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PAMET HARBOR MANAGEMENT PLAN
Truro, Massachusetts

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Planning Committee
Town of Truro
Truro, MA 02652

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1. INTRODUCTION AND PURPOSE

Truro exhibits some characteristics which set it apart from other Cape Cod towns and which mandate special consideration. These characteristics include lack of industry, small tax base, and orientation to water-dependent uses. Development pressures in Truro take a different guise than in many other Cape towns, which are fighting marina development, condominiums on the waterfront, and so on. Through development of a new Comprehensive Plan and the Harbor Management Plan, Truro residents will chart the course for future land development and water uses in Pamet Harbor. Project team members will coordinate their efforts with the ongoing Comprehensive Plan to ensure that the two resulting plans provide a coordinated framework for future land and water-use decision-making.

The intent of the Pamet Harbor Management Plan is to restore the usefulness of the Harbor, while protecting its natural resources and scenic beauty. As a small harbor subject to extreme tidal change (nine-foot rise and fall), the Pamet nevertheless hosts many varied resources and activities. This diversity of natural and human components has sometimes produced competition and conflicts. This Harbor Plan examines these resources, identifies issues relating to their use, and recommends strategies to harmonize conflicts, thereby maximizing enjoyment of the area.

Pamet Harbor is located at the mouth of the four-mile long Pamet River estuary and its tributaries: Little Pamet River to the north and Mill Creek/Eagles Neck Creek to the south. The Pamet is Truro's only boating harbor and has its major shellfish beds and wetland system. In 1987, the Pamet was designated by the Massachusetts Department of Environmental Management as a "local scenic river", the only one on Cape Cod recognized for its recreational assets and aesthetic qualities.

The Pamet Harbor Planning Committee was formed by Truro Selectmen in 1987 at the request of the Harbor Commission. In 1988, the Committee drafted a request for proposals to hire a consultant to advise on the Harbor

Plan. In 1989, the Town was awarded a $14,000 matching grant for the Harbor Plan from the Massachusetts Coastal Zone Management Office (CZM). In 1990, the request for bids was issued, but due to complications of the new state Uniform Procurement Act, no consulting contract was awarded. In 1991, the Committee worked with CZM to issue a new proposal request based on the new harbor planning guidelines of CZM. In February, 1992, the Committee issued the request, screened four applicants, and, in July, 1992, signed a contract with Horsley & Witten, Inc., an environmental consulting firm in Barnstable.

In January, 1993, the environmental consultant's contract was extended, by mutual consent, in order to accommodate results from a separate study by the Massachusetts Department of Environmental Management of the Harbor's bathymetry, in anticipation of dredging the Harbor channel. Horsley & Witten, Inc. submitted a draft Harbor Plan to the Town in September 1993.

2. PUBLIC PARTICIPATION AND EDUCATION

Building a consensus for action is the key to implementing any harbor management plan. The planning process for the Pamet Harbor Management Plan includes broad-based participation by the Truro citizenry; both permanent and seasonal residents alike. The Harbor Management Planning Committee itself represents all interested boards and committees of town government, as well as citizen groups such as the local yacht club and conservation trust (see Appendix A).

All working meetings of the Planning Committee were advertised and open to the public. Well-attended public hearings were held on July 7, 1992; February 23, 1993; and July 15, 1993. The July meetings were purposely held during the height of the summer season to encourage attendance by Truro's large summer population. Comments were recorded and used to refine planning materials.

The Committee also solicited public opinions through the use of a narrative-type attitudinal survey (see Appendix B). The consultants also conducted extensive interviews with Harbor users and town officials for their opinions about harbor planning issues. Commercial fishermen submitted a petition stating their interest in seeing the Harbor become more usable and several of their representatives attended the February, 1993, public hearing.

Media coverage of the planning process has been extensive; samples are found in Appendix C. In addition to regular meetings of the Planning Committee, the consultants presented their Harbor findings to a large audience of the Truro Neighborhood Association forum on the Pamet on August 23, 1993 (see Appendix C).

In July, 1993, with assistance from the Center for Coastal Studies, Truro officials installed permanent interpretive displays at the Harbor parking lot, educating visitors about the Pamet's salt marsh and estuarine resources.

3. BOUNDARIES OF HARBOR PLANNING AREA

The primary study area (Figure 1) for this Harbor Plan was selected by the Harbor Planning Committee in 1991 and confirmed by the consultants and a Planning Committee report of September 8, 1992:

Beginning at a point ten (10') feet below mean low tide from the shores of Cape Cod Bay, a line going east and touching the southern edge of the Corn Hill parking lot (Sheet 45, Parcel 50), thence following said lot line to Corn Hill Road, and then going southerly and easterly along the southern side of Corn Hill Road to a parcel of land, owned by the Town of Truro, known as the "Railroad Right of Way" (Sheet 49, Parcels 17 and 18; Sheet 50, Parcels 38 and 175). Thence, southerly along the east edge of said "Railroad Right of Way" including the parcel known as the Pamet Harbor parking lot, to a point at the southeast corner of the Aubin property (Sheet 50, Parcel 175 on said "Railroad Right of Way". From said point, westerly along the southern

boundary of said Aubin property to the "Toe of Great Hills" at the northeast corner of a parcel of land owned by Paul R. Waldman (Sheet 49, Parcel 25) and thence around the "Toe of Great Hills" to Great Hills Road; thence southerly along the eastern edge of Great Hills Road to the southeast corner of the Dalsheimer property (Sheet 49, Parcel 20) and westerly along the common east - west boundary of the said Dalsheimer property and the Town of Truro property (Sheet 59, Parcel 19) to the shores of Cape Cod Bay, and thence westerly to a point ten (10') feet below mean low tide; thence northerly following the ten (10') feet below low tide line to the beginning point. Sheet and parcel numbers refer to the FY 1991 Truro Map and Ownership Volume and ownership is as stated in that volume.

The rationale for choosing these boundaries include: (1) easily identifiable; (2) they bound the area which has the greatest effect on the Harbor and surrounding estuaries; (3) they bound the area that is consistent with the traditional uses of the Harbor.

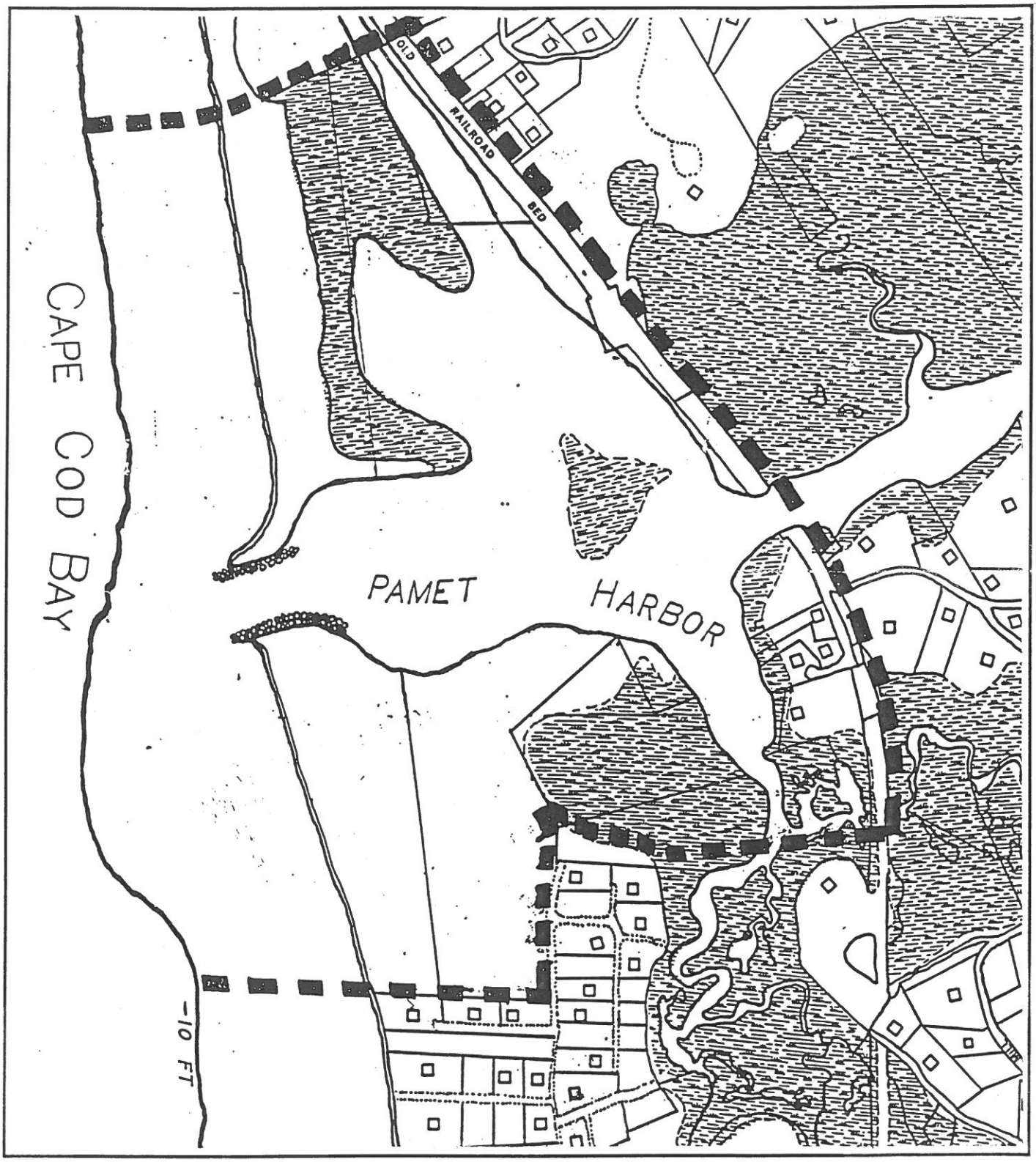


FIGURE 1.
Map Showing Boundaries of Harbor Planning Area
Pamet Harbor Management Plan

Boundary of Harbor Planning Area

North

Not to Scale

Source: Town of Truro, MA, Pamet Harbor Planning Committee, 1992

H&W, Inc.

4. FINDINGS REPORT

The purpose of this section is to evaluate the impact of land use practices, regulations and policies of the Pamet Harbor ecosystem and coastal processes. It is based upon a review of past technical reports, water quality data, aerial photographs, relevant statutes, bylaws and regulations, a series of interviews conducted by the consultant, and an assembly of computerized maps employing a geographic information system (GIS).

The majority of the analyses is focused in the immediate vicinity of Pamet Harbor according to the study area selected by the Truro Harbor Planning Committee. However, Horsley & Witten, Inc. has identified the ground water drainage basin as a project boundary for the purposes of evaluating potential contamination sources, and a more expansive public viewshed.

I. Impacts on the Marine Ecosystem

The Pamet is a deep valley, carved by glacial runoff approximately 15,000 years ago. It is a flood-dominated estuary, meaning that flood tide currents exceed those during ebb tide. This results in a net transport of sediments into the Harbor and causes shoaling. The Pamet's inlet changed cyclically, with the northward migration caused by longshore drift, followed by break-throughs further south. A diverse ecosystem comprised of salt marshes, tidal flats, barrier beaches and dunes provides a unique habitat for a variety of shellfish, finfish, a variable population of terns, mammals, other birds and humans. Although humans probably are the minority (in numbers) within this ecosystem, they have had, and will likely continue to have, the greatest impact on the Pamet.

The most significant disruption to the ecosystem during its first 15,000 years was caused by residents who (beginning in 1869) built railroad bridges, a highway bridge and various other dikes to provide access (and swamp gardens) across the Pamet. This diking converted the upper Pamet to a freshwater system. Some argue that this has provided greater biological diversity within the Pamet, providing freshwater habitat east of Route 6. Others argue for a restored ecosystem in its natural state.

A. Physical Impacts

- Dredging

Dredging is required on a periodic basis to maintain the mooring basin and the channel. Last dredged in 1965 and 1968 (see Map 1 for channel location), another dredging project is currently being planned by the Massachusetts Department of Environmental Management (DEM). Potential impacts during dredging include direct physical disruption of shellfish beds and secondary impacts, including siltation and dredged material disposal which are regulated by the Massachusetts Department of Environmental Protection. Siltation can impact shellfish by clogging their filter feeding organs and by causing oxygen depletion, which results from the biological degradation of resuspended organic materials. The selection of dredged materials disposal sites and methods must be carefully planned so as not to impact sensitive habitat areas. Commonly, a positive impact of dredging is the increase in circulation and flushing rates which tend to dilute and lower pollutant concentrations. Guidance and project review is provided by Massachusetts Coastal Zone Management.

The impacts of siltation can be mitigated by restricting actual dredging to the non-spawning season (generally, November through April) and through the use of siltation curtains. Siltation curtains are synthetic barriers which are suspended from floats during the dredging operation to limit the lateral dispersion of resuspended sediments. The disposal of dredged materials is closely regulated and dependent upon physical and chemical testing of the sediments to be dredged. An environmental notification form (ENF) is currently being prepared by DEM and will be available for public review and comment so that potential environmental impacts can be thoroughly assessed prior to making decisions regarding dredging. A Notice of Intent must also be filed with the Truro Conservation Commission. The majority of the material to be dredged appears to be suitable for beach nourishment.

- Salinity Changes

The most significant impact to salinities in the Pamet has been the placement of a series of dikes (see Maps 1 and 4). Geise and Mello (1985) estimate that 50-60 percent of the Pamet's historical salt marsh has been converted to freshwater wetlands, including all of the Little Pamet, due to such dikes. These dikes were originally constructed in 1869-70 to carry railroads across the river. Dikes were also built to convert wetlands to agricultural uses, such as the Mill Pond and Head O'Pamet cranberry bogs. In most cases, culverts were placed under the dikes allowing only one-way (seaward) drainage.

The intended benefits of the dikes either never materialized or are now obsolete. The railroad is gone. Commercial agriculture is no longer viable, and the cranberry bogs are abandoned. Dikes carrying roads have made townwide transportation more convenient, but bridges or larger culverts could accomplish the same purpose.

Three primary negative impacts of diking on the Pamet Harbor are:

1. Mosquito Control officials report that the effects of the dikes have made their work more difficult. This has resulted in increased debate between Cape Cod Mosquito Control and the Cape Cod National Seashore about the practice of ditching to drain the marshes.

2. The dikes tend to decrease flows throughout the Pamet system thereby increasing sedimentation. This is likely contributing to shoaling in the Harbor and exacerbates the need for maintenance dredging.

3. A smaller volume of seawater, also known as the tidal prism, exists because of the dikes, which limits the area of shellfish propagation and obstructs fish from breeding in the upper reaches of the Pamet.

The effects of diking on salinities and in turn, upon shellfish distribution is evident at Wilder's Dike. Low salinities were documented at Wilder's dike during low tide during a study by Richard G Lewis II (1989). Shellfish require

saline water, and the salinities at this location reach about one part-per-thousand (PPT) for about six hours per tidal cycle.

Another process which effects the salinity of the Pamet system is sea level rise. Estimated at a rate of one foot per 100 years (Geise et al, 1990), sea level rise, and subsequent flooding of tidal areas with organic sediments, is deemed responsible for the increase in elevations of salt marshes in Pamet Harbor relative to the fresh marsh in the upper Pamet. The culvert at Route 6 prevents the upper Pamet from receiving the same sediment supply.

- Boat Moorings, Docks

Boating is currently limited due to shoaling within the Harbor and the resulting shallow depths. Many boats currently sit on dry tidal flats during low tide. Boating facilities include a two-lane, 30-foot wide, concrete boat launching ramp, originally built in 1958 (widened in 1989) with state Public Access Board (PAB) funds, and adjoining parking lot with 125 spaces. In August 1993, the Truro Conservation Commission approved an Order of Conditions for a 75-foot wooden floating pier, funded by the PAB, to replace the smaller float system accompanying the ramp. An adjacent mooring basin accommodates approximately 100 boats (see Map 2). The Pamet Harbor Yacht Club maintains a small boat dock for seasonal use.

These boating facilities require periodic maintenance dredging to keep the mooring basin and the entrance channel at sufficient depth. Last dredged in 1968, a dredging project is currently being planned by Massachusetts Department of Environmental Management.

The concentration of boats and boating facilities near the parking lot and ramp has resulted in decreased opportunities for swimming and shellfishing in that area. Another potential impact associated with boating is the discharge of human wastes. However, none of the boats currently in the Harbor are of sufficient size to allow overnighting; therefore, the likelihood of significant levels of human discharges are limited.

The introduction of metals (from bottom paint) and hydrocarbons (from engine exhaust and discharges) also represents a potential threat to the Pamet Harbor ecosystem. Although no studies of the Pamet are available, shellfish (and finfish) are capable of concentrating small amounts of metals and hydrocarbons from the water column and sediments into their tissue. Many sub-lethal effects, such as mutagenic problems, have been documented in shellfish elsewhere.

Results of the 1992 citizen survey and interviews conducted for the Committee indicate that most people feel the present number of boat moorings is adequate and should not be increased. The Harbor Commission is continuing to make more efficient use of the existing space, primarily by bringing order to the formerly haphazard layout in the basin, rather than by significantly expanding the basin. Dredging the basin will mean that fewer boats will be aground on the flats at low tide. There is also support for a continued limited presence of commercial fishing boats in the harbor.

- Erosion and Sedimentation

Although systemic erosion and accretion patterns are discussed in Section II "Coastal Processes," localized potential erosion problems also exist. Some evidence of small-scale scouring resulting from propeller wash is found at the toe of the twin boat ramps. Also, recent patching with unvegetated soil of the parking lot shoulder facing the water could cause minor sedimentation into the harbor. This bare soil patching is also found at the Mill Pond Road dike repair, conducted in spring 1993.

B. Biological Impacts

- Shellfish/Beach Closures

In November, 1986, under the authority of Massachusetts General Laws, Chapter 130, Section 74A and 75, the Massachusetts Department of Environmental Quality Engineering (now DEP) closed "the waters, flats and all tributaries thereto of Pamet Harbor and Pamet River, east of a line drawn south across the east end of the jetties at the mouth of Pamet Harbor". Prior

to this the Truro Board of Health in 1985-1986 temporarily closed the shellfishing area. The Harbor has been almost continuously closed since then.

These closures have been based upon water quality data collected (primarily) at eight stations along the Pamet. Five of these stations are within the Study Area (see Map 3). Water samples were tested for total and fecal coliform bacteria, both of which are non-pathogenic bacterial indicators of other possible bacteria which may be pathogenic. The water quality standard for shellfishing areas is 14 organisms/ml (fecal coliform). Fecal coliform bacteria are derived from warm-blooded animals (including humans).

Four possible sources of coliform bacteria exist: 1) storm water runoff, 2) wildlife sources/domestic animals, and 3) boat wastes and 4) septic systems. Several surveys of the condition of septic systems within the watershed suggest that failing septics are not the primary source of coliform pollution (Davidson, 1992). Specifically, the Truro Greenway Committee conducted a septic system survey in 1985, based upon septage hauler's reports on file with the Truro Board of Health. This survey identified 14 systems which received more frequent than normal pumpouts. One of these systems, the Pamet Laundry utilized a discharge pipe and was determined to be a source of coliform contamination. In 1986 the Laundry did not receive a permit to open.

Another study of septic systems was completed by Richard Lewis II and C.S. Davidson, M.D. (1990). The authors visited approximately 75% of the septic systems abutting the river. This study concluded that septic systems are not a likely source of the elevated coliform concentrations. Viruses, however, were noted as a possible threat as they are significantly more mobile in ground water and have been demonstrated to travel great distances in sandy soils. For example, a study of septic systems on Long Island, New York, documented viruses at a distance of 183 meters from septics. Based upon ambient ground water temperatures in Truro and an average ground water flow velocity viruses can be expected to move approximately 120 feet from septic systems towards the Pamet. Dilution within the Harbor would significantly affect actual viral concentrations in the shellfishing waters.

Stormwater runoff has been identified as the major contributor to coliform problems in shellfishing areas throughout the Cape Cod region. An analysis of water quality data suggests a relationship between rainfall (runoff) and high coliform levels (Figure 2). Historically, rivers have been used as receiving waters for stormwater runoff to prevent flooding of roadways. Several pipes which discharge road runoff into the Pamet system are located at Meetinghouse Road, South Pamet Road and Wilders Dike (see Map 4). The first two of these have recently been upgraded to prevent in-water discharge.

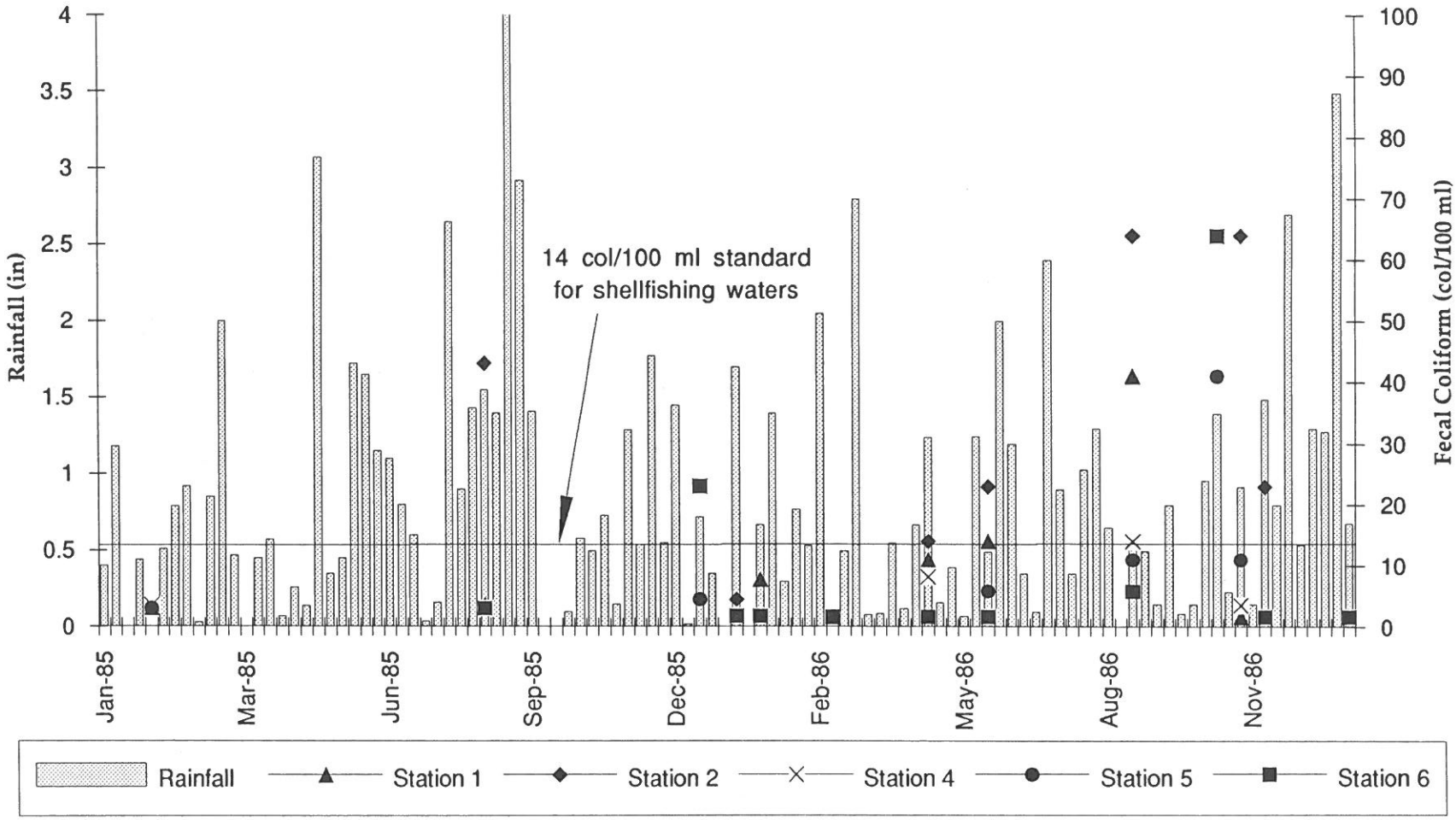
The majority of the runoff from Route 6 (between Edgewood Farm and Unionfield Road) collected in highway catchment basins and discharged into the river at the Pamet Roads exit ramp. A study conducted by M. Kim (1990) included sampling of actual runoff water sources during and after two rain events at the Route 6 bridge demonstrated very high concentrations of fecal coliforms (eleven samples averaging 45,800 organisms/ml). In 1993, the State Highway Department re-engineered this drainage system to divert most highway stormwater to leaching basins. No follow-up water quality monitoring has been conducted at this site to determine if the realignment has had a beneficial effect.

Water quality samples taken from the Depot Road parking lot at the boat ramp also indicated high coliform levels (Snow, 1992). A commitment by the State Public Access Board to divert parking lot runoff into infiltration systems, has been implemented.

Bacterial analyses conducted as part of the EPA Buzzards Bay Project suggest that bacteria may be stored (and possibly concentrated) within portions of the ecosystem. Specifically, beach wrack (which is comprised of decaying plant matter and other debris) has been found to accumulate coliforms and prolongs the survival of the bacteria. Fine-grained sediments within the Harbor near the stormwater discharge points, as well as the extensive salt marsh peat, may function similarly.

A water quality study conducted by Richard Lewis II (1989) analyzed and concluded that "the limit for swimming closure was frequently exceeded at: 1)

FIGURE 2.
Comparison of Rain Events to Coliform Concentrations - Pamet Harbor, Truro, MA



low tide in the river, 2) all the time in the creeks, and 3) everywhere in the basin after a rain event". This suggests that the primary sources of coliform pollution are rain-induced stormwater runoff. Ratios of fecal coliform to fecal streptococcus (of less than one) indicated that animal (versus human) sources were responsible for the elevated bacterial levels.

C. Chemical Impacts

The Massachusetts Division of Water Pollution Control has classified the waters of Pamet Harbor as SA, meaning that the highest standards must be met (see Table 1).

- Acidity

Although the upper Pamet River (east of Route 6) was not included in our study area, water quality analyses reported by Marine Research, Inc. (1985) suggest that this portion of the Pamet is low in alkalinity (ranging between 11 and 24 mg/liter), and therefore is poorly buffered against acidic impacts. Alkalinity is a measure of the ability of the water to withstand pH changes. This suggests that the upper portion of the river sensitive to acidic inputs such as acid precipitation and those fish which spend part of their life cycle in the fresh portion of the river may be effected (both lethally and sub-lethally) by exacerbated acidity in the river. Sub-lethal effects include impacts other than death such as lifespan, reproductive ability, etc.

- Nutrients

Very little information is available concerning nutrient concentrations in Pamet Harbor. However, it is clear from other estuarine studies throughout the Cape Cod area that nutrient enrichment can result in algal blooms (large populations which are normally visible), including those species which attach themselves to the larger vascular plants (such as eelgrass). Blooms cause declines in the these habitats, ultimately leading to declines in shellfish production.

Table 1. Coastal and Marine Water Quality Classifications

Class SA - These waters are designated as an excellent habitat for fish, other aquatic life and wildlife and for primary and secondary contact recreation. In approved areas they shall be suitable for shellfish harvesting without depuration (Open Shellfish Areas). These waters shall have excellent aesthetic value.

- Dissolved Oxygen - (a) Shall not be less than 6.0 mg/l unless background conditions are lower; (b) natural seasonal and daily variations above this level shall be maintained, levels shall not be lowered below 75 percent of saturation due to a discharge; and (c) site-specific criteria may apply where background conditions are lower than specified levels or to the bottom stratified layer where the Director determines that designated uses are not impaired.

- Temperature - (a) Shall not exceed 85°F (29.4°C) nor a maximum daily mean of 80°F (26.7°C), and the rise in temperature due to a discharge shall not exceed 1.5°F (0.8°C); (b) natural seasonal and daily variations shall be maintained, there shall be no change from background that would impair any uses assigned to this class including site-specific limits necessary to protect normal species diversity, successful migration, reproductive functions or growth of aquatic organisms; and (c) any determinations concerning thermal discharge limitations in accordance with Section 316(a) of the Federal Act will be considered site-specific limitations in compliance with these regulations.

- pH - Shall be in the range of 6.5 - 8.5 standard units and not more than 0.2 standard unit outside of the normally occurring range. There shall be no change from background conditions that would impair any use assigned to this class.

- Fecal Coliform Criteria - (a) Waters approved for open shellfishing shall not exceed a geometric mean MPN of 14 organisms per 100 ml, nor shall more than 10 percent of the samples exceed a MPN of 43 per 100 ml (more stringent regulations may apply (see §4.06 (1)(d)(4) of the Massachusetts Surface Water Quality Standards); and (b) waters not designated for shellfishing shall not exceed a geometric mean of 200 organisms in any representative set of samples, nor shall more than 10 percent of the samples exceed 400 organisms per 100 ml. This criterion may be applied on a seasonal basis at the discretion of the Division of Water Pollution Control.

- Solids - These waters shall be free from floating, suspended and settleable solids in concentrations or combinations that would impair any use assigned to this class, that would cause aesthetically objectionable conditions, or that would impair the benthic biota or degrade the chemical composition of the bottom.

- Color and Turbidity - These waters shall be free from color and turbidity in concentrations or combinations that are aesthetically objectionable or would impair any use assigned to this class.

- Oil and Grease - These waters shall be free from oil and grease and petrochemicals.

- Taste and Odor - None other than of natural origin.

A water quality study of the Little Pamet River by William Doolittle (1975) found increasing concentrations of nutrients along the Little Pamet River proceeding from Route 6 toward the river's mouth. The report, however, also indicates that little flow actually enters Pamet Harbor.

A water quality assessment tool developed as part of the EPA-sponsored Buzzards Bay Project may be useful in evaluating nutrient impacts in Pamet Harbor. This tool sets nitrogen loading limits based upon the flushing rate and size of the receiving water body. For a shallow coastal embayment with a flushing rate of 4.5 days or less, SA-classified waters have a nitrogen loading limit of 200 mg/cubic meter/Vr (Vr = Vollenweider flushing term). Waters classified as "Outstanding Resource Areas" have a nitrogen loading limit of 100 mg/cubic meter/Vr.

Horsley & Witten, Inc. applied this tool to the Pamet by analyzing the land uses within the watershed (ground water drainage area) to Pamet Harbor, modeling the existing nitrogen loading. The number of septic systems within the delineated ground water drainage basin was estimated at 725 by counting houses on the USGS Topographic Quadrangle (1972), and updating this with land use/growth data contained within the Greenway Plan (1985). These data indicate that 79 new homes were built within the Pamet area during the 1980-1985 period, suggesting an annual growth rate of 13.2 new homes per year. This growth rate was used for the years 1972-1980. A growth rate of 6.5 new homes per year was used for the 1985-1993 period to reflect the economic recession.

Because no flushing rate is currently available for Pamet Harbor, Horsley & Witten, Inc. chose two conservative values of two and four days to provide a preliminary assessment of nitrogen loading. The results of this modeling indicates that the respective nitrogen loading rates are seven and fourteen mg/cubic meter/Vr. These are well below the recommended standards, indicating that Pamet Harbor does not appear to be in any immediate danger of eutrophication.

- Metals/Hydrocarbons

Stormwater runoff is the most likely contributor of metals, oils and other hydrocarbons to the Pamet Harbor. As mentioned previously in this report, boat bottom paints and engine discharges may also be sources of metals and hydrocarbons. Tributyltin (TBT) was banned as an anti-fouling agent for smaller boats in 1990. Owing to the few numbers of docks and other wooden marine structures, preservatives, such as creosote and CCA treatments, are unlikely to cause much effect on water quality.

II Coastal Processes

The coastal processes at Pamet Harbor interact in a complex fashion to mold the Harbor and beach into a constantly evolving coastal system. The dominant coastal processes include winds, tides, waves and currents. The combination of these processes result in sediment transport along the beach and within the Harbor in the form of shifting shoals. Although the unpredictable nature of the coastal processes at Pamet create a dynamic, constantly changing environment, it is possible to make predictions on future shoreline and Harbor change based on a study of the history of the area.

A variety of studies have been completed describing the history of the Pamet Harbor area. These include Geise and Westcott (1980), Fitzgerald and Levin (1981), Geise and Mello (1985), Robinson (1987), Lewis (1989), Massachusetts Shoreline Change Project (1989), and Geise et al., (1990). These reports indicate that in the early 1800s, the Harbor supported a vibrant maritime economy. Today the Harbor is still an important recreational asset to the Town, but its value has been diminished by severe shoaling, poor water quality and beach erosion. These problems have resulted from the interaction between Man's activities and the dominant coastal processes.

Prior to human influence, the natural inlet at Pamet Harbor showed a tendency for northward migration. This migration was the result of a net northerly longshore sediment transport. The eventual result of such a northward migration would normally be for a new inlet to break through the barrier beach at a more southerly location, allowing the old inlet to shoal and

eventually close off. A modern day example of this inlet formation process is the new breach in Chatham. At Pamet Harbor, this cycle was interrupted by human attempts to stabilize the inlet near its present location. An inlet was dredged in this location in 1918-1919 and was also stabilized by stone jetties. New jetties were constructed at the inlet in 1950-1951 and the channel was dredged in 1965, and again in 1968.

The Pamet Harbor system has also been altered by the construction of dikes with tidal gates that reduce or severely restrict the tidal prism. The major barrier, Wilder Dike, was constructed in 1869 to replace a rotting bridge across the mid-section of Great Pamet, and in the mid-1950s fill for Route 6 was placed across the Pamet valley several hundred feet east of Wilder Dike. A culvert was placed under Route 6 to provide drainage from the freshwater marsh east of the highway. Dikes were also placed across Little Pamet, Mill Creek and Bank's creek for a railway in the early 1870s.

The combination of inlet stabilization and dike construction has resulted in an increase in Harbor sedimentation, a reduction in water quality, and beach erosion. Construction of jetties at the inlet entrance created a temporary block for northward moving littoral drift. Sand accumulated behind the southern jetty until the shoreline built out to the end of the jetty. This interruption in littoral drift resulted in erosion of the shoreline above the north jetty. At this point, the effectiveness of the jetty in blocking littoral drift from entering the inlet was severely reduced. During flood tides, sand is transported around the end of the jetty into the Harbor and deposited on the flood-tidal shoals. During ebb tides, small quantities of this sand are transported back to the ebb-tidal shoal, and are then available for continued northerly transport. However, because of the reduction in tidal prism created by the dikes, the current velocities within the channel have been reduced and the self-flushing capabilities of the channel are limited. This compounds the shoaling problems in the Harbor, since the current velocities are not high enough to scour a natural channel.

The high sedimentation rates within Pamet Harbor are therefore due to accretion of the beach out to the west end of the south jetty, and resultant sediment transport into the inlet entrance during flood tides. Low current

velocities and tidal prism created by construction of the dikes has also contributed to sedimentation within the Harbor. Additionally, the reduction in tidal prism has resulted in decreased water quality and tidal flushing. Erosion of the northern barrier beach has been caused by a reduction in available sediment supply, as northward moving littoral drift is trapped by the south jetty and then transported into the Harbor.

III. Sediment Quality

A knowledge of the sediment quality within Pamet Harbor is important for several reasons. First, the design and construction methods associated with a potential dredging project within the Harbor could be impacted by poor sediment quality. Second, the type and quality of sediments identified can be used to infer potential environmental problems related to oil spills, boating impacts and poor water quality.

On September 22, 1992, Aubrey Consulting, Inc. collected a series of surface grab samples in the Pamet Harbor system. These samples were collected in a variety of locations, including the mooring basin, tidal flats, entrance channel and adjacent barrier beaches. A qualitative analysis was performed on the samples to identify the general sediment characteristics. Samples collected from the outer shoals and barrier beach are composed of clean, well-sorted medium to coarse-grained sand. Those samples collected from the channel and shoals immediately inside the inlet entrance are composed of clean medium-grained sand with trace amounts of organics. Fine gravel sediments with organic deposits were found within the deepest portions of the mooring basin near the public launching ramp. These sediments consisted of silty muds with significant quantities of organic material. Samples collected from the tidal channel leading south from the mooring basin contained medium-grained sand and organics.

Based on the qualitative analysis of sediment characteristics and the proposed plans for channel/mooring basin dredging, it appears that most of the sediments will be of suitable quality for beach nourishment. The only area requiring further consideration and sampling is the mooring basin. Additional samples are being collected in this area, down to the depth of

proposed dredging, and will be tested for contaminants. Although this qualitative analysis indicates that the sediments in Pamet Harbor are generally of high enough quality for dredging and beach nourishment, it is certain that the local, State and Federal permitting agencies will receive detailed grain size and contaminant analyses prior to approval of dredging in the Harbor.

IV. Analysis of Land Use Regulations

Truro's land use regulations provide a blueprint for development and act to discourage or encourage land practices which have a direct impact on the Pamet Harbor's marine resources, water quality, coastal processes, and scenic vistas. There are several regulatory options available to guide land development including: zoning bylaws, subdivision rules and regulations, health regulations, wetlands bylaws, and waterways regulations. This section reviews current land use and water use regulations which affect Pamet Harbor.

A. Zoning Bylaw

The type of land development which will occur in the Pamet Harbor study area is dictated by Truro's Zoning Bylaw. The intensity, location, and type of land development has a direct impact on the level of pollutants which will be released to the Harbor ecosystem. The scale and type of permitted development also affects scenic vistas to and from the Harbor. A recent study of the Pamet River ecosystem indicated that the Pamet River is experiencing increasing problems due to poor water quality. The Harbor is currently closed to shellfishing due to high bacteria levels. Potential sources of bacteria include the release of wastewater effluent from septic systems, stormwater runoff, and wildlife. The density of development provided through zoning would determine the number of septic systems used in the study area, and the volume of stormwater runoff generated owing to increased impervious surfaces such as roofs and driveways.

A buildout analysis was completed for the Town of Truro in 1986 (IEP, Inc.). Results of the buildout analysis indicate that a large increase in development and population is possible.

Land in the drainage area to the Pamet Harbor is located in one or more of the following zoning districts:

1) Residential;
2) Truro Center Limited Business (shown as General Business on the Zoning Map;
3) Route 6 General Business;
4) Seashore District;
5) Flood Plain District.

The majority of the drainage basin is located in the Residential District. Permitted uses include single family dwellings, home occupation, civic uses, and agriculture-related uses. Uses requiring a special permit include: research facilities, raising of livestock, fur-bearing animals, or fowl, and marine installations. Uses which involve the raising or handling of animals may represent a significant source of nutrient and bacteria loading to nearby water supplies; therefore, their impact on the Pamet Harbor and River should be considered before a special permit is issued. Likewise, research facilities and marine installations can pose a threat to nearby water quality due to the handling and storage of hazardous materials.

A relatively small portion of the Pamet Harbor drainage area is zoned for business uses. The Truro Center Limited Business District and the Route 6 General Business District are located in the Harbor's drainage area. These districts allow a range of retail, office, and business uses including activities such as auto service stations and repair garages which typically handle or store hazardous materials. To provide a higher level of review of activities which threaten water quality, it is recommended that all uses which handle, store, or generate hazardous or toxic materials require a special permit for approval.

Land uses located in the Seashore District are restricted to conserve natural conditions, wildlife, and open space. Very little future development is expected in this district due to the lack of large remaining developable tracts of land.

Truro regulates development in its Flood Plain District. Much of the low-land surrounding the Pamet Harbor is prone to flooding. Development in flood-prone areas may be restricted to prevent loss of life and property. On land designated as coastal high hazard areas, Truro requires that new construction be located landward of the reach of mean high tide. Man-made alteration of dunes is prohibited. On lands where construction is permitted, design controls have been adopted to minimize storm damage and loss of flood storage area. Lands located in the Flood Plain District are expected to change over time due to coastal processes such as sea-level rise. The Town of Truro may wish to amend its Zoning Bylaw to require the effects of sea-level rise be considered before any building permits for structures in the Flood Plain District are issued.

In addition to guiding the location, type, and intensity of development, zoning controls may be used to guide the character and aesthetics of an area. Pamet Harbor offers scenic vistas to residents and visitors alike. Land around the Harbor consists of gently rolling bluffs and low-lying coastal dunes. The height and location of structures may be limited through zoning to protect scenic vistas from the water to the land and vice versa. The Truro Zoning Bylaw limits building height; however, vistas could be better protected through requiring structures to be placed at lower elevations whenever possible, rather than on the bluff ridges. Landscaping requirements may also be adopted to provide a natural scenic buffer between structures and the Harbor. A 1990 viewshed analysis of the Pamet River, conducted by the Truro Conservation Trust, provides data on scenic overlooks and public viewsheds.

The Site Plan Review process is one tool which may be used to ensure compliance with design standards (such as building size, location, and landscaping) and water quality criteria. Site Plan Review is currently required for large developments. However, the town may wish to require Site Plan

Review for all new uses and structures located immediately adjacent to the Harbor to provide better control of development impacts.

B. Subdivision Regulations

Subdivision regulations "fine-tune" zoning bylaws by addressing site-specific design concerns such as street construction, utility placement, and traffic patterns in subdivisions.

It is believed that release of stormwater is one cause of high bacteria levels in Pamet Harbor. Subdivision regulations typically provide guidelines for drainage control. In order to minimize release of stormwater to the Harbor, it is recommended that new subdivisions be required to retain stormwater on-site through infiltration whenever possible. The use of vegetated swales and detention areas would also serve to contain stormwater-generated contaminants on-site.

C. Health Regulations

Local Boards of Health may adopt regulations to protect public health. Water quality is one important aspect of public health. The Town of Truro has adopted several regulations aimed at protecting water quality. On-site sewage disposal is often a major source of water pollution. The Truro Board of Health has adopted regulations which require that on-site disposal systems be upgraded to meet Title 5 standards of the State Sanitary Code prior to the sale of property, change of use, and land subdivision, or in cases where a system requires frequent pumping (three or more times annually). Systems must also be upgraded to Title 5 standards before an applicant receives a building permit to increase living space, a special permit, or a new license or transfer of an existing license for operation of a motel, cottage colony, cabins, campgrounds, lodging house, or restaurant.

Regulations have also been adopted to minimize the release of toxic or hazardous materials town-wide. Landowners and petroleum or other chemical distributors are required to register fuel storage tanks with the Board of Health. Old tanks (over 15 years old) must be tested to detect leaks and all

spills must be reported to the Board of Health, Fire Chief, and owner. Use of herbicides are only allowed with the approval of the Board of Health, with the exception of home application. Use of septic tank cleaners or cesspool cleaners which contain organic chemicals is also prohibited.

The Truro Board of Health has adopted regulations which are specifically aimed at protecting the town's surface waters, including Pamet Harbor. In 1987, the Board of Health adopted the Pamet River Protection District. In this district, no new septic systems may be installed within 100 feet of wetlands and all failing septic systems must be upgraded to meet Title 5 requirements. In 1988, the Board of Health adopted regulations aimed at minimizing negative development impacts on the town's surface waters. All commercial and multi-family developments must obtain a permit from the Board of Health to discharge septic system effluent. As part of the permit application, the developer must submit a nutrient loading analysis for nearby surface waters in cases where a septic system or fertilized lawn area would be located within 300 feet of a surface water or in the recharge area of a surface water, such as the Pamet River and Harbor. The developer must also explain how road runoff would be treated. In cases where the development would produce or store hazardous or toxic materials, the applicant must explain how these materials would be handled, stored, and disposed of, and their impact on public health and safety.

D. Wetlands Bylaw

Alteration of wetland areas is overseen by the Truro Conservation Commission in accordance with the Massachusetts Wetlands Protection Act (WPA). However, many Massachusetts communities have adopted wetland bylaws which offer increased resource protection beyond the minimum standards mandated by the WPA The adoption of local wetlands bylaws has been upheld by the Massachusetts Supreme Judicial Court. The Court recognizes that the state act serves as the starting point for wetlands protection. For example, local Conservation Commissions may adopt a local bylaw to protect local marine and inland resources through adopting additional development restrictions for lands directly or indirectly impacting these resources, or through protecting wetlands for specific purposes other

than those included in the state act. Despite at least two attempts in the past ten years, the Town of Truro has not adopted a local wetland bylaw, the only Cape Cod town not to do so.

E. Waterways Regulation

The types and intensity of water uses, as opposed to land uses in Pamet Harbor, may in the future be controlled through adopting waterways regulations, such that the Harbor is effectively "zoned". Alternatively, an actual zoning district can be created separating incompatible waterways uses. In Pamet Harbor, uses such as swimming, SCUBA diving, and snorkeling are prohibited by the Harbor Commission in navigable waters. In addition, jet skis and hovercraft may only use navigable waters of the Pamet Harbor which extend from the launching ramp through the jetties as a means of egress. Speed limits are imposed in the inner Harbor to ensure safety.

Presently, the Pamet Harbor Commission adopts regulations for the harbor and these regulations are implemented and enforced by the Harbor Master. He also oversees the location and use of boat moorings. The town charges a fee for all moorings. Moorings should be installed under the supervision of the Harbor Master and must be placed out of navigation channels and away from other boats. Moorings may not be transferred and reserved mooring locations are lost if they are not used for two consecutive years.

V Summary

1. To date, the most significant impact to the ecosystem of Pamet Harbor has been the construction of a series of dikes and bridges which has significantly changed salinities, temperatures and water flow patterns.

2. Periodic dredging is required to maintain the channel and mooring area in Pamet Harbor.

3. Since 1986 the Massachusetts DEP has closed portions of Pamet Harbor to shellfishing due to high coliform bacteria counts.

4. Available data indicates that the two most significant sources of coliform bacteria pollution are stormwater runoff from roads and wildlife sources within the estuaries extensive wetland system.

5. The high coliform bacteria counts appear to be related to rainfall events, indicating that a "rainfall closure" might be implemented by Massachusetts DEP. This would allow for opening of the shellfishing areas between rain events.

6. A preliminary nitrogen loading analysis indicates that Pamet Harbor does not appear to be significantly threatened by excessive nitrogen inputs from septic systems, lawn fertilizers and road drainage. A more detailed analysis of this will be provided in the next phase of work on the project.

7. The migration of the Harbor inlet is cyclical in nature, moving from south to north. This is a result of northerly longshore sediment transport. The eventual result has been the formation of a breach in the barrier beach at the southerly end, reinitiating the cycle.

8. The establishment of jetties at the inlet in 1918 changed this natural migration by interrupting the sediment movement.

9. Shoaling on the updrift (southerly) side of the jetties has built up and is currently spilling over into the channel, resulting in the need for the currently-proposed dredging project.

10. Preliminary sediment testing within the Harbor indicates that the contamination does not exist, but that grain size may necessitate alternative disposal sites for a portion of the dredged material. The majority of the sediments can be used for beach nourishment.

11. The Zoning Bylaw requires a Special Permit for certain land uses such as research facilities, raising of livestock, fur-bearing animals, or fowl, and marine installations. As these uses represent potential water

quality threats, their impact on Pamet Harbor should be fully evaluated before issuing Special Permits.

12. The Town has adopted a number of innovative Health Regulations. One of these includes the Pamet River Protection District, in which no new septic systems may be installed within 100 feet of wetlands and in which all failing systems must be upgraded to meet state Title 5 requirements.

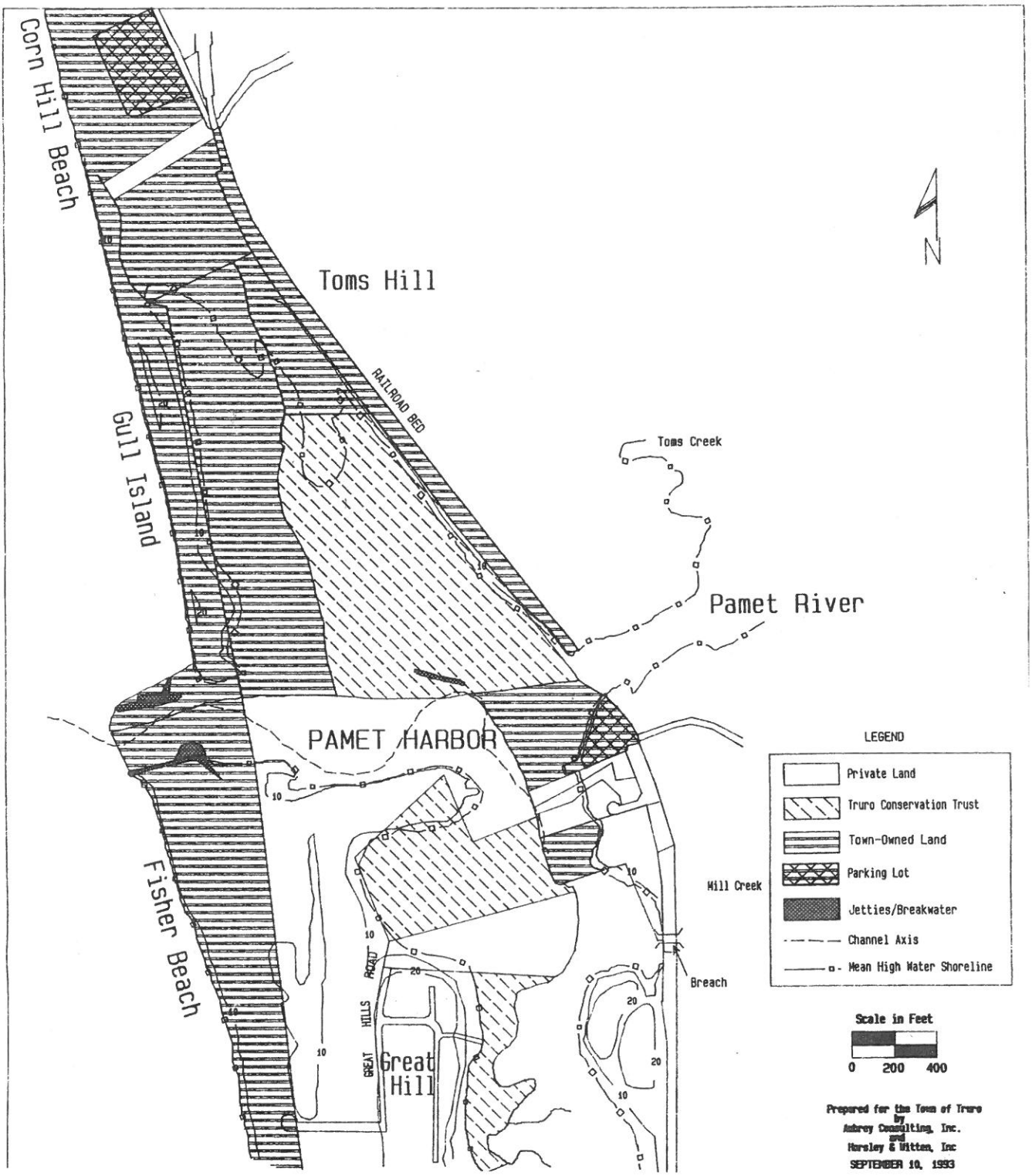
13. Truro is the only town on Cape Cod without a local Wetlands Protection Bylaw. Such bylaws provide significant protection powers to protect resources such as Pamet Harbor.

14. The Town has adopted Waterways Regulations which effectively zone uses such as swimming, SCUBA diving, and snorkeling (which are prohibited in "navigable waters". In addition, jet skis and hover craft may only use navigable waters of the Pamet Harbor which extend from the launching ramp through the jetties as a means of egress. Speed limits are imposed in the inner Harbor to ensure safety.

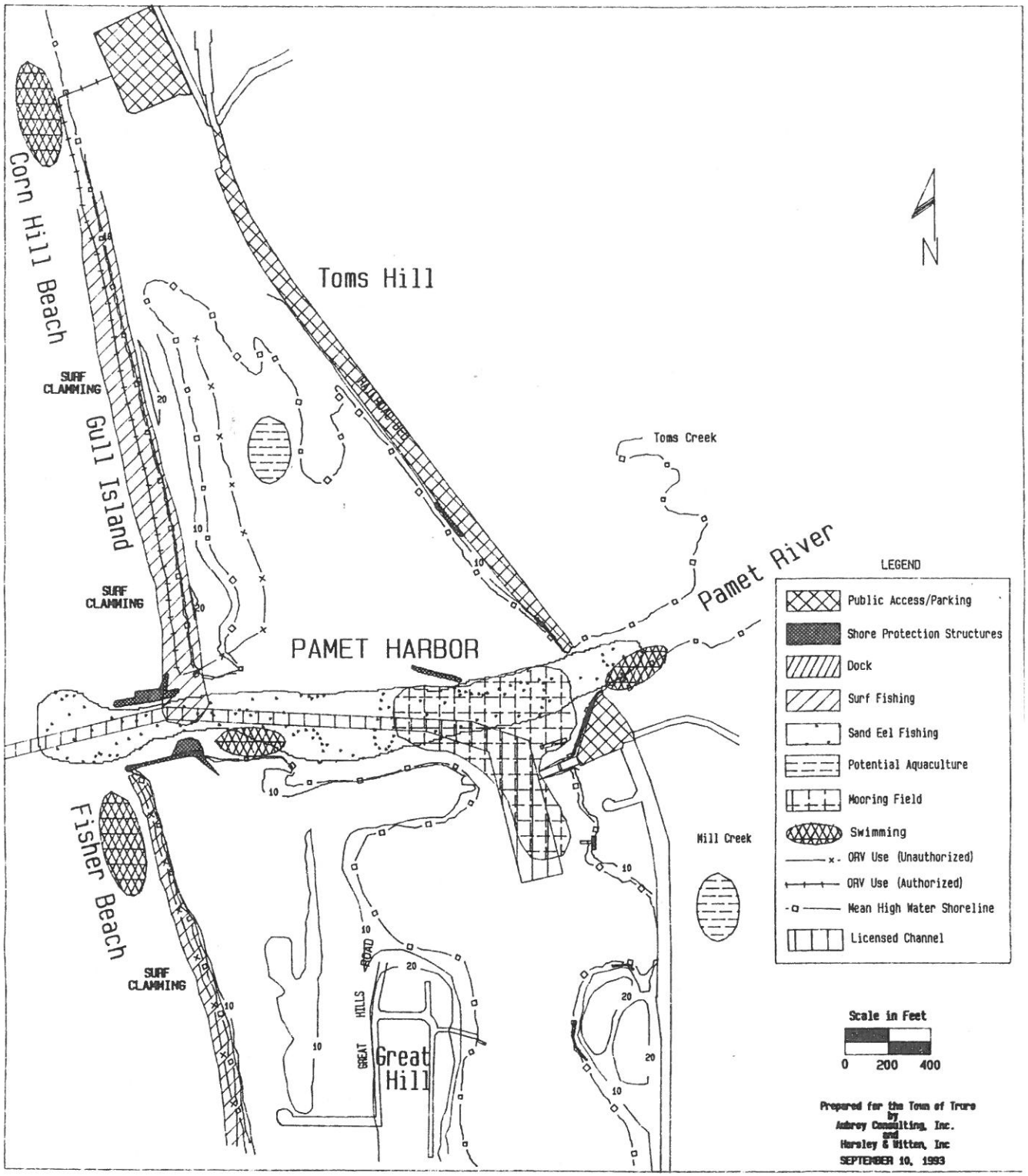
15. Moorings in Pamet Harbor are supervised by the Harbor Master, who oversees the location and use of boat moorings. The Town charges a fee for all moorings.

5. MAPS

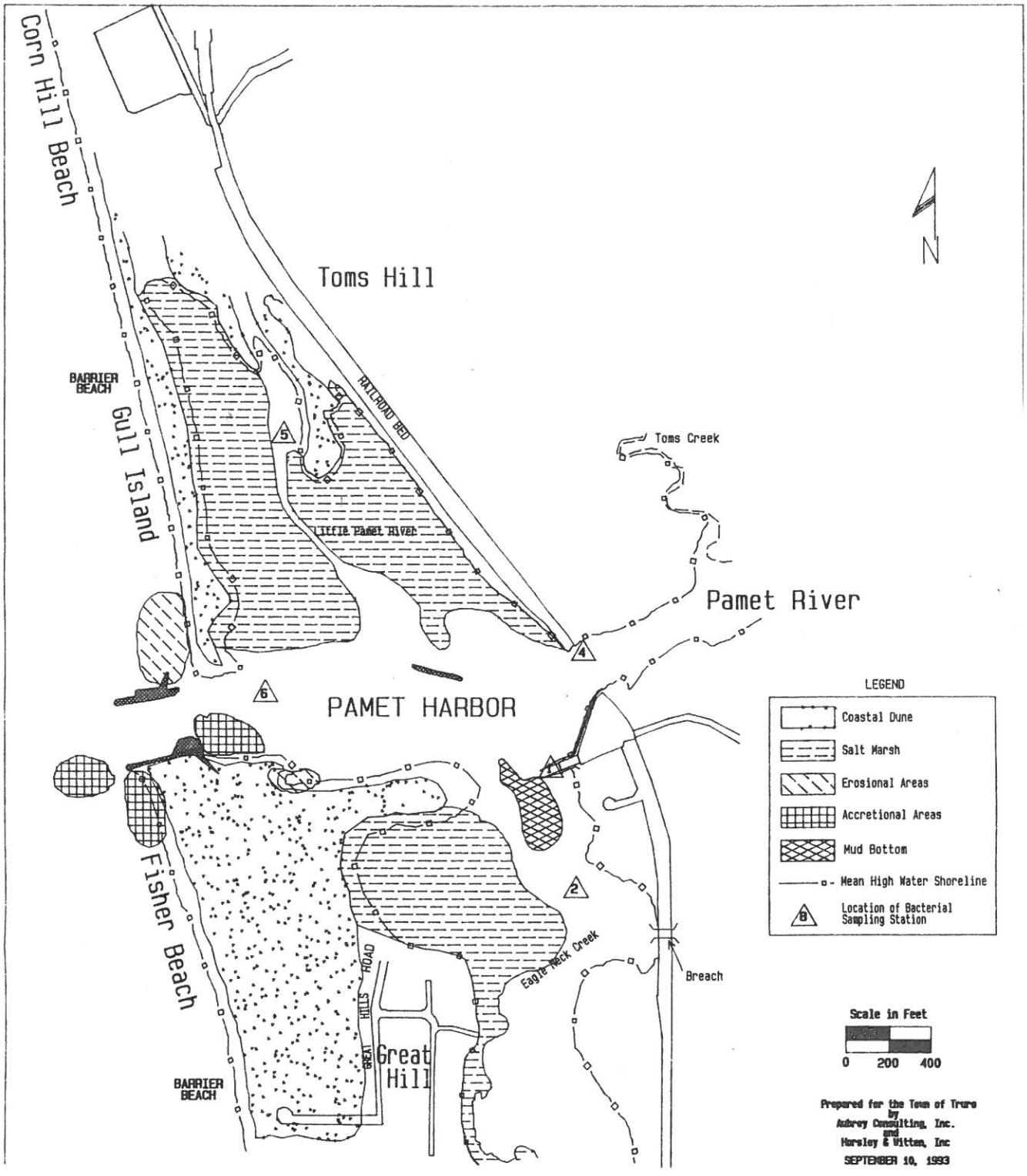
MAP 1.
PAMET HARBOR MANAGEMENT PLAN
BASE AND LAND OWNERSHIP MAP

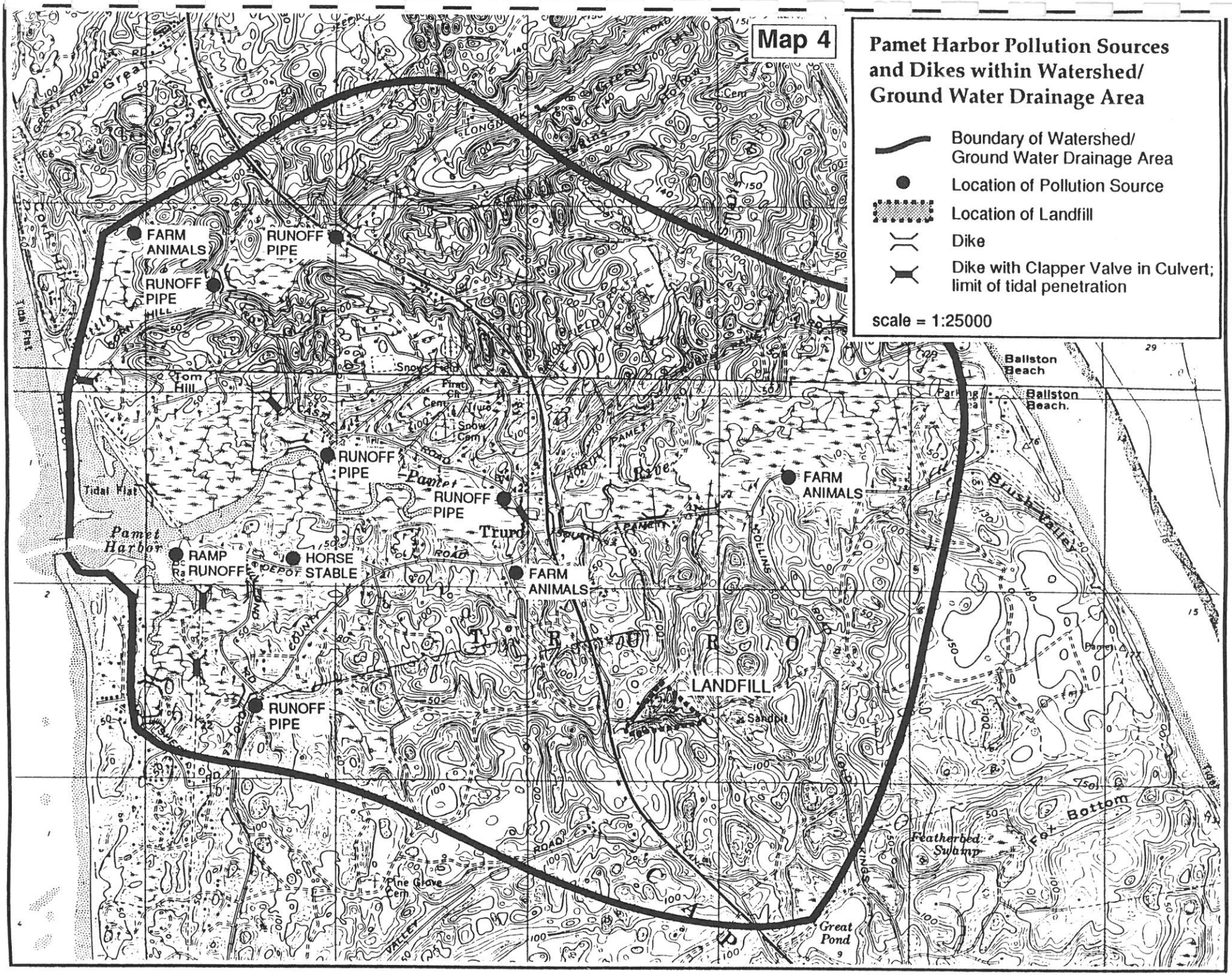


MAP 2.
PAMET HARBOR MANAGEMENT PLAN
EXISTING USES MAP



MAP 3.
PAMET HARBOR MANAGEMENT PLAN
NATURAL RESOURCES MAP




Map 4
Pamet Harbor Pollution Sources and Dikes within Watershed/ Ground Water Drainage Area
Boundary of Watershed/ Ground Water Drainage Area
Location of Pollution Source
Location of Landfill
Dike
Dike with Clapper Valve in Culvert; limit of tidal penetration
scale = 1:25000
FARM ANIMALS
RUNOFF PIPE
RUNOFF PIPE
RUNOFF PIPE
RUNOFF PIPE
RAMP RUNOFF
HORSE STABLE
FARM ANIMALS
FARM ANIMALS
LANDFILL
RUNOFF PIPE
Pamet Harbor
Tidal Flat
Truro
Ballston Beach
Ballston Beach
Pamet River
Pamet River
Tom Hill
Pine Grove Cem
Great Pond
Featherbed Swamp
Bottom
Sandpit

6.0 GOALS, OBJECTIVES, AND POLICIES

I. Water Quality

Goal: To restore and maintain the Pamet Harbor system's water quality to meet state standards for water-related activities and recreation.

Objectives:

1. Maintain the water quality of the Pamet Harbor system in areas which could support water-contact sports (swimming) and recreation.

2. Improve water quality in Pamet Harbor in areas currently closed to shellfishing due to high bacteria counts.

3. Improve the town's ability to detect changes in water quality in the Pamet Harbor system and to identify trends.

4. Minimize release of contaminants associated with typical land and water activities.

5. Prohibit development in critical areas and minimize disruption of natural systems, such as wetlands, which aid in maintaining water quality.

6. Minimize potential degradation of water quality due to accidents or spills involving contaminants.

7. Minimize degradation of water quality due to waterfowl.

Policies:

1. The level of key chemical and bacteriological contaminants shall be monitored on at least an annual basis.

2. Deterioration of water quality shall be minimized through eliminating all direct discharges of untreated stormwater throughout the Pamet watershed, particularly Route 6 and Snows Landing.

3. Public feeding of wildlife shall be prohibited throughout the Pamet Harbor system.

4. Release of nutrients to the Pamet Harbor system shall be minimized through use of best management practices for agricultural practices, such as proper manure storage.

5. The discharge of sanitary wastes from boats shall be prohibited.

6. Educate residents about the connection between typical land use activities and degradation of water quality (for example: use of lawn fertilizers and improper disposal of household hazardous wastes).

7. Land zoned for commercial, institutional or office uses shall meet environmental performance standards aimed at protecting water quality and shall be sited in a way which minimizes impact to sensitive resources.

8. Establish an emergency contingency plan for hazardous materials spills and ensure that all local emergency spill response personnel are trained and are knowledgeable of proper response procedures.

II. Navigation and Harbor Safety

Goal: To restore the usefulness of the Pamet Harbor system as a tidal harbor through enhancing the navigability of the harbor system while ensuring public safety.

Objectives:

1. Provide for safe and adequate access to and from Cape Cod Bay by recreational and commercial boats typically used in the Pamet Harbor system at all periods over an average tidal cycle.

2. Minimize potential conflicts between use of the water for navigation versus other recreational uses.

Policies:

1. Work with state and federal officials to ensure periodic maintenance dredging of channel and mooring basin in Pamet Harbor.

2. Ensure navigational safety through clearly marking and patrolling all navigational channels and mooring areas.

3. Restrict the location of moorings and docks/piers so as to prevent encroachment into navigational channels and open water recreational areas.

4. Establish an emergency response plan which adequately addresses typical harbor safety emergencies.

5. Establish safety regulations for harbor use through town waterway regulations.

6. Promote safe navigational practices through public education and enforcement of safety regulations.

III. Public Access and Recreation

Goal: Maintain and improve public access to the harbor area for residents and visitors alike in order to provide for a quality outdoor experience offering a range of water-related activities and experiences while also ensuring the protection of the harbor's sensitive areas and marine resources.

Objectives:

1. Provide public access to the Pamet Harbor system for a range of uses both in and along the water including water-contact sports (swimming), finfishing, shellfishing, recreational boating, hiking, and environmental education.

2. Maximize public access to the waterfront from town-owned land.

3. Provide handicapped access to the waterfront from public lands.

4. Minimize negative impacts from public access to sensitive areas and marine resources.

5. Establish hiking trails on town-owned parcels located along the waterfront in order to encourage their use for exercise, appreciation of resources, and as an alternative to motorized transportation.

6. Encourage development of interpretive programs in order to educate and enlighten recreational users and visitors about the magnificent and dynamic features of the Pamet Harbor system's natural and cultural history, and the impact of land activities on this system.

Policies:

1. All town lands located along the waterfront shall provide public access which together provide for a range of recreational experiences.

2. Provide handicapped access to any public hiking trails and/or swimming areas established within Pamet Harbor.

3. Preserve and protect water-dependent uses and facilities along the waterfront.

4. Encourage provision of public access to Pamet Harbor by private uses/establishments built along the waterfront, such as the Yacht Club.

5. Site public access areas away from sensitive areas and adopt environmental design standards aimed at minimizing potential impacts to water quality and marine resources.

6. Designate areas not needed for general boating navigation for non-motorized craft and other forms of user access.

7. Designate publicly-owned areas for off-road vehicle (ORV) enjoyment that do not interfere with private property, rare and endangered species habitat, land susceptible to erosion, and sensitive resources.

IV. Shellfishing

Goal: To restore the usefulness of the Pamet as a safe and productive shellfishery, symbolic of the health and quality of the Town's major wetland system

Objectives:

1. To restore and maintain shellfishing waters which meet or exceed state surface water quality standards, particularly for bacterial contamination, for significant portions of downstream sections of the Pamet and its tidal tributaries, to enable the shellfishery to be opened and sustained.

2. Restore and maintain shellfish stocks, particularly quahogs, soft shell clams and blue mussels.

3. Investigate the feasibility of private aquaculture in areas that do not conflict with navigation, public recreation, and recreational shellfishing, as a way to promote jobs and income based on renewable natural resources and as a means to enhance natural shellfish recruitment.

Policies:

1. Re-establish a shellfish propagation program.

2. Investigate standards which allow for private aquaculture through the town's shellfishing regulations.

3. Discourage any water and land activities which would interfere with shellfishing in designated areas.

4. Improve water quality such that shellfishing would be permitted in the Pamet Harbor system.

V. Commercial Fishing

Goal: To sustain a limited presence of commercial fishing boats in the Pamet Harbor so as to diversify the town's economy.

Objectives:

1. Provide modest facilities and services for commercial fishing which do not diminish the harbor's natural and aesthetic resources.

2. Improve the town's ability to detect changes in fish landings in the Pamet Harbor system and nearby Cape Cod Bay and to identify the harbor's contribution to Truro's economy.

Policies:

1. Establish a navigational channel and reserve a safe anchorage to facilitate boat loading and offloading procedures for commercial fishing.

2. Reserve limited deep water mooring space for larger commercial fishing vessels (up to 35 feet in total length) owned and operated by persons who hold a valid commercial fishing license.

3. An unlimited number of moorings shall be permitted for small commercial fishing vessels (under 30 feet), subject to availability on the general mooring waiting list.

VI. Moorings

Goal: To restore the usefulness of the harbor as a safe, efficient anchorage for a diverse mix of small craft, while also guarding against unnecessary encroachment into navigational channels, commercial fishing and shellfishing areas, and other areas used for water-related recreation.

Objectives:

1. Provide secure moorings for a specified number of boats in order to provide public access to Pamet Harbor and Cape Cod Bay.

2. Establish a mooring plan related to the carrying capacity of the harbor system and which considers the need to prevent encroachment on navigational channels, to identify sensitive resources, and to protect areas used for water-related recreation, commercial fishing and shellfishing.

3. Establish funding for harbor improvements to maintain moorings.

Policies:

1. Develop a mooring plan which defines the dimensional limits for a Pamet Harbor mooring basin, and provides for a mixture of boats of varying shape, size and type, while also minimizing the total amount of space which must be devoted to moorings.

2. Assign mooring locations based on size and type of boat, instead of owner preferences.

3. Use town-owned mooring floats to the maximum extent possible in order to provide for the most efficient use of space in the mooring basin.

4. Establish mooring fees, and other harbor fees, which would be at least partially dedicated for harbor use, such that they would provide all of the town's annual harbor operating costs.

5. Encourage a launch service as an alternative to beach storage of individual boat tenders.

VII. Land Use, Landscape and Visual Character

Goal: To preserve or enhance the natural sights, sounds and smells of the Pamet harborscape which contribute to Truro's rural seaside character.

Objectives:

1. Retain the seaside character of Pamet Harbor.

2. Enhance public views of the harbor from town roads.

3. Encourage use of house designs in keeping with the harbor's rural seaside character.

4. Limit noxious odors and noises in the vicinity of the harbor.

Policies:

1. Establish a Pamet River viewshed overlay district within the zoning bylaw, which protects vistas of land areas visible from the waterways and which enhances views of the harbor from public roads located around the harbor.

2. In the proposed overlay district (see #1 above), encourage architectural designs which are compatible with the landscape and which enhance views from the water, perhaps through encouraging the orientation of facades towards the harbor rather than towards the street, or else which either impose design controls for rear facades or require screening from public view through vegetative plantings and height restrictions.

3. Either prohibit or require adequate screening for any uses/activities causing noxious odors and/or noise, or which are visually unattractive (i.e., fish cleaning stations, trash dumpsters, loud generators or machinery, etc.).

4. Utilize selective pruning in order to provide periodic public vistas along town roads of the harbor area.

5. Limit overhead lamps, spotlights, large reflective surfaces and other intrusions into ambient lighting at the harbor.

6. Acquire as much land as possible adjacent to the river and harbor, as appropriate, to preserve natural conditions.

VIII. Natural Resource Protection

Goal: To protect and where possible enhance the quality and productivity of natural resources of the Pamet Harbor system, including its waters, wetlands,

flora and fauna and their habitat for their own sake, as well as for sustainable human recreational and commercial use.

Objectives:

1. Establish an undisturbed vegetated buffer zone along wetlands associated with the Pamet Harbor system.

2. Limit impacts from human-related activities to wetland systems, flora and fauna, and flora and fauna habitat.

3. Preserve the ability of the Pamet Harbor system's natural resources to support recreational activities such as swimming, fishing and shellfishing, boating, and operation of off-road vehicles.

4. Improve the town's ability to detect changes in the Pamet Harbor ecosystem and to identify trends.

5. Encourage investigation of benefits (boating, shellfish, siltation and water quality) resulting from manipulation of existing culverts or dikes to allow more natural patterns of tidal flow in harbor and improved upstream drainage.

Policies:

1. Investigate benefits of adoption of a town wetlands bylaw or revision of the town zoning bylaw in order to grant enhanced regulatory review over new construction and other alterations within 100 feet of the Pamet.

2. Monitor and enforce boat speed limits in the harbor and throughout the estuary system in order to minimize erosion of beach and marsh areas.

3. Prohibit all dredging not related to maintaining a safe navigation channel and public mooring basin, unless dredging is necessary for natural resources enhancement.

4. Establish a monitoring program aimed at evaluating impacts to natural resources in Pamet Harbor, with special attention being devoted to assessment of impacts to vegetation and shellfish.

5. Encourage public acquisition and/or dedication of wetland areas for conservation in the Pamet system, particularly along its salt marsh and dunes.

6. Develop an open space management plan for all town-owned lands located along Pamet Harbor.

7. Educate harbor users and residents about the relationship and impact of boating and other upland recreational uses on natural resources in the harbor.

8. Support natural resource agencies studying upstream drainage improvements.

IX. Fiscal Management

Goal: To maintain, and where possible enhance, the Pamet Harbor system's economic value to Truro residents, including its ability to support tourism, local recreation, commercial fishing and potentially shellfishing, thereby providing jobs and income for local residents.

Objectives:

1. Provide a consistent source of funding for water quality remediation, monitoring and research necessary for restoration of the Pamet Harbor ecosystem.

2. Provide a consistent source of funding for periodic evaluation of harbor and waterfront facilities and services, as well as construction and operation of public facilities and services, where appropriate.

3. Encourage development of appropriate private facilities and services which provide for water-based recreation, waterfront recreation, fishing and shellfishing, and other harbor or tourist-related needs.

4. To identify and acquire non-essential harbor facilities, operations and amenities, to the greatest extent possible, through alternative means such as harbor user fees, donations, volunteerism, or private fund raising.

5. To reduce the local financial burden associated with harbor restoration and use, where possible, through seeking available sources of public funding.

6. Promote public support for harbor-related expenditures through enhanced public education.

Policies:

1. Utilize local authority to appropriate funds and/or bonds for harbor restoration and development.

2. Establish mooring and launching fees necessary to provide funding for harbor and waterfront maintenance and enhancement, and dedicate these monies solely for harbor and waterfront use through an enterprise fund.

4. Seek donations and volunteer services.

5. Adopt local regulations which support private development of limited but essential harbor-related uses, facilities and services.

6. Identify and pursue appropriate subsidies, such as state and federal grants, reimbursements and low-interest loans, foundation grants and charitable donations.

7. Educate residents about the economic benefits associated with restoration and enhancement of the Pamet Harbor system.

7.0 MODELING ANALYSIS OF HARBOR ALTERNATIVES

Management studies of tidally influenced estuaries must include a thorough evaluation of the hydrodynamics of the estuary system. Estuarine hydrodynamics control a variety of coastal processes including tidal flushing, pollutant dispersion, tidal currents, sedimentation, erosion, and water levels. In natural, unaltered estuaries, changes in the hydrodynamics of the system generally evolve over long periods of time, resulting in gradual fluctuations in these coastal processes. In other estuarine systems, however, where proposed management alternatives can sometimes alter the hydrodynamics of the system, changes in these coastal processes can be dramatic. In many cases, the changes can result in detrimental impacts to the environment, although if properly designed, they can result in positive impacts to the environment.

The identification and evaluation of proposed management alternatives for estuarine systems, therefore, depends on a thorough understanding of the hydrodynamics of the system, and how proposed alterations to the system can affect the coastal processes. One of the most accurate ways to determine the hydrodynamics of an estuary is to model the system numerically. For the Pamet Harbor Plan, a one-dimensional (1-D) numerical model was used to quantify the tidal hydrodynamics of the Harbor system.

Three project alternatives for the Pamet Harbor system were investigated using the 1-D model. The first alternative involved the input of a dredged channel from the Harbor entrance to the mooring basin near the boat ramps (Figure 3). The channel leading from Cape Cod Bay to the mooring basin was 60 ft wide and -4 ft MLW. The channel widened to 200 ft and -6 ft MLW in the mooring basin area. This dredging plan has been developed jointly by the Department of Environmental Management (DEM) and the Town of Truro. Modifications to the cross-sections at all affected nodes in the model grid were made to reflect the proposed channel dimensions. A comparison between existing conditions and the proposed channel configuration at node 3 is shown in Figure 4.

FIGURE 3.
PAMET HARBOR
NUMERICAL MODEL GRID

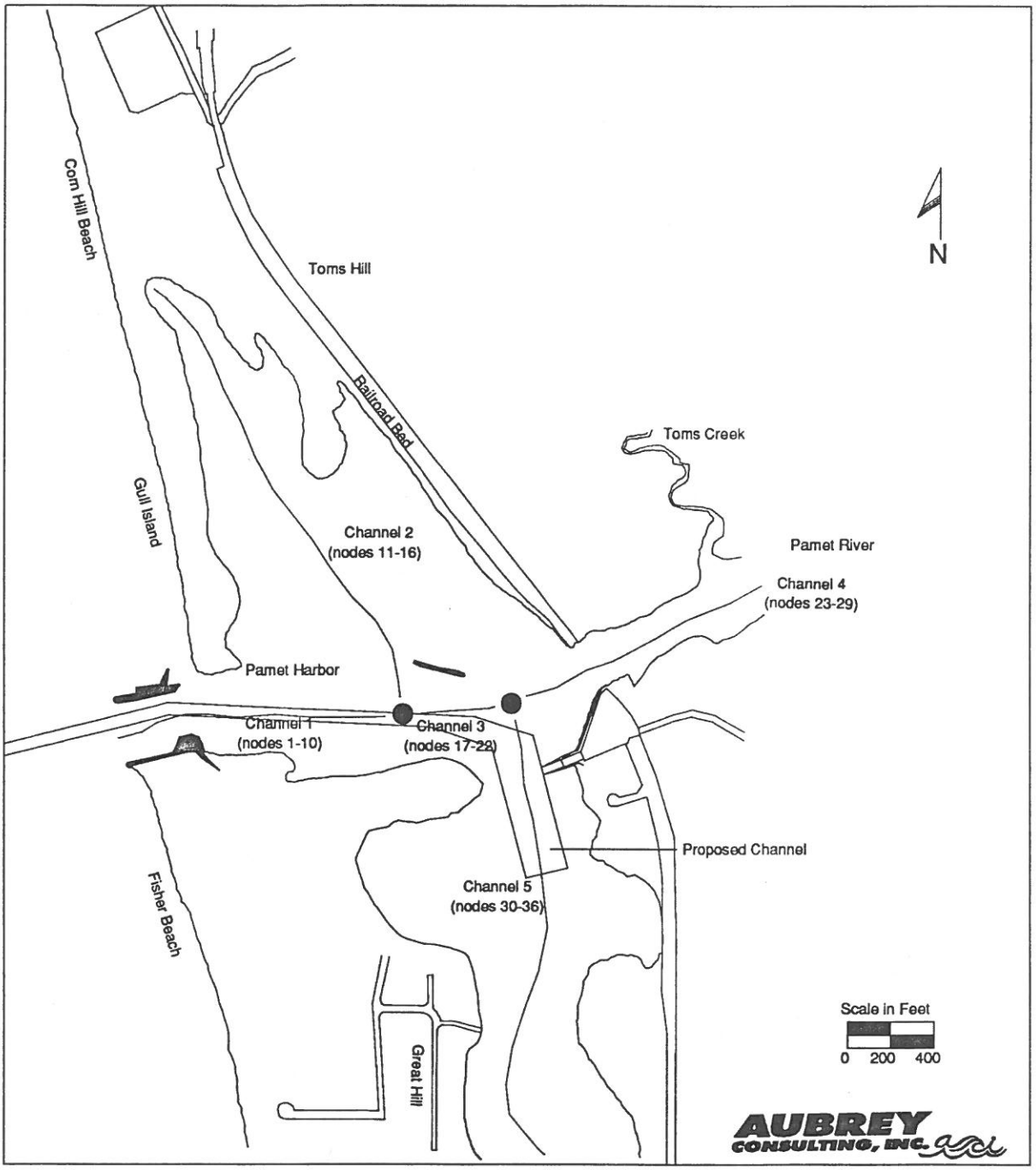
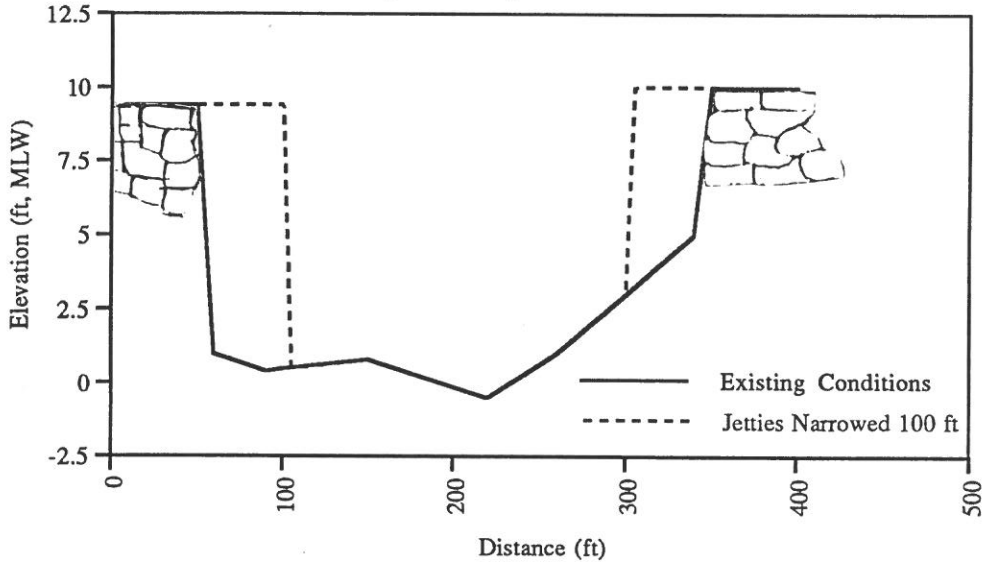


Figure 4.
Channel Cross-Section at Node 3
Existing and Proposed Narrowed Jetties



The second project alternative for Pamet Harbor reflects modifications to the entrance jetties. This alternative was developed jointly by the Harbor Planning Committee and the HWH consulting team. The alternative consisted of narrowing the jetties by 100 ft to a total width of 180 ft. This modification was developed to determine if changes in the jetty configuration would alleviate shoaling problems in the Harbor entrance. Modifications to the cross-sections at the grid nodes between the jetties were made to reflect the proposed jetty reconfiguration. A comparison between existing conditions and the proposed jetty configuration at node 7 is shown in Figure 5.

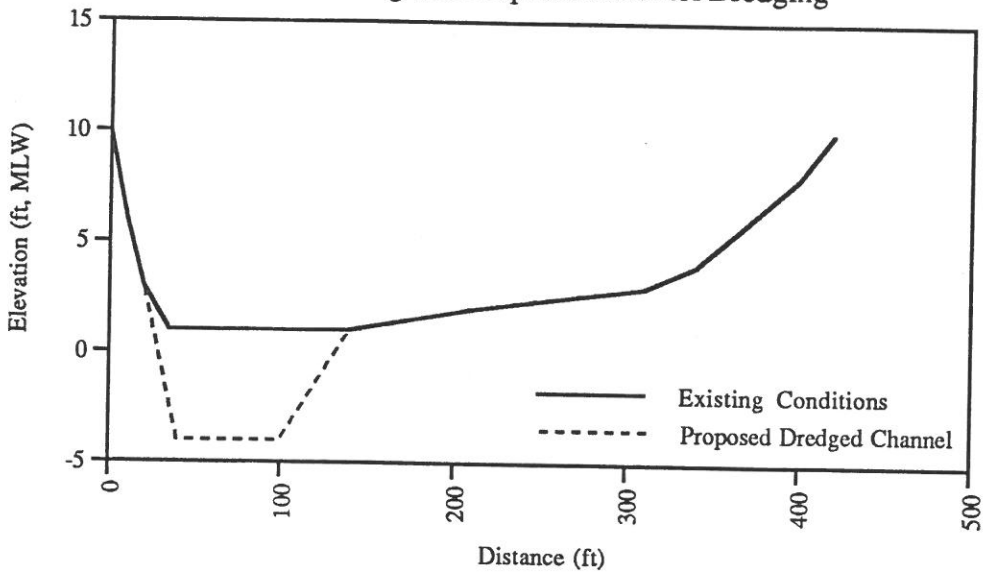
The third project alternative consisted of narrowing the jetties and dredging the channel. The combination of these alternative was made to determine if the proposed changes would improve both tidal flushing and shoaling problems in the Harbor entrance. Modifications to the cross-sections at the grid nodes affected by the dredging and between the jetties were made to reflect the proposed changes.

I. Numerical Model Results

The 1-D model was used to examine the tidal exchange between Cape Cod Bay and the Pamet Harbor system. Water quality within the estuary is highly dependent upon this exchange, which can be quantified using the tidal prism, or volume of water exchanged during an average flood or ebb cycle. Once the tidal prism is known, then residence times can be calculated. The definition of residence time is the average time that a particular water parcel spends in the estuarine system. Very long residence times generally are indicative of sluggish circulation and poor water quality. Short residence times usually indicate a rapid exchange of water between the open ocean and estuary, and can be associated with increased water quality.

For the Pamet Harbor system, residence times were determined for the following four sub-sections of the estuary (Figure D-2 in Appendix D): north channel (includes extensive tidal flats on Channel 2), south channel (includes mooring basin and tidal flats on Channel 5), upper Pamet River (Channel 4),

Figure 5.
Channel Cross-Section at Node 7
Existing and Proposed Channel Dredging



and entire Harbor area (Channels 1-5). The system was divided into sections so that potential problem areas (areas with long residence times) could be identified. One calculation for the entire Pamet Harbor system would simply result in an average residence time, blending together those areas with longer and shorter residence times. From a management standpoint this would not be as desirable as residence times calculated for specific areas within the estuary.

The results from model calculations of tidal prism and residence time for the existing Pamet Harbor system are summarized in Table 2. The tidal prism values indicate that the upper Pamet River exchanges a greater volume of water than the north or south channels. Residence times are relatively short throughout the Harbor, ranging from 0.18 days in the Upper Pamet River to 0.38 days in the south channel. The residence time of 0.30 days for the entire Pamet Harbor reflects an average of conditions across the whole Harbor. The short residence times predicted by the 1-D model are the result of complete drainage of many parts of the Harbor at low tide.

Table 2.
Tidal Prism and Residence Times for Pamet Harbor

Section	Tidal Prism (cubic ft)	Residence Time (days)
North channel	3,710,000	0.34
South channel	3,130,000	0.38
Upper Pamet River	10,300,000	0.18
Entire Pamet Harbor	23,500,000	0.30

Changes in the tidal hydrodynamics for the three project alternatives were modeled and compared with the existing conditions. The changes in residence times for each of the alternatives, in terms of percent of existing conditions, are shown in Table 3. Changes in maximum tidal current velocities within the Harbor entrance for each of the project alternatives are shown in Table 4.

Table 3.
Percent Change in Residence Times Between Existing Conditions
and Project Alternatives

Alternative	Harbor Entrance	Mooring Basin
1) Harbor dredging	- 1.9%	- 3.5%
2) Narrow jetties	+ 1.1%	+ 0.08%
3) Harbor dredging and narrow jetties	-1.9%	-3.2%

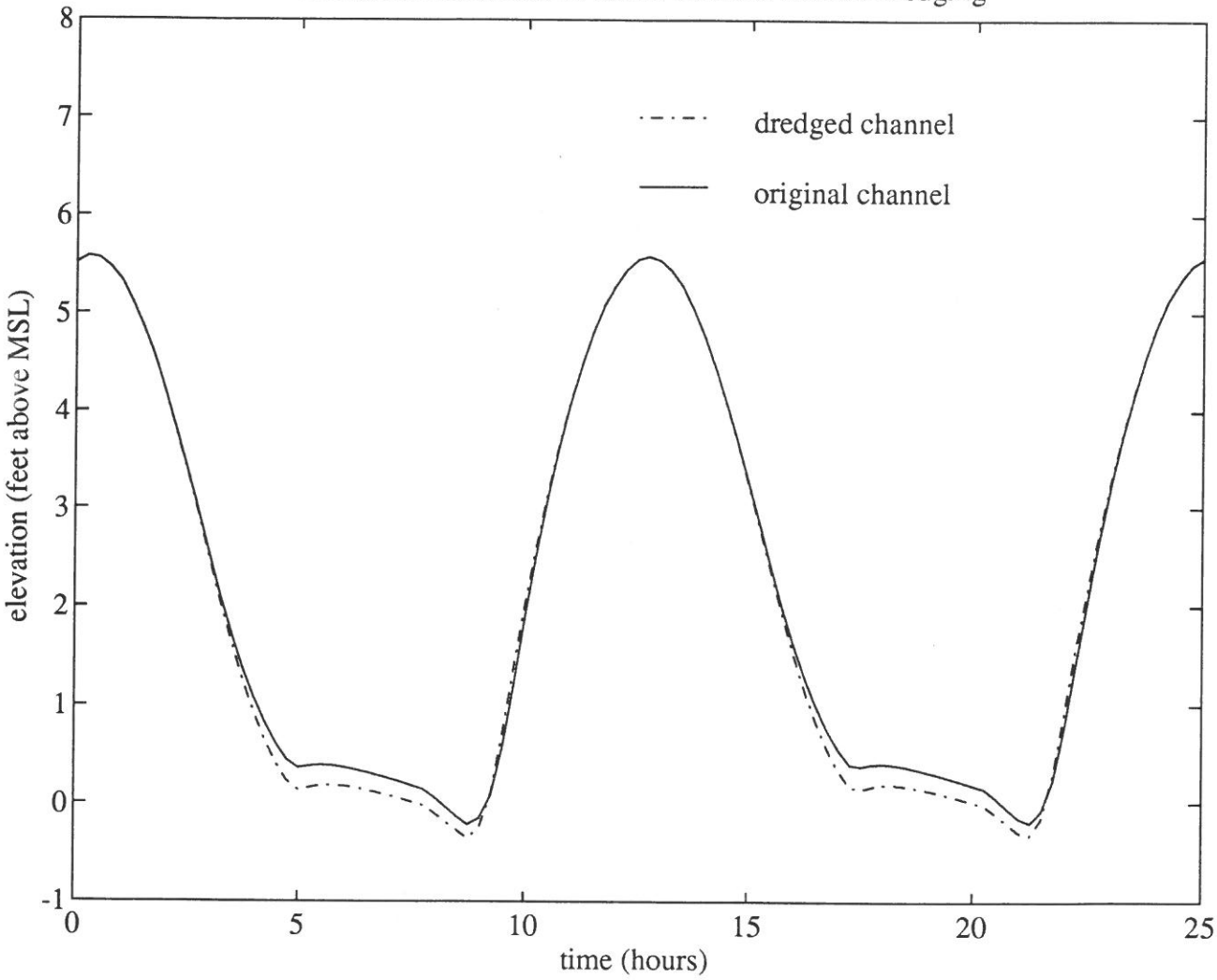
Table 4.
Maximum Tidal Current Velocities for Existing Conditions
and Project Alternatives

Alternative	Flood Velocities (ft/sec)	Ebb Velocities (ft/sec)
0) Existing conditions	1.83	1.69
1) Harbor dredging	1.57	1.51
2) Narrow jetties	2.78	2.49
3) Harbor dredging and narrow jetties	224	2.13

Results from the 1-D model show that the primary impacts of alternative 1 (Harbor dredging) are slightly shorter residence times (improved water quality) and lower current velocities at the Harbor entrance. Additionally, the dredging resulted in slightly lower, low tides in those areas affected by the dredging, as can be seen by Figure 6. The 1-D model predicted few changes elsewhere within the Harbor for alternative 1.

The second alternative of narrowing the jetties resulted in slightly longer residence times (decreased water quality) throughout the Harbor and significantly higher current velocities at the Harbor entrance. Since the area through which the water enters the Harbor is decreased by narrowing the jetties, the volume of water entering and exiting the Harbor is also decreased, thereby increasing the residence times. The increased current velocities at the entrance would likely alleviate some of the shoaling problems, since critical

Figure 6.
Elevation Difference in South Channel Due to Dredging



threshold velocities needed for sediment transport would be exceeded more often.

The third alternative of dredging the Harbor and narrowing the jetties results in slightly shorter residence times (improved water quality) as well as increased tidal current velocities at the Harbor entrance. The improvement in residence times for the third alternative is nearly equal to the improvements estimated for alternative 1. The primary difference in the two alternatives is the increase in current velocities at the Harbor entrance. Increased current velocities in this area will likely alleviate some of the shoaling problems seen in the past, and may reduce the frequency of maintenance dredging.

8. ACTION PLAN

Based upon input received from the Town of Truro, an Action Plan has been prepared for the management of Pamet Harbor. It includes both water-based and land-based recommendations aimed at better meeting the Town's goals and objectives for the protection and use of the Harbor.

Throughout our analysis of Pamet Harbor, several alternative management strategies were identified. This section of the report presents these alternatives and recommended actions. The Pamet Greenway Plan (1986) contains 75 management recommendations for the Pamet. These have been reviewed in the context of this study and, where appropriate, they have been incorporated into the Alternatives Analysis.

I. Dredging

The Pamet Harbor is clearly in need of a dredging project to restore its usefulness as a small boating harbor. Periodic dredging likely will be required as on-going maintenance of the Harbor, despite other structural modifications (such as reconfigured jetties and/or removal of dikes), primarily because Pamet is a "flood-dominant" estuary. This means that water floods the Harbor faster than it ebbs, and therefore flood currents are higher in velocity than ebb currents. Flood-dominant estuaries characteristically experience a net influx of sediment due to the high velocity of the flooding currents. To support analysis of the dredging alternative, a 1-D numerical model was run to simulate changes in Harbor hydrodynamics based on the dredged channel design proposed by the DEM and Town of Truro. Use of this model allowed evaluation of the impacts of the proposed dredging on tidal flushing, tidal elevations and current velocities. The various advantages and disadvantages of dredging the Harbor have been analyzed and are discussed below.

Advantages:

- Enhanced Harbor revenues from increased use.
- Restoration/maintenance of boating uses in the Harbor.

- Potential improved water quality due to better flushing.
- Beach nourishment of eroded Gull Island.
- Slight increase in tidal flushing.

Disadvantages:

- Potential increased traffic on Depot Road.
- Costs: town and state funding needed.
- Short-term potential environmental impacts, such as physical disruption of shellfish habitat and siltation.
- Short-term potential aesthetic impacts, such as noise, odor, eyesore of dredge and spoils.
- Decrease in tidal currents at Harbor entrance.

Recommended Action:

Support the currently proposed DEM dredging restoration project and develop a dredging master plan to include periodic future maintenance dredging (Selectmen).

II. Removal of Dikes

Based upon the impacts associated with the dikes discussed in the "Findings Report", one management option involves the removal/replacement of these structures to restore more natural flow conditions in the Pamet. There appears to be widespread support for this idea among Truro citizens, as indicated by a 1985 poll which showed that only 13% (63 of 523) opposed the idea of opening dikes.

Several studies have been conducted on the impacts of removal of the man-made dikes. In 1983, Graham S. Giese (unpublished) investigated the various effects of the man-made alterations on the natural tidal system. Additionally, he investigated whether removal of some or all of the dikes or changes in their configuration would, in conjunction with well-conceived dredging, restore recreational and commercial uses of the Harbor. Initial projections,

using available mathematical techniques predicted an approximate increase in the size of the tidal prism of 16% if the existing dikes were eliminated.

A second study conducted by Giese et al. (1990) utilized a shallow-water numerical tidal model to estimate the effect on the tidal prism of eliminating the most prominent dikes in the system, Wilder's Dike and the landfill for Route 6, located just east of Wilder's Dike. Wilder's Dike contains a clapper valve that permits discharge of fresh water into the Pamet River, but prevents tidal flow into the fresh water wetlands east of the Dike. The results of this study indicate that removal of Wilder's Dike and the Route 6 landfill would likely not increase the size of the tidal prism by more than 5 percent. Additionally, there would be little change in tidal flushing and sediment transport pathways.

Based on review of these previous studies, it was determined that, while ecosystem benefits might accrue, removal of some or all of the man-made dikes would have little effect on increasing the recreational and commercial uses of the Harbor. Therefore, further consideration of this alternative, through more detailed numerical modeling, was not conducted.

Advantages:

- Improved boating (canoeing/kayaking) access.
- Restoration of the natural hydrologic environment.
- Increase in salt marsh ecosystem east of Route 6.

Disadvantages:

- Financial costs of improvements.
- Alteration to the existing ecosystem.
- Short term water quality impacts associated with the conversion of freshwater marsh to salt marsh in the Upper Pamet.
- Loss of freshwater wetlands east of Route 6.

Recommended Action:

Conduct a feasibility and environmental assessment study of the proposed removal of dikes (Conservation Commission).

III. Modification to Pamet Harbor Jetties

One additional alternative considered as part of this study was the narrowing of the Pamet Harbor entrance jetties. Through modeling, he jetties were moved closer together by 100 ft, for a total width of 180 ft. This alternative was evaluated through the use of the 1-D numerical model, DYNLET1. Use of this model allowed evaluation of the impacts of the proposed dredging on tidal flushing, tidal elevations and current velocities. The impacts of narrowing the jetties have been analyzed based purely on changes in the hydrodynamics of the system, rather than economics and or navigation considerations. The various advantages and disadvantages of narrowing the jetties have been analyzed and are presented below.

Advantages:

- Increase in tidal current velocities at the Harbor entrance.
- Potential decrease in shoaling at the Harbor entrance.

Disadvantages:

- Slight decrease in tidal flushing.
- Significant costs.
- Short-term potential environmental impacts, such as physical disruption of shellfish habitat and siltation.
- Narrowing of navigational channel, creating a potential boating hazard.

Rainfall Closure for Shellfishing in the Pamet

The analysis of fecal coliform data suggest that the high concentrations of bacteria are most closely related to rainfall events (See Figure 2). Stormwater

discharges and drainage from wetland areas during and immediately following a rain event are believed to be the principal contributors of these bacteria, which have been detected above acceptable water quality standards since 1986.

The Massachusetts Department of Environmental Protection, Division of Marine Fisheries, has the authority to change the current status of the shellfish closure to a "rainfall closure". This has been done recently for the Herring River in Wellfleet. A rainfall closure prohibits shellfishing only during a 48-hour period following rain storms. Otherwise, the area is open to shellfishing.

To obtain a rainfall closure, an analysis of water quality and rainfall data must be completed. An interview with DMF staff indicated that it may be a year or more before their staff are able to complete the required analysis. It is possible that the Town could assist in this analysis to complete it in a more timely manner. The analysis conducted as part of this project represents the first step in this process and should be submitted to DMF for their review.

Advantages:

- Possible opening of the Pamet to shellfishing.
- Potential for aquaculture projects.

Disadvantages:

- Possible increased water quality monitoring costs.

Recommended Action:

Submit rainfall vs. bacteria graph (Figure 2) with formal request to Massachusetts Division of Marine Fisheries for a "rainfall closure" (Board of Health; Shellfish Warden).

IV. Stormwater Management

Stormwater discharges from roadways surrounding the Pamet are believed to be a major contributor to the water quality problems which are responsible for the current shellfish closure. Recent projects, such as the drainage improvements at the Route 6 dike, have improved this situation somewhat. However, several other stormwater discharges remain.

All direct stormwater discharges into the Pamet should be mitigated. Possible options include leaching catch basins, infiltration galleries, detention ponds, oil/grease separators, sedimentation basins and constructed wetlands.

Advantages:

- Improved water quality.
- Possible permanent opening of shellfishing area.
- Higher quality of shellfish meats (reduced metals/hydrocarbons).

Disadvantages:

- Costs ($5,000-$50,000 per site).

Recommended Action:

Construct sedimentation/detention basins and/or construct wetlands to interrupt stormwater runoff discharges (Highway Department).

V. Sewage Pump-Out Facilities

Current state and regional policies encourage the establishment of marine sewage pump-out facilities. Such facilities provide a safe and environmentally-sound alternative for the disposal of boat-derived sewage wastes. A facility could be established in proximity to the current boat ramp and could be easily accessed by boaters. The collected septage would be ultimately transported to the Town's septage disposal facility.

Advantages:

- Provide a safe and environmentally-sound marine sewage disposal option.
- Minimize the risks associated with through-hull discharges.

Disadvantages:

- Costs would be high on a per-user basis because of the small number of boats which have marine heads.
- Enforcement.

Recommended Action:

Indefinitely postpone construction of pump-out station until or unless the boating capacity/type is significantly increased (Harbor Commission).

VI Pedestrian Bridge

The abandoned rail bed provides a unique public access opportunity. Hikers currently access the rail bed from the Corn Hill parking lot and hike southerly towards the Harbor. Wonderful sunsets are enjoyed from this vantage point.

This public access could be enhanced with a foot bridge spanning the Harbor and connecting the rail bed on the north side of the Harbor to the parking lot/boat ramp area. Figure 10 shows two photographs taken of Uncle Tim's Bridge in Wellfleet as an example of this type of structure.

Advantages:

- Enhanced public access.
- Linkage of the northern and southern portions of the Harbor.
- Increased aesthetic opportunities to sunset and nature watchers.

Disadvantages:

- Decreased navigation for sailboats into the upper parts of the Harbor/River.
- Costs of construction and maintenance.
- Attractive nuisance and safety hazard associated with bridge diving at high tide.

Recommended Action:

Obtain cost estimates for design and construction of bridge (Recreation Commission).

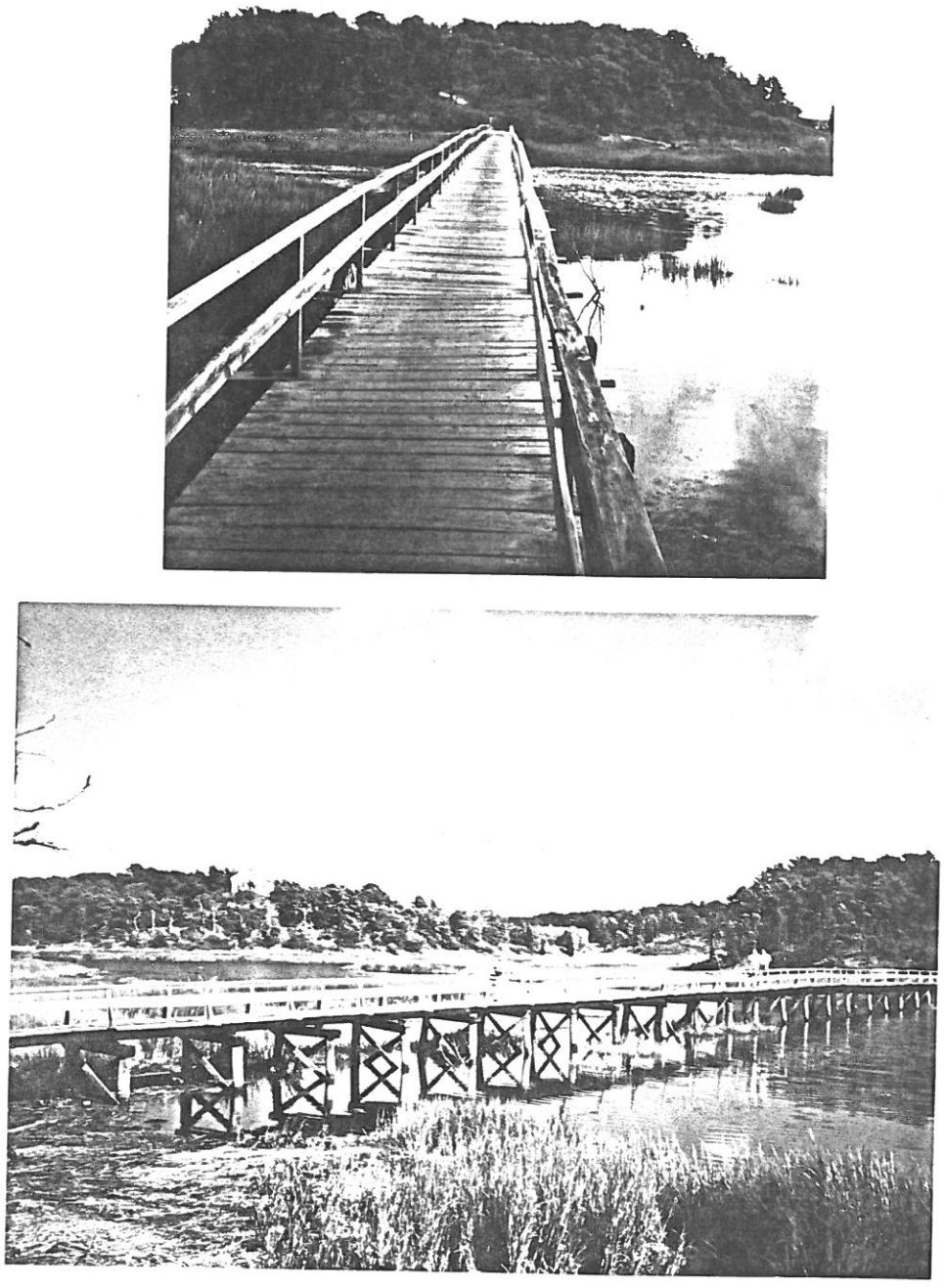


Figure 7. Uncle Tim's Bridge, Wellfleet, Massachusetts

VII. Implementation of Viewshed Overlay District

In 1990, the Truro Conservation Trust conducted a Pamet River Viewshed Analysis, which identified scenic vistas and public overlooks of the Harbor and river system. Ten of the 24 vantage points provided long-distance views of the Pamet Harbor study area from public roads, landings, or public land (Stations K, L, Q-X; see Map 6). Town adoption of this scenic viewshed would provide a zoning framework in which development guidelines could be designed to protect the public's views. For example, houses could be sited away from vista points or fences designed to allow sightlines of the Harbor. In 1987, the Massachusetts Department of Environmental Management designated the Pamet as a Scenic River.

Advantages:

- Protection of scenic views and aesthetic qualities of the Harbor.
- Conformance with state Scenic River policy, while maintaining primary regulatory role at local level.

Disadvantages:

- Perceived additional restrictiveness of Town regulations.

Recommended Action:

Study impact of adopting Viewshed Overlay District zoning (Planning Board.

VIII. Development and Adoption of Local Wetlands Bylaw

The Town of Truro is the only town on Cape Cod not to have enacted its own wetlands protection bylaw. This is inconsistent with the fact that the Town clearly has unique wetlands (including the Pamet system) which are not adequately protected by the Massachusetts Wetland Protection Regulations (310 CMR 10.00). Several key components need to be amplified within Truro's own wetland protection bylaw:

1) Aesthetic wetland values could be added to the list of wetland values contained in the state regulations. The Pamet wetland system provide unique aesthetic values which were not contemplated in the drafting of the state regulations.

2) Sea level rise should be accommodated in Truro's own wetland bylaw. As sea level rises naturally or with the proposed opening of the dike system, existing wetlands will need to migrate inland. The state regulations do not provide for this.

3) An increased jurisdictional zone (beyond the state-prescribed 100 feet) is very important in the Pamet due to the surrounding steep slopes and the sensitivity of the system to changes within its watershed but beyond the arbitrary 100-foot buffer (see Map 5).

Advantages:

- Protection of the aesthetic wetland values intrinsic to the Pamet.
- Protection of wetlands with respect to natural sea level rise and potential opening of the dike system.
- Jurisdiction over uses within the watershed but beyond the arbitrary 100-foot buffer.

Disadvantages:

- Cost of drafting and adopting the bylaw ($3,000 or less).

Recommended Action:

Draft wetlands bylaw (at least for Pamet River) for consideration by Town Meeting (Conservation Commission).

IX. Management of Recreational Vehicles

Off-road vehicles (ORVs) are currently used along both the north and south barrier beaches. Like many other "active" uses of resource areas, ORV usage can conflict with other more "passive" uses such as hiking and birding. The challenge of a management plan is to accommodate as many desired uses as possible, while not excluding others or allowing any significant environmental impacts to the valued resource area.

The most obvious management alternative for ORV usage in the Pamet Harbor area would be to segregate the use geographically and/or temporarily. One option would be to continue to allow ORV access to the northern, town-owned barrier beach, but prohibit such use on the southern barrier beach. Another option would be to restrict the usage times (possibly by only allowing ORV access on odd-numbered calender days).

Advantages:

- Allows both active (ORV) and passive use of the barrier beaches.
- Limits the environmental impacts of chronic ORV use.
- Discontinues the "unauthorized" access by ORVs over the southern, private barrier beach.
- Creates a "vehicle-free" beach for pedestrians.

Disadvantages:

- Decreases the areas currently accessed by ORV users.
- Enforcement requirements by the Town.

Recommended Action:

Prohibit access of ORVs to southern barrier beach (Selectmen; Recreation Commission).

X. Management of Swimming Areas

At present, there are three main swimming areas utilized in the Pamet Harbor area (see Map 2 in Findings section). The swimming area just inside the southern jetty is in close proximity to the navigation channel. This represents a potential navigation and safety problem.

This swimming area could be more clearly marked with buoys to warn both swimmers and boaters of this potential hazard.

Advantages:

- Increased safety to swimmers.
- Allows continued usage of this swimming area.

Disadvantages:

- Does not provide conservative safety buffer between two conflicting uses.
- Potential liability issues for the town in managing the Harbor.
- Costs associated with the establishment and maintenance of swimming area buoys and navigational aids.
- Swimming access is currently on privately-owned land (Dalsheimer).

Recommended Action:

Designate swimming area with buoys (Harbor Commission).

XI. Shellfish Tissue Testing

The findings report indicated that stormwater runoff and boats are sources of metals and hydrocarbons to the Harbor and that shellfish have the ability to bioaccumulate these compounds within their tissue. A representative sample of shellfish meats could be analyzed for metals and hydrocarbons to determine the degree to which this may be occurring within Pamet Harbor. If the meats are found to be very low in metal/hydrocarbon concentrations, it is

possible that shellfish from the Pamet could be marketed as "extra clean" and should demand a higher price when compared to shellfish taken from more urbanized harbors (where presumably the metal/hydrocarbon concentrations may be higher in the shellfish meats). In today's health-conscious society such marketing could be rewarded as evidenced by the restaurant chain, Legal Seafood's marketing campaign.

Advantages:

- A better understanding of the quality of shellfish.
- Possible economic advantage of marketing clean shellfish.
- Evaluation of the impacts associated with long-term chronic discharges.

Disadvantages:

- Costs of analyses (approximately $2,500).

Recommended Action:

Collect and test shellfish tissue for metals and hydrocarbons at Barnstable County Health and Environmental Department laboratory (Board of Health).

XII. Harbor/Waterways Regulations

Because Pamet Harbor is a mixed use Harbor, there are potential conflicts between uses. Some of the potential conflicts include uses such as boating, swimming, and shellfishing. To ensure optimal use of the Harbor, these activities need to be managed spatially and/or temporarily. The best known option to effectuate such management is through clear harbor/waterways regulations. These regulations could be administered by the Truro Harbor Commission.

Advantages:

- Implementation of management program for Harbor uses.

- More clearly defined role for Harbor Commission.

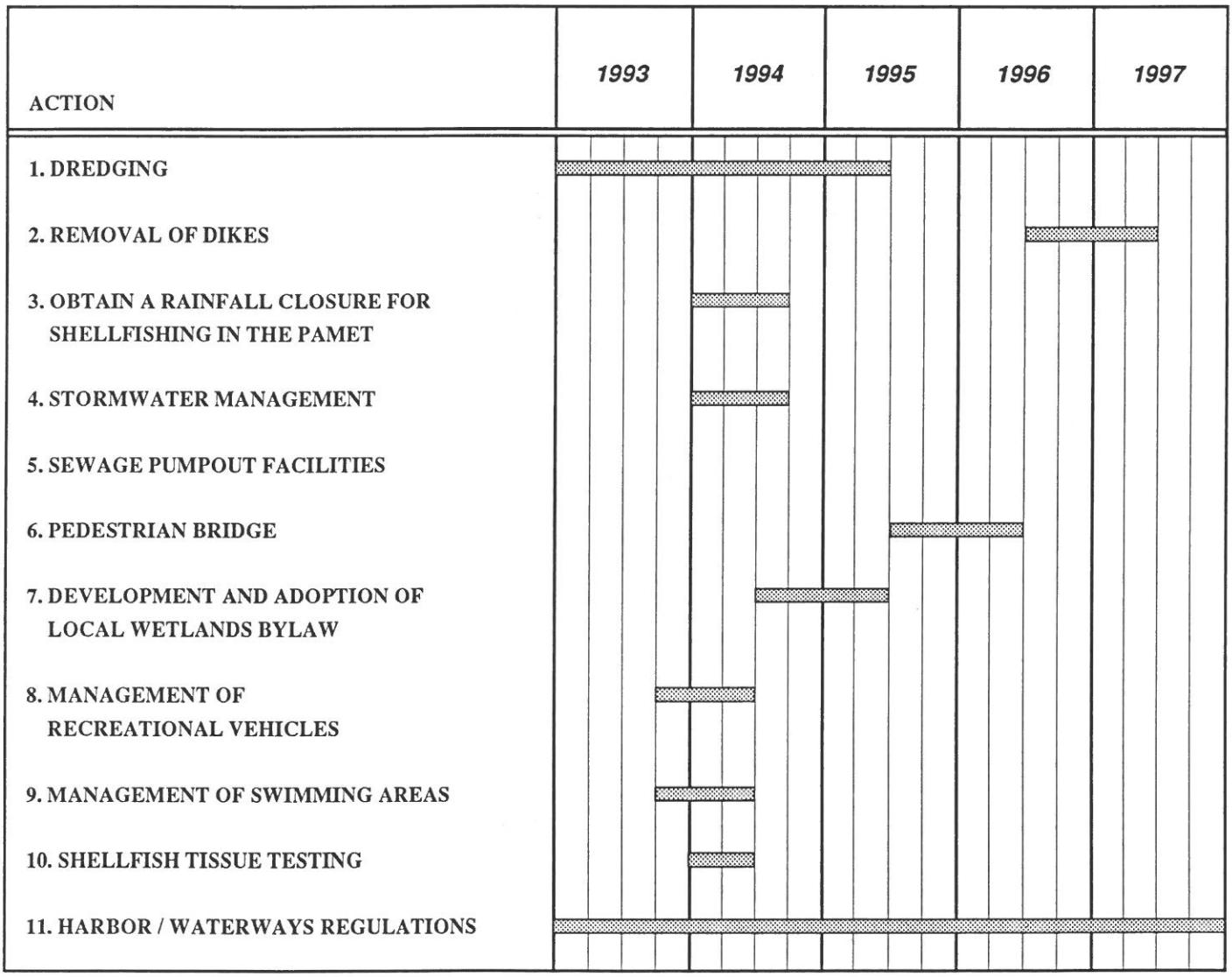
Disadvantages:

- Administrative costs associated with enforcement of regulations.

Recommended Action:

Adopt comprehensive set of use regulations (Harbor Commission).

FIGURE 8.
PAMET HARBOR MANAGEMENT PLAN
Action Plan Implementation Schedule



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APPENDIX A

APPENDIX A

Town of Truro
Pamet Harbor Management Planning Committee
1992 -1993 Membership

Eleanor Fortini, Chair*
Harbor Commission

Reuben Witsokzy, Vice-Chair*
Truro Neighborhood Association

Tamson Garran (ex-Chair)*
Harbor Commission

Marguerite Holway*
Shellfish Constable

Betsey Brown*
Pamet Harbor Yacht Club

Dr. Charles Davidson*
Citizen at Large

Brenda Boleyn*
Truro Representative to Coastal
Zone Management Adv. Committee

Marina Matricardi*
Appeals Board

Albert Kaufman*
Planning Board

David Perry, Publicity
Police Department

Irving Wheeler
Harbormaster

David Kelly
Harbor Commission

Walter Bingham, Jr.
Truro Conservation Trust

Thomas Kane
Harbor Commission

Mark Dundus
Harbor Commission

Harry Towle
Conservation Commission

Albert Silva
Truro Chamber of Commerce

Paul Morris
Highway Department

William Painter. Advisor
Beach Commission

Susan Wilmot, Advisor

Pam Rubinoff, Advisor
Coastal Zone Management Office

Scott Horsley, Project Director
Horsley & Witten, Inc. (Consultant)

Mark Robinson, Project Manager
Horsley & Witten, Inc. (Consultant)

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* (Steering Committee)

APPENDIX B

APPENDIX B

JULY 1992 OPINION SURVEY

Pamet Harbor Commission

Truro Town Hall • P.O. Box U
Truro, Massachusetts 02666

Return to Eleanor Fortini, Harbor Management Planning Committee, Town Hall, Truro 02666

The Town of Truro, through its Harbor Management Planning Committee, has retained HWH, Inc. to prepare a management plan for Pamet Harbor. As part of the public participation process, we seek your opinions on issues related to the harbor, its use and future. The results of this survey will help to suggest goals, objectives and actions related to the plan.

1. How do you use or enjoy the harbor? Why is it important to you?

2. The Committee has stated an operating goal of the plan is to "restore the usefulness of the harbor, while protecting the productivity and natural resources of the estuary and harbor basin." Is this the proper goal?

3. If the harbor can be dredged with little long-term environmental impact, do you think it should be the major part of "restoring the usefulness" of the harbor? What do you think should be dredged--the entrance channel, the existing boat basin, a larger boat basin?

4. Last year about 130 boats had mooring permits in the boat basin. Should the harbor be made to accommodate more boats or simply allow the present number to enjoy better conditions? Should there be fewer boats in the Pamet?

5. Is there adequate public access to the harbor? If not, what more is needed?

6. What are the greatest threats to the harbor, its beauty and its natural resources?

7. What level of commercial fishing support should the harbor provide?

8. How important an objective is it to ensure that shellfish could be harvested year-round in the harbor? Where do you think pollution is coming from?

9. To what degree should the town permit swimming inside the harbor?

10. Is the harbor safe for boaters? What makes it unsafe? How could it be made more safe?

11. Is traffic safety on Depot Road leading to and from the harbor a problem?

12. Should the town as a whole subsidize improvements to the harbor or should the users pay?

APPENDIX C

APPENDIX C

SELECTED NEWSPAPER ARTICLES

The Cape Codder Tuesday, February 11, 1992 Page 13

Hoping to Reverse Tide, Truro Pushes For Pamet Harbor Plan

By Joyce Johnson

For just about as long as anyone can remember, there have been navigational problems at the Pamet Harbor.

Rather than improving, records — and a quick viewing of the harbor entrance at low tide — indicate access is worsening.

But the Pamet Harbor Commission, working with a management group representing about every aspect of Truro life, hopes to turn that tide.

Last night, Committee Chairman Tamson Garran outlined the immediate and long term plans of the group for the Truro Finance Committee.

The plans include installing 100 town-owned moorings by next summer and applying for grants for dredging and other improvements.

But before any of that can happen, the town must have a harbor management plan. Bid specifications for a consultant to develop the plan should be published by this week, Mr. Garran said. About $28,000 will be paid to the consultant through a Coastal Zone Management matching grant. Other grants, if received, would help in replacing the float system and dredging the harbor.

Mr. Garran said the county is considering purchasing dredging equipment that Truro could rent for a nominal fee that would greatly reduce cost of dredging the harbor. Eleanor Fortini, a member of the committee, is also a member of the dredging group that has been analyzing the county's harbor and river needs.

Mr. Garran said, in an effort to improve boating conditions, many of the private moorings in the harbor have been removed and owners have been told to pick them up. They will be replaced with town moorings that will be installed in a "grid" on the Corn Hill side of the harbor, bringing "order and quality" to the mooring system.

Mr. Garran reported that in bad weather, many makeshift moorings, such as two cement blocks tied together, have resulted in boats straying and damaging other boats. Mushroom-style moorings also have caused problems because they have not been dug in deep enough, so vessels scrape against them.

Fees from private moorings and those sold by the town last summer amounted to about $8,000. Mr. Garran expects that sum to reach $9,300 next summer from renting the town moorings.

Last year there were about 650 "day" launchings during the season, he said, a drop from about 1,000 launchings a few years ago, an indication of the deterioration of harbor access from sand building up in the channel.

Mr. Garran said there is now an "official" waiting list for people who want moorings. The study will also determine how many boats can use the harbor comfortably.

Mr. Garran praised Harbormaster Irving Wheeler for his efforts in controlling activity at the harbor and for his diplomacy.

"He is one of the best public relations people on the face of the Earth," Mr. Garran said. "He speaks kindly and gently to all."

Mr. Garran presented the Fiscal 1993 budget of $15,000, which will leave about $13,000 in the harbor account to be held for future expenses. He indicated that the salary account will be increased next year to allow for more coverage at the harbor.

Ms. Fortini noted that charges at the harbor are very low compared to other similar facilities and could be increased.

While the committee does not want to "drive people out," Ms. Fortini said, it does wants funds from the harbor to help pay for dredging. Mr. Garran said he hopes no money will have to be raised and appropriated. If there is a bond issue to pay for dredging, it would be paid for from the harbor's revolving account, he said.

Ms. Fortini said she is encouraged by the progress made by the two committees.

"It's all coming together finally," she said.

Truro hearing launches harbor plan

By HAMILTON KAHN
STAFF WRITER

TRURO – Nearly 100 residents turned out for a public hearing last night, beginning a yearlong process of developing a management plan for Pamet Harbor.

Pamet Harbor's problems are nothing new, said project manager Mark Robinson of Horsley Witten Hegemann Inc. Robinson read from a 1958 Cape Cod Times article, which described the dredging of the harbor channel and installation of a boat ramp.

"The issues . ... are much the same today as in 1958, 1858 or 1758," Robinson said.

The 4-mile Pamet River leading to the harbor may be unique because it starts at the ocean and flows to the bay, Robinson said. However, the construction of 18 dikes near the harbor over the years has greatly reduced tidal flushing, he said.

Project director Scott Horsley said a key question about the feasibility of dredging will be the quality of the harbor sediment. If it contains metals or hydrocarbons, it will be harder to dispose of, he said.

Most questions from the audience concerned dredging. David Dutra, a lobsterman, said he had collected signatures from 30 commercial fishermen who want the harbor channel dredged.

Dredging is only one option being considered, said Eleanor Fortini, vice chairwoman of the town's Harbor Management Planning Committee. The final plan, which will need to be approved at town meeting, will require compromises, she said.

Pam Rubinoff of the state Coastal Zone Management agency said harbor improvements are at various stages of planning or implementation in Provincetown, Wellfleet and Orleans, where hydraulic dredging is being done at Rock Harbor.

The Cape Codder
10/23/92

Comprehensive Pamet Harbor Plan Continues to Make Slow Progress

By Joyce Johnson

Progress is slow but steady for developing plans to upgrade Pamet Harbor in Truro, members of the Pamet Harbor Commission and Harbor Planning Committee reported last week.

The harbor and channel are navigable for only a few hours of each tide because of extensive silting.

A 23-member committee was appointed to develop the plans, but major decisions such as dredging will go before the voters prior to implementation.

"A harbor management plan must consider all aspects of the uses of the harbor, including how these uses will interact with one another, and the committee must have representatives from all areas of government and the private sector which have anything to do with the harbor," the committees said in explaining the unusual size of the planning group.

In addition to the committees, a consultant has been hired, with the state Coastal Zone Management office and town sharing costs.

The consultant's preliminary report, expected to favor a plan to dredge the harbor and the channel to it from Cape Cod Bay, is expected within the month.

Last Wednesday, Special Town Meeting voters approved a $15,000 transfer from the Pamet Harbor fund — derived from mooring and ramp receipts — to be combined with $45,000 from the state to pay for engineering plans for dredging the harbor.

The area to be dredged will follow the dredge plan that was implemented in the 1960s.

The engineering study, which will provide a detailed bathymetric survey to determine the quality of the material to be dredged, will also indicate future dredging needs for the area.

The dredging project has been endorsed by the harbor management planning committee and harbor commission, but no work will be done until voters have an opportunity to evaluate the information and vote on it.

Should the county purchase a dredge, the use of it would cut costs of the project and future maintenance.

In the meantime, projects are already in the works to increase the safety of mooring for all boaters, make better use of available space, and increase income for the harbor facility.

A newly installed shallow water mooring system has been stalled in the area directly in front of the parking lot. It can accommodate up to 80 boats at one time.

The moorings may have to be relocated when the dredging is done, but would remain similar in use and construction.

New town-owned moorings and floats will be installed in the deep water anchorage, south of the boat ramp and towards the Pamet Yacht Club. Construction of those facilities will start next year.

A new, double boat ramp was installed in 1989, paid for by the state Public Access Board of the Department of Fisheries, Wildlife and Environmental and Law Enforcement agency. The town is obligated to conform to state rules and regulations, however controversial, once it accepts such state projects.

The public access board plans to install a new access wharf and float system next year that will replace the present "courtesy" float system. It will parallel the existing ramp and extend into deep water at all tides.

In other plans, the access board intends to rebuild the parking lot and its drainage system to control more effectively road runoff into the Pamet River, considered a major cause in high coliform counts that have closed the area to shellfishing.

(The state Department of Highways recently changed the drainage system on Route 6, which contributed to runoff and pollution of the upper Pamet, as well.)

Increased mooring and ramp fees will probably be one of the negative results of the improvements to the harbor facility, although no increases are planned for the 1993 season.

Although access for large boats will be limited, use of the harbor by commercial vessels is included in the projected plans.

Other potential concerns under review by the committees relate to the expected increase in traffic and parking needs.

Cape Cod Times
SUNDAY, NOVEMBER 22, 1992

PAMET

Continued from B-1

springs, as many residents believe.

The word "pamet," lower case, is, in fact, a geological term, which Woods Hole geologist and former Truro resident Graham Giese says is defined as a dry valley formed by glacial deposits on Outer Cape Cod. (The word is originally derived from the Payomet Indians who orignally settled the valley.) But because the Pamet is not a dry valley, the Pamet itself is not actually a pamet, in the strict sense of the word, Giese says.

In response to a recent survey, Truro residents said their favorite "use" of the harbor is for watching sunsets. And although that may seem superficial, Robinson says appreciation of aesthetics may lead to a wider concern about the Pamet River and valley.

"We have to encourage them to expand on that interest," Robinson says.

Ultimately, the valley will continue to be shaped by the same forces that have brought it to where it is today: mankind and nature, each with its own "agenda," conscious or otherwise.

Charles Davidson, chairman of the Truro Conservation Commission, says he is comfortable that the needs of people can be met without damaging the river. Specifically, he believes that the harbor can be dredged and made into a useful recreational resource without ruining shellfish beds or otherwise harming the environment.

"If I thought for one moment that dredging the harbor would be a major detriment to its future, I would react more strongly to the idea of it," Davidson says.

From the Head of the Pamet to Pamet Harbor, the Pamet Valley has long been its own little world, enclosed by the glacier-formed hills to the north and south. Families whose roots go back several generations live along the river's banks in houses dating back a century or more.

Perry Anthony, who lives in the house on North Pamet Road her parents bought in 1923, remembers a feeling of isolation during the summers she spent in Truro as a child during the '30s and '40s. Few people had cars then, and virutally all the necessities of life were delivered to your door – groceries, fish, ice.

"We didn't see people much," Mrs. Anthony recalls. "I learned to climb trees, my sister learned to read books."

Truro's tranquility appealed enough to her father, illustrator Edward Wilson, so much that he and her mother, Dorothy, left New Jersey and moved to Truro year round, where they lived for 30 years. Mrs. Anthony followed the same pattern in 1976, when she and her husband, stage and film director Joseph Anthony, also moved to Truro.

Today, the open views of the valley from her home have been filled by the trees that have grown up over the years, but the same atmosphere of peace exists, Mrs. Anthony says, which is why she feels so much at home.

"The seasons change so gorgeously in this valley," she says.

TNA looks closely at Pamet watershed

Studies indentify problems, Truro must find solutions

Only town on Cape without wetlands law

By Peter Steele

Truro Neighborhood Association members heard Monday from environmental consultants that they must decide how they want to manage the environmentally sensitive Pamet River watershed area, which has the potential to hold another 500 homes and host expanded recreational and economic activities.

John K. Whiteman, consultant to the Truro local comprehensive plan, told over 150 people at the association's annual meeting that the Pamet watershed area encompasses about one quarter of the land in Truro.

"There is the potential of another 500 homes in this area," he said. "And that is a conservative estimate."

In drafting the wetlands section of the local comprehensive plan, Whiteman said three themes have evolved: the potential for development of the watershed area, the complex mix of social, economic and environmental issues there, and the partnerships that will be needed to address the issues. He said partnerships between the town, the Cape Cod National Seashore and private landowners in the watershed will be needed to manage the area.

The watershed is comprised of 36,000 acres, Whiteman said, of which 50% is protected by the Seashore, the Town of Truro, a conservation trust or private landowners. Thirty percent of that area has been developed, which means there is at least one building on a lot, he said. There are now 700 homes in the Pamet watershed, Whiteman said.

Fifteen percent of the area is still buildable, and five percent of the privately owned land is unbuildable, he said. Whiteman said there are 450 buildable acres left in the watershed, most of which are already divided into small parcels.

Only about 50 parcels actually abut the Pamet River, and only four of those are buildable, he said. The rest of the parcels are mostly wetlands to the north and south of the river, he said. Whiteman suggested the town purchase the parcels that are buildable to protect the river.

Related story page 9

He said the Pamet is an exceptional resource, not only for its environmental value, but for the second-home market and tourist industry. Two-thirds of all the structures in Truro are seasonal residences, he said, each of which brings in $1,000 net revenue to the town without overstressing services, such as schools. If managed properly, the remaining buildable lots in the Pamet watershed area could earn a fiscal net return for the town, Whiteman said.

He told the audience that the town will need a viable long-term water supply and suggested Provincetown, Truro and Wellfleet work together to find one. The local comprehensive plan will urge the town to work with the National Park Service to find a water supply within Seashore boundaries, Whiteman said. The Higgins Hollow area would most likely produce the highest yield for a water supply, he said.

Scott Horsley, consultant to the Pamet Harbor management plan, said the plan studies just the harbor area, not the entire Pamet River valley. Midway through the year-and-a-half long plan, Horsley said, "We see the most significant impact is the placement of the dikes and bridges." He said these structures have had a dramatic effect on the Upper Pamet by stemming the natural tidal flow of the area.

The high counts of coliform, which come from animal feces and cause illness, that have been found in the Pamet are related to storm water run-off that washes into the river, not from septic systems, Horsely said. With data to support that conclusion, he said the state Department of Environmental Protection agency could be persuaded to issue a "rainfall closure" that would allow the opening of shellfish beds 48 hours after a rainfall, he said. There are low-cost options to mitigate storm water run-off, he added.

Horsely urged the crowd to review Truro's bylaws and regulations on wetlands. "Truro is the only town on the Cape that does not have a wetlands bylaw," he said.

The harbor plan will make recommendations, including the rainfall closure, removal of dikes to allow natural flushing of the harbor area, and construction of a pedestrian bridge stretching from the harbor parking lot to the railroad bed to allow access to the recreation area beyond it, Horsley said.

Another recommendation is to close the section of the barrier beach south of the harbor to off-road vehicles, since there is no public access there anyway. The vehicles would still be allowed to the north, where there is public access, he said.

Mark Tabor, on-site planner for the Seashore general management plan, said the Pamet River valley is a microcosm of what is happening in the Seashore. He said the area includes natural resources, such as estuarian systems, ponds and barrier beaches, and cultural resources, such as historical architecture and landscaping, harbor and marine activity, historic trails such as Old King's Highway and possibly prehistoric remains.

The Seashore's job is to balance the uses and decide which gets priority, Tabor said. "The environment must take the priority," he said. "We must defer to the environmental resources."

Tabor said human systems should be adapted to the environmental resources. Faced with the loss of parking at the ocean beaches, residents may decide parking is not the best use of the shoreline and opt for shuttle buses and pedestrian trails to the beaches, he said. "Towns can make a great profit by using alternative transportation," Tabor said.

The Seashore seeks to protect the historical integrity of historical structures and landscaping while respecting he rights of property owners, he said. "But we must plan limits on residential growth and bring the human impact in line with the impact on resources," he said.

He said the question is not how does the Pamet affect the Seashore? The question to ask the Pamet River Valley, Town of Truro and the Seashore, Tabor said, is, "Are you ready for a change?"

Experts explain what's wrong with Pamet

River rising, salt marsh becoming fresh, coliforms from animal waste

By Peter Steele

Sea level at the Pamet River is rising, the saltwater marsh at the Upper Pamet has been transformed into a freshwater marsh and high coliform counts that have forced the closure of shellfish beds come from animal, not human, waste.

The Truro Neighborhood Association heard this account Monday from environmental experts who explained the Pamet River Valley from geological, biological and botanical points of view. The panel discussion of the Pamet watershed was moderated by Brenda Bolelyn, professor of biological sciences at Cape Cod Community College and vice-chairman of the Cape Cod National Seashore Advisory Commission. She is a Truro resident.

Dr. Graham Giese, a founder of the Center for Coastal Studies in Provincetown and professor at Woods Hole Oceanographic Institute, spoke of the formation of the Pamet River valley and its condition today. The Pamet River valley is a flooded glacial outwash left by the last Ice Age, Giese said.

The valley was flooded by sea levels that have been rising over the past 14,000 to 15,000 years since the ice melted, he said. The sea level is still rising at the rate of about one foot every 100 years, he said, and so is the groundwater, but at a much slower rate.

Two saltwater marshes exist on the west side of Wilder Dike near Pamet Harbor. One freshwater marsh exists on the east side of the dike, Giese said. The marshes on the west side are rising with the sea level as sediment is washed in, but the freshwater marsh is not rising because the dike prevents the sediment from reaching it.

The oceanside barrier dune at Ballston Beach is migrating inland to the west about 250 feet every 100 years, Giese said. The dune migrates landward by storm/wave overwash, which carries sediment into the marsh behind the dune and forms the foundation for the dune as it moves inland, he said.

The sand had not been allowed to deposit behind the dune since road crews would remove sand from the road that runs behind it, interrupting the migrating process, Giese said.

On the bay side, the barrier beach from Fisher Beach to Corn Hill has been separated by the tidal inlet that forms Pamet Harbor. The inlet is protected by two jettys jutting into the bay, perpendicular to the barrier beach.

Since sand is washed from south to north along the beach, the beach behind the south jetty has stabilized so much that sand is actually being carried around it and into the harbor, Giese said. The beach behind the north jetty is starved for sand and has eroded, he said.

Removing the jettys is not a good idea if the town wants to keep a navigable harbor, Giese said. But moving sediment from the south side to the north side of the jettys could be part of a dredge project, he said.

Dr. Charles Seymour, a medical microbiologist who studied the Pamet from 1989 to 1991 for MIT and Boston University, spoke of the fecal coliform count in the river and wetlands. He illustrated his comments with slides showing 1930s depictions of typhoid and polio as monsters that needed to be slain. Typhoid and polio originated from human feces in water sources that reentered humans as they consumed the water, he said.

The monster is now the U.S. government with overly stringent regulations because they don't distinguish if the e coli bacteria is from humans or animals, Seymour said. He said MIT/Boston University researchers studied nine sites along the Pamet to determine if the fecal coliform is coming from animal or human waste. The coliform counts necessitate regular closing of the Pamet's shellfish beds.

The coliform bacteria is "not coming from septic tanks," Seymour said. He said the researchers found some "hot spots" of the coliform, but "people are not doing it."

After rainfalls, the fecal coliform counts shot up, he said, as the rain and road runoff washed animal wastes into the water. "It is looking like people are not responsible on circumstantial evidence," Seymour said.

The researchers caught animals and birds to see if they contained carcinogens that would make people sick. "Basically, we found carcinogens everywhere," Seymour said. "We found a large number of birds are carrying all kinds of bacteria."

He said if that is why the shellfish beds are being closed, "we have to not invite birds to come here."

Howard S. Irwin is a botanist, professor, chairman of the Truro Conservation Commission and was a member of the 1961 Department of Interior team that did surveys for the Cape Cod National Seahore. He said botanists interpret flora based on ecosystems, which are dynamic and always in a state of flux.

All over the world, mankind has exerted its influence on ecosystems so that they are now under stress that makes it difficult for species to adapt to genetically, Irwin said. He called for cultural instruments, such as the National Park Service, endangered species legislation, local codes and regulations to increase environmental awareness.

The construction of Wilder Dike in the 1880s isolated the Upper Pamet from the tidal flow and rainfall, Irwin said. That resulted in the transition of a saltwater marsh to a freshwater marsh and "made the Upper Pamet an artifact," he said. The Upper Pamet was then dominated by such flora as cattails, highbush blueberries and poison ivy, all found in fresh water.

Mosquito control ditches drained off more water, he said. Then black cherry, bayberry and golden rod, to name a few, moved in as the area became drier, Irwin said. "The trend was away from a salt marsh to upland woods," he said. Salt marshes are preferable because they feed fish stocks and provide breeding grounds, Irwin said.

Whereas the flora of the Lower Pamet, which is west of Route 6 near the harbor, continues as a salt marsh, the diked off parts east of Route 6 have been artificially maintained, Irwin said. The Upper Pamet is "now characterized by upland woodland," he said.

Giese said the Pamet could become unstable as the salt marsh rises with sea level, but the freshwater marsh sinks relatively lower and lower to sea level. Irwin said it is time to consider removal of dikes and clapper valves to allow the tidal flow along the whole river.

"It is high time that we consider the return," he said. "It requires the will of all of us to see through the long-term problems of the town, not just talk about it."

APPENDIX D

APPENDIX D

NUMERICAL MODELING
Conducted by Aubrey Consulting, Inc.

The 1-D model, DYNLET1, written by the U.S. Army Corps of Engineers, Coastal Engineering Research Center (Amein and Kraus, 1991), was chosen to model Pamet Harbor. This model has the advantage of being more stable than the standard 1-D linked-node tidal models since the numerical scheme uses an implicit solution technique. The numerical model was used to simulate the present conditions within the Harbor, including flushing rates, tidal elevations, and current velocities. Three additional simulations of the model were used to evaluate the potential impacts of the proposed dredging and reconfiguration of the entrance jetties. Changes in tidal flushing, tidal currents, tidal elevations and erosion and scour trends were estimated for each of these model simulations. A brief description of the numerical model theory is given below, followed by a discussion of the model setup.

Numerical Model Theory

A detailed description of the governing equations used in the numerical model can be found in Amein and Kraus (1991). Generally, the two equations necessary to describe the tidal hydrodynamics of a particular system are the following depth-averaged conservation of mass (1) and momentum (2) equations:

$$\frac{\partial Q}{\partial y} + \frac{\partial A}{\partial t} - q = 0 \qquad (1)$$

$$\frac{1}{A}\frac{\partial Q}{\partial t} + \frac{1}{A}\frac{\partial}{\partial y}\left(\frac{Q^2}{A}\right) = -\tau_b \frac{P}{\rho A} + \tau_s \frac{B}{\rho A} - gS_e - g\frac{\partial z}{\partial y} \qquad (2)$$

where:

$A(x,t)$ = cross-sectional area
$Q(x,t)$ = the volume flow rate
q = the lateral inflow or outflow per unit channel length per unit time
τ_b = the bottom shear stress
P = the wetted perimeter of the channel cross-section
ρ = the density of water
τ_s = the surface shear stress
B = top width of the channel cross-section
S_e = rate of head loss with longitudinal distance
g = acceleration due to gravity
z = water surface elevation.

The head loss term in the momentum equation addresses the turbulent losses due to a rapid transition of cross-sectional area of successive nodes. This term is assumed to be negligible in the present analysis. The bottom shear stress consists of frictional stress and eddy viscosity effects. Since the flow velocities within the system are relatively small, the eddy viscosity term may be incorporated within the term describing the bottom friction stress: the empirical friction coefficient. Both equations (1) and (2) are known as the one-dimensional long-wave equations. In general, they area applicable where the assumption of hydrostatic pressure distribution is valid, i.e. flow situations where the wavelength is significantly greater than the water depth.

The 1-D model uses a channel cross-section described by any number of points. For each point in the cross-section the empirical friction coefficient must be specified. A sample cross-section is shown in Figure D-1. Equations (1) and (2) constitute a system of first-order nonlinear hyperbolic partial differential equations. The solution technique used in this model is an implicit scheme which uses centered finite difference equations in both space and time. The two nonlinear algebraic equations are solved by a general form of the Newton iteration method. Since implicit techniques require the simultaneous solution of the governing equations at every node, the procedure needs rapidly convergent matrix solvers. By taking advantage of the coefficient matrix sparseness and bandedness, an accurate solution technique was developed.

The program allows for flexible grid spacing and is unconditionally stable allowing for the use of large time steps. The model can provide detailed one-dimensional velocity information both along-channel and cross-channel in a system of interconnecting channels. Locations of stations along a particular cross-section can be arbitrarily set, allowing the velocity and stage at locations of interest to be obtained readily. The only difference between DYNLET1 and a fully two-dimensional solution technique is that the flow direction is constrained along the axis of the channel in DYNLET1.

Boundary conditions in the numerical model are specified at all free channel ends. These external boundaries are defined by current velocity, tidal amplitude or discharge conditions. The tidal amplitude may be described by a time series of water surface elevations at each time step or by specifying the height and period of sinusoidal forcing.

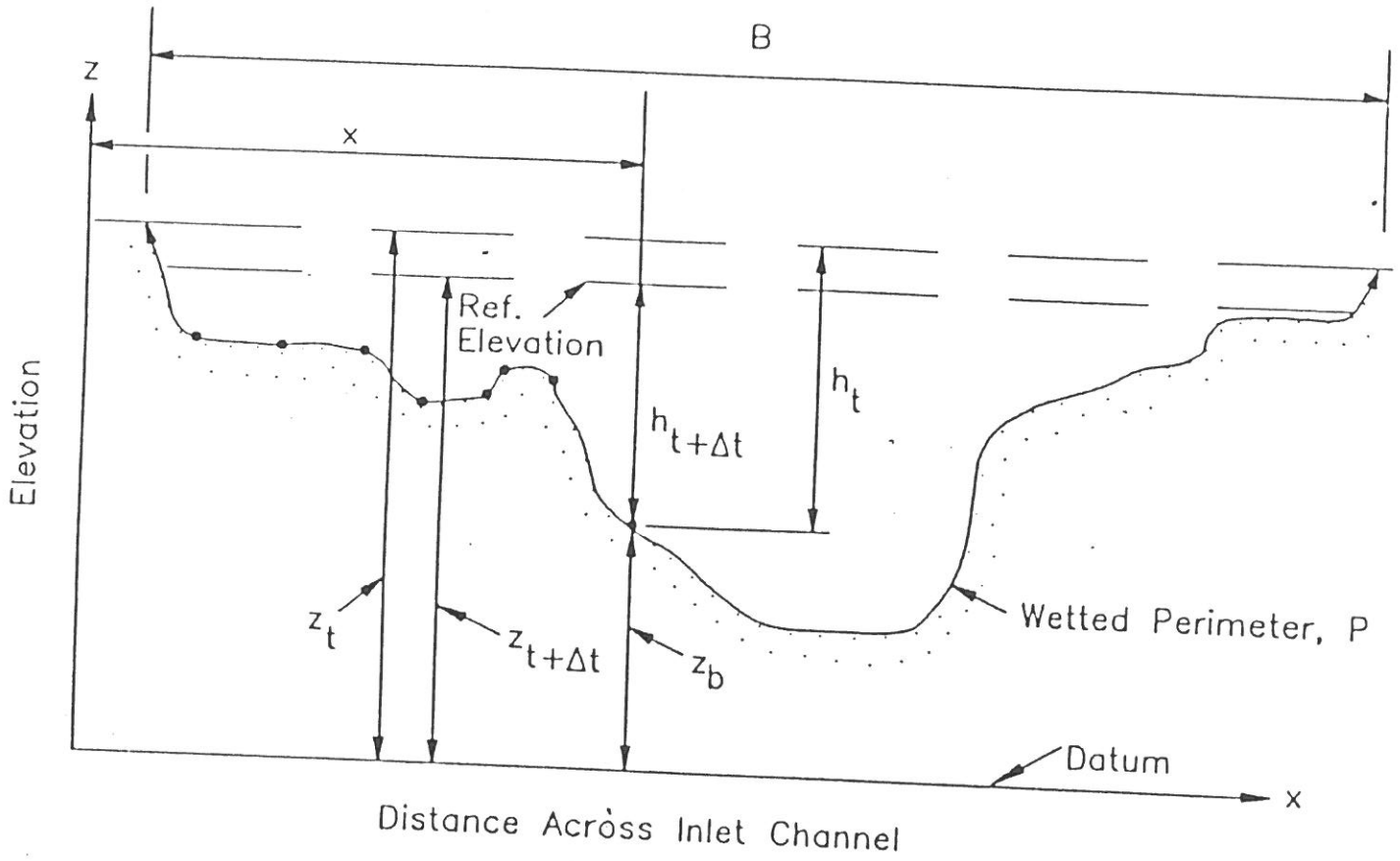

Figure D-1: Definition sketch for inlet channel cross-section (from Amein and Kraus (1991)).

Numerical Model Setup

Implementation of the 1-D numerical model requires that a grid be developed encompassing all areas of the Pamet Harbor system. The grid may be composed of any number of channels (sections of the main estuary or sections that branch off of the main estuary) and nodes (cross-sections along the channels). The location where a channel splits is called a junction. In the model, a junction is defined as the end of one channel and the beginning of another. Multiple nodes exist at each junction, depending on the number of intersecting channels. All nodes at each junction must be defined by identical cross-sections.

The model grid established for the Pamet Harbor system is shown in Figure D-2. Five channels were required to model the Pamet Harbor system: the entrance channel, Little Pamet mouth (includes extensive tidal flats), the central Harbor area, the upper Pamet River, and Mill Creek (includes mooring basin area and tidal flats). The nodes describing the system are variably spaced; the smallest spacing indicates areas of special interest or rapid flow changes. A total of thirty-six (36) nodes were used to model the entire Pamet Harbor system.

Boundary conditions within the model were defined at all free channel ends. The tidal forcing was simulated using the M2, M4, and M6 tidal constituents at the entrance of the Harbor (beginning of channel 1). These constituents were derived through harmonic analyses of previous measurements of tidal fluctuations made by Giese et. al., (1990). The boundaries at the other free channel ends (2, 4, and 5) were defined by a velocity of zero.

The channel cross-section geometry must be supplied to the numerical model at each of the grid nodes. To accomplish this, the model grid was overlain on the most recent bathymetric map surveyed by Coastal Engineering, Inc. (1992). Channel cross-sections were digitized at each of the 36 node locations. Cross-section data for the Pamet River was taken from Giese et. al., (1990) since the Coastal Engineering, Inc. bathymetry map does not extend beyond the railroad dike. By using these data describing the Harbor bathymetry, the numerical model was setup to simulate existing conditions within Pamet Harbor.

FIGURE D-2.
PAMET HARBOR
NUMERICAL MODEL GRID

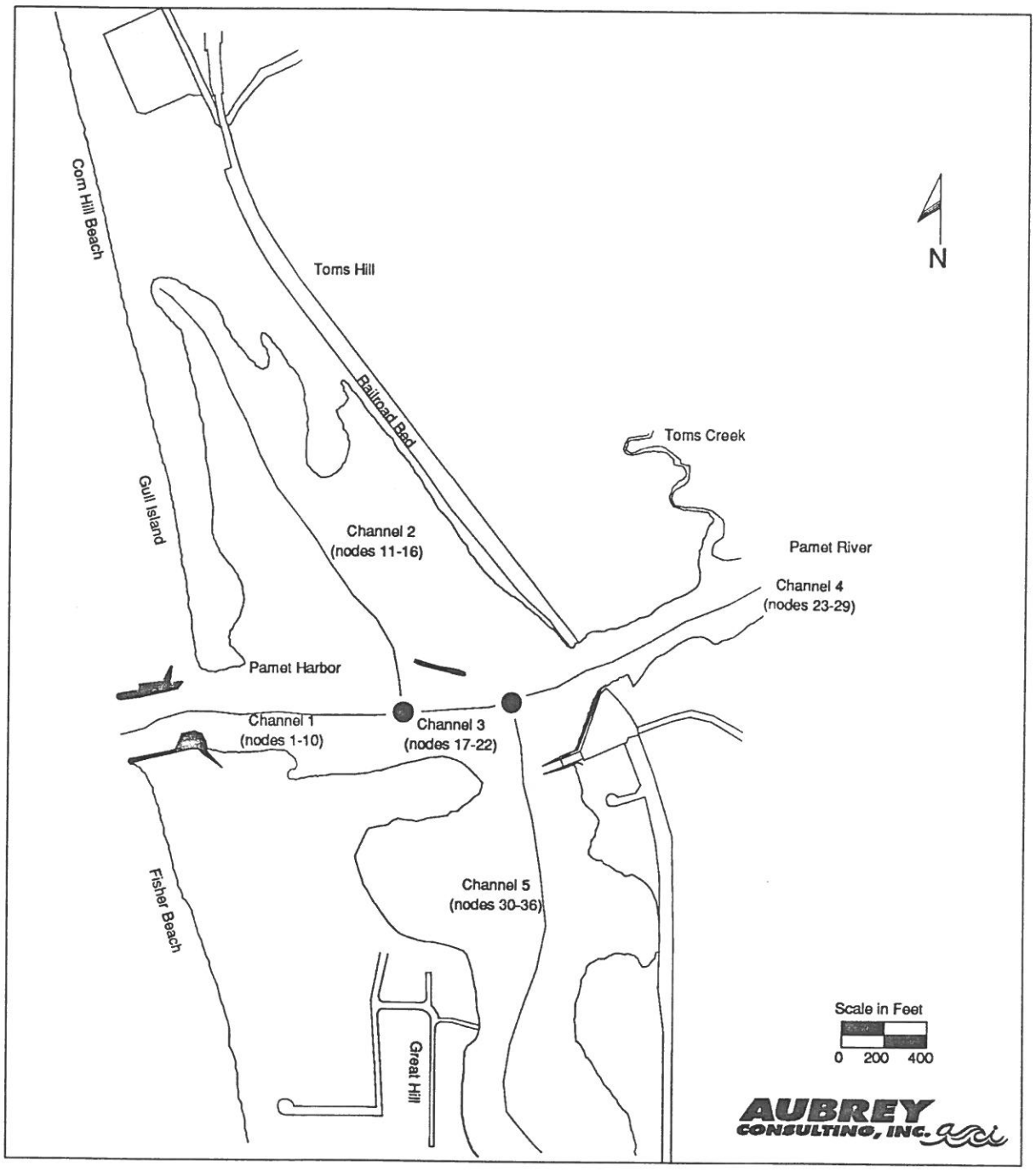

Figure D-3.
Comparison of Model to Field Data at Wilder Dike

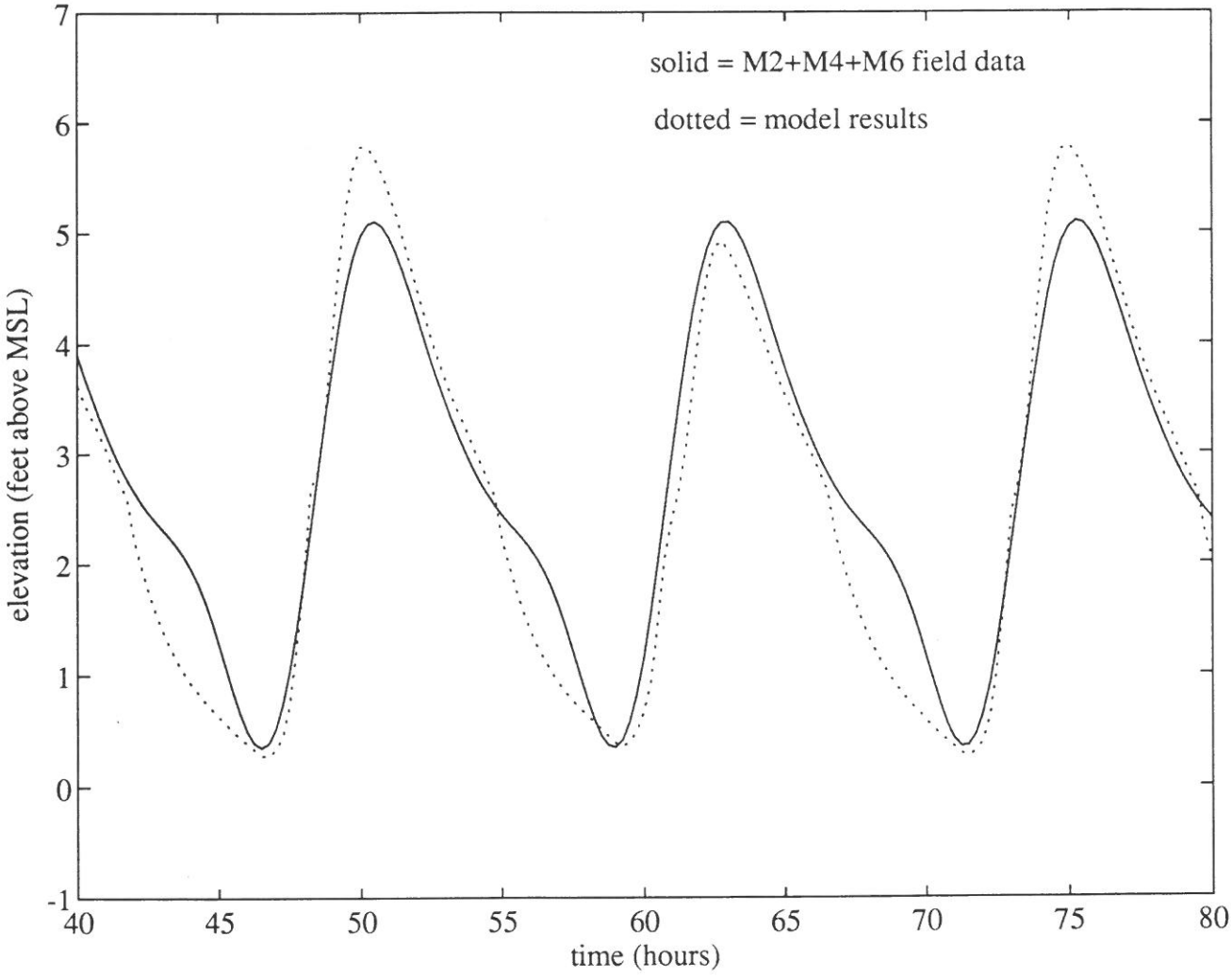

Figure D-4.
Model Results for Locations in Pamet Harbor