LiPari Landfill

200296

Brief

The landfill is located atop a 30-foot escarpment bordering Chestnut Branch, a tributary of the Delaware River. Natural ground and surface water drainage flows into Chestnut Branch. Chestnut Branch is a small stream with headwaters in Pitman and Glassboro, New Jersey and is subject to highly variable flows which overtop its banks during large storm events.

Upland areas are underlain by well-drained soils and a thin veneer of very permeable sand and gravel deposits. These deposits overlie beds of silty, fine sand and clayey silt where the permeability was found to be on the order of 10^{-7} cm/sec. Approximately one-third the groundwater flow issuing from the site comes from precipitation falling on the landfill and two-thirds from horizontal groundwater movement into the landfill from the watershed surrounding the site.

Some relevant chronological events:

1958-May, 1971	-	Operation of LiPari Landfill
1958-1970	-	Liquid and solid chemical waste dumping
May, 1971	-	Solid waste dumping
1974	-	Civil actions brought by NJDEP. Court ordered LiPari to improve drainage and treat leachate
1975-1979	-	Various minor investigations of landfill seepage
April, 1979	-	Interest by Congressman Florio sparked EPA reaction to lack of abatement of leachate at LiPari. A research project was proposed by OR & D.
August 9, 22, 23, 1979	-	S&A sampling of landfill and environs. Benzene, ethylbenzene, phenols, toluene, bis (2-chloroethyl) ether (BCEE) were found in milligram quantities in leachate seeps. The maximum concentration for BCEE, a carcinogen, in the analyses performed was 210 milligrams per liter.
April, 1980	-	Report by Roy F. Weston Inc., consultants to Rohm and Haas on LiPari Landfill submitted to Rohm and Haas.
April, 1980	-	Five month 311 contract to Wright Associates for a study to determine remedial measures on LiPari including collection and treatment of leachate and to provide a bid document for construction. Contract cost $74,000.
June, 1980	-	Four year OR & D contract to Woodward-Clyde for manual on cleaning up hazardous waste sites. LiPari to be used as an example. Contract cost $778,000.
August 20, 1980	-	Meeting of OR & D, Region II and consultants. Relevant points were:

01??

002-022-02

271999

Woodward-Clyde report stated that a geologic relation of sand over clay occurs at about 30 feet below land and that in the area of the landfill about 5 to 30 gpm of groundwater discharges along the escarpment.

September, 9 1980 - Court ordered LiPari to construct fence by October 25th and to refrain from excavating, farming, etc. at landfill.

October 22, 1980 - Meeting at EPA HQ, New York which included representatives from EPA Region II, HQ, U.S. Justice, Woodward-Clyde (W-C) and Coast Guard. Kolmer (W-C) argued that landfill is in sandy sediments that Kimmel had perviously indicated were of low permeability because of its silt content and predominantly clay sediments occur below the landfill and cause outward migration of the contaminated groundwater along the escarpment of Chestnut Branch. A second report from W-C on their geophysical investigations shows:

1. Groundwater is highly contaminated relative to surrounding water at site of the landfill.

2. Three sites of probable drum concentrations to be avoided in drilling.

3. Sites for 25 borings in and around the landfill.

4. Woodward-Clyde experiencing difficulty in access to the LiPari site.

5. Woodward-Clyde estimate that to fulfill their obligation for research program for OR & D, field work would take one year before remedial action could be considered.

November 3, 1980 - Draft of Wright Associates report on remedial measures for landfill.

Conclusions:

- Leachate is treatable, but expensive.

- Drainage ditch system not practical.

- Cut-off wall and containment best solution.

November 7, 1980 - Meeting of Surveillance and Analysis Branch concluded after reviewing LiPari investigations that:

- Can accept the conclusions of the Wright report and develop a scheme for confinement of the landfill with the addition of a drilling and sampling scheme to produce bid documents.

- 311 funds should be applied to effect a final solution to the site forewith, as a faster method of effecting a final solution. OR & D agreed to maintain involvement and afford post-closure monitoring. OR & D has $778,000 committed to LiPari to this effect.

November 14, 1980 - Regional Administrator briefed and agreed to plan of action.

November 8, 1980 to February 9, 1981 - Design of drilling and sampling scheme.

December 11, 1980 - Superfund Legislation Enacted.

December 12, 1980 - Request for bids, drilling program.

January 14, 1981 - Regional Response Team endorses cut-off wall and cap. Request submitted for funding of $1,250,000 through Clean Waters Act.

February 2, 1981 - OR & D Reiterated committment of $778,000.

February 9, 1981 to March 2, 1981 - Review of drilling scheme, scope of work, costing and contracting by U.S. EPA Region II and U.S. EPA OR & D.

March 2, 1981 to March 24, 1981 - Drilling program implemented.

Drilling program designed to:

1. Accurately define the thickness and level of the clay below the landfill to allow a cut-off wall construction bid to be developed.

2. Obtain permeability values for the soil.

3. Obtain contaminant levels and extent in the landfill and upper (Cohansey) aquifer to:

   A. Define the exact line of the cut-off wall.

   B. Check that contaminants are restricted to the upper aquifer.

4. Study the leaching characteristics of the contaminated sediments to answer how long and what method will it take to clean the aquifer.

5. Install long-term monitoring wells.

6. Obtain contaminated soil and leachate to test against the cut-off wall materials (compatibility testing).

7. Monitor the air during drilling to estimate the magnitude of the volatile problem to be encountered during construction phase.

Eighteen wells drilled and piezometers installed.

March 24, 1981 - Laboratory soil testing began.

March 24, 1981 to May 15, 1981 - Development of proper water flows from the boreholes to obtain representative leachate samples.
Field permeability testing.

May 8, 1981 - Design of marsh investigation completed.

May 28, 1981 to June 19, 1981 - Marsh investigation: soils, hydrology, geology and installation of sampling piezometers.

June 15, 1981 - Leachate samples collected from developed wells.

June 15, 1981 to August 10, 1981 - Laboratory chemical analyses of soil and leachate.

August 5, 1981 - Review of data by U.S. EPA, NJDEP, and consultants.

Conclusions:

1. Proceed with cut-off wall design bid documents.

2. Encapsulation not an acceptable solution by itself.

3. Consultants recommendation is cut-off wall plus treatment with recharge, possibly followed by 6 acre cap.

4. Selection of remedial treatment design consultants not firm pending administrative selection.

LIPARI FINANCIAL SUMMARY

I	Item	Invoiced	311 Commitment	Balance/Comments
1[illegible]/79	RRT convened.			RRT advised EPA to seek 311 Funds. POLREP #1.
2/26/80	RFP's mailed out.			
3/3/80	Contractor bid evaluation.			
3/31/80	R. E. Wright (REWAI) contracted for 311 Study ($69,563.00)		50,000	50,000 Project #1-0-0020
4/2/80	POLREP #2; Requested ceiling increase from $50,000 - $100,000.			
4/9/80	Ceiling increase authorized.		100,000	100,000
4/31/80	REWAI Invoice #1848.	8,505.23		Consultant services for the investigation of the hydrogeology of the landfill and plume, leachate characterization, and short-term remedial action.
5/31/80	REWAI Invoice #1884.	10,413.70		
6/30/80	REWAI Invoice #1931.	17,335.79		Consulting services from REWAI.
7/31/80	REWAI Invoice #1984.	10,466.44		Consulting services from REWAI.
8/31/80	REWAI Invoice #2037.	9,059.00		Consulting services from REWAI.
9/30/80	REWAI Invoice #2079.	8,437.18		Consulting services from REWAI.
10/31/80	REWAI Invoice #2126.	4,740.89		Consulting services from REWAI.
11/3/80	Draft report of Wright Study released.			
11/30/80	REWAI Invoice #2169.	4,849.53		Consulting services from REWAI.
		Subtotal 73,807.75	100,000	26,192.25

LIPARI FINANCIAL SUMMARY

Date	Item	Invoiced	311 Commitment	Balance/Comments
1. .9/80	Transmittal of Final Report to Coast Guard.			[redacted]
12/31/80	REWAI Invoice #2204.	4,999.12		Tentative drilling program drafted.
1/16/81	Authorized ceiling raised.		170,000	91,1193.13
1/31/81	REWAI Invoice #2250.	3,517.01		
	REWAI Invoice #2261.	8,357.43		82,323.89 for first contract.
2/13/81	Authorization to Proceed with 311 Study extension to a limit of $95,000 issued to REWAI.			
2/28/81	REWAI Invoice #2290.	8,910.08		
3/2/81	Drilling began on site.			
. ./81	Drilling completed on site.			
3/31/81	REWAI Invoice #2356. REWAI Invoice #2320.	11,715.74 48,239.40 159,546.44		Included drilling costs of subcontractor GEO-FACTS, Inc.
4/8/81	Ceiling increase authorized.		200,000	40,453.55
4/10/81	Authorization to Proceed issued to REWAI to a limit of $200,000.			
4/24/81	Well development and field permeability testing proceeding.			
4/30/81	REWAI Invoice #2390.	14,121.40		Well development by REWAI.
5/23/81	Leachate sampling by ERCO, paid by U.S. EPA, OR & D.			Marsh investigation TAT/REWAI. Marsh investigation TAT/REWAI..

LIPARI FINANCIAL SUMMARY

Date	Item	Invoiced	311 Commitment	Balance/Comments
5/31/81	REWAI Invoice #2446.	12,632.75		Surveying by REWAI.
6/9/81	Letter to Mr. Kerner USCG RE: Rationale for 311 study extension.			
6/30/81	REWAI Invoice #2491.	23,010.67		Consulting services from REWAI.
6/22/81	Ceiling increase authorized.		230,000.00	
7/30/81	REWAI Invoice.	9,589.24		
		Subtotal 218,919.60		136,666.71 total for extension of contract. Balance 11,080.40.

U.S. EPA Office of Research and Development

FINANCIAL SUMMARY

Date	Item	Invoiced	311 Commitment	Balance/Comments
6/30/80	Initial OR&D commitment		778,000	778,000.00
5/6/81	Sample collection and analysis by ERCO	25,850.00		752,150.00

Cost Estimates For Alternatives

1. Entombment, 6 Acre Site. This simple concept presents a cut-off (slurry) wall around the main or principal chemical fill area plus a cap over the contained area. Its primary virtues lie in its low cost and in the encapsulation of the highest TOC leachates. Its shortcomings include:

   a. Excluded from containment: 10 acres of leachate bearing sit[redacted] plus 13 acres of slope and swamp, thus not containing large quantities of highly contaminated leachates, which will continue to flow.

   b. Uncertainties regarding the service life (est. 5 to 30 years) of the cut-off wall materials.

   c. Long term maintenance requirements.

   d. Continued vertical concentrated leachate migration downward thru the Kirkwood clays, the underlying Kirkwood granular strata (an aquifer).

   e. The concept that simple entombment is a solution, rather than a postponement.

A.	Six acre cut-off wall (2200 lin. ft.)	$ 396,000
B.	Safety aspects would raise this cost by increasing labor and equipment costs	79,000
C.	Cap 6 acre (bentonite & asphalt)	800,000
		$1,275,000
D.	Fence, 8 ft. chain link X 2200 lin. ft.	66,000
		$1,341,000

2. Entombment, 16 Acre Site. This concept is essentially the same as the (1) above, except that it includes 10 additional acres of contamination. Other than this, its virtues and faults are the same as for the 6 acre entombment.

A.	Sixteen acre cut-off wall (3000 lin. ft.)	$ 540,000
B.	Safety considerations	108,000
C.	Sixteen acre cap (bentonite & asphalt 3")	2,133,000
		2,781,000
	Alternate 3 ft. clay cap @$10/ton in place reduces cost to $2,042,000	
D.	Fence (3000 lin. ft.)	$ 90,000
		$2,870,000

3. Entombment With Provision For Future Treatment. This concept includes (2) above with the addition of limited facility installations intended to allow the future construction of collection and treatment systems as a phased approach. It promises the advantages and disadvantages of (2), above and gives lip service to an actual solution to the site without actually spending all the money. The major problem associated with the logic is that, once encapsulation is effected, the "imminent threat" is gone and the availability of funding for the "future" collection and treatment portion of the concept becomes doubtful.

4. Entombment With Partial Treatment. This concept adds treatment of swamp leachates on a short term basis to (1, 2, or 3) above. Its virtues include "low" cost and encapsulation of contaminants, and the collection and treatment of contaminants from outside the "tomb". The shortcomings expressed in (1b)

c, d, and e, above remain. Its cost is the highest of the concepts (1 thru 4) thus far considered.

(1) + Swamp + Treatment	
Cut-off Wall, Cap & Fence	$1,341,000
Treatment Systems (9 months)	3,160,000
Swamp Facilities	385,000
	$4,786,000
(2) + Swamp + Treatment	
Cut-off Wall, Cap & Fence	$2,871,000
Swamp Facilities	385,000
Treatment Systems (5 months) including oper. & GAC	1,615,000
	$4,871,000

5. Entombment With Full Collection and Treatment. This concept presents the virtue of total containment with only one (1c) of the drawbacks of (2) above. It is usually presented coupled with a trenched drain dewatering system, and without a recharge system. In this configuration, long term operating requirements make this concept the most expensive of all. The use of a well type dewatering system and a recharge system would improve its total cost picture considerably by shortening its required length of collection and treatment systems operation. It may be that, given the existence of the total encapsulation, the treatment plant influent TOC allowing shut down of treatment operations would be set higher (by the State) than for (9), below, perhaps making this concept cost competitive. Its primary disadvantage as compared to (9) is that recharge by surface spray cannot be used to remove contaminants from sands above the water table, and contaminant removal is limited by this fact.

A. Sixteen acre cut-off wall (3000 lin. ft.)	$ 540,000
B. Safety considerations	108,000
C. Sixteen acre cap (bentonite + asphalt + fence)	2,331,000
D. Treatment system (9 months) including oper. & GAC	3,160,000
E. Swamp treatment	385,000
	$6,524,000

6. Capping With Perimeter Drain Type Collection System and Treatment. This concept is the one used at Love Canal, where it is functional though inefficient. The inefficiency stems from the slow retrieval of contaminants lying below the effective system draw down level and from the obligatory handling of groundwater volumes from outside the perimeter drain. These two factors combine to force the long term operating of a high volume collection and treatment system, with consequent high total cost. The problems above described are inherent in the system. At LiPari these problems would be compounded by the (high velocity) Cohansey groundwater flow, a much higher flow rate than in Love Canal clays.

REJECTED

7. Containment (Full or Partial Cut-Off Wall) With Interior Perimeter Drain Type Collection System and Treatment. This concept removes contaminants more rapidly than (6), above, and uses rainwater as the leaching medium, while excluding high volume groundwater. It does not, however, optimize the rate of removal of contaminants from below the drain invert elevation, nor the over-all rate of contaminant removal from the site. Partial cut-off walls do not guarantee

recovery of all contaminants, given the non-homogeneous nature of most strata. Partial walls are thus a gamble, and are not recommended for consideration.

REJECTED

8. Containment (Full Cut-Off Wall) With Well Type Collection System and Treatment. This concept is a funtional improvement over 7, above, in that it improves the rate of removal of contaminants from the site by pumping the full contained volume. It uses rainwater as the leaching medium, and is thus limited in its contaminant removal rate, and is forced into a longer low rate operating period than 9, below.

A. Full cut-off wall (16 acres)	$ 540,000
B. Safety considerations	108,000
C. Well collection system	100,000
D. Treatment	4,765,000
E. Swamp treatment	385,000
	$5,898,000

9. Containment (Full Cut-Off Wall) With Well Type Collection System, Recharge System, and Treatment. This concept provides the fastest, most efficient, most controllable system for removal of contaminants from this site. It leaches chemicals from above and below the existing water table (recharging treated waters both by aspersion and by injection). High volume groundwaters are excluded.

A. For 16 acre cut-off wall + cross member (3850 lin. ft.)	$ 715,000
B. Safety aspects would raise this cost by increasing labor and equipment costs	140,000
C. Treatment system (9 months)	3,160,000
D. Cap 6 acres	800,000
E. Swamp treatment	385,000
	$5,200,000

10. Well Type Collection System With Treatment. This concept presents the advantage of low cost of construction, but with the disadvantages of high flow rate associated with groundwater flow (see 6, above), with long term operations, (also 6) and lack of assurance that contaminants will all flow to collection wells. It is not a recommended concept, because of the risk.

REJECTED

11. Well Type Collection System With (Dynamic Curtain) Recharge and Treatment. This concept is characteristically a high flow rate recharge system that creates a high flow gradient toward the collection system and a back flow gradient in the surrounding groundwater to cut off contaminant flow away from the site. It is not suited to the site geography and hydrology and, therefore, is not recommended for this site.

REJECTED

Cut-Off Wall

Average cut-off wall depth is 37 ft. if top of wall averages 120 ft. and bottom 83 ft. elevations.
So, average cost/1. ft. ht. 37 ft.^{2}/1. ft. X \$4.75/ft.^{2} = \$175.75

Say =\$180/1. ft.

For, 3,850 1. ft. of wall @ \$180/1. ft. = \$693,000

Say =\$700,000

Safety aspects would raise this cost by increasing labor, equipment, time, and adding equipment to the operation. We estimate a final cost of \$6/sq. ft. and a bid of \$854,700.

Cap-6 Acres

Say, 6 acres, 260,000 sq. ft.
Cap using bentonite into sand, then paving with asphaltic concrete (like driveway).

Say, bentonite into top 6", say 1 cu. ft./10 sq. ft.

@\$12 materials
3 labor
3 equipment
\$18/10 sq. ft. = \$1.80/sq. ft.

So, a) Bentonite worked into soil @\$1.80 = \$468,000
b) Asphaltic paving 3" thick @\$0.60 = \$156,000

Subtotal \$624,000

c) General conditions, move on and off 6% = \$37,440

\$661,440

d) Fine and coarse grading 30,000 c. yds. @\$3/c. yd. = \$90,000

Subtotal \$751,440

e) OH & P 20%, Say \$150,200

\$801,700

Say \$800,000

Alternative Cap For 6 Acres

Plastic + soil cover = \$576,000
Local clay (\$12 sq. ft. in place) = \$520,000

LiPari I ifill Schedule for Cut-Off Wal reatment/Cap

	Item Description	Completed	From	To
1.	Planning	X		3/2/81
2.	Drilling	X	3/2/81	3/24/81
3.	Soil Sampling	X	3/2/81	3/24/81
4.	Well Development	X	3/30/81	5/15/81
5.	Lab Permeability Testing	X	3/30/81	4/15/81
6.	Borehole Logs/Stratigraphy	X	4/10/81	7/17/81
7.	Marsh Geology Investigation	X	5/7/81	6/19/81
8.	Leachability Testing	X	6/1/81	8/1/81
9.	Sampling Liquids	X	6/15/81	6/19/81
10.	Surveying	X	6/10/81	6/18/81
11.	Sample Analysis	X	6/15/81	8/1/81
12.	Soil/Leachate/Bentonite Compatibility	X	6/28/81	8/15/81
13.	Data Analysis		4/10/81	9/16/81
1	>Review EPA & Decisions		8/5/81	9/16/81
15.	>Cut-Off Wall Bid Documents		8/5/81	9/16/81
16.	>Marsh Remedial Bid Documents			
17.	Request for Bid or Sole-Source Contract Negotiations Begin Treatment Method Appraisal OR & D		9/16/81	10/1/81
18.	Award Cut-Off Wall/Marsh Contract		10/1/81	10/8/81
19.	Cut-Off Wall Construction		10/15/81	12/16/81
20	Marsh Remedial Action		10/15/81	12/16/81
21.	Construction of Temporary Fence (16 acres, perimeter of cut-off wall)		11/25/81	12/18/81
22.	Monitoring of Leachate Concentrations and Elevations		12/16/81	2/15/82
23.	Bid Proposal for Treatment			2/15/82
24.	Nine Month Groundwater Recycling and Treatment		3/1/82	9/30/82
2.	Construction of Cap Over 6 Acre Landfill		9/30/82	10/31/82
26.	Construction of Permanent Fence 6 Acre Site		11/15/82	12/15/82

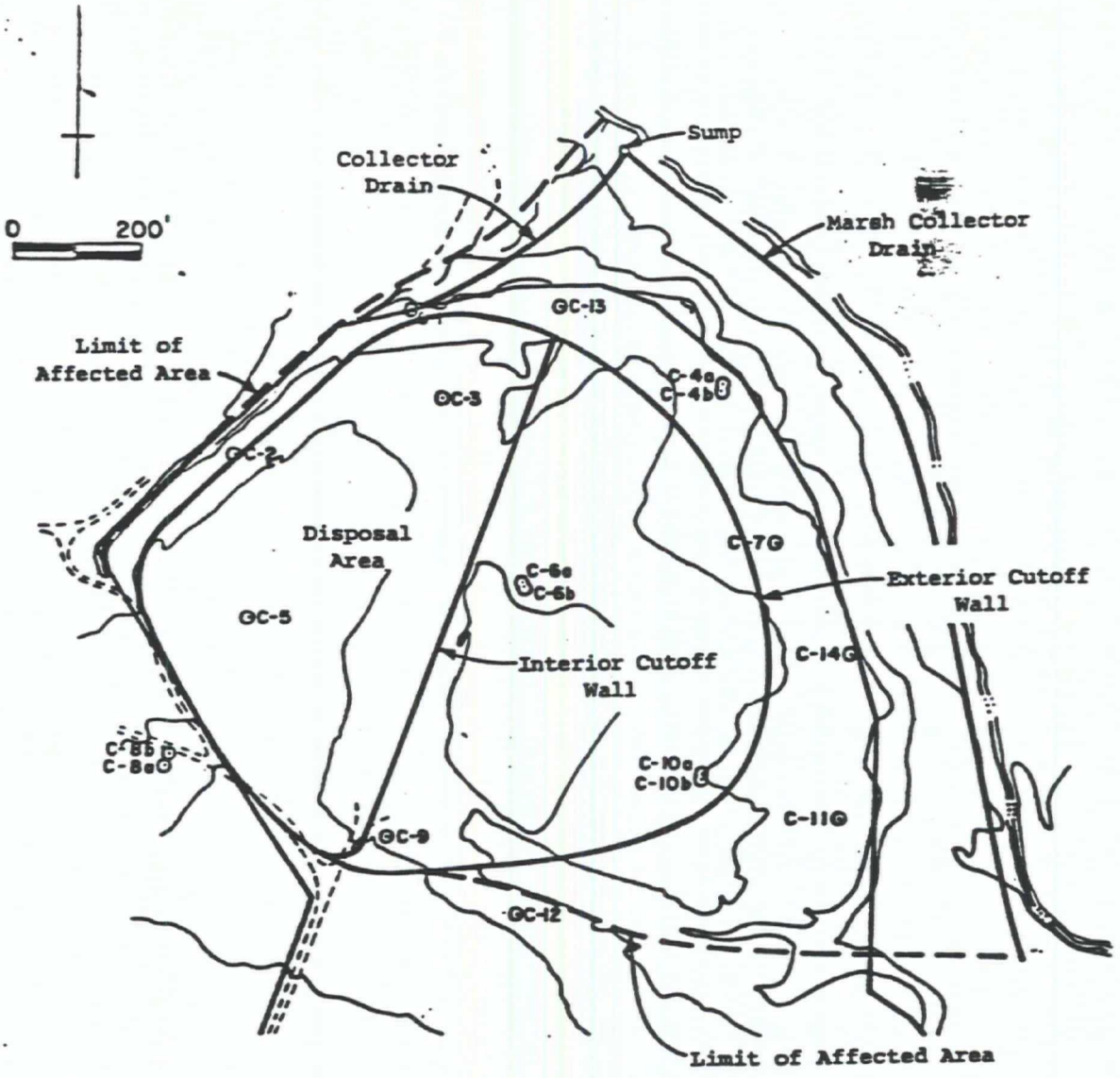


Figure 1.. Long-term abatement system.

ALTERNATIVE 9 CONCEPT

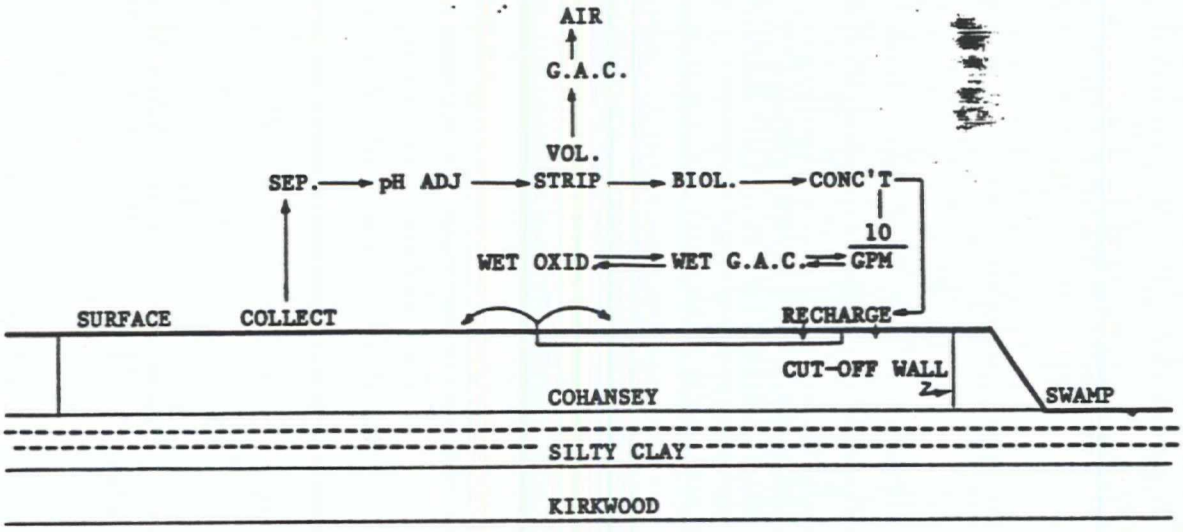


Figure 2

TARGET: To reduce the leachate TOC to a value acceptable to NJDEP.

GOAL: 2-1/2% diminishing returns curve = 87% reduction each 80 days.

COMPONENTS	PURCH. COST EST.	RENTAL COST EST.	POWER DRAIN	9 MOS. COST
›llection System (12 wells)	$100,000 - in place	$10,000 - /mo.	10.0 H.P.	$100,000 - BUY
›ll./Rech. Piping (6" 0)	500,000 " "	50,000 "	20.0 " "	450,000 - RENT
:parator, oil/water (500 SF)	70,000 " "	7,000 "	1.5 " "	63,000 - "
l Adjust & Precipit. (600 SF)	50,000 " "	5,000 "	1.5 " "	45,000 "
ıpor Stripper (100 SF)	150,000 " "	15,000 "	30 " "	150,000 "
GAC dry				
.ofilter (OR&D Option)	50,000 " "	N/Applic.	3 " "	50,000 - BUY
:mbrane Concentrator (2)	240,000 " "	12,000 "ea.	50 " " (2)	210,000 - RENT
:t GAC 10 GPM 3 col.	300,000 " "	30,000 /mo.	3 " "	270,000 "
Recharge System (10 SPR.)				
11 Wells	120,000 " "	N/Applic.	incl. in (2)	120,000 - BUY
:mp Building (4000 SF)				
High Bay	100,000 " "	10,000 /mo.	15 H.P.	90,000 - RENT
›amp System 130,000 SF				
$2/SF	260,000 " "	N/Applic.	5 " "	260,000 - BUY
ıt-Off Wall (110,000 SF)				
$5/SF	550,000 " "	N/Applic.	-	550,000 "
		Sub Total 9 month cost +		$2,364,000

ıel Lubric. Repair & Maint. 9 months @$20,000/mo.	180,000
›e ons 8 men (3 shift X 7 days), say @$50,000/mo.	450,000
ırbon changes, ave. (10,000 ppm X 833 lbs./min. X 1440 min./day X 270 days X) say=	976,000
lbs. carbon/lb. contamin. X $0.75/lb. carbon = $971,611.20)	
Total Estimated Cost	$3,970,000

f NJDEP will accept shut down at 100 ppm, then subtract $600,000.

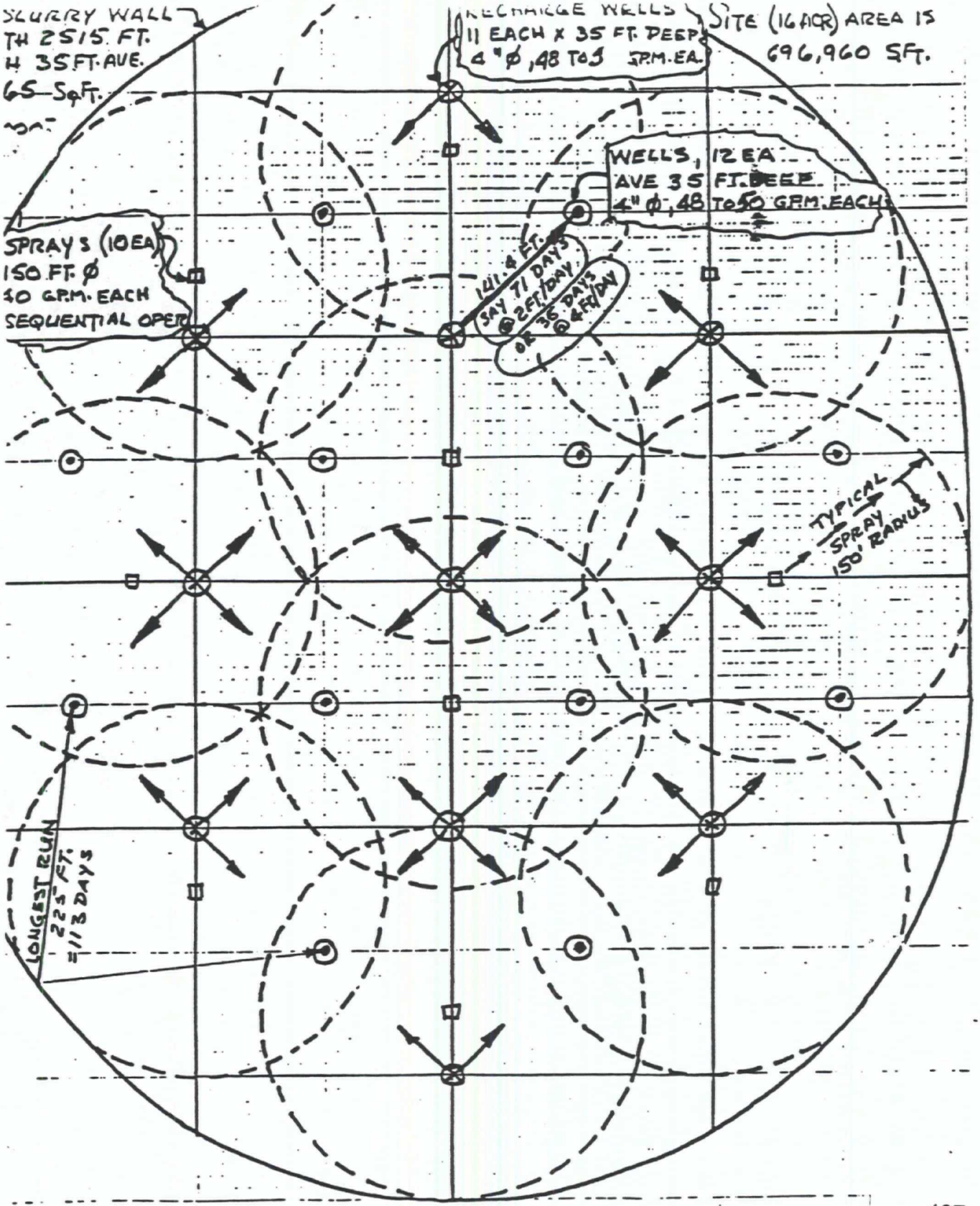

SLURRY WALL
TH 2515 FT.
H 35 FT. AVE.
65 SqFt.
RECHARGE WELLS
11 EACH X 35 FT. DEEP
4" Ø, 48 TO 53 GPM. EA.
SITE (16 AGR) AREA IS
696,960 SFT.
WELLS, 12 EA
AVE 35 FT. DEEP
4" Ø, 48 TO 50 GPM. EACH
SPRAYS (10 EA)
150 FT. Ø
50 GPM. EACH
SEQUENTIAL OPER
141.4 FT.
SAY 71 DAYS
@ 2 FT/DAY
OR 35 DAYS
@ 4 FT/DAY
TYPICAL
SPRAY
150' RADIUS
LONGEST RUN
223 FT.
=113 DAYS

Figure 3

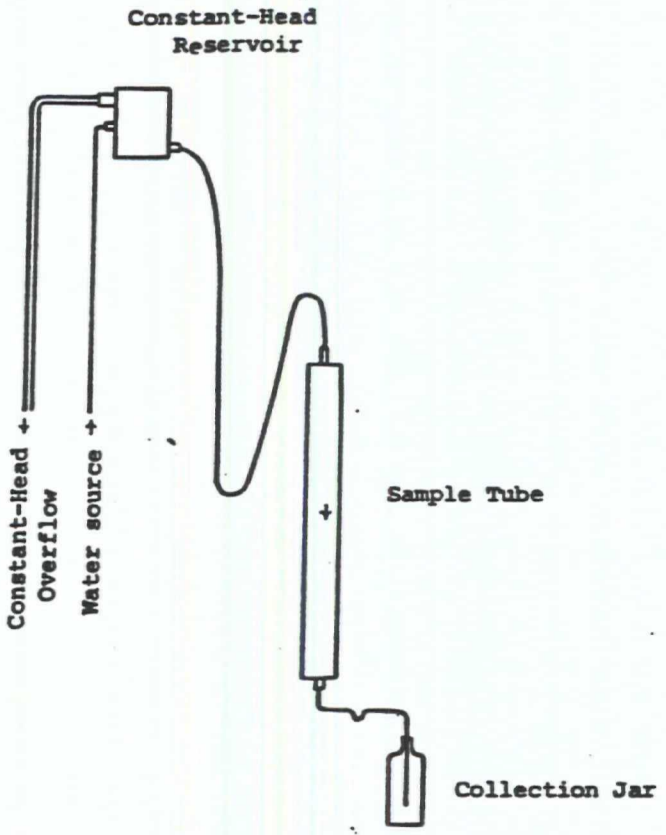


Figure 4. Permeameter system used for leachability experiment.

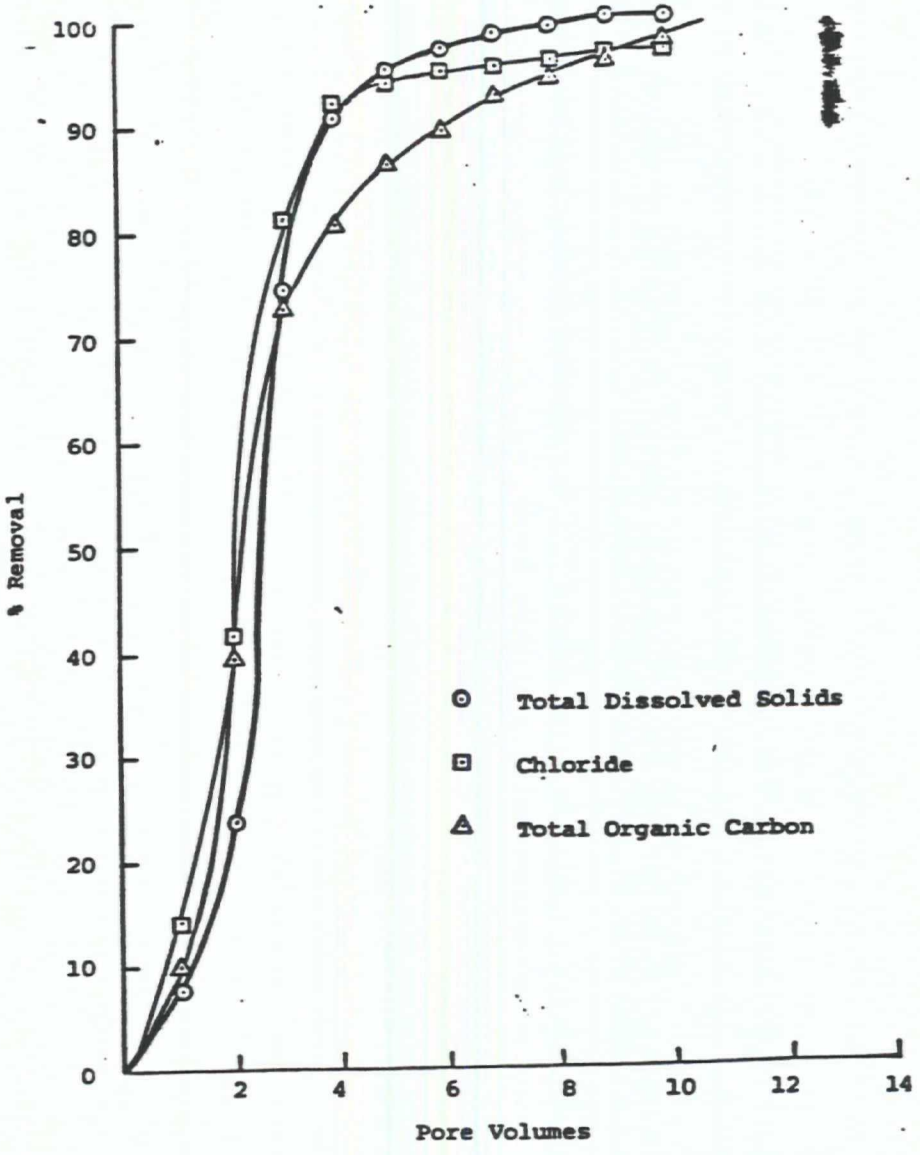


Figure 5. Percent removal vs. number of pore volumes passed through leachability permeameter.

Swamp Treatment

Affected Area:

Say 325 ft. along Rabbit Run
1230 ft. along Chestnut Branch
150 ft. along north limit of leachate plume
1750 Linear ft.

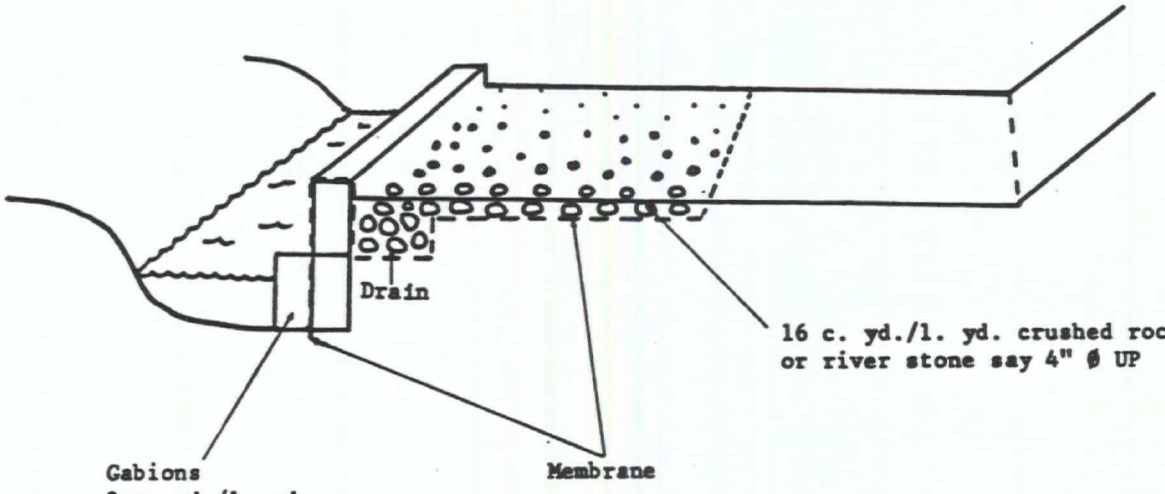


Figure 6

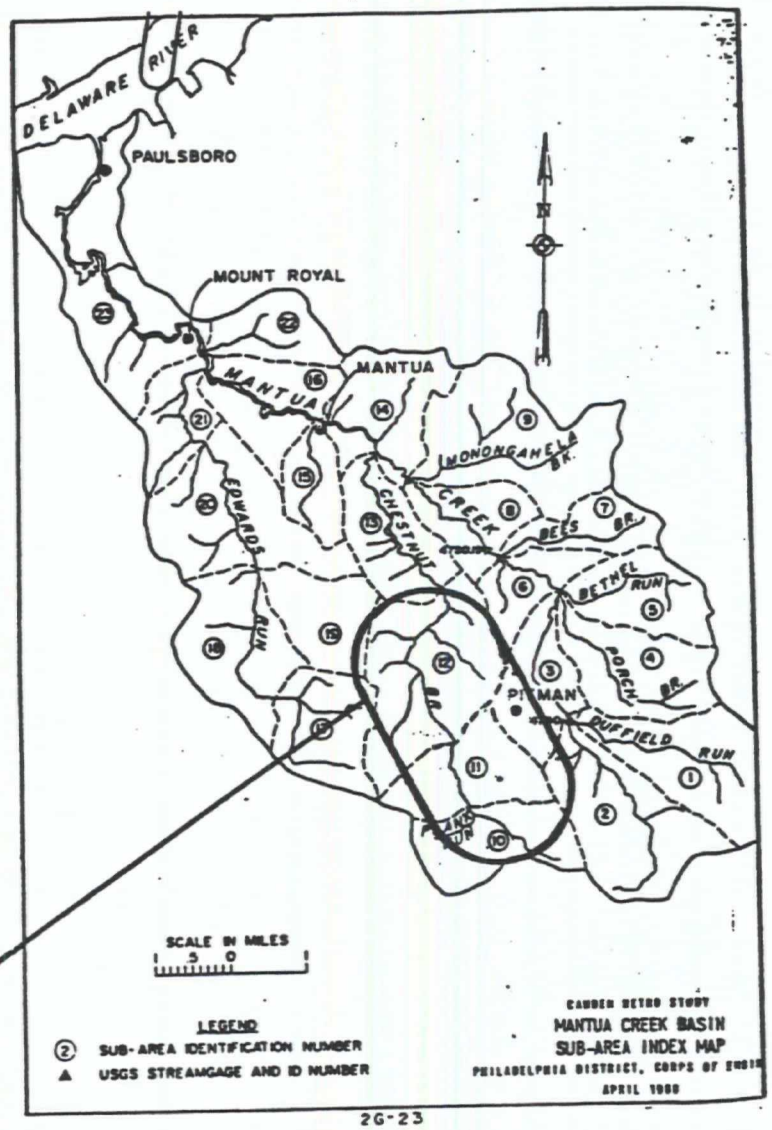
Gabions:

30/c. yd. @ 3 sq. yds./yd. = $90/yd.
17 ft. membrane @ $20/1. yd. = $20/yd.
16 ft. stone @ $20/c. yd. = $320/yd.

a. Say 570 1. yds. gabions @$90 = $51,300
b. 570 1. yds. membrane@$20 = $11,400
c. 410 1. yds. stone blanket @$320 = $131,200
d. Cleaning and grubbing 2.86 acres @$1000 per acre = $2,900
e. Pump manhole = $1,600
f. Piping $825 buried 4 ft. 2 1/2" ø @$11/1. ft. = $9,100
g. Electrical and controls to pump, same trench as pipe, in conduit @$3.20/ft. = $2,640
h. Field safety provisions = $45,000
i. Field supervision and security = $15,000
j. Move on and off = $10,000
k. Contingency = $28,000
l. OH & P 25% = $77,035

Total $385,175

Say $385,000



SITE AREA

2G-23

Figure 7

MAP OF LIPARI LANDFILL AREA.

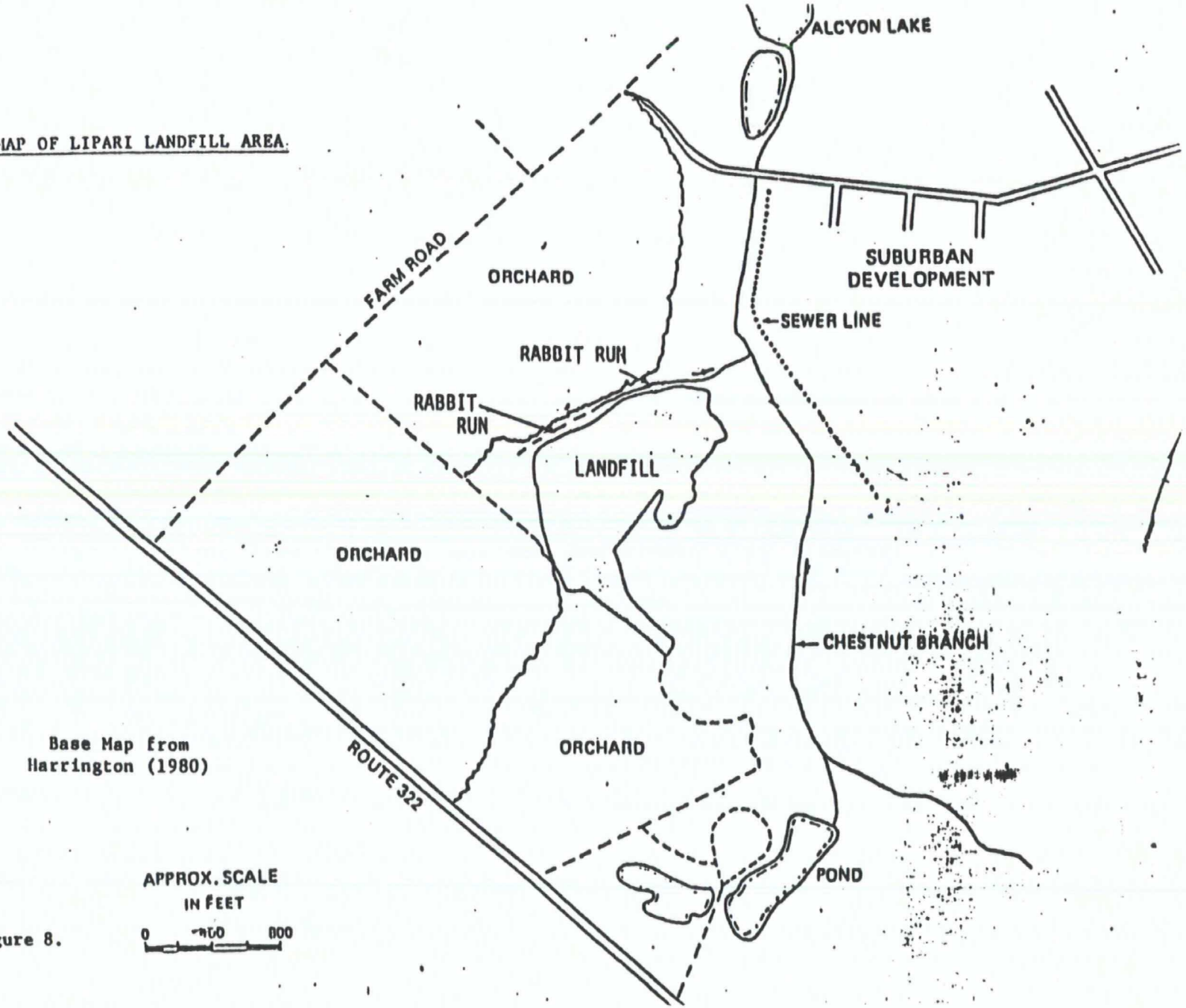


Figure 8.

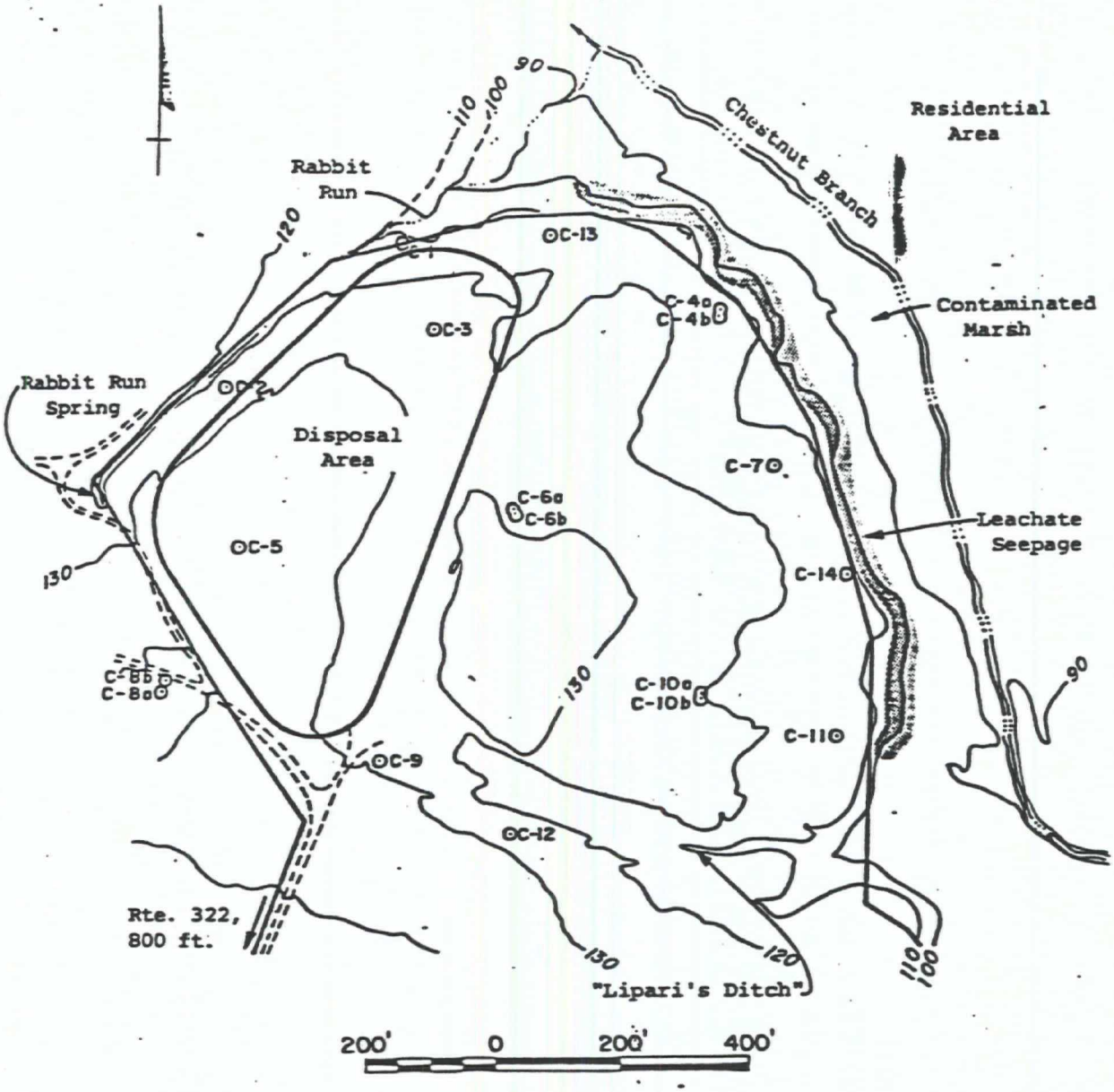


Figure 9. Local setting of the Lipari Landfill, showing the locations of the disposal area and the diffuse leachate seepage.

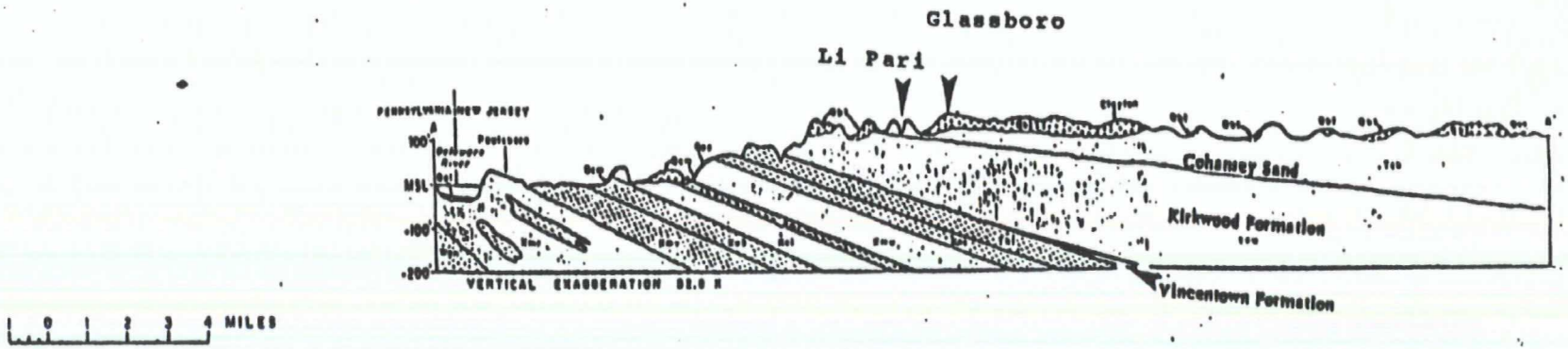
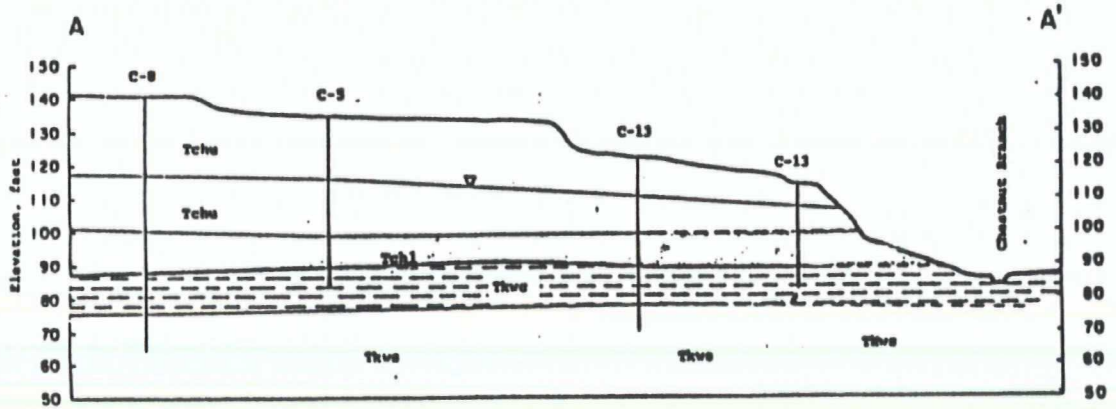
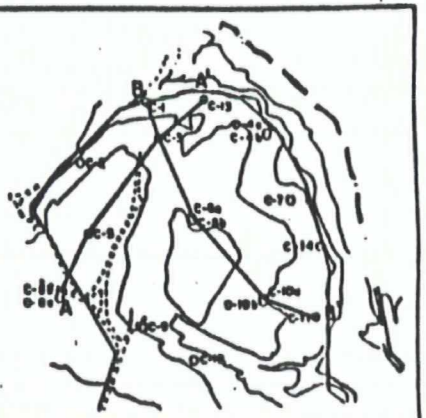
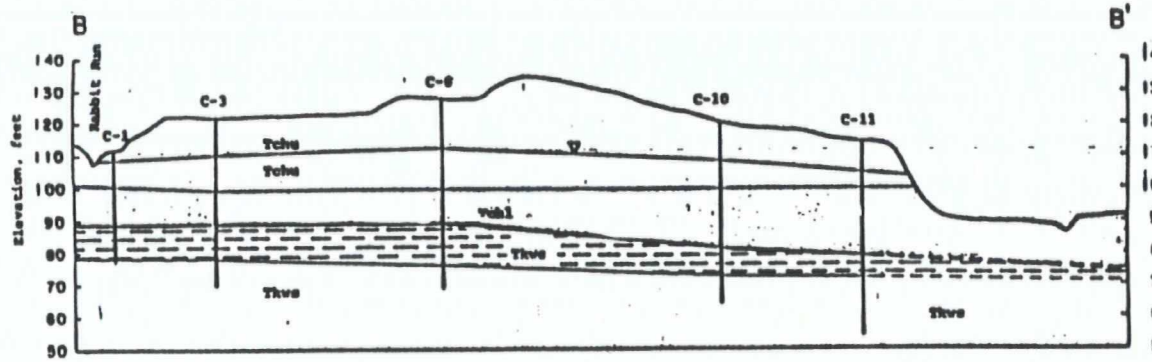


Figure 10.Generalized geologic maps and cross-section of Gloucester County, N. J.





LOCATION MAP



EXPLANATION

C-1 Logged Borehole; Length of line indicates total depth.

▽ Water Table. Measurements made July 17, 1981.

Tchu Tertiary Chesnoy Formation, upper unit. Comprised of sand and gravel; trace to little silt.

Tchl Tertiary Chesnoy Formation, lower unit. Comprised of silty fine to medium sand.

Tkvs Tertiary Kirkwood Formation, clay unit.

Tkvs Tertiary Kirkwood Formation, sand unit. Comprised of silty fine to medium sand.

0 100' 200'
SCALE IN FEET

Figure 11.

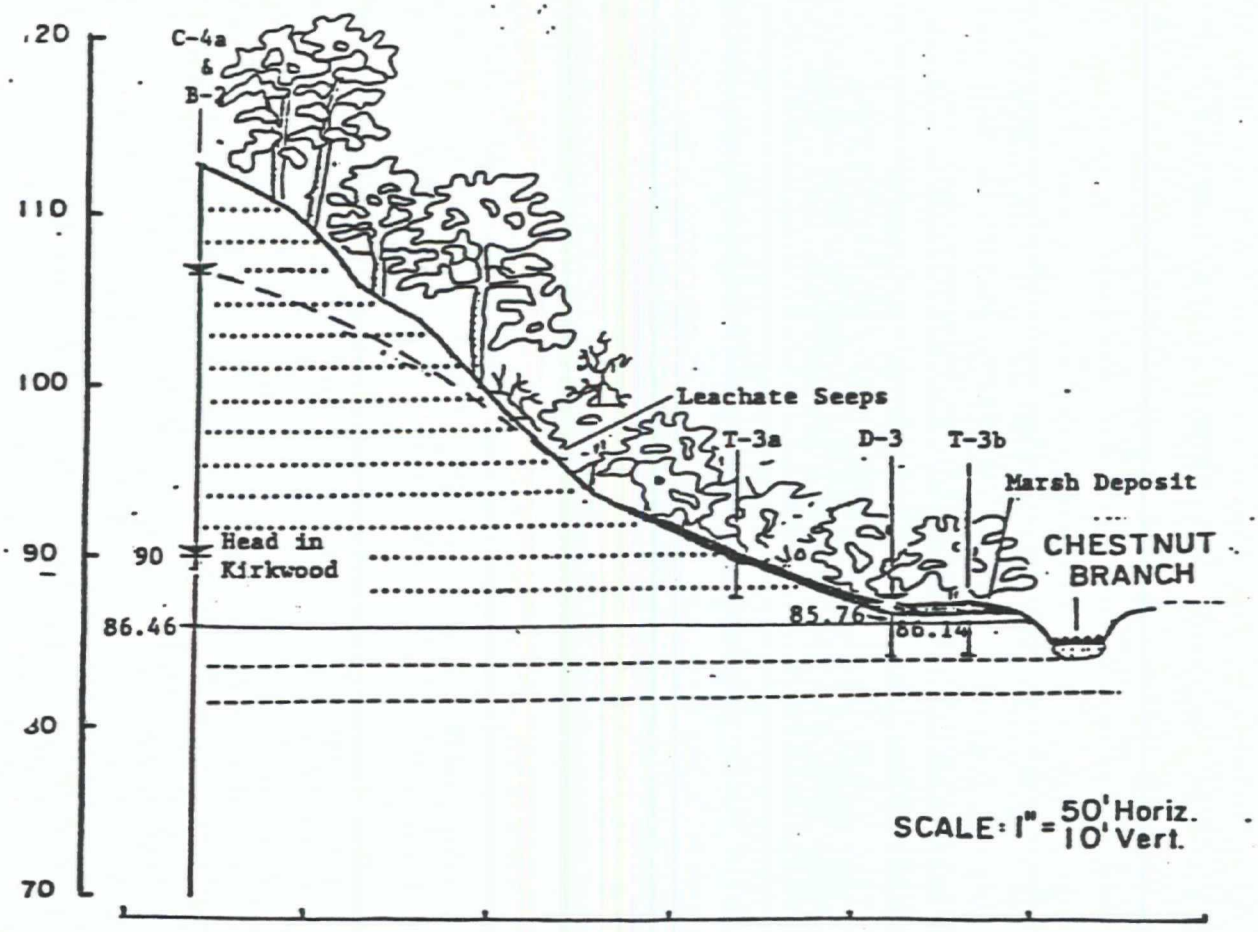


Figure 12. Typical cross-section of the marsh in the Chestnut Branch floodplain.

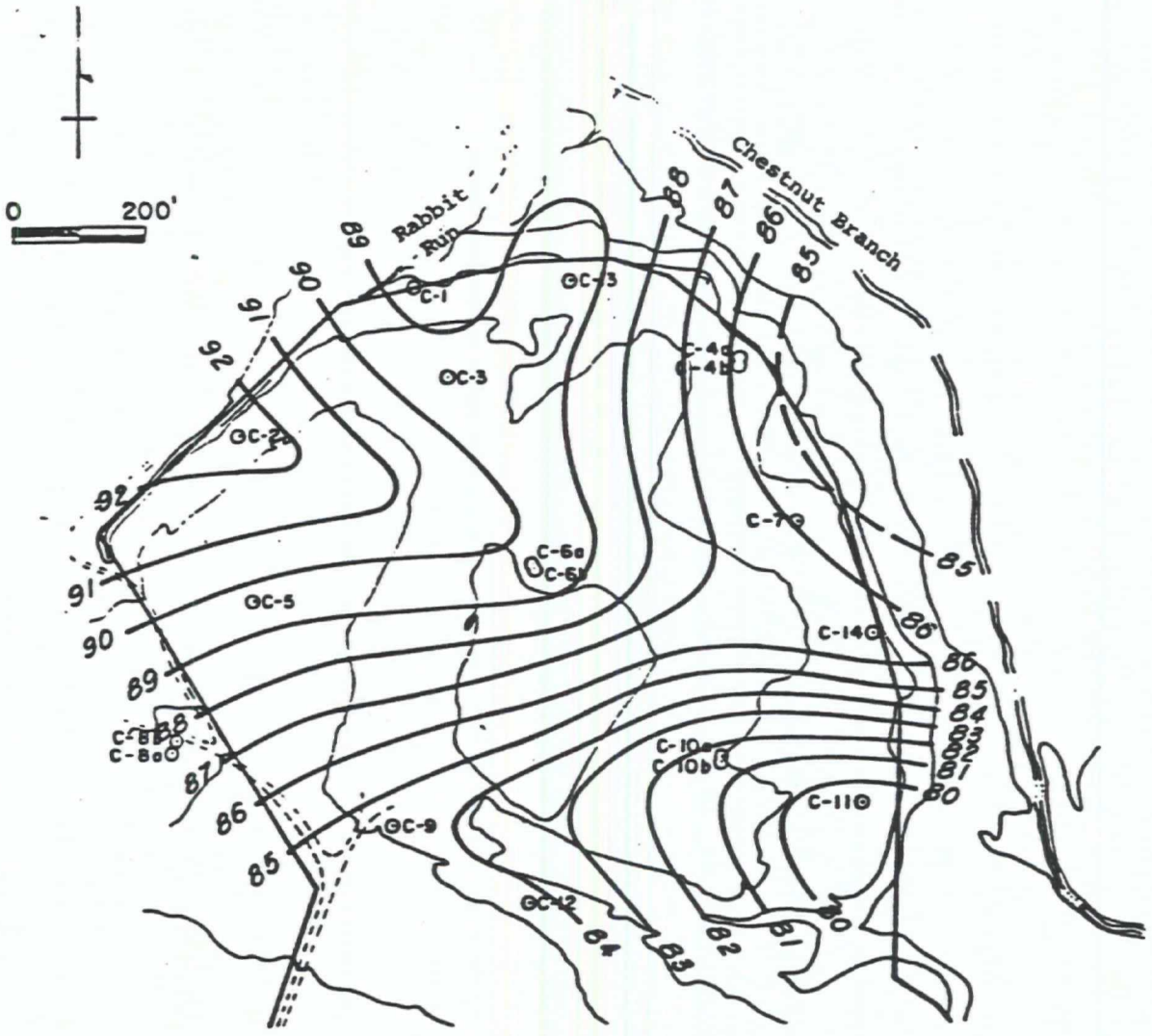


Figure 13. Structural map of the top of the Kirkwood Fm. (Tkw) clay, which directly underlies the Cohansey Sand.

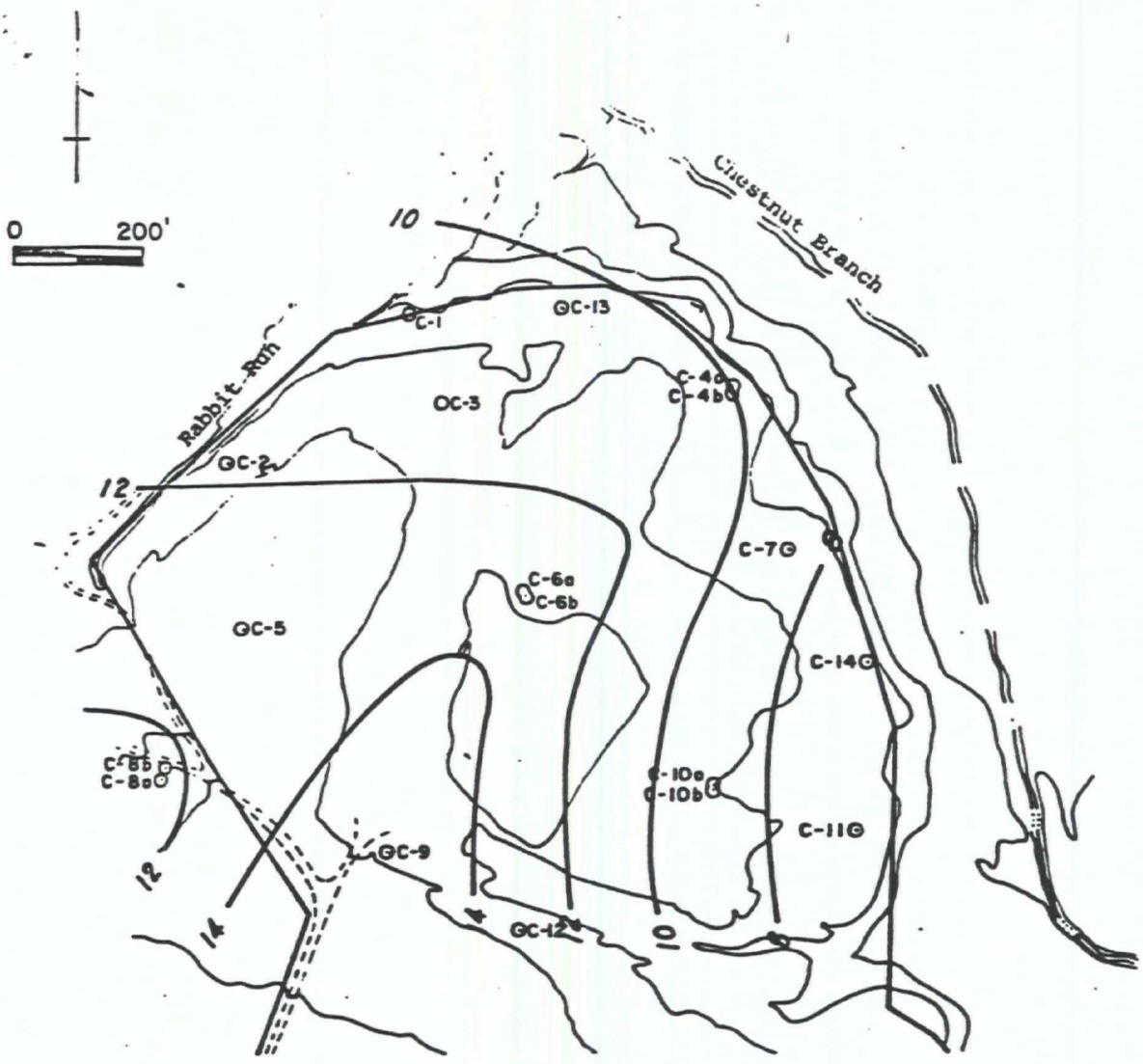


Figure 14. Thickness of the Kirkwood Fm. (Tkw) clay, in feet.