To: Margaret Welch
CC: Howard Kaufman
From: Scott Warren
Date: January 30, 2006
Re: Madison Landing
- Margaret Welch memo of October 24, 2005 to Warren Herzig
- Howes & Samimy report of December 26, 2005

Two related issues are raised in the above noted memos:

1. Potential impacts of groundwater discharge onto tidal wetlands which border the proposed upland development (upland breakout).
2. Potential impacts of increased N_{Total} loading from groundwater discharge on tidal wetlands, coastal waters, and eelgrass beds of the Hammonasset River and Clinton Harbor.

Although related, I will try to address these separately.

GROUNDWATER DISCHARGE ONTO TIDAL WETLANDS. The actual amount of groundwater discharged directly onto the marsh along the upland-marsh border is difficult to quantify, but engineering estimates and my observations of the width of upper border vegetation both suggest that a small fraction of groundwater at the proposed development site breaks out to move directly onto the marsh surface. Current groundwater flux from the site is estimated by BL Companies at 300,000 gal day^{-1}; maximum additional flow from the septic system will be 52,500 gal day^{-1} but realistic operating rates will be closer to 20,000 gal day^{-1}. Assuming *ca.* 5% of groundwater from the proposed septic system reached the marsh through direct breakout at the marsh-upland interface, the additional input from effluent would *ca.* 1,000 – 2,600 gal or 3,800 - 10,000 liters day^{-1}. After mixing with the ambient groundwater, sewage treatment effluent is calculated to increase groundwater N_{Total} concentration at the upland-marsh border from an average of *ca.* 2.3 mg l^{-1} (based on ground water sampling by BL Companies in 2002) to 3.3 mg l^{-1}. Actual patterns of groundwater flux to the marsh surface are likely to be highly variable in both time and space. Potential effects from localized freshwater inputs and from nitrogen enrichment are discussed separately below.

A. Freshwater Impacts. Both personal observations and the literature argue that the vast bulk of groundwater moves seaward through glacial sands of the aquifer, below peat and marine clays. Local "breakouts", however, can occur along the upland-marsh edge; these locations typically are characterized by lower peat pore water salinity and relatively broad bands of somewhat less salt tolerant, upper border, plant species. In very shallow marshes breakouts may also occur as springs, some distance from the upland; the Hammonasset/Clinton Harbor marshes, however, tend to be relatively deep, and I have not seen any indication of such "mid-marsh" springs on this system.

At the proposed development site, the upper border vegetation mosaic has been converted almost entirely to a *Phragmites australis* (hereafter Phragmites) monoculture. The width of this Phragmites border provides a relative estimate of the combined effects of groundwater discharge and upland runoff. Greater freshwater input results in a wider border; this is most readily apparent where mosquito ditches reach to the upland, allowing groundwater to move into ditches, and Phragmites to move seaward down ditch borders. The width of the Phragmites upper border along most of the upland varies from a few to more than 10 meters, indicating spatially uneven upland runoff and, if it is occurring, groundwater breakout.

Impacts from a small increase of groundwater discharging directly onto the marsh surface are likely to be relatively minor, with the principal effect of broadening the brackish vegetation belt of the upper border. This would be a concern with such well established Phragmites; development at this site, however, will be tied to a program of Phragmites control. With Phragmites control one can reasonably predict reestablishment of characteristic brackish upper border species, now locally rare, and re-establishment of a typical brackish-upper border vegetation mosaic. If additional groundwater broadens this border in some locations, I would see this as an ecological enhancement of the Hammonasset/Clinton Harbor marsh system, in which Phragmites is so abundant and natural upper border vegetation is now relatively uncommon.

B. Nitrogen Impacts. Total nitrogen in breakout groundwater at the upland border would be on the order of 1 mg liter^{-1} above an average background groundwater N_{Total} concentration of *ca.* 2.3 mg liter^{-1} (as measured in on-site groundwater by BL Companies in 2002). Assuming an input of 10,000 liters day^{-1}, the design maximum for the septic system and N_{Total} at 3.3 mg liter^{-1}, total loading to the marsh surface at the upland-marsh border would increase from 23 to 33g of N_{Total} day^{-1}. Whenever the marsh surface is not flooded, during the growing season the bulk of this N_{Total} will be intercepted by marsh plants before reaching the estuary.

High N_{Total} loading rates have been shown to significantly increase marsh plant growth and in some instances to shift species composition. N_{Total} impacts in this case are likely to be minimal as increased loading is small, it will be spatially and temporally variable, and probably one to three orders of magnitude below published experimental N_{Total} additions.

In sum, impacts from increased groundwater discharge along the upland-marsh border are likely to be spatially uneven along the marsh upper border, and to be relatively minor. With Phragmites control, additional upper-border freshwater inputs may well increase the extent of brackish plant species, arguably a benefit in this particular marsh-estuary system.

NITROGEN LOADING TO CLINTON HARBOR. The Clinton Harbor estuary already suffers from excess nitrogen loading. The causal link between eelgrass decline and heavy anthropogenic Nitrogen loading has been rigorously documented in the ecological literature. Clinton Harbor is striking in the nearly complete lack of eelgrass beds within an estuary that should, and in the past did, support extensive stands of this species. The impact of Nitrogen loading is a combination of the absolute loading rate (usually expressed in Kg N_{Total} per day or per year on a unit area or unit water volume basis: i.e. Kg Ha^{-1} Yr^{-1}) and the "residence time" of a particle of water in the estuary. Long residence times magnify the impact of Nitrogen loads.

Clinton Harbor is a very open, reasonably shallow estuary relative to its tide range (ca. 1.6 meters). It is, therefore, well flushed by the tides and would be expected to have a relatively short residence time.

Total Nitrogen loading to Clinton Harbor has not been determined, but direct loading to Clinton Harbon from the Hammonasset River alone can be calculated using existing water quality data and flow estimates. BL Companies has informed me that water quality data, including $N_{Nitrate}$ was collected at a surface water sampling location identified as SW-21 on a quarterly basis from March 1995 through December 2001. This data has been reported in a document titled "Town of Clinton, Connecticut, Wastewater Facilities Plan Study – Existing Conditions Phase 3 Deliverable" prepared by Camp Dresser & McKee and dated June 13, 2001. Sampling location SW-21 was located directly east of the development site, and the average $N_{Nitrate}$ concentration for the period of record was 11.44 mg l^{-1}. Low flow (7Q10 – flow exceeded 99% of the time) for the Hammonasset River in the vicinity of Clinton Harbor has been calculated at 3.8 cfs (personal communication from CTDEP to BL Companies), while mean flow has been calculated at 56.47 cfs (BL Companies calculation based on Weiss et al, Connecticut Water Resources Bulletin No. 36, 1983).

- Using these values, $N_{Nitrate}$ loading to Clinton Harbor from the Hammonasset River alone can be calculated at 162 Kg Ha^{-1} Yr^{-1} at minimum (7Q10) river flow and more than an order of magnitude greater (*ca.* 2400 Kg Ha^{-1} Yr^{-1}) at estimated mean flow rates (Table 1, Tables appended).
- Even at the 7Q10 flow rate $N_{Nitrate}$ loading is quite high (Table 2). Total nitrogen loading would be expected to be even higher.

It is not known exactly where groundwater from the upland on this site discharges to Long Island Sound. It may be some distance offshore, but for the purposes of the following calculations it is assumed that the entire discharge is within the Clinton Harbor estuary.

- Groundwater flux to the estuary <u>without septic system inputs</u> is estimated by BL Companies at 300,000 gal day^{-1}, with a background N_{Total} concentration of 2.29 mg N $liter^{-1}$.
- This discharge rate and N_{Total} concentration translate into pre-development N_{Total} loading from groundwater of 3.95 Kg Ha^{-1} Yr^{-1} to the Clinton Harbor estuary (Table 3).
- Maximum design discharge from the proposed septic system is 52,500 gal (199,500 liters) day^{-1} with a N concentration of 10 mg $liter^{-1}$.
- A more realistic discharge prediction is 20,000 gal (75,710 liters) day^{-1}.
- Additional N_{Total} loading from septic system effluent would be 3.03 at maximum design flow and just 1.16 Kg Ha^{-1} Yr^{-1} at typical flow rates (Table 4).
- Current N_{Total} loading from ground water is *ca.* 4 Kg Ha^{-1} Yr^{-1} represents ca. 2.5% of N loading from the Hammonasset River at minimum (7Q10) flow. Added N_{Total} from effluent would only bring groundwater loading up to *ca.* 4.3% of minimum river loading. These groundwater contributions are an order of magnitude less (0.16% and 0.29% respectively) when mean river flow estimates are used (Table 5).

Total N load to the Clinton Harbor estuary has not been estimated. The watershed is heavily developed to the east and north (Fig. 1), however, and it is reasonable to predict that groundwater flux and N content from the developed portion of the estuary's shoreline are at least equivalent to the Airport site, but are likely substantially more given the high density of homes with conventional septic systems on the east side of the Hammonasset River.

Given the known Hammonasset River $N_{Nitrate}$ loading, along with the additional unknown, but undoubtedly large loading from developed uplands to the north and east, and a maximum predicted N_{Total} loading increase of *ca.* 3 Kg Ha^{-1} Yr^{-1} at the design flow from the septic system of 52,500 gal day^{-1}, it is unlikely that impacts from even the maximum load could be detected by any realistically measurable biological responses or physical/chemical assays. Based on a more realistic anticipated flow from the planned development of 20,000 gal day^{-1} N loading would be just ca. 1.2 Kg^{-1} Ha^{-1} Yr^{-1}, and any impacts would be even more difficult to assess.

The report by Howes and Samimy argues that most or all groundwater from the site is discharged to the estuary. They estimate this groundwater flux at *ca.* 100,000 m^3 yr^{-1} or *ca.* 72,000 gal day^{-1}. This is approximately 24% of the groundwater flux determined by BL Companies and appears to be calculated from a groundwater recharge rate of 24 – 25 acre inches yr^{-1} for the 32 acre site as well as on-site measurements; it does not seem to account for groundwater movement toward the Sound from upland landward of the Airport site.

If their assumptions are correct: 1) all ground water flow is to the estuary and 2) flux is 72,000 gal day^{-1}, then current N loading from the site to the estuary is approximately 24% of the rate calculated here (3.97 * 24% = 0..95 Kg Ha^{-1} Yr^{-1}), but the absolute increase in load from septic system effluent would not change, remaining at 1.9 – 0.13% of the N delivered by the Hammonasset River (Table 5). To the extent that all groundwater does not discharge directly to the estuary, N loading from effluent will be proportionately less.

In sum, given the existing high Nitrogen loading to the Clinton Harbor estuary, the additional Nitrogen predicted from the proposed Madison Landing development, even under the most pessimistic scenario, will have no discernable impact on surrounding marshlands, embayment water quality, or any potentially existing eelgrass stands.

Fig. 1. Clinton Harbor estuary: approximate boundaries of proposed Madison Landing property are outlined in red. Note extensive residential and commercial development to the north and east.

Table 1. Hammonasset River water flux and NO_3 loading to the Clinton Harbor Estuary

Parameter	Value	Units
Minimum River Flow	2,455,834	gal d^{-1}
Minimum River Flow	9,296,343	L d^{-1}
Mean River Flow	36,497,515	gal d^{-1}
Mean River Flow	138,158,124	L d^{-1}
Mean River NO_3 concentration	11.44	mg L^{-1}
Riverwater N delivered to Estuary per day at Minimum Flow	106	Kg d^{-1}
Riverwater N delivered to Estuary per Year at Minimum Flow	38,818	Kg yr-1
Riverwater N delivered to Estuary per day at Mean Flow	1,581	Kg d^{-1}
Riverwater N delivered to Estuary per Year at Mean Flow	576,893	Kg yr-1
Clinton Harbor Area	240	Ha
N loading to Estuary from Minimum River Flow	**162**	**Kg ha^{-1} yr^{-1}**
N Loading to Estuary from Mean River Flow	**2404**	**Kg ha^{-1} yr^{-1}**

Table 2. N Loading Rates to Selected Estuaries

Estuary	Kg Ha-1 Yr-1
Charlott Harbor, NC	5
Little Bay, MA	203
Estero Bay, FL	126
Waquoit Bay, MA	35

Table 3. Existing groundwater flux and N loading from Airport site to the Clinton Harbor estuary. Assumes that all groundwater from the upland exits directly into the estuary.

Parameter	Value	Units
BL Companies groundwater flux estimate*	300,000	gal day^{-1}
BL Companies groundwater flux estimate	1,135,500	L d^{-1}
Current groundwater N concentration	2.3	mg L^{-1}
Current Groundwater N delivered to Estuary per day	2.60	Kg d^{-1}
Current Groundwater N delivered to Estuary per year	949	Kg yr-1
Current N loading to estuary from Airport groundwater	**3.95**	**Kg ha^{-1} yr^{-1}**

Table 4. Added groundwater flux and N loading from Airport site to the Clinton Harbor estuary from on-site waste-water treatment plant effluent.

Parameter	Value	Units
Additional groundwater flux from effluent (maximum)	52,500	gal d^{-1}
Additional groundwater flux from effluent (maximum)	199,500	L d^{-1}
Additional groundwater flux from effluent (typical)	20,000	gal d^{-1}
Additional groundwater flux from effluent (typical)	76,000	L d^{-1}
Effulent groundwater N concentration	10	mg L^{-1}
Additional N to estuary per day (maximum)	2.00	Kg d^{-1}
Additional N to estuary per day (typical)	0.76	Kg d^{-1}
Additional N to the estuary per year (maximum)	728	Kg yr^{-1}
Additional N to the estuary per year (typical)	277	Kg yr^{-1}
Added N loading to estuary (maximum)	**3.03**	**Kg ha^{-1} yr^{-1}**
Added N loading to estuary (typical)	**1.16**	**Kg ha^{-1} yr^{-1}**