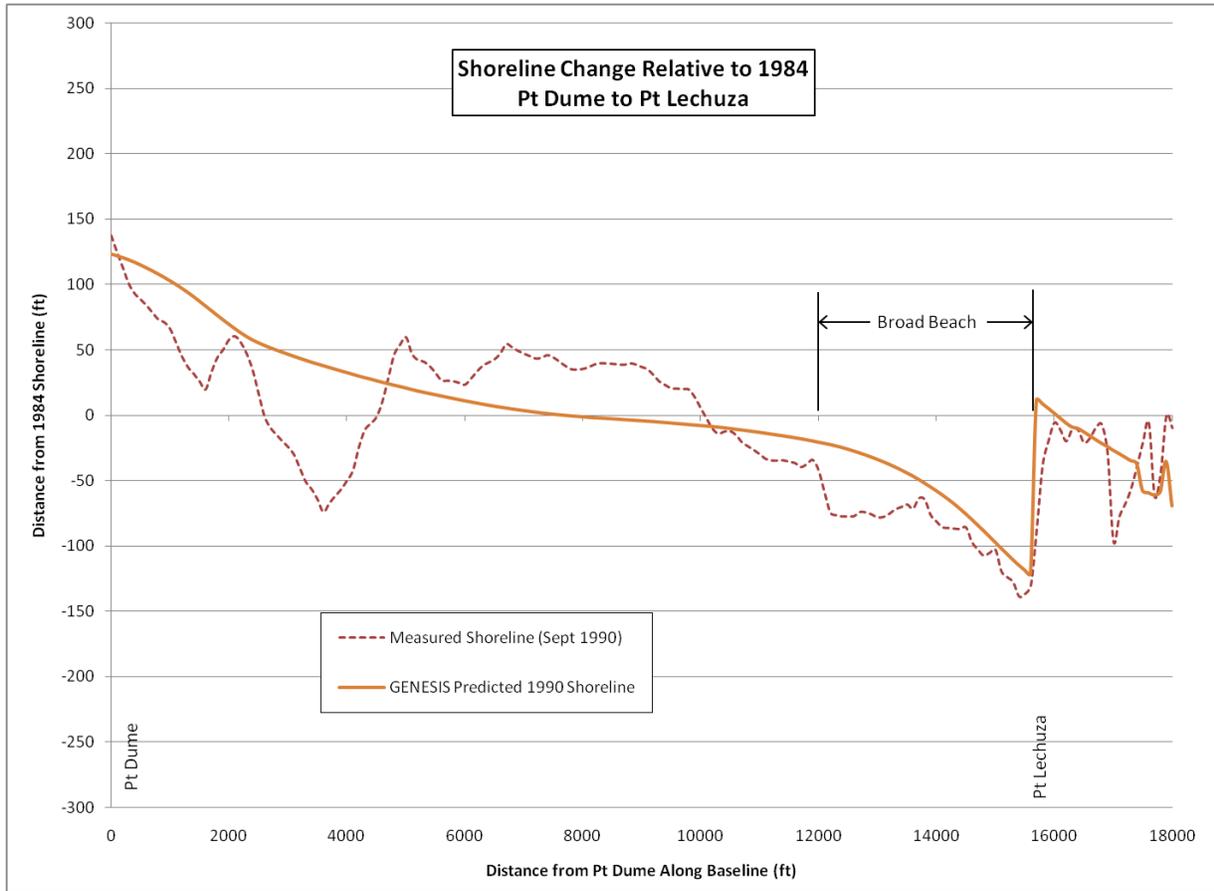


Figure 9-9. GENESIS Calibration Results

9.2.5.2 Verification and Sensitivity

The calibrated GENESIS model was run over a time period from 2003 to 2006 to assess the reproducibility of the model results. The measured shoreline change over the verification period indicates erosion along Broad Beach, little to no change along Zuma Beach, and erosion along Point Dume Beach. The GENESIS model predicted shoreline change during the verification period was not able to capture the trends of erosion measured over the verification period. As shown in Figure 9-10, the GENESIS model predicted erosion updrift and downdrift of Point Lechuza and very little change elsewhere in the model domain.

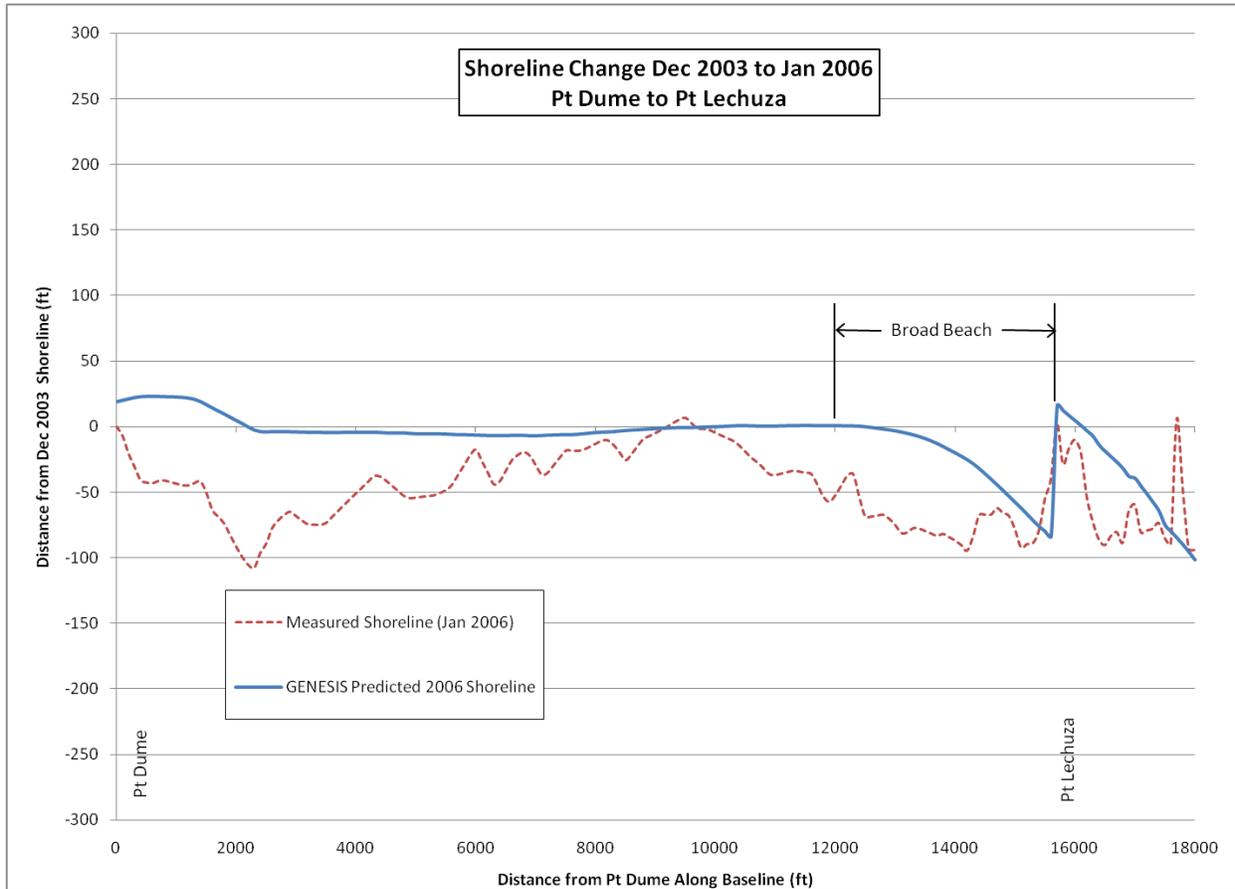


Figure 9-10. GENESIS Verification Results

Considerable effort was expended to improve the accuracy of the model over both calibration and verification periods. The following is a list of some parameters adjusted and evaluated to improve the model results:

- Wave Data Parameters:
 - Nearshore wave data (NS# 260) with internal GENESIS transformation
 - Nearshore wave data (NS# 265) with internal GENESIS transformation
 - Deep water wave data with external transformation by RCPWAVE model
 - RCPWAVE grid resolution: 200 to 500 feet grid size
 - RCPWAVE output locations: 100 to 1000 feet spacing along the GENESIS domain
 - Wave angle offsets: 0 to 33 degrees north of shore normal
 - Wave angle factors: 0.2 to -0.3
- GENESIS Model Parameters:
 - Shoreline Orientation: 115° to 165° measured clockwise from north
 - Longshore sand transport coefficient, K1: 0.2 to 1.0
 - Longshore sand transport coefficient, K2: 0.1 to 1.5

- Groin structure length & permeability (Point Dume, Point Lechuza)
- Median sand diameter: $d_{50} = 0.2$ to 0.9 mm

The objective of the sensitivity analysis was to match the general trends of shoreline change measured over each time period. The measured change over the calibration period was a trend of erosion along Broad Beach and accretion near Point Dume, which was captured reasonably well by the GENESIS model. The measured change over the verification period was an overall trend of erosion except for Zuma Beach, which showed no significant change. Despite numerous model iterations, the results did not accurately capture the measured trends over the verification period; however, it did provide additional understanding about the relative sensitivity of the nourishment performance to physical variables.

Two possible explanations for the lack of correlation with measured shoreline change are: 1) cross-shore influence on the measured shorelines; and 2) periodic reversals in LST direction are not captured by GENESIS. Most likely, both of these contribute to the inaccuracy of the GENESIS model. The model is incapable of predicting shoreline change due to cross-shore movement of sand, which can influence shoreline positions by 30 to 70 feet. The initial and final shorelines were measured from the same season in an effort to minimize the error due to cross-shore sand transport. However, it is entirely possible cross-shore processes contribute to the differences between measured and predicted shoreline positions.

Periodic reversals in LST direction are known to occur along this coastline during summer months in which the dominant wave energy arrives from a southerly direction. A reversal in LST direction would help explain the measured trend of erosion near Point Dume during the verification period. If the LST direction is from east to west, the Point Dume headland would function as a groin and limit the transport of sand to downdrift beaches, resulting in a trend of erosion along Point Dume and Zuma Beaches. As discussed in the previous section, the GENESIS model did not adequately capture the variation in wave angle along the hook-shaped beach between Point Dume and Point Lechuza. The result was a model that predicted LST in one direction dependent upon the defined shoreline orientation and approaching wave direction. Unfortunately, these parameters are defined once for the entire model and cannot vary along the model domain. This limits the ability to predict reversals in LST that may occur within the model domain, and most likely contributes to the error between measured and predicted shoreline change.

The calibration and verification process identified the inherent difficulty in predicting shoreline morphology using a numerical model. Sensitivity analyses suggest that small variations to shoreline orientation cause large changes in the magnitude and direction of predicted LST. Since the shoreline orientation changes by 30 degrees between Point Lechuza and Point Dume, variations in LST within the model domain were expected. Instead, the model predicts a largely uniform LST rate and direction throughout the model. If the wave approach angle is adjusted slightly south of shore normal, the net LST direction is to the west. If the wave approach angle is

adjusted slightly north of shore normal, the net LST direction is to the east. The model may be demonstrating why the shoreline demonstrates such instability at Broad Beach – very small changes in wave angle make large differences in nourishment performance predictions.

To overcome these limitations, the model was calibrated to best predict measured shoreline position and net LST rates in the vicinity of Broad Beach. The result is a model that produces somewhat reliable predictions for Broad Beach but less reliable predictions for the remainder of the model domain. The most recent estimate for net LST along Broad Beach, prepared by Everts Coastal as part of their historic shoreline assessment, ranges from 20,000 to 40,000 cyy toward the east. The calibrated GENESIS model predicts LST rates of 50,000 to 100,000 cyy toward the east along Broad Beach. The model-predicted LST is higher than the estimated historic LST, but is considered appropriate and conservative for modeling the effects of beach nourishment.

9.2.6 GENESIS Beach Nourishment Modeling

The calibrated GENESIS model was used to simulate shoreline morphology after proposed beach nourishment at Broad Beach. The model limitations discussed previously must be kept in mind when evaluating shoreline change predictions resulting from the proposed project. An even more fundamental complication occurs when taking historical wave climate parameters and projecting them in the future. The order and frequency of large storms, changes in large-scale oceanic conditions (PDO, MEI, SOI), and potential changes in “storminess” due to global warming are all unknown.

Thus, the model results should not be interpreted to define specific shoreline position at a specific date. The purpose of the model is to predict general long-term trends in shoreline change. Short-term changes in shoreline positions may vary from these results due to the unpredictable and complicated coastal processes which influence Broad Beach and neighboring beaches. Since the model was calibrated to match estimated historic LST rates and shoreline change along Broad Beach, the results are most reliable near this location and less reliable as they approach the model boundaries.

The beach nourishment is modeled in GENESIS by specifying an added beach width. For a beach nourishment of 600,000 cy, the beach width will be increased by over 200 feet from the October 2009 MHTL immediately following construction. The constructed beach slope will be steeper than the natural beach slope and, therefore, the as-built profile will undergo equilibration in which material is naturally re-distributed throughout the active profile resulting in a narrower dry beach width. The equilibrium dry beach width was added to the shoreline position of the GENESIS model to simulate the effects of a beach fill. The equilibrium dry beach width is a function of the grain size characteristics of the sand source material relative to the native Broad Beach material. Using the Dean (1991) equation for an intersecting beach profile and a nourishment volume of 600,000 cy, the estimated dry beach width after equilibration was performed for median grain sizes (D_{50}) ranging from 0.25mm to 0.85 mm, representing the

potential sand sources. The beach width added ranges from about 110 feet for a D_{50} of 0.25mm up to 152 feet for a D_{50} of 0.85 mm.

The primary means for accounting for beach nourishment grain size in the GENESIS model is by assigning the appropriate equilibrium beach width added. Median grain size is also an input parameter to the GENESIS model, but a grain size sensitivity analysis of the calibrated model resulted in very little change in the rate of sand loss during the simulation.

Figure 9-11 and Figure 9-12 illustrate the GENESIS predicted shoreline changes after beach nourishment for a period of 10 years. Wave data from 1999-2009 were used for beach nourishment modeling since it represents the most recent data and trends. The results are presented in terms of beach width change relative to the pre-project shoreline on the y-axis. The x-axis indicates the location along the model domain following the GENESIS model orientation. Point Dume is located at the origin and Point Lechuza at model station 15,800. Broad Beach is located between 12,000 and 15,800 feet from Point Dume.

The GENESIS model predictions for a 600,000 cy beach nourishment assume the existing revetment is maintained in its current location. The existing revetment is located just landward of the current mean high tide line and limits the landward retreat of the shoreline along Broad Beach. The predicted trend of shoreline change post-nourishment is a loss of material downdrift to Zuma and Point Dume beaches causing a steady retreat of the shoreline along Broad Beach. The rate of beach loss is greatest at the west end of Broad Beach and indicates the nourished beach may last only 3 to 5 years near Point Lechuza. In contrast, the model results suggest beach nourishment may last up to 7 or 8 years at the east end of Broad Beach. The median grain size of the selected sand source will influence the post beach fill equilibrium beach width as well as the duration of dry beach width along Broad Beach. This subject is discussed further in Section 9.3

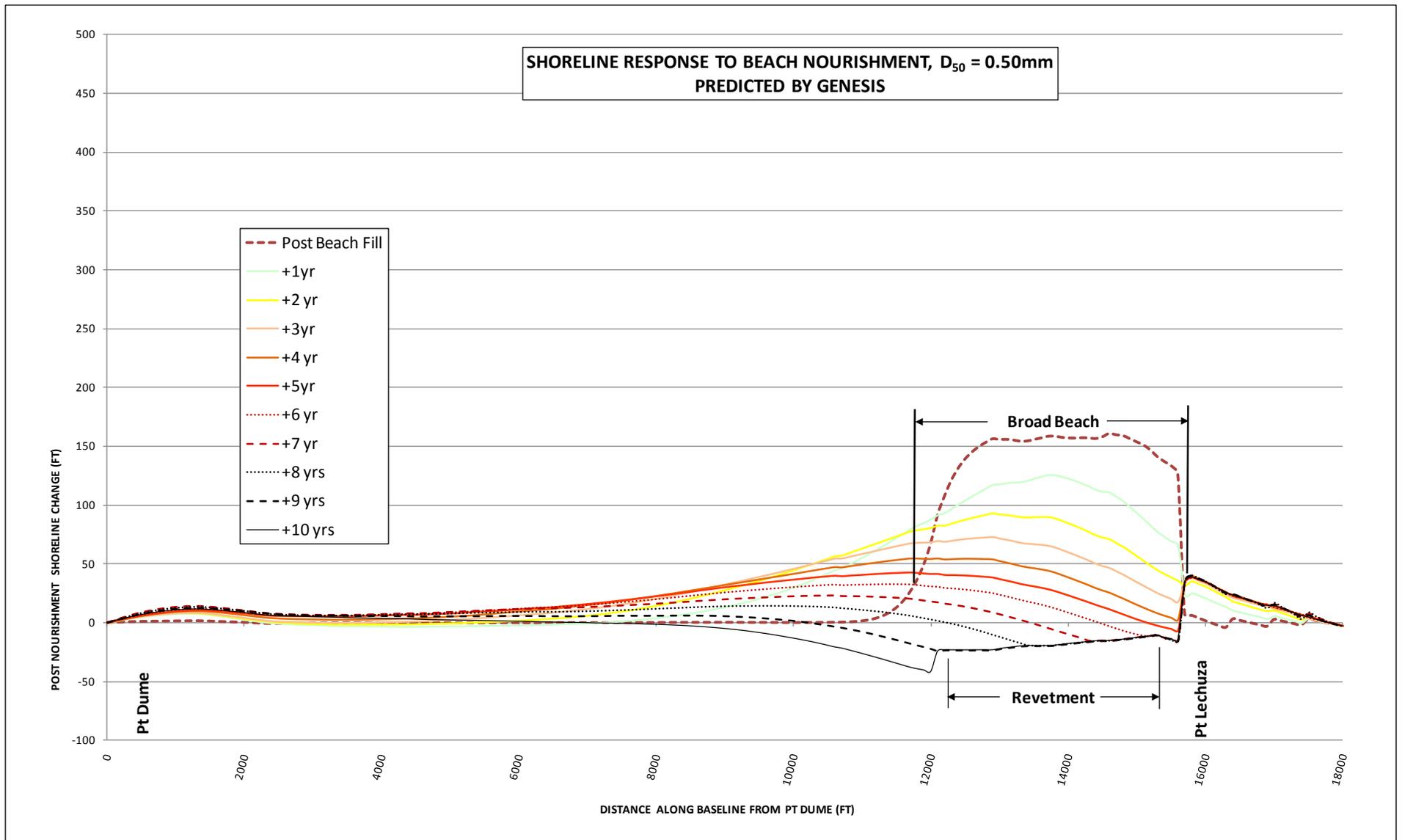


Figure 9-11. GENESIS Results – Proposed Project with 150 ft Equilibrium Beach Width, $D_{50} = 0.50\text{ mm}$

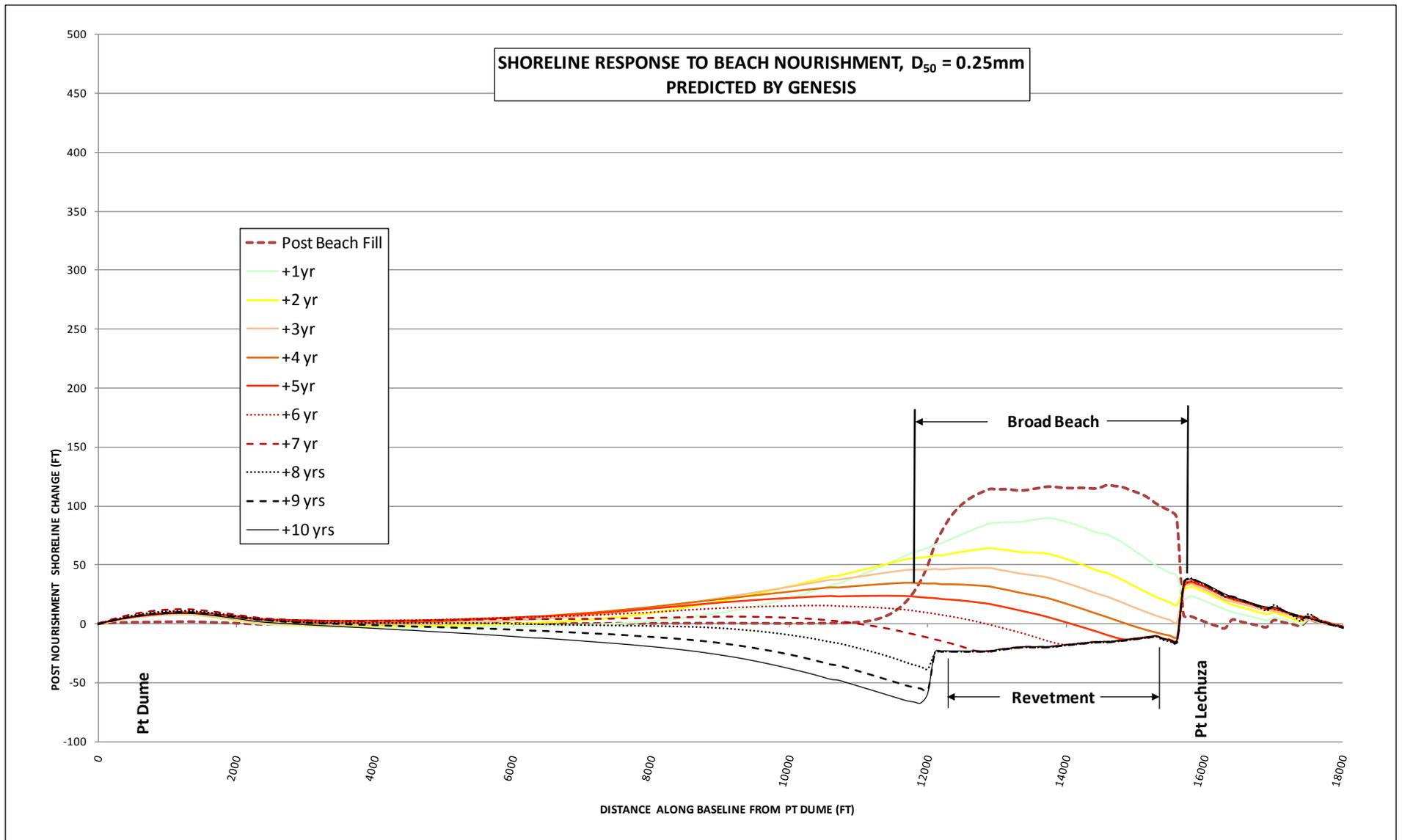


Figure 9-12. GENESIS Results – Proposed Project with 110 ft Equilibrium Beach Width, $D_{50} = 0.25 \text{ mm}$

9.2.7 GENESIS Backpass Modeling

Backpassing is proposed to lengthen the life expectancy of the initial and subsequent beach nourishments. Following guidelines outlined in Section 8.4.4, a GENESIS simulation was run to model the effects of backpassing. In actuality, backpassing may occur from east to west, or vice versa, depending upon the effect wave climate and LST patterns have on the nourished beach. Since modeling results predict LST in one direction (west to east), and the Point Lechuza functions as a natural groin, the western end of Broad Beach is predicted to narrow quicker than the eastern end. Therefore, the GENESIS simulations assume material from east Broad Beach is “backpassed” to nourish west Broad Beach. If the historic LST patterns continue, this will be the most common backpassing scenario for Broad Beach.

Based on modeling results illustrated in Figure 9-11, the beach width at the west end of Broad Beach is significantly less than the average width along east Broad Beach soon after the initial nourishment. If the shoreline adjusts as predicted, the first backpassing event would involve moving sand from east to west to prolong the benefits of shore protection, recreation, and public access at the west end of Broad Beach. Figure 9-13 illustrates the shoreline changes along Broad Beach as a result of the initial backpass event occurring 2 years after the initial beach nourishment. The model results suggest the added beach width will be somewhat short-lived at the west end but increases the average beach width along the length of Broad Beach and prolongs the life of the beach nourishment.

A similar backpassing event was simulated 3 and 4 years after the initial nourishment. Figure 9-14 shows the predicted shoreline positions along Broad Beach after the third backpassing event at year 4. The model results illustrate the benefits of backpassing not only increase the beach width at the west end but preserve the beach width along all of Broad Beach and reduce loss of material to downcoast beaches. A comparison of the year 5 shoreline positions with and without backpassing in Figure 9-14 illustrates the potential benefits to project longevity due to the regular backpassing.

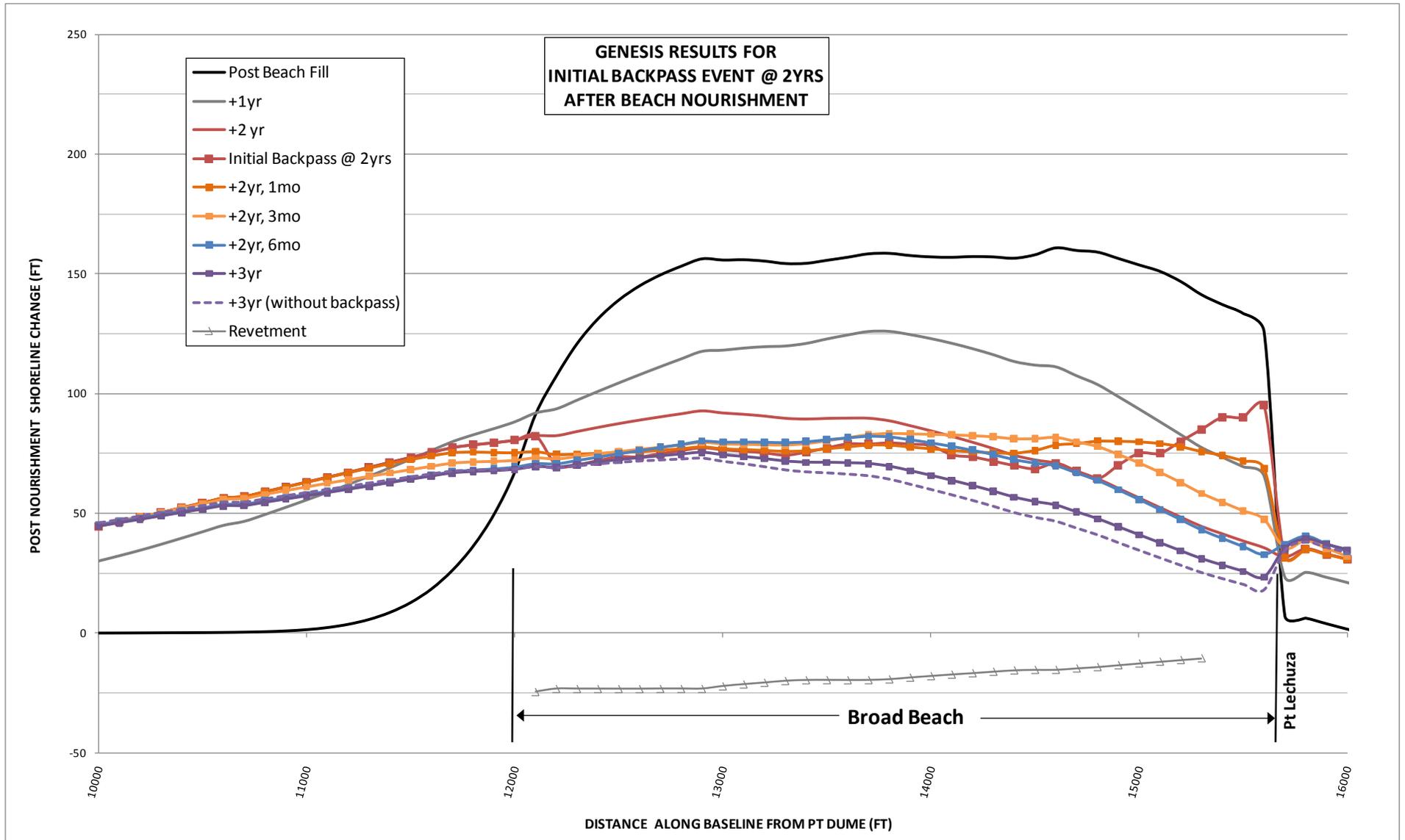


Figure 9-13. GENESIS Results - Initial Backpass at Year 2

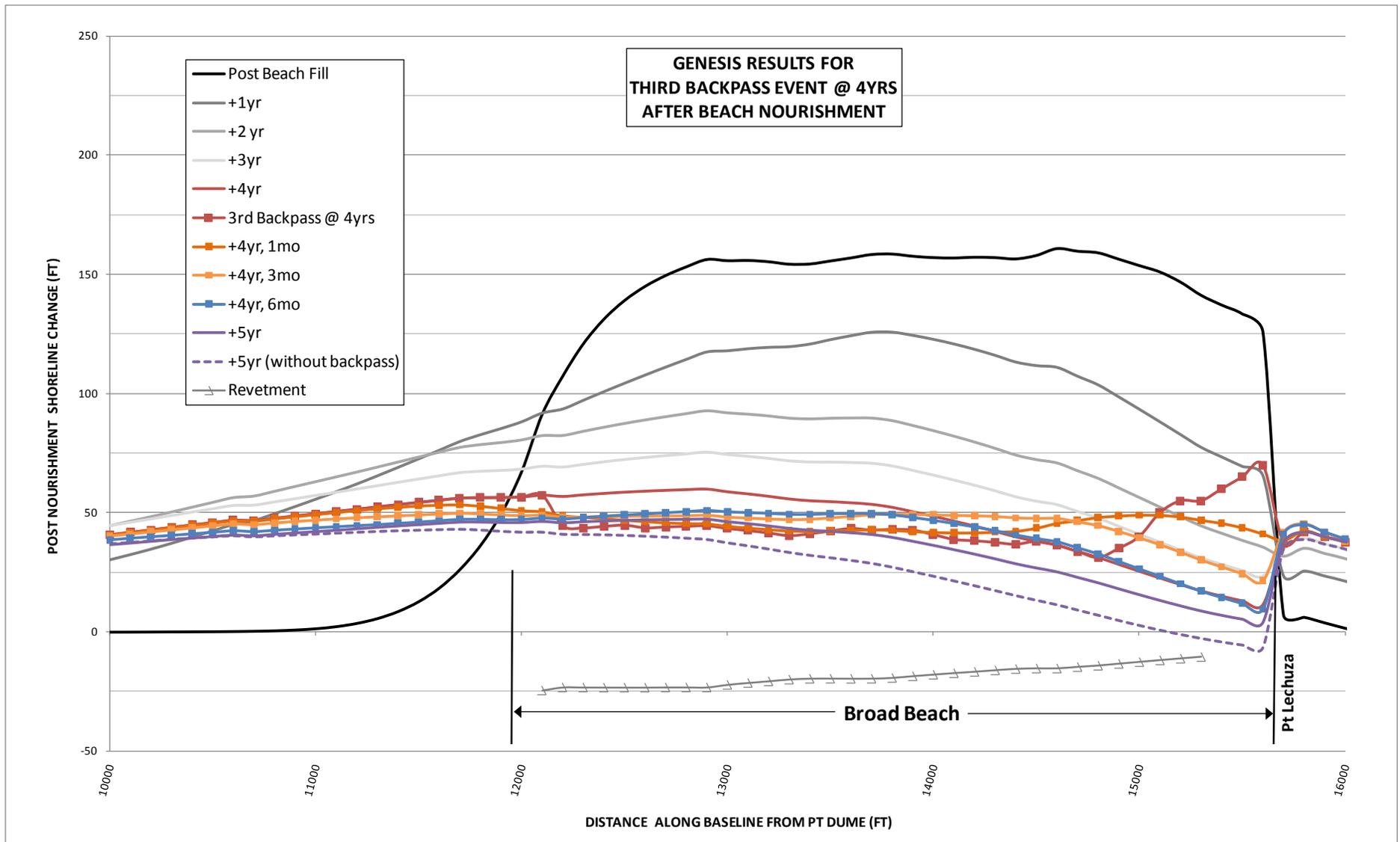


Figure 9-14. GENESIS Results – Third Backpass at Year 4

9.2.8 GENESIS Results Discussion

The GENESIS model was used to predict general trends in shoreline change as a result of the proposed project. The predicted shoreline trends illustrate one of a range of possible outcomes. The accuracy of the results are certainly limited by: 1) the simplification of coastal processes inherent in the model; 2) the difficulty in modeling variations in wave angle and LST along the hook-shaped beaches of the ZLC; and 3) the uncertainty of projecting wave climate parameters into the future. Although it's not possible to remove the uncertainty associated with projecting future wave conditions, an understanding of the GENESIS model assumptions and limitations, and the historical trends in shoreline morphology help to gauge the validity of the results. In terms of project longevity and the fate of the beach nourishment material, the GENESIS results are likely on the conservative side of the spectrum of possible outcomes due to the following reasons:

- As emphasized in the CCSTWS, the GENESIS model computes littoral transport potential only and the actual sediment transport rates for sand limited beaches of the ZLC are generally considerably less than those estimated. For example, the LST rate predicted by the GENESIS model was 50,000 to 100,000 cyy toward the east compared to a measured LST rate of about 20,000 cyy between 1974 and 2007.
- The model does not capture seasonal reverses in LST, which are known to occur along Broad Beach. This is evidenced by the current beach condition in which a significant amount of sand has accumulated near Point Lechuza at the west end of Broad Beach.
- The elevated berm proposed for the west end of Broad Beach is not accounted for in the GENESIS model. A berm elevation of +12 MLLW was defined for the entire model domain, whereas the proposed nourishment plan will construct a berm at +14 to +17 MLLW at the west end of Broad Beach. If this material were accounted for in the model, the rate of erosion at the west end of Broad beach would be reduced.
- The presence of bedrock and reef at the west end of Broad Beach is also not accounted for in the GENESIS results. The GENESIS model assumes a sandy beach downcoast of a groin as opposed to a hard bottom that will resist erosion and help retain sand.
- The GENESIS model does not account for the coarse grain size of beach fill material in calculation of the LST rates. Coarse grained sand provides added resistance against erosion and typically remains on the upper portion of the beach profile for longer time periods.

9.3 INFLUENCE OF SAND SOURCE GRAIN SIZE ON PROJECT LONGEVITY

The project proposes the use of coarser-than-native sand for beach nourishment. Implications on project performance, as well as potential impacts on receiving and downdrift beaches, are addressed in detail in the attached technical report (Exhibit G), *Upland Sand Source – Coarser-Than-Native Grain Size Impact Analysis* (M&N, 2013). Key elements of that analysis relevant to the coastal processes implications related to the project are summarized in this section.

The median grain size of the beach nourishment material will have a direct impact on the dry beach width generated for the project. Figure 9-15 is an example from the CEM (USACE, 2003) of how the grain size compatibility between the sand source and receiver beach will influence the nourished beach profile. A sand source that is coarser than the native material will form an intersecting profile and remain on the upper portion of the beach profile for a longer period of time (Figure 9-15a). The beach nourishment material from local inland sources exhibits median grain sizes ranging from 0.6 mm (Grimes) to 0.95 mm (CEMEX) to 1.0 mm (Gillibrand). For purposes of this analysis, an average median grain size of 0.85 mm was assumed, which is coarser than the native beach material which is about 0.25 mm. A sand source with material equal to the native beach sand will form a non-intersecting profile and distribute sand evenly throughout the profile out to the depth of closure (Figure 9-15b). A sand source with material that is finer than the native sand will form a non-intersecting profile with little or no dry beach width added and most material distributed further offshore and lower on the profile (Figure 9-15c, d).

The equilibrium beach nourishment profiles for a range of sand source grain sizes are shown in Figure 9-16 assuming a 600,000 cy initial nourishment. If a fine grained sand source was used for the beach nourishment, the equilibrium profile would be mostly submerged, resulting in little or no dry beach added. Based on this calculation, the use of fine sand for beach nourishment would not meet the project objectives and is not recommended. Sand sources with coarser material would produce an intersecting beach profile with a dry beach width ranging from 60 to 150 feet depending on the median grain size. The Dean (1991) equation was used to develop a relationship between median grain size and dry beach width added after equilibration. The results are shown in Figure 9-17 and indicate the amount of dry beach width levels off for sand sources with material coarser than about 0.5 mm. In other words, the theoretical post-nourishment beach width for a sand source with a $D_{50} = 0.5$ mm median grain size will be very similar to the post-nourishment beach width for a sand source with $D_{50} = 0.85$ mm.

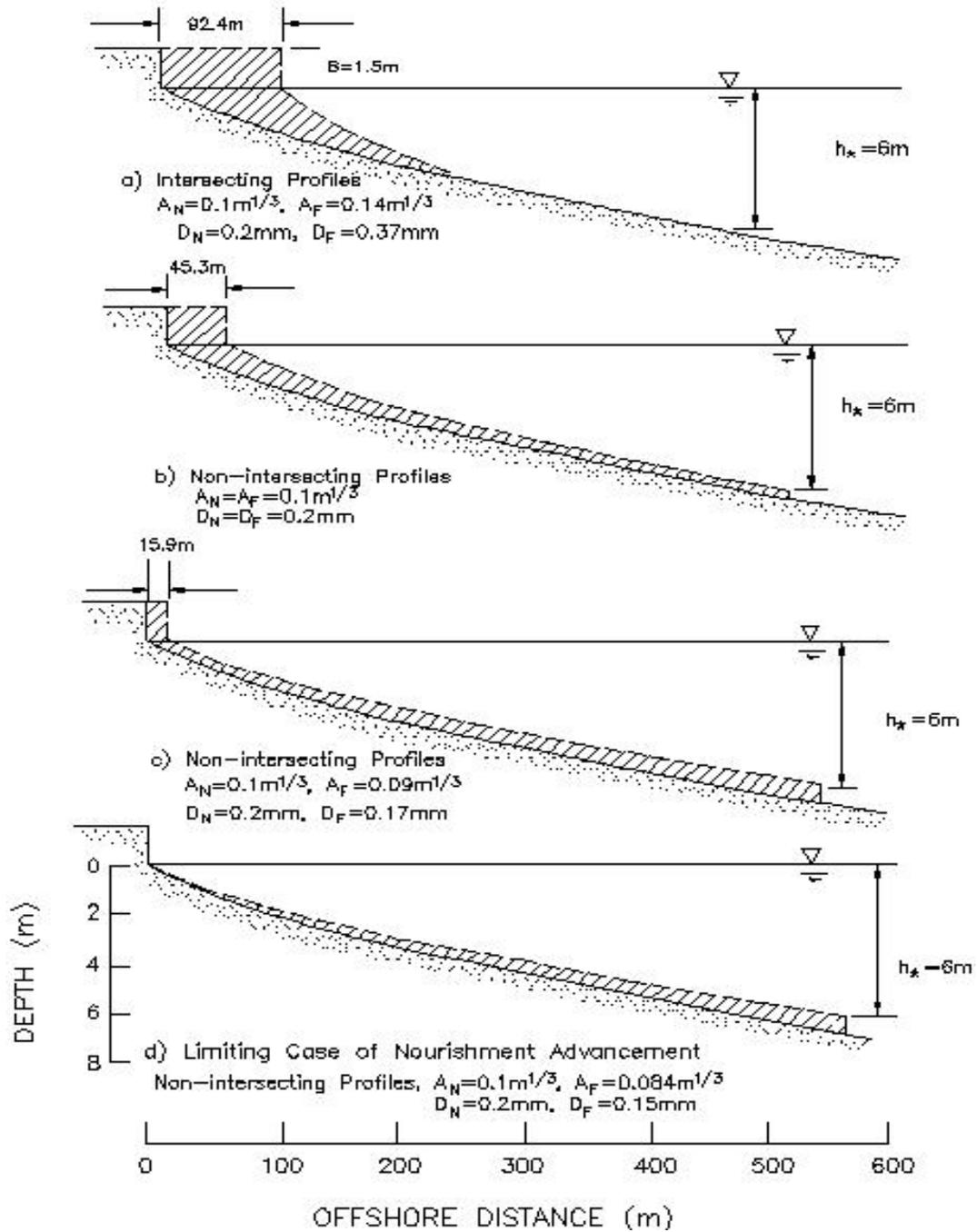


Figure 9-15. Influence of Grain Size on Beach Nourishment Profile (CEM, Figure III-3-21)

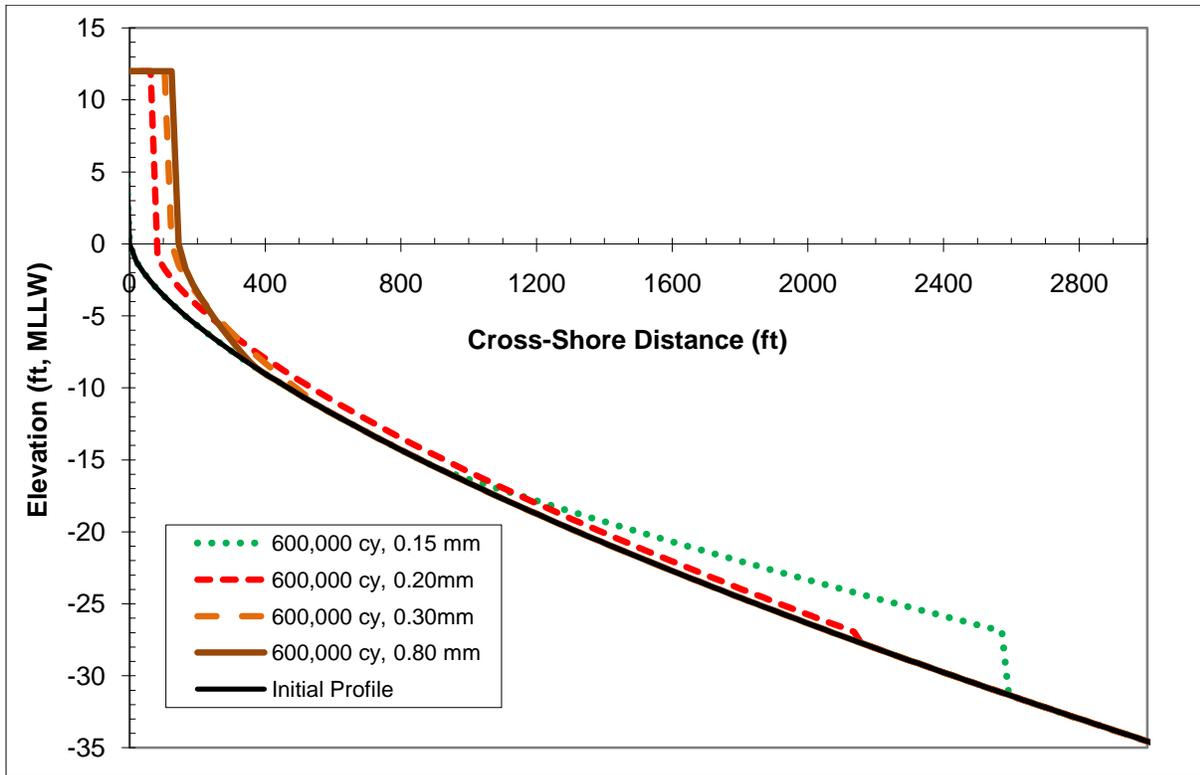


Figure 9-16. Equilibrium Beach Nourishment Profiles

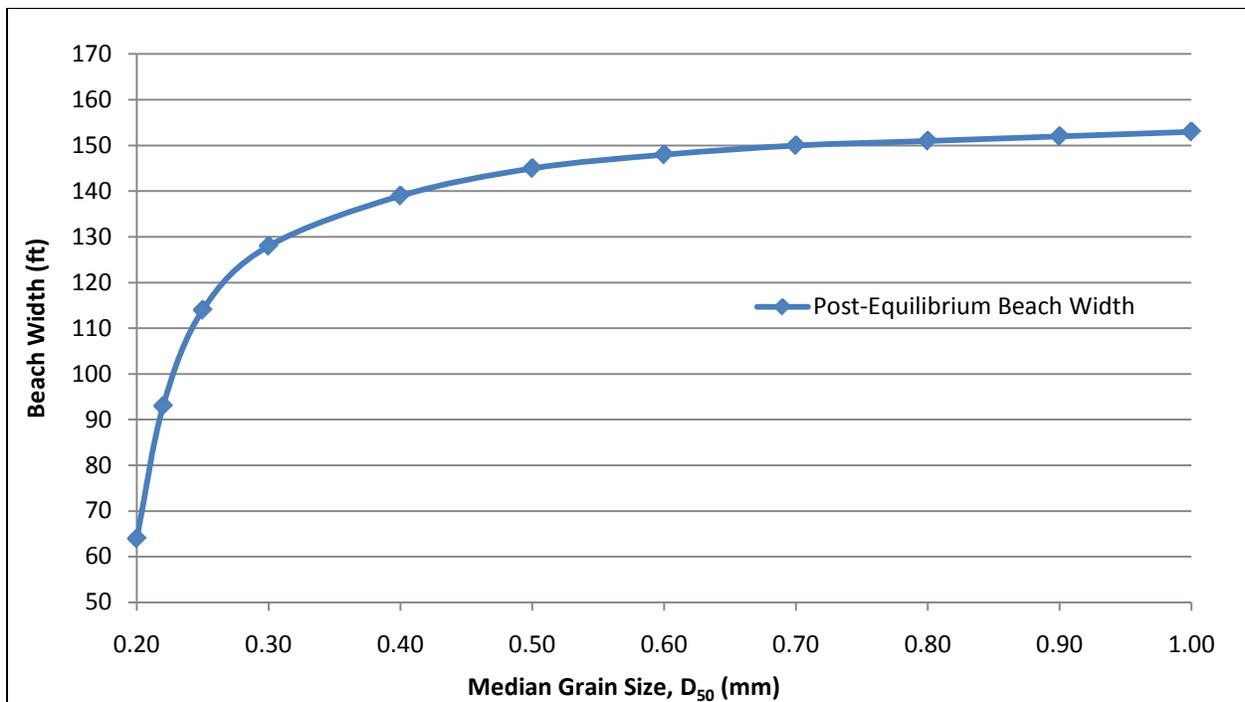


Figure 9-17. Beach Width Added Versus Median Grain Size

9.3.1 Diffusion Method to Estimate Project Longevity

The grain size of beach nourishment material will have a direct effect on the performance and longevity of the proposed project. The grain size characteristics will not only influence the equilibrium beach profile and dry beach width added, but also the rate of sand loss from the project area due to dispersion.

The analytical method referred to as the diffusion method was used to analyze the longevity of the proposed beach nourishment for different grain size characteristics associated with the potential sand sources. Diffusion is a first-order approximation for predicting the lateral spreading of the nourished beach. The method is useful for analysis under simplified conditions as it assumes an idealized straight initial shoreline, a specified beach fill length, a particular sand grain size, and specified values for breaking wave height. It is less suitable for complex coastal sites, and it only serves as a preliminary assessment in those situations. The diffusion method can simulate two-way dispersion on an un-obstructed coastline or one-way dispersion if a littoral barrier is present. In the case of Broad Beach, assuming one-way lateral dispersion would simulate the effects of Point Lechuza on lateral dispersion, although it's not a complete littoral barrier. A true representation of Broad Beach would include a partial littoral barrier, which is beyond the limits of this analytical method. Both one-way and two-way assumptions were considered to evaluate the influence of this assumption on project longevity.

The diffusion method was developed by Pelnard-Considère (1956) who combined the linearized equation of sediment transport with the continuity equation, which assumes a displaced profile, to yield:

$$\frac{\partial y}{\partial t} = G \frac{\partial^2 y}{\partial x^2} \quad (9-1)$$

where:

y = shoreline displacement

x = longshore coordinate

t = time

The longshore diffusivity, G , depends primarily on the breaking wave height as expressed as:

$$G = \frac{KH_b^{2.5} \sqrt{g/k}}{8(s-1)(1-p)(h_* + B)} \quad (9-2)$$

where:

K = sediment transport factor (0.77)

H_b = breaking wave height

g = acceleration of gravity

k = ratio of breaking wave height to water depth
 s = sediment specific gravity (≈ 2.65)
 p = sediment porosity (≈ 0.35)
 h_* = depth of closure
 B = berm height

Breaking wave heights for the analysis were determined using nearshore wave data previously transformed to shallow water as part of the CCSTWS (USACE, 2009 Draft) and covering a period from 1970 to 2005. Based on this data record, a representative breaking wave height of 5 feet was applied for Broad Beach.

Each beach fill was approximated as a rectangular planform. The solution is:

$$y(x,t) = \frac{Y}{2} \left\{ \operatorname{erf} \left[\frac{\ell}{4\sqrt{Gt}} \left(\frac{2x}{\ell} + 1 \right) \right] - \operatorname{erf} \left[\frac{\ell}{4\sqrt{Gt}} \left(\frac{2x}{\ell} - 1 \right) \right] \right\} \quad (9-3)$$

where:

Y = initial beach width (feet)
 x = longshore coordinate (feet)
 ℓ = length of the beach fill
 erf is the error function

The above equation can be integrated, considering the absence of background erosion, to determine the fraction of material M that remains in the fill area. M depends solely on the parameter Gt/ℓ , where ℓ is the length of the initially rectangular project and t is the time as in equation 9-4:

$$M = 1 - \frac{2}{\sqrt{\pi}} \frac{\sqrt{Gt}}{\ell} \quad (9-4)$$

The analytical solution estimates the longevity and spread of the beach nourishment planform, and does not consider cross-shore transport or the effects of storm-related erosion. The analytical method makes the simplifying assumption that the net LST rate is zero. However, a background erosion rate of -3 ft/yr was added to the results to represent the recent effects of net longshore transport at Broad Beach and get a more realistic approximation of project longevity.

9.3.2 Diffusion Method Results

The diffusion model yields the change in beach nourishment planform over time. Model results for a sand source with a median grain size of 0.25 mm and assuming one-way lateral dispersion is shown in Figure 9-18. The horizontal axis shows the distance from the center point of the beach fill (value 0), and the vertical axis shows the distance of the MSL shoreline from the pre-project shoreline position. The figure shows that as the width of the shoreline at the beach fill site decreases over time, the length of the widened area increases as the fill spreads laterally.

Figure 9-19 illustrates the percentage of beach nourishment material remaining within the original placement area versus time. If two-way lateral dispersion is assumed, the longevity of a 600,000 cy beach nourishment with a median grain size of 0.25 mm is estimated to be about 5 years. If one-way lateral dispersion is assumed, the beach nourishment material will remain within the placement area for a period up to 8 years.

Figure 9-20 and Figure 9-21 show the diffusion model results for evolution of 600,000 cy beach nourishment with a median grain size of 0.85 mm. If two-way lateral dispersion is assumed, the longevity of a 600,000 cy beach nourishment with a median grain size of 0.85 mm is estimated to be about 7 years. If one-way lateral dispersion is assumed, the beach nourishment material may remain within the placement area up to 10 years.

The results indicate that grain size characteristics of the beach nourishment material would remain within the original placement area for a longer period of time if a coarser sand source were used. Based on the diffusion method results, use of a coarse grained sand source with a median diameter of 0.85 mm may increase the longevity of the project by 2-3 years when compared to a sand source with a median grain size of 0.25 mm.

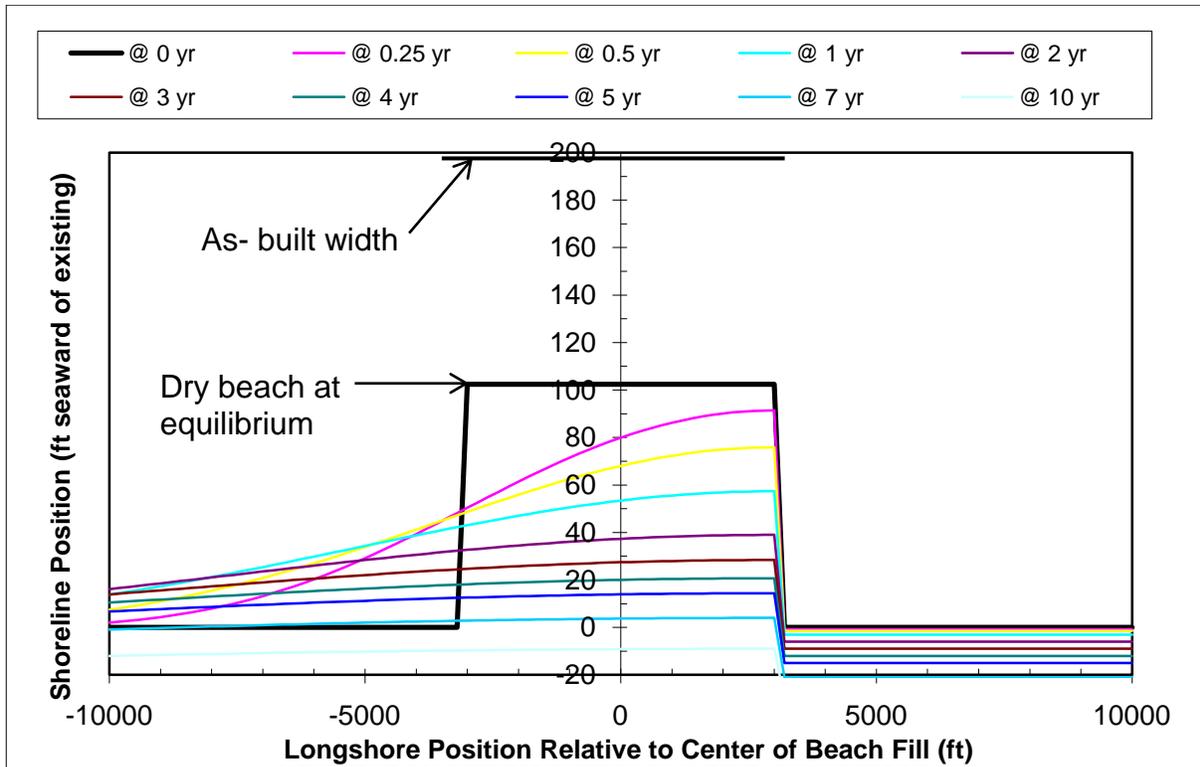


Figure 9-18. Planform Evolution Assuming One Way Dispersion, $D_{50} = 0.25$ mm

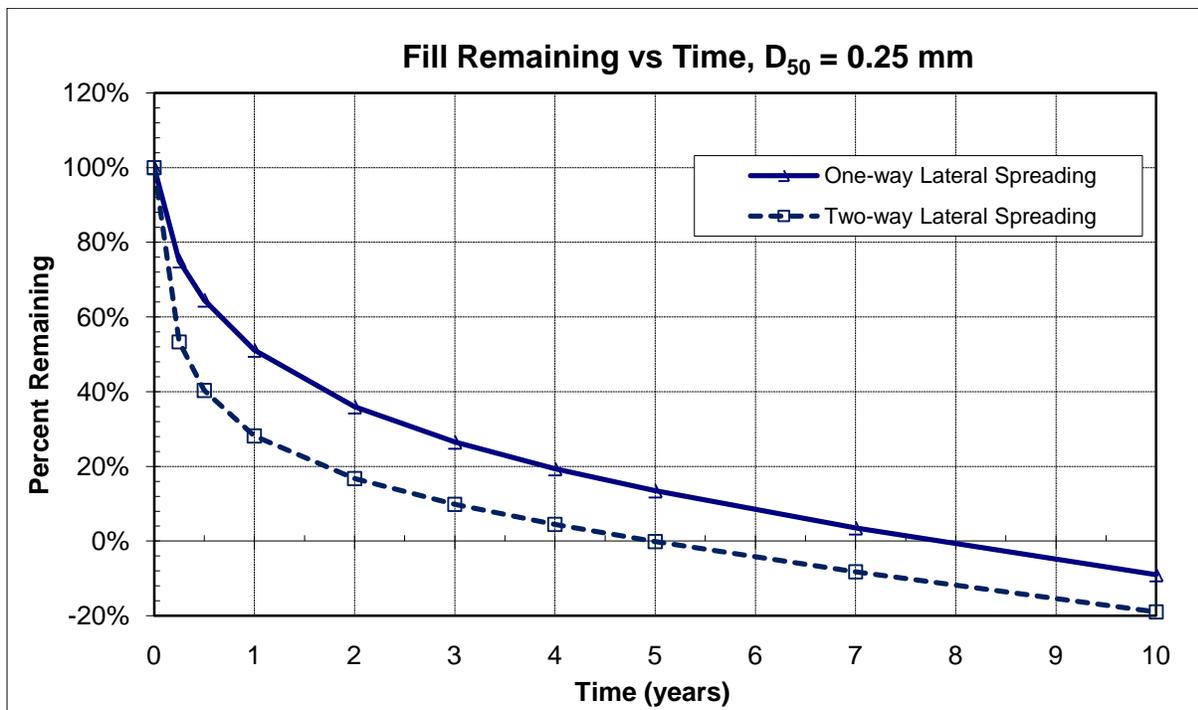


Figure 9-19. Beach Nourishment Project Longevity, $D_{50} = 0.25$ mm

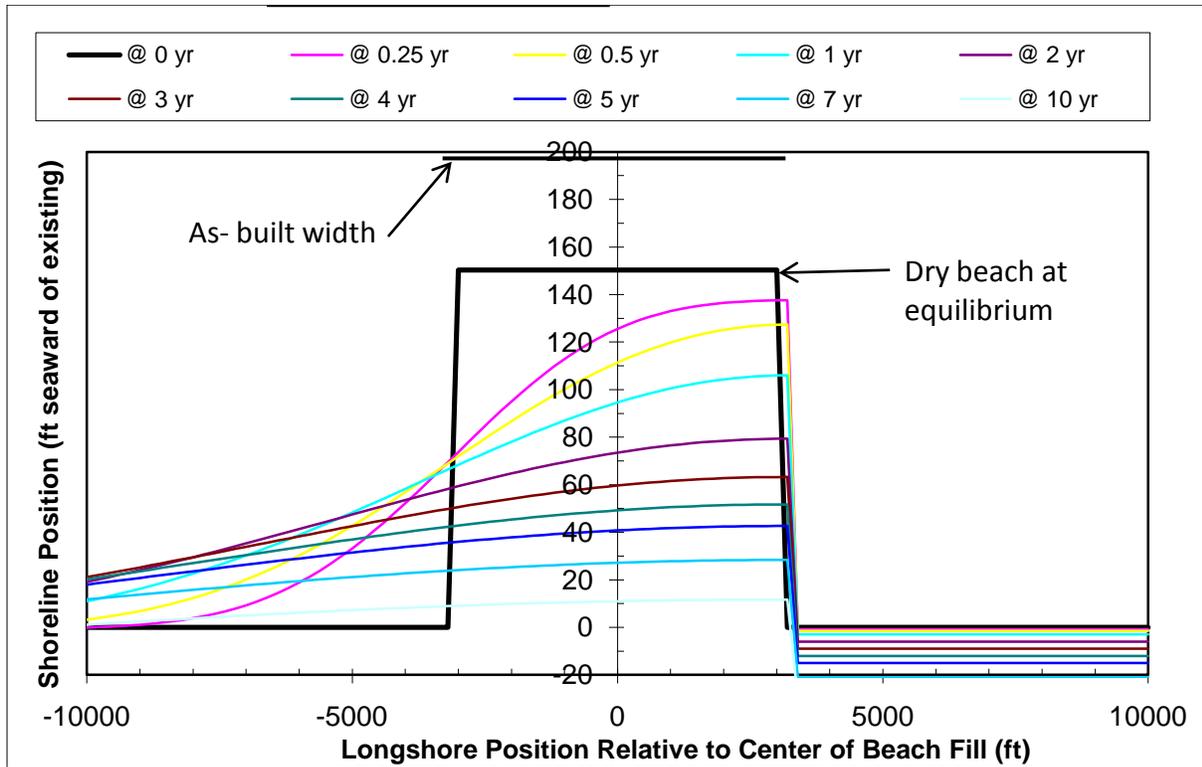


Figure 9-20. Planform Evolution Assuming One Way Dispersion, $D_{50} = 0.85$ mm

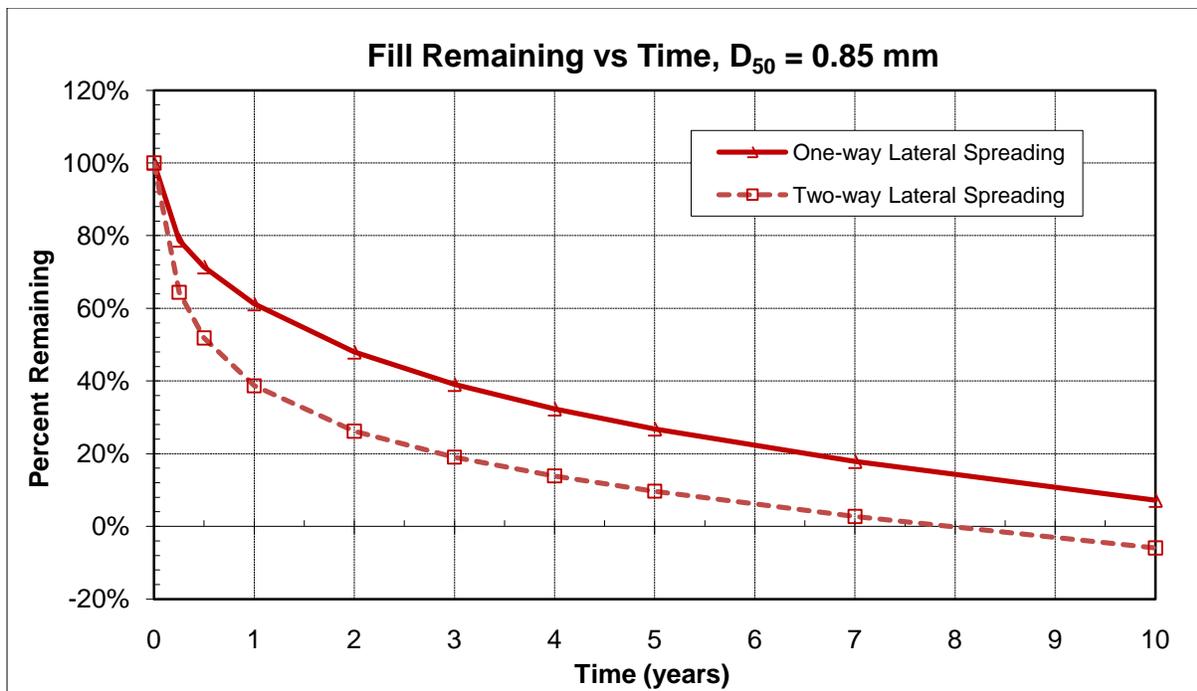


Figure 9-21. Beach Nourishment Project Longevity, $D_{50} = 0.85$ mm