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EVALUATION OF GROUNDWATER FLOW

FOR LOT 387 OF ASSESSOR'S MAP 9
ALSO DESIGNATED AS SEA LEA COLONY LOT ~~221~~ 121

CHARLESTOWN, RHODE ISLAND

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December, 2006

For

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A study of groundwater aquifer conditions at Assessor's Map Lot 387 in Charlestown, Rhode Island, also known as Sea Lea Colony Lot No. 221, was conducted during the period November 2005 to August 2006. The principal objectives of the study were to determine direction and velocity of groundwater flow, groundwater quality, the probable effects of additional new wells in the area, and the probable effect of a new on-site sewage disposal system.

To accomplish these objectives water table measurements were made at twelve locations, including the adjacent salt water cove. The water table levels vary up to 0.1 ft. on a daily basis due to tidal influence, and as much as 1.5 ft. on a long term basis due to seasonal groundwater recharge and atmospheric storm conditions. Depth from the land surface to the water table ranged from 7.0 to 8.0 feet during the period of measurements. Subsurface geo-electrical soundings in conjunction with water level measurements indicate that the aquifer is a "floating" Ghyben-Herzberg fresh water lens, estimated at 20-30 feet thick underlain by salt water. The salt water salinity is probably near that of the cove which is 21 ppt, about 2/3 that of sea water. Fresh groundwater flow at the site is to the N-NW to the pond at an estimated velocity of 2-3 ft/day.

Based on laboratory analysis of water samples taken from two neighboring wells, the chemical content of the local groundwater is good. Total dissolved solids is less than 150 mg/l as compared with recommended health limits of 500 mg/l, and nitrate-nitrogen averages 2.7 mg/l, well below the recommended health limit of 10.0 mg/l. There are no other chemical constituents of note. Coliform bacteria contamination was found in one well, most likely a local problem caused by inadequate well sealing, and is not expected to be a regional problem that would affect the proposed new well.

Water budget analysis of area precipitation provides an area groundwater recharge estimate of 12-18 inches/year. This is sufficient to provide the 300 gpd required for the proposed new residence, without adverse effect on existing wells.

The proposed new well for the planned new dwelling should be a shallow wide diameter dug well with controlled pumping to mimimize drawdown. In the proposed well the estimated maximum long term drawdown effect is 0.3 ft. , sufficiently above the elevation of the cove water to preclude salt water intrusion. Maximum short term draw down with a pump operating at 5 gpm continuously for 12 hours is about 1.5 ft. However, except for system failure, this continuous pumping should never occur; only one hour of pumping at 5gpm is required to meet the 300 gpd dwelling demand. Water level controls can be installed to prevent over pumping. Additionally, the use of roof water runoff from the new dwelling as directed groundwater recharge would enhance the groundwater availability to the new well, as well as providing buffering from the planned sewage disposal system.

Based on field groundwater investigations and the associated analysis, as described in detail herein, the proposed new residence with a new well and on-site sewage disposal is not expected to experience, or cause any, adverse effects.

EVALUATION OF GROUNDWATER FLOW FOR LOT 387 ON ASSESSOR'S MAP 9 ALSO DESIGNATED AS SEA LEA COLONY LOT 221 CHARLESTOWN, RHODE ISLAND

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1) Introduction.

This report has been prepared in response to a request by Frisella Engineering for an evaluation of the groundwater conditions at Lot No. 387 on Assessor's Map 9 (also know as Sea Lea Colony Lot No. 221) in Charlestown, RI with specific reference to the direction and velocity of groundwater flow, the probable effect of an additional well, and the probable effect of a new sewage disposal system. The general location of the groundwater investigation is shown on Figure 1, p. 2 and the study area with the specific site (Lot No. 387) on Figure 2, p.3.

2.0 Methodology.

Water levels were identified and flow paths determined on the broad regional level using existing U. S. Geologic Survey information and accepted hydrologic principals for coastal locations. Specific field work was accomplished at the local area level and on the study site (Lot 387) using direct water table measurements.

Site subsurface sediment samples were taken from the open face cove excavation at the north end of the site. Permeability (hydraulic conductivity) determination, porosity evaluation and sieve analysis were accomplished on the samples. Well drawdown effects were calculated for both short term pumping and long term effects using the Theis (time dependent) and Theim (steady state) equations respectively (Fetter, 2001).

a. Area water level measurements.

In order to determine area water levels, five well points (A, B, D, F1, F2), detailed in Table 1, p. 4, were installed during August, 2006. In addition, an existing 4 inch diameter PVC tube (C), located on Assessor's Map Lot 366 was used for ground water measurements and a reference mark on a dock in Green Hill Pond was used for the adjacent pond measurements. . Locations are shown on the area water table/flow maps Figures 4 and 5, p. 8 and p.9 respectively The elevations of all seven of these measuring points were referenced to the NGVD 1929 Datum, consistent with all other measurements made by Frisella Engineering.

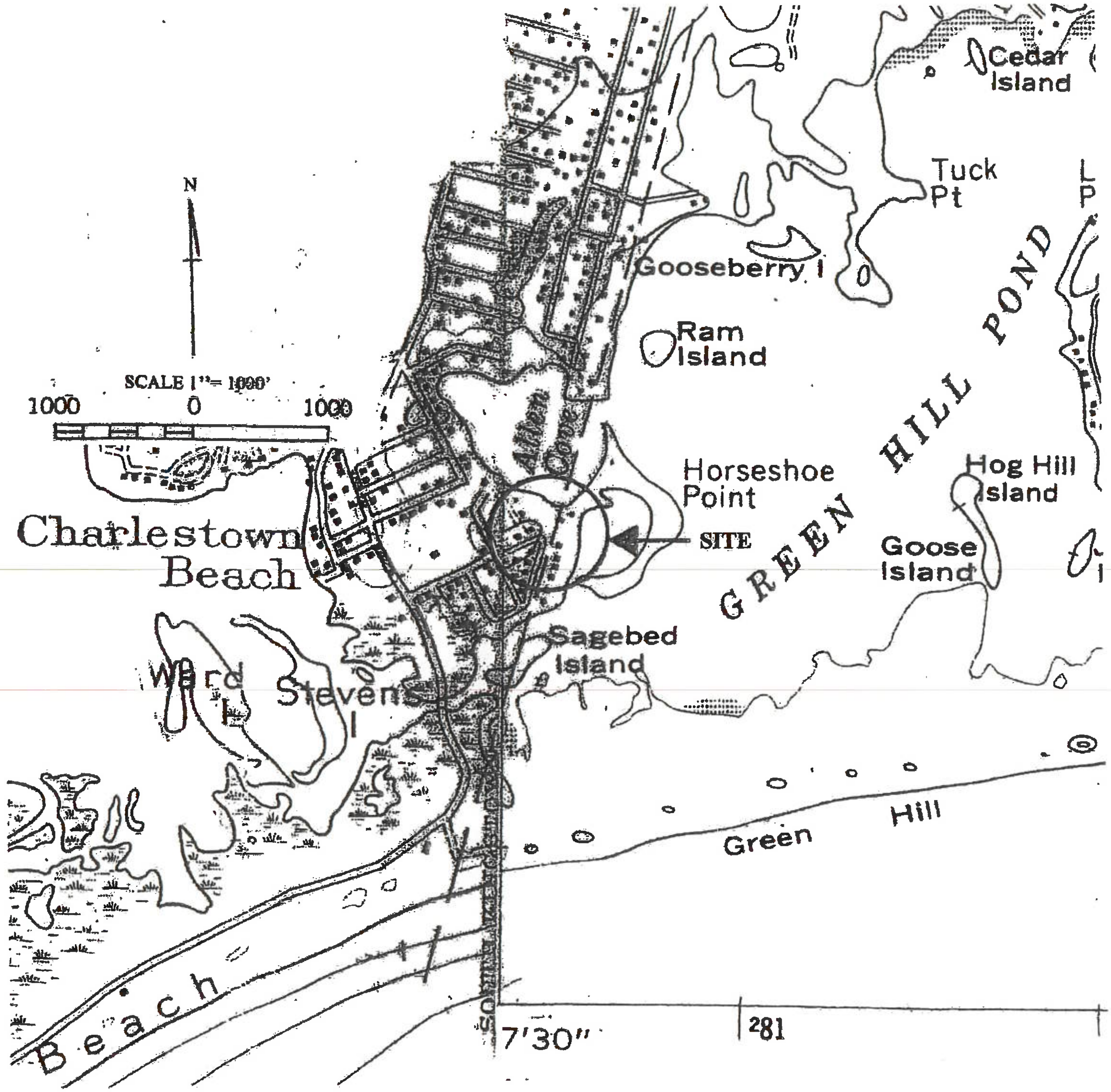

Figure 1. Location Map of Groundwater Flow Investigation

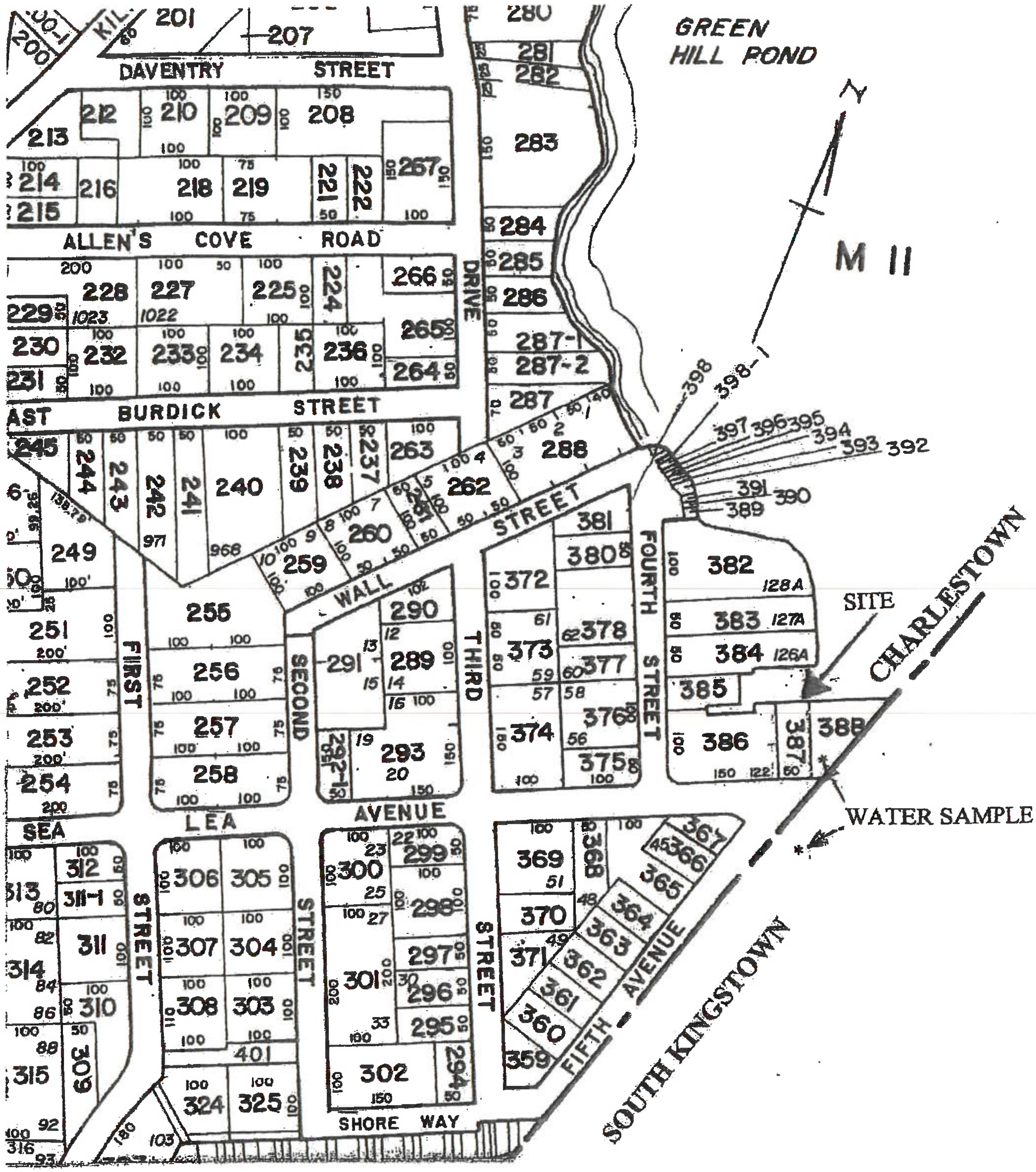

Figure 2. Site Map of Study Area. * Denotes Locations of Water Samples.

Table 1. Sea Lea Colony Area Monitor Location Characteristics.

LOCATION	TYPE	PIPE DIAM. SIZE (in.)	PIPE LENGTH (ft.)	PIPE TOP ELEVATION (ft.)
Dock	edge	N.A.	N.A.	2.68
A	well point	1 ½	9.93	8.92
B	well point	1 ½	9.93	9.95
C	PVC pipe	4.0	8.64	8.22
D	well point	1 ½	8.00	6.34
F1	well point	1 ½	11.50	10.61
F2	well point	1 ½	12.00	12.05

Notes: 1) Locations A and B are on Lot 54, South Kingstown Assessor's Map
2) Location D is on Lot 52, South Kingstown Assessor's Map.
3) Location C is on Lot 366, Charlestown Assessor's Map 9.
4) Locations F1 and F2 are on Lot 387, Charlestown Assessor's Map 9.

b. Site water level measurements.

In order to determine the pattern and velocity of groundwater flow directly on the site, the study used three mini-piezometers and two 4-inch diameter tubes that were set in test hole excavations accomplished on the site in the year 2000. The detailed descriptions of the five measuring locations are given in Table 2, p.5. Water levels were measured using an electrical sensor in the mini-piezometers, and by direct tape measurement in the tubes The elevations of the tops of the mini-piezometers and tubes were determined in 2000 by Frisella Engineering Company (Frisella, 2004a), and verified by the author of this report in the fall of 2005. The locations of the five water level measuring locations were initially established by Frisella Engineering Company in 2000 and also verified in the fall of 2005. These locations are hereafter termed monitor wells (MW).

Additionally, a reference mark was established on a nearby dock to measure the Allen Cove water levels to determine the cove water level relationship to the adjacent site groundwater levels. The fluctuations in Allen Cove relative to the groundwater table were measured using In-Situ and Ecotone water level loggers. All elevations were referenced to the 1929 NGVD Datum. The specific locations of the monitor wells are shown on Figure 6, p.10.

Table 2. Lot 387 Site Water Level Measuring Location Characteristics (see Fig.4, p.8).

LOCATION		PIPE DIAM. SIZE (inches)	DEPTH BELOW GROUND (feet)	PIPE TOP ELEVATION (feet)	GROUND ELEVATION (feet)
AA	test pit tube	4in.	9.9	10.11	9.3
BB	test pit tube	4 in.	9.9	9.83	9.2
CC	mini-piezometer		9.4	8.78	8.8
DD	mini-piezometer		7.3	8.35	8.4
EE	mini-piezometer		9.7	9.26	9.3
	Cove dock		N.A.	3.28	-1.2 (cove bottom)

Note: Elevation datum is NGVD 1929

3.0 Results.

3.1 Water Level Measurements and Flow Patterns.

3.11 Regional. The regional flow pattern was developed from local US Geological Survey published information and typical groundwater flow patterns for coastal locations. Figure 3, p. 6 presents an estimate of the region ground water flow pattern based on limited data from local wells provided by the U. S. Geological Survey (LaSala and Johnson, 1960), and hydro-geologic principles for coastal groundwater. The water table approaches a bedrock high on the western side of the region, while decreasing to mean sea level as it approaches the shoreline. At the location of Lot No. 387 the water table is about one foot above sea level.

3.12 Area. Measurements were taken on four different dates during August 2006 in order to determine area flow patterns. Water level measurements were taken at four different times over the period of 10-17 August, 2006. On 17 August two sets of measurements were taken about ½ tidal cycle apart and averaged to minimize the effect of tidal fluctuation in the pond and nearby well points. Table 3 summarizes the results of these measurements.

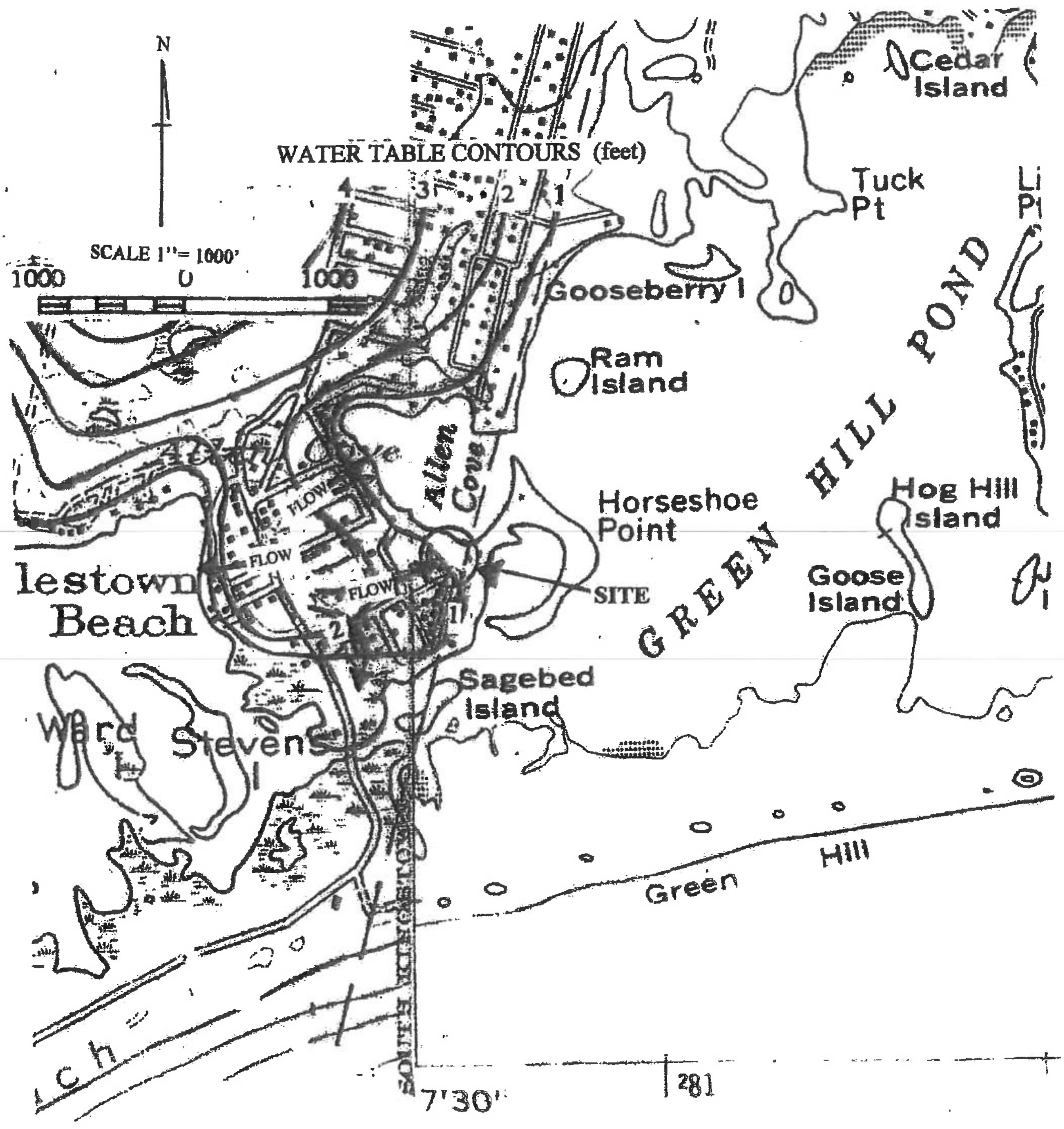

Figure 3. Regional Groundwater Flow Pattern (red contour lines) and Directions (arrows).

Table 3. Sea Lea Colony Area Water Table Elevations.

	LOCATIONS and ELEVATIONS (ft.)						
DATE	Dock	A	B	C	D	F1	F2
08/08/06	1.16	1.34	1.42	1.58	1.31	1.30	1.26
08/09/06	1.33	1.34	1.38	-	1.35	1.29	1.24
08/10/06	1.43	1.37	1.40	1.50	1.39	1.32	1.30
08/17/06*	0.89	1.10	1.20	1.32	1.13	1.08	1.01
AVERAGE	1.20	1.29	1.35	1.47	1.30	1.25	1.25

Notes: 1) Water levels at dock and A exhibit tidal fluctuations.
2) * Values are averages of measurements taken about 6 hours apart.

Two maps delineating the area water table and groundwater flow directions are provided as Figures 4 and 5.

1) Figure 4, p. 8 is a map produced using the average water levels from measurements taken on four different days during the period 8 -17 August. Results show a very low groundwater flow gradient of about 0.002, which is typical of a "floating" Ghyben-Herzberg type lens as described in the original report. Because of the recession of the water table during the summer period this gradient is significantly less than that measured for Charlestown Assessor's Lot No. 387 (Sea Lea Lot 221) during fall and winter, as calculated in the original report. The flow direction, however, is essentially the same as described in the site analysis, and varies from an easterly (So. Kingstown Assessor's Lot No. 54) to northerly (Charlestown Assessor's Lot No. 387) direction, moving to discharge to the pond. It is noteworthy that there appears to be an influence from well withdrawal in Lot 388 at this summer period, which has the effect of flattening out the gradient in the area immediately around the existing well.

2) Figure 5, p. 9 is a map produced using the averages from the two sets of water levels measured on 17 August, 2006. It is noted that all of the measurements on this date are about 0.20 ft. lower than those of a week before. It is believed that this represents the response of coastal groundwater levels to the adjacent pond water level, a controlling boundary condition. The average tide level of the pond was about 0.4 lower on 17 August, 2006. This groundwater level response is also indicated by the much steeper gradients near the shoreline on 17 August. However, the groundwater gradients and the flow directions remain essentially the same as for the average of the seven-day sampling period.

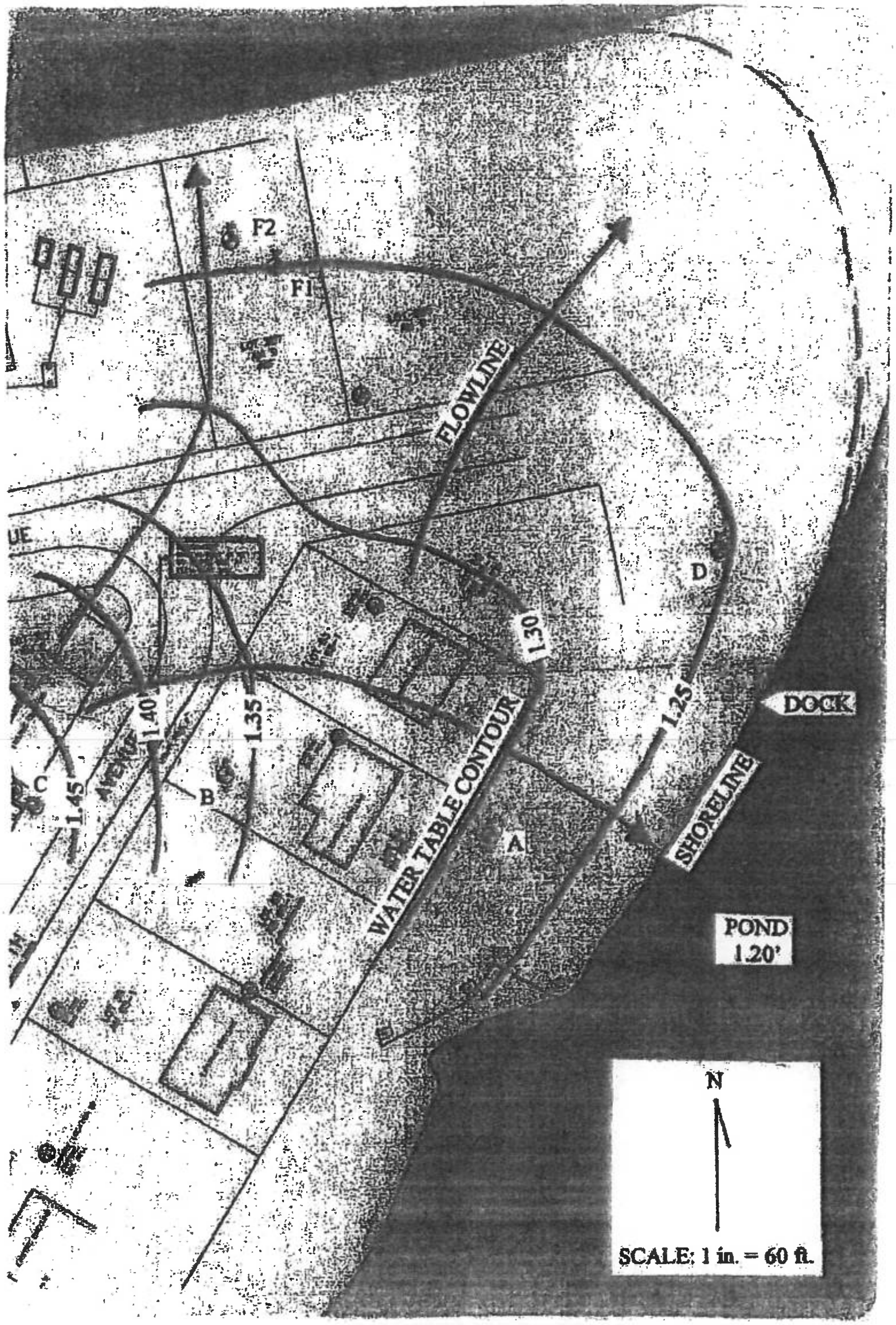

Figure 4. Area Water Table and Flow Map (readings averaged, August 8-17, 2006).

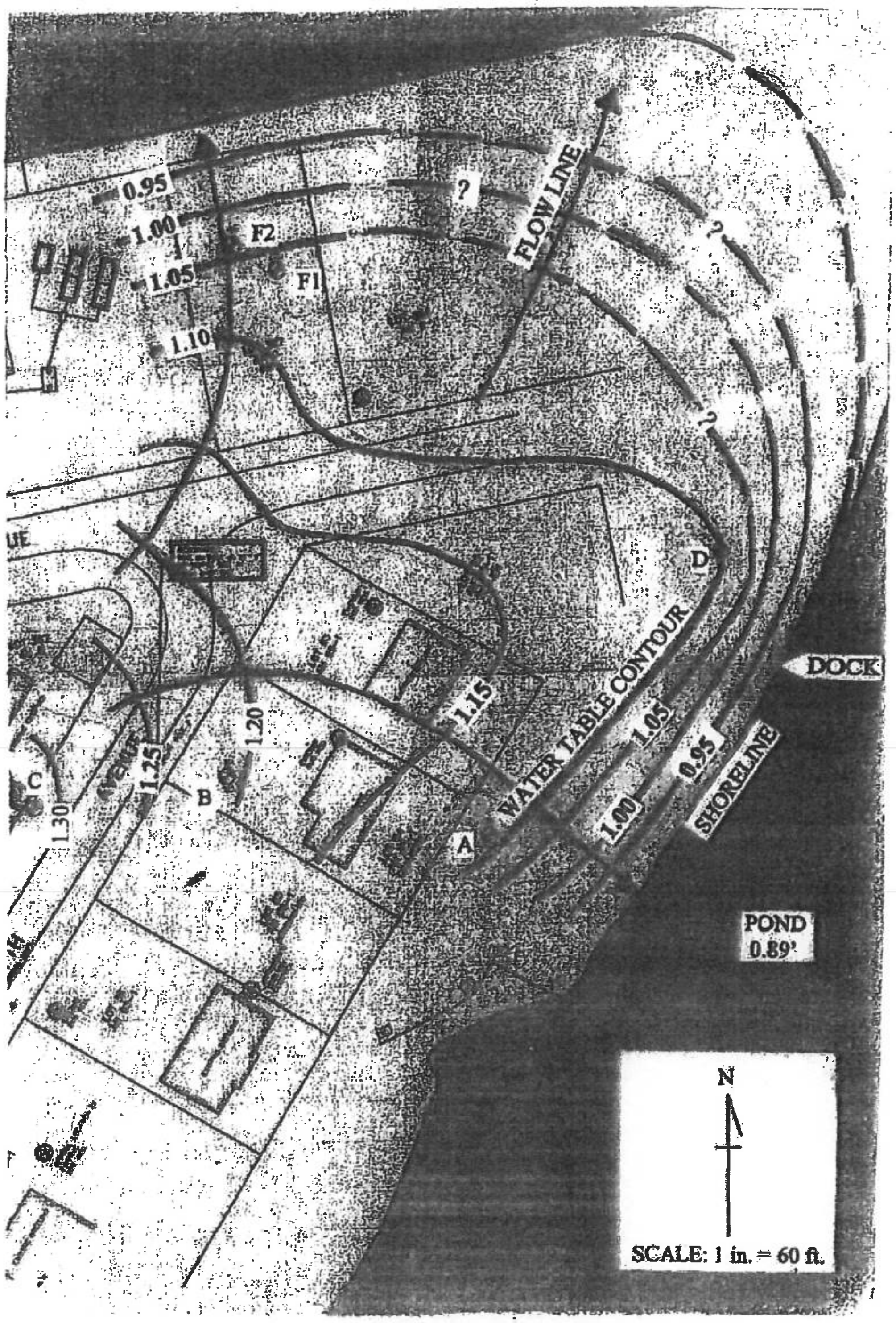

Figure 5. Area Water Table and Flow Map (August 17, 2006).

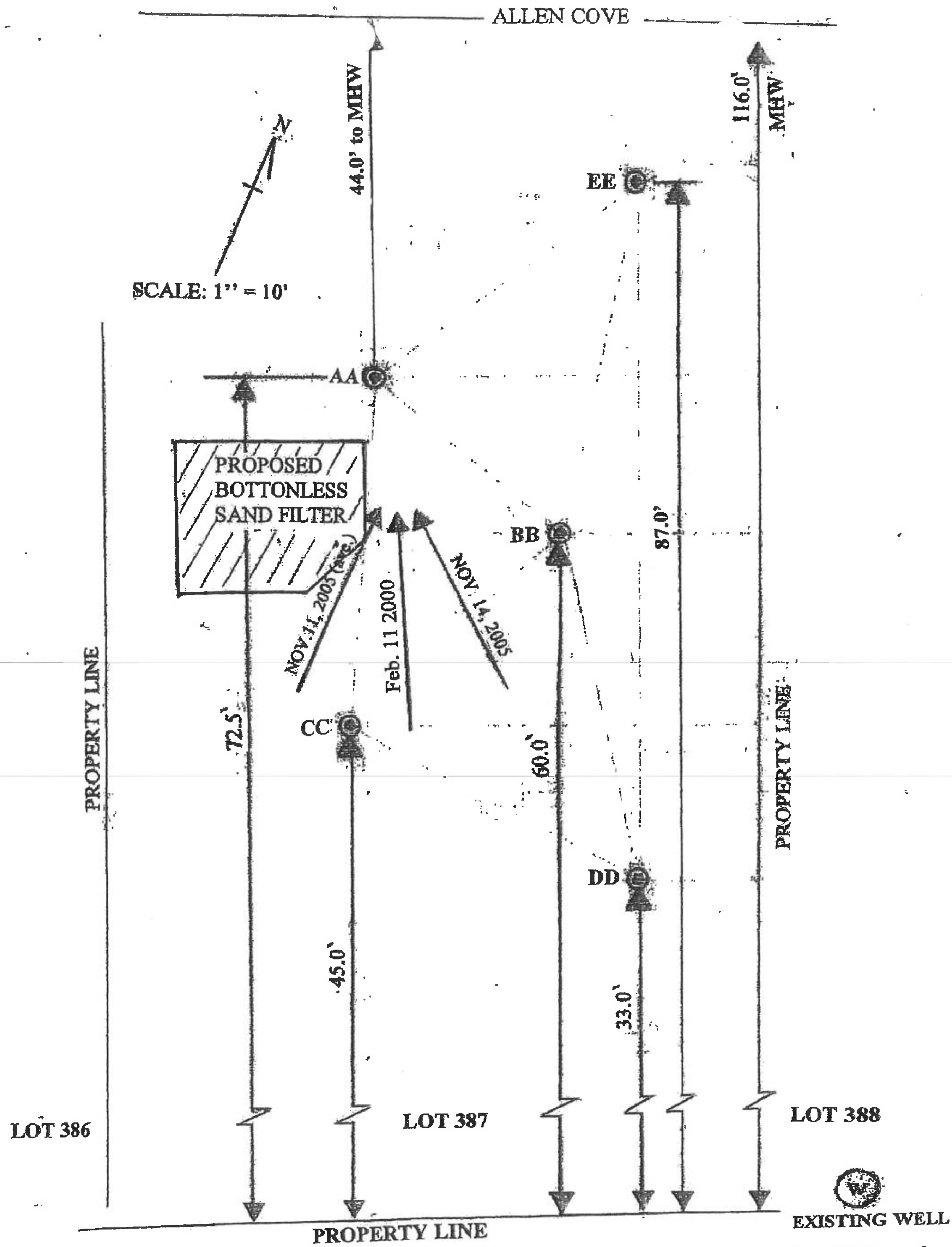

Figure 6. Site Plan for Assessor's Lot 387 (Sea Lea Lot 221) Showing Monitor Wells and Groundwater Flow Direction.

3.13 Site. Water level measurements were taken on four dates at the site Assessor's Lot 387 (Sea Lea Lot 221) during the period October – November, 2005 in order to establish depth to water table and groundwater flow gradients. The results are tabulated in Table 4.

Table 4. Site Water Table Elevations for Assessor's Lot 387 (Sea Lea Lot 221).

LOCATION		WATER LEVELS			
	GROUND ELEVATION (feet)	(11/08/05) ELEVATION (feet)	(11/11/05)[1] ELEVATION (feet)	(11/14/05) ELEVATION (feet)	(02/22/00)[2] ELEVATION (feet)
AA	9.3	-	1.27	0.85	0.70
BB	9.2	-	-	1.10	0.78
CC	8.8	1.27	1.46	1.17	0.88
DD	8.4	1.31	1.47	1.25	0.93.
EE	9.3	1.82	1.41	1.18	0.86
Cove	N.A.	1.78	0.97	0.86	0.46

Notes: 1) The November 11, 2005 values are averages of readings taken 6h 15m (1/2 tidal cycle) apart in order to minimize the effects of tidal fluctuation.

2) These elevations are from a set of 6 random water level readings taken during the period January-February, 2000 by Frisella Engineering (2004a).

Using the water level measurements (Table 4, p.11) and measuring well locations shown in Figure 6, p. 10, a series of groundwater contour maps for the site were constructed both for the year 2000 and the year 2005 water level elevations in order to determine groundwater flow directions. The results for the analyses of February 11, 2000, November 11, 2005 and November 14, 2005 are presented on Figure 6, p. 10. The general flow path direction at mid-site is to the north-northwest. While the calculated directions vary with time of measurement from north to northwest, both the 2000 and 2005 data produce similar results. The direction of groundwater flow fluctuates during the day because of tidal effects on the water levels during each tidal period. There is a higher than expected water level at location MW EE, nearest the cove, which is evident both in the measurements made in 2000 and those made in 2005. This causes substantial deviation of the flow path to the west very near the shoreline. The cause is unknown, but can be from subsurface blockage of the normal discharge to the cove in that area, substrata of reduced hydraulic conductivity, or from an unusual localized concentration of recharge.

In addition, a two day record of the water levels in MW AA (approximately 50 feet from the shoreline) and in the cove were taken at 15 minute intervals with automatic data loggers. The observed response clearly established the "floating" Ghyben-Herzberg lens relationship of the aquifer. A plot of the results is presented as Figure 7a.The cove highs and lows lag the Newport tide by about 5 hours and the amplitude is attenuated to about 1/8 that of Newport. The groundwater tidally induced wave at MW AA, lags the cove by about 2 hours and is attenuated to about 1/5 that of the cove. It can be noted as a matter of interest that during the data recording a severe atmospheric low passed through the area, raising the Newport sea level, the Allen Cove level and the Sea Lea groundwater level all by 1 to 1 ½ feet above normal. This is especially evident in the Newport NOAA tide record (NOAA, 2005), attached as Figure 7b, p.12.

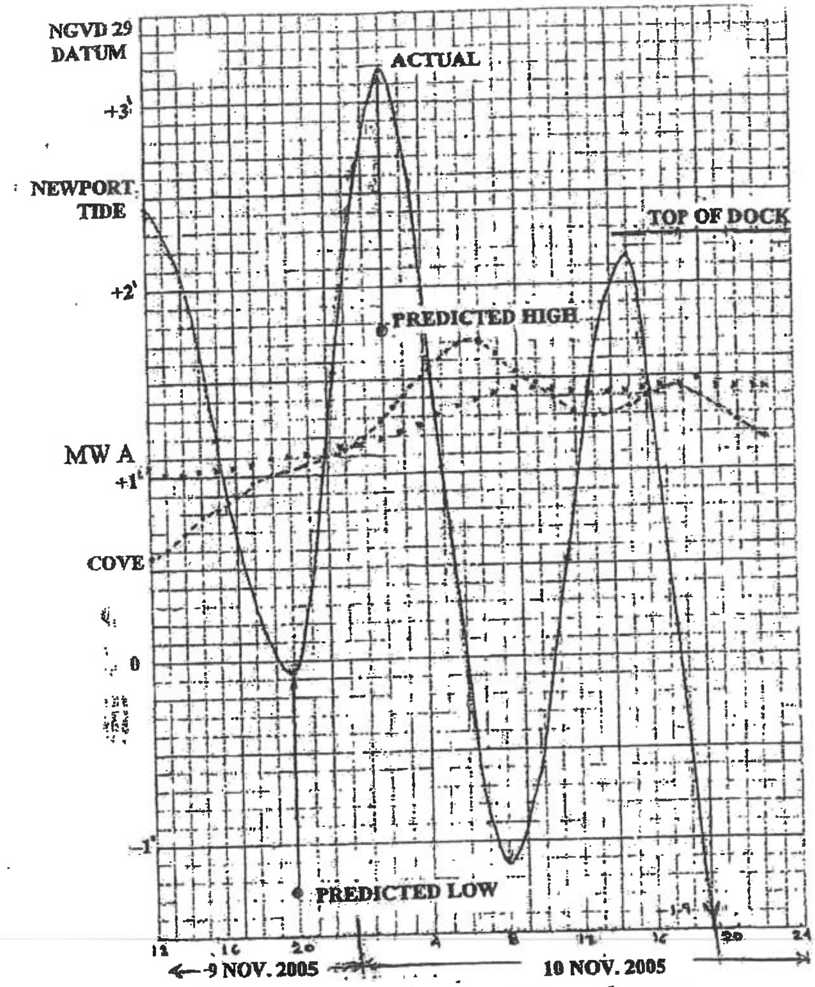

Figure 7a. Water Level Fluctuations in Bay, Cove and Groundwater

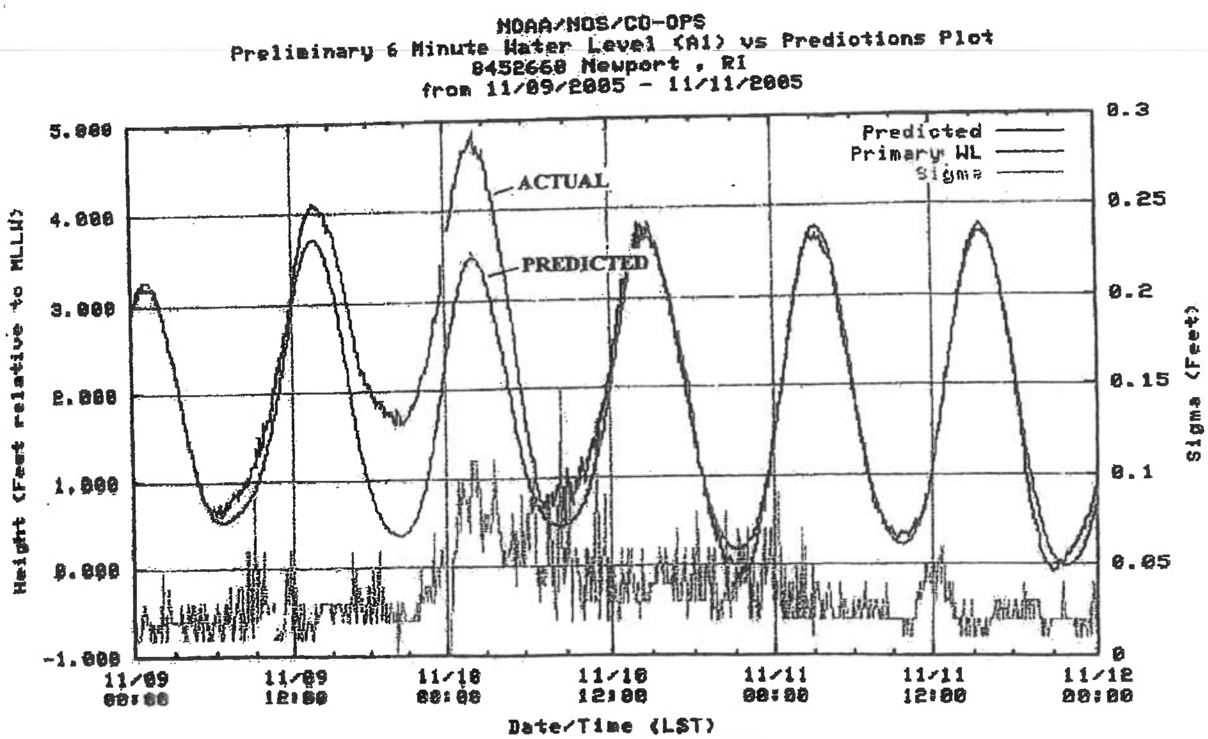

Figure 7b. Predicted vs Actual Tide Levels at Newport, RI

This also indicates a close connection of cove salt water and groundwater at the Sea Lea site.

Figure 8, p. 14 is a plan of the proposed site development on which is superimposed a line identified as A-A'showing the location of a groundwater cross-section (Figure 9, p.15) running across the site to the shore line. The water level elevations for Feb. 22, 2000 and Nov. 14, 2005 are used in this figure. With the exception of MW EE, which is an unexplainable anomaly, the flow is clearly and consistently to the shoreline.

The water levels varied only about 0.1 foot during the period of measurement and generally were no higher that 0.5 feet above Allen Cove water levels, resulting in a very "flat" gradient toward the cove. The water levels and calculated gradients compare closely with those measured in January and February, 2000 by Frisella Engineering (Frisella, 2004a). The average groundwater flow gradient at the mid-location on the site was 0.0069 in November 2005 and 0.0063 in January, 2000.

Due to the tidal influence, the elevations of the groundwater in individual observation locations may vary up to 0.1 foot during the day, and as much as 1 ½ feet over longer periods of time due largely to coastal water level boundary conditions.

3.2 Subsurface Sediments.

The groundwater map for the region (LaSala and Johnson, 1960) describe the sediments covering the area as glacial deposits of "medium to coarse sand and gravel interbedded with fine sand, silt and clay; unconsolidated; generally well sorted and stratified." Depth to bedrock is uncertain, but based on geo-electric surveying in October, 2005 is greater than 50 feet.

The ISDS Application (DEM, 2000) for the site, and sediment sample observations by Frisella Engineering in the year 2000 during test pit excavation describe the sediments as "M-C sand, F-M gravel" at water table.

Analysis of sediment samples from an exposed embankment at the site show undifferentiated glacial sediment with sizes ranging from silt to large gravel. Following are the characteristics derived from sieve analysis:

D50 = 4.00 mm
D10 = 0.20 mm
Uniformity coefficient, D60/D10 = 35

In contrast to the Frisella Report and the U.S. Geological Survey statement, the soil sample from the embankment is very poorly sorted, resulting in relatively low hydraulic conductivity and low porosity. The hydraulic conductivity based on permeameter testing (Fetter, 2001) of 3 separate samples is 18.7 ft/day and the porosity is 19.6 %. This appears to be representative of the unsaturated zone, with the sediments containing less fines and becoming more permeable with depth, with a hydraulic conductivity of perhaps as much as 100 ft/day.

a. Flow Velocity.

The water table gradient is very low, averaging about 0.0069 using both the year 2000 and year 2005 measurements. Because of the tidally induced water table fluctuation the pathway is somewhat circuitous.

Estimated flow velocities on the site were calculated using the measured gradients in

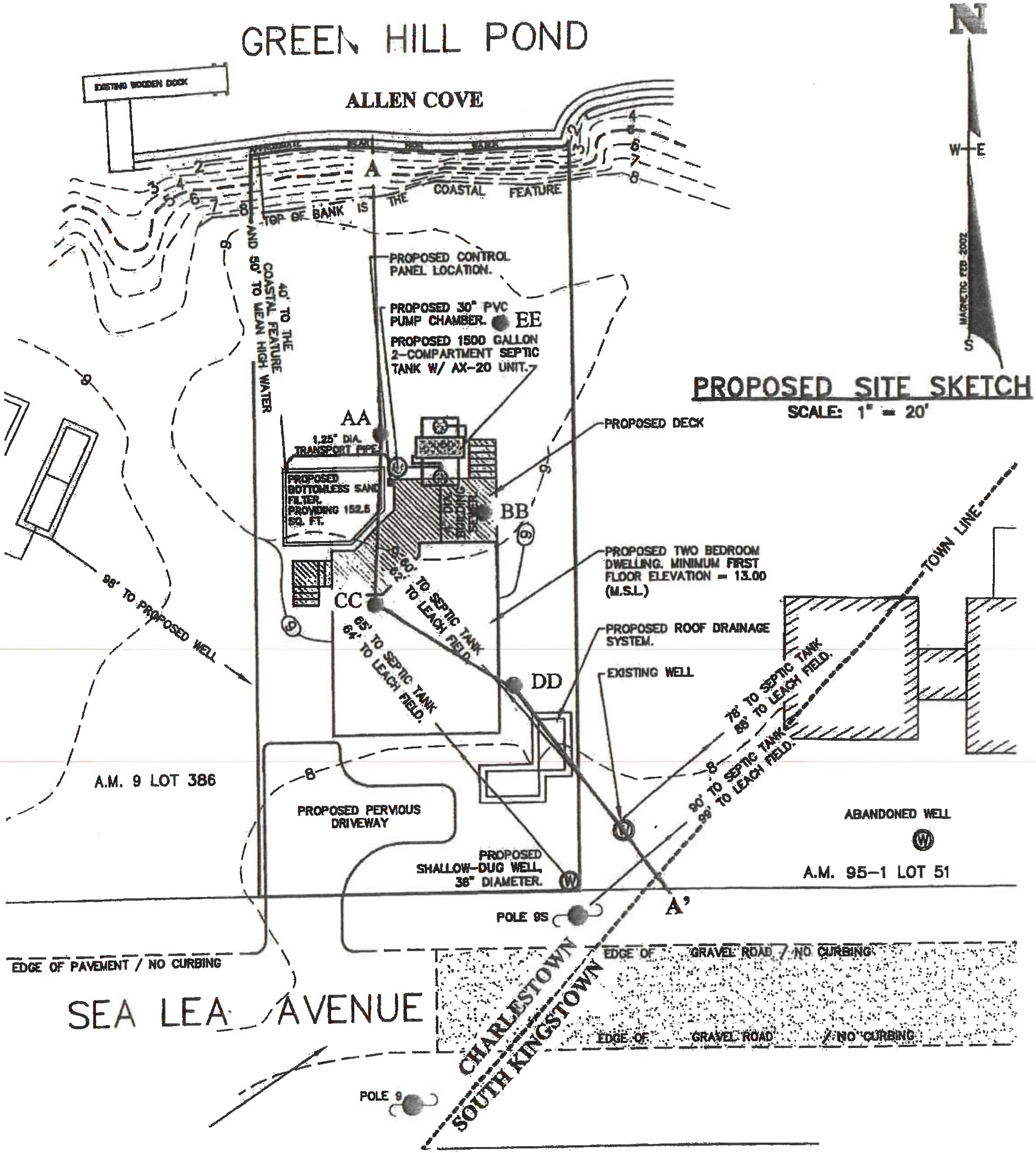

Figure 8. Proposed Site Development with Profile A-A' (Fig. 9) Delineation in Red.

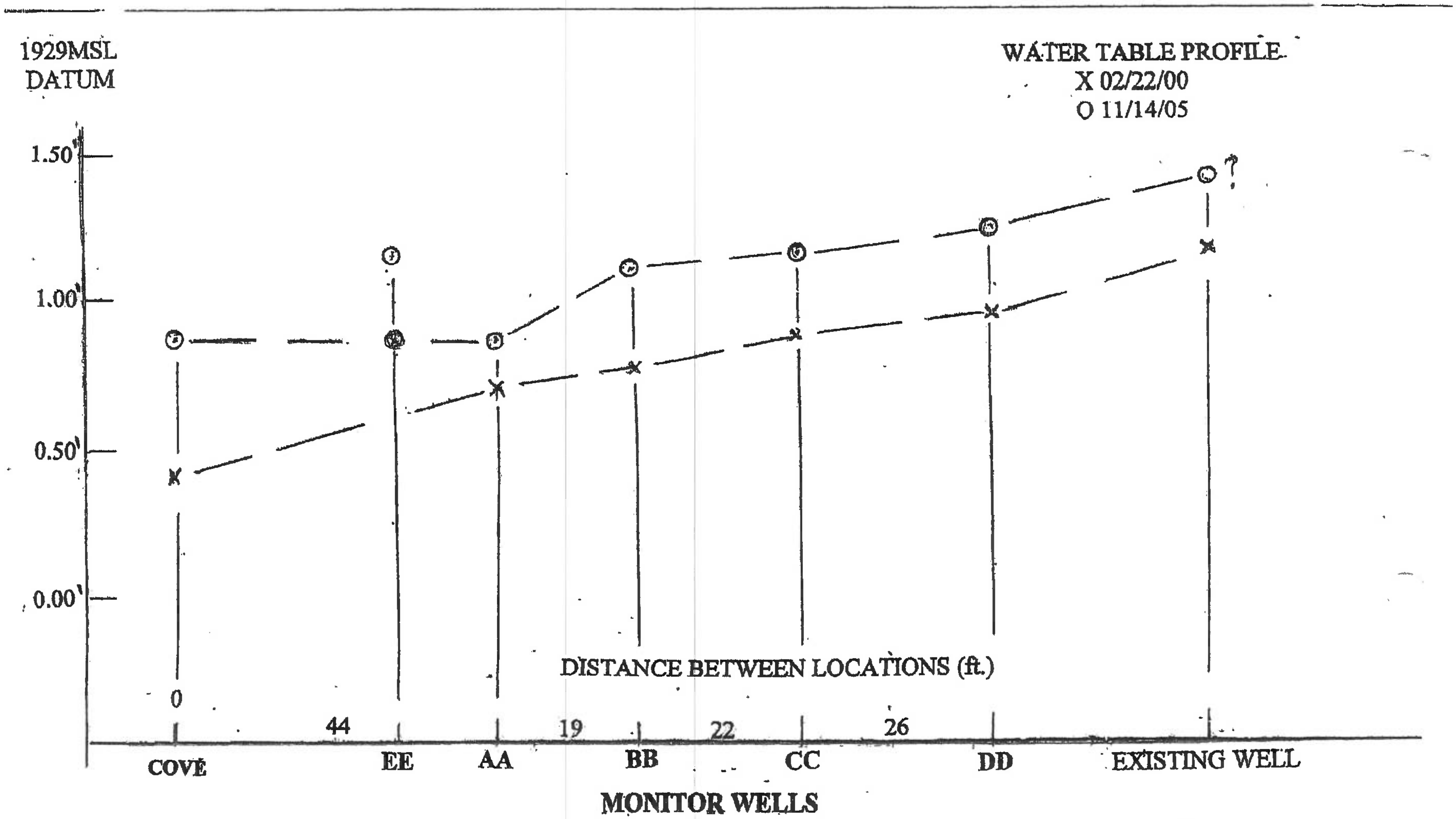

Figure 9. Profile A-A' Showing Location of Water Table Relative to Allen Cove.

conjunction with an estimated hydraulic conductivity of 75 ft/day and an effective porosity of 0.20 (Fetter, 2003). The equation used is a modified Darcy equation as follows:

$$\text{Vest.} = KI/n_e \quad \text{...} \qquad (1)$$

Where Vest. is the estimated average groundwater velocity along a flow path, K is a constant indicating hydraulic conductivity, I is the groundwater gradient, and n_e is the effective porosity through which the water flows.

The estimated average flow velocity for water moving across the middle portion of the site is approximately 2-3 ft./day.

3.4 Groundwater Recharge.

Based on precipitation records at the URI Kingston Weather Station and published U.S. Geological Survey reports for the Rhode Island area, a general water budget can be developed to estimate possible groundwater recharge in the general region of the investigation during the year. Most recharge occurs during the period of October – April when evapo-transpiration is minimal. An estimated water budget is as follows:

	Amount (inches)
Average annual precipitation (URI Kingston Station)........................	48
Estimated evapo-transpiration (U.S.G.S. Water Supply Paper 1821)	24
Surface runoff	6
Groundwater recharge	18

Recharge to groundwater over the region is uneven, but based on topography and soil conditions is probably in the range of 20 to 30 % of the annual rainfall of approximately 48 inches, probably in the range of 12 to 18 inches/year, with substantial variances from year to year. During an average year of groundwater recharge, the water supply requirements for a 2 bedroom house requires an area of about 10,000 s. f. However, the Sea Lea area is self-dependent for both water supply and sewage disposal, with housing units each having their own well and on-site sewage disposal. Hence, the water pumped from wells is largely returned to the groundwater system, albeit in an environmentally degraded condition with regard to chemical input, especially nitrate. As long as the pumped water is returned to the ground, adequate groundwater recharge is not a regional water quantity problem, which might exist if the area were sewered. Further, it appears that most of the homes at Sea Lea are only occupied during the summer, which greatly ameliorates both quantity and quality potential issues that could exist if all residences were occupied year-round.

3.5 Groundwater Quality.

The aquifer is a water table aquifer consisting of a relatively thin fresh water lens overlying denser sea water. This is based on geo-electrical surveys conducted during October, 2005, as well as direct water quality sampling. The salinity of the adjacent cove water averaged about 21 ppt (sea water is 34 ppt) during November, 2005. Because of this situation, any groundwater withdrawals must be limited in both depth and quantity of pumping to avoid salt water intrusion from the surrounding coastal waters. Water sampling in December, 2005, using a stainless steel small diameter probe, hand driven to a depth of 12.2 feet below the ground surface indicated that the groundwater was fresh at least to a depth of 6.5 feet below the water table. Figure 10, p. 18 presents the results of this investigation.

Evaluations of the overall total dissolved chemical content of the area groundwater based on electrical conductivity of the water were made from samples taken from three wells in immediate proximity to the site. The total dissolved solids (TDS) can be estimated at about 0.65 that of the measured electrical conductivity of a water sample (Fetter, 2001). The water sample electrical conductivity values of the three wells averaged 150 micro-Siemens (uS), thus giving an estimated TDS of 100 mg/l, well below the EPA recommended limit of 500 mg/l.

A water sample from the existing well immediately to the east of the site (Lot 388) was analyzed for nitrate-nitrogen and Fecal Coliform bacteria contamination in 2003 (Northeast Environmental Lab, 2003). The results were 3.1 mg/l of nitrogen in the nitrate form (public health limit is 10.0 mg/l) and no Fecal Coliform bacteria. A second sample taken in May, 2006 resulted in 1.8 mg/l of nitrogen and no Fecal Coliform (DOH, 2006). An additional water sample was taken from the residential water supply (South Kingstown Lot 53) directly to the south of the site in December 2005. Analysis by the R.I. Department of Health (DOH, 2005) showed a sodium content of 12.8 mg/l, a nitrate-nitrogen content of 2.2 mg/l, and the presence of Coliform bacteria. The sodium level indicates little salt (NaCl) content. The nitrogen content is well below the DOH limit of 10 mg/l and is of no concern. The presence of bacterial contamination, however, rendered the water non-potable, but corrected by well disinfection. It is most likely that the problem is a local contamination source at the well site and not a regional problem. The nitrate-nitrogen input in the samples is probably from regional on-site sewage disposal and lawn fertilizer. An estimated Total Dissolved Solids of 104 mg/l, based on electrical conductivity measurements, is well below the DOH limit of 500 mg/l.

3.6 Effect of Well Pumping.

It is planned to construct a shallow large diameter dug well on Lot 387(Well No.1), as located on Figure 8, p.14. An additional investigation was made of the existing well (Well No. 2) at Lot 388 to determine its construction details. This well is a minimum depth of 12.4 ft. from the top of the casing with water at a depth of 6.1 ft. below ground surface. It is constructed of 2.0 ft. long – 3.0 ft. diameter precast concrete pipe sections. The intake screen, from which water is withdrawn through a pipe to a pump at the house, appears to be at a depth of 2 to 4 feet below the existing water table. A vertical plan view sketch of the existing well is provided as Figure 11, p.19. The owner indicated that this well functions well with no problems in quality or quantity.

The drawdown effects in the two wells individually and relative to each other during pumping were evaluated using both long term (one year steady state and 180 days unsteady state) continuous usage and short term (12 hours pumping at 5 gallons/minute). Conservative assumptions were made in all cases. The analysis assumes that the proposed new shallow dug well would be of similar construction as the existing well, namely 3-feet diameter, and with a shallow intake.

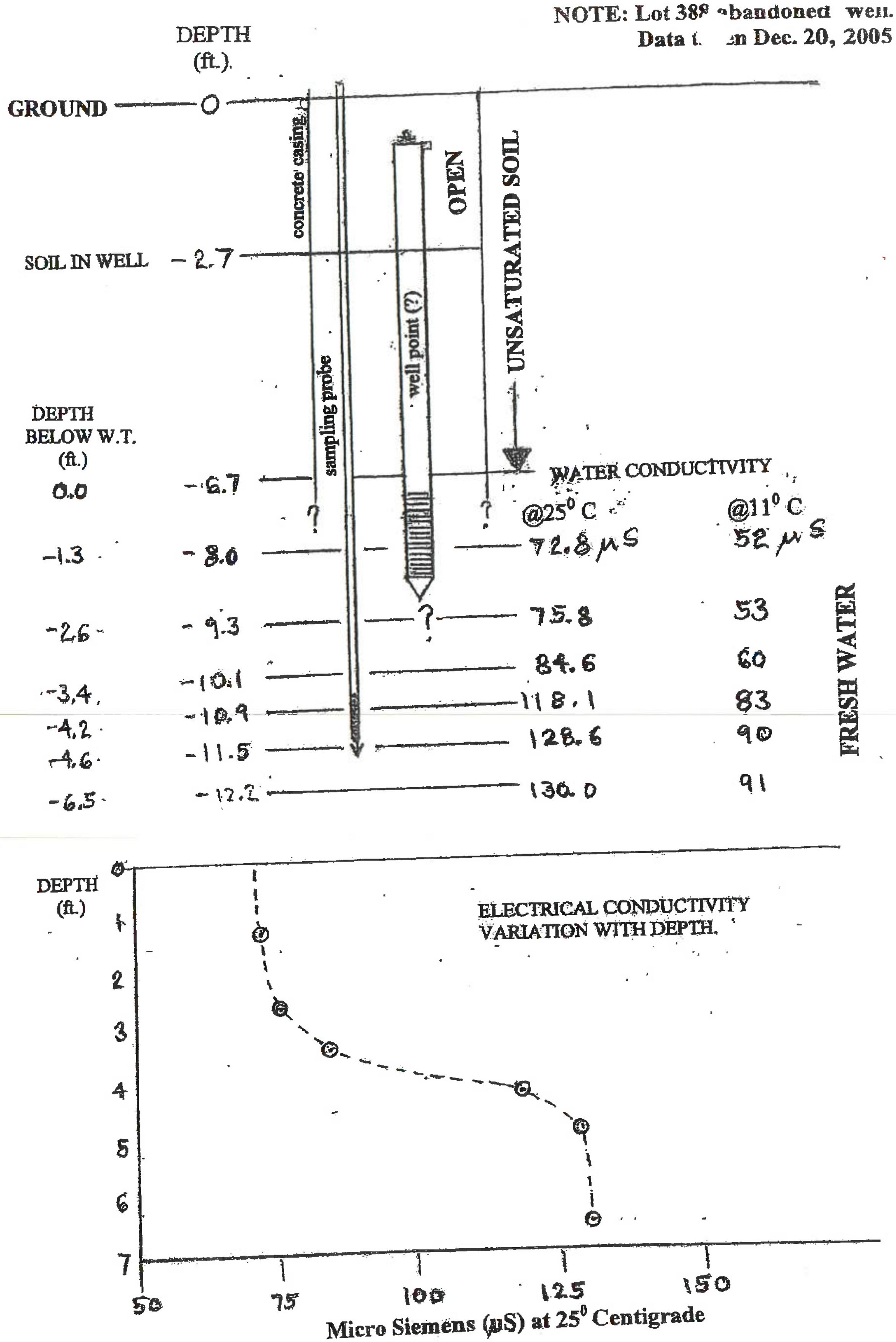

Figure 10. Results of Depth Probe Sampling in Abandoned Well (Lot 388).

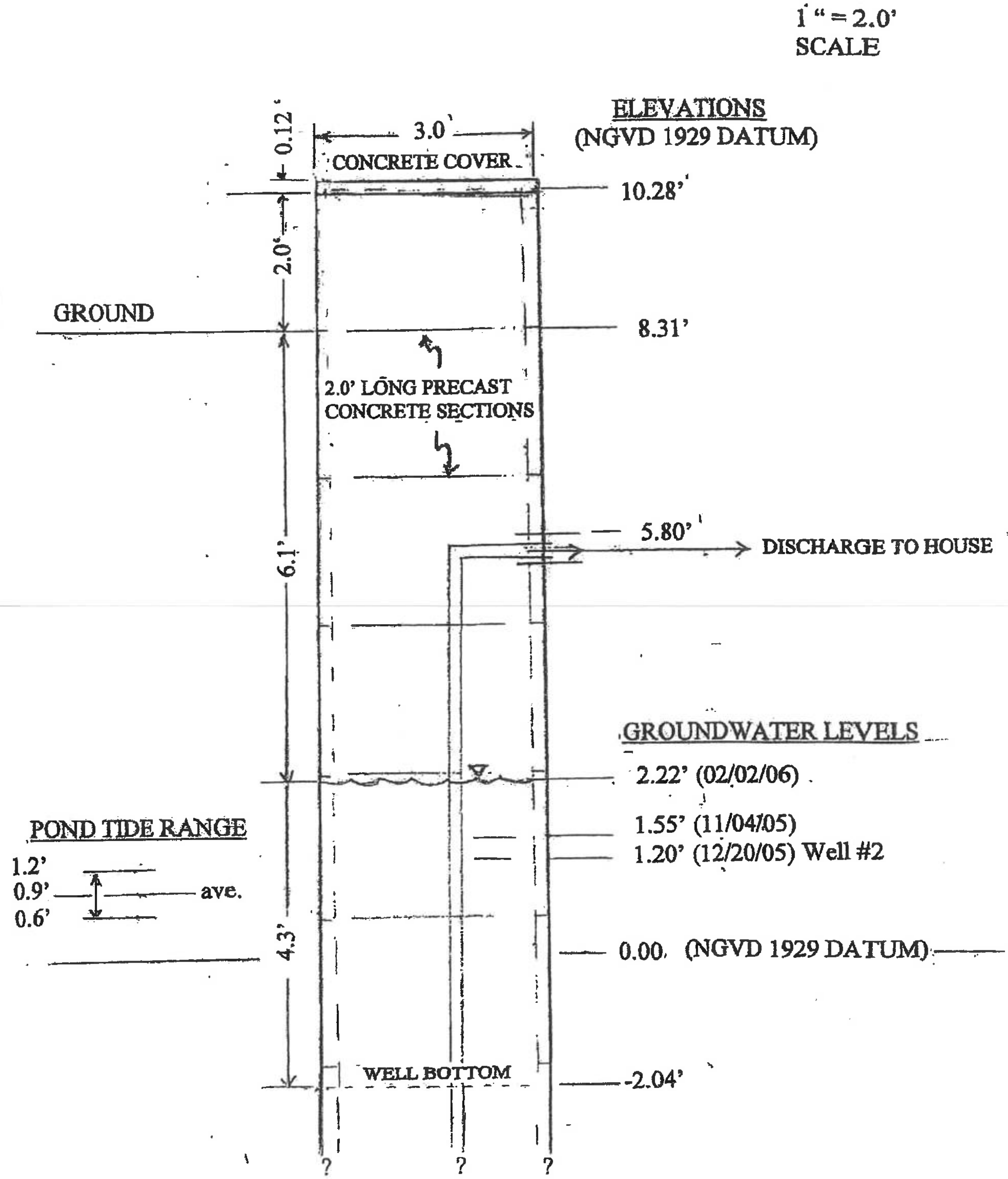

Figure 11. Characteristics of Existing Well (Lot 388)

1) Well number 1 (Lot 387 proposed well) with a requirement of 300 gallons/day (2-bedroom).

Long term drawdown for this well pumping alone at a long term rate of 300 gpd is 0.13 ft. for one year, and 0.08 ft. for 180 days.

Short term drawdown for this well pumping alone at 5 gpm for 12 hours is 1.32 ft. It should be noted that this rate of pumping may be necessary in the short term due to pump characteristics, but would be pumping far in excess of the 300 gpd requirement; in practice the pump would be cycling on and off to meet actual requirements during the day, unless a system malfunction occurred and pumping continued uncontrolled.

Long term drawdown for this well pumping concurrently with well number 2 is 0.24 ft. for one year, and 0.17 ft for 180 days.

Short term drawdown for this well pumping concurrently with well number 2, both at 5 gpm for 12 hours is 1.82 ft.

2) Well number 2 (Lot 388 existing well), with a requirement of 450 gallons/day (3-bedroom).

Long term drawdown for this well pumping alone at a long term rate of 450 gpd is 0.19 ft. for one year, and 0.13 ft. for 180 days.

Short term drawdown for this well pumping alone at 5 gpm for 12 hours is 1.32 ft. It should be noted that this rate of pumping may be necessary in the short term due to pump characteristics, but would be pumping far in excess of the 300 gpd requirement; in practice the pump would be cycling on and off to meet actual requirements during the day, unless a system malfunction occurred and pumping continued uncontrolled.

Long term drawdown for this well pumping concurrently with well number 1 is 0.27 ft. for one year, and 0.19 ft for 180 days.

Short term drawdown for this well pumping concurrently with well number 1, both at 5 gpm for 12 hours is 1.82 ft.

3.7 Salt water intrusion potential.

The estimated average thickness of the fresh water lens at the site is estimated at about 22 feet, with an estimate fresh-salt water transition zone of about 20 to 30 feet below the fresh water. The average elevation of the water table at the site is about 0.5 feet above the average pond level. Therefore long term pumping at the rates indicated would lower the water table about 0.3 feet, and maintain a positive head above the pond level precluding salt water intrusion, though the thickness of the fresh water lens will be reduced. The short term pumping effect evaluated is an extreme case of overpumping which needs to be controlled. In the normal pumping recycling process, the drawdown is mitigated before salt water intrusion can occur. Because the aquifer is a floating lens functioning on the Ghyben-Hertzberg Principle (Fetter, 2001), the density compensation from well withdrawal will reduce long term well drawdown even more.

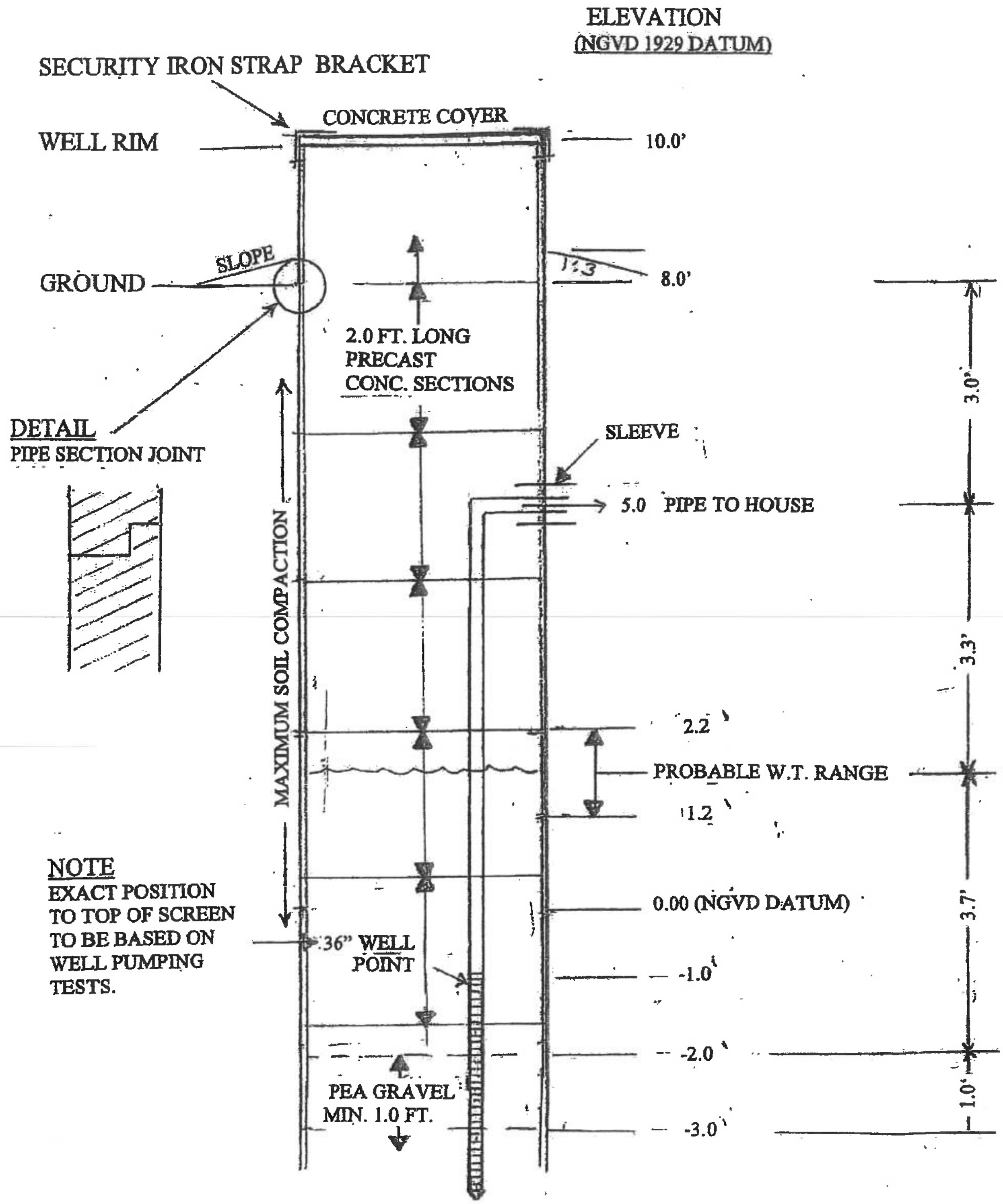

Figure 12. Dug Well Outline Specifications.

The features recommended for new well construction to optimize groundwater withdrawal while minimizing the potential for salt water intrusion are shown in Figure 12, p. 21.

3.8 Effect of New On-Site Sewage Disposal System.

Based on the assigned 2 bedroom criteria with a maximum effluent discharge of 300 gallons/day (Frisella, 2003), the effect of a new on-sewage disposal system (ISDS) at the location indicated is minimal. The effluent discharge will be dominantly to the cove, approximately 50 feet from the proposed ISDS, rather than to any existing or proposed wells. Additionally, the fine-grained nature of the subsurface material in the unsaturated zone below the ISDS and above the water table, in conjunction with the time of travel will tend to mitigate any potential biological hazards. Additionally, it is expected that the planned special sewage disposal system (Frisella, 2004b) will minimize the discharge of nitrate to the shoreline.

3.9 Use of Roof Runoff as Groundwater Recharge.

In a limited groundwater resource situation, the use of precipitation from roof runoff as discrete groundwater recharge can be beneficial. This is especially the case where the runoff would otherwise more rapidly discharge as surface runoff to a coastline or evapo-transpire from the surface and near-surface environment. Recharging the groundwater directly at selected locations using relatively high quality roof runoff can accomplish the following in the Sea Lea coastal environment:

1) Increase the total volume of water stored as groundwater in the immediate vicinity of a well.
2) Provide a hydraulic barrier to groundwater flow from less desirable groundwater quality sources, such as septic disposal systems.
3) Provide a hydraulic dam effect and increase the thickness of the fresh water lens to reduce the possibility of coastal salt water intrusion.

While all of the above applications have been used effectively in concept and practice, because of the wide variability of seasonal precipitation and subsurface conditions, including area well withdrawals, precise predictions of the benefits cannot be made. However, it is possible to devise an engineered approach to optimize the use of roof runoff and provide some estimates of anticipated positive results. Figure 13, p. 23 provides a conceptual design layout for collecting the roof runoff and directing it to a recharge location most beneficial to the planned well on Lot 387. All calculations have been made based on year round occupancy.

The following describes the anticipated results from the engineered collection of roof runoff.

1) The total roof area of the proposed dwelling is 729 sq. ft. Using 90% (assuming 10 % is lost as direct evaporation) of the total estimated annual precipitation of

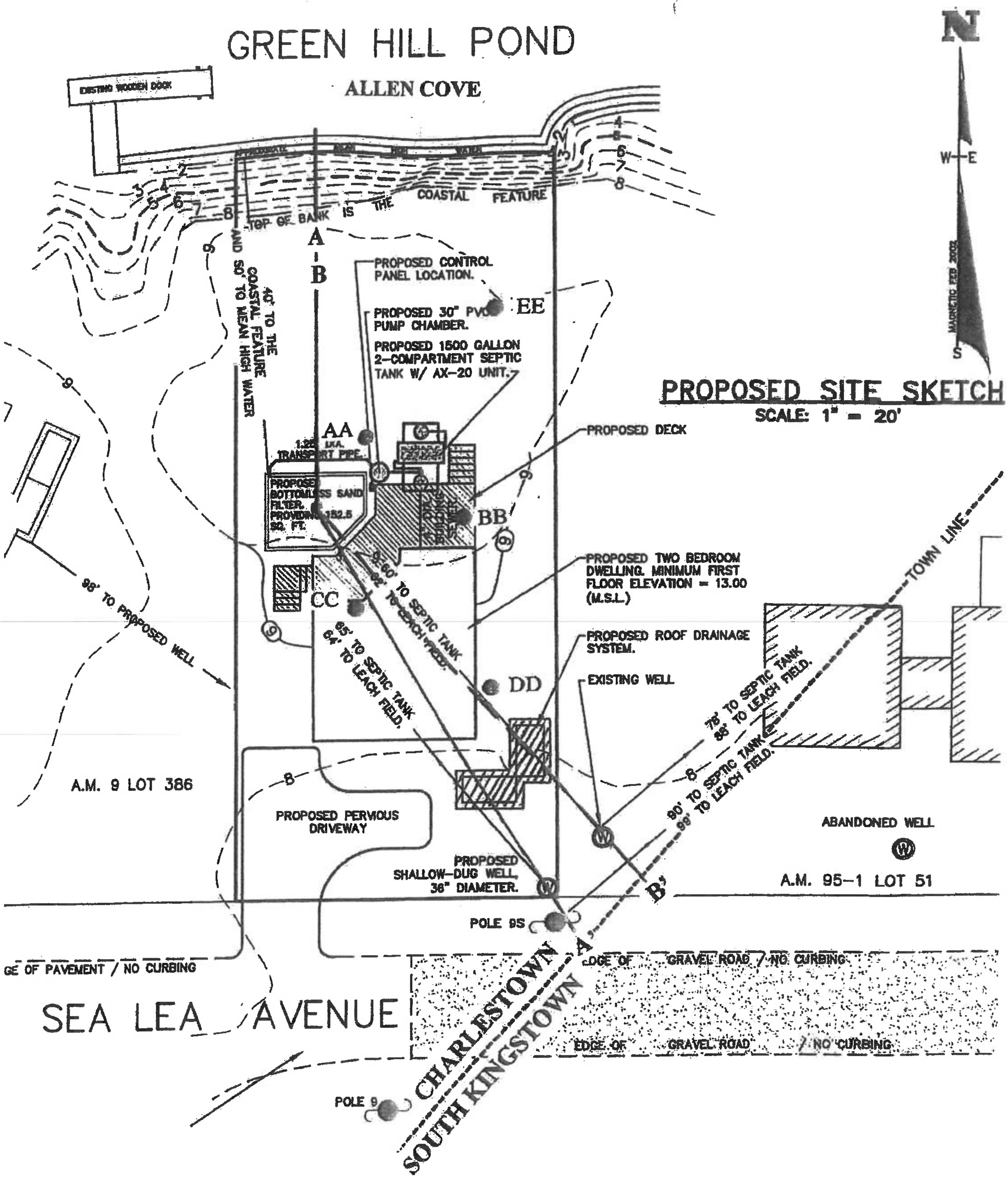

Figure 13. Development Plan for Lot 387 with Cross-Section Locations.

48 inches, the roof area can provide 2609 cu. ft. (19,515 gallons) of collected runoff which can be channeled directly to the groundwater. This is over twice as much as might be provided to groundwater recharge from the usual roof runoff system discharging to the ground surface. The estimated 11,345 gallon annual increase is a groundwater enhancement that will occur throughout the year, even in the summer months when evapo-transpiration normally claims almost all of the precipitation; the immediate capture and transfer to the water table avoids this loss.

1) The general effect of concentrated groundwater recharge between the septic disposal system (BSF) discharge and the proposed well is shown in the vertical cross-section in Figure 14, p. 25. A similar cross-section (Figure 15, p. 26) shows the general effect relative to the existing (Guipponi) well. The locations of these cross-sections is shown in red on Figure 13, p. 23.The current natural water table is from measurements made in August 2006. The directed recharge will produce mounding to the southeast of the septic system serving to increase protection from flow toward the proposed well and existing well locations. The effect would be more pronounced in the months of October – April, when greater precipitation, less evaporation and less residential well water use in the area typically occur. In the winter, with less area residents, the groundwater gradient and flow through the site to the coastline would be increased from the current natural gradient, more effectively purging the area groundwater. In either the summer, or with year round occupancy, an engineered groundwater recharge can have a significant positive effect on the area hydraulic gradients and flow directions.

2) The concentrated introduction of fresh water to the ground as described would increase the fresh water lens thickness in the vicinity of the well. This would be a most important effect that could significantly reduce the possibility of salt water intrusion to the proposed well. This is the result of enhanced groundwater storage which, because of the very slow movement of groundwater, is a long term effect. The suggested recharge system provides an effective increase from the natural annual recharge of 18inches to an equivalent 44 inches of groundwater recharge in the recharge galley area of 64 sq. ft., and an associated increase in freshwater lens thickness of about 4 feet below the recharge area.

3) Maintenance of the roof collection system is essential. Special attention must be given to keeping gutters and components of the collection and distribution system free from debris.

The foregoing has been evaluated on the conditions of the average annual precipitation and environmental conditions. Figures 14, p.25 and 15, p. 26 show the estimated change in water table profile for these conditions. Groundwater measurements over the past year show that the water table fluctuates greatly in response to area precipitation patterns, seasonal water use and the coastal salt water boundary. Additionally, in the short term, namely during times of rainfall

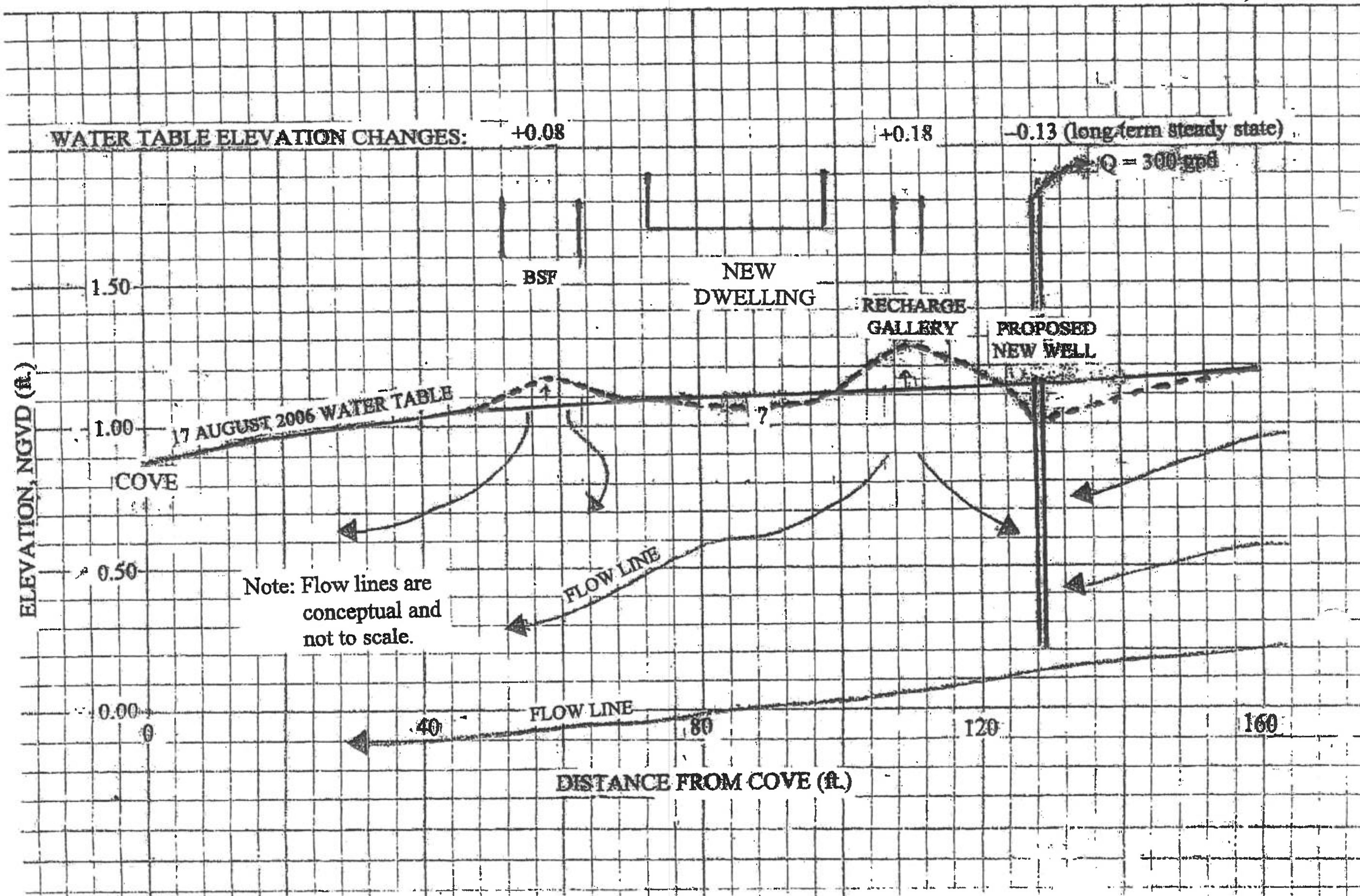

Figure 14. Sea Lea Lot # 221 Water Table Profile at Cross-Section A-A'

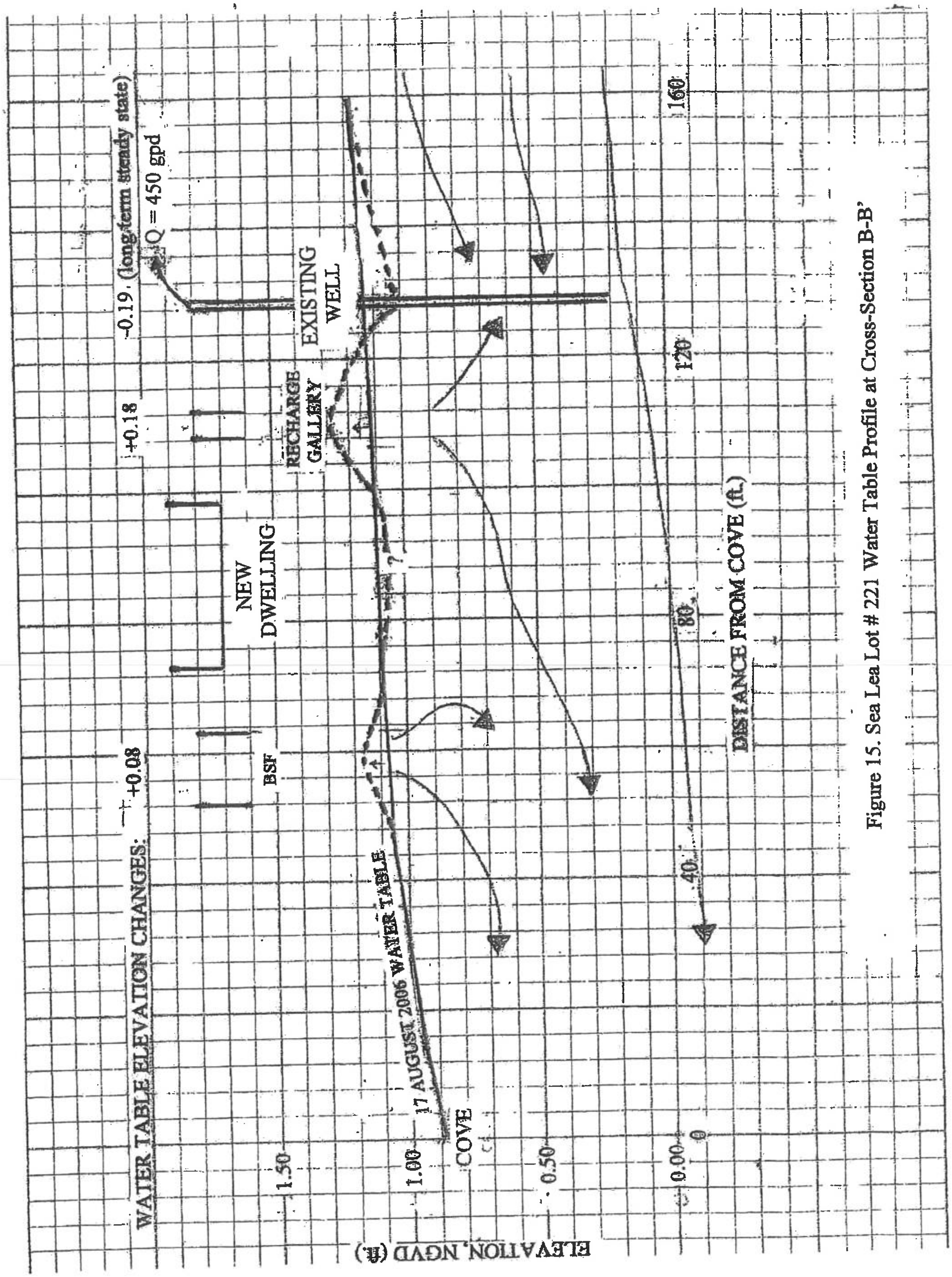

Figure 15. Sea Lea Lot # 221 Water Table Profile at Cross-Section B-B'

and/or pumping there will be much greater variations in the water table. Nevertheless it appears that the effects from an engineered groundwater recharge system would be positive under any conditions.

4.0 Conclusions.

1) In general, the aquifer is a water table aquifer receiving recharge from precipitation, primarily during the period November to March. Though the geographic area is limited, recharge is sufficient to meet the modest requirements of what is largely a summer community.
2) The subsurface material is composed of glacial sediments ranging from silt to gravel size with permeability (hydraulic conductivity) ranging from 20 to 100 ft/day and a porosity of about 20 %.
3) The aquifer is a water table aquifer consisting of a relatively thin fresh water lens overlying denser salt water. Because of this situation, any groundwater withdrawals must be limited in both depth and quantity of pumping to avoid salt water intrusion.
4) Depth to the water table from ground surface at the site during the October – November, 2005 and August 2006 time periods varied from about 7.0 to 8.0 feet.
5) The general pattern of the horizontal component of groundwater flow in the area of investigation is to the north-northwest with discharge to the cove.
6) Area water quality is good based on groundwater water sampling accomplished from two adjacent private wells.
7) Based on the assigned 2 bedroom criteria for the new well with a maximum anticipated groundwater use of 300 gallons/day, the effect of a new well on the naturally occurring groundwater flow is small.
8) Based on the assigned 2 bedroom criteria for the new well with a maximum effluent discharge of 300 gallons/day, the effect of a new on-sewage disposal system (ISDS) at the location indicated is minimal.
9) The employment of directed roof discharge from the proposed new dwelling to discrete groundwater recharge can have beneficial effects for both the proposed new well and the adjacent existing well.

6.0 References.

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