Phase 1 Pamet Inlet Technical Report:
Data Collection, History, Geomorphology, and Sediment Budget

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Symbols and Abbreviations

ADCP	Acoustic Doppler current profiler
AWAC	Acoustic wave and current profiler
CCS	Center for Coastal Studies
CZM	Coastal Zone Management
DEM	Digital elevation model
DSAS	Digital Shoreline Analysis System
EFDC	Environmental Fluid Dynamics Code
GIS	Geographic Information System
GPS	Global positioning system
H&H	Hydraulic and Hydrologic
NAVD88	North American Vertical Datum of 1988
NDBC	National Data Buoy Center
NOAA	National Oceanic & Atmospheric Administration
Town	Town of Truro
USGS	United States Geological Survey
WHG	Woods Hole Group

1.0 INTRODUCTION

Pamet Inlet has vital maritime and environmental importance to the Town of Truro (Town), Massachusetts, since it provides the only access for Pamet Harbor to Cape Cod Bay and is also the mouth of the Pamet River that provides significant estuarine habitat and storm drainage. Severe shoaling and erosion threatens the inlet, which is exposed to tides, storm surge, and waves from Cape Cod Bay (Figures 1a & 1b). The Harbor itself has a history of shoaling, which has been managed by dredging, with spoils placed on the Cape Cod Bay beach north of the inlet to combat erosion. However, progressive erosion is flanking the north jetty, raising concerns about the integrity of the beach, jetty, and navigational channel. A spur was added to the north jetty in 2009 to counter the flanking, however, the erosion and flanking has simply moved north since. More recently, a bioengineered coir bag solution was installed with dredge spoils and plantings and to mitigate the new area of flanking in the short term (Figure 2). While these efforts along with the ongoing dredging and nourishment help maintain the status quo, the Town is interested in developing longer-term solutions to improve inlet stability, promote safe navigation, maintain the adjacent shorelines, enhance water quality and habitat, and ensure efficient Town investment for managing this inlet in the changing climate.

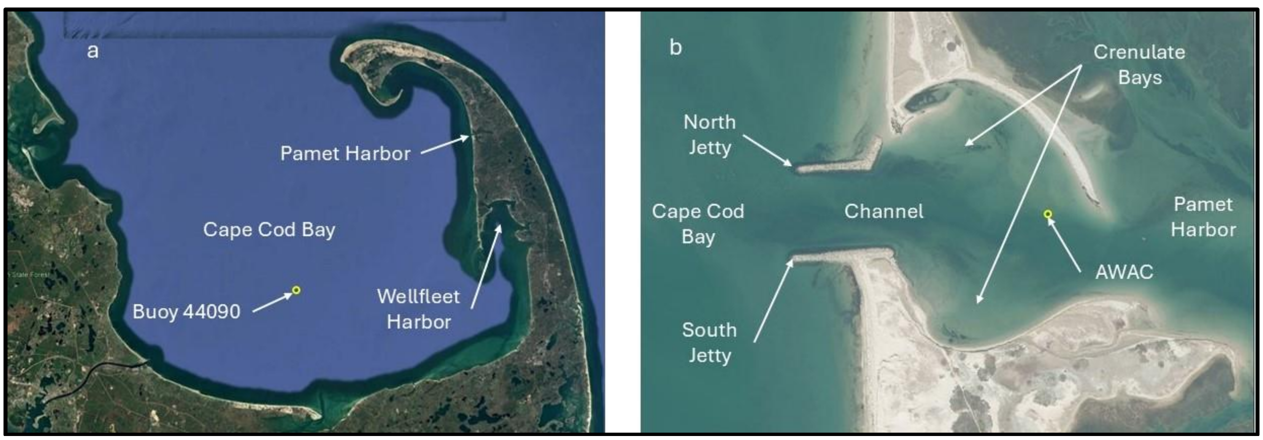

Figure 1 (a) Pamet Harbor in Cape Cod Bay. Buoy 44090 is the National Data Buoy Center (NDBC) wind and wave measurement buoy maintained by the National Oceanic & Atmospheric Administration (NOAA). (b) Pamet Harbor Inlet. AWAC is the acoustic wave and current instrument deployed by Woods Hole Group. Note the separation of the north jetty from the adjacent beach. Figure sources: (a) Google Earth, (b) 2023 MassGIS digital orthoimagery.

Figure 2 Photo of the bioengineered coir bag solution constructed to fill the erosional hotspot between the terminus of the north jetty spur and coastal dune (dated 10/25/2024).

To investigate long-term solutions, the Town tasked Woods Hole Group (WHG) with an analysis of coastal processes to understand the underlying issues and engineering alternatives to provide a long-term solution for the inlet. The study was divided into two phases:

- Phase 1 involved colleting the data needed to conduct a thorough coastal processes analysis to understand existing conditions and

- Phase 2 involves utilizing the results within numerical models to evaluate long term alternatives for the inlet.

This report summarizes Phase 1 findings, entitled "Data Collection, History, Geomorphology, and Sediment Budget" which includes the following tasks:

1. Bathymetric and topographic surveys
2. Tide, current, and wave data collection
3. Inlet current profile measurements
4. Shoreline change analysis
5. Analysis of historical dredging and placement
6. First level sediment budget and inlet stability analysis
7. Crenulate Bay / Inlet literature review

The following sections describe the technical approach (Section 2), results (Section 3), and conclusions and recommendations (Section 4).

2.0 TECHNICAL APPROACH

The goal of the technical approach was to assemble and analyze available and collected data to conduct a coastal processes analysis to understand the underlying processes in phase 1 and evaluate alternatives in phase 2.

2.1 Bathymetric and Topographic Data Sources

WHG utilized bathymetric and topographic elevation data from both available and collected data sources for this study including:

- November 2023 and January 2024 pre- and post-dredge surveys performed by Steele Engineering, Inc.,
- Bathymetric mapping survey conducted by Center for Coastal Studies (CCS) (Figure 3),
- Drone based topographic LIDAR survey conducted by CCS,
- Woods Hole Group ground survey using a Real Time Kinematic (RTK) GPS system, and
- publicly available 2021 USGS LIDAR data.

These data sets were combined to create a Digital Elevation Map (DEM) for the project site referenced to a common datum, the North American Vertical Datum of 1988 (NAVD88). WHG reviewed the survey results and assessed their suitability for the upcoming Phase 2 component of the present project, which will include modeling and evaluation of alternatives.

Figure 3 CCS's survey vessel for the bathymetry survey.

2.2 Tide, current, and wave data collection

Data collection included bottom-mounted 1-MHz Nortek AWAC to collect a time series of measurements including water surface elevation, currents, and waves in the Pamet Harbor approach (Figure 1b). The instrument was mounted in a Trawl Resistant Bottom Mount (TRBM) Platform to protect against currents, debris, shifting sands, and vessel strikes (Figure 4). The measurement period was 19 October through 16 December 2024. WHG rotated the current measurements into along- and cross-channel coordinates, calculated statistics (mean, standard deviation, skewness, and frequency spectra), and fit the measured surface elevations and current velocities to a model with three semidiurnal (M2, N2, and S2), two diurnal (K1 and O1), and one quarter-diurnal (M4) tidal constituents and a non-tidal residual. WHG developed an analytical statistical model forced by waves measured at Buoy 44090 to interpret the wave measurements at the AWAC site.

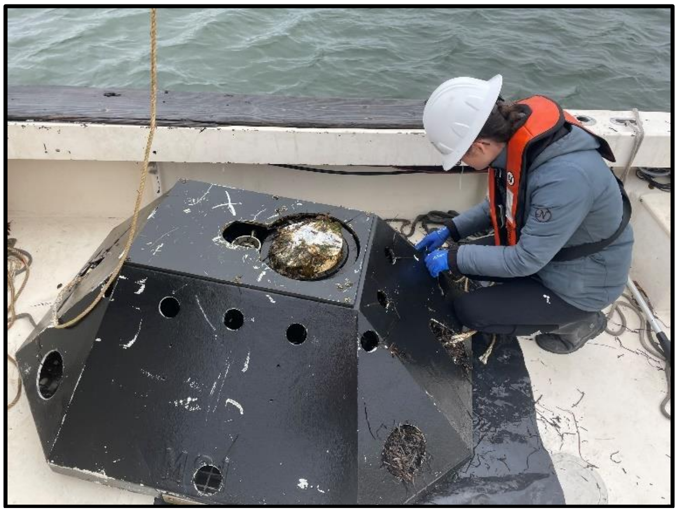

Figure 4 Nortek AWAC mounted in a TRBM platform after recovery in Pamet Harbor approach channel.

2.3 Inlet current profile measurements

WHG performed a shipboard survey of currents throughout the Pamet Harbor inlet, using a SonTek 1-MHz RiverSurveyor acoustic Doppler current profiler (ADCP) (Figure 5a). The ADCP was mounted to a vessel with an RTK GPS receiver overhead (Figure 5b) to provide horizontal positioning and reference to the NAVD88 (feet) vertical datum. The survey was conducted along prescribed lines that were laid out using HYPACK hydrographic software that allowed the lines to be occupied repeatedly during the survey. The measurements began at 12:57 PM on 10 October 2024 and spanned nine hours, capturing maximum flood and ebb currents during the predominantly semidiurnal tidal cycle. The survey resolved the spatial variability of the currents in the navigational channel and the crenulate bays north and south of the channel (Figure 1b).

Figure 5a & 5b SonTek 1-MHz RiverSurveyor ADCP (left) and the vessel mount with RTK GPS integration (right).

2.4 Shoreline change analysis

WHG used a shoreline mapping methodology within a Geographic Information System (GIS) framework to compile and analyze changes in historical shorelines on the Cape Cod shoreline outside Pamet Harbor. Woods Hole Group compiled and analyzed aerial photographs from MassGIS Orthophotography, NOAA National Geodetic Survey, and U.S. Department of Agriculture Data, and more covering (15) time periods were evaluated spanning 52 years from 1971 to 2023 (**Error! Reference source not found.**). The aerial photographs where then geo-referenced in a common coordinate system so that they could overlain with accuracy for analysis. The shoreline position was delineated using the high-water mark on the beach, which is evident in linear features such as a wrack line, change in sediment texture (e.g., smooth swash zone vs. rough upper beach), or change in sediment color (e.g., wet/dry line). After data compilation, spatial and temporal changes were computed using the Digital Shoreline Analysis System (DSAS) version 4.3. Shore-normal transects were established at 100-ft intervals spanning 1,400 feet. At each transect, rates of change were determined using linear regression for the entire period (1971 to 2023) and for a shorter period (2009 to 2023), noting that addition of the northeast-southwest spur in the north jetty (Figure 1b) occurred in 2009 and likely changed the coastal processes.

Table 1 Data sources for shoreline change analysis.

Year	Data Source
1971	UMass Amherst, Barnstable County
1985	Historic Aerials
1990	MassGIS
1994	MassGIS
2001	MassGIS
2005	MassGIS
2009	MassGIS
2011	NOAA National Geodetic Survey
2014	MassGIS
2016	USDA National Agriculture Imagery Program
2019	MassGIS
2021	MassGIS
2022	NOAA National Geodetic Survey
2023	MassGIS
2023	Google Earth

2.5 Analysis of Historical Dredging and Placement

WHG received dredge records for Pamet Harbor between 2000 and 2024 from the Town of Truro and placed the reported dredge volumes in context with the shoreline change analysis (Section 2.4) and the first level sediment budget and inlet stability analysis (Section 2.6).

2.6 First Level Sediment Budget and Inlet Stability Analysis

WHG performed a sediment budget and inlet stability analysis using the in-situ measurements (Sections 2.2 and 2.3), shoreline change analysis (Sections 2.5), and the entire wave record (since 2016) from Buoy 44090 (Figure 1a). Wave-driven longshore transport rates on the beaches outside Pamet Harbor were estimated via wave transformation calculations and a wave-driven longshore transport formula (Dean & Dalrymple, 1984, 2002). An analytical model based on standard tidal hydraulics, with a sediment transport formula (US Army Corps of Engineers, 2015), produced estimates of the sediment transport rate through the inlet.

2.7 Crenulate Bay / Inlet Literature Review

The crenulate bay / inlet literature review consisted of collection and synthesis of relevant publications in professional scientific and engineering journals.

3.0 RESULTS

3.1 BATHYMETRIC AND TOPOGRAPHIC SURVEYS

The Steele Engineering pre- and post-dredge surveys include measurements along four cross-channel lines (Figure 6). The largest removal of material occurred along the farthest landward line, well into Pamet Harbor. The greater accumulation at the farthest landward station indicates flood-dominant sediment transport in the inlet channel, i.e., higher tidal velocities with smaller duration during flooding currents than during ebbing currents, which causes a net landward transport of sediment from Cape Cod Bay to Pamet Harbor.

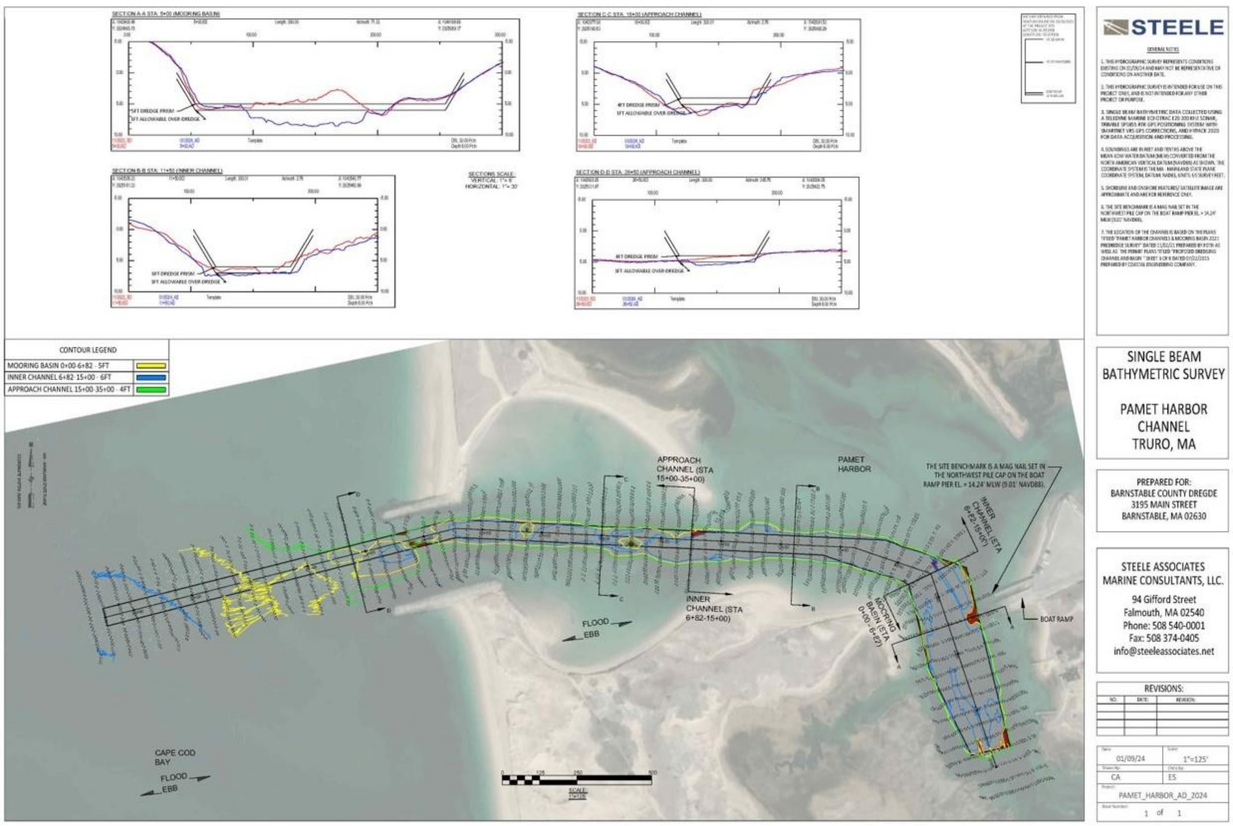

Figure 6 Pre- and post-dredge surveys from November 2023 and January 2024.

The bathymetric and topographic surveys by WHG and CCS (Figure 7) were combined into a DEM for the Pamet Harbor system. The DEM shows a relatively featureless bathymetry in Cape Cod Bay, a dredged entrance channel with modest sand waves, shallow semi-circular crenulate bays inside the jetties and north and south of the channel, and a shallow estuary farther inland to the north and east. The WHG evaluation determined that this information is sufficient for the detailed hydrodynamic and wave simulations that will be conducted as part of the upcoming Phase 2 component of this project.

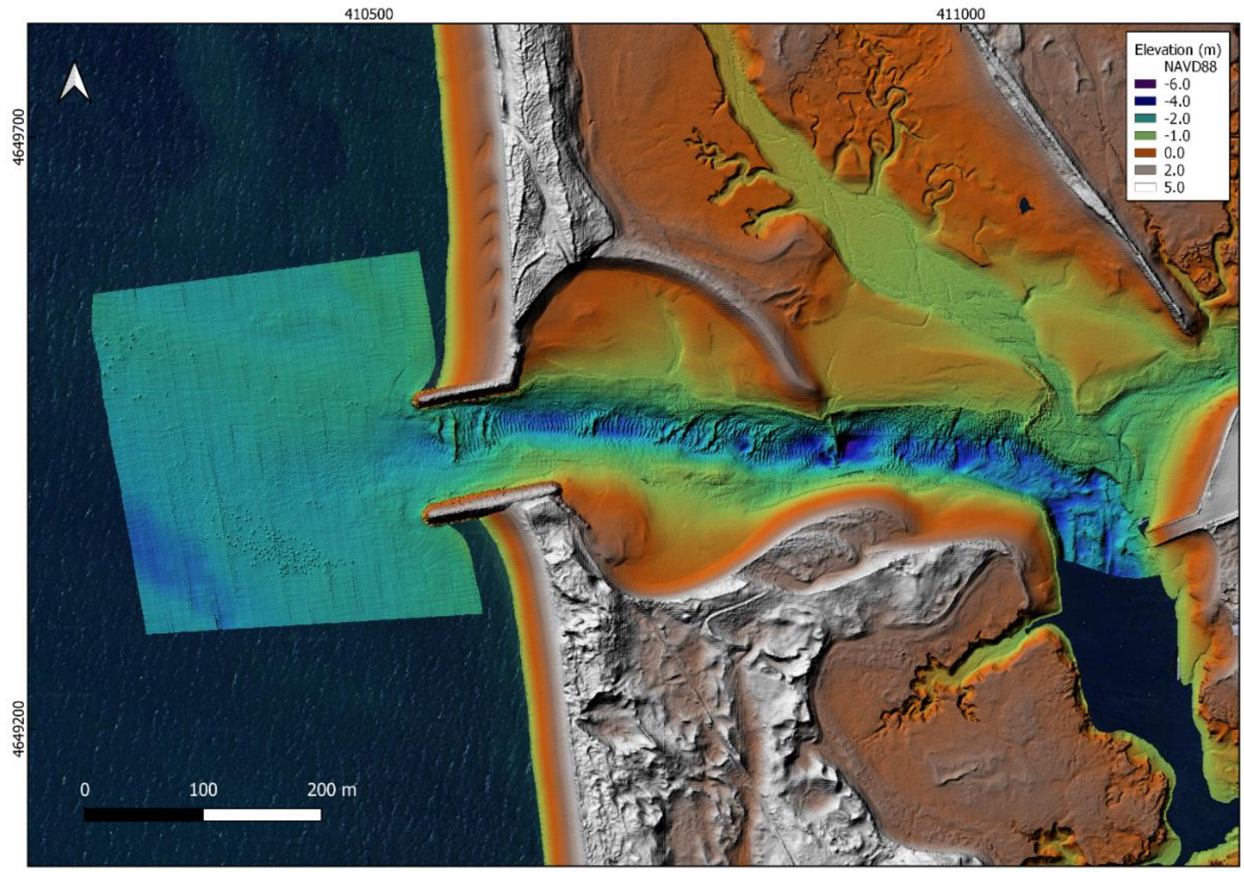

Figure 7 Combined bathymetric and topographic survey data into a DEM.

3.2 Tide, current, and wave data

The measured tides and currents are predominantly semidiurnal with strong spring-neap variability (Figure 8). The fits of the measured water surface elevations and current velocities to the tidal model (Table 2) indicates predominantly semidiurnal components (M2, N2, and S2), with smaller diurnal components (K1 and O1) and a modest quarter-diurnal component (M4). The tidal model captures 98% of the measured variability in surface elevation and 90% of the measured variability in velocity, indicating predominantly tidal processes. The measured current velocities are flood-dominant, meaning that flood currents are stronger with smaller duration than during ebb, indicating net landward transport of sediment in the inlet channel. Spectral analyses of the surface elevations and currents do not indicate other significant oscillations, such as those that are produced in some systems, for example, by harbor resonance.

Table 2 Amplitudes of tidal constituents of water surface elevation and current velocity.

Quantity	Tidal Constituent					
	M2	N2	S2	K1	O1	M4
Water surface elevation (ft)	4.25	1.01	0.67	0.59	0.46	0.05
Current velocity (ft/s)	1.08	0.25	0.16	0.08	0.06	0.33

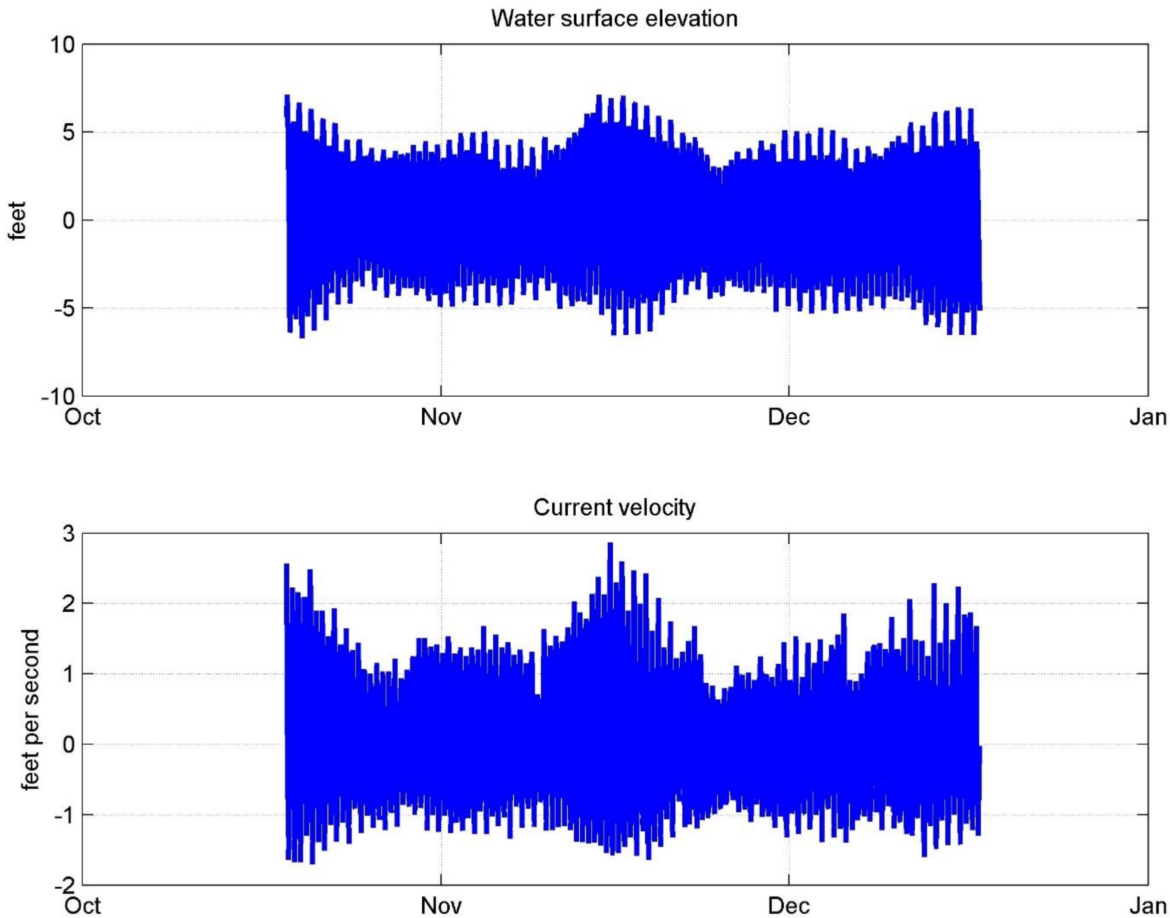

Figure 8 Timeseries measurements of water surface elevation (top panel) and velocity (bottom panel).

The largest waves at the AWAC location in Pamet Harbor were propagating from the west, consistent with entrance through the inlet from Cape Cod Bay (Figure 1b). Large waves in Pamet Harbor coincided with large incident wave events just outside Pamet Harbor in Cape Cod Bay (Figure 9). The wave heights and periods at the AWAC location were approximately 40% and 80%, respectively, of the incident wave heights and periods. The wave heights at the AWAC location were far too small to be consistent with depth-limited breaking. The wave energy loss between Cape Cod Bay and the AWAC location is attributed to the energy dissipation between the jetties, as well as refraction into the shallow crenulate bays north and south of the entrance channel. For example, Figure 10 shows wave refraction into the southern crenulate bay, with negligible waves apparent at the AWAC site, when offshore waves in Cape Cod Bay were incident slightly north of west.

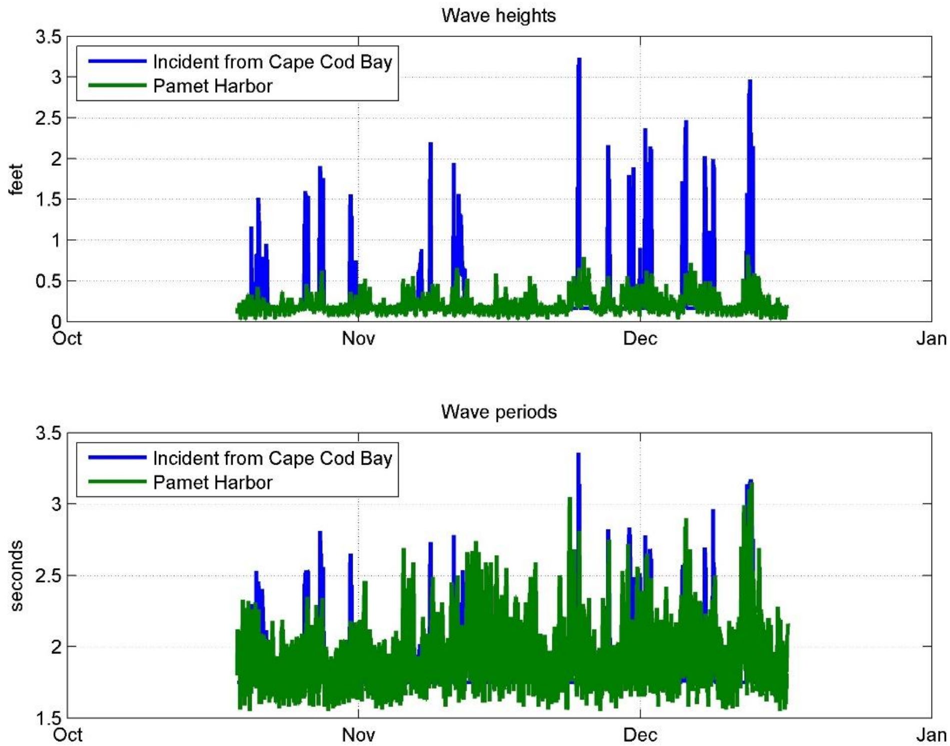

Figure 9 Wave heights (top panel) and periods (bottom panel). The incident wave statistics just outside Pamet Harbor in Cape Cod Bay were estimated from NDBC Buoy 44090 (Figure 1a). The wave statistics inside Pamet Harbor were obtained from AWAC measurements (Figure 1b).

Figure 10 Photo showing waves propagating from Cape Cod Bay and refracting into the crenulate bay south of the navigation channel. Figure source: Google Earth.

3.3 INLET CURRENT PROFILE MEASUREMENTS

The shipboard ADCP measurements indicate that the strongest tidal currents occur in the relatively deep inlet channel, with much smaller currents in shallow water inside the crenulate bays. In particular, Figure 11a, which summarizes all of the velocity measurements as a function of distance from the channel centerline, shows that the velocities in the channel are up to ±2.5 ft/s, while the corresponding velocities in the crenulate bays are weaker than approximately ±0.5 ft/s. Figure 12 shows the spatial patterns of the depth-averaged velocities throughout the approach, inlet, channel, and harbor during maximum flood current and maximum ebb current, again demonstrating that the currents are strong in the channel and weaker in the crenulate bays.

Similarly, calculations of the tidal current-driven sediment transport rate using the velocity measurements based on a standard model indicate that the sediment transport rate in the shallow crenulate bays is negligible compared with the corresponding rate in the deeper channel (Figure 11b). Figure 13 shows the spatial distribution of the sediment transport rates, again demonstrating large rates in the channel and much weaker rates in the crenulate bays. The velocity measurements and sediment transport model indicate that the net sediment transport rate in the channel is landward, i.e. towards Pamet Harbor from Cape Cod Bay.

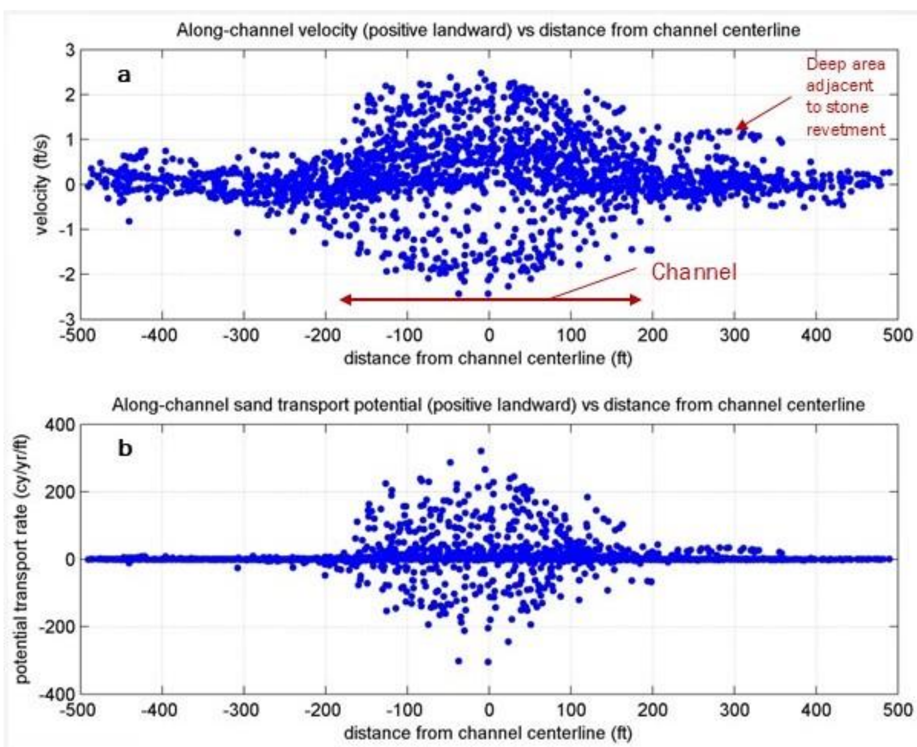

Figure 11 (a) Current velocities and (b) sediment transport rates as functions of cross-channel position.

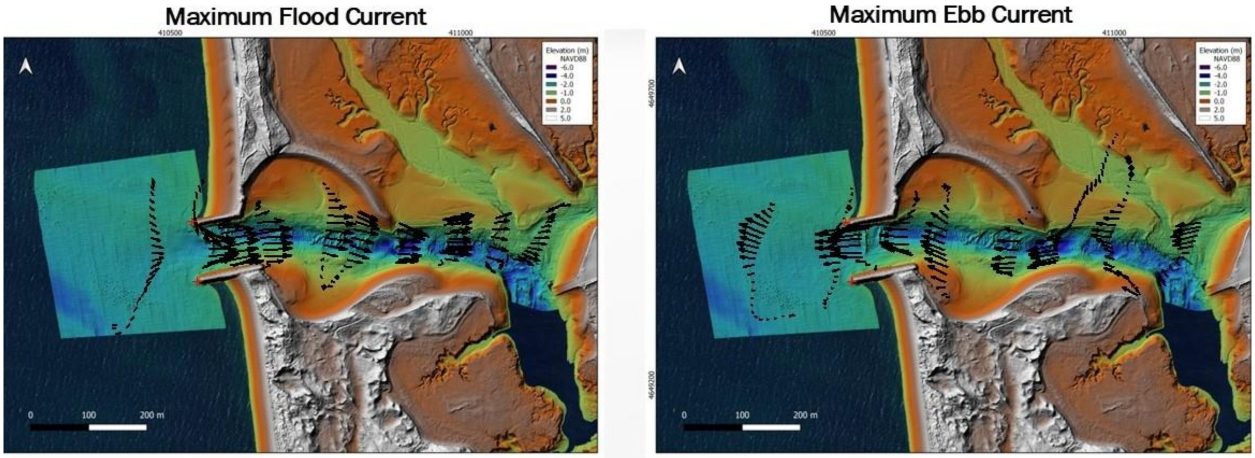

Figure 12 (a) Flow velocities during maximum flood and ebb currents.

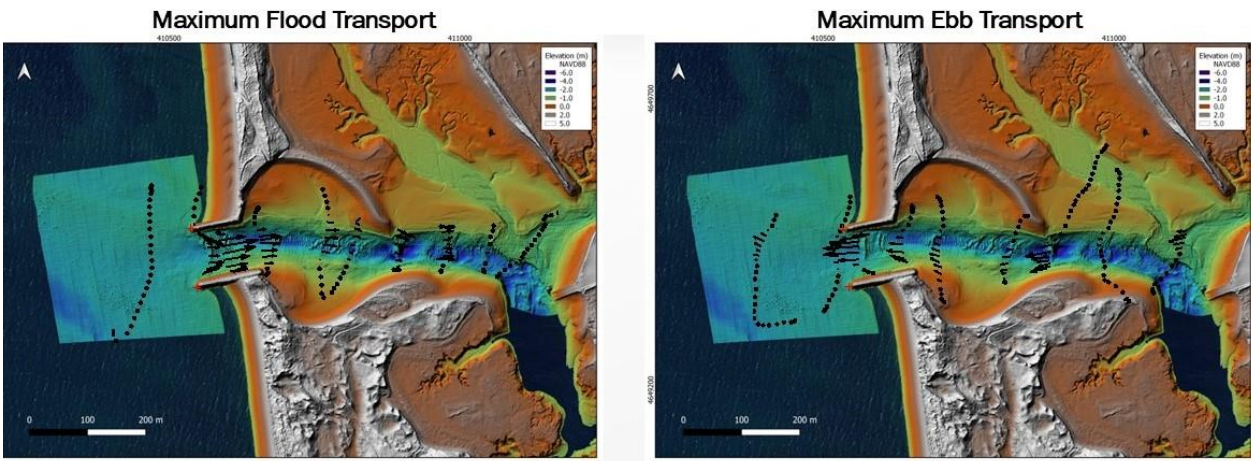

Figure 13. (a) Sediment transport rates during maximum flood and ebb currents.

3.4 Shoreline Change Analysis

The delineated shorelines based on aerial imagery from 1971 to 2023 indicate erosion on Cape Cod Bay south of the jetties and rapid development and evolution of the crenulate bays landward of the jetties (Figure 14). First, shoreline change rates were analyzed for the entire time period (1971 to 2023) to provide long-term trends along Cape Cod Bay facing shoreline (Figure 15a). This study period includes any significant storms this shoreline has experienced over the past 52 years. An examination of the long-term shoreline change rates shows that south of the jetties is erosional, with a minimum shoreline change rate of -1.31 ft/yr, an average rate of -3.65 ft/yr, and a maximum, severe erosion rate of -6.13 ft/yr occurring near the southern jetty. The shoreline change rate to the north of the jetties is slightly accretional with a minimum shoreline change rate of +0.26 ft/yr, an average rate of +0.60 ft/yr, and a maximum accretion rate of +0.82 ft/yr occurring near the northern jetty.

A short-term shoreline change analysis along Cape Cod Bay was conducted to identify the trends over the past (14) fourteen years (2009 – 2023). Because of the substantial configuration changes in coastal geometry that have occurred since installation of the northern jetty spur in 2009, the more recent (2009-2023) shoreline change rates are the most meaningful for the purposes of the present study. The short-term shoreline change transects indicate that the shoreline throughout the study area is erosional at rates averaging -5.81 ft/yr and -3.82 ft/yr on the southern and northern shorelines, respectively, with the greatest rates near the jetties (Figure 15b). This demonstrates how both shorelines north and south of the inlet are erosional and how this rate of change is accelerating since the jetty spur was installed in 2009.

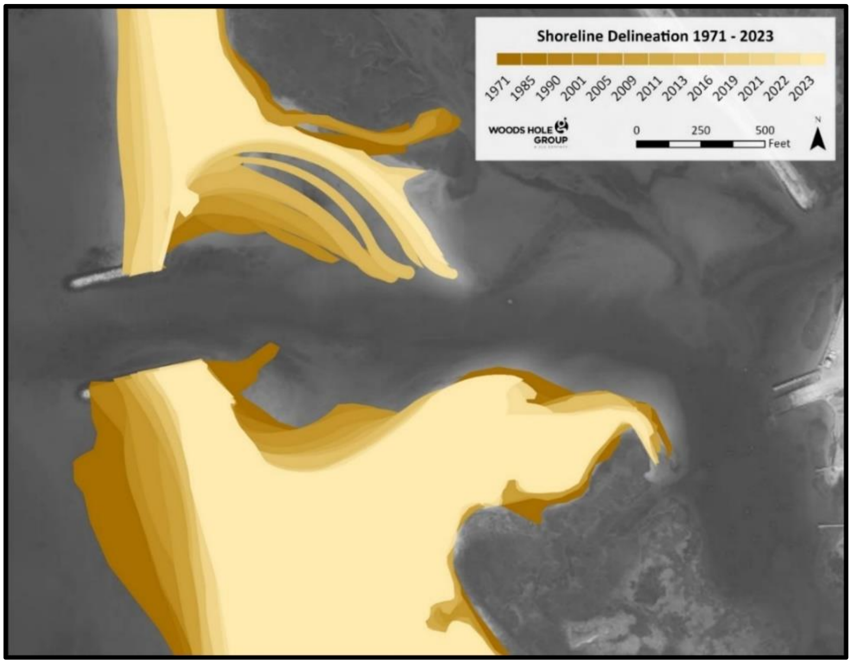

Figure 14 Delineated shorelines from 1971 to 2023, showing rapid erosion on Cape Cod Bay south of the jetties and the evolution of the crenulate bays landward of the jetties.

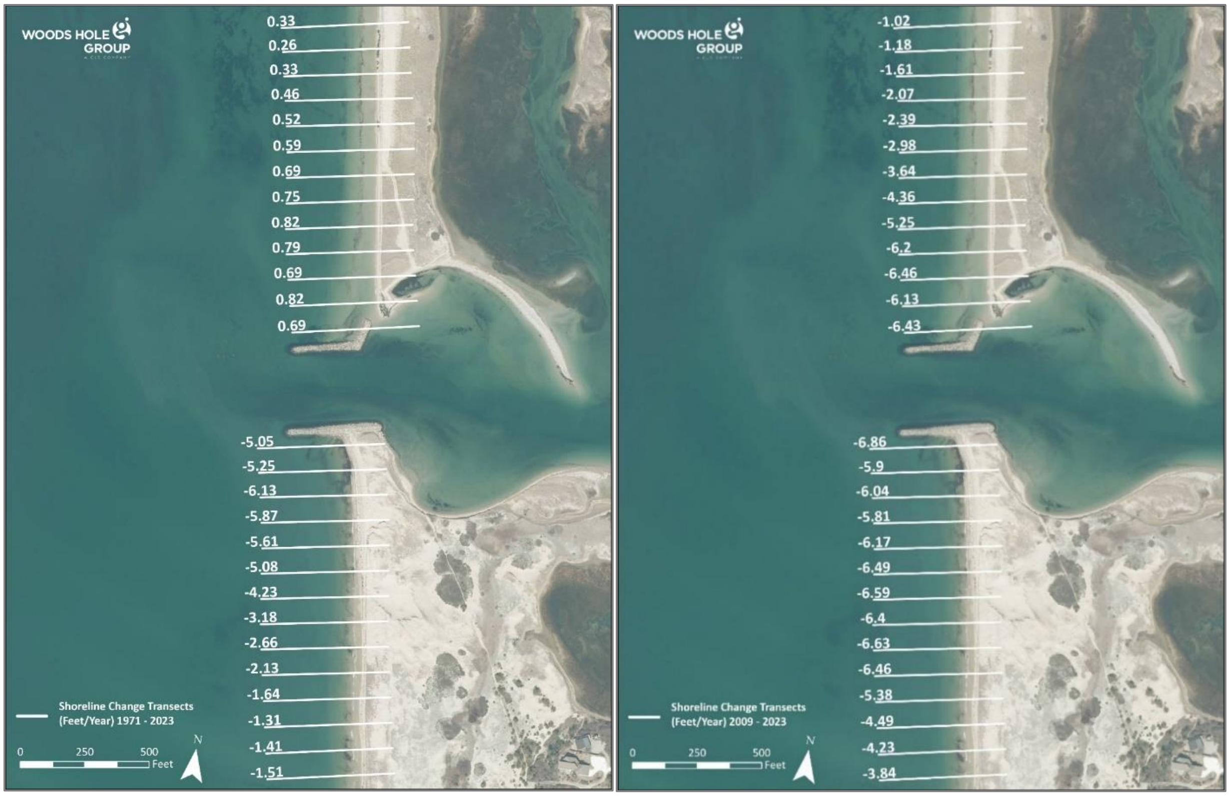

Figure 15a & 15b Shoreline change transects showing long-term (1971 – 2023) and short term (2009 – 2023) trends. Background: 2023 MassGIS digital orthoimagery.

3.5 Analysis of Historical Dredging and Placement

The dredge records (Table 3) indicate a 25-year dredged total of approximately 113,000 cubic yards or approximately 4,500 cubic yards on an annual basis. The source locations are predominantly in the Harbor and the Harbor Channel and Basin, with smaller amounts from the inlet and approach (Table 4).

Table 3 Dredge records for Pamet Inlet and Harbor.

Fiscal Year		Source Location	Cubic Yards
2000		Harbor	13,187
2012		Harbor Channel	12,857
2014		Harbor	2,908
2015		Harbor	22,857
2016		Harbor	10,778
2017		Inner Harbor	8,111
2018		Inner Harbor Basin	5,879
2019		Harbor/Basin	10,000
2020		Approach and Inner Channel/Mooring Basin	14,653
2021		Harbor Approach and Inlet	1,572
2022		Harbor Inlet, Approach, and Basin	3,299
2024		Harbor Inlet, Approach, and Basin	6,570

Table 4 Annualized dredge rates by source area (cubic yards per year).

Approach	Inlet/Channel	Harbor/Basin	Total
400	900	3,200	4,500

3.6 First level sediment budget and inlet stability analysis

A sediment budget is a management tool that calculates an estimate of the sediment transport rates within a pre-defined area of the coastal zone accounting for all sediment sources, sinks, and transport pathways. The regional scale sedimentary regime surrounding Pamet Harbor is characterized by estimates of short-term erosion rates (1970-2018) in the Massachusetts Coastal Zone Management (CZM) Coastal Erosion Viewer. North of Wellfleet Harbor in Cape Cod Bay (Figure 1a), many of the CZM rates along individual cross-shore transects are not statistically different from zero. Taken collectively, however, these rates indicate a predominantly erosional environment in northwest Cape Cod Bay.

Estimates of potential wave-driven longshore sand transport on the open coast outside Pamet Harbor (described above in Section 2.6) indicate episodic, predominantly northward transport with occasional southward pulses (Figure 16). The mean potential transport rate is a few thousand cubic yards per year, and the standard deviation is much larger. These estimates are potential in the sense that they assume an adequate supply of readily transportable sediment on the beach. If the supply of readily transportable sediment is limited by inadequate updrift supply or coarsening and resulting armoring of beach sediments, as is likely given the overall erosional environment on the scale of northwestern Cape Cod Bay, then the wave-driven longshore transport on the open coast is smaller.

Based on these considerations and the results presented in the preceding subsections, the first level sediment budget for Pamet Harbor (Figure 17), indicates mean northward sediment transport on the open beaches outside the Harbor of approximately 30,000 cubic yards per year, landward mean transport through the inlet channel of roughly 3,500 cubic yards per year, to which roughly 600 cubic yards per year is added by wave-driven erosion within the crenulate bays, and enhanced erosion rates immediately north and south of the jetties protecting the inlet. Approximately 25,000 cubic yards bypasses the inlet and continues north. Sand removal by anthropogenic dredging operations balances the net inflows to the approach, inlet and channel, and harbor. The enhanced erosion in the vicinity of the jetties is likely caused by the net landward sediment transport in the inlet channel. The landward transport through the channel is large enough to overcome the buildup of sand just south of the south jetty, which would ordinarily be expected in the presence of the northward net transport on the beach. Sediment accumulation south of the south jetty apparently occurred before 1971, as indicated by Figure 14 (above), but the updrift supply since 1971 has not been sufficient to keep up with the net landward transport through the inlet channel.

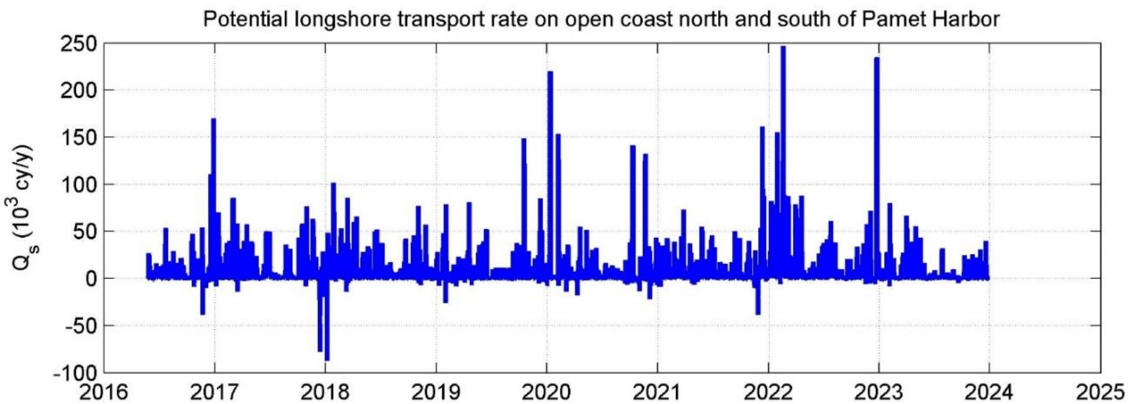

Figure 16 Wave-driven potential longshore sand transport on the open coast outside Pamet Harbor (positive north).

The sediment transported from Cape Cod Bay into the inlet is dispersed within Pamet Harbor and ultimately removed by dredging. If there were no dredging, the Harbor and entrance channel would gradually fill with sand. This analysis neglects sediment input from the Pamet River, at the eastern end of the larger estuary surrounding Pamet Harbor and not shown in Figure 17. The river likely makes a negligible contribution to the sediment budget in the vicinity of the inlet.

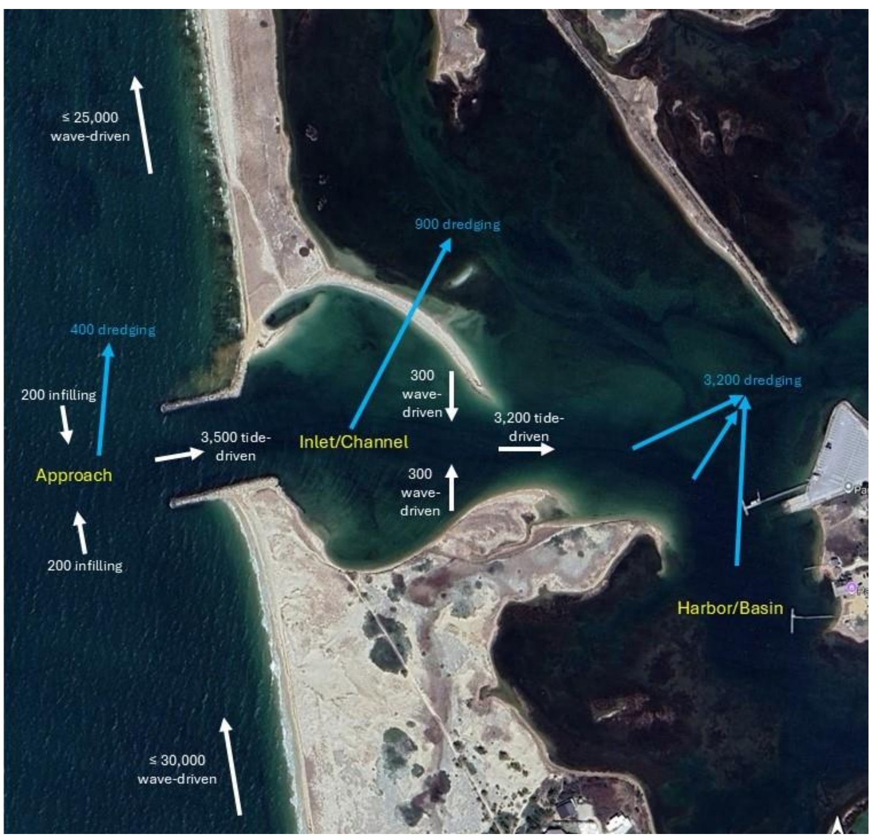

Figure 17 First-level sediment budget for Pamet Harbor. Yellow text indicates names of features. Blue arrows and text indicate dredge operations. White arrows and text indicate wave- and current-driven sediment transport. Numbers are transport rates (cubic yards/yr).

3.7 Crenulate Bay / Inlet Literature Review

The extensive professional engineering and scientific literature on crenulate bays is based primarily on one-line models (e.g., Dean & Dalrymple, 2002), in which the longshore sand transport is determined by the breaking wave height and incidence angle, which are set in turn by offshore shoaling and refraction, varying with the orientation of the shoreline relative to the incidence angle far offshore. The longshore variability of the longshore transport rate creates patterns of erosion and deposition, which can result in crenulate bays. A large incidence angle (i.e., offshore wave propagation nearly parallel to the undisturbed shoreline), facilitates growth of shoreline disturbances including crenulate bays (Ashton & Murray, 2006). Recent examples of one-line models of crenulate bays include Wang et al. (2008), Hurst et al. (2015), Buccino et al. (2021), and Tao et al. (2022).

The existing shape of the northern crenulate bay in the Pamet Harbor entrance is close to that predicted by an equilibrium model presented by Dean & Dalrymple (2002; Figure 18). The spit bordering the northern crenulate bay on the east was likely formed by storm-driven over-wash from Cape Cod Bay. This spit is migrating slowly landward, probably because of overtopping and wave-driven transport during storm surge. Further evolution of this bay is likely limited by sediment supply.

The southern crenulate bay is undergoing active evolution, as evidenced by Figure 12, and is consequently not yet in an equilibrium configuration. The dynamics of the southern bay likely differ from those of the northern bay because of the erodible sediment inside the inlet south of the channel. In time, progressive erosion on the Cape Cod Bay shoreline combined with the evolution of the southern shoreline may allow for flanking of the southern jetty, similar as to what is occurring on the northern jetty.

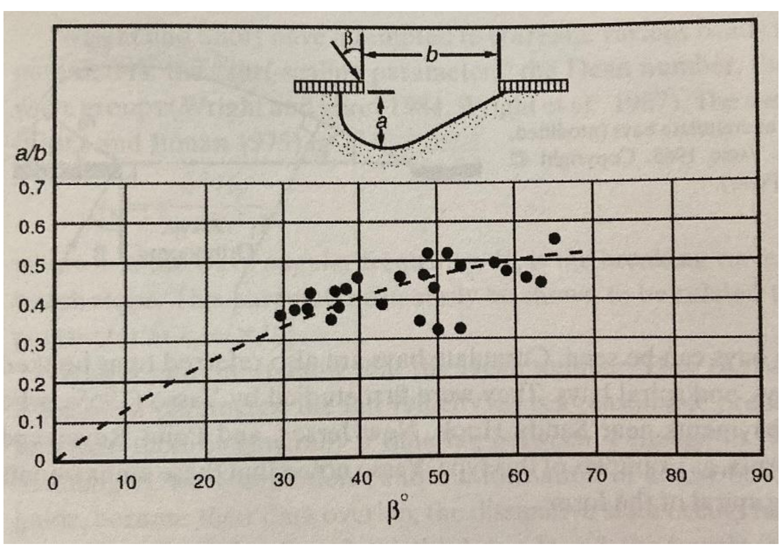

Figure 18 Equilibrium shape of crenulate bays as a function of incidence angle. Figure source: Dean & Dalrymple (2002).

4.0 CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the data and analyses conducted herein, the conclusions of the Phase 1 study are:

1) Pamet Harbor exists within a predominantly erosional environment in the northwest portion of Cape Cod Bay, as evidence by the estimates of short-term erosion rates (1970-2018) in the Massachusetts Coastal Zone Management (CZM) Coastal Erosion Viewer.
2) The tidal dynamics within Pamet Harbor and the adjacent estuary produce a net landward transport of sand through the entrance channel and into the Harbor, as evidenced by the measurements of tidal currents, the analytical model of tidal currents and sediment transport, and the dredge records.
3) The net landward transport of sand into the Pamet Harbor through the inlet is exacerbating erosion on the Cape Cod Bay beaches just north and south of the inlet.
4) Sand transport forced by waves entering Pamet Harbor from Cape Cod Bay causes erosion within the crenulate bays north and south of the inlet channel and is causing ongoing growth of the crenulate bays, as evidenced by the wave measurements, analytical wave model, and professional literature on crenulate bays.

The recommendations for the upcoming Phase 2 study are:

1. The Phase 2 study should focus on detailed analysis and design of promising alternatives aimed at the goals of mitigating erosion on the beaches outside the Pamet Harbor entrance and in the crenulate bays within the Pamet Harbor system.
2. Candidate alternatives aimed at these goals (Table 5) include no action, continued/expanded use of coir envelopes, nourishment, dune restoration, installation of an angled jetty entrance (Figure 19a), and landward jetty extension and installation of a modified terminus (Figure 19b).
3. The analytical tools should include targeted numerical simulations of (a) wave transformation, hydrodynamics, and sediment transport in the inlet and channel within the Pamet Harbor system, and (b) longshore and cross-shore transport on the beaches outside Pamet Harbor.

Table 5 Candidate alternatives, goals, and anticipated maintenance requirements.

Alternative		Goal		Anticipated Maintenance Requirements
Number	Name	Mitigate erosion on beaches outside inlet	Mitigate erosion in crenulate bays	
1	No action			Major

2	Continued/expanded use of coir envelopes	✓	✓	Moderate
3	Nourishment	✓	✓	Moderate
4	Dune restoration	✓		Moderate
5	Jetty modification: angled entrance		✓	Low
6	Jetty modification: landward extension/diamond terminus		✓	Low

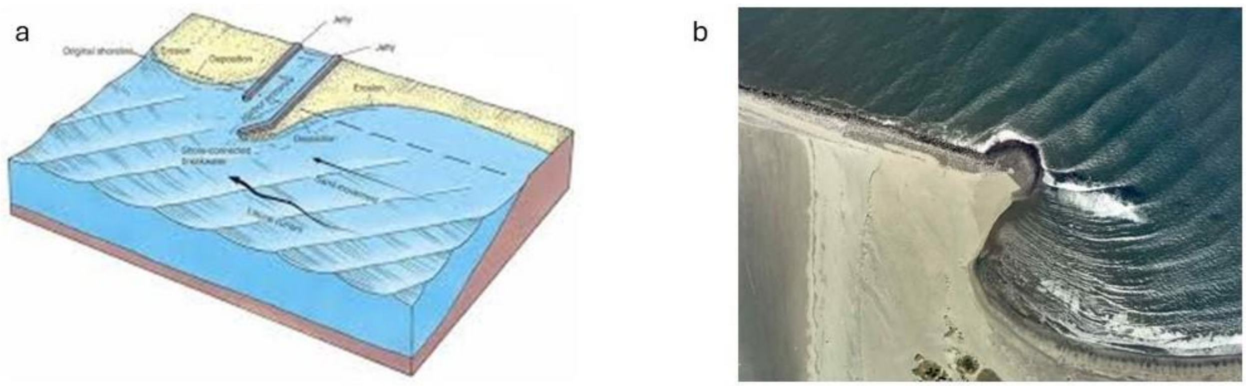

Figure 19 (a) Schematic diagram of an angled jetty entrance designed to mitigate wave attack from a preferred direction (from https://www.geocaching.com/geocache/GC964B0). (b) Aerial photograph of a diamond-patterned terminus at the landward end of a jetty, designed to modify wave refraction and diffraction patterns and mitigate erosion and expansion of Half Moon Bay in Gray's Harbor, Washing (from Seabergh, 2002).

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