ENVIRONMENTAL TECHNOLOGY AND PRESERVATION: THE PINE BUSH, LANDFILLS, AND GROUNDWATER INTEGRITY

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INTRODUCTION

The active Albany Interim Landfill and the closed Albany City Landfill are located in the City of Albany, New York, in a region of stabilized dunes known as the Pine Bush (Figure 1). Surface deposits in the Pine Bush consist of highly permeable sands originally deposited by the paleo-Mohawk River as delta deposits during the high stand (maximum extent) of glacial Lake Albany. The sands constitute a large unconfined aquifer. Subsurface investigations have shown that the nearby unlined Albany City Landfill, which was opened in 1969, has contributed both organic and inorganic contaminants to the Pine Bush aquifer. The lined Albany Interim Landfill was designed in a manner intended to protect groundwater integrity in the surrounding Pine Bush region. Groundwater contamination on the scale of the area of the Albany City Landfill can be difficult to remediate. Remediation of smaller commercial sites with contaminated groundwater is a somewhat more tractable problem. This field trip provides an opportunity to visit the Pine Bush, the Albany Interim Landfill, the Albany City Landfill, and a small commercial site (Stewart's Shop #182) that is currently undergoing groundwater remediation.

THE PINE BUSH

The Pine Bush is a region of about 40 square miles of sand dunes and bogs covered by pitch pine and scrub oak forests located between Albany and Schenectady, New York. The Pine Bush occupies part of the townships of Colonie, Guilderland, and Rotterdam, and the western arm of the City of Albany. It is bounded by the Schenectady City Line and New York State Route 5 on the north, the Normans Kill on the west and south, and New York State Route 85, Osborn Road, and Albany-Shaker Road on the east (Figure 1).

The Pine Bush is a small segment of a dune field that extends from South Glens Falls to Delmar. The Mohawk River and the inlets and outlets to Saratoga and Round Lakes dissect this field. Dunes of windblown sand range from hundreds to thousands of feet long. The dunes lie on a nearly level surface known as the Lake Albany Plain which represents the bed of a glacial lake that existed 20,000 years ago (Dineen, 1975).

Bedrock Geology of the Pine Bush

Bedrock underlying the Pine Bush is dominated by Middle Ordovician shale and sandstone. The bedrock has been mapped as two units: the Schenectady Formation, which is mostly sandstone with some shale, and the Normanskill Formation, which is shale with some sandstone and chert (Fisher et al., 1977). The Schenectady Formation is jointed, locally faulted, and relatively flat-lying (see Kidd et al., this volume). The Normanskill Formation is highly faulted and folded. In general, the Schenectady Formation underlies hills and ridges and the Normanskill Formation underlies the preglacial valleys (Dineen, 1975).

In Garver, J.I., and Smith, J.A. (editors), Field Trips for the 67th annual meeting of the New York State Geological Association, Union College, Schenectady NY, 1995, p.

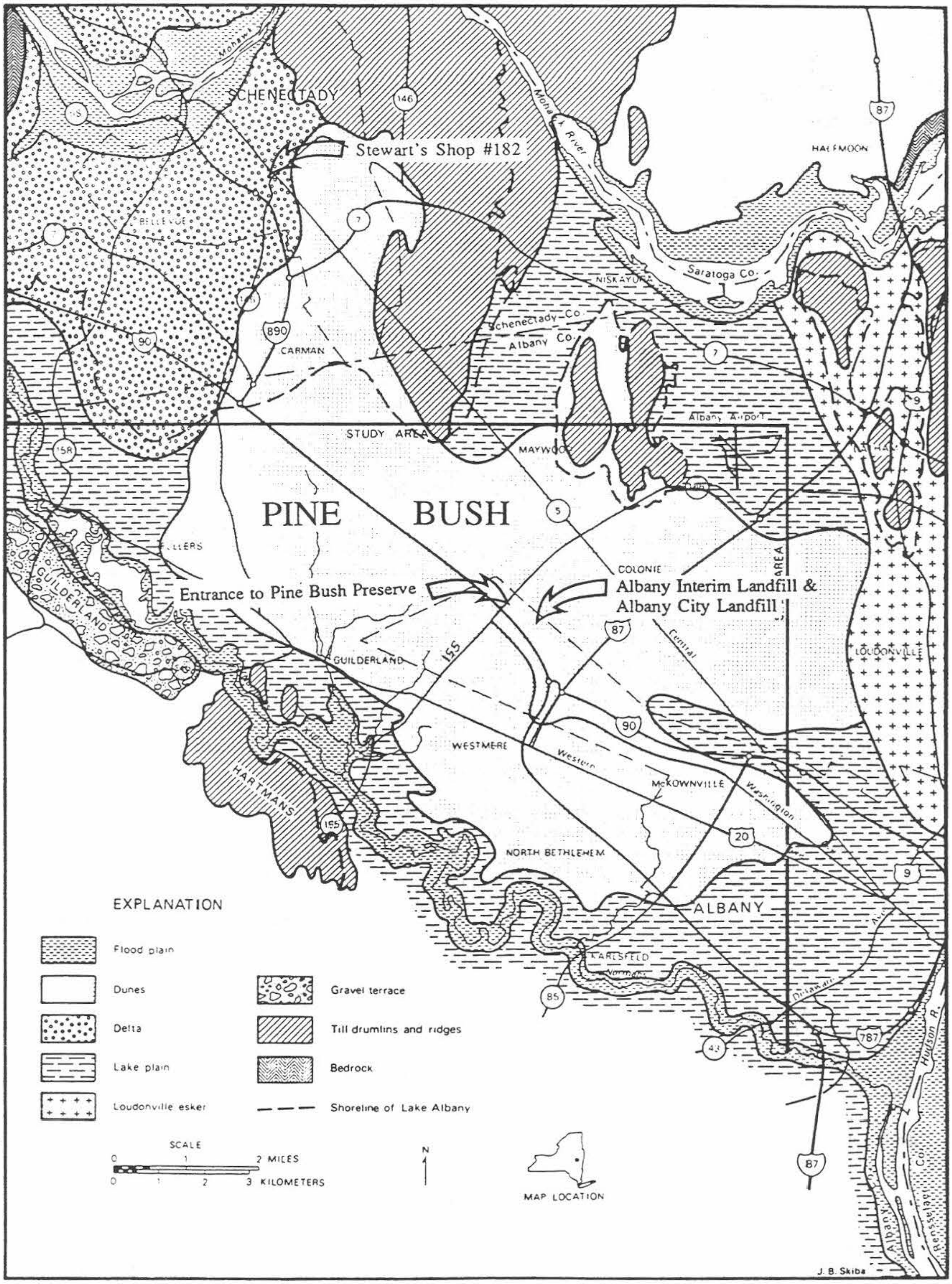

Figure 1. Generalized glacial geology map of the area between Albany and Schenectady. The Pine Bush is the area of dunes in the center of the map (modified from Dineen, 1975).

Prior to the last glaciation, major streams in the Capital District preferentially followed valleys in the less resistant shale; these streams included the preglacial Mohawk, Alplaus, and Colonie Rivers. The Mohawk and Alplaus Rivers met beneath present-day Guilderland; the Mohawk and Colonie Rivers met beneath the present site of the village of Karlsfeld and flowed south, west of the current Hudson River valley. The preglacial Mohawk and Colonie channels underlie the southern and eastern parts of the Pine Bush, respectively (Dineen, 1975; 1976; 1982). Because the Colonie channel has the flattest gradient of the tributaries as presently known, it may have been the major river draining the southeastern Adirondack region in Tertiary times (Isachsen, 1965). Figure 2, which is from Dineen (1976), shows the bedrock topography in the Pine Bush.

The buried bedrock surface in the Pine Bush has over 300 feet of relief. The bedrock surface with the highest gradient is toward the preglacial Mohawk Channel, which lies along the southern edge of the Pine Bush. The gradient eastward, towards the preglacial Colonie Channel, is gentler. A bedrock terrace with elevations of 275-300 ft above sea level (ASL) underlies the Pine Bush. The bedrock terrace is cut by tributaries to the Mohawk Channel at its western side and along its southeastern portion. The bedrock valleys acted as sedimentary basins that received thick accumulations of glacial sediment; the glacial sediments are thin on the bedrock terrace (Dineen, 1982).

The complex subsurface relationships of buried channels and overlying glacial deposits determine the local potential for groundwater under the Pine Bush (Dineen, 1976).

Glacial History of the Pine Bush

At its maximum extent about 20,000 years ago, the last major ice sheet covered all of eastern New York and New England north of Long Island and Staten Island. Ice thickness in the Capital District at this time may have exceeded 3,000 feet, while sea level stood about 350 feet below present sea level, exposing much of the continental shelf. Downwarping of the crust under the weight of glacial ice has been estimated at 1,000 ft in southern Québec and about 0 ft in New York City at the ice margin. Crustal uplift occurred during the glacial retreat as the weight of the ice decreased. In the Hudson-Champlain Lowland, a sequence of glacial lakes and marine invasion has been related to episodes of crustal uplift (LaFleur, 1976).

During 5,000 years of recession of the ice front, the terminus of the glacier withdrew from Long Island to Albany. Meltwater filled the Hudson Valley and the surrounding area with water to a level of 330 feet above present sea level, forming glacial Lake Albany, which extended from Glens Falls to Newburgh at this time. The entire Pine Bush region was submerged. During Lake Albany time, the glacial Mohawk River flowed through the Mohawk Valley and entered Lake Albany at Schenectady, depositing the extensive Schenectady delta (see Wall and LaFleur, this volume). There, delta deposits consisted mainly of cobbles and gravel. Glacial Mohawk River currents carried sand, silt, and clay further eastward into Lake Albany (Stoller, J. H., 1911; Dineen, 1975; Wall and LaFleur, this volume).

The draining of Lake Albany is generally attributed to post-glacial crustal uplift which favored a more active southward drainage by increasing regional gradient. The successor to Lake Albany was Lake Quaker Springs. Discharges through the Mohawk Valley of normal river flow alternating with catastrophic lake outbursts from central New York produced a series of channels beginning with the narrow valley now occupied by Ballston Lake and the Mourning Kill. Lowering of Lake Albany by 30 feet (to 300 feet above present sea level) to the Quaker Springs level exposed the Schenectady delta as a land mass, and required Mohawk drainage to flow northward around its western edge and through the Ballston Channel. An embayment of Lake Quaker Springs extended through the Pine Bush area where fine sands continued to accumulate in shallower water. Some winnowing of exposed Schenectady delta sands also occurred during this episode (LaFleur, 1976; Wall and LaFleur, this volume).

As the water level receded in Lake Quaker Springs, a temporary stillstand occurred near 190 feet. All of the Pine Bush stood high and dry during this episode. Wind deflation and incipient dune formation altered the original lake floor configuration. Catastrophic discharges through the Mohawk from a draining Lake Iroquois in central New York occupied the Ballston-Round Lake channel and may have initiated the modern course of the Mohawk from Alplaus to Cohoes (LaFleur, 1976; Wall and LaFleur, this volume).

With the recession of Lake Albany and the smaller lakes that succeeded it,.the drained lake bed was exposed to the action of wind and streams which eroded channels into the exposed lake bottom. A cool, dry climate prevailed as the water and ice retreated farther north. The climate and the lack of subsoil on the lake floor inhibited development of vegetation. Wind action caused the sand to be eroded into finer particles and accumulate into dunes that currently characterize the Pine Bush. These dunes covered the old lakebed, and depressed areas around dunes developed into bogs (Dineen, 1975; Donahue, 1976).

Glacial Deposits in the Pine Bush

Seven units have been defined within the glacial deposits in the Pine Bush. Most of the glacial deposits are wedge-shaped masses that are draped against the bedrock terrace (Dineen, 1982). Figure 1 is a map of the glacial geology of the Pine Bush from Dineen (1975). A tabulation of glacial deposits in the Pine Bush is included as Figure 3 (Dineen, 1982). A generalized stratigraphic column for the glacial deposits is as follows (youngest deposits at the top, oldest at the bottom):

Dune sand
Lake Albany Sand
300-foot clay
Lake Albany silt and sand
Lake Albany Silt and Clay
Ice-contact Sand and Gravel
Till

Descriptions and interpretations are combined in the following introduction to each of the seven units, which are arranged in order from oldest to youngest to clarify the depositional sequence. The following is summarized from Dineen (1975 and 1982) and Donahue (1976).

1. Till

Till is a mixture of boulders, gravel, sand, silt, and clay. Generally, till overlies bedrock and underlies other units. Thickness ranges from 5 to 150 feet. Till is thickest in preglacial valleys of the Pine Bush (e.g., the valley of the preglacial Mohawk River) and thin-to-absent elsewhere. Till is thicker towards the northeast (in the vicinity of a drumlin field located just north of intersection of Rts. 5 and 155). Till was deposited directly beneath and on the glacier.

2. Ice-contact Sand and Gravel

Stratified sand and gravel deposited by the meltwater in contact with the glacier underlies much of the Pine Bush. Locally, this unit lies above the till and below the Lake Albany silt and clay. Exposures are few. Ice-contact sand and gravel partially fill the small tributary valleys that are cut into the bedrock terrace. This is a relatively thin unit that grades vertically and laterally into the basal Lake Albany silt and clay. Ice-contact sand and gravel (and the lower part of the Lake Albany silt and clay) were deposited in 150-foot-deep water of glacial Lake Albany between 0.5 and 2 miles of the retreating glacial terminus, at a time when the water elevation of Lake Albany was at 340 feet.

3. Lake Albany Silt and Clay

Very-fine-grained glaciolacustrine silt and clay grades downward into ice-contact sand and gravel and upward and laterally to Lake Albany silty sand and Lake Albany sand. This unit rarely extends above 260 ft ASL; it pinches out against the bedrock terrace, causing a "drape effect" on underlying bedrock. Local wedges and lenses of silty sand and sand are present. The lower part of the Lake Albany silt and clay (and the ice-contact sand and gravel) were deposited in 150-foot-deep water of glacial Lake Albany between 0.5 and 2 miles of the retreating glacial terminus, at a time when the water elevation of Lake Albany was at 340 feet.

4. Lake Albany Silty Sand

Lake Albany silty sand contains 10 to 50 percent silt. The unit grades upward and eastward into lake sand and thickens toward the south and southeast. The silty sand pinches out toward the east and is dominant above an elevation of 200 ft ASL. Several elongate valleys or depressions are present in the upper surface of the unit. Lake Albany silty sand was deposited offshore of a sand bar system in water that was 50 feet deep during successively lower water levels of Lake Albany (Dineen, 1982).

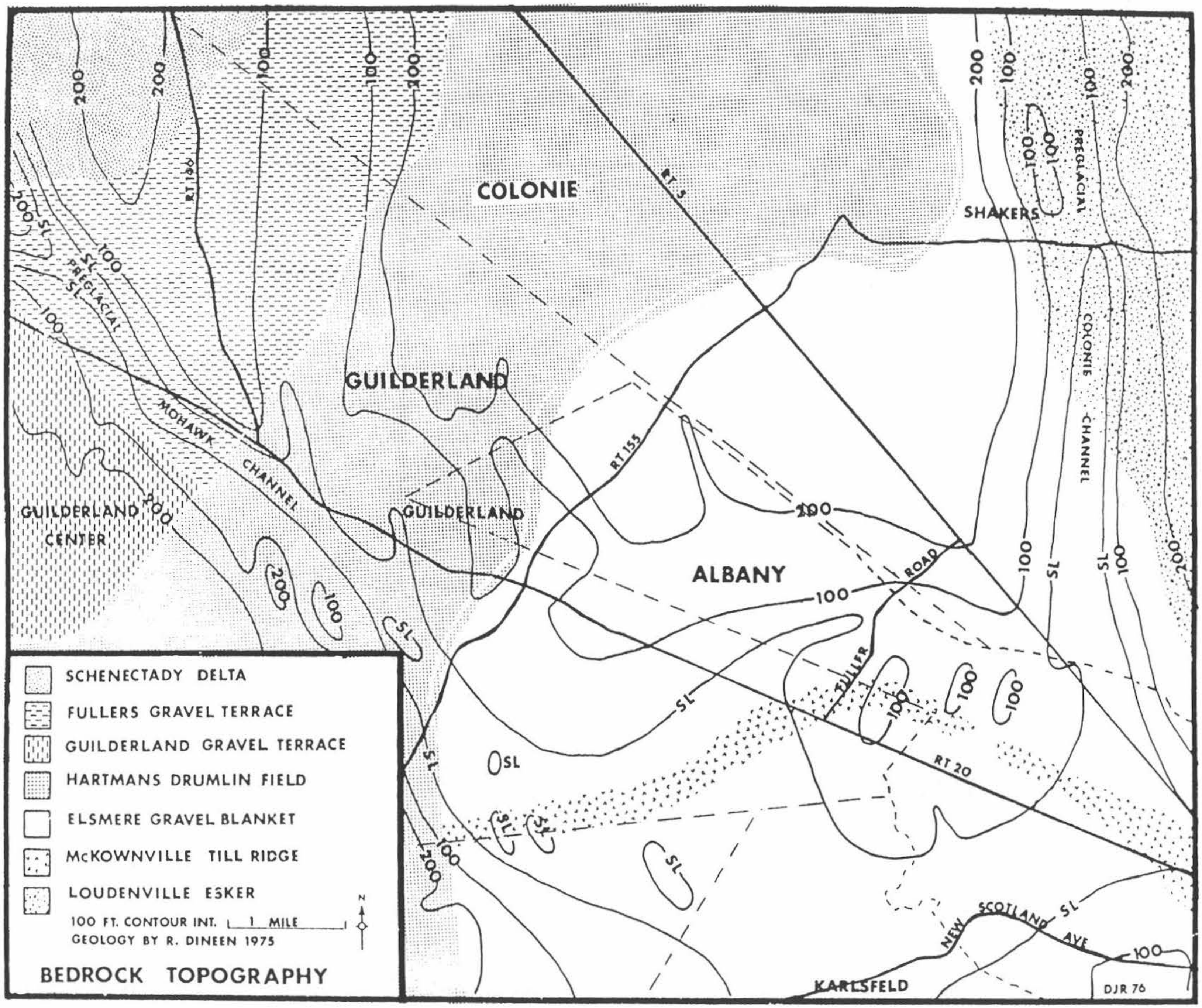

Figure 2. Bedrock topography of the Pine Bush. Note the locations of the Mohawk Channel at left and the Colonie Channel at right (from Dineen, 1976; used by permission).

AGE		UNIT	MAP SYMBOL	DESCRIPTION	SEDIMENTARY STRUCTURE	THICKNESS: METERS	NOTES
RECENT		ARTIFICIAL FILL	AF	Heterogeneous, with concrete fragments, boulders, cobbles, sand, silt, clay, and organic matter. Color is variable.	Massive to thickly bedded.	0.3 to 15, 1 average	Permeable to impermeable, loose to very compact, can contain leachable materials and chemicals.
		Unconformity					
HOLOCENE		DUNE SAND	QDS	Slightly silty, light yellow brown, fine to very fine sand, grains are subangular to subrounded.	Cross-bedded, >15° dip	1.5 to 30, 6 average	Highly permeable, loose, weathered to 6m, readily eroded by wind and water.
		Disconformity					
PLEISTOCENE	Woodfordian	LAKE ALBANY SAND	QLAS	Slightly silty, light yellow brown to light gray, subangular, medium to very fine sand.	Thin bedding, some ripple cross-laminae.	0.3 to 15, 1 average	Highly to moderately permeable (vertical permeability impeded where silt layers are present), loose to compact, unstable in steep slopes, easily eroded by water.
		300 FT. CLAY	QLAV	Silty, varved, light gray to light brown clay, siltier at top and bottom.	Varves and 0.3m beds	0.3 to 5, 1 average	Impermeable, plastic, unstable in slopes, spring lines form at upper contact with sand, is an aquiclude, impedes vertical water movement.
		Disconformity to gradational contact					
		LAKE ALBANY SILT & SAND	QLAM	Silty to very silty, light yellow brown to light gray sand.	Horizontal to ripple laminated.	0.3 to 15, 8 average	Moderately permeable, loose to compact, silt unstable in steep slopes, impedes water movement and "clouds" water, erodes easily by water.
		Disconformity to gradational contact					
		LAKE ALBANY SILT & CLAY	QLAC	Varved, brown to gray silty clay and clayey silt, trace sandy beds.	Varves with ripple cross-laminated silt beds.	8 to 50 15average	Impermeable, plastic, some water movement along silt beds, flows or slumps in slopes >12°, flows under load, is aquiclude.
		Unconformity to gradational contact					
		ICE-CONTACT SAND & GRAVEL	QI	Stratified brown to dark gray gravel to silty sand and gravel, tends to fine upward into silt.	Graded bedding is frequent, ripple-laminated (sand & silt).	0.3 to 3	Permeable, loose to compact, water is frequently under artesian pressure.
		Unconformity to disconformity					
		TILL	QT	Dark gray to dark brown, bouldery, gravelly, sandy clay with few lenses of gravel.	Massive	1.5 to 15, 5 average	Impermeable, compact, sometimes permeable at base.
		Unconformity					
ORDOVICIAN		BEDROCK		Black shale and dark gray graywacke	Well bedded		Impermeable, and compact except where fractured.

NEW YORK STATE GEOLOGICAL SURVEY Geology, R. Dineen Graphics, J. Skiba 12/80

Figure 3. Summary of glacial deposits in the Pine Bush (from Dineen, 1982).

5. Lake Albany Sand

Lake Albany sand consists of fine- to medium-grained sand with thin laminae of silt. Lake Albany sand is overlain by dune sand. Differentiation of lake and dune sand is based on vertical change from horizontal and ripple-laminated lake sand to dune sand with thick, high-angle (>30°) foreset beds. Lake Albany sand thickens towards the east. Thick wedges of lake sand were deposited offshore along a sand bar system, creating a lagoon where the 300-foot varved clay (below) was deposited. Silty sand (above) was deposited offshore of the sand bar system.

6. Lake Albany 300-foot Clay

The 3-to-6-foot-thick 300-foot clay layer is a varved clay deposit located within the upper section of the lake sand. The 300-foot clay has a distinct upper contact, which slopes downward toward the south and east. Several 200-to-500-foot gaps are present in the layer, coinciding with the depressions or valleys in the surface of the underlying silty sand. The gaps allow recharge to the lower units. The 300-foot varved clay was deposited in a lagoon protected by thick wedges of lake sand.

7. Dune Sand

Cross-bedded dune sand is the surficial deposit in about 80 percent of the Pine Bush. The steepest internal layers of the dunes (i.e., slipfaces) dip to the northeast to southeast, suggesting that the dune-forming winds were from the southwest or northwest. The lower contact of the dune sand is a thin, shale-granule lag-concentrate that overlies the lake sand. Particles of quartz dominate the dune sand. The dunes, which are between 5 and 50 feet high, form a discontinuous, irregular mantle over the lake sand. With a decrease of the level of glacial Lake Albany to 270 feet, wind and streams began to erode the exposed shore and sand plain sediments and the construction of large sand dunes began. Streams eroded valleys through the 300-foot varved clay, carrying sand to the near-shore zone of the lake, while additional varved clay was deposited in deeper water offshore. The exposed sand plain increased in width as the lake level continued to fall to 250 feet. Wave action formed a beach along the southern shore and large streams cut into the exposed lake floor. Dune formation continued until approximately 5,000 years ago. The cessation of dune formation has been attributed to dune stabilization by vegetation.

The Pine Bush Aquifer

The Pine Bush aquifer comprises the “silty sand”, “lake sand”, and “dune sand” units. These sands are widespread, thick, and permeable. The Pine Bush aquifer consists of very-fine to medium sand and ranges in thickness from 5 to 150 feet. Depth to the water table is 10 to 15 feet in most of the Pine Bush and rarely exceeds 20 feet. Hydraulic conductivity ranges from 65 to 70 feet per day. Finer grained silt and clay form the base of the aquifer, and discontinuous lenses of silt and clay are prevalent (Snavely, 1983).

Recharge of the aquifer occurs near a groundwater divide that is located near the intersection of Rt. 155 and Washington Avenue Extension. Groundwater drains westward into the Hunger Kill, southward into the Kaikout Kill, and eastward into Patroon Creek. Silt and clay and the 300-ft varved clay are aquicludes that underlie the aquifer; they impede the vertical movement of water. Groundwater generally migrates downward along the top of the silt and clay until it enters a stream valley. The presence of the 300-ft clay causes perched water tables (Dineen, 1982), which increase the complexity of the hydrology of the Pine Bush aquifer.

Mean annual recharge in the Pine Bush, based on calculation of mean annual base flow, is estimated to be 12.7 inches. Precipitation is the only source of recharge, and approximately 38 percent of the annual precipitation recharges the Pine Bush aquifer, while the rest is lost to direct runoff to streams and evapotranspiration (Snavely, 1983).

Computer modeling has been used to simulate drawdown by a pumping well that taps the center of the surficial aquifer. Results of the simulation indicated that a yield of 150 to 600 gallons per minute (216,000-864,000 gallons per day) could be obtained with maximum drawdown of 80 percent of the saturated thickness of the aquifer at hydraulic conductivity of 25, 50, or 100 feet per day (Snavely, 1983).

Groundwater of the Pine Bush aquifer was sampled for phosphorus, nitrogen, and chloride by the U.S. Geological Survey in April 1979. These constituents were chosen because they are the most common chemical contaminants from septic-tank effluent and sewer-pipe leakage. Chloride was also of concern as an

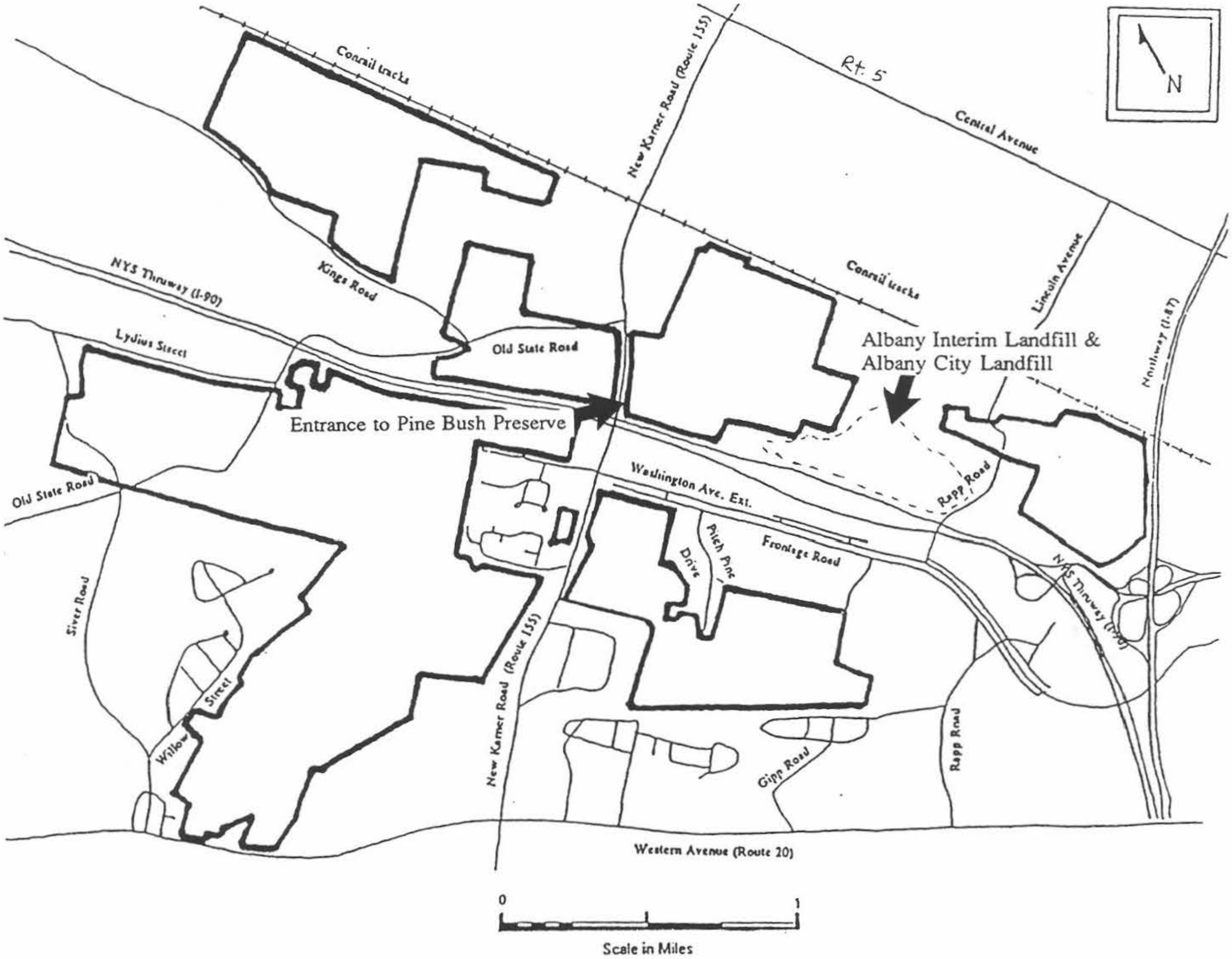

Figure 4. Boundaries of the Albany Pine Bush Preserve and approximate locations of the Albany Interim Landfill and the Albany City Landfill (modified from Albany Pine Bush Preserve Commission, 1995).

indicator of contamination from the nearby Albany City Landfill and from road salting on major roads and highways. The highest phosphorus concentrations were only slightly above the laboratory detection limit. The few high nitrogen concentrations were in shallow private wells near septic tanks. Chloride concentrations, however, ranged over two orders of magnitude (1.1 milligrams per liter, or mg/l, to 340 mg/l). Milligrams per liter are approximately equivalent to parts per million. Three of the thirty wells sampled had chloride concentrations that exceeded the 250-mg/l maximum level established by the State Sanitary Code in 1979. The highest chloride concentrations were generally in the central part of the Pine Bush near major highways. Because of this correlation, road salting was suspected as the source of the higher chloride concentrations. Wells that were located in the area farthest from the nearest major road and upgradient from the highway had the lowest chloride concentrations. Water from the deeper wells had higher chloride concentrations than water from the shallow wells, which was interpreted to suggest a chloride stratification in groundwater (Snavely, 1983).

The sand deposits that are the primary source of shallow subsurface water in the Pine Bush have high permeability and contain relatively large quantities of water. Groundwater in the sand is readily contaminated by seepage from septic tanks and landfills, oil or chemical spills at construction and industrial sites, and from salt stockpiles and winter de-icing operations. Contamination may be especially severe where the water table is close to the surface (Dineen, 1975). Such a setting seems an unlikely location for a major municipal landfill.

The Albany Pine Bush Preserve

Approximately 2,000 acres of Pine Bush have been permanently protected through the cooperative efforts of The Nature Conservancy, the State of New York, and various local municipalities. Figure 4 shows the current boundaries of the Albany Pine Bush Preserve. In 1988, the New York State Legislature created the Albany Pine Bush Preserve Commission, which coordinates the management of protected lands within the Pine Bush (Albany Pine Bush Preserve Commission, 1995).

ALBANY CITY LANDFILL

The Albany City Landfill (the landfill) covers approximately 80 acres of the Pine Bush. The landfill is located on the north side of the New York State Thruway between Rapp Road, the Conrail railroad tracks, and the Pine Bush Preserve. The landfill has been capped and permanently closed since 1994.

The landfill is of a relatively simple design: it is unlined, it has no leachate collection system (Malcolm Pirnie, 1988), and it is believed to be a surface waste pile rather than an excavated pit refilled with waste (Engineering-Science, 1992). During its years of operation, the landfill was filled using conventional sanitary landfilling techniques of compaction and daily covering of waste. Methane and leachate were not extracted during operation. Methane extraction wells and automatic burners were installed in 1991 after methane migration toward the south (under the Thruway) was discovered.

The landfill began operations in August 1969. It was operated by a private company under contract to the City of Albany until 1974, when the Albany Department of Public Works assumed operational responsibility. At the time of the transfer of responsibility, weight scales were installed and the City began to keep records of the incoming waste. Until that time, the waste had been largely unrecorded and uninspected. It is suspected that during the 1969-74 period and potentially until the 1980s, numerous area industries had disposed of various amounts of industrial and hazardous wastes at the landfill (Malcolm Pirnie, 1988; Engineering-Science, 1992).

Beginning in 1983, a portion of the waste brought to the landfill was used as fuel for the ANSWERS Refuse-Derived Fuel (RDF) plant located on Sheridan Avenue in Albany. Fly ash from the incinerator at the ANSWERS RDF plant was brought to the landfill for disposal (Malcolm Pirnie, 1988). Between 1983 and 1987, approximately 203,265 tons of fly ash were disposed of at the landfill. In addition, approximately 343,143 tons of municipal and other waste were deposited at the landfill during the same period (Engineering-Science, 1992). The municipal and other wastes brought to the landfill for disposal included bypassed solid waste (waste not used as RDF), excess RDF, petroleum-contaminated soil,

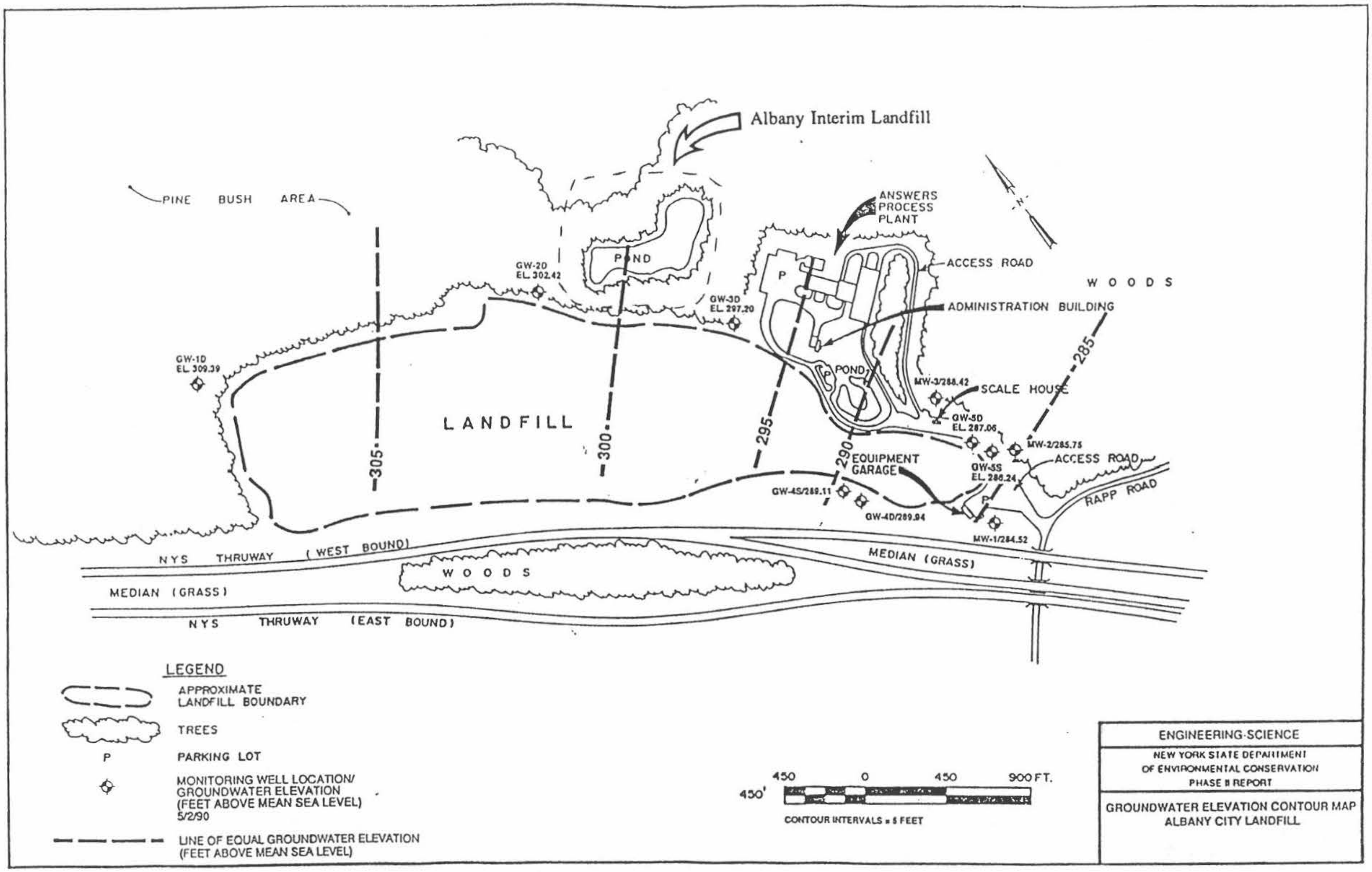

Figure 5. Albany City Landfill (circa 1990), monitoring well locations, groundwater elevations in wells (5/2/90), and groundwater elevation contour map (adapted from Engineering-Science, 1992). The approximate location of the Albany Interim Landfill is indicated by the dotted line.

picked material (unshreddable material removed during RDF processing), and ferrous material (Malcolm Pirnie, 1988), plus pharmaceutical wastes, iodine/soil wastes, and asbestos (Engineering-Science, 1992). The landfill began accepting petroleum-contaminated soil in 1987 (under the approval and recommendation of the New York State Department of Environmental Conservation, or NYSDEC), primarily for use as daily cover material; the landfill accepted approximately 14,000 tons of petroleum-contaminated soil in 1987 (Malcolm Pirnie, 1988).

Closure of the landfill began in 1982 under a phased approach. In 1985, the City of Albany signed a NYSDEC Order of Consent for the final closure of the landfill. In 1986, the City of Albany proposed an expansion project of the existing landfill to facilitate and expedite the closure process (Malcolm Pirnie, 1988). The expansion was approved by NYSDEC in 1989 (Engineering-Science, 1992), which resulted in the construction of the Albany Interim Landfill during the early 1990s.

At least three rounds of groundwater samples were collected at the landfill by Bender Hygienic Laboratories between 1981 and 1988. Several downgradient samples showed elevated values for a number of solid waste regulation baseline parameters, including iron, manganese, total phenols, and chloride (Engineering-Science, 1992).

The consulting firm of Malcolm Pirnie installed fourteen monitoring wells, including five deep-shallow pairs, in the location of the proposed expansion area in 1986. At that time, a fire-suppression pond occupied part of the area north of the landfill. Groundwater levels in the wells indicated groundwater flow from west to east and northeast across the site. The flow in the shallow groundwater appeared to be affected by surface topography such that a portion of the flow was toward the northeast (Malcolm Pirnie, 1988).

The Malcolm Pirnie wells were sampled in October 1986 and April 1987. Only the groundwater samples from two of the wells located closest to the landfill (MW-9D and MW-10S) were found to contain detectable concentrations of priority organic pollutants: 5 parts per billion (ppb) toluene in groundwater from MW-9D, 19 ppb benzene and 11 ppb ethylbenzene in groundwater from MW-10S. These three compounds are commonly found in petroleum products and solvents. Current New York state groundwater standards for these three compounds are 5 ppb, 0.7 ppb, and 5 ppb respectively (New York State Department of Environmental Conservation, Division of Water, 1993). At that time (1987), there were no NYS groundwater standards for toluene and ethylbenzene, although guidance values of 50 ppb had been established; the standard for benzene was then "non-detectable" (Malcolm Pirnie, 1988). Malcolm Pirnie concluded that the chemical analyses of samples taken from six of the monitoring wells did not show high concentrations of parameters often characteristic of landfill leachate plumes, but that higher than background levels of other parameters (e.g., iron, calcium, magnesium, specific conductance, and chlorides) in samples from MW-10S, coupled with relatively lower than background levels of the same parameters in downgradient well MW-4, suggested that those two wells may have delineated "the fringe of a weak plume from the existing landfill" (Malcolm Pirnie, 1988). In well designations, the suffix "D" indicates a deep well and the suffix "S" indicates as shallow well.

The April 1991 edition of the NYSDEC publication "Inactive Hazardous Waste Disposal Sites in New York State, Volume 4" listed the Albany City Landfill as inactive hazardous waste disposal site Number 401001. The landfill was given a classification code of 2a, which is a temporary classification assigned to sites that have inadequate and/or insufficient data for inclusion in any of the other classifications. The landfill was described as being located in the Pine Bush, as having allegedly received various amounts of industrial wastes from industries in Albany and Rensselaer Counties, and as having sandy soil and an existing high groundwater table. At that time, a groundwater monitoring program had been implemented. The City was implementing a phased closure under a consent order as a municipal landfill and closure was being negotiated. A Phase II (subsurface) investigation was in progress. The field work for the Phase II was complete and a Supplemental Search for documentation of disposal of hazardous waste was in progress. The Phase II draft report had been submitted for review (NYSDEC, 1991). The landfill was eventually (by the 1993 edition) removed from the NYSDEC listing of inactive hazardous waste disposal sites.

The Phase II investigation of the Albany City Landfill was completed by Engineering-Science for NYSDEC Division of Hazardous Waste Remediation. Field work for the investigation was performed

				Water Level Data			
				Date: 4/23-25/90		Date: 5/2/90	
Well I.D.	Ground Surface Elevation (Feet*)	Top of PVC Well Pipe Elevation (Feet*)	Well Screen Interval Elevation (Feet*)	Depth To Water Level (Feet**)	Water Level Elevation (Feet*)	Depth To Water Level (Feet**)	Water Level Elevation (Feet*)
GW-1D	348.5	351.04	307.5-297.5	41.6	309.44	41.65	309.39
GW-2D	320.8	323.40	295.8-275.8	20.85	302.55	20.98	302.42
GW-3D	301.3	303.33	266.3-246.3	5.95	297.38	6.13	297.20
GW-4D	299.5	301.79	238.5-218.5	11.7	290.09	11.85	289.94
GW-4S	299.6	301.36	277.6-257.6	10.0	291.36	12.25	289.11
GW-5D	292.0	294.11	231.0-211.0	7.0	287.11	7.05	287.06
GW-5S	292.1	294.09	278.1-258.1	7.7	286.39	7.85	286.24
MW-1	291.9	295.04	Unknown	--	--	10.52	284.52
MW-2	292.2	295.88	Unknown	--	--	10.13	285.75
MW-3	297.8	299.88	Unknown	--	--	11.46	288.42

Figure 6. Monitoring well information and water level data, Albany City Landfill (from Engineering-Science, 1992).

* Feet above Mean Sea Level

** Water level depth from top of PVC well pipe in feet

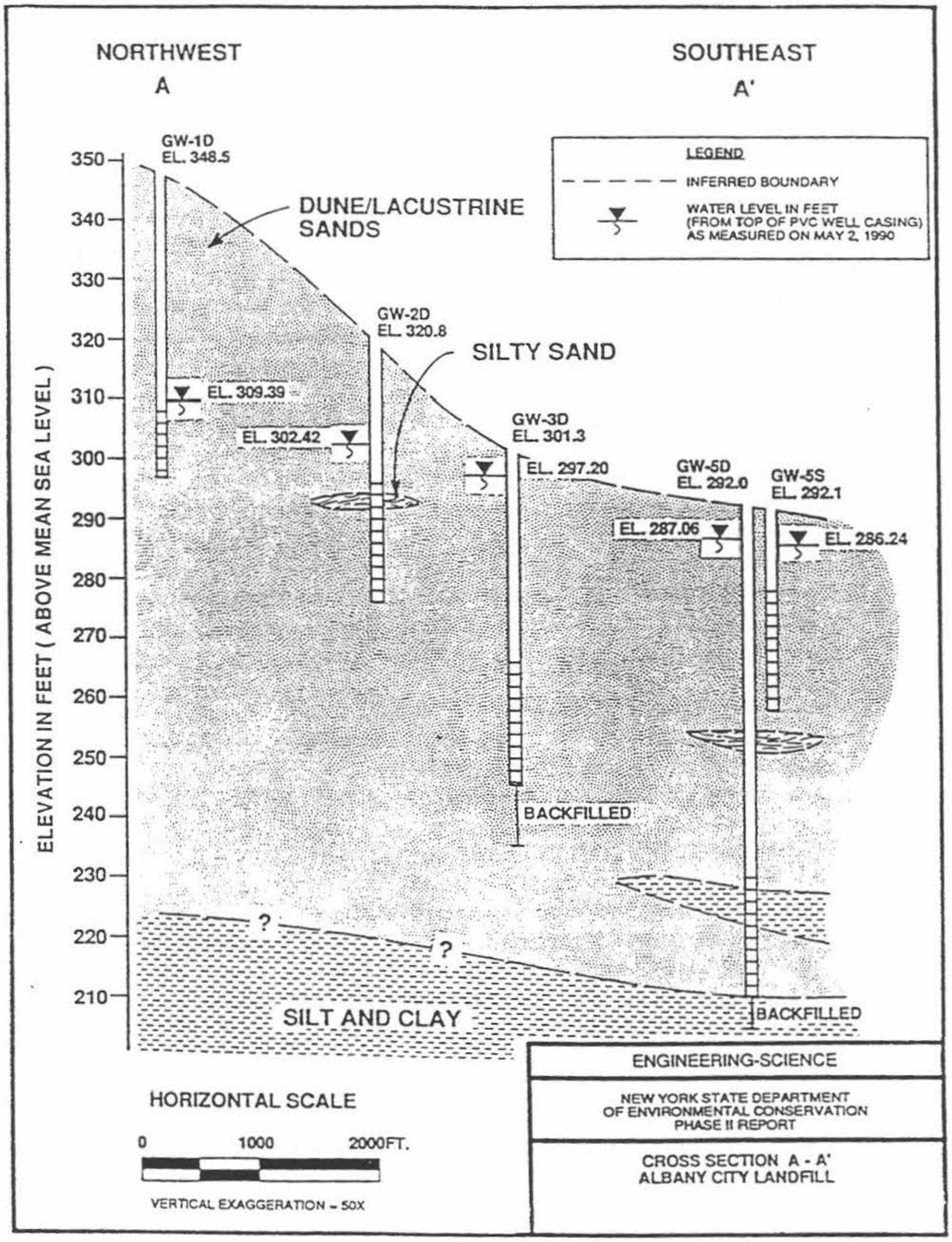

Figure 7. Cross-section through five monitoring wells at the Albany City Landfill showing subsurface materials, screened intervals, elevation of water table on 5/2/90, and decreasing elevation of water table from west to east (from Engineering-Science, 1992).

between September 1989 and May 1990. The investigation included completion of a geophysical survey using electromagnetic (EM) methods and installation of seven monitoring wells (Figure 5).

The geophysical survey was performed during September and October 1989. The geophysical survey indicated the potential presence of conductive contaminant plumes, and the monitoring wells were located so as to intercept the plumes. Groundwater, soil, and leachate samples were collected to determine whether hazardous substances or hazardous wastes were present at the landfill site (Engineering-Science, 1992).

The seven 2-inch diameter monitoring wells were installed into saturated sands of the Pine Bush aquifer to depths of 34 to 81 feet along the northern, eastern, and southeastern edges of the landfill in April 1990. The depths to water in the monitoring wells ranged from about 4 to 40 feet (Engineering-Science, 1992). Well depths, elevations, and other data are summarized in Figure 6. The data presented in Figure 6 and a cross-section showing the locations of well screens and the water table elevation in the wells (Figure 7) indicate that all of the wells were screened entirely below the top of the water table. The report indicates that the screened intervals were positioned to intercept contaminant plumes detected by the geophysical survey.

The upgradient well, GW-1D, was installed at the west end of the landfill. Wells GW-2D and GW-3D were installed on the north side of the landfill. Wells GW-5D, GW-5S, GW-4D, and GW-4S were installed at the east end of the landfill, the former two on the northeast side and the latter two on the south side. The suffix "D" indicates a deep well and the suffix "S" indicates as shallow well.

Based on the water levels measured in the seven wells, local groundwater flow was calculated to be mainly to the east and southeast (although elsewhere in the report, groundwater flow to the north is suggested). A vertically upward component of flow was inferred from the finding that the water levels measured in deep wells at the east end of the site (MW-4D, MW-5D) were higher than those in adjacent shallow wells (MW-4S, MW-5S).

Composite soil samples collected in the borings for the five deep ("D") wells were analyzed for organic compounds, metals, and cyanide. The analyses indicated low concentrations of toluene in two samples (GW-1D and GW-5D, 9 and 13 micrograms per kilogram, or μg/kg, respectively) and moderate concentrations of acetone in one sample (GW-2D, 170 μg/kg). Micrograms per kilogram are equivalent to parts per billion. Concentrations of metals did not exceed referenced naturally occurring ranges (Engineering-Science, 1992).

Groundwater samples were collected from the seven Engineering-Science wells and one well that had been installed previously (MW-1, Figure 5) in May 1990. The groundwater samples were analyzed for organic compounds, metals, and cyanide. Benzene was detected in the samples from GW-5S (5 micrograms per liter, or μg/l) and MW-1 (8 μg/l). Chlorobenzene was detected in the sample from GW-2D (140 μg/l). Micrograms per liter are approximately equivalent to parts per billion. Detectable concentrations of other organic compounds (e.g., acetone) were either below applicable standards or attributed to laboratory contamination, or both. Sixteen metals were detected, and downgradient concentrations consistently exceeded concentrations in the sample from the upgradient well (GW-1D) by more than three times, indicating an intermediate source (i.e., the landfill). Concentrations of seven metals (arsenic, chromium, iron, lead, magnesium, manganese, and sodium) exceeded applicable standards in one or more wells (the standard for iron was exceeded in all wells). The report of the Phase II investigation concluded that the landfill was adversely affecting groundwater quality in the Pine Bush Aquifer (Engineering-Science, 1992).

Three leachate samples that were collected north and south of the landfill showed some contamination by organic compounds and metals. Two organic compounds (chlorobenzene and 4-methylphenol) and five metals (iron, lead, manganese, sodium, and zinc) were detected at concentrations that exceeded NYS groundwater and surface water standards in one or more samples (Engineering-Science, 1992).

The Phase II Investigation report concluded that releases of organic compounds and metals to groundwater and leachate could be attributed to the landfill and that the data suggested that contaminants were migrating radially outward from the landfill, most notably to the north and east "in the direction of groundwater flow". The report stated that the "potential exists for off-site migration of contaminated groundwater through the sands of the Pine Bush Aquifer" (Engineering-Science, 1992). The landfill was, however, subsequently removed from the NYSDEC list of inactive hazardous waste sites.

ALBANY INTERIM LANDFILL

The Albany Interim Landfill (AIL) covers an area of approximately 12 acres on the west side of Rapp Road in the City of Albany (Hansen, 1995). The AIL was constructed in the early 1990s with a double composite liner. The closed Greater Albany Landfill and the New York State Thruway lie to the south. A residential trailer park is located several hundred feet to the north. The Pine Bush Preserve borders the AIL to the west. Landfill service buildings and Rapp Road lie to the east. Figure 5 shows the approximate location of the AIL relative to the surrounding properties.

The AIL is operated by Landfill Technologies, Inc. (LTI) of West Sand Lake, New York. In 1991, a program of biostabilized solid waste placement was proposed at the AIL. The program began with a pilot project in 1989.

Biostabilized solid waste placement

Biostabilized solid waste placement is described in general terms by LTI literature (Hansen, 1995) as follows:

> Solid waste to be landfilled is first shredded and moisture adjusted using mobile slow-speed shredding equipment. Such equipment is operated daily at the Albany, NY landfill. The prepared waste is placed in one hundred foot wide mats, six to eight feet high, and is immediately covered with Posi-Shell® synthetic cover. The length of the mat is continually extended as additional material is added to the mat's working face. Perforated ADS pipes provide aeration for a period of 60-90 days. Following this aerobic biostabilization period, the waste is compacted with standard landfill compaction equipment. A new stabilized layer is then placed above the compacted materials.

The process as performed by LTI is called In-Place Stabilization^{SM} and has been granted U.S. patent 5265979; international patents are pending. Eight basic process steps are involved, as described in Hansen (1995) and summarized below:

1. Removal of recyclable material, specifically bulk metals (curbside recycling generally removes other recyclable materials).

2. Shredding by a mobile slow-speed shear mill with four-inch cutter spacing.

3. Moisture adjustment to 40-60% through addition of water by the dust suppression water spray system with which the shredder is fitted.

4. Placement of the shredded, moisture adjusted material in stabilization mats (100 feet wide and 8-10 feet high along the length of the landfill) by a track loader.

5. Covering with Posi-Shell® synthetic cover.

   The Posi-Shell® synthetic cover consists of an aqueous slurry of 100% recycled material including a recycled pozzolon binder agent such as cement kiln dust and a minor quantity of recycled reinforcing fibers. Collected landfill leachate can be used as the aqueous liquid because the pozzolonic binder neutralizes odors and balances low pHs with its high pH. The Posi-Shell® cover is spray applied by mobile equipment capable of traversing all areas of a landfill. The Posi-Shell® material stiffens to a stucco-like consistency in a matter of hours and does not erode in subsequent rainstorms. The shell has sufficient pores to allow release of aeration gases, but is restrictive enough to maintain elevated temperatures immediately beneath its surface (necessary for extermination of fly and other insect larvae). The Posi-Shell® cover performs the functions of a soil cover during the temporary biostabilization period (e.g., prevention of litter and fire, odor suppression, vector control).

6. Maintenance of the stabilization mats' interstitial oxygen and temperature conditions by addition of air.

   Perforated pipes are placed within the mat at approximately 20-foot intervals. The pipes are manifolded to a high-volume, low-pressure blower that provides the air necessary to maintain aerobic conditions. Areas of higher temperature generally require more air to replace oxygen depleted by biological activity. Oxygen, temperature, and methane measurements are taken daily to determine appropriate aeration patterns.

7. Maintenance of the stabilization mats' interstitial moisture by addition of water.

   The air blown into the stabilization mats is humidified by spraying small amounts of water in the blower discharge pipe; this water replaces evaporation losses.

8. Final compaction at the desired state of maturity.

   The mat subsides to an average height of about 5 feet after 60-90 days of biostabilization. The mat is then compacted with standard landfill equipment to an average height of about 3 feet.

Petroleum-contaminated soil at the Albany Interim Landfill

The AIL accepts non-hazardous petroleum-contaminated soil for disposal. This soil is then used to construct roadways and driving surfaces within the landfill itself, because the stabilized waste and the Posi-Shell® cover are not suitable for vehicle traffic.

Methane and leachate at the Albany Interim Landfill

Methane is actively extracted from the AIL, in large part as an odor control measure. Three horizontal hoses run from the AIL to a burner on the west side of the AIL. Commercial use of the methane is being explored.

Leachate is actively collected and removed from the AIL. Leachate can then be either reinjected or routed to holding tanks and eventually to the sanitary sewer for disposal (provided it meets disposal criteria).

Conventional sanitary landfilling techniques

Solid waste disposal methods in the U.S. have evolved considerably during the twentieth century. The open or burning dump is generally a thing of the past, having been replaced by the sanitary landfill, so called primarily because of the "sanitary" manner in which waste is covered daily. The term "sanitary landfill" was apparently coined during the 1930s at a pioneering landfilling operation in Fresno, California, where the "cut and cover" or "trench" method of landfilling was first used in the U.S. (American Public Works Association, 1970).

Conventional sanitary landfilling procedures, as described in American Public Works Association (1970) and Sorg and Hickman (1970), consist of the following steps:

1. waste is dumped directly onto the landfill from collection trucks
2. waste is spread and compacted by a tractor
3. waste is covered with a 6-inch layer of compacted soil ("daily cover") before the end of the day
4. when the landfill space is full, the landfill is capped with a 2-to-3-foot layer of compacted soil

Conventional sanitary landfilling procedures differ from biostabilization procedures in several ways. Specifically, conventional sanitary landfilling involves no shredding or initial moistening of waste, no direct mechanical compaction after the daily cover has been applied, no aeration, no active methane or leachate extraction, and no moisture adjustment. Before the advent of landfill liners, moistness was considered conducive to groundwater pollution (American Public Works Association, 1970).

Evaluation of biostabilization techniques

The fundamental criterion upon which the stabilized waste placement process at the AIL has been evaluated is the amount of waste that can be placed, which is evaluated in terms of effective density and airspace conservation. In general, LTI has found that 40% to 60% more waste can be placed in a given volume under stabilized placement techniques than under conventional landfilling techniques. Effective densities were found to be higher with the use of stabilized placement (Hansen, 1995).

Additional criteria have been used by LTI to evaluate the success and practicality of stabilized waste placement, including litter generation, odor emission, vector control, pathogen potential, and orderliness of operation. LTI found that the Posi-Shell® synthetic cover was highly effective in the control of litter after waste placement. Odor emissions were generally found to be a problem only if the mats were less than approximately 1000 feet from the receptors, particularly during warm weather. The Posi-Shell® was found to be a highly effective vector (e.g., rats, seagulls, flies) deterrent. Fly larvae were generally killed by the high temperatures in the stabilization mats. Rats and birds were not observed; only a few individual mice were observed. The average temperatures of 130-150°F recorded within the aerated mat were judged to be highly destructive to most human pathogens. The stabilized placement method received high ratings for orderliness from the project foreman or engineer and the landfill superintendent (Hansen, 1995). The additional costs for stabilized placement were estimated by Hansen (1995) at about $12 to $24 per ton.

STEWART'S SHOP #182

The volatile organic compounds benzene, ethylbenzene, and toluene, which were detected at relatively low concentrations in groundwater at the Albany City Landfill in 1990, are commonly found as groundwater contaminants at sites that have experienced subsurface gasoline spills. The volatile natures of these and many other compounds typically found in gasoline offer a means of remediating, or cleaning up, the contaminated groundwater by encouraging volatilization, or evaporation, of the compounds. One method of encouraging volatilization of compounds is to pump contaminated groundwater through an air stripper. This remediation method is being used at Stewart's Shop #182, a small site on South Brandywine Avenue in Schenectady, New York (Figure 8).

The following information is summarized from Passaretti Geological & Environmental Consultants, Inc. (1991).

Groundwater Study

Stewart's Shop #182, a convenience store and gas station, is located at 100 South Brandywine Avenue in Schenectady, New York. In 1991, three underground gasoline storage tanks and one underground waste oil tank were removed from the site as part of a tank upgrading program. Petroleum-contaminated soil was encountered during the tank removal. Approximately 250 cubic yards of soil were removed from the former tank pit for offsite disposal. New underground storage tanks were installed in a different part of the site. The site had reportedly been a Stop & Go Station prior to being a Stewart's Shop. The contiguous site to the northeast had also reportedly been a gas station. The NYSDEC representative requested completion of a groundwater study at the site.

Passaretti Geological & Environmental Consultants, Inc. (Passaretti) of Saratoga, New York were contracted to perform the groundwater study at the site. On October 30, 1991, three monitoring wells were installed at the site: one 4-inch diameter well (MW-1) and two 2-inch diameter wells (MW-2 and MW-3). Figure 8a is a copy of a site plan showing the layout of the site and the location of the first three wells and of seven wells installed at and around the site later. Groundwater was encountered during drilling at a depth of approximately 19 feet. The wells range in depth from 25 to 35 feet. Petroleum odors were detected in soils and groundwater from MW-1 and MW-3. No odors were detected in groundwater from MW-2. Data collected during a November 1991 site survey and corrected for the presence of free product discovered in MW-3 at that time indicated that groundwater flow was toward the southwest to west at a gradient of about 1%.

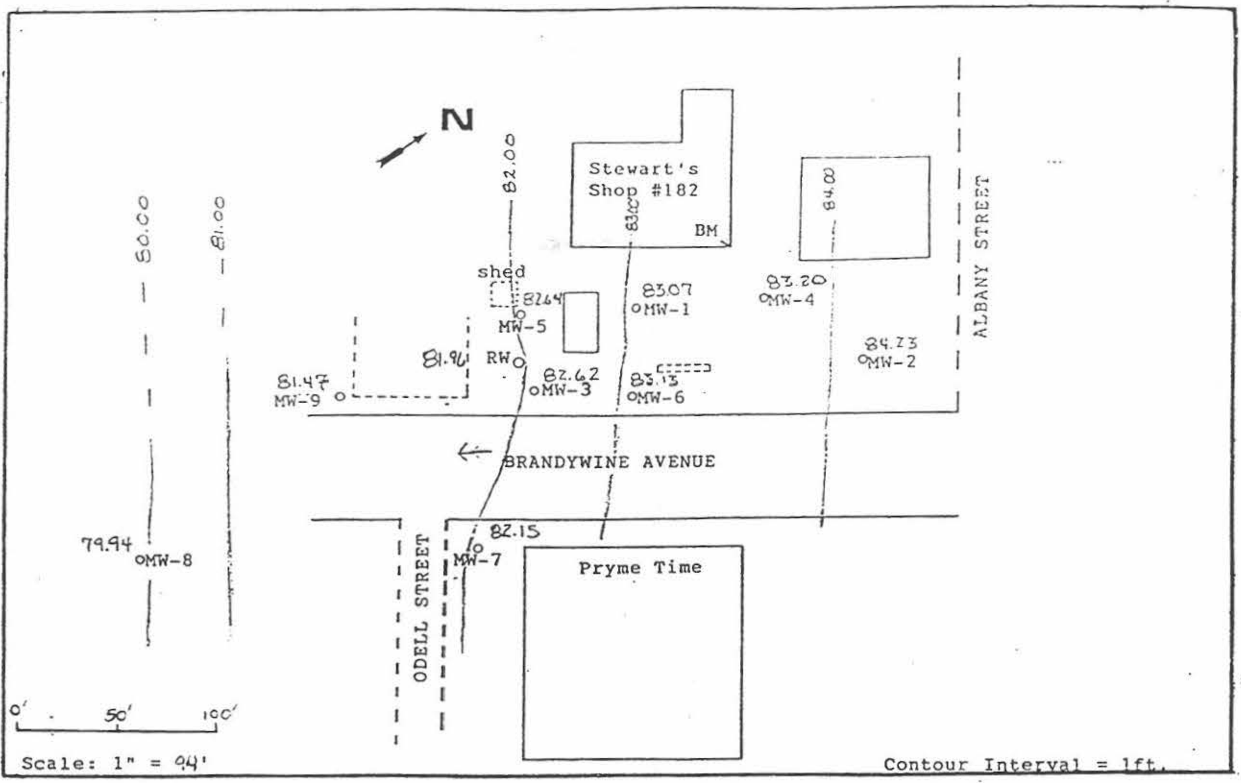

Figure 8a. Monitoring and recovery well locations, static groundwater elevations (5/25/93), and static groundwater contour map at Stewart's Shop #182, 100 South Brandywine Avenue, Schenectady, New York (adapted from Passaretti, 1994).

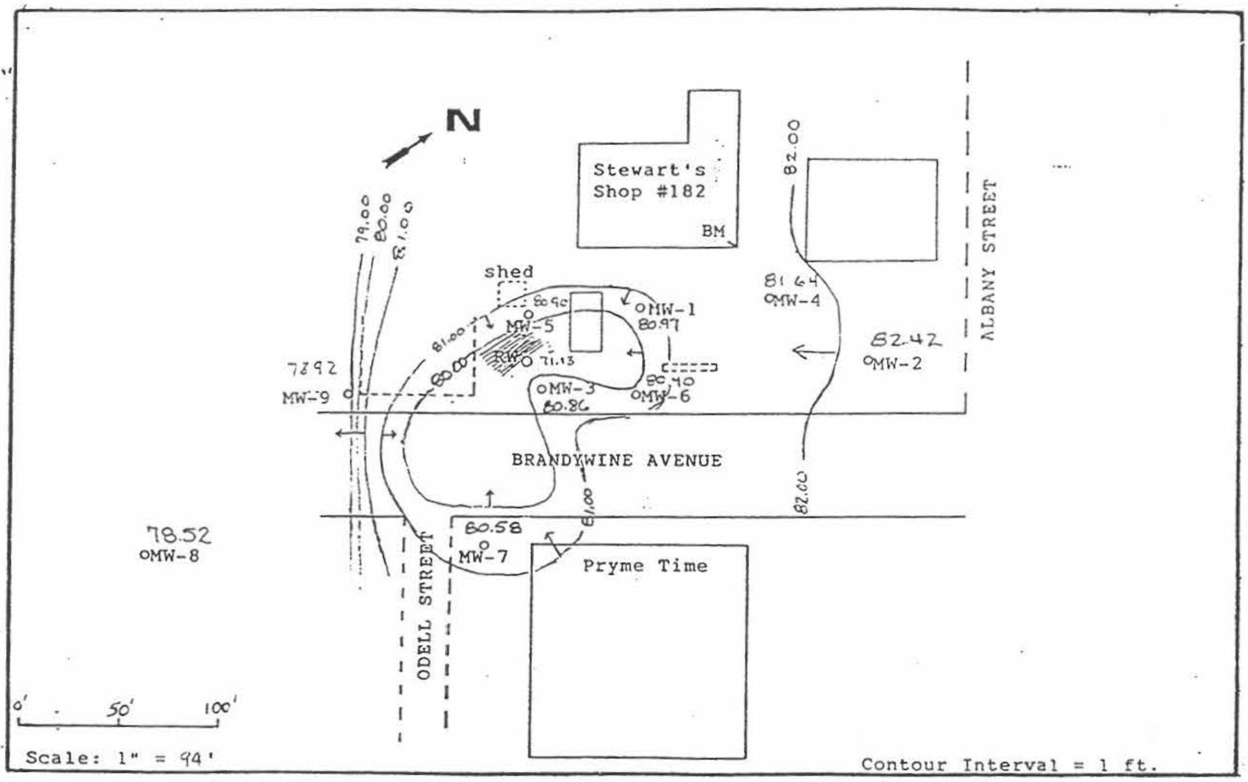

Figure 8b. Monitoring and recovery well locations, pumping groundwater elevations (11/19/93), and pumping groundwater contour map at Stewart's Shop #182, 100 South Brandywine Avenue, Schenectady, New York (adapted from Passaretti, 1994).

Groundwater samples were collected from the three wells on November 3, 1991. Analysis for volatile organic compounds indicated contamination by gasoline compounds of groundwater from MW-1 and MW-3. Total BTEX (benzene, toluene, ethylbenzene, and xylenes) concentrations in the samples from MW-1 and MW-3 were 903 and 27,581 ppb, respectively (excluding MTBE, a gasoline additive). [These are typically considered to be moderately high (MW-1) to high (MW-3) BTEX concentrations.] A trace amount (4.4 ppb) of the solvent tetrachloroethene was detected in the sample from MW-2.

Grab and split-spoon sampling during drilling indicated that the site is underlain by well-sorted, interbedded medium- and coarse-grained sands to a depth of about 20 feet (approximately to the water table), and below this by fine-grained sand with variable silt and clay content. These deposits are part of the Schenectady delta sediments.

Passaretti recommended installation of additional wells to define the plume of contamination and the extent of free product, bailing of free product from MW-3 and storage of the bailed product in a 55-gallon drum, remediation of groundwater with a pump and treat system, and remediation of remaining areas of contaminated soil with a soil vent system (following recovery of the free product). Passaretti recommended that the additional monitoring wells be installed with slotted screen from about 5 feet below the surface to below the water table so that they could serve both as groundwater monitoring points and as vertical vents. [The soil vent system was not installed.]

Site Remediation

The following information is summarized from Passaretti Geological & Environmental Consultants, Inc. (1994).

Between November 1991 and April 1992, seven additional wells were installed at and around the site to define the contaminant plume. In December 1991, three wells were installed onsite (MW-4, MW-5, and MW-6). In February 1992, three wells were installed offsite and downgradient of the site (MW-7, MW-8, and MW-9). In April 1992, a 40-foot, 4-inch diameter recovery well was installed onsite (RW). Figure 8a shows the locations of the original three wells and the seven additional wells, the static groundwater levels, and the calculated elevation of the static water table.

A remediation system was installed in June 1993, using the recovery well (RW) that was installed in April 1992. The soil vent system that was recommended by Passaretti in 1991 was not installed. The remediation system was described as follows in the 1993 Engineer Report prepared by Passaretti (1993):

> A one-half horsepower, submersible pump pumps water from the recovery well into a 275 gallon separator tank. The tank contains a solitary baffle and a submersible pump. Volatilization of contaminants occurs across the separator. By decreasing the contaminant level in the water prior to its entering the shallow tray system, the need for carbon polishing is negated, as is the associated cost.
>
> Currently the system treats 31 gallons of water per hour. Recent adjustments of the downhole electrical probes are intended to enhance this recovery rate. Draw down around the recovery well is excellent as indicated by the most recent groundwater contour data.

Figure 8b shows the locations of the ten wells, the groundwater levels during pumping, and the calculated elevation of the pumping water table. Note the drawdown of the top of the water table around the recovery well.

Between June and December 1993, approximately 98,000 gallons of groundwater were treated by the system. Analytical results for groundwater samples collected in the monitoring wells through November 1993 generally showed decreases in the total concentrations of volatile organic compounds detected in the samples (Passaretti, 1994).

Tabulations of readings of the water meter on the remediation system and calculated pumping rates through April 1995 show that as of April 12, 1995, 269,039 gallons of groundwater had been pumped into the system. The average pumping rate was 14.47 gallons for the one-week period April 5-12 (Passaretti, 1995a).

A tabulation of groundwater analytical results for samples collected from the onsite wells, the offsite wells, and the remediation system through April 1995 shows mixed results. Improvement in groundwater quality can be seen in some, but not in all, wells (Passaretti, 1995b).

Our thanks to Mary Passaretti of Passaretti Geological & Environmental Consultants, Inc., for providing us with information about this site.

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ENVIRONMENTAL TECHNOLOGY AND PRESERVATION: THE PINE BUSH, LANDFILLS, AND GROUNDWATER INTEGRITY

FIELD TRIP GUIDE

Meet in the Geology Department on the second floor of Butterfield Hall at Union College in Schenectady. We will begin with a slide show by David Hansen, P.E., of Landfill Technology, Inc. The slide show will provide an introduction to the design and operation of the Albany Interim Landfill.

After the slide show, we will leave Union College and take I-890 eastbound to the NYS Thruway (I-90) eastbound. We will leave the Thruway at Exit 24 (Albany). The road log starts at the Exit 24 toll booth.

Mileage	
0.0	After exiting from the eastbound lanes of the Thruway, set the odometer to 0.0 in the toll booth at Exit 24 (Albany) of the NYS Thruway. Bear right out of the toll booth toward Exit 1S.
0.1	Take Exit 1S (Western Avenue/Route 20). You are now on the southernmost section of the Northway.
0.7	Exit right up the ramp that leads to Crossgates Mall Road.
0.9	Bear right through the light and yield sign onto Crossgates Mall Road.
1.05	Bear right at the sign for Washington Avenue Extension.
1.25	Turn left at the sign for Washington Avenue Extension Westbound. Continue on Washington Avenue Extension westbound to the intersection with Rapp Road.
2.1	Turn right onto Rapp Road at the light.
2.3	The access road for the Albany City Landfill, the Albany Interim Landfill, and the public solid waste tipping station is on the left. We will meet our guide at a prearranged location inside the landfill property.

STOP 1: Albany Interim Landfill

Access to the landfill is restricted. Call Landfill Technologies, Inc. (518-674-8694) in West Sand Lake, New York, to arrange a tour of the active and closed landfill areas.

Because the distance that we will drive inside the landfill property is unknown, we will reset the odometer to 0.0 at the intersection of the landfill access road and Rapp Road.

0.0	Set the odometer to 0.0 before turning onto Rapp Road from the landfill access road. Turn right onto Rapp Road.
0.2	Turn right onto Washington Avenue Extension westbound at the light.
1.4	Turn right onto Route 155 (New Karner Road) at the light. Turn right onto Route 155 (the sign says "east"). Almost immediately, you are crossing over the Thruway. Look at the right side of the road. A guardrail begins where the overpass ends. At the end of the guardrail is the beginning of an unpaved track that runs along the east (right) side of Route 155.
1.75	Pull off the right side of Route 155 onto the gravel shoulder and continue onto the unpaved track. Continue along the dirt track to the informal parking area marked by the "Albany Pine Bush Preserve" sign.

Mileage

1.85 Park near the entrance to the Albany Pine Bush Preserve marked by the sign and the wooden post-and-rail fence.

STOP 2: Albany Pine Bush Preserve

The Albany Pine Bush Preserve is open to the public. Sign in at the box near the entrance. We will walk generally east, pausing atop and between dunes to note the morphology and vegetation, eventually ending up at the west end of the closed Albany City Landfill. On the way, we will pass a monitoring well that is most likely GW-1D, the upgradient well installed by Engineering-Science in 1990. After looking at the landfills from this different perspective, we will make our way back through the Pine Bush to the vehicles.

Return to Route 155, either by continuing along the unpaved track to the entrance road for the State Employees Federal Credit Union or by backtracking. Head back to the Exit 24 toll booths.

1.9 Turn left onto Route 155.

2.35 Turn left onto Washington Avenue Extension eastbound at light.

4.2 Turn right at the sign for Crossgates Mall Road.

4.35 Turn left at stop sign onto Crossgates Mall Road.

4.7 Turn left at light onto the access ramp for I-87 (north). The signs indicate that this road leads to I-87 and I-90.

5.5 Take Exit 1W (to New York and Buffalo). Merge into westbound traffic on I-90 and continue west to the toll booths.

Reset the odometer to 0.0 in the toll booth at Exit 24 (Albany) of the NYS Thruway.

0.0 At the toll booth, get ticket, then leave toll booth and bear left onto I-90 westbound (to Buffalo).

5.4 Take Exit 25 to I-890 (Schenectady). Pay toll ($0.20). Go west on I-890.

9.1 Take Exit 6 (Michigan Avenue). Turn right onto Brandywine Avenue at the stop sign at the end of the offramp.

9.4 Stewart's Shop #182 is on the left (west) side of Brandywine Avenue (#100) between the first and second traffic lights. Signs advertising Mobil gasoline are visible as you approach.

STOP 3: Brandywine Stewart's Shop

The site is a convenience store and gas station. The remediation shed is closed to the public. Please do not take up customer parking spaces or block customer access to the store or gas pumps.

End of trip.