CHAPTER 207

EVALUATION OF A BEACH DEWATERING SYSTEM: NANTUCKET, USA

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Abstract

A commercial multi-segmented beach dewatering system became operational December 1994 on the eastern shoreline of Nantucket Island, Massachusetts, USA. The objective of the installation was to cost-effectively stabilize a critically eroding reach of shoreline with minimal environmental impact. To assess the potential for wider use of beach dewatering in coastal erosion management, a comprehensive and independent monitoring program was developed and implemented to objectively evaluate the beach dewatering project. Observational methods and analyses are discussed relative to the ability to differentiate between the influence of the dewatering segments on beach response, in contrast to 'natural' shoreline response to coastal processes. Economics, measurement needs, measurement accuracy, and temporal and spatial resolution of data acquisition are discussed and evaluated.

Introduction

Nantucket Island is the eastern most member of the Elizabethan Island chain located 48 km southeast of the New England coast, USA (Figure 1). The eastern shoreline of the island is exposed to direct attack from the high-energy wave environment of the North Atlantic. Mean offshore significant wave heights are on the order of 2 m. However, offshore significant wave heights in excess of 5 m are frequently measured, particularly during winter storms. The maximum wave height offshore measured between 1984 and 1993 was 11.6 m (Hubertz, 1995). Historical charts and aerial photography indicate that, for at least the past 150 years, the beach face, dune line and bluff face have experienced episodic accretion and recession (Tiffney et al., 1991). Present estimated erosion rates along the eastern shoreline range from 0.8

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m/yr to 4.6 m/yr, depending on location. An analysis of wave refraction patterns suggested that episodic erosion events are due primarily to the focusing of storm wave energy by an offshore shoal complex along the south eastern shoreline of Nantucket (Weishar et al., 1991).

Bluff and dune recession are presently encroaching on private and public facilities of several Nantucket coastal communities. On the eastern shore of the island, where coastal storm damage has been catastrophic, increased coastal development has led to serious consideration of beach management and land use practices.

In 1990, the Siasconset Beach Preservation Fund (SBPF), a private organization of Nantucket homeowners, sponsored an evaluation of shoreline stabilization options. Results of the evaluation revealed that structural shoreline protection alternatives such as large stone revetments and cement seawalls are not economically feasible to construct at Nantucket. In addition, state and local regulatory agencies firmly restrict use of permanent shoreline structures. Beach nourishment was also evaluated, with a projected cost of $20 million (US) with an annual maintenance cost of $1 million (US) to protect approximately 4.27 km of shoreline. In light of these costs, the SBPF opted to privately fund the installation of three commercial beach dewatering-system segments. The dewatering-system segments cost $1 million (US) to construct. Projected annual maintenance costs are approximately $100,000 (US) for the three segments.

Installation

The three beach dewatering segments were developed and installed by Coastal Stabilization, Inc., under license to the Danish Geotechnical Institute (DGI) and became fully operational in December 1994. The project at Nantucket Island is the third commercial installation of beach dewatering technology in the United States, and one of several prototype or full scale facilities installed on North Atlantic coastlines by DGI or under license to DGI (Ovensen and Schuldt, 1992; Lenz, 1994).

Each STABEACH segment consists of buried, perforated drain pipes installed in a shore-parallel orientation below the beach face swash zone. The pipes slope toward wet wells located in the back shore region of the beach. Two dewatering segments drain by gravity, while drainage at the third segment is aided by a vacuum pump. Water collected in the wells is pumped offshore through a 35.5 cm discharge pipe by a 25 hp pump. The stated operational concept of the system is to induce continuous draw down of the watertable at the beach face, enhancing the depositional effect of wave uprush and reducing the erosive effect of wave backrush during natural accretionary periods.

In total, the project spans 9.8 km of shoreline (Figure 2). The northern most segment is referred to as Lighthouse North (*LHN*). The segment immediately to the south of *LHN* is referred to as Lighthouse South (*LHS*). The southern most segment is referred to as Codfish Park (*CFP*). The three systems are separated by stretches of beach outside the influence of groundwater draw down. Figure 3 illustrates the plan-view design of the *LHN* system. Constructed STABEACH segments at *LHS* and *CFP* are similar in concept. STABEACH system parameters are presented in Table 1. Each drain pipe connects to a 1.2 m diameter wet well.

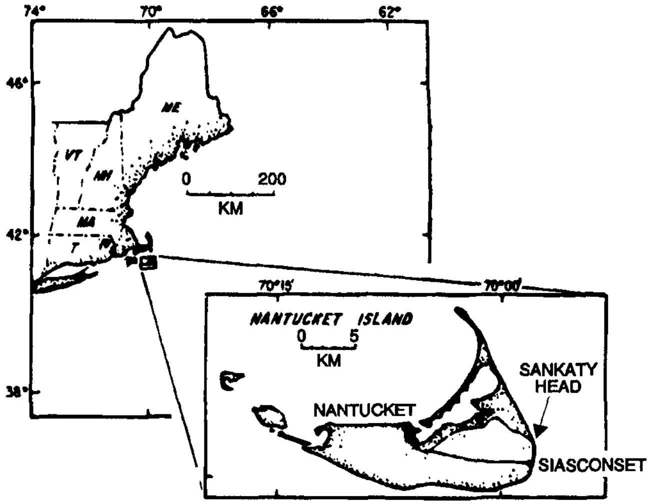

Figure 1. Location of Nantucket Island relative to New England mainland (after Oldale, 1987).

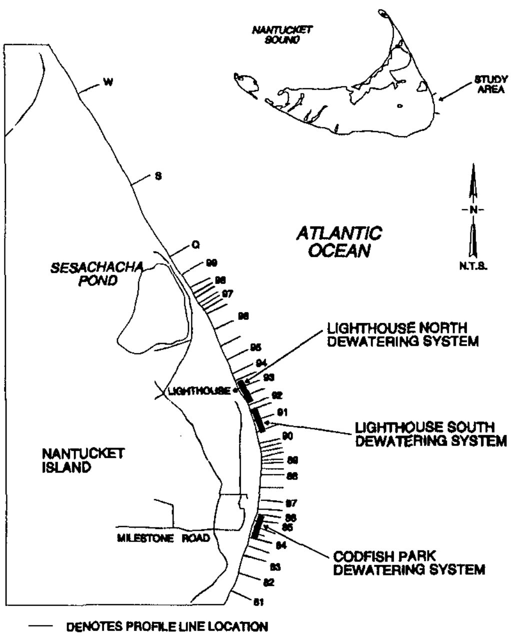

Figure 2. STABEACH segment and profile transect locations (after Coastal Planning and Engineering, Inc., 1996).

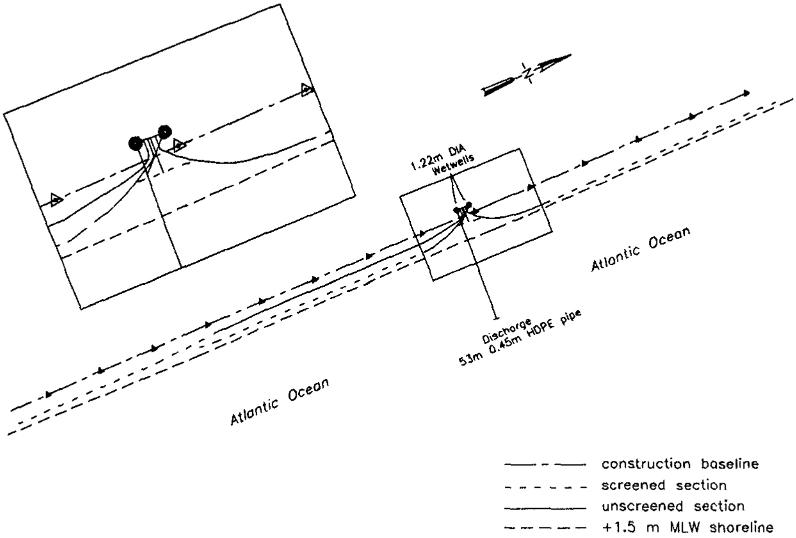

Figure 3. Plan-view schematic of Lighthouse North STABEACH segment.

Table 1. STABEACH Installation Parameters

Segment	Drain Length	Drain Diameter	Drain Elev. (-MSL)	Drain Method	Pump Capacity	Initial Flow Rate
LHN	405 m	30.5 cm	2.4-3.6 m	gravity wet well	22716 lpm 6000 gpm	52 lpm/m 4.2 gpm/ft
LHS	309 m	30.5 cm	2.4-3.6 m	gravity wet well	22716 lpm 6000 gpm	30 lpm/m 2.45 gpm/ft
CFP	357 m	30.5 cm	2.4-3.0 m	low vac. wet well	11350 lpm 3000 gpm	28 lpm/m 2.25 gpm/ft

Note: gpm = gallons (US)/minute, lpm = liters/minute.

Prior to installation of the STABEACH segments, a series of tests were performed by Coastal Stabilization, Inc., to characterize hydrogeological properties of the project site. Subsurface borings identified vertical and horizontal variation of grain-size distributions. Hydraulic conductivity tests were used to optimize vertical and horizontal placement of drain lines and optimize discharge pump design. Table 2 presents average subsurface soil properties for each STABEACH location.

Table 2. Average hydrogeologic properties of project area (Coastal Stabilization, Inc., 1994).

Location	Soil Type	Hydraulic Conductivity (calculated)
CFP	med-coarse sand, no fines clean, uniform	0.233 cm/s
LHS	fine-coarse sand, clean	0.089 cm/s
LHN	fine-med sand, silt/clay	0.2 cm/s

Monitoring Program

Laboratory and prototype field demonstration studies suggest that beach dewatering technology has the potential to stabilize a shoreline. However, the practical application of the technology as a viable means of coastal protection has yet to be adequately documented (Turner and Leatherman, 1996).

To assess the potential for the wider use of beach dewatering in coastal erosion management, a comprehensive and independent monitoring program was developed and implemented by the US Army Engineer Waterways Experiment Station (WES) to objectively evaluate the STABEACH project underway on Nantucket Island. Thc primary emphasis of the monitoring program is to evaluate whether observed beach changes can be attributed to the dewatering segments. If successful, data from the monitoring program will be used to address quantitative guidelines for the design, construction and operation of future beach dewatering-systems.

Elements of the monitoring program include measurements of beach profiles, bathymetry, hydrogeology, sediment characteristics, coastal processes and system parameters. System parameters such as discharge, operational period, and power requirements have been measured at each dewatering segment for the duration of the monitoring program. The elements of the monitoring program are described in more detail below.

Quarterly Beach Profiles

Beginning in November 1994 (pre-construction), forty-two transects have been established and surveyed on a quarterly basis (Figure 2). The project extends 9.8 km with survey transect 81 at the south end and transect W at the north end. Profile transects are regularly spaced at 305 m intervals, with the exception of 122 m intervals in the vicinity of system drain pipes. For reference, *CFP* system extends from 67 m south of transect 81 to 44 m north of transect 84; *LHS* system extends from 131 m south of transect 91 to 83 m north of transect 91; *LHN* system extends from 46 m north of transect 92 to 122 m north of transect 93.

Each transect extends from the crest of the dune or base of the coastal bank to wading depth (-1.5 m MLW) and was surveyed with a total station and prism rod system. Elevations were surveyed at inflection points in the profile slope and at 6 m intervals from the baseline to wading depth.

To date, quarterly beach profile data have been analyzed for volume and shoreline change. Quarterly measurements document seasonal variability, and comparisons to the pre-construction surveys document the longer-term trends. Figures 4a and 4b present the variation in shoreline position (as defined by the 0.0 m MLW contour) for June 1996 data compared to pre-construction (November 1994) data. When considering profile transects 81-96.5, dewatered beaches have experienced an average shoreline recession of -5.2 m and non-dewatered beaches an average recession of -8.2 m between November 1994 and June 1996. North of transect 96.5, the averaged shoreline has accreted since projcct installation (0.1 m).

Figures 4a and 4b suggest that rates of recession generally decrease from south to north along the project area. Figure 5 confirms the inference as volumetric changes of the beach profiles between November 1994 and June 1996 range from -115 m^3/m at profile 81 to +12.5 m^3/m at profile W. The trends are consistent with longshore currents which are gcnerally from south to north and dominated by tidal currents (Gutman et al., 1979).

Bi-Monthly Beach Profiles

Spatially and temporally dense data were acquired and are being analyzed to understand small scale variations in beach morphological dynamics as influenced by the system segments. Beach profiles were obtained at 15 day intervals for a six month period (June-November 1996) at eleven transect locations in the vicinity of and outside the influence of the *CFP* segment. Transect locations (82.6, 83.0, 83.5, 84.0, 84.3, 84.6, 85.0, 86.0, 86.4, 87.0, 87.4) were spaced at 122 m intervals in the longshore direction and had a cross-shore spatial resolution of 1.5 m from the dune to -0.9 m MLW. The objective of the high resolution profiling initiative is to correlate beach profile response with concurrent dewatered and non-dewatered groundwater elevation measurements. Through a statistical correlation of profile data with groundwater measurements, an assessment of the system-induced manipulation of beach groundwater on morphological response will be quantified.

Bathymetry

The forty-two transects established for beach profiles were extended offshore using a ship-mounted digital fathometer interfaced to the Coastal Oceanographic HYPAC program. Hydrographic surveys were conducted November 1994, December 1995 and September 1996 using standard fathometer techniques. In September 1995 and June 1996 Scanning Hydrographic Operational Airborne Lidar System (SHOALS) surveys were conducted (Lillycrop et al., 1996). Complete SHOALS surveys of the *LHN* and *LHS* offshore regions were obtained on both occasions, while surveys offshore

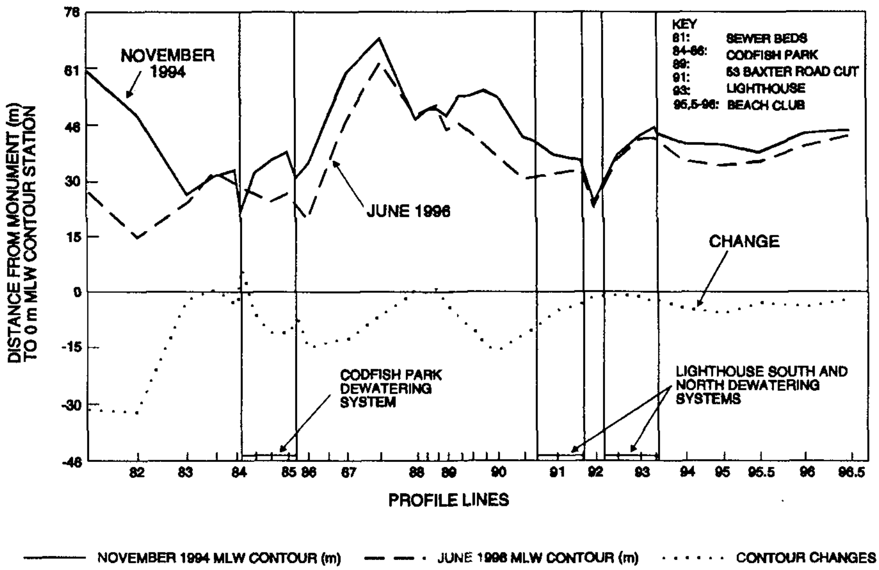

Figure 4a. Contour changes at elevation 0.0 m MLW: November 1994-June 1996 (after Coastal Planning and Engineering, Inc., 1996).

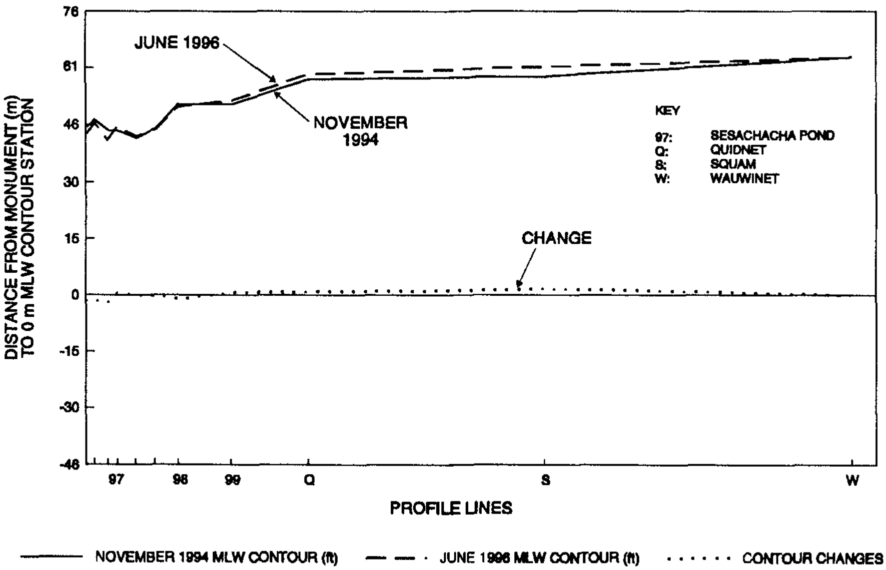

Figure 4b. Contour changes at elevation 0.0 m MLW (continued): November 1994-June 1996 (after Coastal Planning and Engineering, Inc., 1996).

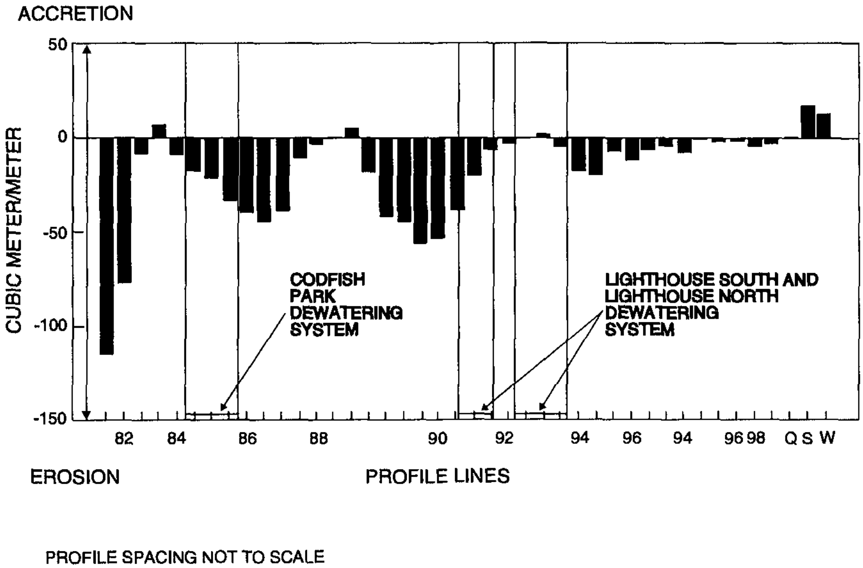

Figure 5 . Volumetric changes at -1.5 m MLW: November 1994-June 1996 (after Coastal Planning and Engineering, Inc., 1996).

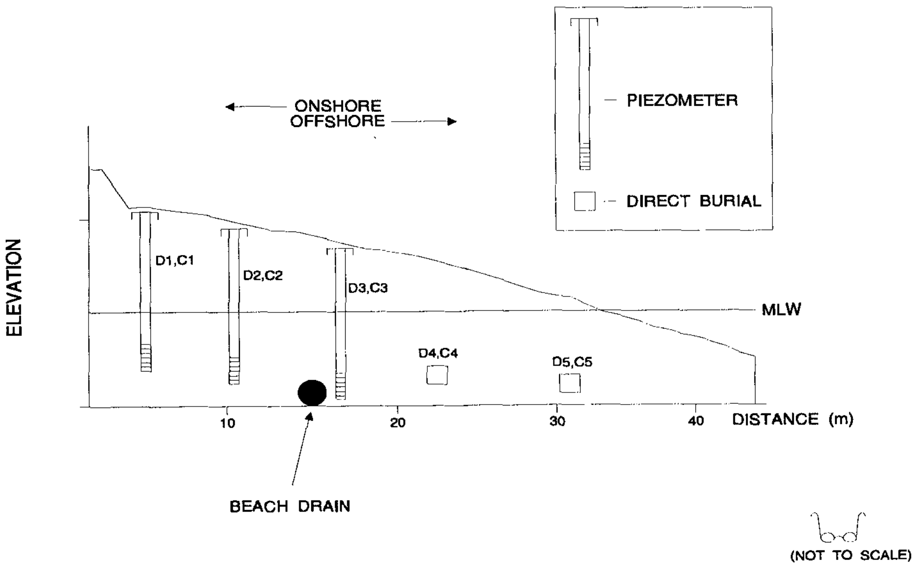

Figure 6. Cross-sectional schematic of the groundwater monitoring installation at Codfish Park STABEACH segment and adjacent control beach.

CFP were unobtainable due to water clarity and weather limitations. Data obtained using standard fathometer and SHOALS methods will be used in combination with the beach profiles by comparative analysis to assess the response of morphological processes to the STABEACH segments.

Groundwater Elevation

Two cross-shore transects of buried pressure sensors were installed in December 1995 and re-installed in May 1996 following storm damage at the project site to monitor the variations of watertable elevation below a dewatered and non-dewatered beach (Figure 6). Groundwater monitoring transects are located at *CFP* and at the non-dewatered beach between *CFP* and *LHS*. Sensors are either directly buried or encased in screened wells and connected to recording instruments. Data loggers sample watertable fluctuations every 30 seconds and average them over 5 minutes at 15 minute intervals. A barometer and internal thermometers are used to correct absolute pressure measurements for low-frequency barometric and temperature fluctuations. The objective of the measurements is to determine the influence of a STABEACH segment on beach groundwater dynamics and address key issues such as the effect of dewatering on bed saturation characteristics at the beach face, the influence of dewatering during storms and during post-storm recovery of the beach profile, and the effect of dewatering on the local fresh groundwater supply. The second transect of pressure sensors outside the influence of the *CFP* system will be used as a control for comparative analysis.

Other Morphological Monitoring Elements

Additional WES-sponsored monitoring include quarterly controlled aerial photographic surveys and use of a video imaging system. Aerial photographic surveys will be used to compliment analyses of shoreline and coastal dune position for the project.

A digital imaging system was installed on a lighthouse located on the bluff above the *LHN* segment. The cameras were located approximately 55 m above the beach. Three cameras were needed to photograph the full extent of the beach within view of the lighthouse. The imaging system is capable of quantifying beach changes and patterns of incident wave breaking within the camera's field of view (Lippman and Holman, 1989). The system obtains instantaneous images of the beach (Figure 7) on the hour during daylight. In addition, the system produces a 10 minute time-averaged image (Figure 8). The time averaged image is produced by sampling at a rate of 3 Hz for 10 minutes and applying an averaging routine to produce a statistically stable image. Images will be used to analyze variations in foreshore morphology at a dewatered and adjacent non-dewatered beach.

Wind and Wave Parameters

Deep water wave parameters are measured on the continental shelf at approximately 500 km east and at 223 km southeast of Nantucket Island. The moored discus buoys are maintained by the National Data Buoy Center and provide directional wind spectra, non-directional wave spectra and climatic data. Unfortunately, no shallow

Figure 7. Instantaneous digital image of Lighthouse North dewatered swash zone.

Figure 8. Time-averaged digital image of Lighthouse North dewatered swash zone and adjacent non-dewatered shoreline to the north.

or intermediate depth wave parameters are measured in the nearshore region. However, given the NDBC buoy data, shallow or intermediate water depth equivalents can be estimated. In addition, the SBPF sponsors data collection of local climate variables (e.g., wind speed, direction and barometric pressure).

Monitoring Elements of Public Concern

The SBPF sponsors environmental impact monitoring of the STABEACH segments. Parameters of public concern are measured quarterly and include the impact of beach groundwater draw down on the public fresh water supply, on dune vegetation communities, on beach meiofauna, and on system discharge quality.

Discharge Quality

Salt water is discharged offshore from all three dewatering segments. Salinity of the discharged water ranges from 21-33 ppm and is comparable to nearshore ocean water (30-33 ppm). Bacteria levels of water discharged offshore are an order of magnitude below the standard acceptable for safe swimming. Measured nitrate levels are slightly higher at the *CFP* discharge (0.21-0.54 mg/l) than the *LHS* and *LHN* discharges (0.07-0.29 mg/l). The close proximity of residential septic systems to the dewatering segment is responsible for the higher nitrate measurements at *CFP*. Variations in the elevation of the public fresh water supply aquifer are monitored at 0 m, 70 m, 104 m, 453 m and 640 m landward of the *CFP* wet wells. Monitoring results follow the fluctuation trends in the elevation of the regional aquifer landward of the wet wells, as measured by the United States Geological Survey (USGS) (Figure 9).

Maritime Vegetation and Meiofauna

Monitoring transects were established at *CFP* and *LHS* for evaluation of the impact of groundwater elevation draw down on dune vegetation communities. Variations in the vegetative communities are not influenced by dewatering-system operation. Since project construction, variations in the vegetative communities are primarily due to vegetation lost during wave erosion events. Attempts to quantify dewatering effects on beach meiofauna are not definitive. Spatial and temporal variability in taxonomic richness, diversity, evenness and total number of organisms per sample was significant at dewatered and non-dewatered sample stations (Figure 10). The influence of the STABEACH system on local meiofauna communities is not detectable from the available monitoring data.

Summary

The objective of this paper is not to present definitive conclusions as to the effectiveness of the STABEACH installations at Nantucket Island. Rather, the emphasis has been to convey elements of an independent monitoring program which was established to evaluate beach dewatering technology as a means to stabilize sand on a receding shoreline in a high wave energy environment. Shoreline position of Nantucket Island is highly variable when considering temporal scales ranging from several hours to decades. Monitoring efforts were established to identify trends in shoreline

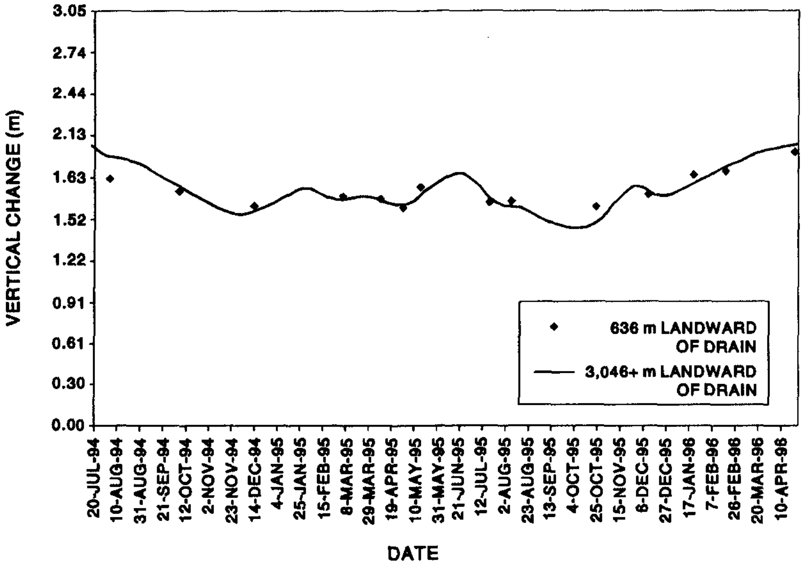

Figure 9. Vertical changes in groundwater elevation landward of Codfish Park STABEACH segment (after Fugro East, Inc., 1996).

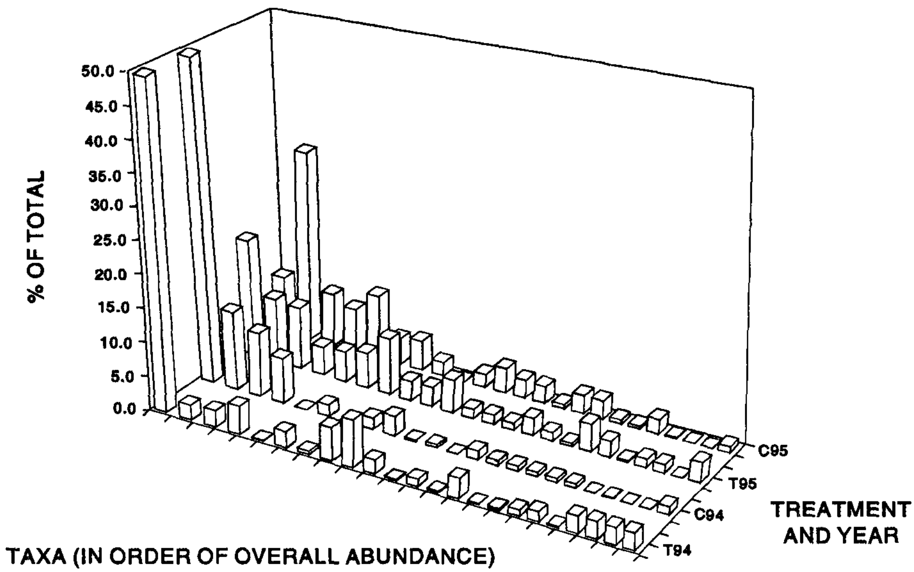

Figure 10. Meiofauna count for dewatered and non-dewatered beaches: 1994 and 1995 (after Fugro East., Inc., 1995).

morphodynamics on varying temporal scales as influenced by operational STABEACH segments.

WES-sponsored monitoring was initiated in June 1995 and is scheduled to terminate in May 1997. After the data collection is terminated, a comprehensive evaluation of use of the STABEACH system as a shoreline stabilization method at Nantucket Island will be presented in the literature.

Three STABEACH segments have been in operation at Nantucket Island for two years. Operation of the *LHN* segment has been nearly continuous since installation. Discharge pumps located at *LHS* were damaged during a storm in January 1996 and returned to operation at 70% capacity in July 1996 and 100% capacity in September 1996. The pump which draws water through the drains at the *CFP* segment was rendered inoperable February 1996. It is speculated that the *CFP* segment operated at 50% capacity under gravity drainage, until the pump returned to operation in August 1996.

Following 18 months of quarterly monitoring, visual and statistical analyses confirm that both dewatered and non-dewatered beaches have highly variable seasonal profile fluctuations. Quantification of the influence of drainage of the beach face on sand stabilization at the project site is presently under investigation.

SBPF-sponsored monitoring reveals that the quality of discharged water has negligible impact on water quality offshore of the dewatering-system segments. Groundwater draw down attributed to the STABEACH segments has had no discernable impact on local vegetative and meiofunal communities. In addition, the drainage of the beach face has no adverse impact on the local public freshwater aquifer.

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References

Coastal Planning and Engineering, Inc. (1996), "Coastal engineering analysis of the Siasconset, Nantucket Island erosion control project", *Sixth Qtr. Rpt: June 1996*, Coastal Planning and Engineering, Inc., Boca Raton, FL.

Coastal Stabilization, Inc. (1994), "Geotechnical and hydrological investigation and design for the installation of a STABEACH system: Nantucket, Massachusetts", *Int. Doc.*, Coastal Stabilization, Inc., Rockaway, NJ, 11p.

Fugro East, Inc. (1996), "Winter quarterly report (December 1995-February 1996): Siasconset erosion control project, Nantucket, Massachusetts", *Int. Doc.*, Fugro

East, Inc., Sandwich, MA.

Fugro East, Inc. (1995), "Summer quarterly report (June-August 1995): Siasconset erosion control project, Nantucket, Massachusetts", *Int. Doc.*, Fugro East, Inc., Sandwich, MA.

Gutman, A.L., M.J. Goetz, F.D. Brown, J.F. Lentowski, and W.N. Tiffney (1979), "Nantucket shoreline survey: An analysis of Nantucket shoreline erosion and accretion trends since 1846", *MITSG 79-7*, Massachusetts Institute of Technology Sea Grant College Program, Cambridge, MA.

Hubertz, J.M. (1995), "Variation of measured meteorologic and oceanic variables off the U.S. Atlantic coast: 1980-1994", *4th Int'l. Workshop on Wave Hindcasting and Forecasting*, Banff, Canada, October 16-20, 1995, 45-57.

Lenz, R.G., (1994), "Beach face dewatering - a tool for coastal stabilization", *Proc. 1994 Nat'l Conf. on Beach Pres. Tech.*, 27-52.

Lippman, T.C. and R.A. Holman (1989), "Quantification of sand bar morphology: A video based technique on wave dissipation", *J. Geophys. Res.*, 94(C1), 995-1011.

Lillycrop, W.J., L.E. Parson and J.L. Irish (1996), "Development and operation of the SHOALS Airborne Lidar Hydrographic Survey System", SPIE: Laser Remote Sensing of Natural Waters: From Theory to Practice (unpublished).

Oldale, R.N. (1987), "Wisconsinian and pre-Wisconsinian drift and Sangamonian marine deposits, Sankaty Head, Nantucket, Massachusetts", *Centennial Field Guide-Northeastern Section*, Geological Society of America, 221-224.

Ovensen, N.K. and J.C. Schuldt (1992), "Beach Management System", *Int. Doc.*, Danish Geotechnical Institute, 20p.

Tiffney, W.N., L.L. Weishar and J.C. Andrews (1991), "Nantucket Island's shifting shoals and moving shores: Nearshore bathymetry controls beach deposition and erosion", *Coastal Zone '91*, American Society Civil Engineers, N.Y., vol. 3, 2421-2433.

Turner, I.L. and S.P Leatherman (1996), "Beach dewatering as a 'soft' engineering solution to coastal erosion - a history and critical review", In press, *J. Coast. Res.*

Weishar, L., W.N. Tiffney, N. Kempe and M. Fields (1991), "Shoreline response to offshore shoals and storms: Low Beach, Nantucket, MA", *Coastal Zone '91*, American Society Civil Engineers, N.Y., vol. 3, 2435-2449.