

Models of Ponding In Two Flooded Recharge Basins

Abstract

Groundwater recharge basins are the primary method of managing stormwater runoff on Long Island. Many of the basins excavated on the Ronkonkoma and Harbor Hill moraines contain standing water, and do not drain (Aronson and Seaburn). The interest of this study is a system of connected recharge basins that are perpetually flooded. The basins receive a constant input of industrial cooling and leak water, in addition to stormwater from paved surfaces over a large portion of Stony Brook University's West campus. Initial investigations indicated that the basins might intersect a groundwater mound (Tuomey). In this study, several scenarios were modeled using Visual MODFLOW and MOUNDHT software. Researchers also collected well data and took sediment samples, which assisted in calibrating the models. A better understanding of the hydrogeologic framework of the basins as well as subsurface stratigraphy is important for understanding the management of stormwater systems.

Introduction

The residents of Nassau and Suffolk counties rely on groundwater from unconfined aquifers as a sole source of water (Oliva). In order to ensure a sufficient supply of fresh water reaches the aquifer, the use of conservative measures, such as artificial recharge basins, is necessary. In addition to providing recharge to the aquifer, artificial recharge basins are an effective means of managing stormwater runoff in urbanized areas (Aronson, 1979).

Many artificial recharge basins on Long Island contain standing water. Standing water in recharge basins can be caused by clogging, which is the accumulation of fine sediments and organic matter on the basin floor (Aronson and Seaburn). They may also be flooded, due to intersection of the water table (Aronson and Seaburn), intersection of a perched water table (Aronson and Seaburn), placement in deposits of low hydraulic conductivity (Aronson and Seaburn), or due to intersection of a groundwater mound formed by a high inflow of water into the recharge basin (Fig. 1) (Pizzulli). Flooded basins drain directly into the saturated zone, since there is no intervening unsaturated zone between the water in the basins and the water table. Since the hydraulic gradient between flooded basins and the water table is small, flooded basins drain slowly (Aronson).

The basins on the northwest side of Stony Brook University's West Campus (Fig. 2) are continually flooded. In at least one past occasion, the basins overflowed, damaging the nearby Long Island Rail Road tracks, as well as several residential properties along State Route 25A.

Groundwater mounding (fig. 1) is the rise of the local water table in response to excessive recharge (Fetter). Mounding appears on water table contours in a similar fashion to the way a hill would look on a surface elevation contour map. Mounding is

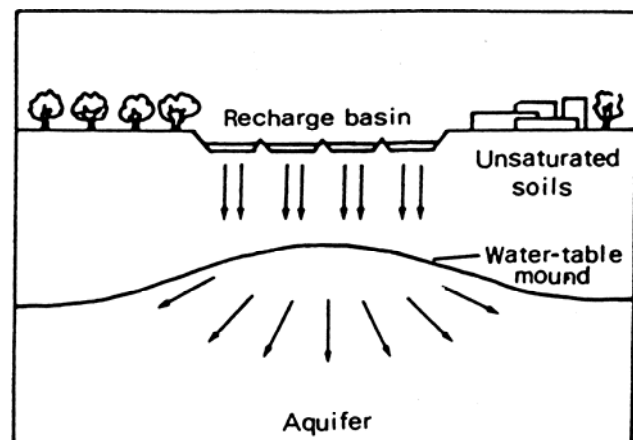


Figure 1: Flow of water from a recharge basin through the unsaturated zone, after Pizzulli (1999).

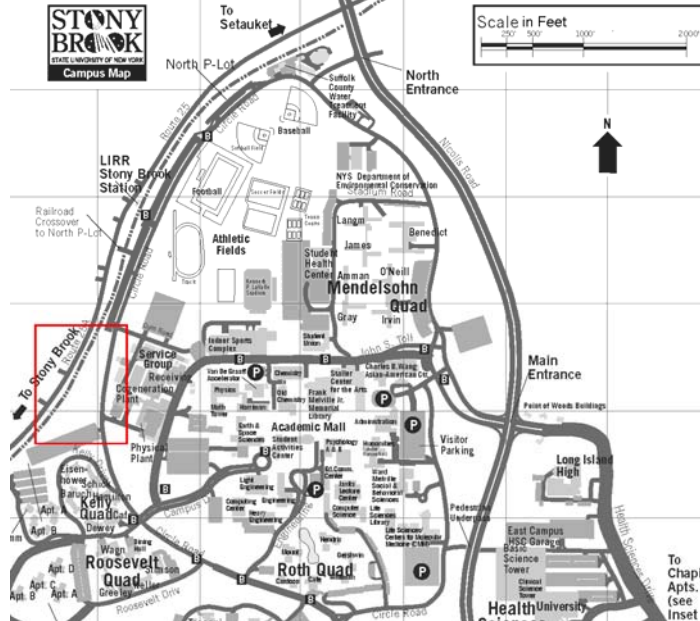


Figure 2: Area map for the project. The study area is highlighted in red.

typical under storm water and wastewater recharge basins. Typical mounding under stormwater basins on Long Island ranges from one to six feet after storm events (Haskell and Bianchi). The basins on the northwest side of Stony Brook University's West Campus (Fig. 2) are unique in that they receive a constant influx of water from cooling and leaks, and an episodic influx due to storm water. This means the average inflow to the basins is 100,000-500,000 gallons per day (Rispoli). This large amount of water must flow out of the basins to prevent them from overflowing. The average hydraulic conductivity of the sediments in the area is quite low, since there are many layers of glacial clay and silt in the sediments beneath the basins.

Therefore, the water escapes the basins slowly, and exacerbates the local mounding effect.

We have a poor understanding of the stratigraphy beneath the basins. A clay lens was encountered at an elevation of 50', when a well was drilled 45' north of the northernmost basin (Basin 1). Based on the texture and color of the clay, and the stratigraphy of the region, it could be a lens of the Smithtown Clay, which has been observed nearby in Nissequogue (Krulik and Koszalka). Glacial tectonics has strongly influenced this area, and the clay lens underlying the basins, it may be dipping, or may terminate abruptly. The modeling in this study did not consider the clay, due to limited knowledge of the stratigraphy of the area, including the spatial extents and orientation of the clay lens.

The purpose of this experiment was to model the effects of groundwater mounding on the elevation of the water table on Stony Brook's West Campus (fig. 2), and relate it to the elevation of standing water in the recharge basins. I made several maps with potential water table contours using groundwater-modeling software in conjunction with Geographic Information System (GIS) software (ArcGIS). Groundwater mounding underneath the recharge basins may cause slower drainage in the basins, and in some cases, the mounds may intersect the basins, causing them to be perpetually flooded. My hypothesis is that groundwater mounding significantly alters groundwater flow in the local area, and prevents the basins from properly draining.

Methods

A conceptual model was designed based on the potential inputs and outputs for the basins, and potential causes for the standing water. A research group then collected sediment samples from the bottom of one of the basins, to evaluate clogging as a potential cause of the standing water. Next, a separate research group collected well data and standing water

elevations. Finally, the data was combined with published data in the creation of a groundwater model and subsequent sensitivity analysis using Visual MODFLOW 4.1.

The sediment samples were collected by a team using a rowboat, a grab sampler, several grab sample coring tubes, and several whirl-pak bags. We collected the sediments from Basin 2, which is the middle basin in the 3-basin complex, on November 10, 2005. Sediments had been collected in Basin 1 during an earlier experiment (Pizzuli). Basin 2 is a man-made basin that was constructed in a glacial tunnel valley (Hanson, July 2005). Basin 2 is excavated in a deposit of primarily coarse sand and gravel, and it had been expanded and scarified approximately 6 months prior to the sampling (Rispoli). The water level in the basin was 14 feet \pm 1 foot, according to the gauge pole on the day of sampling.

In order to measure the extent of the mounds, we collected data on the elevations of several monitoring wells in the area. We also measured the elevation of the surface water level in the two basins that contain standing water (Basin 1 to the north, and Basin 2 in the middle of the three basins). For this task, we used the technique of differential leveling. In differential leveling, one uses a level to sight a measuring stick. The height of the level is first determined by referencing the level to a point of known elevation, in this case the floor of the Stony Brook West Campus Heating Plant. Next, one measures the elevation of other points of interest relative to the level. This gives the elevation relative to the level, which one can then relate back to the reference point. At that point, we may move the level and reference it to the points that we measured the elevation of. We continue in that fashion until we have referenced all points of interest.

The group also measured depth to water and depth to bottom in the wells for which we had measured the surface elevations. We accomplished this with a weighted steel tape. We lowered the tape into the well until we were confident it was below the water table. We recorded the depth of the tape we lowered down the well by reading it against the well's edge. Next, we raised the tape and recorded the location of the water table in relation to the tape by noting where the tape was wet. By subtracting the relative location of the water table from the depth to which we lowered the tape, we arrived at the depth to water. We subtracted the depth to water from the well's elevation to obtain the elevation of the water table.

GIS is a computer tool for making maps containing various layers of geographic data. This enables all or just selected portions of the data to be displayed on a map in a number of ways. We used ArcGIS version 9.1 for Windows PCs, published by ESRI, Inc. We used existing GIS shapefiles to display surface elevation contours, buildings, roads, well locations (Kilb, "Groundwater Mapping"), and basin locations (based on contour data) on the map. We drew a shapefile of approximate water table contours based on the well data by "heads-up digitizing." This map was compared to the models, as a quick method of testing their predictions.

In order to model the extent of the mounds, I used published data concerning the regional hydrology of northern Brookhaven township (Jensen; Koszalka 1980; Olanrewaju) to construct a regional flow model (Figure 3, Appendix A), using Visual MODFLOW 4.1. This flow model assumed a vertical hydraulic conductivity of 230 feet per day, and a horizontal hydraulic conductivity of 23 feet per day. The model's boundary conditions were set to a constant-head boundary at the 50-foot regional water table contour on the current USGS regional water table contour map (Busciolano), and a constant-head boundary of 0' according to a map of the Long

Island coastline. The regional flow model was set to run until a steady state was reached, after approximately 10 years. Once a regional flow model was created, several scenarios were tested by varying conductivity values, conductance of the beds of the basins, and the volume flux of water through the basins.

Results and Discussion

Fine sediments in Basin 2 ranged in thickness from less than 1 mm on the northeastern side, near the gauging pole, to approximately 5 cm in the center. The sediments appeared to be stratified in 4 layers, perhaps indicating storm events. The lowest layer appeared to consist of a light-colored silt. The next layer was thicker, and was composed of dark, cohesive, possibly organic-rich sediment. The next layer resembled a grey clay, and the last layer was made up of loosely bound organic matter, mostly leaf litter. Results from Basin 1 (Maher) indicated that the sediments on the bottom of Basin 1 were between 5 cm and 13 cm thick.

The mapping group began by mapping the elevations of several monitoring wells near the West Campus Heating Plant. We had previously measured the elevations for a Field Geology class, (Kilb, "Groundwater Mapping"), but we desired better closure. Our calculated closure for those wells was 0.573m. This is a good closure compared to previous results.

We then took elevations of several landmarks (light poles and fence posts) as intermediate reference points. Along the way, we took several intermediate closures, all of which were small. We used the intermediate points to measure the elevation of the well near Basin 1, and the surface water in the Basin 1 and Basin 2. Table 1 summarizes the results. All elevations are in feet.

Table 1: Depth to water and elevation of the water table for the wells.

Trial Number	Depth to Water (ft)				Elevation (ft)			
	B1 MW	MW2	MW3	MW8	B1 MW	MW2	MW3	MW8
1	44.417	67.20833	70.875	70.19792	51.539	39.03896	39.27333	39.04938
2	44.083	67.20833	71.01042	70.17188	51.872	39.03896	39.13792	39.07542
3	44.813		70.99479		51.143		39.15354	
4	44.813				51.143			
5	44.5				51.456			
Top of Well	0	0	0	0	95.956	106.2473	110.1483	109.2473
Bottom of Well	50.063				45.893			
Average Water Table	44.525	67.20833	70.96007	70.1849	51.431	39.03896	39.18826	39.0624
Standard Deviation	0.3053	0	0.074085	0.018414	0.3053	0	0.074085	0.018414

Note that in table 1, I calculated the elevation of the bottom of the basins. The basins do not have flat, uniform bottoms, and the elevations shown indicate the deepest portions of the basins. I based elevation of the bottom of Basin 1 on a gauging pole installed in the basin, which is accurate to within a foot, based on prior studies. I based the elevation of the bottom of Basin 2 on a bathymetric study performed by Michelle E. Pizzulli (Pizzulli 1999).

Next, we calculated the depth to water in the wells (Table 2, Appendix A). Due to difficulty in measuring, we took several readings for each well. I have displayed the average and standard deviation for the measurements at each well. I used the average values along with the elevation values to calculate the elevation of the water table. The elevation of the water in the well near Basin 1 is of particular interest. The water table at that point is only one meter below

the elevation of the deepest part of Basin 1, so I expect that the water table may intersect the bottom of the basin.

Figure 4 (Appendix A) shows the estimated water table contour map created in ArcGIS. The regional water table should be at an approximate elevation of 35 feet, and regional flow should be to the northwest. Note that the estimated contours indicate that local flow seems to radiate outward from the basins.

The first series of models of the recharge basins tested whether uncertainty in the horizontal and vertical hydraulic conductivities of the aquifer material in the area would significantly influence drainage patterns from the basins. The model was also used to determine the maximum amount of mound growth that could occur beneath the basins, for a given value of the hydraulic conductivity of the sediments on the basin floors.

Figures 5-9 (Appendix A) show the results of models assuming typical conductivity values for the Upper Glacial aquifer (Jensen; Koszalka 1980; Olanrewaju). Next, and an unlimited input was allowed to the basins, so that the maximum extent of the mound could be observed, if clogging due to aquifer conductivity or basin floor sediments was limiting. This was obtained by treating the basin as a stretch of river, using the river package in Visual MODFLOW. The thickness of basin floor sediments was input based on observations in the sediment study. Figures 5-8 display the results of models assuming that the conductivity of the basin floor sediments is 0.5, roughly the equivalent of fine clay (Fetter). Note that aquifer conductivity values are in no case limiting, since these models all produce identical results, despite variation within acceptable ranges for horizontal and vertical hydraulic conductivities. Based on this assessment, vertical and horizontal hydraulic conductivities were not varied after this point. Assuming that the basin floor sediments are composed of fine clay the basins would still be fairly permeable, and steady state mounding as high as 73 feet could occur. Figure 9 displays the results of a model assuming that the conductivity of the basin floor sediments is 0.005, roughly the equivalent of concrete (Fetter). Note that some steady state mounding could still occur in this case, although it is unlikely that bed conductivities would be so low.

Figures 10-14 show the results of models assuming acceptable conductivity values for the Upper Glacial aquifer, with a horizontal conductivity value of 100 feet per day, and vertical conductivity of 10 feet per day. In these cases, conductivity of the basin floor was disregarded. Instead, volume flux through the basins was considered. This was accomplished by modeling the basins as two injection wells screened above the water table using the injection well package in Visual MODFLOW, and varying the rate of injection, based on estimated values of steady input to the basins. Figure 10 displays the results of mounding under the basins for 150,000 gallons per day, which is the minimum value of cooling and leak water entering the basins, estimated based on discussions with Bruno, Lefferts, and Rispoli. Such a case would result in steady state mounding of approximately 3' at the maximum. Figures 11 and 12 display the results of mounding under the basins for 250,000 gallons per day, which is a conservative mid-range estimate of cooling and leak water entering the basins, based on discussions with Bruno, Lefferts, and Rispoli. Such a case would result in steady state mounding of approximately 7' at the maximum. Figures 13 and 14 display the results of mounding under the basins for 500,000 gallons per day, which is a conservative mid-range estimate for the combination of stormwater runoff and cooling and leak water entering the basins, based on discussions with Bruno, Lefferts and Rispoli, along with Pizzuli's estimates of runoff from paved surfaces minus infiltration.

Such a case would result in steady state mounding of approximately 17' above the regional water table at the maximum, resulting in a water table elevation of 52'.

Conclusions

Groundwater flow on the northwest part of Stony Brook campus is strongly influenced by recharge mounding under the recharge basins located there. A groundwater mound with a maximum elevation of at least 51.43 feet exists below Basin 1, based on well data. Modeling predictions of a steady-state groundwater mound based on reasonable basin bed sediment conductivity values, and reasonable estimates for the daily flux of water through the system, arrive at similar results (Fig. 14).

It is not likely that clogging hinders the draining of the basins. Based on basin bed sediment profiles, estimated conductivity values (Figs. 5-9), and well data (Fig. 4), it is unlikely that clogging is causing the basins to remain flooded, given the size of the mound that is present.

A clay layer may reside beneath the basins, which could cause a perched water table to form, rather than a mound. This would significantly increase the maximum height of the water table, possibly causing the basins to flood to their current levels of standing water. Further investigations, including vibrocore drilling and possibly "Chirp" seismic profiling of the basins is recommended.

It is possible that the basins are flooded due to a combination of mounding, clogging, and large, continuous inputs of water to the basins. Mounding would, at the least, decrease pore pressures in the unsaturated zone, and if the mounds intersected the basins, then there would be no unsaturated zone, and drainage would be severely limited (Aronson and Seaburn).

Recommendations

Several engineering practices have been employed to allow the basins to drain better. First, the basins have been routinely scarified to eliminate clogging by fine particulate matter. Scarifying is the process of removing fine-grained material, exposing the sandy-gravelly sediment underlying the basins (Aronson and Seaburn).

A retention basin system (Fig. 15) was inherent in the design of the basins, although that system has since been modified. Retention basins management involves the use of several basins. All runoff is

input to the first basin, where sediment is allowed to settle over a period of time. A pipe connects the top of first basin to the second basin, allowing sediment-free overflow to spill into the second basin, where it should be readily able to drain. Originally, the basins on the northwest side of Stony Brook University's West Campus were arranged in this fashion, with all runoff entering Basin 1, and only overflow entering Basin 2. Several construction projects (construction of the West

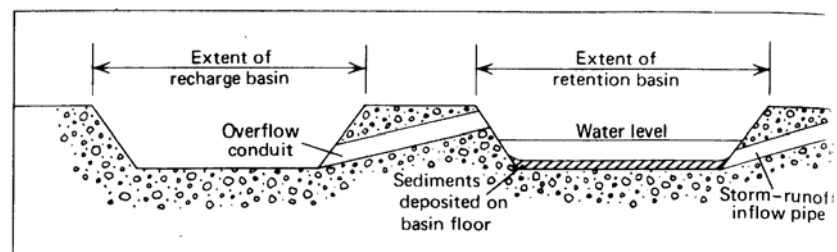


Figure 15. Diagram of a Retention Basin management system. After Aronson and Seaburn.

Several construction projects (construction of the West

Apartments, and several road maintenance programs) have diverted runoff directly to Basin 2, causing silting to occur, as evidenced by the sediment survey.

Based on the bathymetry of the basins (Pizzuli), it appears that auxiliary infiltrating areas (Fig. 16) have been employed. The purpose of auxiliary infiltrating areas is to allow sediment-laden water to enter the basin, and settle in a deeper part of the basin that is wet more frequently. If that area becomes clogged, the water level will rise, and the overflow will spill over the unclogged, auxiliary infiltrating area, allowing the water to

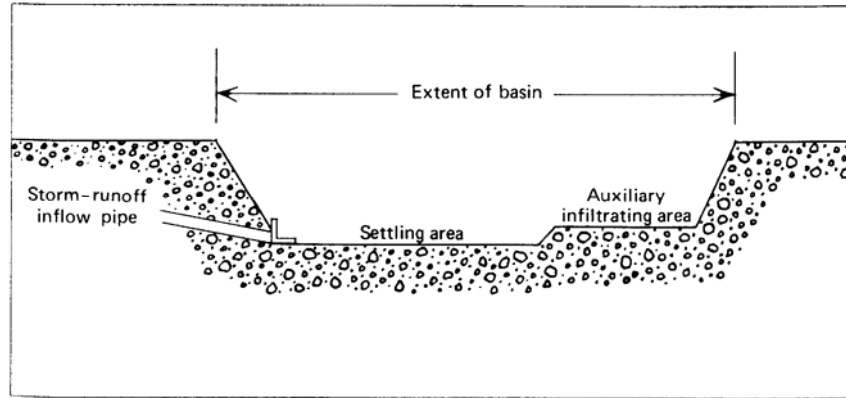


Figure 16. Diagram of an Auxiliary Infiltrating Area management system. After Aronson and Seaburn.

infiltrate (Aronson and Seaburn). Currently, the auxiliary infiltrating areas are submerged, and the full extent of the basin is subject to silting.

Recently, fourteen diffusion wells were installed, when Basin 2 was scarified (Rispoli).

Diffusion wells are sometimes used to combat clogging, although in areas prone to clogging, the diffusion wells become clogged and cease to function rather quickly (Aronson and Seaburn). More often, diffusion wells are used in basins that are placed above deposits of low hydraulic conductivity, such as clay lenses (Fig. 17). Diffusion wells consist of several concrete infiltration rings that are buried to a level below the deposits of low hydraulic conductivity, and then capped by a sand and gravel filter pack, to prevent silt from entering the wells. The wells installed in Basin 2 consist of two 8' concrete rings, which are buried to a depth of 12' below the basin floor (and elevation of 53', which is 2' above the elevation of the top of the clay layer found in the monitoring well), and 4' above the basin floor. They are fitted at the top by large metal gratings, and

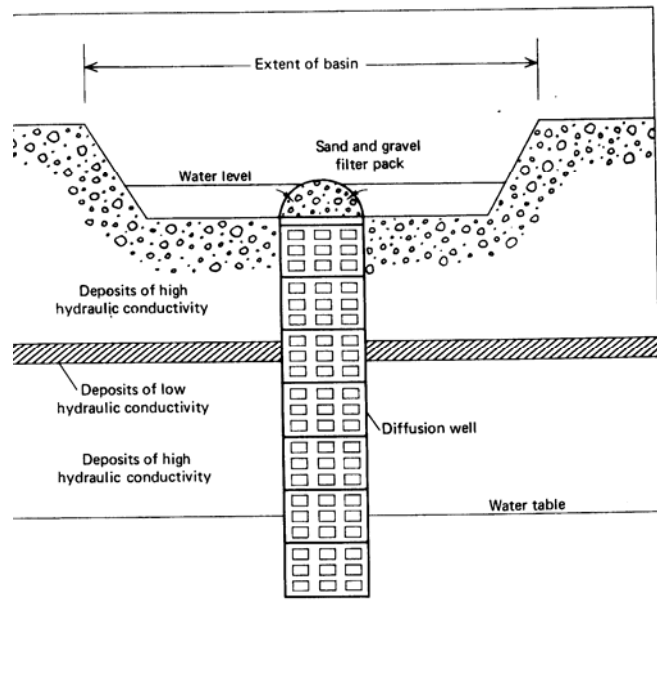


Figure 17. Diagram of a Diffusion Well management system. After Aronson and Seaburn.

have not been covered with filter packs. Currently, ten of the diffusion wells are fully submerged.

I recommend that any future stormwater runoff be diverted to Basin 1, to maximize the usage of the Retention Basin management plan. Further, I recommend that future construction budgets for the basins include stratigraphic analysis of the underlying sediments, to determine if infiltration is being limited by deposits of low hydraulic conductivity. If this is the case, I recommend that diffusion wells be installed to a depth well below the deposits, and that they be covered by a sand and gravel filter pack, to prevent silt clogging within the concrete rings.

References

- ArcGIS 9.0. Computer Software. ESRI, 2004.
- Aronson, D.A. "Use of storm-water basins for artificial recharge with reclaimed water, Nassau County, Long Island, New York: a hydraulic feasibility study." *Long Island Water Resources Bulletin* no. 11, 57 pages. 1979.
- Aronson, D.A. and Seaburn, G.E. "Appraisal of Operating Efficiency of Recharge Basins on Long Island, New York, in 1969." USGS Water Supply Paper 2001-D. Washington, D.C. 1974.
- Bruno, P. Personal interview. SUNY at Stony Brook, New York. Fall 2005.
- Busciolano, R. "Water-Table and Potentiometric-Surface Altitudes of the Upper Glacial, Magothy, and Lloyd Aquifers on Long Island, New York, in March-April 2000, with a Summary of Hydrogeologic Conditions: Second Edition." USGS Water-Resources Investigations Report 01-4165. Coram, New York. 2002.
- Fetter, C.W. Applied Hydrogeology, 4th Edition. Upper Saddle River, NJ: Prentice Hall. 598 pages. 2001.
- Hanson, G.N. Personal conversations. SUNY at Stony Brook, New York. Fall 2005.
- Hanson, G.N. "Glacial Geology of the Stony Brook-Setauket-Port Jefferson Area." Long Island Geology Research Papers on the Web. July 13, 2005. April 21 2006.
< http://pbisotopes.ess.sunysb.edu/reports/dem_2/index.htm>
- Haskell, E.E., Jr., and Bianchi, W.C. "Decelopment and Dissipation of Groundwater Mounds Beneath Square Recharge Basins." *American Water Works Association Journal* vol. 57, no. 3, p. 349-353. 1965.
- Jensen, H.M. "Hydrogeology of Suffolk County, Long Island, New York." USGS Hydrologic investigations atlas HA-501. Washington, D.C. 1974.
- Kilb, N. "Mapping Bodies of Water on Stony Brook Campus." GEO 305: Field Geology Course Work. SUNY at Stony Brook, New York. September 2005.
- Kilb, N. "Groundwater Mapping." GEO 305: Field Geology Course Work. SUNY at Stony Brook, New York. September 2005.
- Kilb, N. "Optional Report." GEO 305: Field Geology Course Work. SUNY at Stony Brook, New York. December 2005.
- Kilb, N. "Recharge Basin Field Trip." Proc. of Geology of Long Island and Metropolitan New York Conf., 22 Apr. 2006, SUNY at Stony Brook, New York.
- Koszalka, E.J. "Hydrogeologic data from the northern part of the town of Brookhaven, Suffolk County, New York." *Long Island Water Resources Bulletin* no. 15, 80 pages. 1980.
- Krulikas, R.K. and Koszalka, E.J. "Geologic Reconnaissance of an Extensive Clay Unit in North-Central Suffolk County, Long Island, New York." U.S.G.S. Water-Resources Investigation Report: 82-4075 Coram, New York. 1983.
- Lefferts, R. Personal interviews. SUNY at Stony Brook, New York. Fall 2005.
- Maher, N. Personal conversations. SUNY at Stony Brook, New York. Fall 2005.
- Misut, P. Personal conversations. USGS Water Resources Division, Field Office, Coram, New York. Fall 2005.
- Olanrewaju, J.N. "Hydraulic conductivity, porosity, and particle size distribution of core samples of the upper glacial Aquifer: laboratory observations: a final report." Research

Nicholas D. Kilb (100882207)
SUNY at Stony Brook, Fall 2005

Geology Department
Undergraduate Research Report

Report: Stony Brook, N.Y.: State University of New York at Stony Brook, Dept. of Earth and Space Sciences. 50 pages. 1994.

Oliva, James A. "Operations at the Cedar Creek Wastewater Reclamation-Recharge Facilities, Nassau County, New York." In Asano, Takashi, (ed.), Artificial Recharge of Groundwater: London, Butterworth Publishers, p.397-424. 1985.

Pizzulli, M.E. "Fate of Nitrogen in a Poned Recharge Basin." Proc. of Geology of Long Island and Metropolitan New York Conf., 24 Apr. 1999, SUNY at Stony Brook, New York. 18 December 2005. <http://pbisotopes.ess.sunysb.edu/lig/Conferences/Conf_99/Program.htm>.

Rispolli, L. Personal interviews. SUNY at Stony Brook, New York. Fall 2005.

Tuomey, A.M.

Visual MODFLOW 4.1. Computer Software. Waterloo Hydrogeologic Inc., 2005.

Appendix A: Modeling Results



Figure 3. Initial model of regional flow conditions, assuming standard conductivities for the Upper Glacial aquifer: horizontal conductivity of 230 feet per day, vertical conductivity of 23 feet per day, and with no input from the recharge basins.

Table 2: Elevation data for the wells and recharge basins.

Point from	Point to	Foreshot (ft)	Backshot (ft)	Elevation (ft)	Closure (ft)	Description
Building	Map			106.94	NA	Heating Plant floor elevation
1	Building		5.21354167	112.1535417	NA	HI at Point 1
1	MW3	2.00520833		110.1483333	0	Flush Mount Well
1	MW2	5.90625		106.2472917	0	Stand Pipe Well in Lawn
1	MW8	2.90625		109.2472917	0	Stand Pipe in Parking Lot
2	Building		2.29166667	109.2316667	NA	HI at Point 2
2	MW2	2.92708333		106.3045833	0.0572917	Stand Pipe Well in Lawn
2	LP1	7.05208333		102.1795833	-	Light Pole near basins
3	LP1		3.5625	105.7420833	NA	HI at Point 3
3	LP2	7.14583333		98.59625	-	Next Light Pole NE of LP1
4	LP1		0.28125	102.4608333	NA	HI at Point 4
4	LP2	3.82291667		98.63791667	0.0416667	Next Light Pole NE of LP1
4	LP3	6.45833333		96.0025		Next Light Pole NE of LP2
4	L B2 GP	7.5625		94.89833333	-	Left Basin 2 Gate Post
4	R B1 GP	7.66666667		94.79416667	-	Right Basin 1 Gate Post
5	R B1 GP		0.22916667	95.02333333	NA	HI at Point 5
5	AP1	8.5625		86.46083333	-	Arbitrary Point 1
6	AP1		0.484375	86.94520833	NA	HI at Point 6
6	B1 WL	6.96875		79.97645833	-	Water Level in Basin 1
7	LP2		1.56770833	100.1639583	NA	HI at point 7
7	LP3	4.14583333		96.018125	0.015625	Next Light Pole NE of LP2
7	B1 MW	4.20833333		95.955625	-	Monitoring Well near Basin 1
8	L B2 GP		0.72916667	95.6275	NA	HI at Point 8
8	AP2	8.36979167		87.25770833		Arbitrary Point 2
9	AP2		0.15625	87.41395833		HI at Point 9
9	B2 WL	7.63020833		79.78375		Water Level in Basin 2
9	Pole	22		65.41395833		Bottom of basin 2, according to Gauge Pole
Pole	B2 WL		14.3333333	79.74729167	0.0364583	Water Level in Basin 2
B1 WL	B1 Bottom	27		52.97645833		Bottom of Basin 2, according to Pizzuli

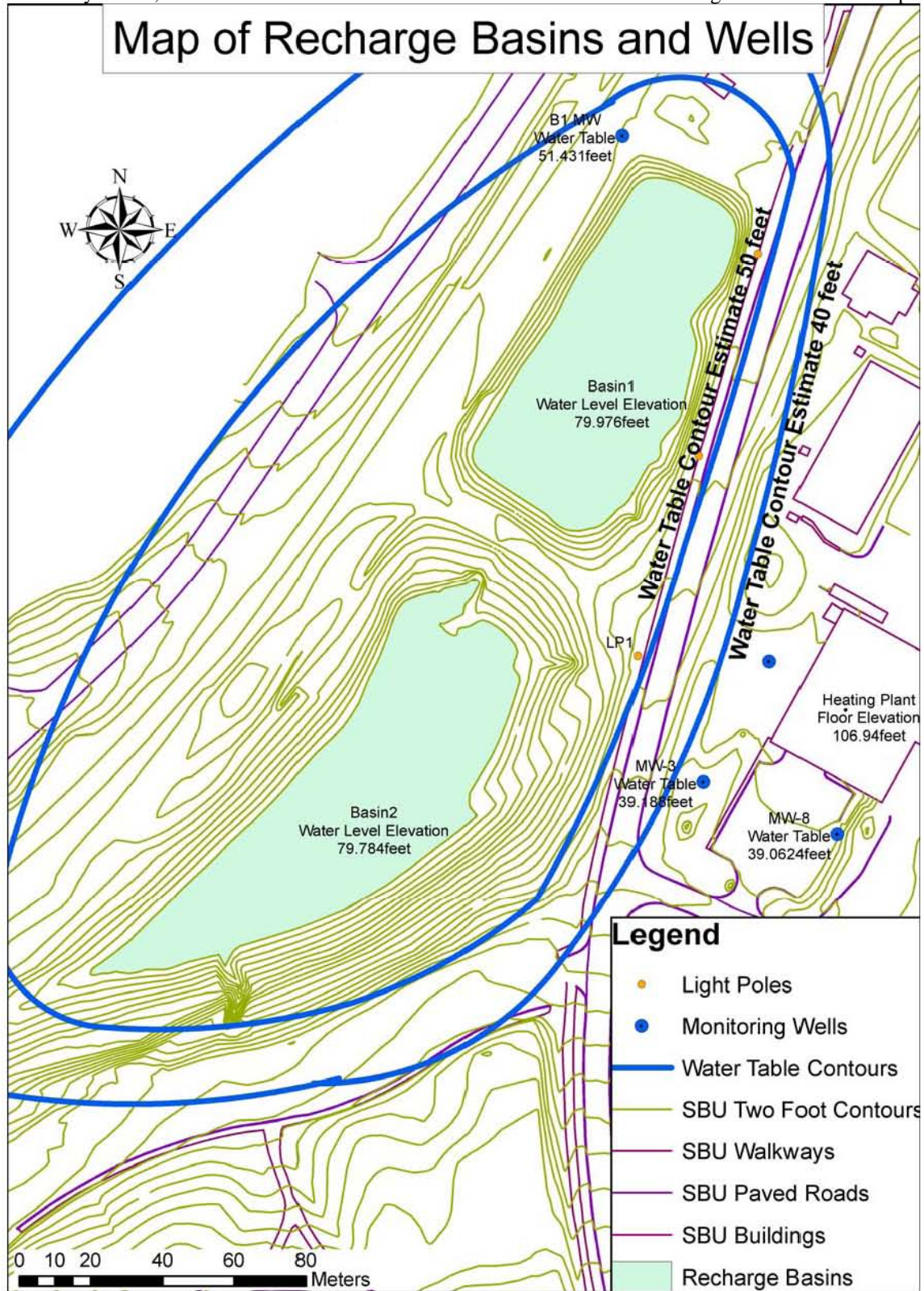


Figure 4: Contour map of Stony Brook Campus, with overlay of shapefiles based on the mapping data in table 1 and water table contours based on the well data in table 2. Page 13 of 23

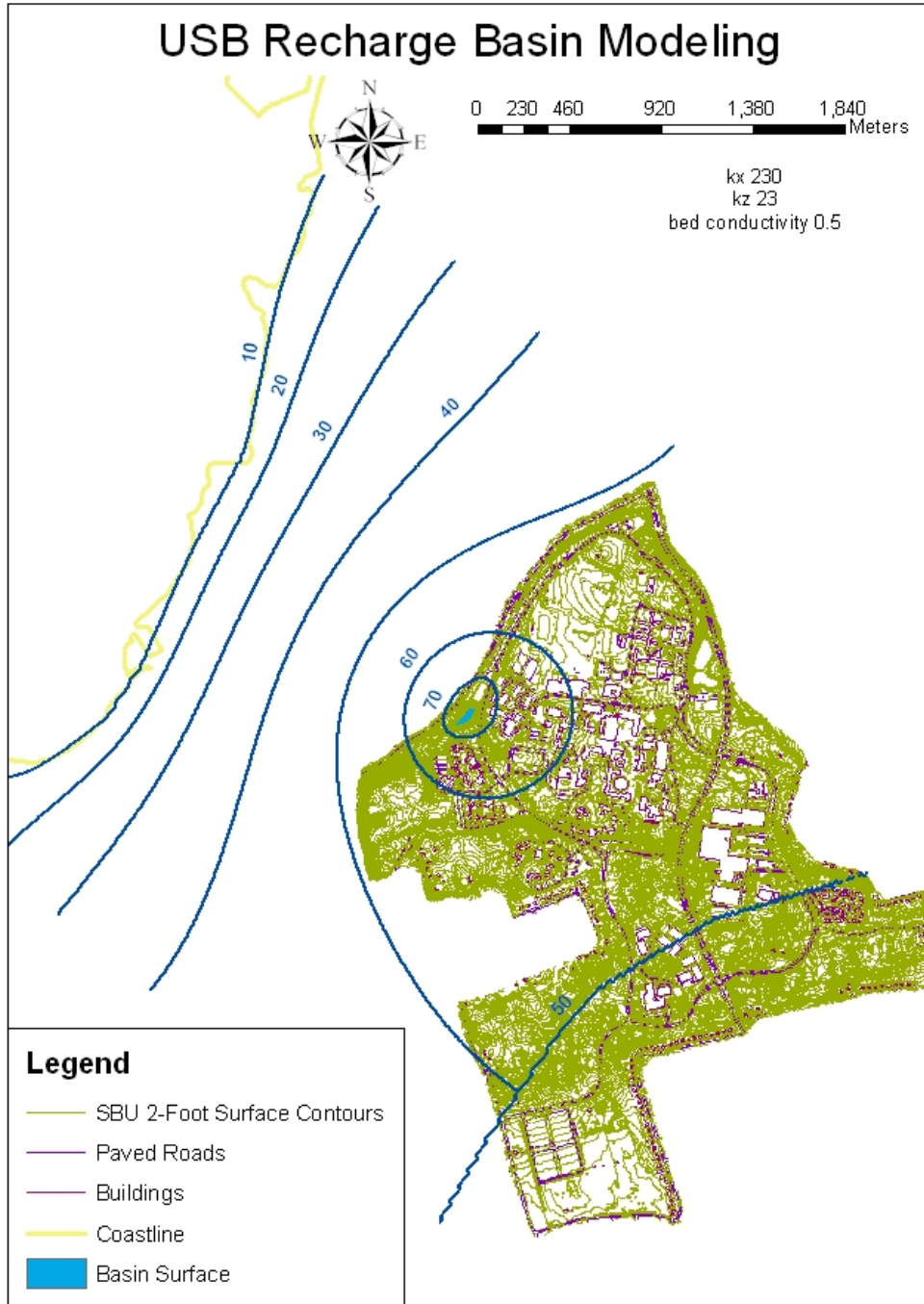


Figure 5: 10' interval water table contours, assuming standard conductivities for the Upper Glacial aquifer: horizontal conductivity of 230 feet per day, vertical conductivity of 23 feet per day, unlimited flow into the basins, and with conductivity of basin floor sediments of 0.5 feet per day.



Figure 6: 10' interval water table contours, assuming local conductivities for Upper Glacial aquifer: horizontal conductivity of 100 feet per day, vertical conductivity of 1 foot per day, unlimited flow into the basins, and with conductivity of basin floor sediments of 0.5 feet per day.



Figure 7: 10' interval water table contours, assuming local conductivities for Upper Glacial aquifer: horizontal conductivity of 100 feet per day, vertical conductivity of 0.1 feet per day, unlimited flow into the basins, and with conductivity of basin floor sediments of 0.5 feet per day.

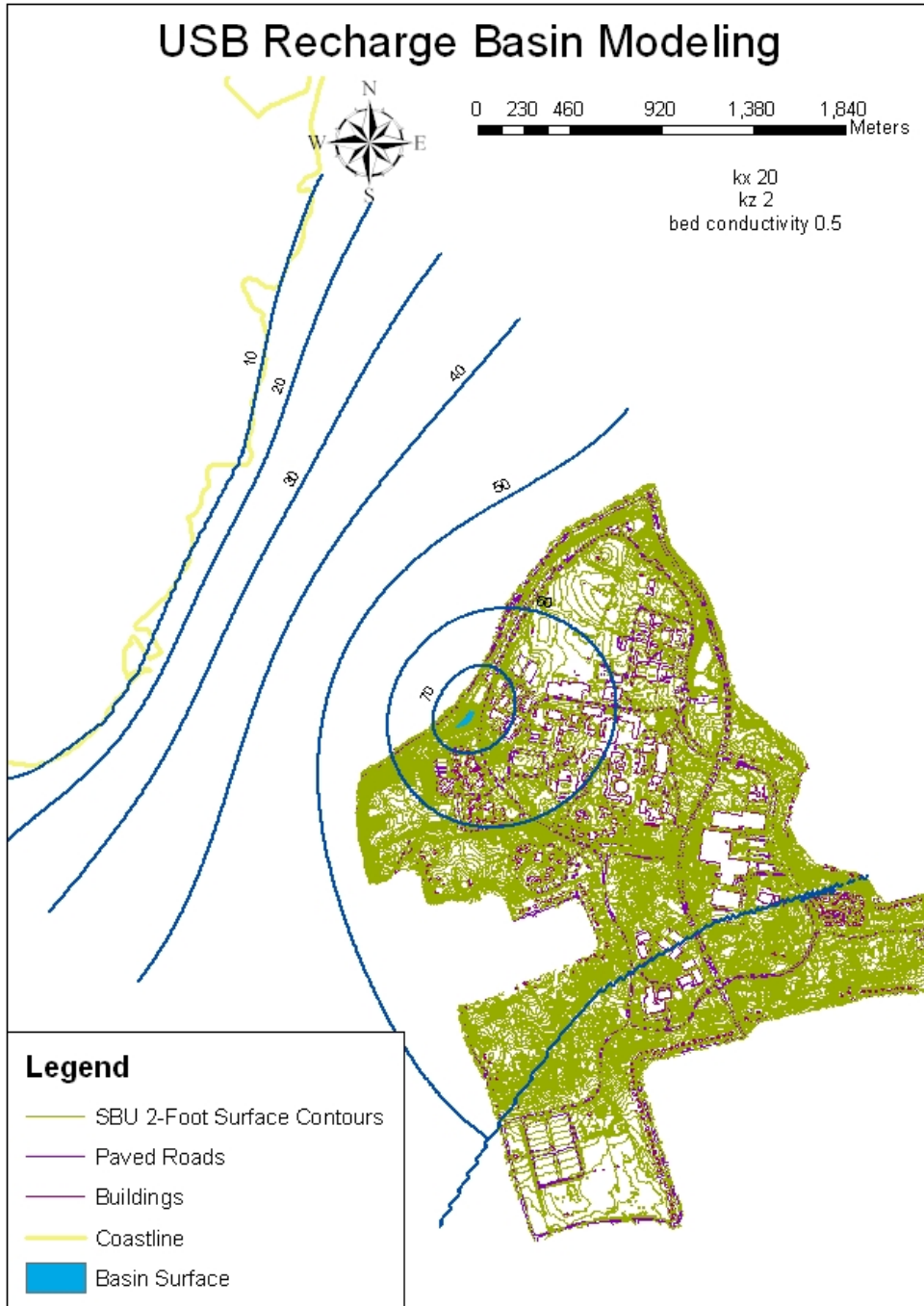


Figure 8: 10' interval water table contours, assuming local conductivities for Upper Glacial aquifer: horizontal conductivity of 20 feet per day, vertical conductivity of 2 feet per day, unlimited flow into the basins, and with conductivity of basin floor sediments of 0.5 feet per day.

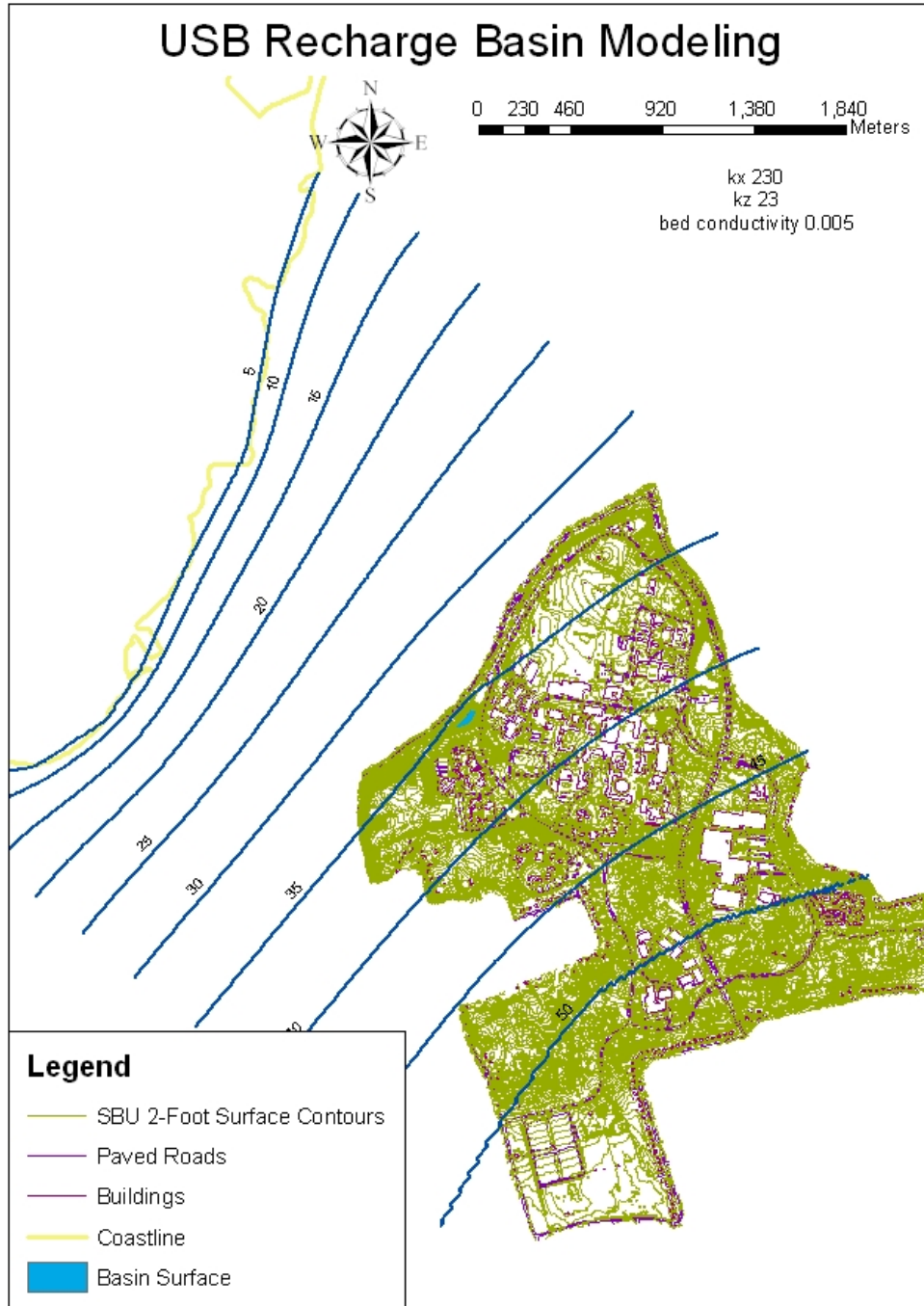


Figure 9: 5' interval water table contours, assuming standard conductivities for Upper Glacial aquifer: horizontal conductivity of 230 feet per day, vertical conductivity of 23 feet per day, unlimited flow into the basins, and with conductivity of basin floor sediments of 0.005 feet per day.

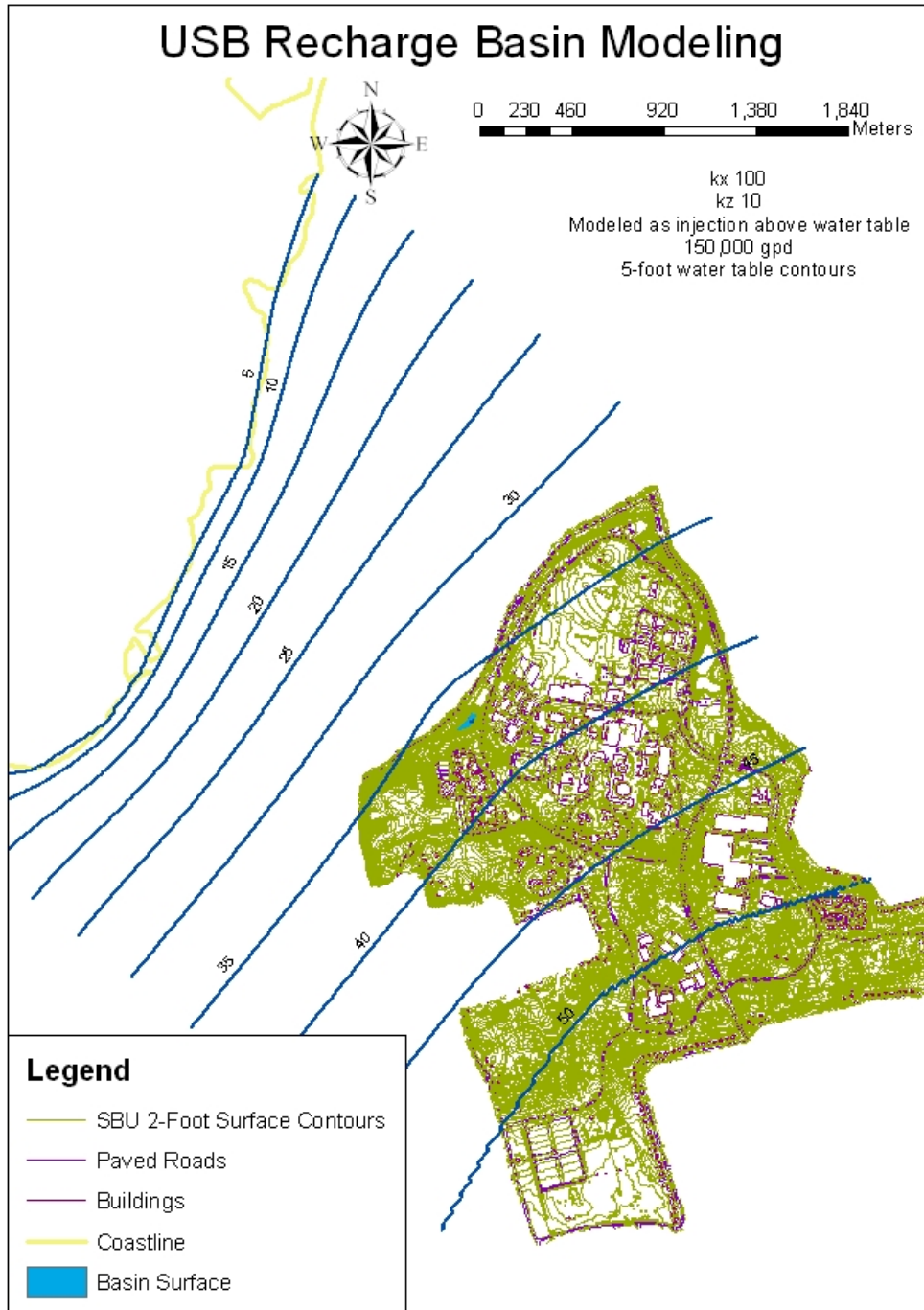


Figure 10: 5' interval water table contours, assuming acceptable conductivities for Upper Glacial aquifer: horizontal conductivity of 100 feet per day, vertical conductivity of 10 feet per day, and a flow out of the basins of 150,000 gallons per day. The center of the mound is approx. 3' higher than the regional water table.

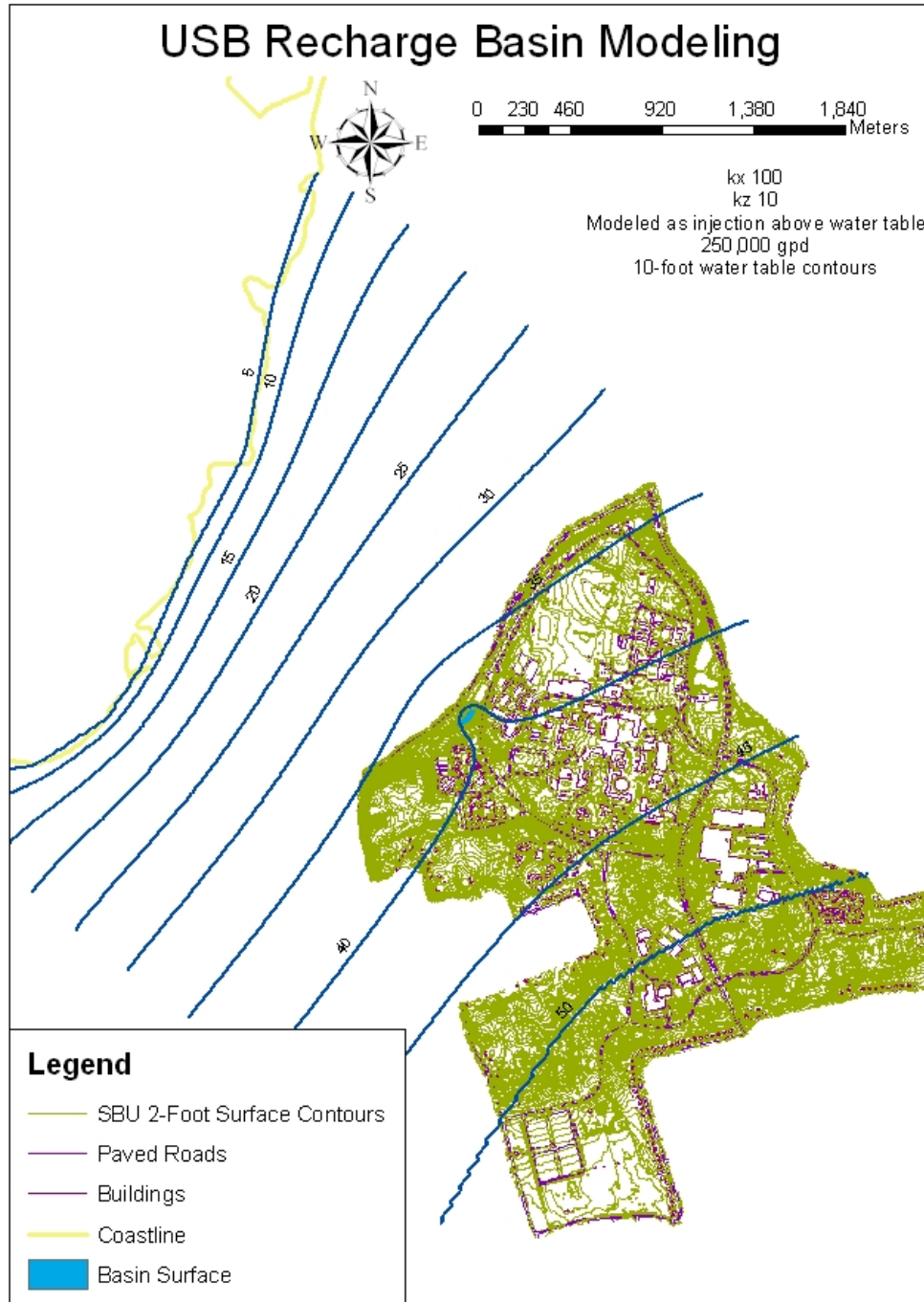


Figure 11: 5' interval water table contours, assuming acceptable conductivities for Upper Glacial aquifer: horizontal conductivity of 100 feet per day, vertical conductivity of 10 feet per day, and a flow out of the basins of 250,000 gallons per day. The center of the mound is approx. 7' higher than the regional water table.

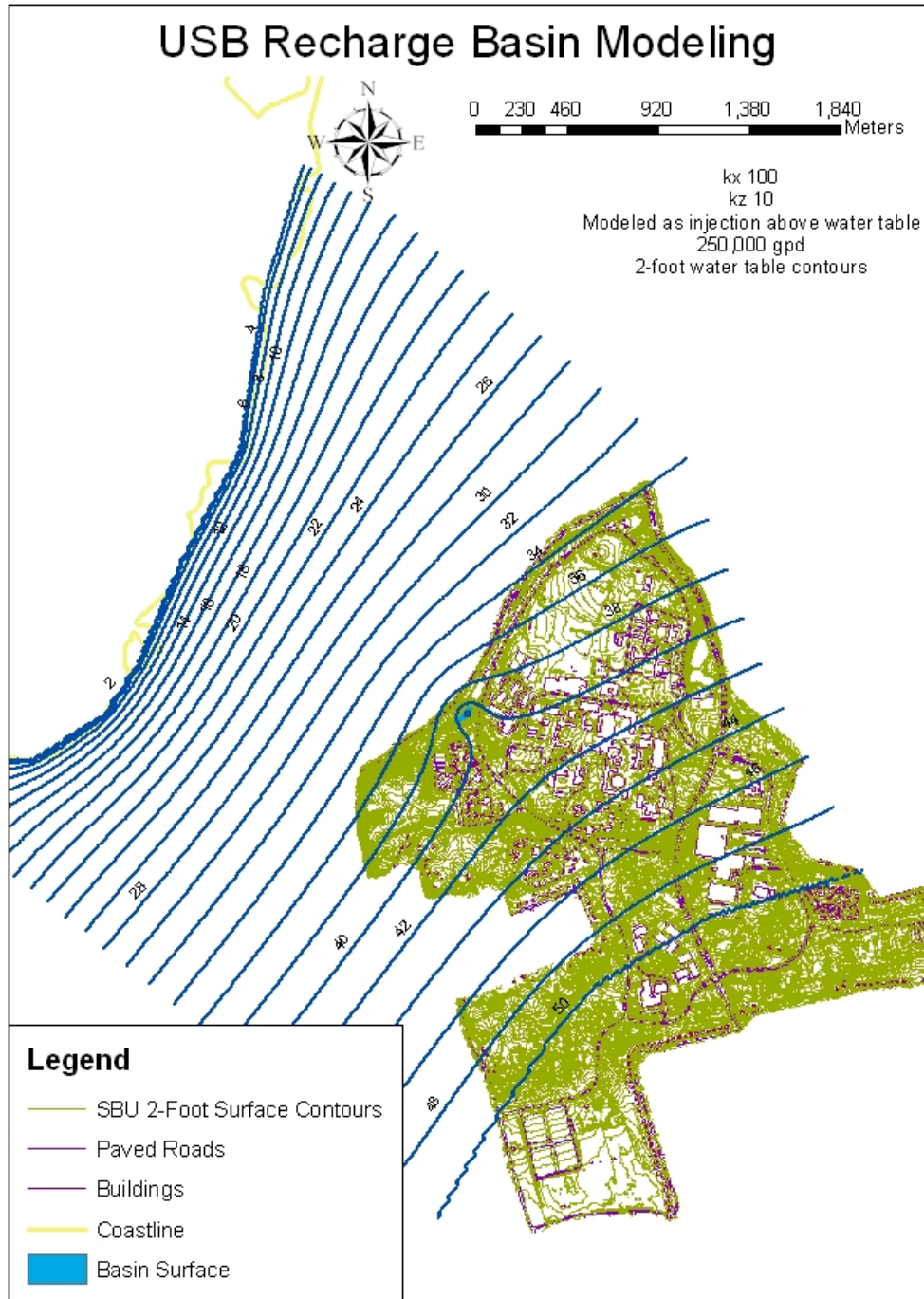


Figure 12: 2' interval water table contours, assuming acceptable conductivities for Upper Glacial aquifer: horizontal conductivity of 100 feet per day, vertical conductivity of 10 feet per day, and a flow out of the basins of 250,000 gallons per day. The center of the mound is approx. 7' higher than the regional water table.



Figure 13: 10' interval water table contours, assuming acceptable conductivities for Upper Glacial aquifer: horizontal conductivity of 100 feet per day, vertical conductivity of 10 feet per day, and a flow out of the basins of 250,000 gallons per day. The center of the mound is approx. 17' higher than the regional water table.

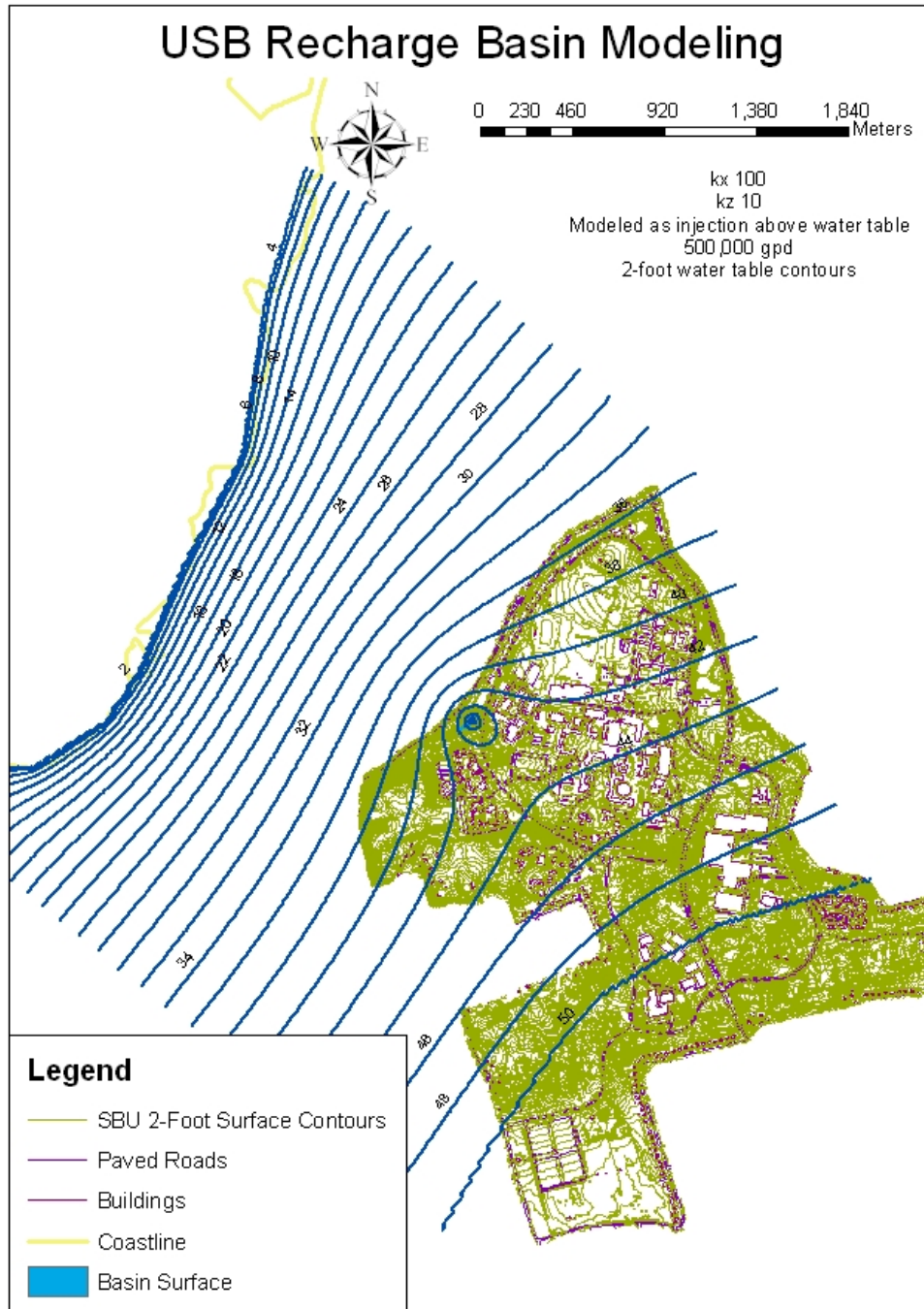


Figure 14: 2' interval water table contours, assuming acceptable conductivities for Upper Glacial aquifer: horizontal conductivity of 100 feet per day, vertical conductivity of 10 feet per day, and a flow out of the basins of 500,000 gallons per day. The center of the mound is approx. 17' higher than the regional water table.