MEMORANDUM

TO: Ed Eichner, Cape Cod Commission
FROM: Joe Costa, Buzzards Bay Project
DATE: September 29, 1994
RE: Waquoit Bay N calculations and appropriate management strategies

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As you know, the Buzzards Bay Project has been involved with nitrogen management issues in Waquoit Bay for the past four years. Your correspondence to me last week has prompted me to address some major issues and difficulties in developing a nitrogen management strategy for the Waquoit Bay drainage basin, and to propose one possible management strategy for the Cape Cod Commission and the surrounding municipalities to follow.

Application and Appropriateness of BBP tiered limits

The differences in the Buzzards Bay Project target nitrogen loadings for Waquoit Bay sent to the Cape Cod Commission in 1992 and the calculations you sent me last week can be easily explained as follows:

1) The volume of Waquoit Bay used in your calculation is incorrect.

You indicated that Rocky Geyer stated that the volume of the bay is 230,000 m^3, but you note the area of the bay (not including the side ponds like Jehu and Hamblin) is 389 hectares. Since 1 hectare = 10,000 m^2, this is 3,890,000 m^2. If the bay has an average depth of 1 m at half tide, this would equal 3,890,000 m^3. I think the 230,000 m^3 figure Rocky mentioned was really the tidal prism and not the bay volume.

Because I considered the entire watershed, I considered the volume of the Waquoit Bay-Eel Pond-Jehu-Hamblin-Sage Pond complex in my 1992 calculations. In my spreadsheet I have listed the area of these surface waters as 6.56 km^2, and I used 6,040,000 as the volume at <u>half-tide</u> (volume at MLW+ 1/2 tidal prism) for all these embayments (I don't recall if this is a guesstimate or based on some WBNERR report).

2) **We used different flushing times for the bay.**

I used 5.0 days which was based on some discussions I had with Steve Aubrey about the flushing time in the <u>upper third</u> of the estuary-complex. Geyer came up with a flushing time of 2.7 days, which as I recall was for just Waquoit Bay, and represented the average for the whole bay not just the upper bay. Use of 5 days puts the calculation into the area-based loading scale, 2.7 days requires use of the Vollenweider calculation.

3) **Different standard should be used.**
In your calculation you used a water quality standard for SA waters. Because of Waquoit Bay's ACEC designation and because it contains (or formerly did) valuable resources and habitat, the ORW designation should be adopted.

Using the ORW designation, 5 day flushing time, and 6.56 km^2 area, the N loading limit for the entire estuary complex should be 31,000 kg/yr. Using the ORW designation, 2.7 day flushing time figure you mention (I think much too low for upper third of entire complex), and 6,040,000 m^3 volume, and 100 $mg/m^3/V_r$ limit, then the N loading limit for the entire estuary complex would be a remarkably high limit of 82,000 kg/yr.

But there are several problems here, and Waquoit Bay challenges the appropriateness of applying the tiered limits recommended in the Buzzards Bay CCMP. (Actually the tiered limits should not be adopted for embayments already impacted, and I discuss that issue below.)

First of all, it may not be appropriate to develop a single nitrogen management target for the entire Waquoit Bay estuary complex. Clearly Jehu Pond and Hamblin Pond have not seen the kind of algal proliferation and eelgrass bed collapse as observed in Eel Pond and Waquoit Bay, which also receive most of the nitrogen inputs. The Sage Lot drainage subbasin has little potential for new development because most if this subbasin is included in the State park, and that embayment may not require any management action. In practical terms, we may not be able to separate Eel Pond from Waquoit Bay because so much of the Childs River nitrogen inputs end up in upper Waquoit Bay. This suggests we should have three complimentary management districts: one for Waquoit Bay-Eel Pond, and one each for Hamblin Pond, and Jehu Pond respectively.

If we were to apply the BBP tiered limits for Waquoit Bay under this scenario, then we would need an estimate for flushing time in the upper 1/3 of the Eel Pond-Waquoit Bay estuary complex, and depending on flushing time, use the half-tide volume or area of that complex.

Different Approach Needed

The tiered limit approach identified in the Buzzards Bay CCMP however should not be used for Waquoit Bay. The tiered loading limits were meant to be used especially where critical impacts have not yet occurred. Where critical impacts have already occurred, historical trends should be evaluated, and a water quality-habitat condition "target year" should be established, and nitrogen loading limits should be based on estimates of actual loadings entering the bay for that target-year. In Waquoit Bay, historical trends and nitrogen loadings have already been identified, so clearly this is the management approach that should be adopted. Identification of a water quality-resource target year is a management decision; in a previous correspondence I suggested that 1971 was a pragmatic choice.

What was the nitrogen loading to the entire Waquoit Bay watershed in 1971? That depends on what assumptions are made. Loadings estimated by the Buzzards Bay Project and the Cape Cod Commission would be fairly consistent because we use the same assumptions of loading, but our numbers are different from those of the LMER group because they use different assumptions or the loadings reported by Chi Ho Sham[1], who only quantified septic system loadings. From a policy and management point of view, it is very important that the Cape Cod Commission establishes nitrogen loading targets for Waquoit Bay that are consistent with the nitrogen loading calculations it imposes upon applicants. Another way to state this problem is that the Commission would have to adopt the LMER's nitrogen loading assumptions as part of its regulatory process if it were to adopt a nitrogen loading target based on the LMER loading estimates.

Since this is not practical (the Commission and BBP does not consider undeveloped land as a nitrogen source for example), we must instead use Chi's findings to interpret our own loading estimates. One of the most important estimates by Chi that needs to be considered is that of lag times between nitrogen loading to the watershed and loadings to the bay. Chi's model for 1990 loadings to the watershed suggested that if development were to cease in 1990, actual loadings to the estuary would continue to increase for many decades, although approximately 3/4 of this future increase in nitrogen loadings would reach Waquoit Bay after only ten years because most development is concentrated near shore or a relatively short distance from the rivers and streams entering the bay. Another important conclusion was that 64% of the nitrogen from development that existed in 1990 was already reaching the bay in 1990. Furthermore, nearly 90% of the watershed loadings would reach the bay in ten years. Chi indicated that data on the actual age of each dwelling was underestimated for some parts of the watershed, so these percent values also underestimate actual loadings.

For circa 1971, it appears from Chi's data that there are somewhat less than 2000 developed parcels in the watershed. Using the 1971 MassGIS data and BBP GIS methodologies, the Project estimates there were 1331 units (using the most recent drainage basin). WBNERR 1993 versions of Chi's data files indicate 1489 units. Using this latter value and a 2.0 person per unit occupancy (this is probably a realistic annualized occupancy rate that includes 3 months of summer intensive use of seasonal units), and the septic system loadings and other assumptions for residential and other land uses adopted by the CCC and BBP[2], this translates into a 33,440 kg/y watershed loading

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[1] In this correspondence, I use transport data from a 1994 preprint by Chi Ho Sham, J. W. Brawley, and M. A. Moritz "Analyzing septic nitrogen loading to receiving waters: Waquoit Bay, Massachusetts" 6pp. in the forthcoming <u>Proceedings of the Second International Conference/Workshop on Integrating Geographic Information Systems and Environmental Modelling, Fort Collins Colorado, 1994.</u> It is important to recognize that Chi et al. estimate only septic system N loadings, and that their estimate for total N loading for 4230 parcels is 18,000 kg/yr which is very close to a Buzzards Bay Project estimate of 22,700 kg/yr assuming 2.7 kg per person per year and a 2.0 annualized occupancy rate. In fact, the difference in Chi et al.'s estimate and the one presented here may be solely due to the use of different occupancy rates.

[2] Key assumptions are: 2.7 kg N per person per y, average lawn = 1.4 kg N/y, impervious lot contribution = 0.1 kg N/y, acid rain contribution to embayment area is included in mass loading estimate to

for 1971[3].

In 1971, it is likely that a greater preponderance of development was clustered along shore than Chi's 1990 model uses. If we assume that approximately 75% of the nitrogen from 1971 development (as opposed to the 64% for 1990) was already reaching the bay at that time, then a nitrogen loading target for the entire estuary complex watershed would be 23,600 kg/y. Chi should be able to tell us what his model predicts as the ratio of watershed to embayment loadings in that year if we need a more precise estimate.

There are two caveats with regards to the above calculations that you should consider. I used a 1993 land use file for the Waquoit Bay-Eel Pond subwatershed that is not completely consistent with land use data for the entire watershed provided to me by Chi earlier this year. The discrepancies are modest for the residential land use coverage, so this discrepancy may not be important. The second issue is that we are concerned with the ground water travel times that Chi reports. In a figure in his 1994 manuscript, groundwater is traveling 6 inches per year for the upper most portion of the Childs river watershed and during the last ten years of travel near Eel Pond still only moves 16 inches per year (see attached figure). These estimates are half the 12 inches to 36 inches per day groundwater travel time that is widely reported as typical for outwash plains on Cape Cod. With these higher rates, nitrogen would be reaching Waquoit Bay about twice as fast as what Chi reports. I have brought this issue to Chi's attention and I expect he will address this point shortly.

Ignoring these two issues, if we pursue separating Waquoit Bay-Eel Pond complex from the rest of the estuary complex, then we must repeat the 1971 calculation process for just the Waquoit Bay-Eel Pond subbasin. I have available data from a 1993 GIS basin data for this subbasin area (which may contain errors), and Chi's estimate of 1264 homes for the subbasins excluding Jehu, Hamblin, and sage ponds, which results in the following loadings for Waquoit Bay-Eel Pond basin: watershed loading = 23,900 kg/y, assuming 75% is already reaching the bay then 17,900 kg/yr was reaching the bay in 1971.

Since the land area in this subbasin complex covers 3264 hectares (8064 acres), then this mass loading suggests that target loadings for the entire watershed that would achieve water quality and habitat restoration goals should be set at no more than 2.2 kg/acre (under the BBP/CCC loading assumptions) and that all new and existing development should meet this goal. Since it is unreasonable to assume all the land is developable in the watershed, and with existing open space and MMR land perhaps only 50% of the watershed land will be developed, a more rational target to

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embayments, other loadings from Mass GIS coverage according to Costa et al. (1994), "Use of a Geographic Information System to estimate nitrogen loading to coastal watersheds.", BBP draft technical report March 2, 1994.

[3] The revised watershed now includes a remarkably large area in the "urban Transportation" land use category, which I presume represents MMR airport area in the Quashnet basin. This category now contributes an unsettling 4,600 kg/y.

achieve 1971 water quality-habitat conditions would be 4.4 kg/acre.

Is such a mass loading goal achievable? A 1 acre parcel (typical nowadays) with a 5000 sq foot lawn, typical impervious surface area, and using the regional 2.0 occupancy rate contributes about 6.9 kg N/y to the watershed. If a nitrogen removal septic system were employed that had 80% nitrogen removal efficiency[4] were required, this same parcel would only contribute 2.9 kg/y, well below the 4.4 kg/y target. Retrofitting existing septic system is more problematic, but with the promulgation of the new Title 5 regulations requiring system inspection and possible cesspool replacement at time of property transfer, and with the passage of the betterment bill, the Towns of Falmouth and Mashpee could implement a program of say upgrading 50% of all cesspools in the drainage basin over a 20 year period with N removing systems.

Of course the use of N-removing alternative septic systems is not the only management option. Others include sewering, procurement of open space, private sewage treatment facilities with advanced N removal, reducing lawn size, to name a few other options. In addition, you may want to do a detailed buildout analysis to project actual buildable land so that a more precise allowable kg/acre target could be established.

I hope you find this information helpful. Please note that I am ccing Chi, WBNERR, LMER investigators and others on this communication to facilitate a review of these calculations and exchange of ideas. Please do not hesitate to call me if you have any questions.

cc. Chi Ho Sham- Cadmus Group
Maggie Giest- WBNERR
Ivan Valiela, Ken Foreman- LMER-BUMP
Jim Kremer, Glynnis Collins- LMER-USC
Rockey Geyer, WHOI

waqcalc

[4] The 2.7 kg per person per year used by the BBP is based on 30% nitrogen removal for a conventional system. Another way to think of this n removing systems with 80% N removal efficiency is that effluent reaching groundwater must not exceed 9.1 ppm instead of the 35.0 ppm assumed for conventional systems.