ENVIRONMENTAL GEOLOGY OF THE HACKENSACK MEADOWLANDS

SAM L. AGRON

Department of Geological Sciences, Rutgers University, Newark, New Jersey

Introduction

This trip to the Hackensack Meadowlands District has several purposes:

1. To observe the natural environment of the Meadowlands, the problems and challenges it poses, and to gain some understanding of how the geologic history gave rise to that environment.

2. To see how numerous, complex, diverse, and seemingly incompatible land uses can be carried out harmoniously and profitably if a region's geology and ecology are adequately understood by planners; and if imaginative engineering, political and economic planning are applied.

3. To inspect several of the major projects that have been erected in the Meadowlands, consider their operational processes and how they impact on the environment and, above all, how geologic constraints were dealt with in designing foundations, etc.

The pioneering work done by the Hackensack Meadowlands Development Commission in planning and overseeing the harmonious growth of the District is unique in this country. A long-blighted area, where land was almost worthless some four decades ago, now contains some of the most valuable acreage in the country. What can be learned here may very well have application elsewhere.

Acknowledgement

I am grateful for the cooperation I have received from individuals and agencies in setting up this trip. Particularly helpful have been: Patricia Q. Sheehan, former Executive Director of the Hackensack Meadowlands Development Commission; Donald Smith, John Bolan, Vincent Nykiel and Louis J. Degange, all of the Commission staff; Michael Graime and Francis H. Werneke of the New Jersey Sports and Exposition Authority; Jerome F. Sheehan and Philip Bober of the Bergen County Utilities Commission; and Michael McNally of Hartz Mountain Industries, Inc. I also wish to thank Muriel Meddaugh, John Szalkowski and Phil Kortis of my own Department for their help.

Geology of the Meadowlands

The Hackensack River Valley, including the Meadowlands, lies in the Piedmont physiographic province of northeastern New Jersey. The bedrock is the Brunswick Formation of the Late Triassic Newark Group, 225 to 200 million years in age (Van Houten, 1970). The formation consists of fluviatile and lacustrine reddish-brown shales and some fine-grained sandstones. Associated basalts of the Newark Group include three younger lava flows forming the Watchung Mountains several miles west of the Meadowlands; the Palisades sill, in part a dike, bordering the Meadowlands on the east; and Laurel Hill (Snake Hill), a basalt plug adjacent to the New Jersey Turnpike in the southern part of the Hackensack Meadowlands.

The extrusive Watchung basalts and the intrusive Palisade diabase post-date the Brunswick beds in this area. They manifest volcanism accompanying the initial stages in the opening of the Atlantic basin (Manspeizer et al, 1978). Subsequent faulting has left the Newark Group with a dip of approximately 20 degrees to the northwest. Post-Newark erosion produced a very flat topography. Stream valleys such as the Hackensack were eroded in the weak shales, and NE-SW trending cuestas such as the Palisades and the Watchung Mountains formed on the resistant basaltic rocks.

The region was covered by at least three glacial advances in the Pleistocene. The last of these, the Wisconsin ice sheet, moved south across the area as far as Perth Amboy. Being over 1000 feet thick, it exerted a pressure of almost 400 pounds per square inch (JMA, 1978). A blanket of till was deposited as ground moraine over the Newark red beds. The till, consisting mostly of red and reddish-brown sandstone and shale fragments of the Newark Series, varies in thickness from 0 to at least 30 feet, as indicated by borings (JMA, 1974).

Glacial Lake Hackensack began to form about 15,000 years ago as a proglacial lake impounded behind the terminal moraine on the south. Its axis extended north along Arthur Kill, Newark Bay, the Hackensack River, and into New York State through West Nyack and eastward to Mount Ivy. Its greatest width, about 15 miles, was near the city of Hackensack (Schuberth, 1968). All of the Hackensack Meadowlands was submerged by Lake Hackensack, which was one of several adjacent proglacial lakes, separated by divides such as the First Watchung Mountain, the Palisades Cuesta, and Manhattan Island.

About 10,000 years ago the terminal moraine was breached and Lake Hackensack was drained into the Atlantic (Widmer, 1964). During the time the lake existed, varved clays, more than 200 feet thick in places, accumulated as seasonal deposits (Widmer 1963). There are at least 2,550 varves, each consisting of a lighter-colored silt (summer) layer and a darker-colored clay (winter) layer. The regularity of the varves was disrupted in places by local conditions. For example, coarser sediments washing down from the Secaucus Ridge masked the normal varve pattern on the adjacent lake bottom (JMA 1978). Even more striking is the unusual series of cores taken in the vicinity of Cromakill Creek, where varved segments of the cores were interrupted by coarse sand or other unvarved sediment, and where horizontal continuity of bedding was not very evident in the different test holes. This is attributed to the presence there of an unusually deep bedrock valley of the ancestral Hackensack River and of the nearby Bergen Ridge to the east. The ridge shed gravels, red sand and red silt into Lake Hackensack, producing a local sedimentary environment uniquely different from that prevailing generally in the lake (JMA, 1978).

Borings done for the U.S. Army Corps of Engineers (Fig. 1) show that the glacially scoured bedrock valley under the Hackensack Meadowlands is from one to two miles wide and lies buried under till and varved clay and silt, in places over 170 feet thick (U.S. Army Corps of Engineers, 1962). The valley of the present Hackensack River is incised in varved lake sediments to a maximum depth of about 35 feet and its width varies from several hundred feet to more than 1000 feet.

Following the breaching of the terminal moraine, some 10,000 years ago, and the draining of Lake Hackensack, the area was a level wetland for several millenia, with stands of lowland forest and grassy marshes. About 3,000 to 5,000 years ago, rising sea level accompanying the melting of the ice sheets, reached the elevation of the narrow outlets of the Hackensack River at Kill Van Kull and Arthur Kill, exposing the river to the tides. As sea level continued to rise, estuarine conditions extended northward into the Hackensack River Valley, producing the salt marsh environment that has existed into the present (Fig. 2).

A U.S. Geological Survey map of surficial deposits indicates Quaternary deposits (Qm) covering the area, and summaries the geologic, hydrologic and engineering conditions as follows:

> "Quaternary marshes, swamps, estuaries, and artificial fill...interbedded silt fine-grained sand, clay, and organic material in differing proportions...upper part dominantly organic..,soft noncompact, in part semifluid...commonly overlain by artificial fill...underlain by till...silt and clay...esturaries, salt marshes present below level of high tide...bearing capacity very poor. Compressibility high. Unstable, flows readily into underwater excavations. Very small water yields to wells. Has high porosity...low permeability." (U.S.G.S., 1967).

The Hackensack Meadowlands Development Commission

The Hackensack Meadowlands Development Commission, established by the New Jersey Legislature in 1968, was mandated to regulate land use in the Hackensack Meadowlands District, comprising 19,730 acres. This area is larger than Manhattan Island (32 square miles vs. 22-1/4 square miles). Despite its central location in the northern New Jersey - New York City metropolis (Fig. 3), the area was long avoided by developers because of the high costs and technical problems involved in building in an estuarine marsh with substrate of peat and clay. Consequently, it has been used largely as a waste—disposal site by the region's municipalities which grew up over the years on the surrounding higher elevations.

Development in the District had also been retarded because the land overlapped 14 municipal jurisdictions and because of complex riparian disputes. The Hackensack Meadowlands Development Commission's Master Plan (HMDC, 1972), while responding to mounting pressure to utilize this favorably situated real estate more intensively, also seeks to encourage balanced development between residential, commercial, industrial, and recreational uses. In addition to building and preserving parks, wetlands and wild life refuges, the Commission is concerned with sanitary landfills, transportation, liquid natural gas storage facilities, the Sports Complex and other uses of the land. The land use plan in force in the District (Fig. 4) regulates land use in 14 municipalities; nowhere else in the United States does a land use plan regulate more than one municipal jurisdiction. The Hackensack Meadowlands District, lying in the middle of the Northeast Corridor, is probably one of the most intensely used land areas in the world from the standpoint of the numbers of people crisscrossing it; the diverse industrial, commercial, residential, and recreational activities going on there; and the vigorous utilization of the wetlands by the wildlife.

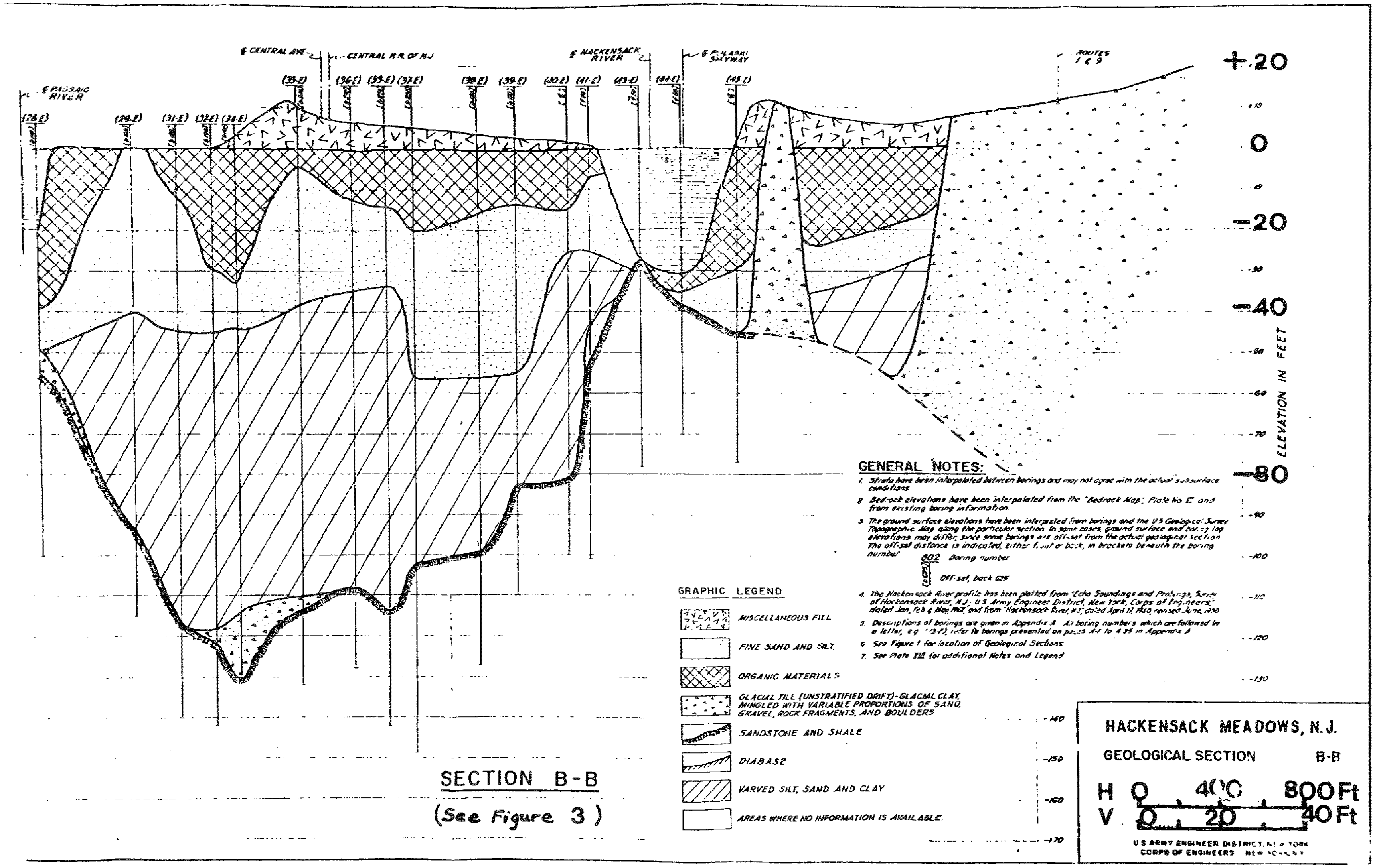


Fig. 1 Geologic section along Pulaski Skyway, south end of Hackensack Meadowlands (see Figure 3, B-B). Note the deep, glacially scoured bedrock floor of the ancestral Hackensack River. The present river bed is incised in lake sediments and organic deposits indicating Recent crustal rebound (U.S. Army Corps of Engineers, 1962).

Fig. 2 Tidal wetlands, Sawmill Creek Wildlife Management Area at high tide. Towers of railroad bridge across the Hackensack River can be seen in the distance, to right of center. Two LNG storage tanks are in extreme top right. View to north. (Courtesy, Chet Mattson, Hackensack Meadowlands Development Commission).

The region is expected to undergo intensive development during the next few years (JMA, 1974). By the year 2000, it is anticipated there will be 140,000 jobs, with annual wages of upwards of $1 billion in the Meadowlands (Hanley 1979c). The Commission projects that, upon full development, net tax revenues to each of the 14 municipalities, over the cost of delivering services to the District portion of the town, will average $2.9 million. In seven of the 14 towns this will pay for more than 85 percent of the total town budget (HMDC, 1979).

Transportation in the Meadowlands

The transportation problem in the Meadowlands is too costly for government alone to solve, without the private sector, according to the State Transportation Commissioner. He estimated it would cost more than $1 billion to build a highway system to serve a fully developed Meadowlands district (Roberson, 1980). Outside consultants had to be retained to evaluate the transportation impact of the 645 development applications that were pending before the Hackensack Meadowlands Development Commission at the beginning of 1980. By the year 2000, according to Senator Harrison A. Williams, Jr. of New Jersey, there will be an estimated 75,000 peak-hour trips to the Meadowlands, compared to the 30,000 peak-hour trips now (Roberson, 1980). The Meadowlands transportation master plan must envisage wider use of mass transit in the years ahead.

Currently, the transportation modes in the Meadowlands are highway, rail, pipeline, water, and air. The major highways are the east and west spurs of the New Jersey Turnpike, running north-south; Route 3, the major east-west highway, crosses the District near the midline; and the Belleville and Newark Turnpikes cross it in the south. Paterson Plank Road, Meadowlands Parkway, Washington Avenue, and Moonachie Avenue are also heavily trafficked arteries. Complex cloverleaf interchanges mark the intersections of some of the highways. Of the 19,730 acres in the Meadowlands, 2,100 are zoned for turnpike and limited access roads, and 430 for local roads. There are also 400 acres zoned for railroads, 670 for airport facilities, and 205 for transportation centers (bus and railroad stations). Thus, a total of 4,005 acres, about 20% of the total acreage, is zoned for transportation (HMDC, 1972).

Hackensack River Estuary and its Ecosystem

The Hackensack River flows in a glacially modified valley from Haverstraw, New York, south to Newark Bay, where it meets the Passaic River. In its lower 22 miles, the Hackensack is an estuarine, meandering, brackish stream flowing alternately south and north with the ebb and flood of the tides. Since 1922, when a dam was built by the Hackensack water company at New Milford to form the Oradell Reservoir, the impounded fresh water has been diverted to residential and industrial use leaving little fresh water to flow into the lower 22 miles of the river. Most of the freshwater that does enter arrives as run-off via storm drains and sewers, as industrial discharge, and as effluent from sewage treatment plants. The river's flow is now mostly tidal water, with a salinity range of 1 to 18 ppt from north to south. When the tidal water enters the Hackensack Estuary it has already acquired much fresh water from the larger Hudson and Raritan Rivers in New York Bay, and its salinity has been reduced from the 35 ppt in the ocean to the levels found in the river (Mattson and Vallario, 1976).

The Hackensack follows a meandering course for 13.6 miles approximately down the Middle of the Hackensack Meadowlands District, dividing it into an eastern part and a slightly larger western part (Fig. 3). The river's course covers some 1400 acres, and adjacent wetlands another 6,300 acres, both areas constituting about 39 percent of the total 19,730 acres in the District.

Five Wetland Bio-Zones are recognized in the District, based on salinity and vegetation (Mattson and Vallario, 1976):

Bio-Zone I -Shallow tidal bays, Mudflats (5-15 ppt salinity)
Bio-Zone II - Low salt marsh (5-15 ppt salinity)
Bio-Zone III - High salt marsh (5-15 ppt salinity)
Bio-Zone IV - Low salinity reed, cattail and cordgrass marsh (3-9 ppt salinity)
Bio-Zone V - Fresh water marsh (0-3 ppt salinity)
Their distribution is shown in Figure 5.

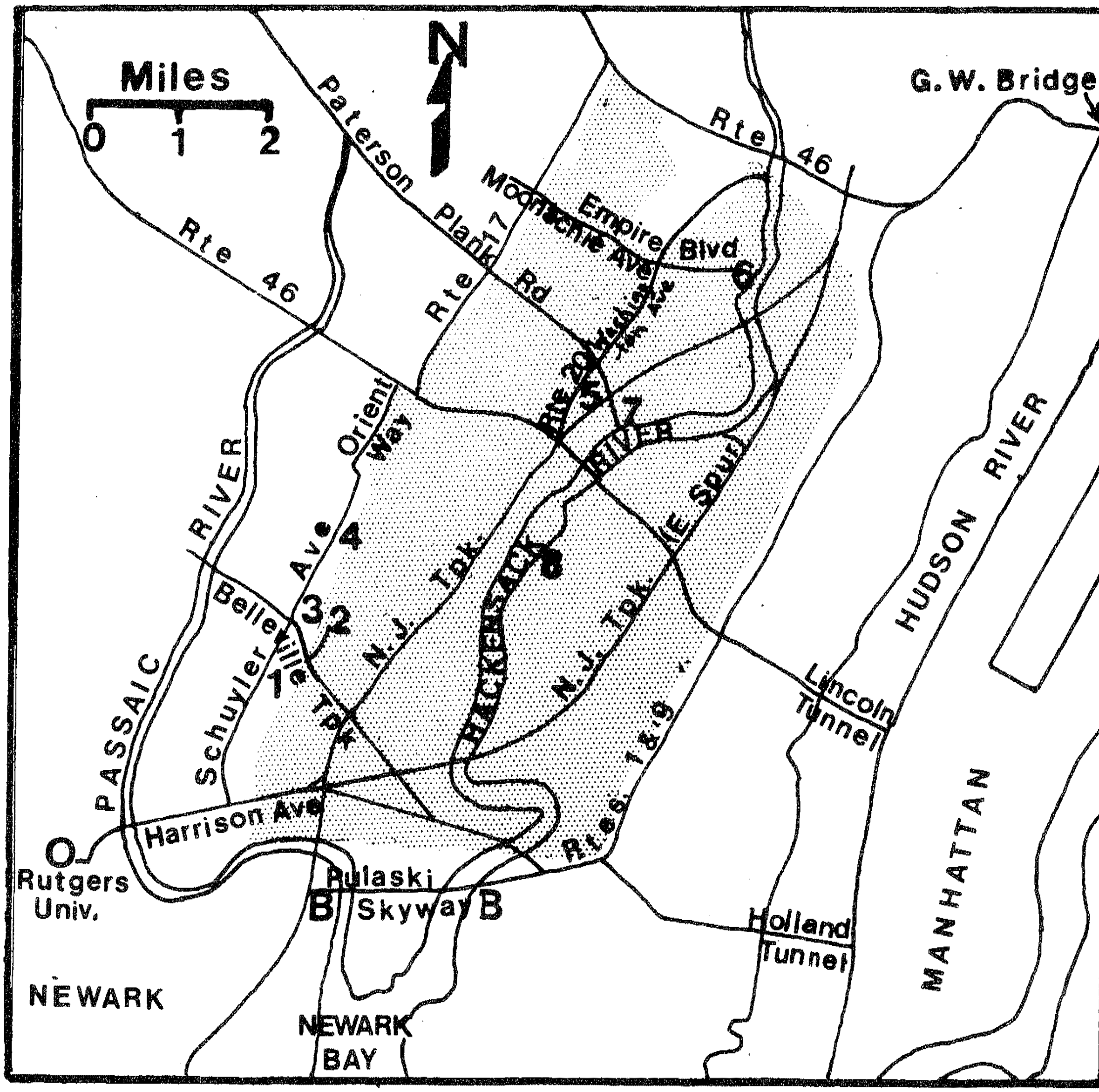


Fig. 3 Field trip stops (Nos. 1-8). Shaded area is Hackensack Meadowlands District. See Figure 1 for geologic section along B-B.

Early attempts to dike, drain, and tidegate the marshes for farming were not very successful because of muskrat damage. Dikes with sheet iron cores to thwart the muskrats were built in Kearny and North Arlington, but they failed when the sheet iron sank into the underlying peat (Kardas and Larrabee, 1976).

Railroad embankments built from 1830 to 1840 affected the movement of water and so did the construction of dikes, decades later, by the Mosquito Commissions in Bergen and Hudson Counties. In more recent years Route 3 and the east and west spurs of the New Jersey Turnpike were built on massive earth fills which have been very effective dikes offering security to fresh wetlands. Many dikes and tidal gates along the Hackensack River marshes were destroyed by a hurricane in 1950. As a result tidally responsive vegetation *(Spartina alterniflora, Spartina patens, Dichilis spicata, Typha latilfolia, Typha latifundia,* etc.) have replaced fields of *Phragmites communis* (Mattson and Vallario, 1976).

The Hackensack Meadowlands ecosystem is not a remote tropical rainforest, nor is it like Alaska or the Mississippi River delta, or almost any other ecosystem because it lies inside, at the very center of the nation's most dense megalopolis. Here has been sent the sewage from 52 New Jersey towns and the garbage from 144 towns. Interwoven with this stressed estuarine ecosystem are 8,000 acres of developed land, 41 percent of the total area of the Hackensack Meadowlands District (Mattson, 1978).

Wetland ecosystems are remarkably strong, simple, and contain a comparatively low variety of species. But the lines between the survival, transformation and destruction of these ecosystems are very fine, and our

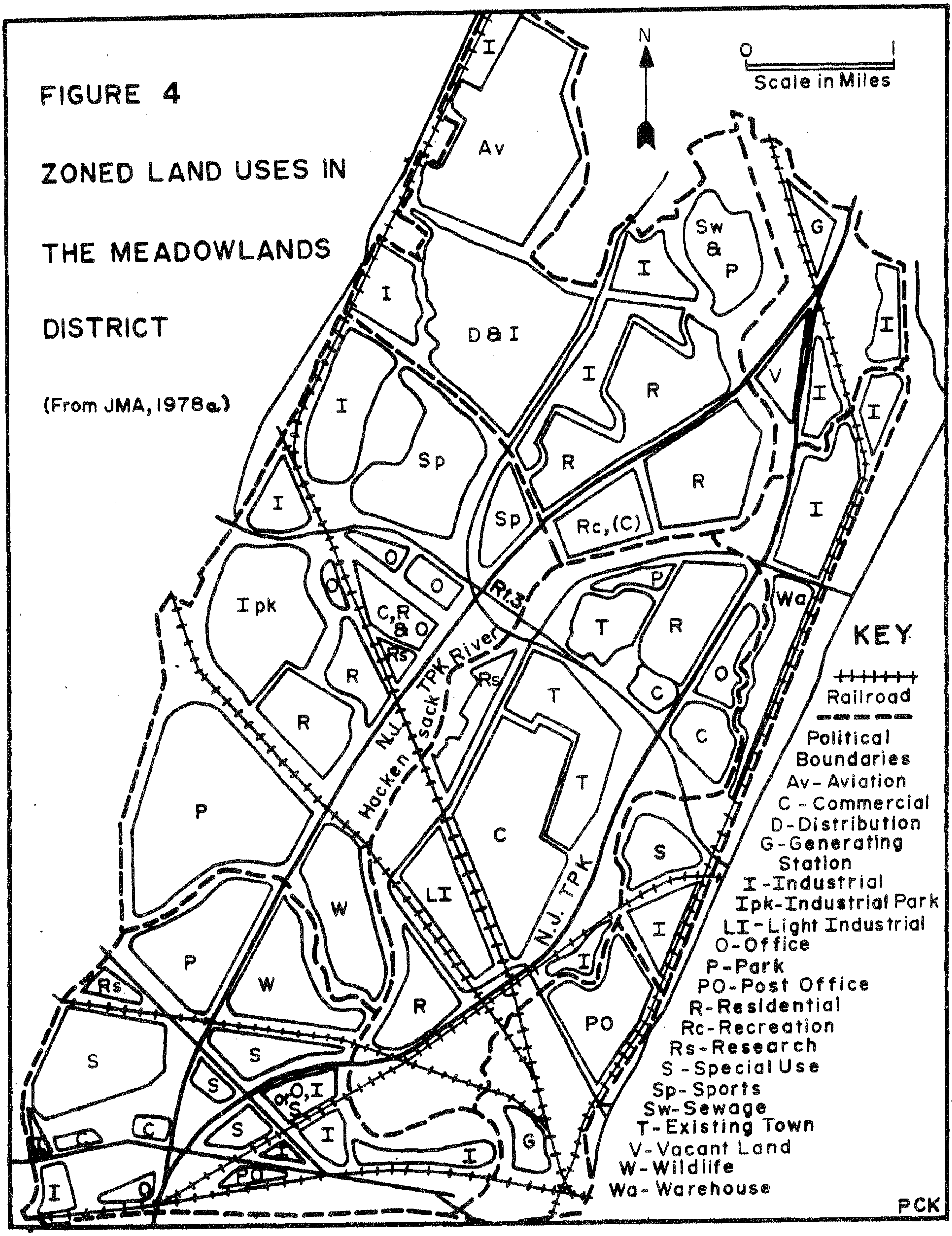
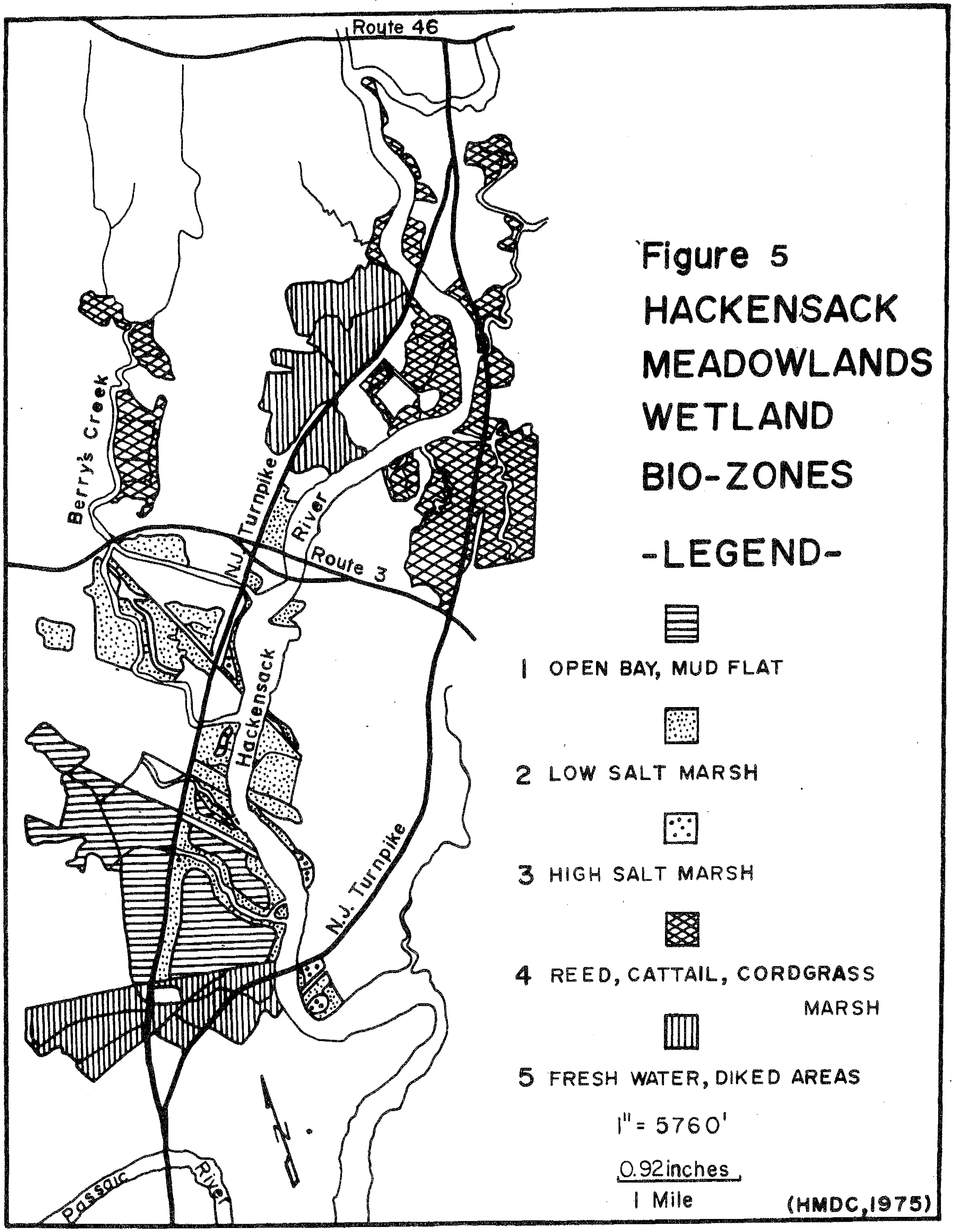


FIGURE 4
ZONED LAND USES IN
THE MEADOWLANDS
DISTRICT
(From JMA, 1978a.)
N
0 1
Scale in Miles
KEY
Railroad
Political Boundaries
Av - Aviation
C - Commercial
D - Distribution
G - Generating Station
I - Industrial
Ipk - Industrial Park
LI - Light Industrial
O - Office
P - Park
PO - Post Office
R - Residential
Rc - Recreation
Rs - Research
S - Special Use
Sp - Sports
Sw - Sewage
T - Existing Town
V - Vacant Land
W - Wildlife
Wa - Warehouse
Rt.3
N.J. TPK
Hackensack River
PCK


Route 46
Berry's Creek
N.J. Turnpike
River
Route 3
Hackensack
N.J. Turnpike
Passaic
River
Figure 5
HACKENSACK
MEADOWLANDS
WETLAND
BIO-ZONES
-LEGEND-
1 OPEN BAY, MUD FLAT
2 LOW SALT MARSH
3 HIGH SALT MARSH
4 REED, CATTAIL, CORDGRASS MARSH
5 FRESH WATER, DIKED AREAS
1" = 5760'
0.92 inches
1 Mile
(HMDC, 1975)

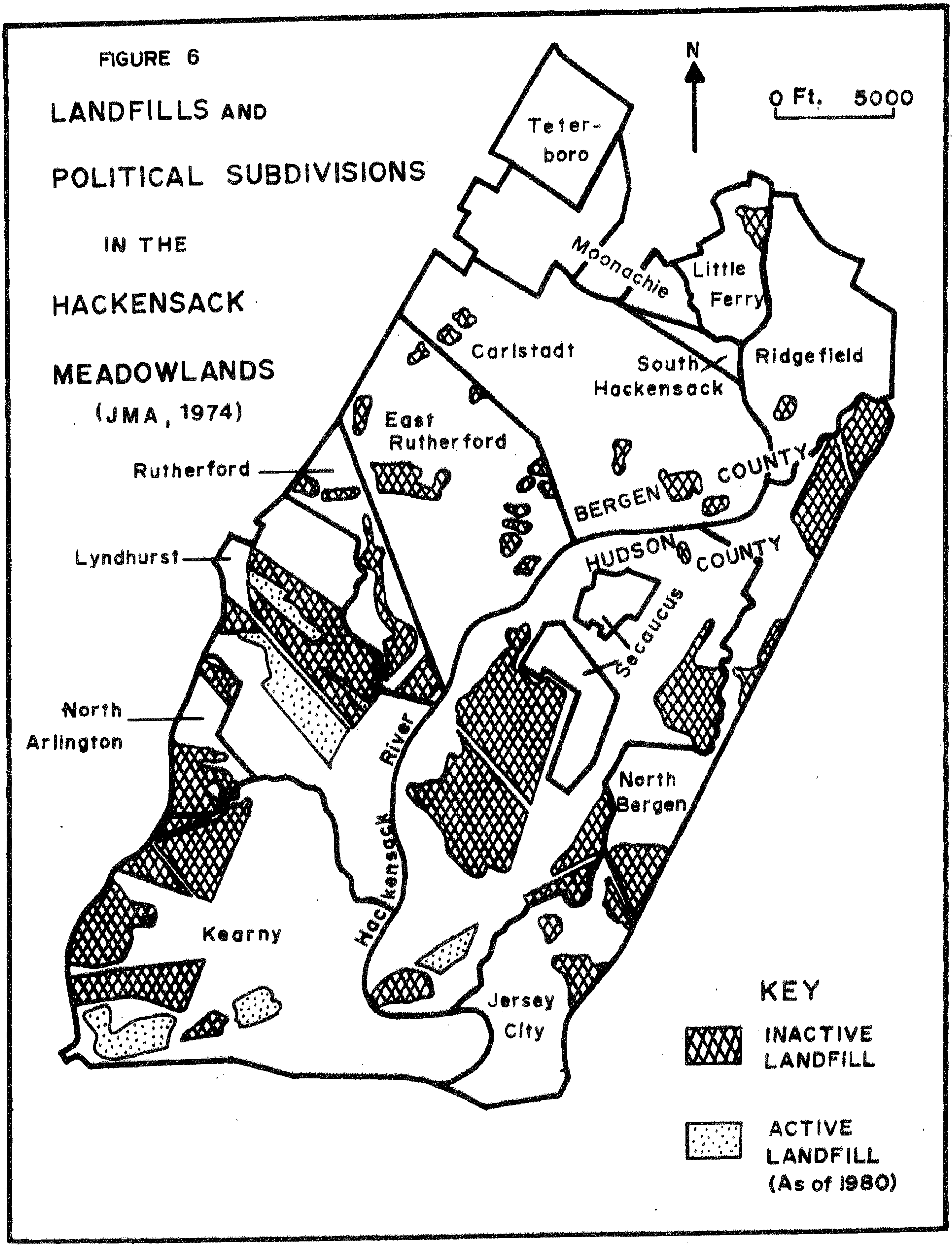


FIGURE 6
LANDFILLS AND
POLITICAL SUBDIVISIONS
IN THE
HACKENSACK
MEADOWLANDS
(JMA, 1974)
N
0 Ft. 5000
Teterboro
Moonachie
Little Ferry
Carlstadt
South Hackensack
Ridgefield
East Rutherford
Rutherford
BERGEN COUNTY
HUDSON COUNTY
Lyndhurst
Secaucus
North Arlington
Hackensack River
North Bergen
Kearny
Jersey City
KEY
INACTIVE LANDFILL
ACTIVE LANDFILL (As of 1980)

understanding of the combinations of complicated disrupting elements is inadequate (Mattson, 1978). It is, therefore, very gratifying to note the progress that has been made in the decade of the 1970's in stemming the deterioration of the Meadowlands ecosystem and in upgrading its quality.

An inventory of organisms in the several bio-zones of the District includes 19 varieties of wetland vegetation, 111 aquatic and wetland-associated birds, both breeding and migratory, 3 mammals (and 5 more around the edges of the marshland), 6 reptiles, 2 amphibians, 17 invertebrates, and 35 varieties of fish (HMDC, 1975).

Sanitary Landfill and Solid Waste Baler

According to the Solid Waste Administration Chief of the State Department of Environment Protection, 30,000 tons of waste are deposited each day (more than 10 million tons yearly) in the 300 solid-waste landfills of New Jersey. Slightly more than 20 percent comes from out of state: 1.7 million tons from Pennsylvania, 603,000 tons from New York, and 61,000 tons from Delaware (Friedman, 1980). Since these landfills will be filled to capacity by 1984, the state faces a formidable problem.

In the Hackensack Meadowlands in 1979, the active landfills were receiving 50,000 tons of solid waste weekly from 124 municipalities in six New Jersey counties (Fig. 6). The Hackensack Meadowlands Development Commission succeeded in reducing the 2,508 acres of garbage dumps and had sought to have all the landfills in its jurisdiction closed at the end of 1979. It has not been fully successful as the Legislature and the courts have granted brief extensions in some instances. Dumping of garbage from New York in the Meadowlands has been prohibited since 1973, but illegal dumping by private carters has taken place on a scale sufficiently large to disrupt the schedule for the gradual end to landfill dumping in Meadowlands (Boyd, 1980a). To complicate the matter further, the State Attorney General's office declared in June, 1980, that the Hackensack Meadowlands Development Commission cannot ban out-of state garbage from its landfills (Boyd, 1950b).

In order to block the migration of leachates into the water table, six-foot-high dikes have been built around the active land fills. At the DeKorte State Park site, excavations 15 to 20 feet deep were made through the peat, into the underlying clay. The excavations were back-filled with clay brought in from outside, except when it was locally available.

Solid Waste Baling Plant

The Baling plant was built by the Hackensack Meadowlands Development Commission at a cost of $6.9 million to dispose of garbage by compacting it into bales to be used as building blocks to contour the land for the Richard W. De Korte State Park. The 2,000-acre park will be built over dumps in the southwest part of the Meadowlands in the next decade or two.

The baler (Fig. 7) is on a 12.7 acre site about 0.4 miles north of Belleville Turnpike and 0.3 miles east of Schuyler Avenue, North Arlington, It is the largest garbage baling facility in the United States and has broken the world's record for compaction of garbage when it compacted 1,023 tons in 18-1/2 hours (Curico, 1980). It is a modular design; a second 1,000-ton per day unit will be installed at the plant by the end of 1981, at a cost of about $2 million. Twenty-eight private carting companies using the baler are charged $8.70 per ton for the waste processed there.

Baler Process:

Trucks enter into the warehouse and dump their garbage on the floor. Commercial trash is dumped on one side and residential garbage on the other. Front-end loaders move the trash and garbage onto a conveyor belt located at the bottom of a shallow trench in the middle of the floor, between the two types of garbage. Proportions of commercial and residential garbage are adjusted to maintain the desired density. The conveyor belt carries the trash and garbage up to a scale. When the pre-selected weight is reached, the conveyor belt automatically stops and the material drops into the compression chamber. It is compressed into a bale approximately 3 X 3 X 4 feet by three compression rams, delivering a final pressure of 2800 psi. The weight is kept constant, so that the size of the bale will vary with the type of garbage used. Straight cardboard or paper products produce a larger bale. The bales emerge from the compression chamber onto a loading platform and are automatically loaded onto a flat-bed trailer which hauls a load of 16 bales to the balefill site. There the bales are stacked to required elevations. They are stacked three bales high and covered with one foot of soil, giving a lift of 10 feet. There will be seven such 10-foot lifts, one above the other. The top will be covered with five feet of fill and topsoil, and will be landscaped to form a park. The first phase, about 10 percent of the park, at the south end of the landfill, should be completed by 1981. A total of 210,080 bales will be placed in the first bale-fill area. The end product of this operation is the State park which the bales will make possible. The average weight of a 3 X 3 X 4-foot bale, having a volume of 1 1/3 cu. yds. is 1.5 tons, (= .042 tons/cu. ft.). Five cu. yds. of residential garbage weighs about 1

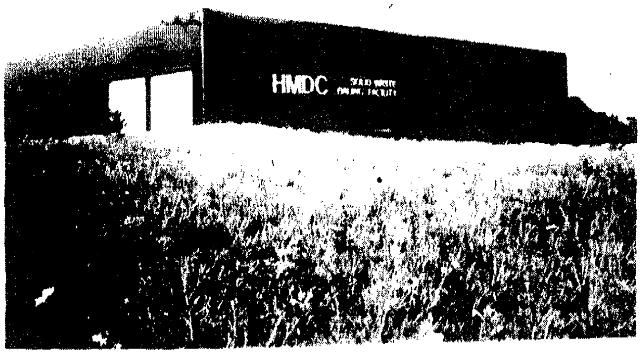


Fig. 7 Solid Waste Baler Facility in North Arlington, operated by the Hackensack Meadowlands Development Commission. A second baler unit will be installed in the two bays on the left. (Courtesy HMDC).

ton (= .0056 tons/cu. ft.). The bales are about seven times as dense as domestic garbage. They are so dense and coherent that a 50-ton truck can safely be driven over them, and sea gulls cannot penetrate them to get at the garbage.

Resource Recovery

The baler, which reduces the pressing need for new landfill sites, is an interim solution to the waste disposal problem in the Meadowlands. It will operate for 10 years and will be replaced by resource recovery plants to be built within the decade by counties now dumping solid waste in the Meadowlands. Bergen County's plant will be built in Ridgefield, next to Public Service Electric and Gas, to whom it will sell fuel recovered from garbage (Boyd, 1980 d). Ultimately, the solution would be total recycling of solid waste to yield fuel and resources recovery.

The New Jersey Department of Environmental Protection has proposed a bond issue to provide $50 million for planning, design, and construction of resource recovery facilities (Friedman, 1980). Senator Bill Bradley (N.J.) is planning to sponsor Federal legislation to authorize $196 million in loans over the next three years for facilities to convert waste into energy, from the nation's current level of 2 million tons a year to 18 million tons a year by 1990 (Gettlin, 1980). The Hackensack Meadowland Commission's chief engineer estimates that the legislation would provide up to $28 million in federal loans locally for a project to convert 3,000 tons of urban waste daily into fuel, having an equivalence of 1.2 million barrels of oil per year (Gettlin, 1980). However, an estimated $100 million would be needed to construct the two huge garbage recycling plants needed to handle the 50,000 tons of waste that the 120 or so New Jersey towns now dump in the Meadowlands (Hanley, 1979).

Methane Gas

Recovery of methane gas from the Meadowlands dumps has been considered by Public Service Electric and Gas. One engineer's conservative estimate in 1979 was that the dumps could yield 100 billion B.T.U.'s per year, with a then sales value of $200,000. The quantity of methane available, however, may possibly be 10 to 20 times the estimate (Hanley, 1979).

It obviously makes sense to make of garbage a valuable resource rather than a burdensome, land-consuming problem. This approach must be implemented quickly, before we run out of landfill space.

De Korte State Park

The Richard W. De Korte State Park will be created over garbage landfill in the southwest part of the Meadowlands (Fig. 8) and will extend from Kearny through North Arlington into Lyndhurst. The park will cover 2,000 acres, 814 of which are landfill where, over a period of 40 years, mounds of garbage have grown to heights of over 100 feet. Altogether, some 16 million cubic yards of garbage dumped in landfills or baled will be transformed into landscaped hills between 120 and 140 feet high in the finished park. The park will also include the 405-acre Kearny fresh-water marsh, the best such wildlife wetland in New Jersey (Kane, 1978).

Within 10 miles of the park live more than 11 million people. The park will be two-and-one-half times larger than New York's Central Park. Its master plan calls for walkways, hiking and horse trails, wildlife observation areas, boating, fishing, ballfields, campsites, tennis, swimming, and skiing "facilities" (Fig. 8).

According to the Chief environmental officer of the Hackensack Meadowlands Development Commission, the park could be fully developed in from 10 to 20 years, at a cost of between $50 and $85 million (Grant, 1980).

This was one of three state urban parks given priority in the Green Acres bond issue referendum, successfully passed in 1979, which permitted the first phase of construction to get underway. Public demand and the availability of funding will determine how soon the park can be completed.

Real estate values are expected to appreciate markedly along the western border of the park. The development of a 25-story condominium complex overlooking the park and Meadowlands has already been proposed for North Arlington. This could mean millions of

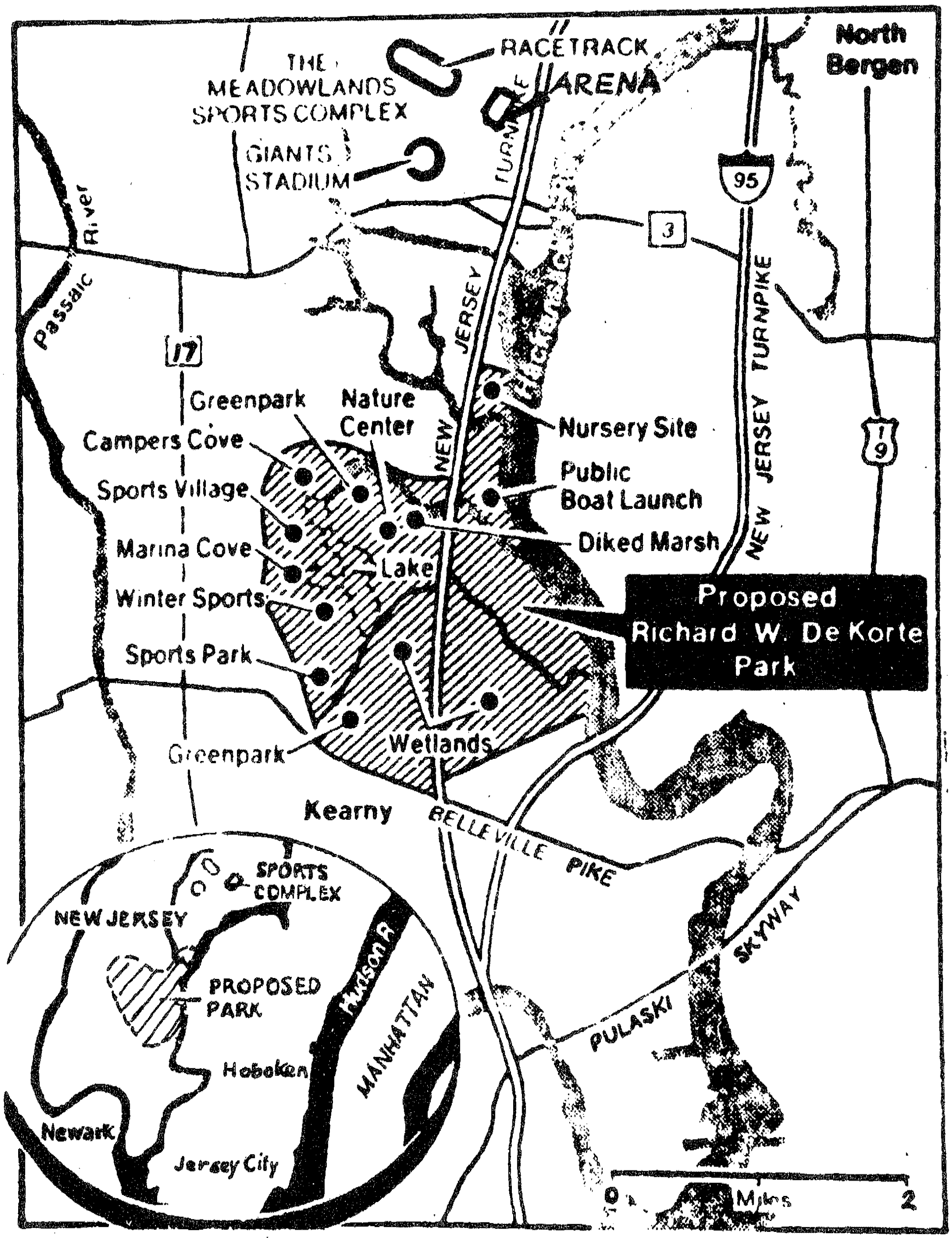


Fig. 8 The proposed Richard W. DeKorte State Park, extending over 2,000 acres, will afford a variety of recreational activities for urban dwellers, as well as wetlands for wildlife (after Hanley, 1979a).

dollars in new tax revenues for North Arlington (Fritzky, 1980).

Mercury Contamination (Berry's Creek)

The west boundary of the Meadowlands Sports Complex is Berry's Creek, which meanders southeastward before joining the Hackensack River at a point opposite the south end of the Harmon Cove development. Mercury contamination of the Berry's Creek tidal marsh was discovered in 1972, in an environmental impact study made prior to the construction of the Giants Stadium and the Meadowlands Racetrack.

Federal and New Jersey environmental and health authorities were already aware of the source of the contamination in 1969. That year they complained about mercury-laden waste water being discharged by a mercury processing plant located on a small upstream tributary of Berry's Creek, in the Borough of Wood-Ridge. The plant was shut down in 1973, but in the 36 year of its operation, an estimated 300 tons of mercury were discharged into drainage ditches and dumped onto the land. Levels of mercury exceeded the standard of 1 ppm in the marsh several miles downstream from the plant.

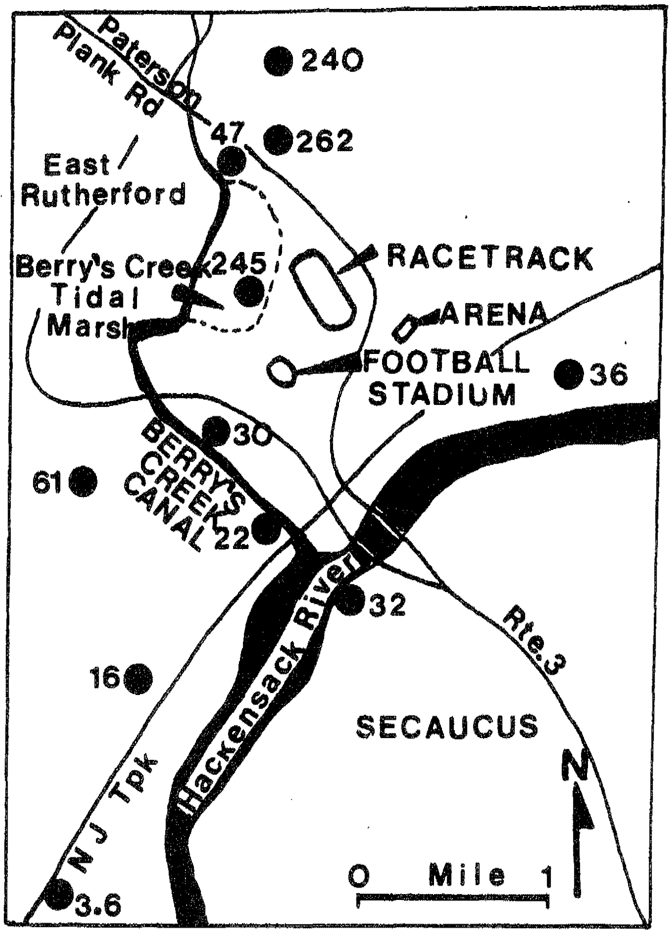


Fig. 9 Maximum mercury concentrations in parts per million at several soil sampling sites in the Hackensack Meadowlands. Mercury contamination begins at 1 ppm (After Hanley, 1978).

Jack McCormick and Associates of Berwyn, Pennsylvania, estimated that the soil in the 40-acre site once occupied by the plant still contained 286 tons of mercury (Hanley, 1978). This represents a mercury content 123,000 times higher than the normal concentration of mercury in soils and sediments, which is about 0.05 ppm (Klein, 1972). Soil samples in the Berry's Creek tidal marsh showed excessive levels of mercury to depths of over six feet. High mercury levels were detected to a distance of up to three miles south, and to lesser distances east and north of the marsh (Fig. 9).

Sediments near the plant contained up to 8,475 ppm of mercury, which is two-and-a-half times as high as any previously reported in the world. The water of Berry's creek, two-and-a-half miles south of the plant, averaged 9.9 ppm of mercury in 1974-1976 (Hanley, 1978).

An impermeable dike around Berry's Creek may be relied upon to keep the mercury from moving into the creek, until a better, more feasible way can be developed. Paving the marsh with asphalt and using it as a parking lot could also help contain the mercury.

Preliminary evidence from plant and animal tissue studies indicates that alarming amounts of mercury have not entered the food chain in the Hackensack Estuary. Monitoring may be necessary for decades before we will know the extent of the risk the mercury represents, if any, to people in the area. This, however, is not being done.

Meadowlands Sports Complex

The New Jersey Meadowlands Sports and Exposition Authority has constructed the Meadowlands Racetrack, Giants Stadium, and the Meadowlands Arena. This Sports Complex lies four miles west of the Lincoln Tunnel to Manhattan. It is bounded by Paterson Plank Road on the north, New Jersey Route 3 on the south, the New Jersey Turnpike on the east, and the estuarine Berry's Creek on the west (Fig. 10). The total area of the complex is 558 acres, of which 67 acres on the east side of Route 20 are devoted to the arena, which was constructed after the racetrack and stadium.

The racetrack has complete facilities for thoroughbred and harness racing. There is a one-mile convertible track constructed of compacted limestone for harness racing with an overlay of sandy loam for thoroughbred racing. Inside the one-mile track is a 7/8 mile turf track for the thoroughbred racing. There are a six-level heated and air-conditioned grandstand seating 9,300 spectators, and an out-door standee ramp for about 26,000 spectators.

The football stadium (Fig. 11) seats 76,500 spectators and has adjacent parking for 20,000 automobiles and 400 buses (N.J. Sports and Exposition Authority, 1975). The racetrack and stadium opened in 1976. The arena, to be completed in 1981, will seat 20,000 spectators for indoor sports such as basketball, hockey, ice-skating, as well as exhibitions. The trusses supporting the roof (Fig. 12) will span 428 feet, producing a column-free interior. There will be additional parking for 4,000 cars adjacent to the arena.

Extensive supporting facilities were constructed. For example, the racetrack has 12 barns to provide housing for a total of 1,320 horses, blacksmith shops, five dormitories providing facilities for 560 grooms, administration and cafeteria building, and storage facilities for feed, harness, and other equipment. The Pegasus Restaurant atop the track's grandstand can serve 2,250 patrons nightly. It employs over 300 people and occupies 100,000 square feet of floor space. Geologists may be particularly interested to know that 36,000

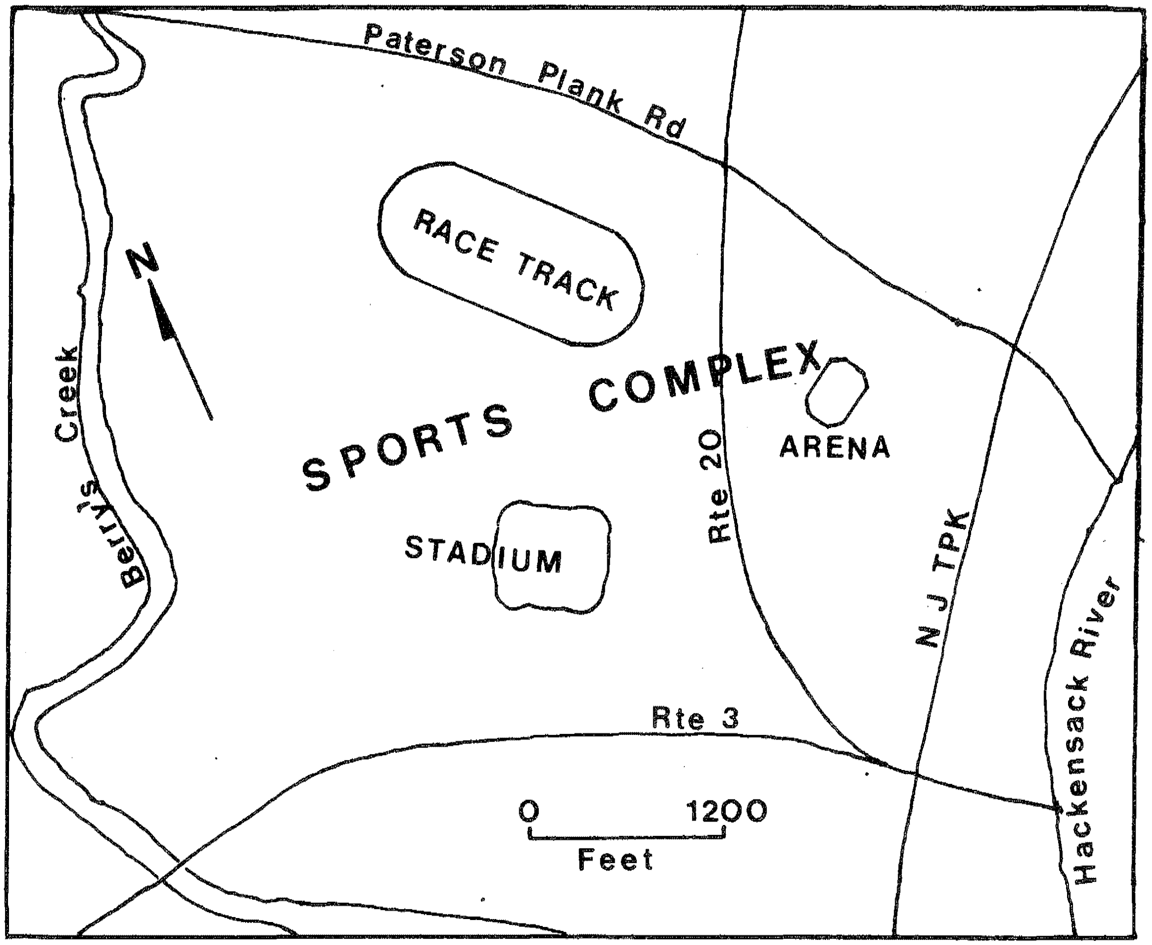


Fig. 10 New Jersey Sports Complex in the Meadowlands is bounded by Paterson Plank Road on the north, Rte 3 on the south, Berry's Creek on the West, and New Jersey Turnpike on the east.

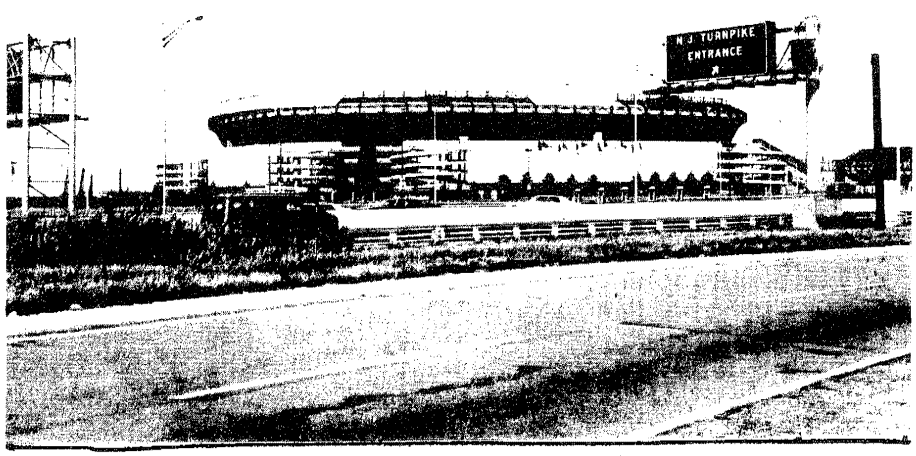


Fig. 11 Giants Football Stadium, Meadowlands Sports Complex, looking NE. The Racetrack is to the left and the Arena to the right.

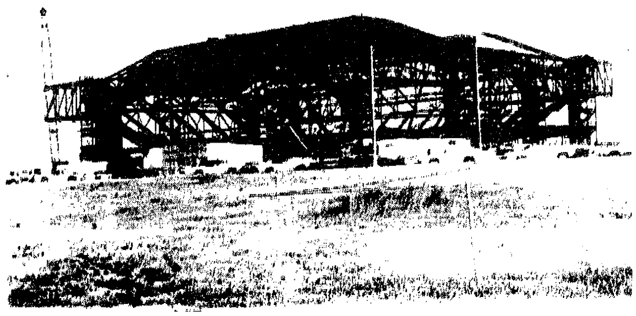


Fig. 12 Meadowlands Arena under construction.

square feet of marble, weighing 350,000 lbs. were used for the floors. Dolcetto, a beige-colored marble from Italy and Verde antique, a green-colored variety from Vermont, cover pedestrian walkways and heavily travelled areas such as dining rooms, bars, and mutuel windows. If the 11,516 pieces of marble used in Pegasus were held end-to-end, they would cross the Verrazano bridge between Brooklyn and Staten Island two and a half times (Anonymous, 1979).

In the Sports Complex area west of Route 20 (racetrack and stadium) about 3.2 million cubic yards of sand (15,000 cu. yds/day) were pumped in hydraulically via an 18-inch steel pipeline originating at the Hudson River. The sand was dredged from the New York Bight, barged up the Hudson River, mixed with river water, and pumped five miles to the site. It was spread in a layer two-to-eight feet thick over the miscellaneous fill. The Hudson River water, having a salinity of 15 ppt, drained from the discharged sand into the Hackensack River at a rate of 20 million gallons per day, changing the salinity gradient of the river that year (1974). Instead of a consistent salinity gradient for an estuary, the river showed higher salinities in its upper portions and lower, downstream, over the discharge period (HMDC, 1975). One thousand cu. yds. of sand fill were put under the racetrack to aid settlement. (Oral communication, F.H. Werneke, Director Engineering, N.J. Sports and Exposition Authority, May 19, 1980). At the arena site, within the area enclosed by the cofferdam, all the existing fill and the organic soil were removed down to the varved clays. Engineered fill was then deposited to achieve subgrade level for the concrete floor slabs. The varved clays below subgrade level at the arena site are 14 to 23 feet thick (CWDD, 1978). The parking lots are underlain by engineered fill placed over the meadow mat.

The major buildings are supported by steel H-piles or concrete-filled pipe piles driven to refusal in the glacial till or the bedrock.

In the construction of the west spur of the New Jersey Turnpike, incidently, the sand foundation was hydraulic fill dredged from Raritan Bay and barged up the Hackensack River to various points from where it was pumped to the turnpike.

Since colonial days significant development of the Meadowlands has been deterred because of tidal flooding and the presence of peat underlain by weak, varved clay deposited on the bottom of glacial Lake Hackensack. Since the Sports Complex site lies in the flood plains of the estuarine Hackensack River and Berry's Creek, it had to be protected from flooding with cofferdams and a system of dikes, reaching an elevation of 10.0 feet above mean sea level. The land elevation within the diked area was raised to an elevation of 6.0 feet (msl) by moving in fill. The maximum high-water elevation attained here was 8.4 feet in 1960 (N.J. Sports and Exposition Authority, 1975).

The dikes are 12 feet in vertical dimension. Their top is at an elevation of 10.0 feet; thus they extend down several feet into the underlying clay. Along the middle of the dikes is a two-foot-wide core of bentonite and sand emplaced as a slurry (oral communication, F.H. Werneke, May 19, 1980). The site is diked along Berry's Creek and along the roadbeds of the highways around the site's perimeter: Paterson Plank Road, Route 20, Route 3, and the New Jersey Turnpike (Figure 10). Where the roads are below 10.0 feet in elevation, the land is sloped up to that elevation away from the road.

Cofferdams of corrugated sheet-steel piling were constructed around the football stadium, race track grandstand, and arena to protect the building sites from flooding during the excavation and foundation work. The cofferdam piles, about 12 to 15 feet long, were driven down to refusal, the longer piles being nearer the river, as the valley floor slopes in that direction. The cofferdams were left in place to afford additional protection.

Using a calibrated computer model of the Hackensack Meadowlands channels and marshes, the maximum elevations of the Hackensack River were predicted for the Army Corps of Engineers, for 10 and 100-year intervals (TAMS, 1975). The model was modified to include anticipated development according to the Master Plan for the District (HMDC, 1971). The projections suggest that the maximum water elevation near the Sports Complex (probable recurrence interval of 100 years commonly used for design purposes) will be 6.4 feet (msl) by 1984, which is safely below the 10-foot elevation of the dikes. The projection for the highest level of flooding, however, is 10.7 feet (msl). It would occur in 1984 by the Standard Project Tide, whose return period is undetermined but in excess of 100 years (TAM, 1975). This could pose a problem in the near future.

Fig. 13 Sawmill Creek Wildlife Management area, Kearny, N.J. Cedar stumps, exposed at low tide, indicate the former presence of Cedar forests in the Meadowlands. This area will be part of the DeKorte State Park. View is to NW from Conrail tracks. (Courtesy J. Szalkowski).

The natural surface of the Meadowlands consists of a highly organic soil, either peat or meadow mat. If woody fragments are abundant, the organic deposit is called peat; if the material is mostly root stalks of the common root grass it is called meadow mat. Woody remains of the cedar forests that covered much of the meadowlands a couple of centuries ago are common in the peat (Fig. 13). In addition to the organic material, in various stages of decay, there is fine-grained admixed mineral matter that is carried into the estuary at high tides and settles in the quiet water among the marsh plants during slack water intervals. During dry periods in the summer months the meadow mat and peat may catch fire, often by spontaneous combustion, burning for days and constituting a serious pollution and safety hazard.

Two subsurface investigation programs were conducted before the racetrack and stadium were built. A preliminary program, included seven deep borings, 10 shallow borings, and 12 probes. The second program consisted of 118 borings, 306 auger holes, 250 probes, and 15 test pits (N.J. Sports and Exposition Authority, 1975). At the arena site there were, in addition, seven exploratory borings, two undisturbed sample borings and 11 test pits (CWDD, 1978).

The borings show (Figs.14 and 15) that man-made fill, four to sixteen feet in thickness, covered about half the area of the site. The meadow mat (peat and organic silt) was about two-to-eight feet thick, but generally less than five and one-half feet. Elsewhere in the Meadowlands, it may reach 12 feet in thickness.

Under the meadow mat is a gray medium-to-fine sand between one-and-four feet thick. It overlies gray to red-brown varved clays and silts varying in thickness from near zero to about 110 feet. The varves are alternating one-eighth-inch layers of silt (summer deposition) and clay (winter deposition) in glacial Lake Hackensack.

Underlying the varved clay is glacial till, five-to-forty feet in thickness. It consists of red-brown coarse-to-fine sand, some clay and silt, and medium-to-fine gravel. Below the till is the red-brown shale of the Newark series, whose quality is extremely variable, from decomposed to sound (CWDD, 1978). The top of the bedrock varies in elevation from - 10 feet under Route 20, to -120 feet at the western corner of the site (N.J.S.E.A., 1975).

The meadow mat, a highly organic soil compresses in three stages when loaded. They are: initial compression, primary consolidation, and secondary settlement. The first two stages occur quickly, within a few weeks, but the last, secondary settlement stage takes place gradually, over a period of years.

Engineered and miscellaneous fill, that had been present in almost half the site, supported some pre-existing buildings and roads. Engineered fill, such as compact select sand, when placed on top of the varved clay proved a stable foundation for light buildings and roads. However, the miscellaneous fill, which includes concrete, bricks, steel, wood and other demolition materials, when dumped directly on the meadow mat, consolidated it unevenly and resulted in mud waves. Polito Road, in Lyndhurst, a heavily used truck route south of the intersection between Routes 3 and 21 has developed a washboard surface because of unequal settling. The road was built over the meadow mat without a proper sub-base.

Bergen County Sewage Disposal Plant

The Bergen County Sewage Disposal plant is operated by the Bergen County Utilities Authority. It is located on a 100-acre site at the foot of Mehrhof Road, on the west bank of the Hackensack River in Little Ferry. The eastern Bergen County area served by the plant includes 43 municipalities with an estimated population of 500,000. The area is about 90 percent sewered. The plant was originally built in 1950, with a capacity of 20 million gallons per day. In 1960 it was expanded to 50 mgd. In 1975, the first phase of a new expansion brought the capacity to 62.5 mgd. The current, second phase, costing $37 million will give the plant a capacity

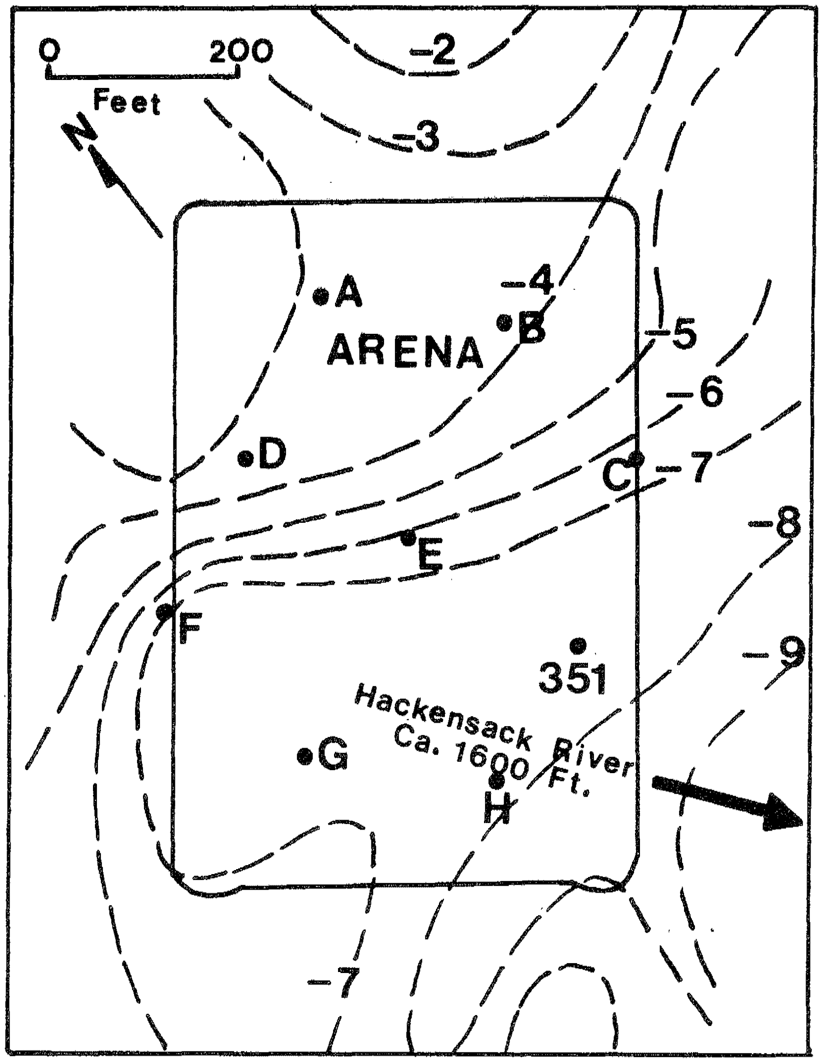


Fig. 14 Meadowlands Arena showing boring sites (black dots) and subsurface contours to top of firm material (top of sand stratum of top of varved clay). See Figure 15. (After CWDD, 1978).

of 75 mgd which, it is anticipated, will do until the year 2000. The plant currently gets an average flow of 65 - 70 mgd. During severe rainstorms, or prolonged periods of rain, when the inflow reaches 100 mgd, the excess is by-passed into the river.

The establishment of this plant permitted the continuing rapid expansion of the population of Bergen County in the years following World War II. Prior to the plant's completion, sewage treatment plants in several towns in eastern Bergen County were discharging inadequately treated effluent, polluting surface drainage. Some towns stopped issuing building permits because overflowing septic tanks were saturating the ground. The plant has caused a reversal of the pollution problem, an upgrading of the quality of ground and surface water in the area, and it has permitted the elimination of 130,000 septic tanks (Bergen County Sewer Authority, 1975). Borings for the new construction extend down to glacial sands at a depth of 70 feet. Overlying the sands are lake clays, organic clays, and silts. Timber piles are used for the structures (Fig. 16), except where hard clay must be penetrated by steel piles. The last two buildings are supported by steel sheeting which penetrates 10 feet of glacial material.

Treatment Process Description

Raw sewage enters the plant by gravity flow through 8-foot-diameter trunk sewer lines about 30 feet underground. The raw sewage, mostly water, contains less than one percent residential and industrial solids. After screening, blending, and removal of grit, the raw sewage is pumped into eight primary settling tanks (four more will be added), where it is retained for one hour

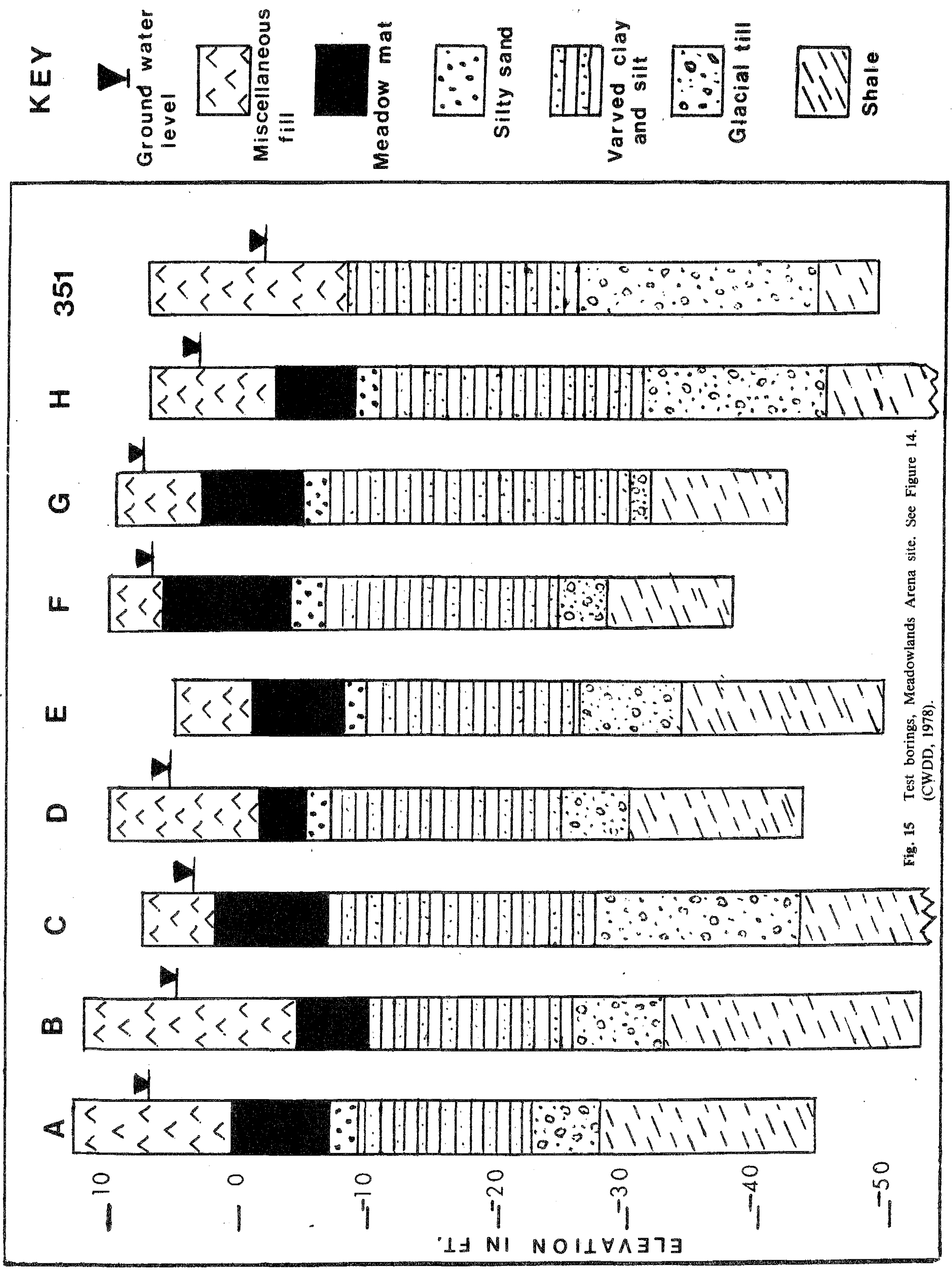


Fig. 15 Test borings, Meadowlands Arena site. See Figure 14. (CWDD, 1978).

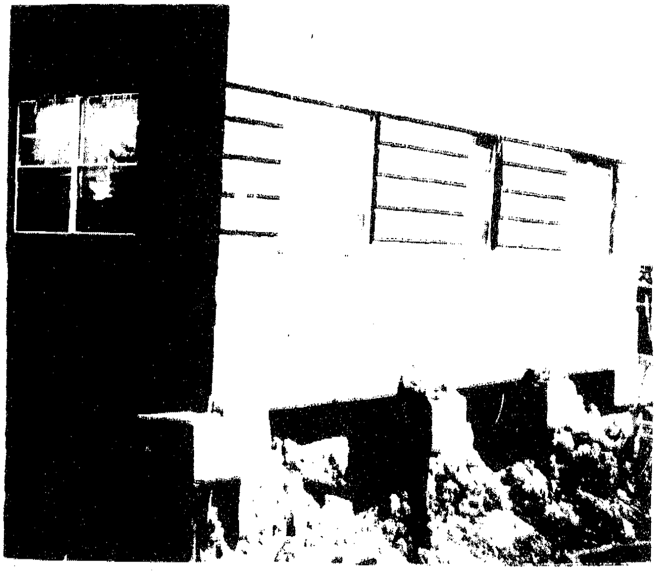


Fig. 16 Bergen County Utilities Authority, Sewage treatment plant office building, Little Ferry, N.J. Excavation has exposed concrete cap foundation over timber pilings.

while the sludge settles to the bottom. The sludge is then pumped to sludge thickening tanks. Grease and scum, skimmed from the top of the sewage waters in the primary settling tanks, is stored in scum tanks for use in the anaerobic digestion process. The effluent from the primary settling tanks flows by gravity to aeration tanks where activated sludge (micro-organisms) are mixed in. The micro-organisms are brought in from the settled matter in the final settling tanks. Air, bubbled through the mixture in the aeration tanks, furnishes oxygen for the micro-organisms which degrade the organic matter in the sewage in six hours. The aeration tanks effluent flows by gravity into the secondary settling tanks. There, the suspended material is removed, leaving a clarified effluent low in suspended solids and dissolved organic content. This effluent is disinfected by treatment with chlorine and discharged into the Hackensack River.

The secondary settling tank sludge is routed to the sludge thickening tanks for mixing with the primary sludge. The sludge mixture, containing 94 percent water, is pumped to the anaerobic digesters where it is retained for fifteen days, at a temperature of 95 °F, for bacterial decomposition to gas containing approximately 65 percent methane and 35 percent carbon dioxide. About one million cubic feet of methane gas, with a heat content of 600 Btu per cubic foot, are produced daily. The gas fuels the three 900-H.P. and one 500-H.P. diesel engines that run the aerators in the aeration tanks. The digested sludge is pumped into holding tanks and then barged to a disposal site in the New York Bight.

About 237,000 lbs. of wet sludge are produced daily. Because of its heavy metal content (Table 1) and the great variability in composition from day to day, the sludge cannot be used in agriculture. The toxic substances dumped into the sewer system by industry make this sludge unusable, unlike the sludge from a residential community.

Liquid Natural Gas Storage Tanks and View of Hackensack River

Two large liquid natural gas storage tanks stand on a 44-acre marshland site on the west side of the Hackensack River, about 1,000 feet from the river and less than one mile from the Meadowlands arena (Fig. 17).

The first of the 135-foot high tanks was built for the Transcontinental Gas Pipeline Corporation (Transco) in 1970, and the second one shortly thereafter. Each tank can hold 290,000 barrels of L.N.G., equivalent to one billion feet of natural gas (Hanley, 1979). The gas arrives at the tanks via pipeline from the Gulf of Mexico fields and is liquified at minus 260 degrees Fahrenheit. During the heating season, from November to April, it is reheated to a gaseous state and is distributed by several utility companies for residential and industrial use.

At first the Hackensack Meadowlands Development Commission tried to stop the construction of the LNG tanks in the Federal courts, and went all the way to the U.S. Supreme Court, but lost. The Commission argued that the presence of the tanks would disrupt its zoning plans for housing developments around the site. Concern was expressed for the danger of huge combustible vapor clouds of LNG which might leak from the tanks. One industrial zoning and environmental expert declared he "wouldn't want to live within a mile of a tank site" (Hanley, 1979).

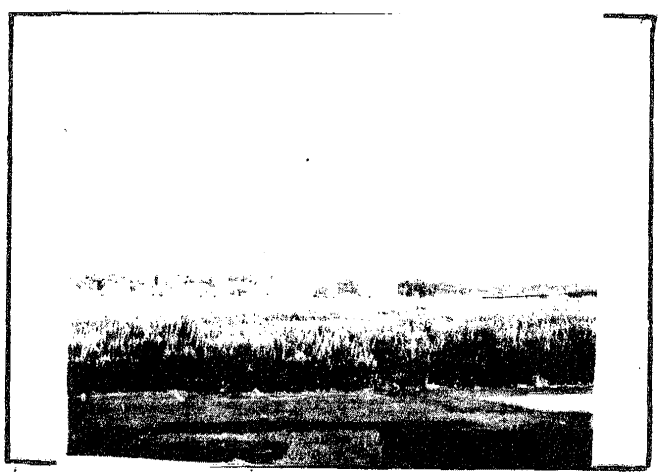


Fig. 17 Liquid Natural Gas storage tanks, Carlstadt N.J. looking E from Washington Ave., about one mile away. Behind the tanks is the back-slope of the Palisades ridge and, in the far distance, the New York Skyline.

TABLE 1

SLUDGE ANALYSIS

Bergen County Sewage Disposal Plant, Little Ferry, N.J. (CBA, 1978)

(All results as mg/l)

Heavy Metals	Raw 12/1-2/77		Digested 12/1-2/77		Raw 12/7/77		Digested 12/7/77	
	Total Sludge	Sludge Filtrate	Total Sludge	Sludge Filtrate	Total Sludge	Sludge Filtrate	Total Sludge	Sludge Filtrate
Mercury	.31	.008	.25	.005	.55	.005	.29	.006
Lead	25.3	< .10	23.6	< .10	29.2	< .10	24.2	< .10
Copper	48	.04	41	.06	61	.04	49	.06
Zinc	107	.03	83	.05	130	.04	84	.07
Tot. Chromium	40.4	< .05	31.4	< .04	44.5	< .05	34.0	< .06
Nickel	17.9	.68	13.8	.14	19.4	.76	14.5	.13
Cadmium	2.48	<0.01	2.38	< 0.01	4.10	< 0.01	2.76	<0.01
Selenium	< .02	< .004	< .02	< .004	.10	< .004	< .02	< .004
Vanadium	1.1	< .3	.6	< .3	.8	< .3	.8	< .3
Arsenic	.38	< .004	.40	< .004	.49	< .004	.42	< .004
Beryllium	.08	<0.02	0.04	< 0.02	0.06	< 0.02	0.04	<0.02

Now, ironically the Commission's master plan envisages a 781-acre development of mid-and high-rise apartment houses for 35,000 people to be located approximately within one mile of the tanks; and the Commission is fighting in the courts the opposition to its plan from a group of local mayors. The Commission argues that the Federal courts, in accepting the safety standards employed by Transco, has in effect discredited those who would question their safety. According to the Commission's chief environmental officer, "The courts held that the tanks were designed to be safe and we were told that our vapor-cloud argument was none of our business to make." (Hanley, 1979). The capacity of these L.N.G. tanks, incidentally, is about seven times larger than that of the two tanks that split apart in Cleveland in 1944, producing a fireball and explosion killing 130 people.

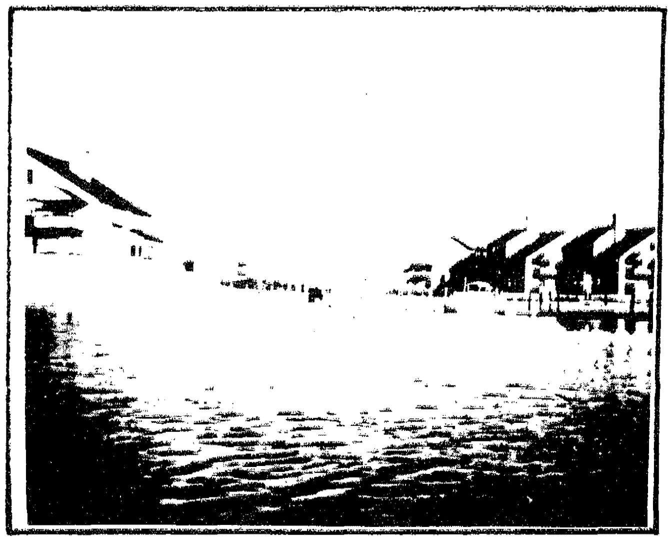


Fig. 18 Townhouse and Marina Harmon Cove Development of the Hartz Mountain Industries, Inc., Secaucus, N.J. (Courtesy HMDC).

Harmon Cove Development, Hartz Mountain Industries

Harmon Cove has been called "one of the most remarkable of all developments in the metropolitan area" (Oser, 1980). So far, Hartz Mountain Industries has invested some $300 million in this planned unit development in Secaucus. There is a housing component of 600 townhouses along the river (Fig.18), a 312-room Hilton hotel, racquet club, movie theatres, marina, 10-story office building, multi-deck parking garage, hospital, and an industrial park of some 80 structures. At the south end of the tract is the 25-story, high-rise condominium, Harmon Cove Towers, consisting of 1,480 apartments. An additional 1,215 units of mid-rise and low-rise buildings will be built by 1985 or 1987, depending on market conditions (Oser, 1980).

Hartz Mountain Industries purchased this 238-acre site in 1969. It extends along the east bank of the Hackensack River for about 1.7 miles and has a width of about 0.3 miles. Development of the site began almost immediately. The following engineering details were provided by Mr. Michael McNally, Vice President of Engineering and Planning, Hartz Mountain Industries (oral communication, June 3, 1980).

In 1970, two million cubic yards of natural fill was brought in at $1.63/yrd (in place). The fill came from a Federal dredging operation off Staten Island. It was carried by the dredge Hydromar to Jersey City. From there is was pumped via a two-mile, 18-inch diameter, steel pipeline which was strung to the site. The fill was deposited to a depth of five to six feet through 12-inch diameter distribution pipes.

Miscellaneous fill, as needed in construction, is trucked in currently from Manhattan and New Jersey. The fill consists of Manhattan schist from building-site excavations, bricks, stone, and debris from demolished buildings, and miscellaneous overburden.

Miscellaneous artificial fill and dredge spoil up to 10 feet thick were present in portions of the site prior to construction. The sub-fill stratigraphy is in general similar to that at the Sports Complex site (Fig. 15). Tidal marsh deposits 3 to 12 feet thick occurred at the surface, where fill had not been placed. The marsh deposits consist of peat and partially decomposed organic materials admixed with some fluviatile silts, clays, and fine sands (JMA, 1974).

The organic accumulations are considered to be highly compressible, to approximately 25 percent to 50 percent of their original thickness, over a period of a century (Woodward-Clyde and Associates, Inc., in JMA, 1978). The organic deposits are, therefore, commonly removed and replaced with relatively incompressible fill.

Beneath the meadow mat are varved silts and clays ranging in thickness from about one foot under Meadowlands Parkway to more than 50 feet near the Hackensack River (JMA, 1974). The varved clays have an upper, stiff zone that is incompressible, possibly because of past dessication. Here it is not more than 10 feet thick. The clays underneath are soft and highly compressible (JMA, 1974). Most of the compression would occur within 3 to 5 years after fill is placed over the clay, but some compression could be expected for many years. (JMA, 1978).

The till under the varved clays is the highest layer capable of supporting heavy foundation loads on pilings. It is very dense and consists of heterogeneous fragments of the Brunswick Formation ranging in size from clay to boulders. The till thickness is uneven, but may be 20 to 30 feet thick in some borings. The till surface slopes from an elevation of -10 feet (msl) beneath Meadowlands Parkway to more than -70 feet (msl) beneath the Hackensack River, towards the northwest (JMA, 1974).

The bedrock is the soft red shale of the Brunswick Formation of the Newark Series. It dips northwestward at between 15° and 20°. The bedrock surface is higher toward the east, where its elevation is approximately -40 (msl). In the southwest corner of the site its minimum elevation is about -100 (msl). About 500 feet east of the site, however, bedrock lies at about +1 foot (msl) (JMA, 1974).

All the initial buildings on the site (larger warehouse buildings) were built on 40-ton-capacity steel pilings, driven to depth of refusal, which is about two-to-five-feet penetration into the glacial till. Refusal is reached at a depth of 25 to 50 feet. The town houses were constructed next. They were built on 20-ton-capacity piles of timber and steel. This was an innovative piling system developed here. First, untreated timber piles of 40-to-60-feet in length are driven in their entirety below the ground water table, which stands uniformly at an elevation of 3 feet (msl). Only immediately adjacent to the Hackensack River does it fall to sea level. The water table shows no significant fluctuations with seasons or rainstorms. Since air is excluded below the water table, rotting of the wood doesn't take place and untreated wood pilings can be used at considerable savings, as compared to treated pilings ($0.45 per linear foot vs. $2.00 per linear foot). Steel pipe of eight-inch diameter and 12-foot length is driven several feet into the top of the wood piling, affording a tight seal. The pipe is filled with concrete and capped at the required height.

The 24-story high-rise structures are supported by 1/2 inch, steel-walled, 12-inch-diameter piles. The piles are 35 to 70 feet long, lengthening towards the river, and 80 feet long at the river's edge. They rest on 3/4 inch steel bearing-plate, within till overlying the bedrock. The pilings have a designed load of 100 tons and are tested to 200 tons. The pilings are filled with concrete. Corrosion of the steel in the upper few feet of the pilings is anticipated, where they pass through cinder surface-fill. To compensate for the corrosion, steel bars of equal surface area to the pipe are embedded in the concrete, near the top of the pilings.

Under warehouses, seven piles are used per 1,000 square feet of building. Stringer floor-supports bridge the pilings. Under certain warehouses, where organic material was thin (two to three feet thick), surcharges of sand were placed over the meadow mat for six months to compress the underlying organic material. The top of the surcharge is 15 to 18 feet in elevation. After the primary settlement was gotten out, all but about five to eight feet of sand was removed, leaving a finished floor elevation of 10 feet. The excess sand was trucked away for use elsewhere in the development. Additional minor settlement that may occur later does not affect the building, as it rests on pilings that extend down through the organic material and clay.

Where the organic material was thicker, it was mucked out and new fill put in its place. Muck-out can be a resource or an expense for the builder depending on the circumstances. It costs $1.50 per cubic yard to excavate and $1.50 per cubic yard to truck off the site. Compacted, new fill costs $5.00 per cubic yard, in place. If the muck-out can be sold for use nearby, as daily soil cover in a sanitary landfill, for example, then it can be a resource and a source of revenue.

Incidentally, borings and other soil investigations, foundation loads, footings, pilings, and similar matters must conform to the Master Plan - Building Code Foundations, developed by the Hackensack Meadowlands Development Commission (HMDC, 1969).

ROAD LOG

Mileage	Refer to map showing numbered stops (Fig. 3).
0.0	Parking lot S of Boyden Hall, Rutgers University, Newark. Go E, N, and E via Warren, Washington and Bridge Streets.
0.8	Cross Passaic River, E on Harrison Street.
1.8	N on Schuyler Avenue which follows bluff marking west margin of Hackensack Meadowlands.
3.2	Midland Ave. Turn right, park immediately. **STOP 1** (Kearny) Overlook, south end of the Hackensack Meadowlands. Panorama (left to right) shows sanitary landfills, more than 100 feet in elevation, over which the first section of the De Korte State Park will be erected; the New York City skyline including the World Trade Center towers (about 7 miles distant); Snake Hill; New Jersey Turnpike; Pulaski Skyway (Routes 1 and 9); and the Bayonne Bridge arch to Staten Island. The southern boundary of the Hackensack Meadowlands District, which is under the jurisdiction of the Hackensack Meadowlands Development Commission, lies about ½ mile north of the Pulaski Skyway. The meadowland environment continues south of the District boundary.
3.9	Turn right on Belleville Turnpike which descends into the Meadowlands.

4.4 Turn left immediately after passing under RR trestle. Take left fork. Follow Baler Blvd.

4.9 HMDC Solid Waste Baling Facility. Park adjacent to the large brown building (Fig. 7).
STOP 2. Tour of facility. See text above.

Return to Schuyler Ave.

3.9 N on Schuyler Ave., at Belleville Turnpike.

3.95 Right turn on Morton Place to dead-end (1 block). Follow dirt path at right corner of street partially down the bluff. Baler building and sanitary landfills to the east (Fig. 19).

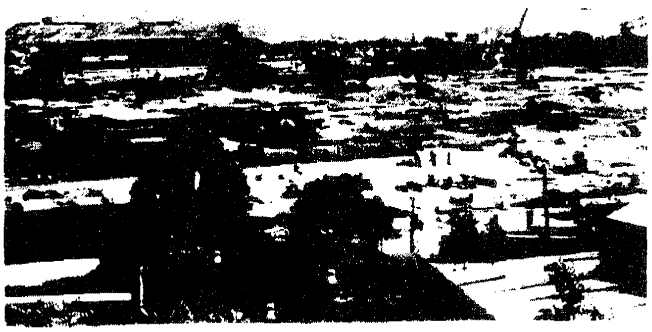


Fig. 19 Looking E across Meadowlands from vicinity of Schuyler Copper Mine, North Arlington, N.J. The Baler facility and landfill mounds are in middle distance; World Trade Center towers in the distance.

STOP 3 (North Arlington)

This is the approximate location of the Schuyler copper mine. The shaft was a couple of hundred feet to the NW. The mine was discovered about 1719 and was probably the first copper mine in the United States. It shipped 110 casks of ore from New York in 1721 (Lewis, 1907). Much detailed historical information can be found in Woodward (1944).

The mine was a source of considerable wealth before the Revolutionary War and continued to be worked intermittently until 1865. The primary ore mineral, chalcocite, occurs in unaltered gray arkosic sandstone overlain by red shale and intruded by small, irregular basalt dikes. The major secondary mineral is the bluish-green copper silicate chrysocolla which penetrates the rock along joints and bedding planes.

Return to Schuyler Ave.

3.95 N on Schuyler Ave.

4.7 Pull over to the right, onto a short "Y" driveway, just N of Carrie Rd.

STOP 4 (North Arlington)

Fig. 20 Looking E from Schuyler Ave. (near Carrie Rd.), North Arlington to wetlands in Lyndhurst, N.J. Kingsland Creek, in middle, flows towards the Hackensack River. To the right are landfills and the Sawmill Creek Wildlife Management area.

Overlook showing a panorama of the Meadowlands N of the one in Stop 1. Kingsland Creek, in the foreground (Fig. 20), lies towards the N end of the Sawmill Creek Wildlife Management Area (Fig. 13). The panorama from left to right shows the Meadowlands Racetrack, Giants Stadium, and the Arena; sanitary landfill; twin towers at S end of the Harmon Cove development; Empire State building and mid-town Manhattan skyline behind the Palisades ridge; sanitary landfill, World Trade Center towers are almost in line with Kingsland Creek. The W spur of the N.J. Turnpike is in the middle distance; the E spur passes behind Snake Hill, at the right. Note the wetland dikes.
Continue N. on Schuyler Ave.

7.9 Right on Orient Way (Route 11).

8.2 Right on Valley Brook Ave., descend to Meadowlands.

8.4 Left on Polito Ave.

8.65 Bricked-up entrance to copper mine exploration shafts in red beds behind Kuttner Prints plant on left. This is the Lyndhurst Office Industrial Park, one of 11 industrial parks in the Meadowlands. This park includes the Meadowlands Corporate Center and tenants such as Pugeot, Citroen, etc.

8.7 Polito Ave. has developed a "wash board" effect because the road was built directly on the meadow mat, which doesn't support the heavy truck traffic very well.

8.75 Follow signs to Route 3 East, around Holiday Inn.

10.00 Cross Berry's Creek. The very serious mercury pollution problem in Berry's Creek and its environs originated in an industrial plant about 3 miles upstream (see text above). The Creek forms the W boundary of the Meadowlands Sports Complex, whose three major structure loom large on the left.

10.4 Right to Rte. 20 N.

10.7 Passing under Route 3.

11.7 Stay left on Rte. 20 N.

(Note: Mileage and routing directions to parking site will be made available by the Sports Authority at time of the trip).

STOP 5. Meadowlands Sports Complex (East Rutherford). See text above.
Leave Sports Complex, Rte. 20 N to Washington Ave.

13.5 N on Washington Ave.

15.0 Right on Empire Blvd. (traffic light).

15.6 Turn ¼ left, follow Merhof Road towards two tall smoke stacks. Pass through gate at sign reading "Bergen County Utilities Authority."

16.2 Right at end of road.

16.3 Left into parking lot in front of office building, Bergen County Utilities Authority.

STOP 6. Sewage Treatment Plant (Little Ferry).

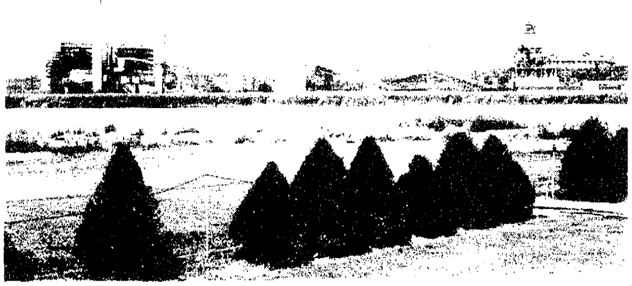


Fig. 21 Bergen Generating Station, Public Service Electric and Gas Co., Ridgefield Park, N.J. Looking NE across Hackensack River from Bergen County Sewage Disposal Plant in Little Ferry, about three-quarters of a mile distance. Conveyor belt ramps transport coal from storage pile into the plant.

Tour of the plant and new construction in progress. *See text* above. Opposite this stop, across the Hackensack River in Ridgefield Park, is the Bergen generating station of Public Service Electric and Gas Company (Fig. 21). This plant is in the extreme northeast corner of the Hackensack Meadowlands District. It is a conventional oil-burning power plant, but is also equipped to use coal and natural gas. In 1983 it will also burn garbage from the resource recovery plant to be constructed adjacent to it by Bergen County (Boyd, 1980d). Procedures are employed to minimize thermal pollution of the Hackensack River, to condense spent steam from the turbines for reuse in the boiler.

Several ponds to the northwest of the Sewage treatment plant were clay pits. Little Falls was once the center of a major brick-manufacturing industry.

Return to Washington Ave. (traffic light).

15.0 Left on Washington Avenue (Rte. 503). Look for sign "Paterson Plank Road East"

16.0 Two LNG storage tanks to the east (Fig. 17).

17.1 Turn left (U-turn).

17.7 Left to Paterson Plank Road East.

17.9 Right on Paterson Plank Road East.

18.4 Passing over N.J. Turnpike (W spur).

18.6 Dead End at Hackensack River.

STOP 7 - Stone pier S of Sky Harbor Marina (Carlstadt). Walk to end of pier for view of Hackensack River (Fig. 22). Sand and gravel storage facility can be seen on opposite (E) shore of the river, in Secaucus. Route 3 bridges cross the river to south. Behind bridge is the Harmon Cove development, our next stop.

Two LNG storage tanks can be seen about 0.7 mile to the NE very close to a superhighway (Fig. 23). Most of the area between here and the tanks has been rezoned for residential use. See text above.

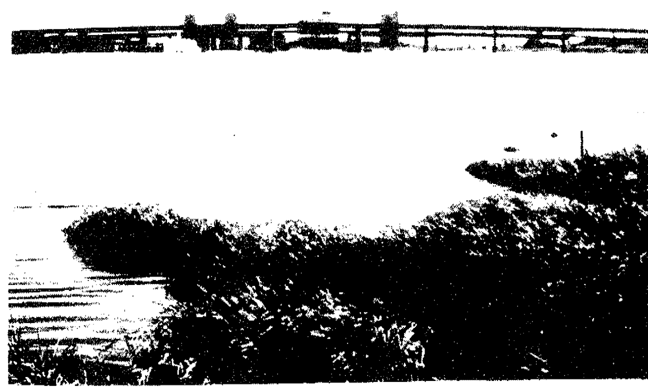


Fig. 22 Route 3 crossings of Hackensack River five-eighths of a mile distant, as seen from stone jetty at foot of Paterson Plank Road. Harmon Cove buildings are in the center distance. Looking S.

18.6 Proceed back to Rte. 20 S via Paterson Plank Road.

19.9 U-turn to Rtes. 3 and 20 S. Keep to right, Rte. 3E.

21.4 Bridge crossing Hackensack River. Harmon Cove development on the right.

21.7 Turn right for Meadowlands Parkway.

21.9 Left at light to Harmon Towers.

22.2 Turn right. Park alongside parking deck.

STOP 8 - Harmon Cove Development, Hartz Mountain Industries, Secaucus. See text above.

Fig. 23 LNG storage tanks about one-half mile E of N.J. Turnpike toll gate. View from Paterson Plank Rd. overpass, Carlstadt, N.J.

We will leave the bus here and board it at the Twin Towers high-rise condominium at the south end of the development. Start walking along the bicycle and jogging path that winds southward through the area of town houses that stand between Meadowlands Parkway and the Hackensack River (Fig. 24). The top of the 25-story Twin Towers affords a spectacular view of the entire Hackensack Meadowlands District lying on the floor of post-glacial Lake Hackensack. The Manhatan skyline looms impressively beyond the back slope of the Palisades, which marks the eastern border of the District. The Hackensack River can be seen as the central artery sustaining the watery ebb and flow of estuarine life in the wetland habitat. The network of highways includes the Pulaski Skyway, East and West Spurs of the New Jersey Turnpike, Rte. 3, and others. Five highway bridges and six railroad bridges cross the Hackensack River in the District. Landfills towards the SW mark the site of the De Korte State Park. To the north can be seen the Sports Complex, the LNG storage tanks and the PSE & G electric generating plant. Another power plant is at the far south end of the area. Several industrial parks are distributed throughout the District.

23.0 Board bus, go north on Meadowlands Parkway.

23.2 Right turn to Rte. 3 and N.J. Turnpike. Keep right for Turnpike South.

25.1 N.J. Turnpike toll gate.

26.1 Secaucus water tower on right. The town of Secaucus forms two "islands" inside the Hackensack Meadowlands District (Fig. 6). Its location was determined by the presence of bedrock at the surface, which posed none of the foundation problems found elsewhere in the Meadowlands.

26.6 Little Snake Hill on left.

27. Snake Hill (Big Laurel Hill) on right.

These are diabase plugs which may have served as vents or feeders for the Watchung lava flows. Snake Hill has been largely quarried out for trap rock crushed for use as road metal. It supplied crushed stone for Hartz Mountain Industries. Snake Hill is zoned for residential use (Fig. 4). Because the basalt provides an excellent foundation, housing can be built more cheaply here than at Harmon Cove or elsewhere in the District where costly pilings must be used. Low-cost housing has been suggested for the site because the cost per unit would be lower. The site's isolation, however, mitigates against this type of housing.

27.3 Sawmill Creek Wildlife Management Area to the right (Fig. 2). This will be part of the De Korte State Park.

28.7 Exit 15W - leave N.J. Turnpike.

29.7 E on Rte. 280 (Harrison Ave.) to Newark.

31.7 Cross Passaic River into Newark.

32.4 Arrive Rutgers University Campus, University Ave.

REFERENCES CITED

Anonymous, 1979, Pegasus - a memorable dining experience, Meadowlands/USA, v. 4, No. 4, p. 32.

Bergen County Sewer Authority, 1975, Annual Report for 1975, Little Ferry, New Jersey.

Boyd, F., 1980a, Illegal dumping likely to upset HMDC plans, Star Ledger, Newark, New Jersey, May 30, 1980.

______________, F.V., 1980b, State rules meadows agency can't prohibit 'imported' waste, Star Ledger, Newark, New Jersey, June 26, 1980.

______________, F.V., 1980c, HMDC wants more time to study landfill park, Star Ledger, Newark, New Jersey, July 31, 1980.

______________,F.V., 1980d, DEP endorses solid waste disposal plan for the Meadowlands, Star Ledger, Newark, New Jersey, August 1, 1980.

Converse Ward Davis Dixon, 1978, Report of Soils and Foundation Investigation, Proposed Meadowlands Arena, East Rutherford, New Jersey. Prepared for New Jersey Sports and Exposition Authority, Caldwell, New Jersey, September 21, 1978.

Clinton Bogert Associates, 1978, Sludge Management Facility for Bergen County Utilities Authority, August 1978.

Curico, D., 1980, Trash baler sets world mark, The News, Passaic County, April 25, 1980.

Fritzky, R., 1980, North Arlington condos reaching for the sky, Meadowlands/USA, v. 5, No. 1, p. 36.

Friedman, A., 1980, Waste Dumping 'high noon', DEP faces '84 deadline to find landfill solution, Star Ledger, Newark, New Jersey, March 30, 1980.

Gettlin, B., 1980, Loans backed for Meadows garbage fuel, Star Ledger, Newark, New Jersey, February 29, 1980.

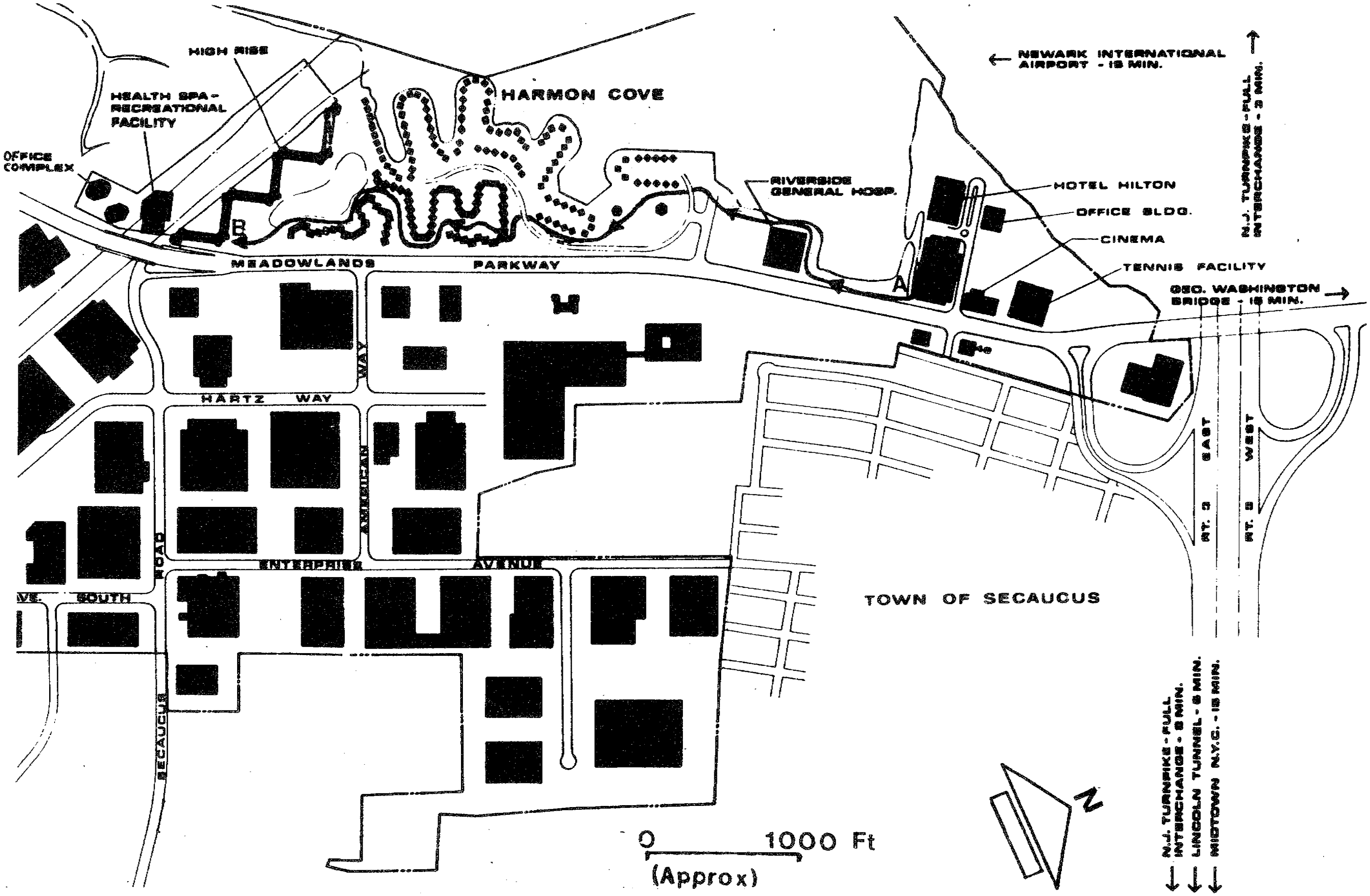


Fig. 24 Harmon Cove Development, Hartz Mountain Industries, Secaucus, N.J. The winding, solid line of arrows indicates route of walking tour through the townhouse complex (small dots), from the parking deck (A) to the zig-zag-shaped twin towers high-rise apartment complex (B). An industrial complex (partially shown) stands east of Meadowlands Parkway. (Courtesy Hartz Mountain Industries, Inc.)

Grant, R.C., 1980, Work to begin shortly on the Richard W. De Korte Statê Park Meadowlands/USA, v. 5, No. 1, p. 5.

(HMDC) Hackensack Meadowlands Development Commission, 1969, Master Plan-Building Code Foundations, State of New Jersey, 56 p.

(HMDC)____________, 1971, Master Plan Hackensack Meadowlands District Zoning Regulations, Lyndhurst, New Jersey, 171 p.

(HMDC)____________, 1972, Master Plan, Hackensack Meadowlands District Zoning Regulations (Revised and Amended, 1973; Amended, 1978). The Commission, Lyndhurst, New Jersey, 180 p.

(HMDC)____________, 1975, Wetlands Biozones of the Hackensack Meadowlands: An Inventory, A Report of the Hackensack Meadowlands Development Commission, 42 p.

(HMDC)____________, 1979, Annual Report 1979, Hackensack Meadowlands Development Commission, East Rutherford, New Jersey.

Hanley, R., 1978, Mercury Polluting Meadowlands; Scientists Uncertain About Impact, New York Times, May 19, 1978.

____________, 1979a, Utility May Tap Jersey Park Site for its Methane, New York Times, April 1, 1979.

____________1979b, The Long Rocky Journey From Marsh to Meadowlands, New York Times, May 13, 1979.

________________________1979c, Buildup in Meadowlands Expected to be Curtailed, New York Times, September 18, 1979.

(JMA) Jack McCormick and Associates, Inc. 1974, Environmental Impact Assessment on the Construction and Operation of an Island Residential Development on Specially Planned Area 1, Town of Secaucus, Hudson County, New Jersey, Hartz Mountain Industries, Secaucus, New Jersey, 241 p.

(JMA)____________ 1978a, Full Environmental Impact Statement for the Proposed Meadowlands Arena, The New Jersey Sports and Exposition Authority, East Rutherford, New Jersey, May 24, 1978.

(JMA)____________ 1978b, Environmental Impact Statement on a Multipurpose Development (North Bergen and Secaucus), Hartz Mountain Industries, Inc., Secaucus, New Jersey, October 19, 1978.

Kane, R., 1978, Birds of the Kearny Marsh, New Jersey Audubon, v. 5, No. 5, Occasional Paper No. 135, P. 22-27.

Kardas, S. and Larrabee, E., 1976, Historic Survey for proposed U.S. 1 and 9 Freeway, Hudson and Bergen Counties, New Jersey, Phase I. (Prepared for New Jersey Department of Transportation by Louis Berger and Associates, East Orange, New Jersey), 28 p.

Klein, D. H., 1972, Some general and analytical aspects of environmental mercury contamination, Jour. Chemical Education, v. 49, p. 7-10.

Lewis, J.V., 1907, The Newark (Triassic) Copper Ores of New Jersey, New Jersey St. Geol. Survey, Ann. Rept. 1906, p. 131-164.

Manspeizer, W., Puffer, J.H., Cousminer, H.L., 1978, Separation of Morocco and eastern North America: A Triassic-Liassic stratigraphic record. Geol. Soc. America, Bull, V. 89, p. 901-920.

Mattson, C. P., 1978, An Ecological and Resource Management Plan for the Hackensack Meadowlands, State of New Jersey, Hackensack Meadowlands Development Commission.

Mattson, C. P. and Vallario, N.C., 1976, Water Quality in a Recovering Ecosystem - a Report on Water Quality Research and Monitoring in the Hackensack Meadowlands 1971-1975, State of New Jersey, Hackensack Meadowlands Development Commission.

New Jersey Sports and Exposition Authority, 1975, Official Statement Relating to $302,000,000 Sports Complex Bonds, 1974 Series, July 1975.

Oser, A.S., 1980, Developer in Jersey offers help on mortgage payment, New York Times, April 18, 1980.

Roberson, E., 1980, Transport Chief wants Meadows "teamwork," Star Ledger, Newark, New Jersey, January 23, 1980.

Shuberth, C.J., 1968. The Geology of New York City and environs. Published for the American Museum of Natural History, the Natural History Press, Garden City, New York, 304 p.

(TAMS) Tippetts-Abbett-McCarthy-Stratton, 1975, Hackensack Meadowlands mathematical study. Prepared for Department of Army, New York District, Corps. of Engineers, New York, N.Y., 42 p.

United States Army Corps of Engineers, 1962, Hackensack Meadows, N.J. Geological Sections, Prepared by Joseph S. Ward, Inc., Caldwell, New Jersey, June 29, 1962.

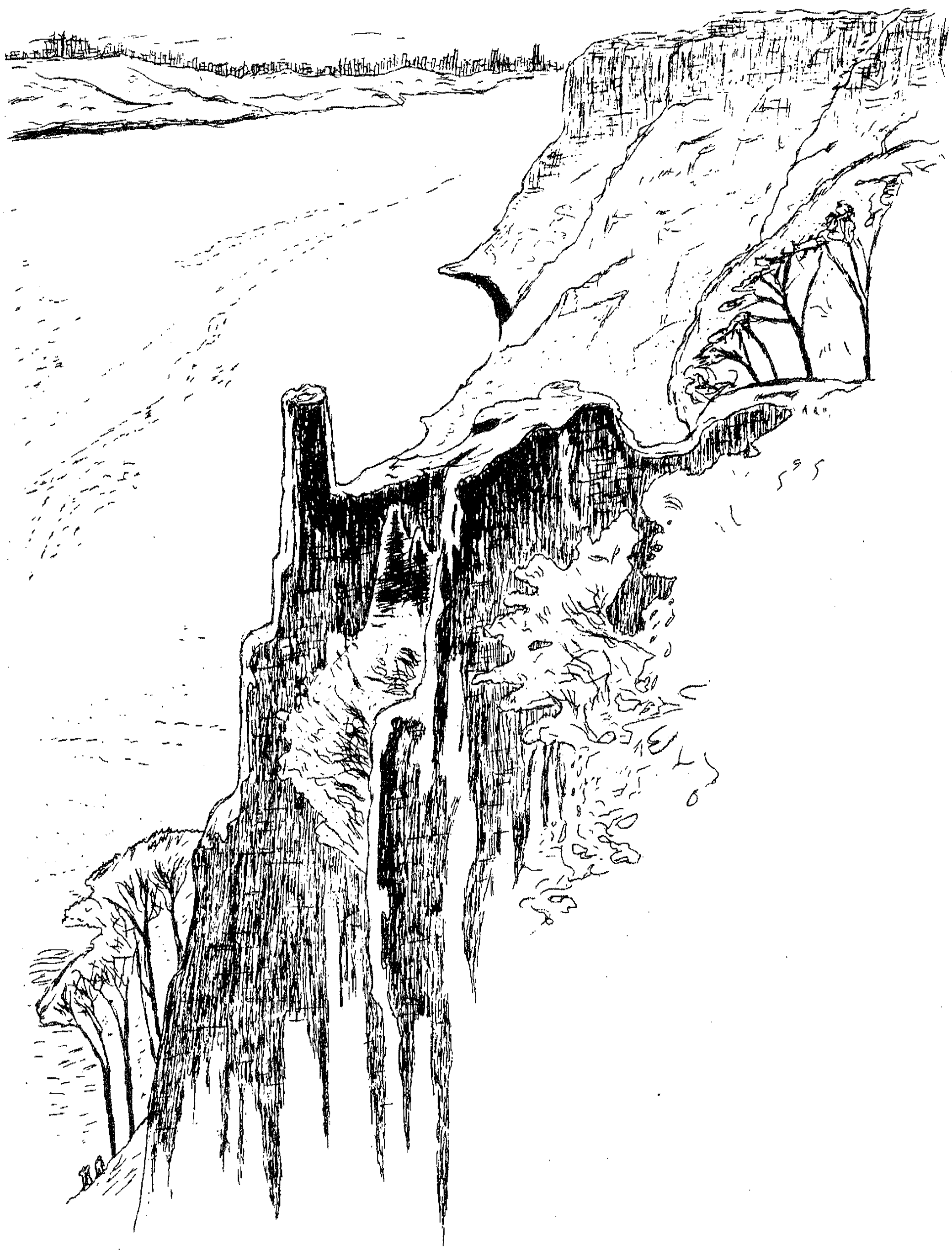
United States Geol. Survey, 1967, Engineering Geology of the Northeast Corridor, Washington, D.C., to Boston, Massachusetts: Coastal Plain and Surficial Deposits, Misc. Geol. Inves., Map I-514-B (Sheets 3,6,7).

Van Houten, F.B., 1970, Late Triassic Newark Group, north central New Jersey and adjacent Pennsylvania and New York. In Subitzky, S. (Editor), Geology of selected areas of New Jersey and eastern Pennsylvania and guidebook of excursions, Rutgers University Press, New Brunswick, New Jersey, p. 314-347.

Widmer, Kemble, 1963, The geology of New Jersey. In Kennedy, S.M., et al, The New Jersey Almanac, 1964-1965. Tercentenary edition. The New Jersey Almanac Inc., and the Trenton Evening Times, Upper Montclair, New Jersey, p. 49-60.

Widmer, Kemble, 1964, The geology and geography of New Jersey, D. Van Nostrand Company, Inc., Princeton, New Jersey, The New Jersey Historical Series 19:1 - 193.

Woodward, H.P., 1944, Copper mines and mining in New Jersey, New Jersey Dept. Conserv. Geol. Ser. Bull. 57, 156 p.



MINE HILL, FRANKLIN FURNACE
by H. Carmiencke
from Delaware
N.J.G.S., 1856, 2nd Annual