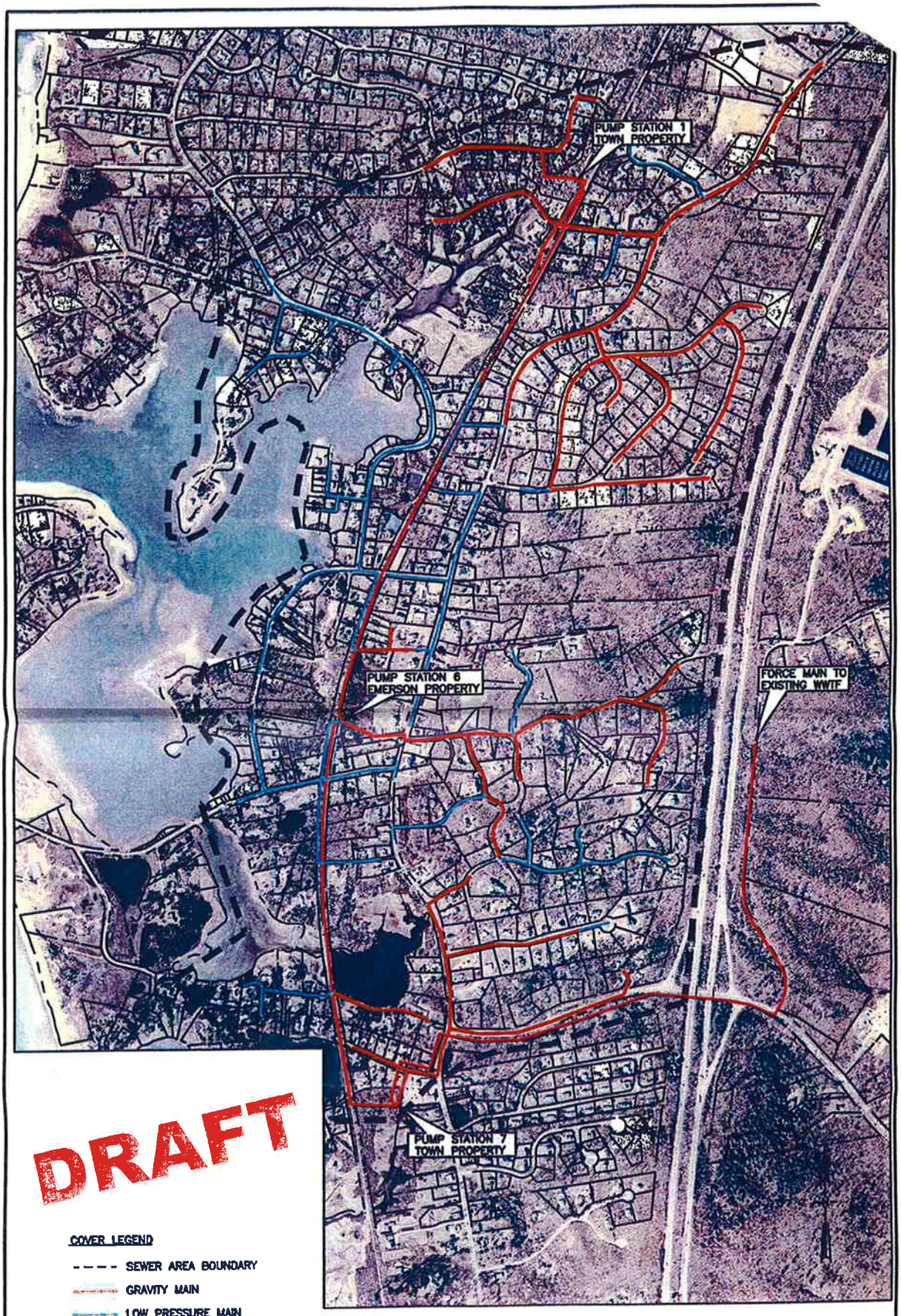
Appendix D

Preliminary Sewer Layout for West Falmouth Harbor Sewer Extension Area, 2005



Stearns & Wheler, LLC
Environmental Engineers and Scientists
HYANNIS, MA
DATE:1/05 JOB No.:30143

TOWN OF FALMOUTH
WASTEWATER PLANNING SERVICES

FIGURE 2
WEST FALMOUTH HARBOR AREA

Appendix E

February 2007 Technical Memorandum Summarizing Additional Scenario Runs of West Falmouth Harbor MEP Linked Model

SMAST University of Massachusetts Dartmouth
The School for Marine Science and Technology

********** **Technical Memorandum** **********

To: Korrin Petersen, Advocacy Director, Coalition for Buzzards Bay
Mark Rasmussen, Executive Director, Coalition for Buzzards Bay
From: Brian Howes, Director Coastal Systems Program
Roland Samimy, Coastal Systems Program
John Ramsey, Applied Coastal Research & Engineering, Inc.
Sean Kelley, Applied Coastal Research & Engineering, Inc.
Ed Eichner, Cape Cod Commission
RE: Scenario Runs of West Falmouth Harbor MEP Linked Model
Date: February 22, 2007

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The present Technical Memorandum details the results of 3 Scenario Runs (in addition to 3 in the MEP Technical Report 2006) of the MEP Linked Watershed-Embayment Model developed for West Falmouth Harbor as described in the MassDEP/SMAST MEP Nitrogen Threshold Report for West Falmouth Harbor (May 2006). The Scenarios focus on determining whether different watershed N loadings meet or exceed the nitrogen threshold at the sentinel station in Snug Harbor. Meeting the nitrogen threshold at the sentinel station is needed to restore the currently impaired eelgrass and benthic infaunal habitats within the West Falmouth Harbor System.

At present, historic eelgrass and benthic animal habitat within much of West Falmouth Harbor is significantly impaired owing to watershed nitrogen inputs that exceed this estuary's assimilative capacity, thereby resulting in eutrophic conditions. However, the Town of Falmouth has recently upgraded its WWTF and improved the quality of the facilities treated effluent discharging to the watershed. These improvements have reduced the effluent total nitrogen concentration from 26.5 mg N L^{-1} to 3 mg N L^{-1}, with a corresponding decrease in nitrogen load to the Harbor watershed. Unfortunately, there is a 7 year groundwater travel time between the WWTF land discharge site and the estuary, which means that the higher nitrogen load (pre-2006) of 13,300 kg N yr^{-1} is still moving through the aquifer toward the bay. The result is that the "old" WWTF discharges will continue to impact the harbor waters for approximately 6 more years. In contrast, the newly upgraded WWTF is presently discharging 1,698 kg N yr^{-1} into the watershed to West Falmouth Harbor, which will ultimately yield a substantial improvement and a benefit to the Harbor resources. It is the relationship between lag time, future build-out loads and the attainment of the nitrogen threshold level for restoration of the Harbor's habitats that is the focus of the scenarios presented below. These scenarios have been performed at the request of the Coalition for Buzzards Bay to provide additional information to MassDEP, municipal officials, private citizens and environmental groups in order to support decisions regarding the restoration and stewardship of this critical coastal system.

Support provided by environmental organizations for the management of coastal systems has a significant history in the Commonwealth. The MassDEP with SMAST previously received such

support for the conduct of a scientific analysis to develop permit targets for the West Falmouth Harbor WWTF (2000). The present effort is nearly identical in spirit in that it provides information to the Town, MassDEP and the Cape Cod Commission (a) that would otherwise not be available, (b) is part of a public process with the information freely available, and (c) underscores the importance of an involved citizenry in the stewardship of the Commonwealth's critical estuarine resources.

The present effort builds upon the MassDEP/SMAST MEP Nitrogen Threshold Report for West Falmouth Harbor (May 2006) which presented the results from 5 different watershed loading scenarios relative to meeting the nitrogen threshold to support healthy habitat quality throughout the Harbor system:

- Present watershed N loading impinging on the Harbor, using pre-2006 WWTF effluent discharges and present development;
- Present watershed N loading with the WWTF discharge removed from the watershed;
- No anthropogenic nitrogen loading (except related to atmospheric deposition)
- Build-out at existing zoning including the newly upgraded WWTF discharging at the planned 1.0 MGD flow, with no sewers within the watershed
- Build-out at existing zoning including the newly upgraded WWTF discharging at the planned 1.0 MGD flow, with sufficient sewers in the watershed to meet the threshold.

The results of these 5 scenario runs indicated that at Build-out and under the new WWTF effluent quality at 1.0 MGD flow, sewering or other nitrogen management actions would be required to lower the nitrogen inputs to the Harbor to meet the nitrogen threshold required to restore the currently impaired eelgrass and infaunal animal habitats.

However, it is clear from points raised at the Town of Falmouth Public Presentation of the MEP Nitrogen Threshold Report (January 16, 2007) and the results of the MEP scenarios, that additional watershed loading scenarios would be needed to support nitrogen management decisions regarding this estuary. The additional 3 scenarios and the results relative to habitat restoration and management are presented below:

Scenario 07-1: If no additional nitrogen from any source is added to the West Falmouth Harbor watershed over 2006 levels, either from development or through additional effluent discharge from the WWTF, would the nitrogen management threshold be achieved?

This scenario used the present discharge of treated wastewater effluent from the newly upgraded WWTF and the existing watershed land-uses (level of development) to project conditions after the WWTF groundwater plume from the old WWTF facility has "washed out" (2012-2014).

WWTF discharge = 0.4096 MGD
Effluent TN = 3 mg N L^{-1}
Effluent discharge of 57% to basins, 43% to irrigation

Model Output: *If the nitrogen concentrations within West Falmouth Harbor were allowed to come into equilibrium with the nitrogen loading presently to the watershed (i.e. no new*

development, present 0.409 MGD from newly upgraded WWTF, and the "old" WWTF plume washes out) ***the sentinel station will be 0.347 mg TN L^{-1} or less than the 0.350 mg TN L^{-1} Threshold level*** *required to restore the eelgrass and infauna animal habitats throughout this estuarine system.*

Scenario 07-1A: Scenario 07-1 (no additional nitrogen over 2006 from any source) yielded nitrogen inputs to the Harbor that meet the nitrogen threshold needed to restore the eelgrass and infaunal habitats with present locations of effluent discharge, how much more "improvement" in Harbor nitrogen levels would be achieved by shifting effluent discharge from the WWTF entirely to the basins (zero to irrigation)? The purpose of the shift in the location of discharge is to minimize the amount of effluent plume directly entering the harbor in groundwater seepage and maximize the amount entering the Mashapaquit Creek salt marshes. Present, WWTF discharge is 57% to basins, 43% to irrigation.

The concept is that effluent discharged to areas that flow to the Mashapaquit Creek salt marsh will result in attenuation of nitrogen by the marshes prior to entering the Harbor. At present, the discharge to the basins and irrigation sites results in only ~64% of the effluent entering the salt marshes and the rest entering Snug Harbor and the Inner Harbor basins. Shifting all of the discharge solely to the basins shifts most of the effluent plume into Mashapaquit Creek salt marsh. Note that even if all of the discharge is to the marsh system, the resulting nitrogen load to the salt marsh is still several-fold lower than in 2006 due to a more than an 80% reduction in WWTF N load.

WWTF discharge = 0.4096 MGD
Effluent TN = 3 mg N L^{-1}
Effluent discharge of 100% to basins, 0% to irrigation

Model Output: *If the nitrogen concentrations within West Falmouth Harbor were allowed to come into equilibrium with the nitrogen loading presently to the watershed (i.e. no new development, present 0.4096 MGD at newly upgraded WWTF, and the "old" WWTF plume washes out)* ***the sentinel station will be 0.348 mg TN L^{-1}, compared to 0.347 mg TN L^{-1} using the present distribution of land disposal sites and less than the 0.35 mg TN L^{-1} Threshold level*** *required to restore the eelgrass and infauna animal habitats throughout this system. The reason for the slightly higher (0.001 mg N L^{-1}) Snug Harbor TN level is the shift of the watershed nitrogen load out of the Inner Harbor basin (Chappaquoit) and into the marshes, which discharge to Snug Harbor. However, while this shift does not change Snug Harbor, it does slightly lower the levels in the Inner Harbor basin and Harbor Head.*

Scenario 07-2: Since Scenario 07-1A yielded nitrogen inputs to West Falmouth Harbor watershed that result in TN levels within the Harbor that are below the nitrogen threshold needed to restore the eelgrass and infaunal habitats, how much more nitrogen could be discharged from the new WWTF (i.e. increase in flow over 0.4096 MGD) and still not exceed the nitrogen Threshold? This scenario holds the current land-use loading constant at present levels and varies only the N load from the newly upgraded WWTF (flow based increase in load). The plume from the "old" WWTF has been "washed out" for this analysis.

WWTF discharge increased from present 0.4096 MGD in steps up to 1.0 MGD
Effluent TN = 3 mg N L^{-1}
Effluent discharge of 100% to basins, 0% to irrigation (scenario 1A distribution)

Model Output: *Scenario #1A indicated that if the nitrogen concentrations within West Falmouth Harbor were allowed to come into equilibrium with the nitrogen loading presently to the watershed (i.e. no new development, present 0.4096 MGD at the newly upgraded WWTF, and the "old" WWTF plume washes out, all discharge to Mashapaquit Creek sub-watershed)* ***the sentinel station will be 0.348 mg TN L^{-1}, below the 0.35 mg TN L^{-1} Threshold level*** *required to restore the eelgrass and infauna animal habitats throughout this system. Under these conditions, if effluent discharge from the newly upgraded WWTF increases, with the same level of treatment (i.e. 3 mg TN L^{-1}), the nitrogen concentration at the sentinel station increases proportionally (Figure 1). Increasing the discharge to 0.5 MGD from the present 0.4096 MGD raises the TN at the sentinel station to 0.352, slightly above the threshold level. But increases to 0.7 and 1.0 MGD result in large exceedences of the threshold. It should be noted that if the discharge is left in its current position, the sentinel TN level (Y axis) values are reduced ~0.001 mg TN L^{-1} at each modeled point and the trend remains the same.*

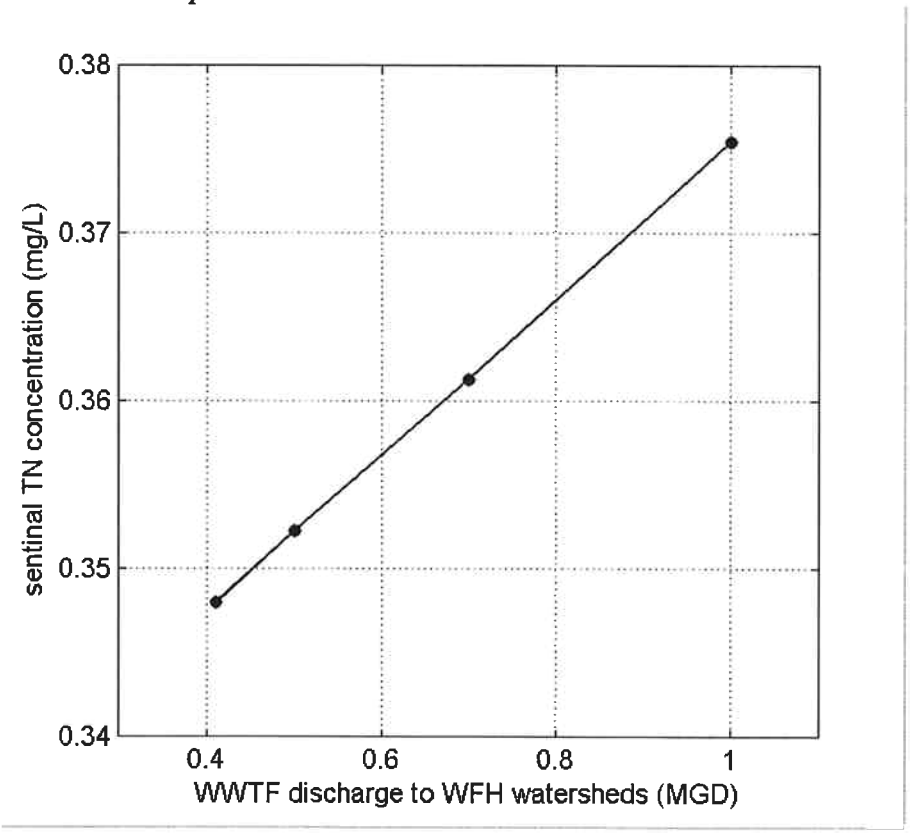

Figure 1. Relationship of tidally averaged TN level at the sentinel station in Snug Harbor to effluent discharge volume (at 3 mg TN L-1) at the newly upgraded WWTF, after the "old" plume is "washed out". The nitrogen threshold level is 0.350 mg TN L^{-1}.

Table A. Comparison of model average total N concentrations resulting from each of the indicated loading scenarios. The Sentinel Station in Snug Harbor is shown in bold print, the nitrogen threshold at this station to restore eelgrass and infaunal animal communities throughout West Falmouth Harbor is 0.350 mg N L-1. . The "Scenarios" are part of the present exercise, the other model runs are from the MEP Nutrient Threshold Report. Scenario 2 values are based upon 0.5 MGD discharge from the newly upgraded WWTF.

Sub-Embayment	Monitoring Station	Present (mg/L)	Present with no WWTF (mg/L)	Scenario 1 (mg/L)	Scenario 1A (mg/L)	Scenario 2 (mg/L)	Full Buildout + Sewering (mg/L)	Full Buildout NO Sewer (kg/day)
Mashapaquit Cr. at Bridge.	PWF1	0.627	0.362	0.396	0.404	0.414	0.412	0.453
Harbor Head/Chappaquoit R	PWF2	0.437	0.361	0.372	0.365	0.367	0.353	0.402
Chappaquoit Basin	PWF3	0.382	0.321	0.330	0.325	0.327	0.326	0.349
Inner West Falmouth Hbr	PWF4	0.370	0.311	0.319	0.318	0.319	0.320	0.334
Snug Harbor	**PWF5**	**0.464**	**0.329**	**0.347**	**0.348**	**0.352**	**0.353**	**0.378**
Outer West Falmouth Hbr	PWF6	0.327	0.302	0.306	0.305	0.306	0.306	0.313
Outer West Falmouth Hbr	PWF7	0.312	0.299	0.301	0.301	0.301	0.301	0.305
Oyster Pond	PWF8	0.534	0.460	0.470	0.464	0.465	0.407	0.509

Table B. Sub-embayment loads used for total nitrogen modeling of the West Falmouth Harbor system, with total watershed N loads, atmospheric N loads, and benthic flux, for **Scenario 1**.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Outer West Falmouth Harbor	1.690	0.921	-2.868
Inner West Falmouth Harbor	4.173	0.866	-4.731
Harbor Head	1.085	0.153	-0.372
Oyster Pond	1.359	0.079	0.000
Snug Harbor	3.888	0.455	-2.744
Mashapaquit Creek	5.690	0.019	0.000

Table C. Sub-embayment loads used for total nitrogen modeling of the West Falmouth Harbor system, with total watershed N loads, atmospheric N loads, and benthic flux, for **Scenario 1A**.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Outer West Falmouth Harbor	1.690	0.921	-2.895
Inner West Falmouth Harbor	3.268	0.866	-4.894
Harbor Head	1.085	0.153	-0.368
Oyster Pond	1.359	0.079	0.000
Snug Harbor	3.458	0.455	-2.852
Mashapaquit Creek	6.496	0.019	0.000

Table D. Sub-embayment loads used for total nitrogen modeling of the West Falmouth Harbor system, with total watershed N loads, atmospheric N loads, and benthic flux, for **Scenario 2**.

sub-embayment	watershed load (kg/day)	direct atmospheric deposition (kg/day)	benthic flux net (kg/day)
Outer West Falmouth Harbor	1.690	0.921	-2.895
Inner West Falmouth Harbor	3.268	0.866	-4.921
Harbor Head	1.085	0.153	-0.372
Oyster Pond	1.364	0.079	0.000
Snug Harbor	3.562	0.455	-2.865
Mashapaquit Creek	7.049	0.019	0.000

Table E. Comparison of of sub-embayment total watershed loads (including septic, runoff, and fertilizer, and the WWTF) used for modeling of each of the indicated loading scenarios. The "Scenarios" are part of the present exercise, the other model runs are from the MEP Nutrient Threshold Report. Scenario 2 values are based upon 0.5 MGD discharge from the newly upgraded WWTF.

Sub-Embayment	present (kg/day)	Present Land-Use with no WWTF (kg/day)	**Scenario 1** (kg/day)	**Scenario 1A** (kg/day)	**Scenario 2** (kg/day)	Full Buildout + Sewering (kg/day)	Full Buildout NO Sewer (kg/day)
Outer West Falmouth Hbr	1.690	1.690	1.690	1.690	1.690	1.359	2.633
Inner West Falmouth Hbr	10.386	3.268	4.173	3.268	3.268	5.301	6.734
Harbor Head	1.085	1.085	1.085	1.085	1.085	0.592	1.334
Oyster Pond	1.359	1.359	1.359	1.359	1.364	0.718	1.468
Snug Harbor	9.570	2.986	3.888	3.458	3.562	3.715	5.523
Mashapaquit Creek	17.649	3.986	5.690	6.496	7.049	6.844	8.466
TOTAL	**41.739**	**14.374**	**17.885**	**17.356**	**18.018**	**18.529**	**26.158**