APPENDIX A through APPENDIX H

AR101668

APPENDIX A

EVALUATION OF GROUND WATER AVAILABILITY AND PUMPING CAPACITY

LLANGOLLEN AREA

Problem

Leachate from the old Llangollen Landfill has entered the underlying Potomac aquifer and is moving in the direction of high volume wells approximately 3,000 feet southeast of the landfill. The leachate contains high concentrations of dissolved metals, salts and organic compounds. The taste and odor as well as the objectionally high concentrations of certain of the chemical species renders the leachate totally unacceptable for potable or most other water uses.

Geologic Setting

The geology of the Llangollen area as it affects the leachate problem has been described in an earlier project report. Briefly, the area is blanketed by approximately 30 - 60 feet of generally coarse sandy sediments of Pleistocene Age. This veneer has been extensively quarried in the Llangollen area. The Llangollen Landfill itself is constructed in such an old gravel pit.

The Pleistocene sands directly overlie the Lower Cretaceous Age Potomac Formation. The Potomac was deposited by sluggish streams and consists of an interbedded sequence of clay, silt and fine to medium sand with smaller amounts of coarse sand and fine gravel. Some parts of the formation are predominantly sandy and have been developed for water supplies, while others are predominantly clayey or silty and retard the movement of water. In the Llangollen area the upper part of the Potomac Formation is an aquitard which seperates the Pleistocene sands from the deeper Potomac sands. The aquitard confines water in the Potomac sands under artesian pressure so that water in a well screened in the Potomac sand rises above the level of top of the sand.

Large scale withdrawals from wells in the Potomac aquifer have lowered water pressure through the formation. The result has been to create a water pressure gradient from the Pleistocene sands to the Potomac sands and -- once in the Potomac acuifer -- towards the pumping wells. This situation has caused the migration of leachate from the landfill into the Potomac aquifer where the aquitard is absent and the front of leachate contaminated water is moving toward the existing major wells in the aquifer.

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Aquifer Evaluation

An extensive test drilling program in the Potomac aquifer has defined the approximate extent of leachate contamination in the aquifer. This pattern of contamination is shown in Figure 1.

In order that the contaminants be prevented from spreading further through the aquifer and eventually reaching the existing wells a contaminant recovery program has been initiated. The program is intended to intercept and recover contaminants through properly located wells.

The recovery wells are being drilled in the part of the aquifer which has already been contaminated to minimize the amount of good water which is removed. The recovery wells must locally reverse the present water pressure gradient towards the existing wells so that all contaminants move to the recovery wells. In order that this be accomplished it was necessary to evaluate the aquifer parameters governing water movement so that a quantitative ground water management program could be established.

Because little quantitative information on aquifer transmissivity, storage and boundary conditions existed prior to the need to design the recovery system, Roy F. Weston undertook an aquifer evaluation program. This program consisted of pumping and recovery tests of wells drilled for New Castle County during the contaminant investigation and the existing wells belonging to the Artesian Water Company.

The aquifer transmissivities calculated from these tests ranged from 40,000 gpd/ft. to 150,000 gpd/ft. Storage coefficients ranged from 5.7×10^{-5} to 5.6×10^{-4}. The transmissivities are greater along the axis of the old sand filled channels and across channels. Average aquifer parameters used in the ground water management calculations were as follows:

1. along aquifer strike (NW - SE direction)
   transmissivity = 74,000 gpd/ft., storage coefficient = 2.87×10^{-4}

2. along aquifer dip (SW - NE direction)
   transmissivity = 40,000 gpd/ft., storage coefficient = 5.7×10^{-4}

Ground Water Management Plan for Contaminant Recovery

Any increase in withdrawal of ground water from the aquifer down-gradient from the Llangollen Landfill would accelerate the rate of movement of the front. For example, if the wells in the nearby well fields are pumped at 3,000 gpm, the front could travel 100 feet in only 75 days. On the other hand, the front could take 226 days to travel 100 feet if the wells are pumping at 1,000 gpm. In any case the velocity of contaminant movement will increase as the front approaches the pumping centers. Although it does not appear that the front is moving at an alarming rate now, it would be a matter of time before most of the wells in the aquifer start pumping contaminated water if present conditions were to persist. If permeability of the aquifer material in a zone between the Llangollen landfill and the nearby well fields is as high as 6,000 gpd per square foot, which appears to be the upper limit of the permeability of the aquifer material in this area, the front could travel 100 feet in 18 to 20 days.

The most desirable solution would be to curtail the large well fields, presently pumping several million gallons of water from the aquifer. If these wells were to stop pumping as soon as possible and not restart until most of the contaminated water has been removed, the recovery operation could be accomplished with minimum withdrawal and a shorter time span with the absence of competing wells.

In view of the increasing demand of ground water during the incoming summer, it may not be practical to shut down all existing well fields. A reduction in the present pumping rates will be necessary to slow down the contaminant movement so that the retrieval wells would be more effective in creating the desired ground water divide.

It appears that if the existing well fields continue to pump at the present rates and the retrieval wells have started pumping, a ground water divide would exist at about 500 feet from well 23 along a line between wells 30 and J-1 (figure 1,2). Under these conditions, the gradients to northwest (toward landfill) and to southeast (toward well field) of the ground water divide would be approximately 7.38×10^{-3} ft./ft. and 4.94×10^{-3} ft./ft., respectively. Although the retrieval wells would create local cones of depression and gradients thereby causing the contaminant front to move ultimately towards the landfill, there will be an overall gradient towards southeast.

Conclusions

The main influence of the retrieval wells is limited to a radius of approximately 250 feet downdip in the aquifer if the existing well fields continue to pump at the present rates. Movement of contaminants downdip past this radius would probably not be reversed to the recovery wells. Thus, the recovery wells would have a greater chance of success in recovering all contaminants if the pumping rates of the existing wells are reduced.

Another important factor to be considered is the capacity of the aquifer which may not be able to sustain 3,000 gpm of the retrieval wells in addition to the pumping rates of the existing well fields. Although necessary and sufficient data are not available a rough estimate indicates that approximately 6.83×10^{-3} gpd/sq. ft. may be available for recharge from the annual precipitation. Overpumping the aquifer is not a sound practice and it seems necessary that in order to recover the contaminated water from the aquifer, the pumping rates of the wells in the existing well fields should be reduced as soon as possible. In any case, no additional wells should be allowed to start pumping in the nearby well fields.

APPENDIX B

Contaminant recovery program at Llangollen Proposed work schedule (May, 1973)

1. Drill contaminant monitor (4") and recovery (10") wells - Delmarva Drilling Company - initiated May 7th

2. Pump sample all existing 4 and 6" diameter wells - Delmarva Drilling Company - to start May 9th

3. Initiate emergency retrieval of contaminants by installing pumps in Well Nos. 28, 29, 30, and 31 @ 125 gpm each monitor water levels and water quality.

4. Jet shallow ground water monitoring points in the Pleistocene sand around and down dip from the landfill - Econo Shallow Well Drilling - to start May 10th

5. Auger monitoring points in the landfill - Thomas Keyes - to start May 11th

6. Pump test and sample contaminant monitor and recovery wells - Delmarva Drilling Company - as wells are completed

7. As large recovery wells are completed, select and install permanent pumping equipment in order to initiate the retrieval system as soon as possible

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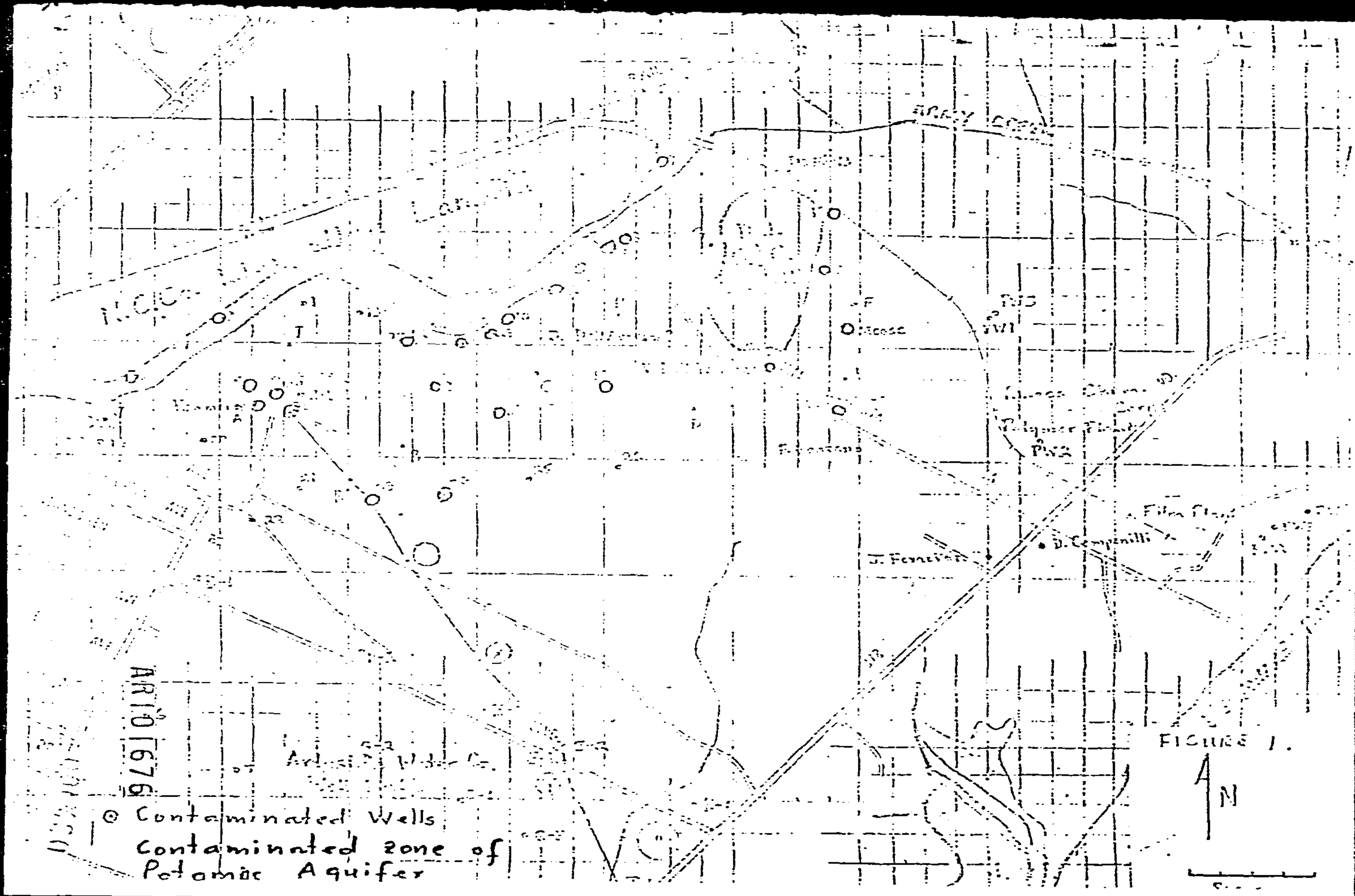

FIGURE 1.

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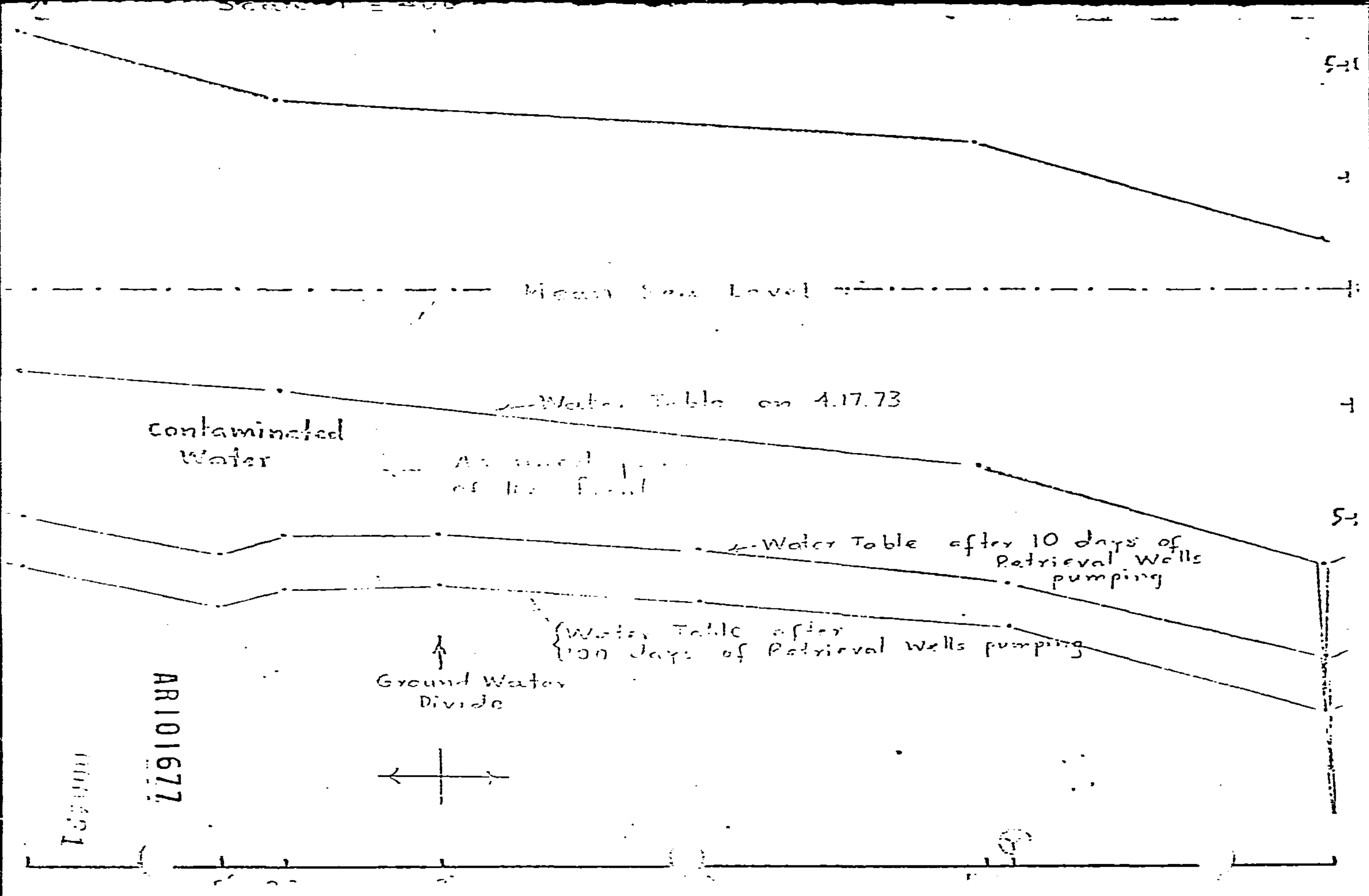

Mean Sea Level
Water Table on 4.17.73
Contaminated Water
Water Table after 10 days of Retrieval Wells pumping
Water Table after 100 days of Retrieval Wells pumping
Ground Water Divide

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[illegible]

[illegible] Landfill [illegible] on Contaminant [illegible] ry and Treatment

May, 1979

[illegible]

Recovery [illegible] initiated by the Del[illegible] Drilling Company under Roy F. [illegible] 7, 1979. Based on the analysis of the [illegible], the recovery system was planned to consist of 10 - 12 strategically located [illegible] diameter production wells. This well diameter was chosen to [illegible] a turbine pump capable of producing at least [illegible] gallons per minute. Proposed locations for the recovery wells are shown on Figure 1.

Due to the variability in water transmitting characteristics and the non-uniform [illegible] of [illegible] of the aquifer, some prospecting for the [illegible] of recovery wells was necessary. Thus, 4-inch pilot wells were constructed [illegible] at locations where recovery wells might later be constructed. This permits an appraisal of the aquifer prior to [illegible] recovery well and design of recovery well specifications. [illegible] in the drill rig time which [illegible] for the well screen to be constructed.

Well [illegible]

To date, [illegible] completed. The locations [illegible] these wells [illegible] Logs of these wells are appended to this report. [illegible] analysis of drill cuttings, discussions [illegible] electric and [illegible] geophysical logs run in the [illegible].

Water [illegible]

[illegible] analyses [illegible] from these wells from May 9 to [illegible] This report. [illegible] samples were collected [illegible] portable generator. The [illegible] per minute.

Water from [illegible] 27, [illegible] improved dramatically [illegible] the wells were drilled [illegible]. Most likely, [illegible] water from a sand unit under the greater hydraulic pressure encountered to move into the well [illegible] around the well which were present when the well was drilled.

Based on this sampling round, the section of the [illegible] aquifer believed to be at least in part contaminated is shown in Figure 2.

Recovery Well Construction

One recovery well [illegible] has been completed and tested. This well should be able to sustain [illegible] without [illegible] the [illegible]

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the screen. However, [illegible] level will draw back into the aquifer as [illegible] the direction of contaminant movement towards the [illegible] analysis of water from well [illegible] 1 is included in Table 1.

000402

Well [illegible] have limited its [illegible], surging and jetting is

Behavior of Water in the Pleistocene

Wells jetted in the Pleistocene sand only a few feet north of the landfill margin appear uncontaminated (samples are undergoing analysis at present). Water levels in these wells appear higher than that of Army Creek, although the jetted wells have not yet been surveyed and their measuring point elevations are only estimated. These two lines of evidence indicate that water is moving into the landfill from the north and discharging out into Army Creek on the south. Unfortunately, some of this water infiltrates through the landfill floor into the Potomac Aquifer. However, it does not appear that leachate is not mounded in the landfill, which would permit it to outflow in all directions and increase its vertical gradient to the aquifer.

Two wells jetted into the Pleistocene along the south bank of Army Creek near wells 28 and 31 encountered water levels at -0.5 and -3 feet below sea level respectively. At the same time, Army Creek had an elevation five to six feet above sea level, and the Delaware Sand & Gravel dredge pond was between 0 and 1 foot above sea level. This data indicates that the Pleistocene sands along the south bank of Army Creek is locally the area of most rapid recharge to the Potomac aquifer, and 2) vertical leakage through the bottom of Army Creek is very slow. Such a situation should permit removal of the Delaware Sand & Gravel Company's pond on Army Creek without dropping the water level in the dredge pond.

Availability of Ground Water in the Llangollen Area

Estimates of ground water availability in New Castle County and the Delmarva Peninsula have been made previously by investigators of the U. S. Geological Survey, the Delaware Geological Survey and private consulting firms.* Using estimates from the previous investigations and data collected during the present investigation, the ground water available from the Pleistocene and Potomac aquifers in the Llangollen area is in the range of 5 to 6 million gallons per day (MGD).

The present daily usage in the area by the Artesian Water Company and the Amoco Chemical Corporation is approximately 4.6 MGD. A system of retrieval wells have been designed to recover the contaminants. The proposed yield of the retrieval wells when the system is in full operation would be 4 to 6 million gallons a day.

Thus, Artesian, Amoco and Retrieval wells, if allowed to pump together, would be pumping 9 to 11 million gallons a day - a rate which the aquifer in the area would not be able to sustain. Since the retrieval of contaminants is the interest of the present users, pumping of retrieval wells should be given preference over other users. It seems imperative that the quantity of water pumped by Artesian wells should be regulated.

* see references

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It has been documented that the contaminants are moving in a southeasterly direction from the Llangollen landfill and if the contaminants movement is not reversed, it will only be a matter of time until the contaminants would arrive at the Artesian wells. Analysis of the pumping test data also indicated that the closer the front gets to the Artesian, the harder it will be to recover the contaminants. The actual position of the contaminant front is not known at present. However, it is between Wells Nos. 23, 24, and the Artesian wells.

If the Artesian Company should be allowed to pump additional water, the data cited above would indicate overpumping of the aquifer which would also cause the front to move faster and get closer to the well field, thereby making recovery of the contaminants more difficult if not impossible.

On the other hand, if the present pumpage from the Artesian wellfield can be reduced to 1000 gpm, the rate of flow of contaminants would be slowed down and the contaminants would be recovered relatively easily.
1.4 MGD

Analysis of the pumping test data also indicated that the aquifer in the landfill area would not be able to sustain the proposed pumpage of the recovery wells and even the present pumpage at Artesian.

The existing water levels in the Artesian wellfield area are so close to the top of the aquifer that if Well E-2 is restarted, the water level could be lowered below the top of the aquifer in a matter of a couple days of pumping.

It will be in the interest of the Artesian Water Company that the present pumpage be reduced to at the most 1.5 million gallons a day pumping preferably from the old Artesian wellfields. The Kelly wells (e.g. 2,3, [illegible] 6) in the old wellfields could be used perhaps relatively safely because they are not in the line of stratigraphic deposition or natural piezometric gradient in the Potomac in relation to present distribution of contaminants, and they obtain a considerable portion of their water from the underlying Pleistocene aquifer.

Contaminant Recovery Program at Llangollen Landfill

Proposed work schedule for June, July 1973

1. Construct and test pilot wells at locations of proposed retrieval wells Nos. 4 - 10. - Delmarva Drilling Company (in progress)

2. Design and construct retrieval wells Nos. 3 - 10 - Delmarva Drilling Company (in progress)

3. Negotiate removal of Delaware Sand & Gravel Company dam on Army Creek at eastern end of landfill. (in progress) This will lower the water table in the landfill area and permit more rapid exit of contaminants which do enter the creek from the area of direct recharge to the Potomac aquifer.

4. Initiate emergency retrieval of contaminants from the Potomac aquifer by installing pumps and providing electrical power hookups in Wells Nos. 27, 28, 29, and [illegible]. [illegible] of contaminants would go untreated to Army Creek. (by mid-June) - Delmarva Drilling Company and Isaac [illegible], Electrical Contractor.

5. Negotiate with [illegible] & Ferrara for permission to construct additional wells between well No. [illegible] and Artesian Water Company's new wellfield and between [illegible] and Artesian Water Company's old wellfield for water quality and water level monitoring.

6. Collect and analyze water samples from all wells as they are completed and/or equipped for emergency pumpage. (in progress)

7. Jet well points into the Pleistocene sand south of the landfill and in the vicinity of the contaminant retrieval system for water level and water quality monitoring. - Econo Shallow Well Drilling Company (in progress)

8. Construct 6-inch wells in the landfill itself with an air rotary drill rig for water level monitoring and possible contaminant recovery. (Specifications prepared for bids

9. Prepare landfill covering specifications for bids (in progress)

10. Construct cross-connections between Artesian Water Company and Wilmington Suburban Water Company to provide ½ mgd to the Artesian System - Artesian Water Company (completion by end of June)

11. Complete design and specifications for cross-connections to provide an additional transfer of 2 mgd from the Wilmington Suburban Water Company to the Artesian Water Company. (in progress)

12. Complete contaminant treatability studies for potable water requirements. (in progress)

13. Select a permanent treatment process for ultimate contaminant disposal.

14. Continue the program of biweekly water level monitoring from all wells and surface water bodies in the Llangollen area.

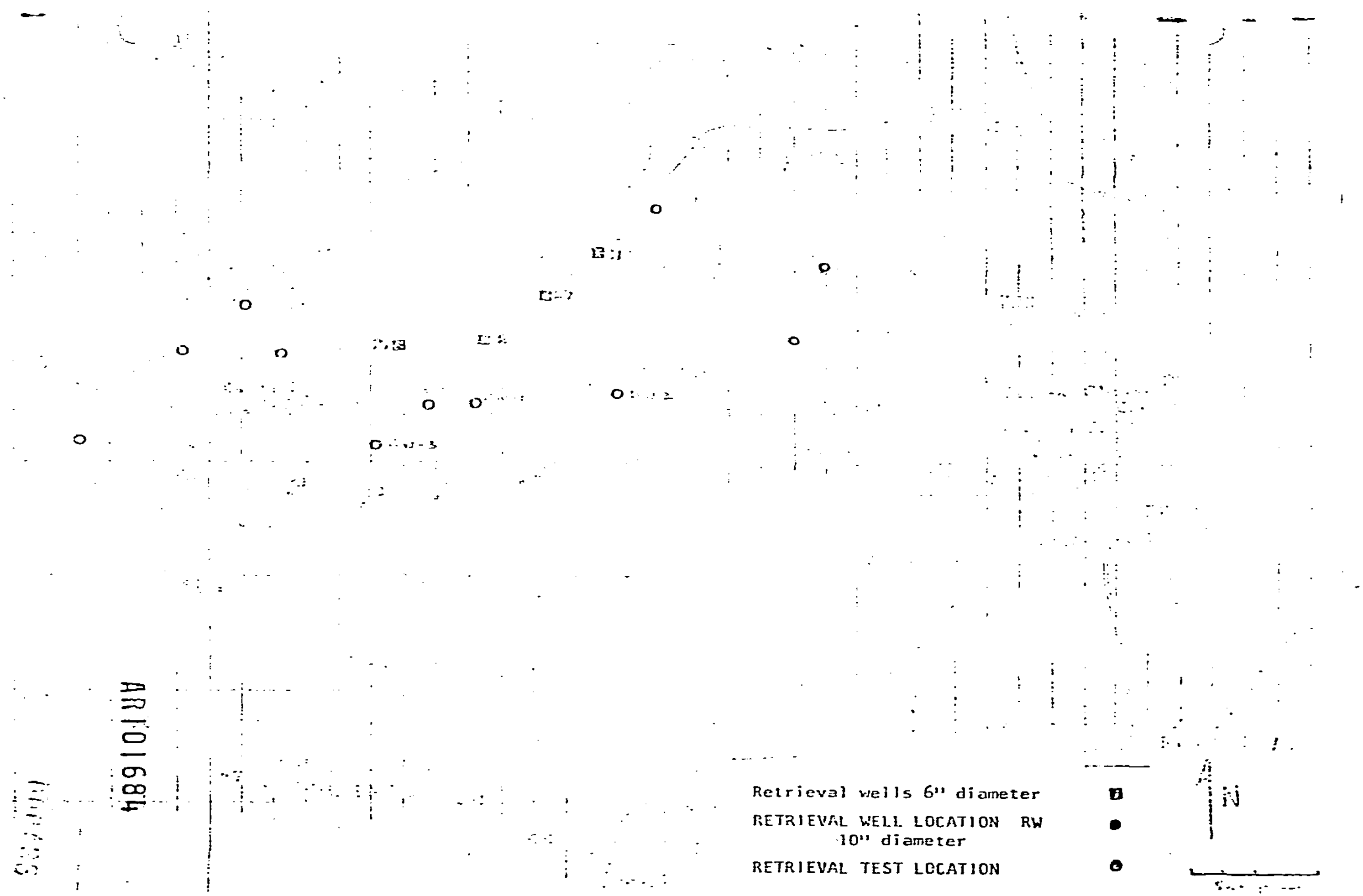
References

1. "Water Resources of the Delmarva Peninsula: Summary Report to Congress" by E. M. Cushing, I. H. Kantrowitz, and K. R. Taylor U.S. Geological Survey, News Release, November 5, 1972

2. The Availability of Ground Water in New Castle County, Delaware; R. W. Sundstrom and T. E. Pickett, University of Delaware, Water Resources Center, July, 1971

3. Availability of Ground Water in New Castle County, Delaware; Report prepared by Roy F. Weston, Environmental Scientists and Engineers, West Chester, Pennsylvania, July 1972

4. Letter to Mr. Lester Meyer, Division of Environmental Control, Department of Natural Resources and Environmental Control, Dover Delaware; by Kenneth D. Woodruff, Senior Hydrologist, Delaware Geological Survey, March 13, 1972


N
Retrieval wells 6" diameter
RETRIEVAL WELL LOCATION RW
10" diameter
RETRIEVAL TEST LOCATION

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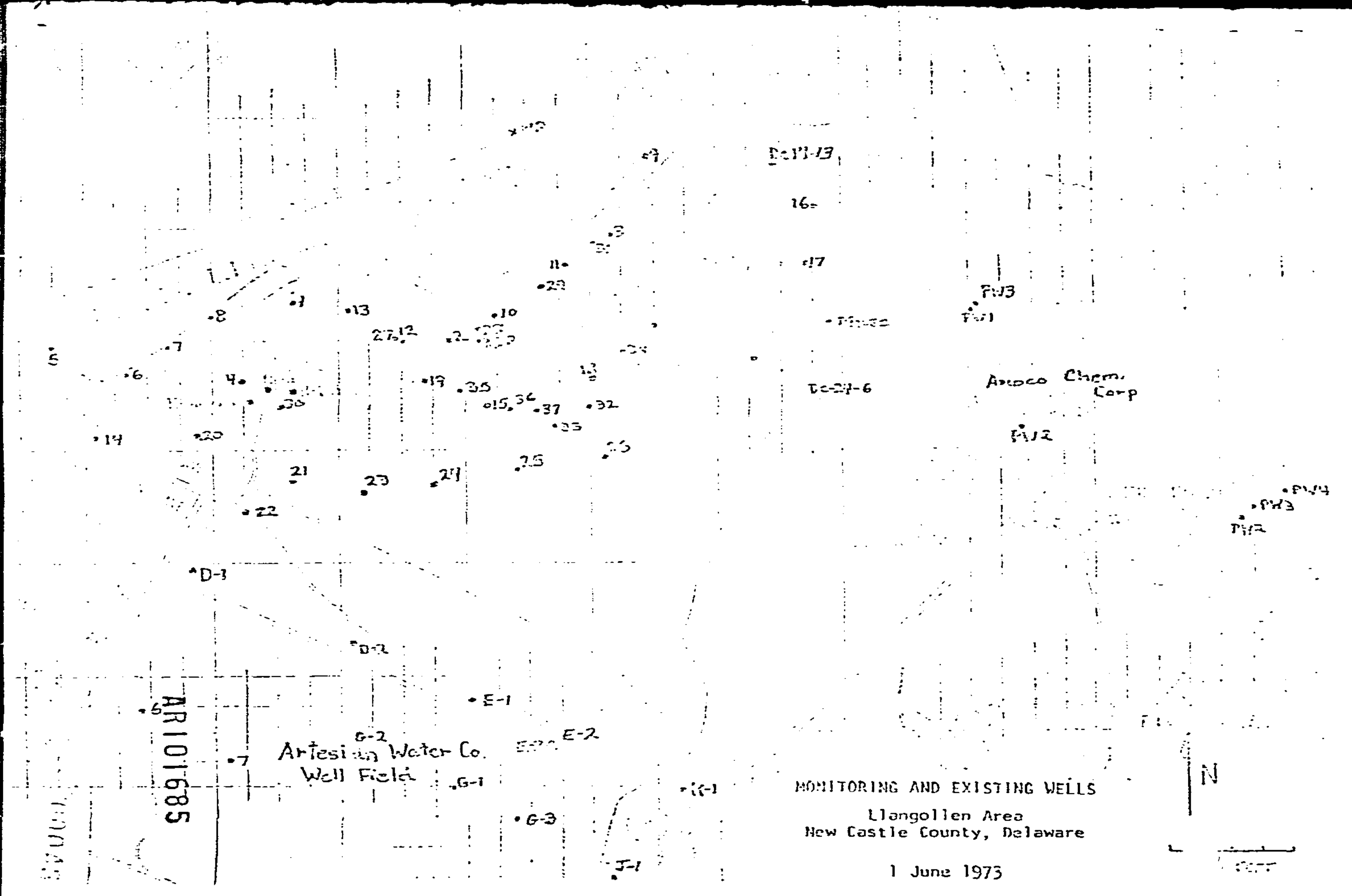
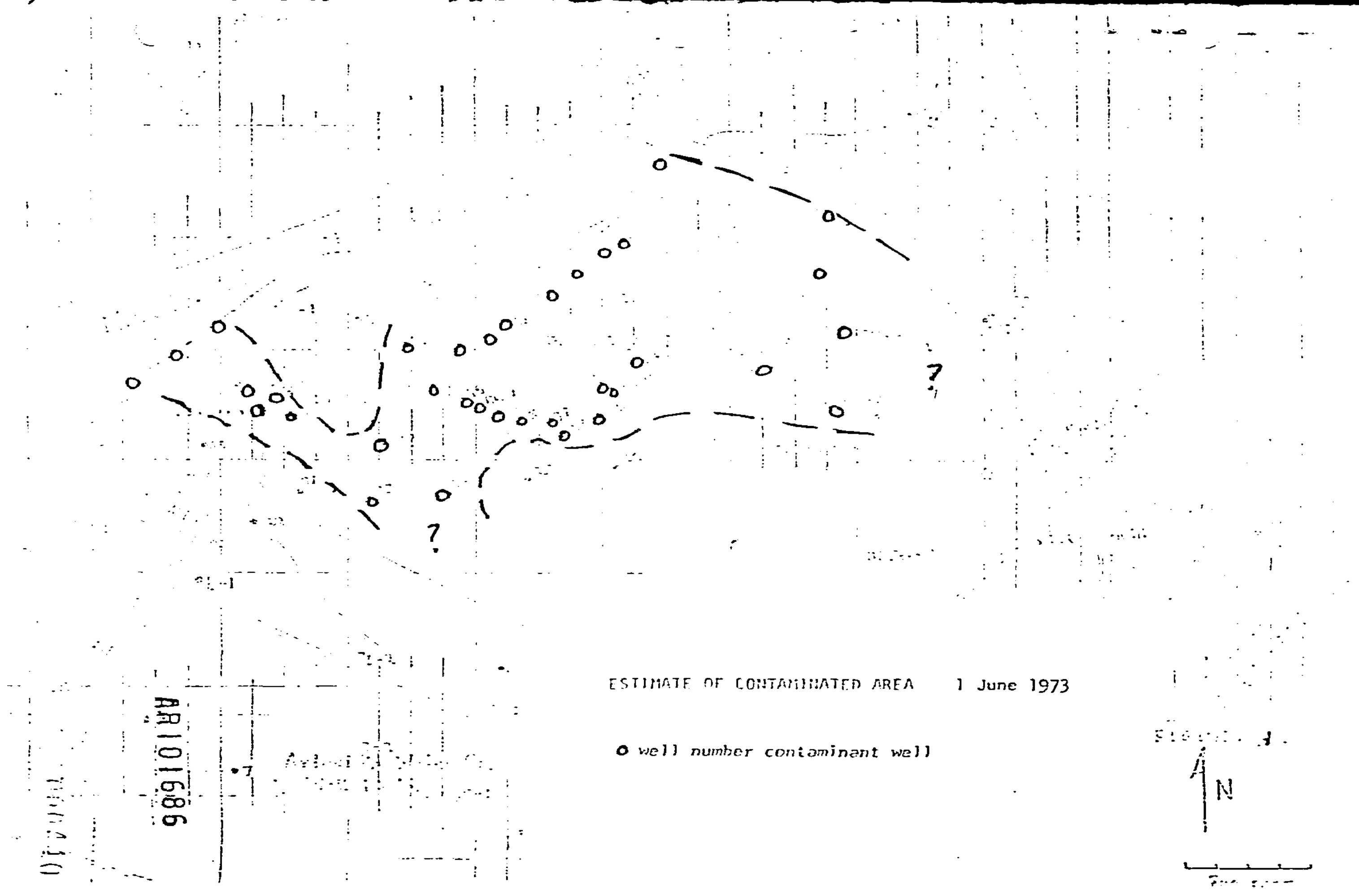


MONITORING AND EXISTING WELLS
Llangollen Area
New Castle County, Delaware

1 June 1973


ESTIMATE OF CONTAMINATED AREA 1 June 1973
o well number contaminant well
N
?
?

WAT[illegible] QUAL[illegible] DA[illegible] [illegible]ECTI[illegible] POINT[illegible]
IN THE VICI[illegible] OF [illegible]EN [illegible]FILL

May 1973

Sample Description	Date Collected	COD	SS	TDS	pH	Alk.	Acid.	Cl	SO_4	Fe	Mn	NH_3-N	TOC
Well 27	5/9/73	20	< 1	94	5.4	9	49	11.4	<1	0.3	0.07	<0.5	
Well 28	"	60	12	321	6.3	129	108	93.2	<1	9.2	2.9	<0.5	15.5
Well 29	"	170	68	933	6.7	635	287	501.0	<1	43.0	10.5	72.2	71
Well 32	"	40	1	334	6.7	134	10	86.1	10	6.2	<.05	1.12	
Well 33	"	30	6	125	5.6	20	62	33.6	<1	0.2	<.05	<0.5	
Well 34	"	30	266	206	7.1	70	8	37.3	6	5.7	0.40	<0.5	
Well 21	5/10/73	20	16	48	6.3	18	17	5.52	11	0.7	0.07	<0.5	
Well 22	"	20	27	122	5.3	8	69	13.5	<1	0.2	0.15	<0.5	
Well 23	"	50	60	62	6.1	46	36	10.9	<1	5.0	0.95	<0.5	12.5
Well 24	"	< 5	10	136	6.3	46	34	34.0	<1	0.2	0.15	<0.5	2.5
Well 25	"	20	14	47	6.0	14	10	12.8	11	3.9	<.05	<0.5	
Army Creek	"	50	108	131	6.9	34	6	26.3	19.1	8.0	0.35	0.56	6
Gravel Pond	"	30	37	19	6.4	6	4	5.7	1	1.5	0.07	<0.5	
Well 16	5/11/73	20	< 1	63	5.6	10	18	10.1	<1	0.10	<0.05	< 0.5	
Well 28P	"	20	66	182	6.5	70	42	36.7	13	27.0	5.5	< 0.5	
Well 30	"	10	< 1	94	5.6	12	20	10.7	< 1	0.2	<.05	< 0.5	
Well 31	"	50	26	392	6.8	296	110	110.0	< 1	23.0	2.0	46.5	37.5
Well 31P	"	10	8	160	6.5	78	42	34.7	< 1	1.0	13.5	< 0.5	
Well 34	"	< 5	15	166	6.5	73	56	39.3	< 1	0.8	0.60	0.56	
Well 36	"	10	53	141	6.8	28	12	33.5	13	1.0	<0.05	< 0.5	
Well 5P	5/17/73	10	--	173	--	--	--	12.8	25.6	0.65	0.25	1.4	
Well [illegible]	5/18/73	30	--	193	--	--	--	46.6	19	0.65	1.0	0.7	
Well 35	"	< 5	--	118	--	--	--	36.4	14.4	15.25	0.15	2.1	
Well 37	"	< 5	--	81	--	--	--	24.0	19.6	14.25	0.10	< 0.5	
RW-1	5/22/73	78	--	353	--	--	--	96.0	12.0	4.65	1.55	17.5	

All concentrations are in milligrams per liter
with the exception of pH, which is reported in standard pH units.

[illegible] LANDFILL INVESTIGATION

TA[illegible] IT: VER[illegible] [illegible]TIME

MILESTONE CHART

Updated 1 June 1973

NO.	TASK/SUBTASK TITLE	April	May	June	July	Aug.	Sept.						
	YEAR: ___ ___ ; MONTH ___ /WEEK ___ OF PROJECT												
	Definition Leachate Contamination Front			[illegible] wells beyond [illegible] completed May 2									
	Pump Tests Recovery Well Network and Analysis			completed									
	Pumping Tests-Artesian Water Company and Amoco			completed									
	Determine Reduced Pumping Rate for Artesian Water Company				completed May 8								
	Drill and Test Additional Recovery Wells					RW 1 completed 2 construction, developing							
	Design of Contaminant Recovery Program												
	Treatability Study			Started May 8 Continue using potable water standard if approved by State									
	Determine Temporary Treatment Requirements												
	Initiate Emergency Pumping From Recovery Wells												
	Design Temporary Treatment Facilities												
	Construct Temporary Treatment Facilities												
	Design Permanent Treatment System												
	Design Permanent Recovery System												

Note: Dotted Line Indicates Time Extensions.

AR101688

Well 33 (5-27-73)

Depth	Description
0-6	white & tan med-coarse sand & fine rounded gravel
6-12	gray-green med-fine sand w/ muscovite flakes
12-17	yellow-gray green clayey sandy silt (4-inch dia rounded qtzite boulder @ 17'
17-22	yellow-buff-gray green silty clay interbedded w/ dirty white & tan med rounded gravel
22	ironstone layer
22-29	red lignitic clay interbedded w/ buff fine sand
29-42	buff fine-med silty sand
42	ironstone layer
42-56	red-brown silty lignitic clay
56-63	buff fine-v. fine sand w/ stringers of white v. fine sandy silt
63-75	buff-tan silty sand w/ iron stains
75-79	buff-tan silty v fine sand w/ iron stains interbedded w/ string of gray-green clay
79-85	buff fine-v fine sand
85-103	reddish brown & yellow clay w/ intermixed buff med-coarse silty san
103-120	buff-white v coarse sand & gravel intermixed w/ reddish brown & sandy silt
120-141	red-brown fine-coarse silty sand
141-160	red & white clay - silty clay

AR101689

Well 53 (5-7-73)

Depth	Description
0-4	white & brn medium-coarse sand w/~10% rounded gravel
4-16	white & buff v fine sand interbedded w/ white silt and clayey silt (finer grained material becomes more predominan w/ depth)
16-32	red & white smooth clay w/ some thin interbeds of white v fine sandy silt
32-45	white - light gray v. fine sandy silt
45-52	buff v fine sand interbedded w/ occasional v thin stringe of red, orange, dark gray & red-brown clayey silt
52-55	mostly red, orange, dark gray & red brown clayey silt
55-66	same as 45-52
66-85	red & white clay interbedded w/ occasional v. thin stringers of buff v fine sand
85-89	buff v. fine sand
89-94	same as 66-85
94-97	same as 85-89
97-104	buff f-med sand w/ some thin white silty clay string.
104-116	buff f-med mostly clean sand
116-131	buff f-med sand w/ some interbedded beds of ⅛" grave (the gravel also mostly clean contains some clay)
131-140	red & white clay

AR101690

Well 34 (5-9-73)

Depth	Description
0-6	buff to tan med-coarse silty sand w/ muscovite flakes (~1%) and a few thin stringers of gray green clay
6-11	reddish brown med-coarse silty rounded sand
11-17	red & white lignitic clay w/ a few thin stringers of buff fine-med silty sand
17-23	red clay w/ interbedded stringers of white silty clay and thin stringers of buff medium silty sand
23-26	buff fine-coarse dirty sand
26-41	red & white silty lignitic clay
41-46	buff med-v coarse silty angular sand
46-52	red & white silty lignitic clay
52-56	predominantly lignitic in red & white clay
56-60	gray silty clay w/ a few thin stringers of buff fine-v fine sa
60-72	buff fine-coarse silty clayey rounded sand w/ gray clay strin (as least 50% clay)
72-74	tan fine-coarse w/ thin interbedded ironstone layers and a few very thin stringers of yellow-gray clay
74-85	buff fine-coarse angular sand w/ thin interbedded ironstone layers and a few v. thin stringers of gray clay
85-96	tan to buff v fine-med silty angular sand w/ thin interbedded ironstone layers and a few thin stringers of gray clay
96-102	gray silty clay
102-116	white to tan med-v coarse angular to sub[rounded] AR100694 sand w/ thin ironstone layers
116-119	white & gray silty clay w/ interbedded white to tan med-v coarse silty clayey sand (~50% clay)
119-12?	buff to tan med-coarse sand w/ a few thin stringers of

Well 34 (cont)

129-135	white to buff fine-med sand w/ thin stringers of white & gray silty clay
135-136	ironstone cemented layer
135-140	red & white clay

AR101692

Well 35 (5-9-72)

Depth	Description
0-2	tan predom. medium sand w/ rounded 1" gravel
2-5	tan & white fine - coarse sand
5-6	yellow-brown silty clay
6-13	brown & white fine - coarse silty sand
13-32	red, white & gray silty clay
32-41	buff fine - coarse sand w/ stringers of white & gray silty clay
41-45	buff fine sand w/ streaks of white & gray silty clay
45-62	buff fine to medium sand
62-74	buff fine to coarse sand
74-76	gray silty v fine sandy clay
76-100	buff fine - medium sand w/ stringers of gray & white silty [illegible]
100-110	buff fine - coarse sand w/ stringers of gray & white silty cl
110-122	buff fine - medium sand w/ " (≥2
122-130	buff fine - coarse sand w/ " (≥25.
130-141	red & white clay

AR101693

Well 37 (5-15-73)

Depth	Description
0-2	Yellow & white fine ~~sand~~ to coarse sandy gravel
2-10	White to buff fine to v. fine sand w/ a few thin yellow clay stringers
10-21	tan to buff fine to v. fine silty sand
21-22	red sandy clay w/ buff fine-med sand stringers
22-31	red & white clay - silty clay, lignitic
31-37	tan to buff rounded to subangular fine to coarse sand w/ minor interbedded red & white clay stringers
37-43	red lignitic clay interbedded w/ white & sandy silt
43-57	buff to tan fine-coarse silty angular sand
57-62	red & gray lignitic clay
62-66	tan to buff angular fine - v. fine silty sand
66-70	tan to gray fine - v. coarse sand w/ thin scattered ironstone la
70-76	tan to buff fine - v fine silty sand interbedded w/ red & white clay stringers & thin ironstone bands (clay
76-84	buff fine - coarse silty sand interbedded w/ red & white (clay clay stringers & thin ironstone bands
84-100	tan to buff med - coarse silty sand w/ red & white clay stringers & thin ironstone bands (25-50% clay)
100-125	tan to light gray fine - v. fine silty sand w/ interbedded white clayey silt beds
125-132	red & white clay

AR101694

Well 38 (5-29-73)

Depth	Description
1-5	white-gray coarse clean sand
5-15	yellow med.-coarse clean sand
15-21	tan & black (~10%) "salt & pepper" medium sand
21-24	yellow-brn coarse- v coarse sand & fine gravel
24-31	gray-tan & black (5-10%) uniform med.-coarse sand
31-44	yellow, brn & white v coarse mostly clean, uniform s
44-50	gray fine silty lignitic sand interbedded w/ buff me
50-56	red & white clay possibly w/ some thin stringers of buff fine sand
56-83	buff fine med. mostly clean sand becoming coarse w/ depth
83-120	buff med.-coarse clean sand coarser w/ dep white v coarse sand - fine gravel intermixed w/
120-127	buff fine sand & white-gray clayey silt
127-148	buff fine sand & white-gray clayey silt buff & orange coarse - v coarse sand interbedded w/ some thin stringers of red & white clay
148-160	red & white clay

AR101695

APPENDIX C

AR101696

ROY F. WESTON
ENVIRONMENTAL SCIENTISTS AND ENGINEERS
LEWIS LANE • WEST CHESTER • PENNSYLVANIA • 19380

INTER-OFFICE MEMORANDUM

DATE 31 July 1973

TO H. Haley, S. Siddiqui, M. Apgar, J. Dougherty, M. Fiore, P. Marks, J. Weaver, A. Madora, S. Kowalchuk, D. Clark, M. Hurd, T. Luce

FROM W. B. Satterthwaite

SUBJECT: Alternatives available for New Castle County to be evaluated in terms of overall impact in treatment schemes from Llangollen Landfill

W.O Nº

In the present situation, movement of leachate from the landfill into the aquifer has been clearly documented. At the present time, leachate has moved over one-half the distance between the landfill and the Artesian wellfield at one area. In other areas the extent of contamination is much closer to the landfill.

Leachate movement has occured in the permeable units in the direction of the natural gradient. In some locations much leachate movement has been accentuated by pumpage from the Artesian wellfield.

The proposed leachate collection system will operate as a two-prong program. The present emphasis is directed toward leachate already in the aquifer; a parallel program will emphasize collection of leachate as it is produced while still within the landfill or in the immediate proximity to the fill. The leachate collection system for the aquifer is presently under construction and will be at best a precariously balanced pumping system which will require the most distant retrieval wells to be within 300 feet of the leachate front. The system is designed to initiate pumping in the retrieval wells immediately after construction to create a cone or easily visualized as a trough in order to reverse the direction and therefore gradient direction of leachate movement away from the wellfield. If pumping is not initiated in the very near future, it will certainly be necessary to drill additional wells closer to the Artesian field and therefore lower the probability of preventing contaminants from reaching the Artesian facilities.

At the present time, any pumping retrieval has been prevented through the unavailability of electric power and the leachate is presumably moving at higher rates through increased pumping at the wellfield. The question of site access, power sources, and treatment requirements must be clarified immediately so that pumping can begin.

A variety of alternatives with highly varied positive and negative impact must be considered above and beyond the immediate problems in order to determine a course of action to be followed in collecting and treating the leachate already in the aquifer and in the soon to be implemented direct or nearby collection from the landfill.

The alternatives are outlined below with positive and negative impact. If other alternatives are viable or worth consideration, they should be considered now.

ALTERNATIVE 1

Pump leachate from the aquifer starting immediately with no treatment of effluent to be discharged to Army Creek with ultimate flow to and dilution in the Delaware River.

Positive Impact:

1. A necessary step in order to retain design basis, minimize the number of wells, and hopefully reverse leachate movement sooner.

2. Utilize retrieval system presently under construction.

3. Reduce potential of contaminants reaching the Artesian wellfield.

4.

5.

6.

Negative Impact:

1. Contaminated effluent pumped directly to Army Creek and the Delaware River.

2. Potential of infiltration and dispersion of contaminants into the Pleistocene aquifer.

3.

4.

5.

6.

Associated Cost

ALTERNATIVE 2

Pump and treat to minimum standards, removing metals only.

Positive Impact:

1. A necessary step in order to retain design basis, minimize the number of wells, and hopefully reverse leachate movement sooner.

2. Utilize retrieval system presently under construction.

3. Reduce potential of contaminants reaching the Artesian wellfield.

4.

5.

6.

Negative Impact:

1. With metals removal, contaminants would certainly affect Army Creek.

2. Potential infiltration into Pleistocene aquifer.

3. Sludge from precipitation of metals procedures at present can not be disposed of legally (no permitted facility in reasonable proximity).

4.

5.

6.

Associated Cost

ALTERNATIVE 3

Pump contaminated water from aquifer (at maximum rate), treat for metals and ammonia, release to Army Creek, and supply deficit water quantity to the Artesian Water Company from other water systems.

Positive Impact:

1. Fastest retrieval program, highest probability of retrieving the majority of contaminants from aquifer.
2. The leachate within the aquifer may not need a high degree of treatment over a long period of time.
3. The next increment increased cost of treatment facility and operation.
4.
5.
6.

Negative Impact:

1. Artesian Water Company will need alternate supply when the majority of water is pumped in the retrieval program and the wellfield is shut down.
2. Amoco Chemical may need alternative supply when heavy pumpage reduces water availability in their well system below present needs.
3. Sludge disposal location, procedures, and costs must be determined.
4.
5.
6.

Associated Cost

ALTERNATIVE 5

Utilize retrieval system - design treatment to meet minimum standards acceptable for direct Delaware River discharge, provide alternate water source to shut down Artesian-Llangollen field by means of County securing control of the public water systems within the county.

Positive Impact:

1. Minimize treatment cost.
2. Utilize high pumping rate to minimize removal time.
3. On the basis of present water company estimates, other companies could divert sufficient water to the Llangollen area to replace this field.
4. Would allow time for exploration to secure additional water supplies that could operate on a county basis to utilize the potential ground and surface water sources.
5.
6.

Negative Impact:

1. Opposition by private water companies.
2. Inter-connection problems.
3. Increased county expense to acquire water companies.
4.
5.
6.

Associated Cost

ALTERNATIVE 6

Utilize retrieval system at minimum standards acceptable for direct Delaware River discharge; utilize reverse osmosis (R.O.) plant on the river for alternative supply to be used in an injection well scheme to facilitate more assured and rapid removal of contaminants and supply the Artesian wellfield.

Positive Impact:

1. Create a ground water high to assist in contaminant reversal and movement to the collection system.
2. Achieve shortest retrieval time.
3. R.O. supply will exceed drinking water standards.
4.
5.
6.

Negative Impact:

1. Cost of two sophisticated systems to retrieve contaminants and supply water company.
2. High cost of R.O. for a Delaware river supply system.
3. Potential for loss of injected water into the aquifer (not all would be retrieved by the Artesian system).
4.
5.
6.

Associated Cost

ALTERNATIVE 7

Treat leachate in the aquifer and landfill to drinking water standards utilizing a combination treatment program based on metals removal, amonia and other contaminants removal including complex organics. Treated water would be either piped directly to Artesian or preferably utilized in an injection system to provide supply for Artesian and assist in adding rapid contaminant retrieval.

Positive Impact:

1. Entire water supply secured from immediate area as previous to landfill problem.
2.
3.
4.
5.
6.

Negative Impact:

1. Design construction and operation of two complex plants.
2. Indefinite feasability, capital cost of water facilities.
3. Exceedingly high cost per 1,000 for drinking water necessitating either greatly increased cost to the consumer or the County.
4. Operation of facilities that will require highly sophisticated operator and program at all times.
5. Public opposition to drinking treated leachate.
6.

Associated Cost

ALTERNATIVE 8

Allow leachate to move in the aquifer to the Artesian wellfield. Plan to pump from present facilities, County to pay for present facilities plus value of water supply. Treatment plant at the Artesian facilities for either discharge to surface supply or as direct source of drinking water.

Positive Impact:

1. None.
2.
3.
4.
5.
6.

Negative Impact:

1. Highest cost in terms of dollar value.
2. Poor image value in terms of State, Delaware River Basin Commission, and residents.
3. Uncertain availability to treat at required standards for direct supply of drinking water.
4. Guaranteed longest term of operation affecting largest possible area.
5.
6.

Associated Cost

ALTERNATIVE 9

Allow leachate movement to Artesian wellfield then cease water supply operation at the Artesian facilities essentially write-off the aquifer permanently.

Positive Impact:

1. None.
2.
3.
4.
5.
6.

Negative Impact:

1. Will in all probability not be permitted by the State, Delaware River Basin Commission, and other governing bodies.
2. Uncertain area of ultimate distribution of leachate which could affect water supply presently considered unrelated in Delaware and New Jersey.

Associated Cost

FIELD WORK SUMMARY

Monday, 7/16/73

Reverse rotary rig drilling RW-5 at 51 feet, slow drilling in red clay and pebbles clog the bit; standard rotary drilling machine finished 48-A; pump crew pulled pump from RW-3 and installed in RW-4; pumped RW-4 from 4:45 to 5:45; static water level approximately 20 feet; pump set at 80 feet - screen 85 to 115 feet; pumped at approximately 800 gpm - approximately 77 feet water level; pumped at approximately 600 gpm - approximately 70 feet water level; pumped 45 minutes - no surging; pumped 15 minutes - approximately 10 gpm; collected 40 gallon treatment samples; water sample from RW-4 - Temp. 14.5°

Water Levels - From Ground Surface

31p	20.90'	Water Level
28p	25.10'	
28	29.95'	

No. 11 Elevation 9.93	16.7'	- top of gray cap
	18.0'	- top of stake

3B	19.65'
A-10	Dry
A-9	21.8'
A-8	21.9'
A-7	21.75'
A-6	20.57'
A-5	11.61'
A-4	13.03'
A-3	13.0'
A-2	19.82'
A-1	27.44'
5p	18.9'
4p	27.58'
3p	21.77'
2p	9.65'
1-C	1.1'

Stake near RW-5 8.62'
- 2.80'
5.82' Water Level

AR101707

Tuesday, 7/17/73

Standard rotary drilling machine completed development of 48-A and moved to 49; blowing approximately 30 gpm from 48-A; made access road and cleared drill site with back hoe; Reverse rotary rig still drilling RW-5; hung up on boulders and gummy clay; depth approximately 55 feet; Roy F. Weston representative delivered two probes to Artesian Water Company; they began their pumping test around 11:45; set up recorder on No. 23; changed charts on Nos. 22 and 26; changed charts on Nos. 30 and 24 also later that after noon; collected water sample from 48-A.

Water Levels 7/17/73

No.	Water Level	Time
24	69.25'	2:45
25	68.23'	3:00
30	70.73'	3:15
RW-3	48.73'	3:30
RW-4	22.24'	3:40

Wednesday, 7/18/73

Check on drilling progress of RW-5 and No. 49; end of the day RW-5 - 105 feet and No. 49 - 60 feet; RW-5 and No. 49 should both be completed in the early afternoon or late morning; arrange for Schultes to log holes; change chart on No. 30.

Water Levels 7/18/73

No.	Water Level	Time
25	69.32'	1:30
RW-3	49.44'	1:45
30	70.41'	2:00
•RW-4	22.84'	3:45

Artesian pump test on E-1 continuing; collected water sample from E-1.

Thursday, 7/19/73

Supervise drilling; Standard rotary drilling machine completed No. 49 to a depth of 165 feet and hole was logged by Schultes; hole was screened to 105 to 155 feet, cement 70 feet to surface; initial blowing of well less than 30 gpm; water had no noticeable odor, no foaming; development will be completed tomorrow and a sample will be collected; Artesian pump test on E-1 ended at 1:10 - pumping about 325 to 350 gpm; collected a water sample from E-1; Reverse rotary rig completed RW-5 at 4:30 - T.D. 145 feet.

Thursday, 7/19/73 (cont.)

Water Levels: from top of casing

No.	Water Level
38	19.93'
31p	16.41'
31	21.30'
39	14.69'
28p	20.56'
28	30.63'

Landfill Wells - Thursday afternoon 3:00 to 6:00 - from ground level

A-1	28.02'
A-2	18.43'
A-3	13.05'
A-4	13.10'
A-5	11.53'
A-6	20.67'
A-7	21.13'
A-8	21.80'
A-9	21.62'
A-10	Dry
2p	10.0'
3p	21.85'
4p	28.90'
5p	18.90'

Water levels do not appear to have changed much since Tuesday - mostly in the range of ± .1 foot.

Friday, 7/20/73

Collect water sample from No. 49 after blowing for 6 hours; water level measurements:

No.	Water Level	
26	63.90'	- (this well had about 2½ feet of draw-down from start to finish of E-1 pump test)
25	68.22'	
24	69.47'	
23	59.85'	(during E-1 test, fall from 59.08 to 60.80)
22	73.40'	(during E-1 test, fall from 73.0 to 74.0)
21	63.03'	

AR101709

Friday, 7/20/73 (cont.)

No.	Water Level
48-A	12.30'
48	12.43'
8	25.81'
5-B	21.70'
5-A	8.45'
RW-3	49.07'
30	70.05'
41	22.40'
1-B	17.70'
1-A	17.21'
1-C	2.30'
27	22.26'
2-A	28.07
2-B	27.68'
2-C	Dry
RW-1	20.85'
36	16.22'
47	66.25'
46	49.73'
46-A	45.97'

Standard rotary drilling machine moved to No. 50; Reverse rotary rig completed RW-5; Roy F. Weston representative pointed out site for RW-6 (next to 3-A) for reverse rotary rig.

Roy F. Weston, Inc.
31 July 1973

A PROGRAM OF PROCEDURES TO BE UTILIZED IN REGRADING, COMPACTING, COVERING, AND SEALING OF THE LLANGOLLEN LANDFILL, NEW CASTLE COUNTY, DELAWARE

Statement

An investigation program relative to the Llangollen landfill in New Castle County has determined that the landfill occurs in the geologic condition where leachate excapes from the landfill directly into the underlying fresh water aquifer. A portion of the leachate seeps from the side wall of the landfill directly into Army Creek. The quantity of leachate generated at the present time is undoubtedly a very substantial quantity, since the upper surface of the landfill is composed of a variable but normally highly permeable material. In addition to allowing direct infiltration through the cover material, settlement has occurred on the landfill surface allowing water to accumulate and more readily enter the landfill.

In order to minimize the quantity of leachate production, a necessary program outlined in these specifications will be required to regrade and seal the surface, thereby allowing maximum run-off prior to entry into the landfill.

Purpose

A four-step program will be required in order to adequately seal and minimize water entry into the landfill.

The first step will utilize heavy construction and compaction equipment in a limited grading program to locate the subsidence areas, compact the present cover material, and essentially stabilize the present top for as long a period as possible.

A second step in the program would utilize grading material and heavy construction equipment to create the minimum slopes necessary to conduct precipitation run-off from the seal cover and thereby prevent contamination. In this project step ventilation ports will be installed in the landfill cover to prevent gas pressure build-up.

A third step of the program will be based on provision, grading, compaction of a sealing material of sufficient thickness, to reduce the permeability of the cover to minimize water entry. The proposed sealing material can utilize a locally available clay which shall be placed in thin layers in suitably dry state to allow maximum compaction resulting in a final one to two foot thick seal over the entire surface of the landfill.

Upon completion of the clay seal and testing to assure sufficient compaction and reduction of permeability, a final vegetative supporting silt loam soil cover will be installed in the fourth and final step of the program. At the present time a final cover of approximately one foot in thickness is visualized as being necessary to prevent cracking of the clay seal cover.

AR101711

In order to construct a tight clay seal to prevent precipitation entry into the landfill, it will be necessary to use special procedures, construction and compaction equipment, daily inspection and testing, and supervision of construction by the county or its designated consultant.

The program which is described herein is a basis of procedures, materials, equipment and inspection. The program is based on field inspection and cooperation with the construction operation to insure rapid response to changing or unforeseen conditions. The construction work will utilize the described procedures unless modified by the county or its consultant.

DETAILED PROGRAM

Step 1 - Compaction and Grading Present Surface of the Landfill

A program to compact and rough grade the present landfill surface in order to achieve readily available settlement and surface grading to allow precipitation run-off.

The contractor shall provide acceptable heavy duty earth moving equipment which will be utilized in compacting, rough grading and achieving readily available settlement on the present landfill surface.

Construction equipment shall be of sufficient size to partially achieve compaction in a program of discing, compaction, and rough grading. Compaction equipment shall be of suitable size and should include sheep's foot and/or vibratory compactors. All construction equipment should be of an approved standard or type and any such equipment which is unsafe shall not be used on this project.

In that settlement has continued in some portions of the landfill in the time since completion of the Hached plan, this segment of work shall be coordinated by the county surveying crews and/or the consultant. The compaction program shall continue until relative stabilization of the landfill surface has been attained as determined by the surveying crews on-site.

AR101713

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DETAILED PROGRAM

Step 2 - Rough Grading and Gas Ventilation Program

In order to prepare the top for the seal cover, a rough grading and construction of the gas ventilation system will be accomplished. The rough grading of the seal should be accomplished in coordination with the compaction program in order to achieve a minimum slope of the surface on the landfill of one-half percent the minimum slope in the depressions and run-off channels shall be in a direction away from the fill area.

The regrading and compaction program shall utilize additional gravel fill material in the event of exposure of the actual landfill material of where necessary to attain the minimal slopes outlined above.

Gas Ventilation: In that a dense clay cap is planned for installation over the entire landfill surface, it will be necessary to install gas vents to prevent pressure build up within the landfill. The gas vents will be staggered on a 200-foot separation in two lines across the landfill. Gas vents shall be constructed of a 4-inch galvanized steel pipe and equipped with a "U" on the top to prevent water entry. The vents shall protrude into the landfill to a sufficient depth to obtain stability. Openings shall be provided in the vent pipe to allow easy entry of any gas production into the vent pipe. The vent pipe shall protrude at least 10 feet above the finished landfill surface to minimize the potential for explosion and/or fire.

Where the cover material surrounding the prescribed ventilation device is composed of a low permeable material, the surface material shall be removed and replaced with a gravel material surrounding the vent to allow easy entry of gas into the vent.

AR101714

Step 3 - Provision, Construction and Compaction of an Impermeable Seal Material

Step 3 will include provision, installation of a compacted clay seal cover to minimize water entry into the fill. A minimum thickness of one foot of clay seal is to be placed over the entire surface area. Should the quality of clay or compaction conditions indicate, it may be necessary to install up to a two foot thick clay seal in order to insure minimum precipitation reaching the landfill.

The proposed cover material shall be subjected to sieve analysis and qualified in accordance with the Unified Soil Compaction System (USCS) in order to be considered as an acceptable material (see Figure 1). The proposed material should contain at least fifty percent clay size particles. The total of clay and silt size particles should represent at least 70 percent of the total volume. A sieve analysis report, estimate of available quantity shall be furnished as a part of the submission by each bidder. The exact location of source material shall be indicated so that the company and/or its consultant may visit and inspect the site prior to selection of a contractor.

After the subgrade has been prepared as hereinbefore specified, the material shall be placed thereon and built up in successive layers until it has reached the required elevation.

Layers shall not exceed six inches in thickness before compaction. The layers shall be slightly dished toward the center. In general, the finer and less pervious materials shall be placed in the center, and the coarser and more pervious materials, upon the outer parts of embankments.

Each layer of material shall be compacted by the use of approved rollers or other approved means so as to secure a dense, stable, and thoroughly compacted mass. At such points as cannot be reached by mobile mechanical equipment, the materials shall be thoroughly compacted by the use of suitable power-driven tampers.

Previously placed or new materials shall be moistened by sprinkling, if required, to ensure proper bond and compaction. No compacting shall be done when the material is too wet, from either rain or too great an application of water, to compact it properly; at such times the work shall be suspended until the previously placed and new materials have dried out sufficiently to permit proper compaction, or such other precautions shall be taken as may be necessary to obtain proper compaction.

Compaction of each layer of the cover shall be compacted to a uniform density of not less than 90 percent of the maximum density obtained by modified A.A.S.H.O. method of compaction testing, "Moisture-Density Relations of Soils using a 10 lb. Rammer and an 18" Drop" (T180-61) as verified by density control test in the field as directed by the owner.

Should the density of the compacted material not meet the specified requirements, the material shall be recompacted until the density requirement is met or removed and replaced with other clay material.

Step 3 - (Continued)

The county shall have the right to suspend work due to weather conditions in the event that the cover material is visually determined as not meeting specifications. The county or its representative shall have the right to reject such material.

Step 4 - Final Vegetation Cover

Upon completion and compaction of the seal cover a final cover of silt loam or other vegative supporting cover shall be placed to a minimum thickness of eight (8) inches with an average cover thickness of one (1) foot.

The final cover materal shall be essentially a silt loam material as determined by USCS sieve analysis. In the event that alternate material should be proposed information as to the source and character, USCS or USDA should be submitted as a part of the proposal.

The final cover shall be installed, graded and prepared for seeding.

The Contractor shall remove loam and topsoil, loose vegetable matter, stumps, large roots, etc., from the areas upon which material will be placed for final grading. The subgrade shall be shaped as indicated on the drawings and shall be so prepared by forking, furrowing, or plowing that the first layer of the new material placed thereon will be well bonded to it.

On paved surfaces, the contractor shall not use or operate tractors, bulldozers, or other power-operated equipment the treads or wheels of which are so shaped as to cut or otherwise damage such surfaces.

All surfaces which have been damaged by the Contractor's operations shall be restored to a condition at least equal to that in which they were found immediately prior to the beginning of operations. Suitable materials and methods shall be used for such restoration.

During the progress of the work, the Contractor shall conduct his operations and maintain the area of his activities so as to minimize the creation and dispersion of dust. If the company decides that it is necessary to use calcium chloride for more effective dust control, the Contractor shall furnish the material, load, deliver, and spread it as directed.

APPENDIX D

ROY F. WESTON, INC.

[illegible]

INTER-OFFICE MEMORANDUM

DATE 30 October 1973

TO Project Files

FROM J.A. Weaver, Assistant Project Engineer

SUBJECT Llangollen Landfill Treatment Alternatives, W.O. No. 463-10
Interim Report

Attached is an Interim Report detailing:

1. Economic estimates for implementing various treatment alternatives.

2. Technical reservations applicable to each alternative

3. Estimation of the remaining data acquisition steps necessary for final determination of most feasible treatment method.

4. Elimination of certain alternatives.

AR101719

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PROJECT PARTICIPANTS

The following members of the Staff of Roy F. Weston have participated in the planning and preparation of this report.

Thomas E. Cadwallader Project Manager	Concept Technology Division
James A. Weaver Assistant Project Engineer	Concept Technology Division
Michael A. Apgar Geologist	Geological Services Division
Walter R. Niessen Project Coordinator	Concept Technology Division
Thomas E. Taylor Cost Engineer	Engineering Design Division

SUMMARY

An interim report presents economic and technical rationale for initial reduction of the number of potential alternatives for treating the Llangollen Landfill in order to prevent its contamination of a major potable water aquifer.

Further definition is made of future data acquisition requirements necessary for ultimate selection of landfill treatment method.

Total haulage of landfill materials to a new site, as well as lining the landfill bottom have been ruled out as viable solutions. Furthermore, certain options of controlling water infiltration have been discussed and rationalized.

Interim Report

Llangollen Landfill Treatment Alternatives

INTRODUCTION

General

The Llangollen Landfill is situated in New Castle County, Delaware as shown in Figure 1. Previous studies conducted by Roy F. Weston, Inc. under contract to New Castle County, have shown that the leachate from the Llangollen landfill has caused major contamination of an important source of potable groundwater.

Effort to recover leachate contamination already in the aquifer is currently underway, however, elimination of future contamination will require further additional measures directed at controlling leachate generation at the Llangollen landfill itself.

Scope and Objectives

In an effort to eliminate the Llangollen landfill as source of aquifer contamination, New Castle County has requested Roy F. Weston to determine the most feasible means for treating or renovating the Llangollen landfill as part of the general effort being undertaken.

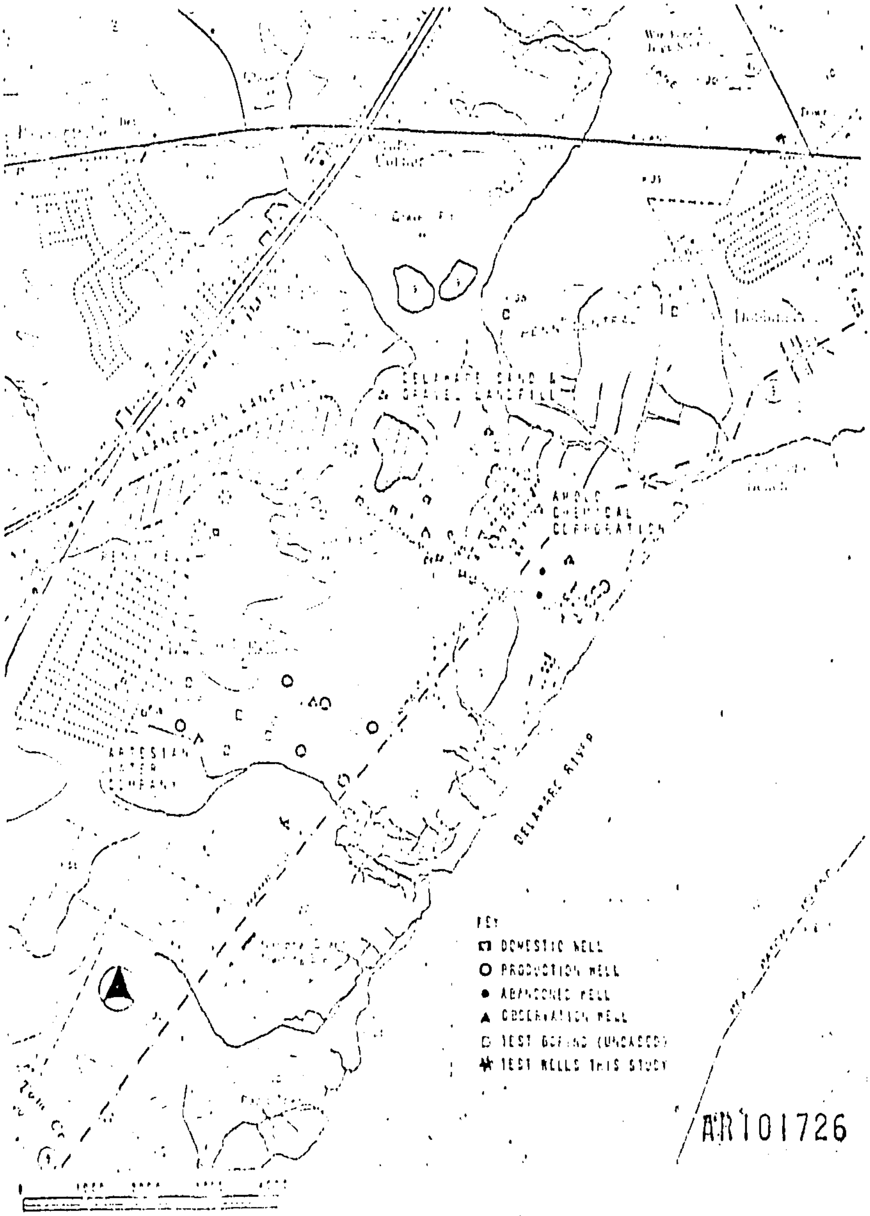
By mutual agreement, the scope of this study includes consideration of a broad selection of potential schemes for satisfactorily treating the Llangollen landfill, as part of the overall determination of a most feasible solution.

Development of rationale sufficient for accurate evaluation of potential landfill treatment alternatives has resulted in compilations of both economic feasibilities and technological applicability of the various alternatives.

This interim report is intended to document the evaluation effort expended to date, as well as present preliminary findings relative to the various alternatives. Furthermore, estimation is presented of the remaining evaluation effort required for final determination of the most feasible alternative.

FIGURE 1

PORTION OF WILMINGTON SOUTH U.S.G.S. 7½ MINUTE TOPOGRAPHIC MAP SHOWING THE LOCATIONS OF THE LLANGOLLEN LANDFILL AND ALL WELLS AND BORINGS IN ITS VICINITY, SEPTEMBER, 1972



AR101726

ROY F. WESTON, INC.

PROBLEM DEFINITION

Landfill Physical Description

The Llangollen landfill was constructed from 1960 to 1968. The landfill is approximately 4400 feet long, 250 to 900 feet wide and approximately 30 feet thick, containing an estimated 3 million cubic yards of municipal and industrial refuse material.

Test borings conducted during the month of October 1973 have developed a more accurate picture of the exact landfill depth and thickness and are presented in rough sketch form in Figures 2 and 3.

The sand excavated from the quarry was part of the Pleistocene Columbia Formation, fluvial deposit which consists predominantly of medium to coarse sand with gravel beds. In the Llangollen area, this sand, the Columbia Formation, forms a nearly continuous surficial cover up to 60 feet in thickness. The base of the formation ranges from about 10 feet above to 20 feet below mean sea level in the vicinity of the landfill.

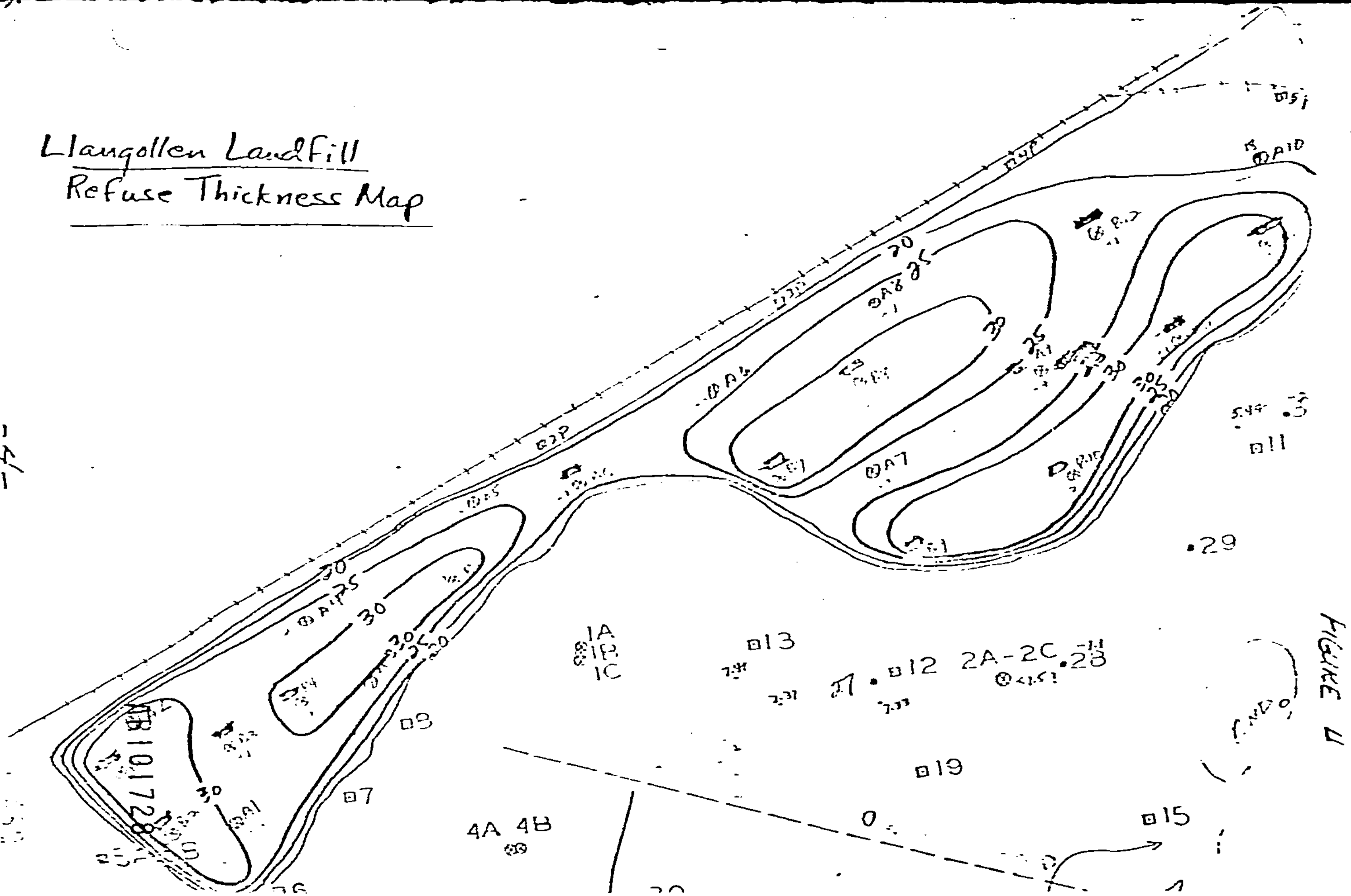
The underlying Potomac Formation consists of stream-deposited unconsolidated sands, silts and clays of Lower Cretaceous Age. The sand units are channel-shaped, with extensive interbedded lenses of clay and silt which accumulated on ancient floodplains and estuaries. The Potomac Formation thickness and dips towards the southeast at approximately 40 to 140 feet per mile (uppermost and lowermost beds respectively) in the study area.

Hydrologically the generally coarse Columbia deposits serve as an infiltration and recharge gallery for the Potomac sands. Ground water in the Potomac sands becomes confined (artesian) beneath relatively impermeable beds of clay and silt as it travels seaward down dip in the formation. The approximate thickness of the Potomac confining units immediately beneath the Columbia sands are shown in Figure 2. Immediately beneath the landfill these clay and silt deposits are shallow, thin or--in the area of the southeast corner of the fill--absent.

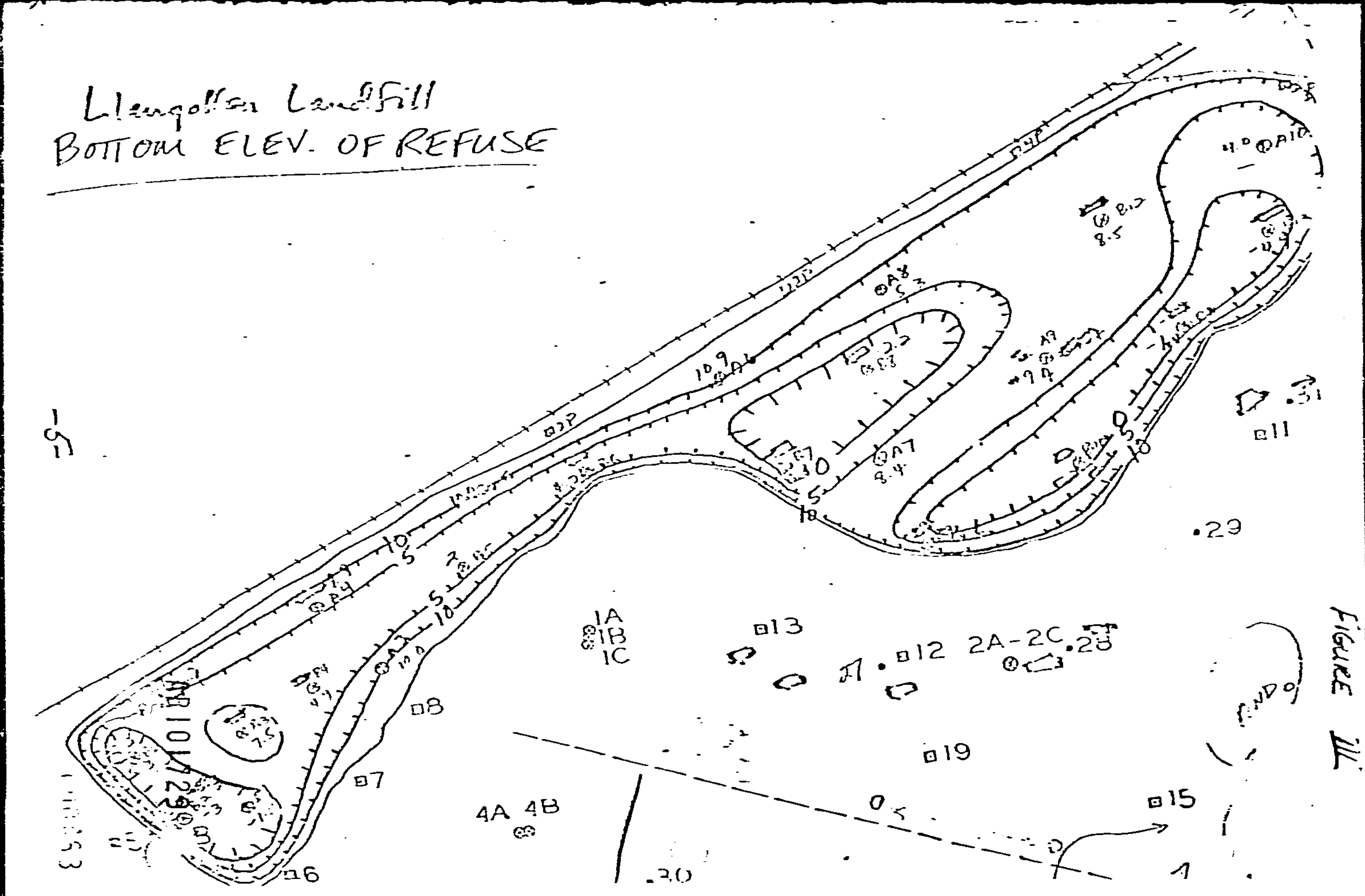
Landfill Construction

The gravel pit in which the Llangollen landfill is constructed was excavated with a dragline down to a "hard zone"--generally non-cemented conglomerate making the base of the Columbia--or

FIGURE 4



Llangollen Landfill
Refuse Thickness Map


Llewellyn Landfill
BOTTOM ELEV. OF REFUSE
FIGURE III
1A
1B
1C
13
12
2A-2C
.28
19
15
.29
11
.31
4A 4B
8
7
6
.30
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red Potomac clay was encountered. Clay was not removed during the sand and gravel operation, because it would have interfered with the washing process. Aerial photographs taken in the end of the late 1950's and early 1960's show large pools of standing water on the floor of the sand pit.

When landfilling operations commenced around 1960, refuse was dumped rather haphazardously, starting at the eastern end and proceeding back towards the pit enterance on the west. All types of wastes, including liquid waste chemicals and oils, were dumped at the site. The existing ponds were filled with refuse, and compaction and covering of the refuse was generally poor.

Refuse covering operations were conducted by the quarry operator using the quarrying equipment which was already on the site. All intermittent cover material was obtained within the pit from waste piles and siltation basins. As time progressed, cover material and landfill space became critically depleted--a situation which encouraged deeper excavation on the western end of the pit. This excavation removed some--and in a few places probably all--of the confining clay on top of the Potomac sands. Such conditions permitted direct access to the Potomac sands by leachate from the landfill.

Leachate Generation

Ground water, infiltrating surface water or combination of both when moving through landfill solid wastes, results in the production of a complex solution of dissolved and suspended material and is known commonly as leachate.

While the leachate characteristics appear to be unique for any given landfill, it is generally recognized that landfills normally have a certain definite retention capacity for leachate such that unless surface water and ground water infiltration is sufficiently high, no leachate will actually leave the landfill site.

Particularly high levels of ground water infiltration and surface water infiltration are indicated as prime causes of substantial leakage of leachate from the landfill into the aquifer.

TECHNICAL EVALUATION OF LEACHATE CONTROL ALTERNATIVES

Technical Approach

It was recognized that widely different schemes could potentially achieve the desired objective of leachate control. It was simultaneously recognized that the aggregate of these alternative solutions would span a broad range of required dollar expenditure. Furthermore, depending upon respective technical reliability and adequacy, a divergence in the cost-effectiveness for any given alternative was expected.

Consequently, initial efforts were directed towards cost and adequacy analyses for a full list of alternatives, with the intention that many would be eliminated from further consideration.

Presentation of Alternatives

Consideration was given to a broad list of conceivable methods for leachate control. Some alternatives were eliminated relatively quickly due to their lack of available technology or uncertain adequacy.

Examples of solutions falling into this category were: 1) complete fusion of landfill material in a polymeric resin; 2) chemical addition to the landfill, in situ, to render it totally inert to leaching reactions. The first example was eliminated primarily on the basis of known instances where the polymerized resin actually contributed significant levels of leachable contamination. In the second case, elimination was made because of the lack of any chemical treatment adequate for totally preventing the leaching process.

The list of alternatives remaining was as follows:

1. Total removal of the landfill and haul to new site.

2. Removal of the landfill, lining of the existing site, and replacement of the landfill.

3. Incineration of the landfill, and landfill of the residue.

4. Hydrogeologic control of all water infiltrating the landfill.

5. Acceleration of the rate of decay of leachable materials.

While various sub-options are recognized for all of the alternatives, alternative number 4 was especially in need of further breakdown which was made as follows:

4. Hydrogeologic control of all water infiltrating the landfill.

   a. Lateral infiltration control

      1. by bentonite walls

      2. by perforated drain pipe

      3. by well point system

   b. surface water infiltration

      1. regrade and recover

      2. crenulation schemes

   c. Desaturation of the landfill

      1. infiltration gallaries

      2. wellpoint systems

<u>Economic and Technical Considerations</u>

A summary of the economic and technical considerations of the various alternatives is presented in Table 1.

Estimations of alternative costs were derived by making reasonable estimates of the quantities, manhours, and related expense items associated with implementation of each alternative. It must be noted however that in certain instances costs were dependent upon items such as shipping distance, which were not fully determined. Reasonable approximations were made in these instances and identified specifically.

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SUMMARY OF ECONOMIC AND TECHNICAL CONSIDERATIONS

TABLE 1

	ALTERNATIVE	ESTIMATED COST	RESERVATIONS	RESEARCH/ENGINEERING TASKS	ALTERNATIVE PERFORMANCE
I	Total Removal of Landfill to New Site	$18,030,000 (1973) Excavate & Load 4,100,000 Rail Haul 6,000,000 Unload Haul 700,000 Gate Charge 3,700,000 Steel Pilings 3,500,000 Leachate Control 100,000 - [illegible] (N.B. Excavate Time 2 3 yrs)	1. New Site Availability 2. New Site Distance 3. Railway Availability 4. Odor Control not included	Find New Site 6 mo. - 2 yrs* Transportation Req'ts } 2 mos. Contracting	3 years
II	Excavate, Line, and Refill	$8,100,000 (1973) Excavate 4,800,000 Lining [illegible],000 Leachate Control 100,000 Pilings (Steel) 2,600,000 [illegible] (Cost [illegible] as [illegible] approx. [illegible])	1. Uncertain Lining Technology a. Chemical Attach b. Stretchability 2. Odor Control not included	Liner Tests Not Feasible Engineering } 3 mos. Contracting }	3 yrs. - 3 mos.
III	Excavate, Incinerate, Landfill Residue	$2,300,[illegible] (1973) Incinerator 2,185,000 Permits, [illegible] 115,000 2,[illegible] 1. Based on 8,200,000 initial investment a. Plant Life 25 yrs. b. Capacity equal approx. [illegible] disposal rate in 1975 c. Initial operation burning 50% Llangollen, 50% new Refuse. d. Llangollen refuse [illegible] time [illegible] 7 yrs. 2. Operating Cost = [illegible]/year	1. Optimum Ratio of Dry to Wet Refuse for Good Combustion	1. Test Combustibility of Llangollen Material W/ Operating Incinerator Engineering } 2.5 yrs. Procurement Construction }	7 years

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ALTERNATIVE	ESTIMATED COST	RESERVATIONS	RESEARCH/ENGINEERING TASKS	ALTERNATIVE PERFORMANCE
IV Hydrogeologic Control IV a. Lateral Infiltration Control				
IV a.1 Using Bentonite Wall	2,025,000 (1973) Slurry Trench: North Side 1,350,000 South Side 675,[illegible] 2,0[illegible]	Reliability	Contracting, Engineering } 2 mos.	10 mos.
IV a.2 Using Perforated Pipe	6[illegible] (1973) Excavate 135,000 Piping [illegible] Shoring 33[illegible] Crushed Stone [illegible] [illegible]	1. Effect of Discharge on Environment (Erosion) 2. Exact Length of Pipe 3. Need for Shoring Doubtful if Well Points (Alt. IV.a.3) Used to Dewater First	Study Surface (Hydrology) Impact Contracting, Engineering } 3 mos.	6 mos.
IV a.3 Using Well Point System	$60,000 Wells 40,000 Piping & Pumping 20,000 [illegible] [illegible] wells	1. Can this system reduce excavation and shoring costs of Alt IV a.2 2. Total number of wells required	Contracting, Drilling/Jetting } 4 mos.	Undetermined
IV b. Surface Water Infiltration Control				
IV b.1 Regrade and Cover with 5' Cover	$2,500,[illegible] (1973) Purchase 1,[illegible] Haul [illegible] Grade [illegible] [illegible] Cover Material Available locally, $3.0/yd³	1. Availability of Material 2. Impact of Removing Cover Material	Inquiry for Cover Material, Impact Assessment, Engineering } 3 mos.	20 mos.

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	ALTERNATIVE	ESTIMATED COST	RESERVATIONS	RESEARCH/ENGINEERING TASKS	ALTERNATIVE PERFORMANCE
IV b.2	With 2' Cover & Additional Amount to Even Old Surface	1,[illegible] (1973) Purchase 8[illegible],000 Haul 31[illegible],000 Grade 322,[illegible] 1,[illegible] Does not reflect new refuse disposal cost savings Cover material locally available at $1/yd	1. Availability of Material 2. Impact of Removing Cover Material	Inquiry for Cover Material Impact Assessment 6 mos.	10 mos.
IV b.3	Crenulating	$2,3[illegible] (1973) Grading 1,[illegible],000 Hauling [illegible] Purchase 1,[illegible] 2,[illegible]	1. Feasibility of Simultaneous Regrade and Cover 2. Impact of Removing Cover Material	Inquiry for Cover Material Impact Assessment 6 mos.	15 mos.
IV c.	Desaturation				
IV c.1	Infiltration Galleries and Wellpoints	8[illegible] (1973) Excavate 1[illegible],600 Shoring [illegible] Stone 2[illegible] Sumps [illegible] 16,[illegible] Pumps [illegible] [illegible] [illegible] Well Constr. 8,[illegible] Piping, Install [illegible] Install, [illegible] [illegible] 8[illegible]	1. Is Desaturation Required after Lateral Water & Surface Water is Controlled - Could lead to much reduced size of collection network 2. Effect of Discharge 3. How much Desaturation Required to Halt Leachate	Testing not initially recommended, rather proceed with Lat. & Surface Water Control and determine future needs subsequently Possible Test Prog. Construction Engineering Impact Assessment	Undetermined
IV c.2	Infiltration Gal Galleries and Wells, in Conjunction with Leachate Recycle	$1,3[illegible],000 (1973) As in IV.c.1 8[illegible],000 [illegible] [illegible],000 Spray System 1,3[illegible]	Same as IV.c.1, Applicability of Recycle - (Note Recycle could be commenced some time after Desat. had been initiated) 9 mos.	Recycle Tests Technology Search Engineering Construction	Undetermined

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[illegible]

It is further noted that costs do not reflect non-predictable price fluctuations typically attributable to problems of material availability, interest rate increases, local labor and overhead charges, weather, etc. While these elements remain undetermined, it is fully expected that the final cost estimations for each alternative are sufficiently accurate to permit the needed comparison of relative expenses. More specifically, such comparison would lead to 1) elimination of the obviously disproportionately expensive alternatives, and 2) definition of further analysis required for rationalizing alternatives appearing close in cost.

General technical adequacy was also evaluated while no attempt was made to optimize final design parameters such as volume or weight, for particular engineering aspects of the various alternative solutions, it is felt that the derived summary will serve usefully in weighing alternative desirability and defining further data aquisition requirements.

In some cases, it is recognized that significant differences in cost may arise due to exceptional deviations from the basis for estimation (such length of haul).

In the paragraphs following, some attempt is made to discuss specific cases where potential exists for exceptional deviations in the cost estimation basis. Furthermore, it is realized that substantial cost savings may be realized by "better-than-anticipated" performance of specific precursor engineering tasks. Effort has been made to identify such cases as well.

<u>Alternative I</u> "Total Removal of Landfill to New Site"

Gross uncertainties exist in two items. "Rail haul" has been estimated at $6,000,000 on the basis of quotation from the Penn Central Railroad of $.49 for each pound of material hauled 100 miles.

Furthermore, uncertainty exists as to the availability of new sites and as a gauge for estimating the expense of disposal, a value of $1.20/cu.yd. was used.

<u>Alternative III</u> "Excavate, Incinerate, Landfill Residue"

It is necessary to emphasize that the stated capital expenditure of $2,300,000 does not represent the initial installation cost. Rather this figure represents 7/25 this of the initial cost,

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or $8,200,000, which is the rough proportion of the total plant life which would be dedicated to incineration of Llangollen landfill material.

It has been estimated that by burning a 50/50 mixture of wet (Llangollen) refuse and dry (new) refuse, incineration of the entire Llangollen landfill could be accomplished in about 7 years, with the simultaneous benefit of having eliminated an equal amount of new refuse that would have been landfilled elsewhere. Operating costs are estimated at approximately $860,000/year.

Furthermore:

1. Costs given include expense for Air Pollution Control.

2. Do not reflect savings realized in disposal of non-Llangollen material.

3. The rate of incineration of Llangollen material may be significantly increased, depending upon closer estimation of the required rates of dry to wet refuse.

<u>Alternatives IV a1 and IV a2</u>, "Perforated Pipe," and "Well Point System"

It is noted that $300,000 has been allowed for shoring costs in installation of the perforated drain pipe to be run along the long northern end of the landfill, and situated approximately 30 feet deep. It is felt that a substantial reduction in this figure could be obtained by prior desaturation of the area to be excavated by use of the well point system estimated in Alternative I. a3, as $60,000. Furthermore, it is noted that a portion of the $60,000 may be saved since it may be found that fewer wells are actually needed to perform the desaturation.

<u>Alternative IV c1</u> "Infiltration Gallaries and wellpoints"

Roughly $900,000 has been estimated for a system of infiltration Gallaries (actually deep stone filled trenches) and wellpoints which would collect leachate directly in the landfill, or as nearly so as possible. The estimate is based on the saturation conditions observed at present and since it is expected that the saturation characteristics will change markedly once lateral water and surface water infiltration are prevented, substantial savings may be affected here as well.

Alternative IV c2 "Infiltration Gallaries and Wells, in Conjunction with Leachate Recycle"

Leachate recycle is being considered as the most appropriate means for accelerating refuse material decay rates. The infiltration gallaries and wellpoints system described in the preceding paragraph would provide the leachate collection system that would permit recycle of the leachate onto the landfill surface by a spray scheme. Since such recycle would preclude any control of rainfall or other surface water infiltration, it is considered that no size reductions could be made in the collection system as described previously.

Several uncertainties exist relative to the technical applicability of the recycle system that require additional research and perhaps test. Current data indicate that recycle of leachate recycle may provide accelerated bio-degradation of refuse material. However, recent research in this area shows recycle may not greatly shorten the ultimate period required for total landfill degradation, the more refractory materials continuing to exist at least a chemical oxygen demand for some time.

Additional reservations exist over existence of quantities of potentially toxic or harmful substances deposited by industrial or commercial users of the landfill. These materials may currently exist in an unaffected state which could be altered by a recirculation scheme. Recirculation of such materials would appear undesirable.

CONCLUSIONS AND RECOMMENDATIONS

As a consequence of the economic and technical feasibility study which was conducted, several alternatives are eliminatable:

1. Alternative I - "Total Removal of Landfill to New Site", on the basis of very high cost, and uncertainty of new site location.

2. Alternative II - "Excatave, Line, and Refill" on the basis of high cost and uncertain performance of lining material.

3. Alternative IV al Bentonite Wall - North Side on the basis of more economical means of lateral water infiltration control for the north side of the landfill.

Furthermore, a more detailed ordering of the remaining alternatives were derived. This ordering is mostly chronological and reflects that certain alternatives should be begun initially in order to minimize subsequent expenditures for other alternatives. Furthermore, decisions on several alternatives must be deferred until more data is collected.

A summary of this ordering is presented in Figure IX. In addition a detailed list of the required data acquisition measures for determining final courses of action is presented in Table 2.

At this point in the Llangollen landfill treatment study it is not possible to assign specific performance dates for all of the data collection measures which are required for ultimate decision of the most feasible treatment method. It is expected that a more accurate definition of the scope of work remaining and consequently time involved will be possible after review and comment of the current findings is made at the October 30, 197[illegible] meeting to be held in New Castle County, Delaware.

TABLE 2

DATA ACQUISITION REQUIREMENTS

I. Incineration

A. Executive prohibitions, fiats ?
B. Combustion: optimum mixture of wet/dry refuse
C. Test mixture in operating incinerator
D. Landfill of residue - leachate ?, volume ?, site work ?
E. County Solid Waste disposal requirements - optimize incinerator capacity
F. Assess more accurately
   actual labor and utilities
   local charges for current landfill solid waste dispos.
   financing, and construction time.

II. Hydrologic Scheme

A. Recycle Technology
   - Rate of decay W & W/O EPA Studies
   - Feasibility of test cell study research
   - Leachate age determination
   - Adequacy of leachate collection
   - Toxic or hazardous material release
   - Differentiate decay rates, wet & dry conditions

B. Assess relative amount of infiltration from [illegible] surface, Army Creek, other
C. Observe dewatering effects of hydrologic controls and determine final dewat. requirements
D. Feasibility, need for Army Creek drain
E. Discharges - quantities, impact, disposal

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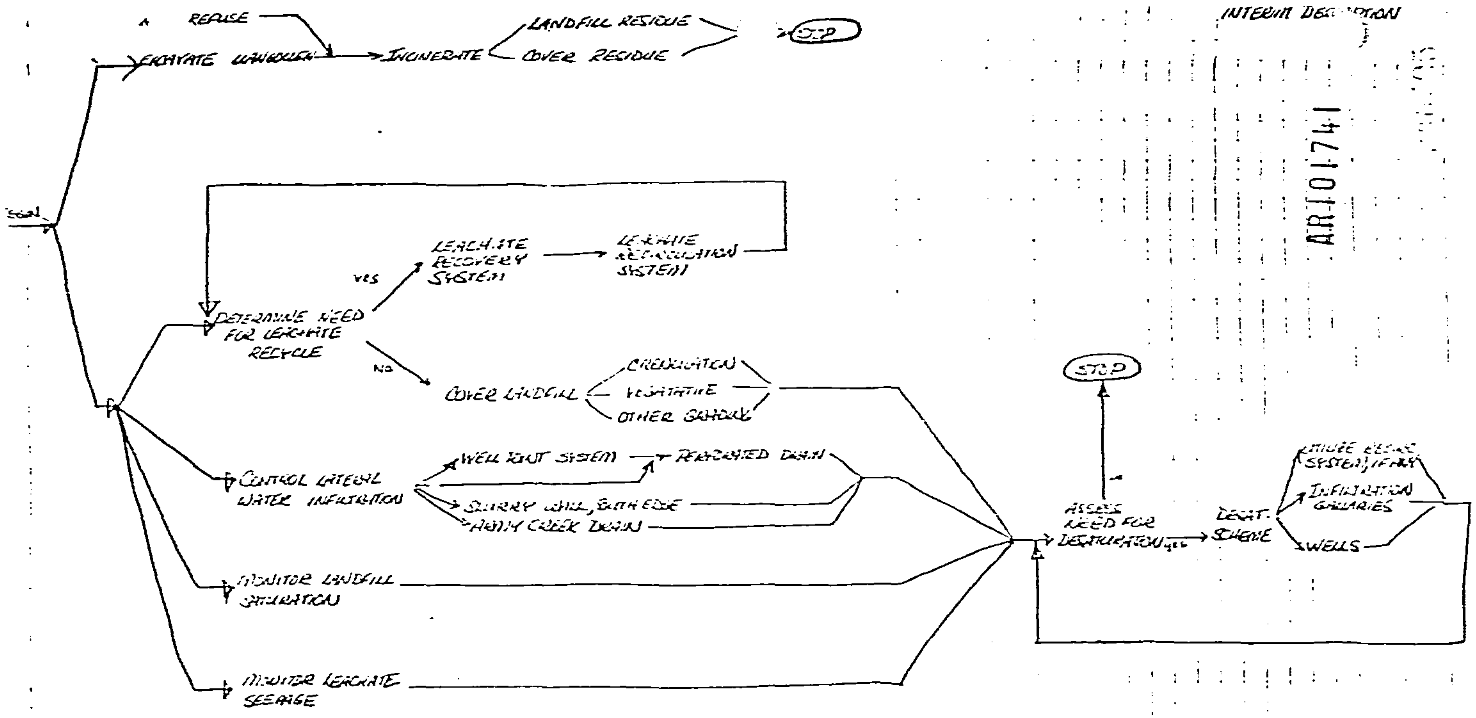
REDUCE
INCINERATE
LANDFILL RESIDUE
COVER RESIDUE
STOP
DETERMINE NEED FOR LEACHATE RECYCLE
YES
NO
LEACHATE RECOVERY SYSTEM
COVER LANDFILL
OTHER
CONTROL LATERAL WATER INFILTRATION
SLURRY WALL
MONITOR LANDFILL SATURATION
MONITOR LEACHATE SEEPAGE
STOP
INFILTRATION GALLERIES
WELLS
INTERIM

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APPENDIX E

CONCEPTUAL DESIGN REPORT

Lime Treatment Facilities for
Treatment c' Groundwater

LLANGOLLEN LANDFILL
NEW CASTLE COUNTY, DELAWARE

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W.O. 463-11
12 November 1973

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SUMMARY

Llangollen Landfill, in New Castle County, Delaware, is a possible source of contamination of groundwater in that area. The contaminated zone of the underlying aquifer is spreading toward the Delaware River. Currently planned/operating recovery wells will have an estimated maximum flow of 4.75 MGD from the aquifer in order to prevent further spreading of this contaminated zone. Previous studies have indicated that the contaminated groundwater was amenable to physical-chemical treatment for the reduction of dissolved metals content. Consequently, Roy F. Weston, Inc. was retained to develop a conceptual design for the required metals removal treatment plant.

Results of the treatability studies and conceptual design by Roy F. Weston, Inc. have confirmed that the groundwater pumped from the recovery wells is amenable to physical-chemical treatment for the reduction of metals. Based upon the treatability studies, the recommended treatment process includes the following systems:

1. Oxidation/equalization, to oxidize ferrous iron to ferric iron, and to equalize wastewater quality.

2. Chemical treatment with lime to a pH of 9.0.

3. Flocculation-clarification, using Dow A-23 as a floc aid.

4. Post neutralization of the clarifier effluent to a pH of less than 8.0.

5. Vacuum filtration of the thickened clarifier underflow sludge.

The capital cost for these treatment facilities was estimated at $1,251,000. Annual direct operating expenses are estimated at $207,200.

CONCEPTUAL DESIGN REPORT

Lime Treatment Facilities for Treatment of Groundwater

LLANGOLLEN LANDFILL
NEW CASTLE COUNTY, DELAWARE

INTRODUCTION

Background

The Llangollen Landfill site was a countywide solid waste disposal site near New Castle, Delaware, operated by the New Castle County Department of Public Works from approximately 1960 to 1968. The landfill location is shown in Figure B-1. The total area of landfill operations was approximately sixty (60) acres. Currently, leachate from the landfill is entering an aquifer and the contaminated zone is spreading toward the Delaware River. In previous programs, Roy F. Weston, Inc. had established the extent of possible contamination of the aquifer through the use of test wells. Preliminary treatability studies have also been performed[1], from which the conclusions were made that lime treatment could be used for the removal of metallic contaminants prior to discharge to a large body of water such as the Delaware River.

(1) Roy F. Weston, Inc. Interim Report, "Leachate Treatability Study, New Castle County, Delaware."

Consequently, New Castle County has retained Roy F. Weston, Inc. to determine and design effective treatment of pumped groundwater for prevention of the spread of this contamination in the aquifer.

Investigative Approaches

Using the information from previous studies, the following approaches were taken to providing a technically acceptable, reliable, and economical solution in the development of a process for treatment of the contaminated groundwater:

1. An analysis of well records was made in order to develop an effective sampling program which would provide representative raw wastes for treatability studies.

2. Treatability studies were performed to develop a lime treatment process to remove metals and control pH of the contaminated groundwater. These studies included oxidation of ferrous ion to ferric ion, addition of lime for metals precipitation, evaluation of polymer flocculation aids, settling tests, sludge tests, and post neutralization.

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3. Based upon the results of the treatability studies, a conceptual design of the required treatment process to provide economical, practical, and reliable treatment was prepared.

This report presents the results of these studies, including a conceptual design of the required lime treatment facilities for reduction of metals concentrations and control of the groundwater pH prior to discharge to the Delaware River. Conceptual capital and operating cost estimates for these facilities are also included.

PROBLEM DEFINITION

Wastewater Flow Estimation

A series of recovery wells is currently being installed to pump groundwater from the aquifer to a pretreatment facility prior to discharge to the Delaware River. When all the recovery wells are installed and in operation, the total maximum and average pumpage rates from the aquifer are estimated at 4.75 and 4.00 million gallons per day, respectively. This continuous pumping is intended to prevent the spread of contaminants into the aquifer.

Wastewater Sampling Program

In order to determine the points at which representative water samples could be obtained for subsequent treatability testing, a review was made of all water quality and flow data from existing recovery wells. In addition, flow estimates for proposed wells and wells under construction were obtained. Based upon analysis of these data, four wells were selected for sampling and preparation of composite samples which would be representative of expected raw water quality. These wells, Nos. 27, 28, 29, and 31, are shown on Figure B-1.

The four wells indicated above were chosen as representative sampling points specifically because of:

1. The wells have been pumping continuously since 6 September 1973. Consequently, the raw water quality obtained from these wells is more representative of long-term pumped water characteristics than would the characteristics obtained from inactive test wells.

2. These four wells cover essentially the entire landfill frontage across the aquifer. Consequently, the water quality of composites obtained from these wells would represent the most concentrated conditions which would normally be encountered. Thus, treatment of samples from these wells would provide a reasonably conservative basis for the establishment of design information.

The wastewater sampling was conducted during the period 23 September - 3 October 1973. Ten (10) daily grab composite samples from Wells 27, 28, 29, and 31, were collected during this period. One (1) additional grab composite sample from Wells 2 and 4 in the landfill itself was also taken to test for the worst possible case which might occur. For the samples from Wells 27, 28, 29, and 31, the daily grab composite sample of 20 gallons was made up of 5 gallons from each well. The landfill wells - 2 and 4 - were also combined on an equal volume basis, prior to dilution with 20 volumes of the composite from Wells 27, 28, 29, and 31. All samples were transported daily to the Roy F. Weston, Inc. Laboratory in West Chester, Pennsylvania for analysis and treatment.

Wastewater Characteristics

The preliminary findings developed in the Roy F. Weston, Inc. Interim Report entitled, "Leachate Treatability Study, New Castle County, Delaware", indicated that, for those parameters which are amenable to lime treatment, suspended solids, total iron, copper, and silver concentrations, and pH, were in excess of allowable criteria for discharge to the Delaware River. Consequently, all raw water samples were analyzed for these parameters in order to establish a basis for performance evaluation during treatability studies.

The results of the individual analyses for each raw waste sample are presented in Table A-1. These results indicate that silver and copper concentrations are now extremely low, but that the total iron concentrations uniformly exceeded the Delaware River discharge criteria (also shown in Table A-1). In addition, the raw waste pH exceeded the allowable discharge pH of 8.0 on two occasions.

To further illustrate the levels of iron which are present in the raw water, a probability-of-occurrence plot is shown in Figure B-2. From this plot, the 50% probability-of-occurrence level (the level at which 50% of the time, the parameter is less than or equal to the stated value) for iron is 14.4 mg/L or 480 pounds per day (at 4 MGD). Similarly, the 90% probability-of-occurrence level is 42 mg/L, or 1,401 pounds per day.

Based upon the raw waste characteristics outlined above, treatment must be provided to reduce the total iron concentrations to 1.0 mg/L and control the pH so that it does not exceed 8.0.

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Approach

Prior experience indicated that several unit operations and processes were applicable to removal of metals in the form found in this wastewater, including: equalization to homogenize wastewater quality; aeration to oxidize ferrous ion to ferric ion; precipitation of metal hydroxides by elevation of pH; coagulation by inorganic and/or organic chemical addition; sedimentation; filtration; and, various combinations of the above. The present treatability studies were conducted to confirm the preliminary studies previously cited and to provide a valid basis for the sizing and conceptual design of required treatment facilities.

Consequently, repetitive was conducted to develop reliable information relative to lime (chemical) dosages, clarification rates, post neutralization acid requirements, and vacuum filtration rates. In addition, a brief analysis was made of the recalcination requirements for possible reuse/recycle of the lime sludge. The data obtained was then subsequently used to develop the conceptual design outlined in a later section of this report.

Treatability Results

The treatability studies outlined above were conducted in the Roy F. Weston, Inc. Laboratory at West Chester, Pennsylvania during the period 23 September - 10 October 1973 using the wastewater samples obtained from the recovery wells at the Llangollen Landfill during the period 23 September - 3 October 1973. The results of these treatability studies are outlined below.

Oxidation of Ferrous Ion

Soluble iron found in groundwater is normally present in two ionic states: ferrous and ferric. Only ferric iron will form a readily insoluble precipitate when reacted with lime. Consequently, all ferrous iron must be converted to ferric iron by oxidation. Determination of the concentration of ferrous iron is also difficult and requires immediate analysis in the field. Due to the logistics involved, however, these analyses could not readily be accomplished. Therefore, all samples were aerated for a minimum of 0.5 hours prior to treatment in the laboratory. It should be noted that, prior to aeration, the samples were essentially colorless. Upon aeration, the wastewater samples developed a brownish color indicative of the oxidation of ferrous to ferric iron. Consequently, aeration to provide oxidation of the ferrous iron appears to be required.

Chemical Treatment

The previously cited preliminary studies had indicated that lime treatment to a pH of 10.5 would provide extremely effective metals removal and that treatment with lime to a pH of 9.0 would also provide adequate metals removal. Consequently, screening tests were conducted to develop a chemical treatment system based on these two levels of lime, augmented by polymer addition to increase settling rates. Based upon these initial screening tests, two chemical treatment procedures were selected for further repetitive performance testing of aerated samples. These treatments are as follows:

1. Treatment with lime only to a pH of 10.5.

2. Treatment with lime to a pH of 9.0 - 9.5, followed by the addition of 1.0 mg/L polymer (Dow A-23) to aid in subsequent coagulation/sedimentation.

The reduction in iron concentrations obtained using these two treatments are presented in Table A-2. These results indicate that both treatments provide approximately the same degree of iron reduction. However, based upon the operating costs involved, lime treatment to a pH of 9.0, followed by the addition of 1 mg/L polymer, was chosen as the more economical treatment to be implemented. AR101758

Figure B-3 is a probability-of-occurrence plot for the iron concentration which was achieved using the treatment to a pH of 9.0 - 9.5 and polymer addition. From this plot, it can be seen that the average effluent concentration of iron (indicated as the 50% probability-of-occurrence value) is 0.55 mg/L.

Figure B-4 is a probability-of-occurrence plot for the amount of lime required to increase the wastewater pH to 9.0. The average (50% probability-of-occurrence) lime dosage required was 140 mg/L.

Flocculation-Clarification

A series of five (5) flocculation-clarification rate tests were conducted for each of the two chemical treatments previously described. These tests were conducted using an 8 ft. high sedimentation column. Figure B-5 shows the overall suspended solids reductions achieved using chemical treatment to a pH of 9.0 and polymer addition as related to the clarification overflow rate. The average effluent suspended solids concentration achieved in these tests was 64 mg/L, well below the required effluent limitation of 100 mg/L. The clarifier underflow suspended solids concentration was found in the range 1 - 3%.

Effluent Neutralization

The maximum allowable pH for discharge to the Delaware River is 8.0. Consequently, the acid requirements for neutralization of the clarifier effluent were determined in the treatability tests. The sulfuric acid requirements for neutralization of the treated samples are shown in Table A-3. The average required sulfuric acid dosage for neutralization to a pH of approximately 7.5 was 50 mg/L.

Vacuum Filtration

A series of vacuum filtration tests were performed using thickened sludges obtained during the clarification tests. For the sludges obtained using chemical treatment to a pH of 9.0, Figure B-6 shows the filtration rate versus filter feed suspended solids concentration for Buchner funnel tests. The average filter cake solids content was 30%.

Recalcination

Recalcination of the filter cakes to recover lime for reuse in the wastewater treatment process was considered as a possible means to reduce the operating costs of required treatment facilities. Thus, two tests were run on typical filter cakes obtained during vacuum filter tests to determine the concentration of metals and the calorific content of the filter cake. These analyses are shown in Table A-4 . These analyses indicate that essentially all of the energy required for recalcination must be externally supplied.

Subsequent economic analysis indicated that the operating costs for disposal of filter cakes and use of virgin lime was substantially less than that required for recalcination. Consequently, recalcination of the filter cake to recover/reuse lime was not included in the conceptual design.

PROPOSED WASTEWATER TREATMENT FACILITIES

Design Basis

Lime treatment facilities were designed on the basis of the expected wastewater flow and characteristics and the current treatability study results, which were previously discussed. The major processes include equalization/oxidation, chemical treatment using lime to a pH of 9.0, coagulation with a polyelectrolyte (Dow A-23 @ 1 mg/L), clarification, post neutralization with sulfuric acid, and vacuum filtration of the clarifier underflow sludge. Table A-5 summarizes the design parameters, sizing, and expected performance of the proposed treatment units. A schematic flow diagram of the recommended treatment process is shown in Figure B-7. A tentative plant layout for the proposed treatment plant is shown in Figure B-8. Each of the individual process units are discussed in further detail below.

Process Description

Groundwater Collection/Pump Station

Groundwater pumped from the individual recovery wells (shown on Figure B-1) will flow to a wet well at the collection/pump station. The pump station, equipped with three 1,650 gpm horizontal centrifugal pumps, would be provided to transfer the combined groundwater from the recovery wells to the 4-hour oxidation/equalization basin. No further pumping of the flow would be required since the elevation of the oxidation basin would be sufficient to allow gravity flow through the remainder of the treatment facilities.

The location of the collection/pump station should be selected so as to minimize the piping required for collection of groundwater from the recovery wells and delivery to the downstream treatment facilities.

Oxidation/Equalization Basin

Aeration of laboratory samples was shown to be sufficient to oxidize ferrous iron to ferric ion, as shown by the subsequent removals of iron during chemical precipitation. Since no laboratory efforts were directed at determining the oxygen requirements for this wastewater, a theoretical analysis, coupled with experience, has been used to develop a design basis for the aeration capacity required for this system.

Ferrous iron is oxidized to ferric iron in accordance with the following simplified chemical reaction:

$$4\ Fe^{+2} + 3\ O_2 + 6\ H_2O \longrightarrow 4\ Fe\ (OH)_3$$

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In order to provide sufficient oxygen for this reaction to occur, approximately 50% excess oxygen should be supplied via the aerators. For a flow of 4.75 MGD at a maximum iron concentration of 30 mg/L (assumed all ferrous), approximately 22 pounds/hour of oxygen are required to complete this reaction. Consequently, a minimum of 33 pounds/hour of oxygen should be supplied via aerators.

While the laboratory samples were adequately aerated in approximately 1/2 hour, prior experience has indicated that a more suitable detention time for operating facilities is approximately two hours. In addition, the oxidation system should provide for equalization of the water quality prior to the chemical facilities. Consequently, a conservative 4-hour detention time was selected for design of the oxidation/equalization facility.

The oxidation basin would be equipped with two, 25 HP floating surface aerators which would be capable of transferring approximately 81 lbs O_2/hour. This oxygen transfer rate is more than adequate to supply the required oxygen for oxidation of ferrous iron. Two, 25 HP aerators are necessary, however, to maintain all the suspended solids in suspension in the oxidation basin.

Lime Treatment

The aerated wastewater would flow by gravity to the Flash Mix Tank, which has a four minute detention time where lime would be added under pH control to a pH of 9.0. This pH level was found to provide satisfactory metals removal. The average lime dosage is expected to be approximately 140 mg/L.

Flocculation-Clarification

After addition of lime, the flow would be divided in a splitter box and flow by gravity to the flocculation zones of each of two clarifiers. Polyelectrolyte (1 mg/L Dow A-23) would be added to the flocculation zones which would have a detention time of approximately five minutes. The flocculated metal hydroxides and unreacted lime would settle to the bottom for subsequent removal and dewatering. Provision for sludge recycle to maintain maximum effluent clarity and floc settleability is included.

The clarifier zone is sized on the conservative basis of 1,000 gallons/day/ft^2. Using this overflow rate, the required overall clarifier diameter is 65 feet for 4.75 MGD maximum flow. Two clarifiers would be provided in order to allow for flexible and continuous operation in the event that one clarifier is out of service for maintenance.

Post Neutralization

The treated wastewater would flow to the Post Neutralization Tank by gravity. In this tank, the effluent pH would be reduced to less than 8.0 by addition of sulfuric acid under pH control. The Post Neutralization Tank would have 10 minutes detention time and would be equipped with one, 15 HP mixer. The final effluent would then flow via gravity to the effluent sewer which would discharge to the Delaware River.

Chemical Feed Systems

Lime slurry, polyelectrolyte, and sulfuric acid must be added to the wastewater treatment process described above. The sulfuric acid would be fed from a 3,500 gallon storage tank under pH control to the Post Neutralization Tank.

Because of the large amounts of lime required (4,670 to 7,670 lbs/day as $Ca(OH)_2$) for wastewater treatment, a quicklime (CaO) storage and slaking system would be most economical. The system would consist of one bulk quicklime storage silo, two dry volumetric feeders, two slakers, and a surge tank for dilution, mixing, and feeding a 5% hydrated lime slurry to the Flash Mix Tank. These facilities would be located at the Control Building, as shown on Figure B-8.

Sludge Thickening

The underflow from the Flocculator-Clarifier (at about 1-3% solids) would be pumped to a Sludge Thickening/Holding Tank for storage/concentration prior to final dewatering. The underflow from the clarifier would be pumped for four hours each day to the holding tank, which has a 16-hour detention time. Due to the high solids concentration of underflow from the clarifier, a separate sludge thickening unit is not necessary.

The required facilities include a 31,000 gallon Sludge Holding Tank and a Clarifier Sludge Pump Station. The Clarifier Sludge Pump Station would also provide capacity for recycling sludge back to the Flocculator-Clarifiers. The Sludge Holding Tank would concentrate the influent sludge from 1 - 3% to 5% or more, and provide storage and equalization for the thickened sludge prior to feeding to sludge dewatering facilities. Thickener overflow would recycle by gravity back to the Oxidation/Equalization Basin.

Sludge Dewatering and Disposal

Sludge from the Sludge Holding Tank would be pumped by a positive displacement pump to two Vacuum Filters located in the Control Building. These filters would be operated one shift per day. Dewatered cake from the filters would be conveyed to Cake Hoppers (Dempster Boxes) for storage before final disposal. Filtrate would flow by gravity to the

Oxidation/Equalization Basin.

The Vacuum Filters would be sized to provide effective sludge dewatering in the event one filter is our of service, by increasing throughput rates or running the operation on a two-shift basis. Based on the vacuum filtration test results shown in Figure B-6, a rate of 5 lbs dry solids/hour/ft^2 was used in sizing the filters. Depending upon the cake moisture and sludge production rates, an average of 4.4 cubic yards of cake are expected for disposal each day.

Control Building

The Control Building would have an area of approximately 3,000 $ft.^2$. This building would contain the Polymer Feed System, Lime Slakers, Lime Slurry Tank, Vacuum Filters, Control Systems, Motor Control Center, and miscellaneous equipment.

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COST ESTIMATES

The capital cost estimate for the required treatment facilities is $1,251,000 (1973 dollars). This cost estimate is summarized in Table A-6. Included in the capital cost estimate are all process unit purchase and installation costs, yard and mechanical piping within the battery limits of the treatment plant, electrical, instrumentation, site work, and building construction. Also included are construction contingency and engineering charges. The capital cost estimate excludes the recovery well collection pipe network, the effluent sewer to the Delaware River, and purchase of necessary land for these facilities.

The direct annual operating cost estimate for these facilities is $207,200. This operating cost estimate is summarized in Table A-7 . Labor requirements are estimated at two (2) men on a 7-day, 3-shift basis. Utilities, maintenance, chemical costs, and sludge disposal are also included in the direct operating cost estimate. No capital recovery costs have been included.

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the treatability studies, the following conclusions can be made:

1. Groundwater from the recovery wells at the Llangollen Landfill site are amenable to physical-chemical treatment for the removal of dissolved metals.

2. The most economical process for removal of the dissolved metals includes aeration to oxidize ferrous iron to ferric iron; equalization of wastewater quality; lime treatment to a pH of 9.0; flocculation-clarification using Dow A-23 as a coagulant aid; and, post neutralization. The clarifier underflow would be thickened and dewatered via vacuum filters.

3. The required treatment facilities would cost approximately $1,251,000.

4. The annual direct operating cost for these treatment facilities would be approximately $207,200.

Based upon these studies, it is recommended that New Castle County consider the installation of the required facilities for the removal of dissolved metals from the contaminated groundwater.

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APPENDIX A

TABLE A-1

Llangollen Landfill
New Castle County, Delaware

SUMMARY OF RAW WASTE ANALYSES[1] FROM GROUNDWATER RECOVERY WELLS

Sample No.	Date	Total Fe, mg/L	Suspended Solids, mg/L	Cu, mg/L	Ag, mg/L	pH
1	9/23	3.6	40	0.08	<0.05	7.8
2	9/24	26.6	41	<0.05	<0.05	7.8
3	9/25	21.0	45	<0.05	<0.05	8.5
4	9/27	7.5	46	<0.05	<0.05	7.8
5	9/28	18.8	41	<0.05	<0.05	7.8
6	9/30	10.5	33	<0.05	<0.05	8.3
7	10/1	11.5	40	<0.05	<0.05	7.6
8	10/2	5.9	40	<0.05	<0.05	7.7
9	10/3	20.6	38	<0.05	<0.05	7.8
10[2]	10/3	8.85	314	<0.05	<0.05	7.6
Delaware River Discharge Requirement		1.0	100	0.5	0.1	8.0

(1) Raw waste is an equal volume composite of groundwater pumped from Recovery Wells 27, 28, 29, and 31.

(2) Raw waste is composite of wells 27, 28, 29, 31, and Wells 2 & 4 (inside the landfill). The volume ratio for composite is 20:1.

AR101773

TABLE A-2

Llangollen Landfill
New Castle County, Delaware

SUMMARY OF IRON REMOVAL RESULTS BY CHEMICAL TREATMENT

Sample Date	Chemical Treatment Conditions		Total Iron Concentration, mg/L		
	Adjustment with Lime to pH	Dow A-23 Polymer Dosage, mg/L	Raw	Treated	% Reduction
9/23/73	10.5	0	3.6	0.3	92
9/24/73	10.5	0	26.6	5.0	81
9/25/73	10.5	0	21.0	0.3	99
9/25/73	9.0	1	21.0	1.8	91
9/27/73	10.5	0	7.5	1.6	79
9/27/73	9.0	1	7.5	0.6	92
9/28/73	10.5	0	18.8	0.5	97
9/28/73	9.0	1	18.8	1.0	95
9/30/73	10.5	0	10.5	<0.1	>99
9/30/73	9.0	1	10.5	<0.1	>99
10/1/73	10.5	0	11.5	0.2	98
10/1/73	9.0	1	11.5	0.7	94
10/2/73	10.5	0	5.9	<0.1	>98
10/2/73	9.0	0	5.9	0.4	93
10/2/73	10.5	0	45.5[(1)]	0.7	98
10/2/73	9.0	1	45.5[(1)]	0.2	99.6
10/3/73	10.5	0	20.6	1.0	95
10/3/73	9.0	1	20.6	0.9	96
10/3/73	10.5	0	8.9[(2)]	<0.1	>99
10/3/73	9.0	1	8.9[(2)]	<0.1	>99

(1) Raw composite sample from Well #2 and #4 in landfill.

(2) Raw composite sample from Recovery Wells 27, 28, 29, 31, and Landfill Wells 2 and 4. The volume ratio between sample from Recovery Wells and Landfill Wells is 20:1.

TABLE A-3

Llangollen Landfill
New Castle County, Delaware

SULFURIC ACID REQUIREMENTS FOR NEUTRALIZATION OF TREATED WASTEWATER SAMPLES (1)

Sample No.	H_2SO_4 Used, ml
1	3.8
2	5.2
3	4.1
4	5.2

(1)
Sample volume: 50 ml
Sulfuric acid concentration: 0.02 N
pH Adjustment to 7.5 from 9.0 - 9.5.

TABLE A-4

Llangollen Landfill
New Castle County, Delaware

SUMMARY OF SLUDGE RECALCINATION TESTS

Sample	ANALYTICAL RESULTS Ca, mg/gr	Mg, mg/gr	Fe, mg/gr	Cu, mg/gr	Heat Content BTU/lb.
1 - Dry Sludge	200	90	113	0.065	0
Ash	61.5	27	106	0.065	
2 - Dry Sludge	224	124	50	0.024	0
Ash	60.5	34	42	0.024	
3 - Dry Sludge	200	138	27	0.098	0
Ash	111.5	57.2	49.2	0.098	
4 - Dry Sludge	194	134	25	0.024	0
Ash	60	41.5	32.6	0.024	

TABLE A-5

Llangollen Landfill
New Castle County, Delaware

SUMMARY OF DESIGN BASIS AND MAJOR UNIT SIZES

DESIGN BASIS

A. Wastewater Characteristics

1. Total Expected Wastewater Flow, MGD		
Average	4.00	
Maximum	4.75	
2. Influent Suspended Solids	mg/L	lbs/day (Average Flow)
50% Probability-of-Occurrence	40.1	1,338
90% Probability-of-Occurrence	45.0	1,501
3. Influent Iron		
50% Probability-of-Occurrence	14.4	480
90% Probability-of-Occurrence	42.0	1,401
4. Influent Copper	<0.05	
5. Influent Silver	<0.05	
6. Influent pH, Range	5.6 - 8.5	

B. Delaware River Discharge Standards

	mg/L
1. Suspended Solids	100
2. Iron	1.0
3. Copper	0.5
4. Silver	0.1
5. pH	8.5

C. Recommended Chemical Treatment — Raise pH to 9.0 with Lime (150 mg/L avg.) and add polymer (Dow A-23) - 1 mg/L

TABLE A-5
(Continued)

D. Expected Concentrations and Loads Discharged to Army Creek After Treatment	mg/L	lbs/day (Average Flow)
1. Suspended Solids		
50% Probability-of-Occurrence	64	2,135
90% Probability-of-Occurrence	118	3,936
2. Iron		
50% Probability-of-Occurrence	0.54	18
90% Probability-of-Occurrence	1.75	58
3. Copper	<0.05	
4. Silver	<0.05	
5. pH	8.0 - 8.5	

E. Expected Sludge Production

	lb/day Dry Solids	yd^3
1. Quantity		
Average	7,764	4.4

2. Clarifier Design Underflow Sludge	
Concentration, Average	3%
Gallons/day, Average	31,000
3. Sludge Dewatering	
Filtration Rate, Average	5 $lbs/hr/ft^2$
Filter Area	260 $ft^2 \times 2$
Expected Filter Cake Solids, %	30

F. Chemical Consumption (Based on Average Flow)	lbs/day as $Ca(OH)_2$	Gallons/Day as $Ca(OH)_2$ at 5% Slurry
1. Lime		
50% Probability-of-Occurrence	4,760	11,200
90% Probability-of-Occurrence	7,672	20,800
	lbs/day	Gals/day @ 0.2% Solutio
2. Polymer (Dow A-23) Dosage	33.4	2,376
	lbs/day	Gals/day @ 100%
3. Sulfuric Acid		
Average Dosage	1,780	116
Maximum Dosage	2,631	173

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TABLE A-5
(Continued)

MAJOR UNIT SIZES

A. Wastewater Pump Station

Wet Well	
Dimensions	22' x 10' x 20' deep (10' SWD)
Capacity	16,500 gallons (2,200 cu.ft.)
Detention Time	Five (5) minutes
Material of Construction	Reinforced concrete
Dry Well	
Dimensions	22' x 10' x 20' deep
Space	2,200 cu.ft.
Material of Construction	Reinforced concrete
Pumps	
Function	To pump raw wastewater to the oxidation basin
Number of Units	Three (3)
Type	Horizontal centrifugal
Capacity	Three (2 constant, one variable speed at 1,650 gpm each at 50' TDH)
Control	Liquid Level

B. Oxidation Basin

Function	To convert ferrous iron to ferric iron and equalization of wastewater quality
Number	One (1)
Dimensions	71' x 100' x 17' deep (15' SWD)
Capacity	791,700 gallons (106,000 cu.ft.)
Detention Time	Four (4) hours
Aerators	Two (2), 25 HP Surface Floating Aerators
Material of Construction	Reinforced concrete

C. Flash Mixing Tank

Number	One
Dimensions	17' x 15' x 10' deep (7' SWD)
Capacity	13,200 gallons ([illegible] cu.ft.)
Detention Time	Four (4) minutes
Mixers	One (1) at 3 HP (constant speed)
Material of Construction	Reinforced concrete

TABLE A-5
(Continued)

D. Flocculator-Clarifier

Number	Two (2)
Dimensions	65' diameter x 14' deep (12' SWD)
Capacity	297,700 gallons (39,800 cu.ft.)
Detention Time	2.0 hours at maximum flow
Overflow Rate	1,000 gals/sq.ft./day
Material of Construction	Reinforced concrete
Sludge Collection	Unit provided with sludge raking mechanism (sludge raked to center)
Flocculation Zone	15' diameter x 6' skirt

E. Clarifier Sludge Transfer Pumps

Function	To pump the clarifier underflow to the vacuum filter and recycle to clarifier inlet
Volume of Sludge, Average	31,000 gals/day at 3%
Number	Two (2) (one alternating stand-by)
Type	Non-clog centrifugal
Capacity, each	100 gpm
Material of Construction	Abrasion resistant
Control	Manual, using Flow Meter
Dry Well	
Dimensions	7' x 7' x 10' deep
Material of Construction	Reinforced concrete

F. Sludge Holding Tank with Mixer

Number	One (1)
Dimensions	20' diameter x 16' high (13' SWD)
Capacity	31,000 gals (4,150 cu.ft.)
Detention Time	16 hours
Material of Construction	Steel
Mixer	One (1) at 10 HP

G. Vacuum Filtration Unit

AR101780

Number	Two (2)
Filter Area	260 sq.ft. per each
Filter Feed Pump	Two (one stand-by)
Normal Operating Time, hours/day	Eight (8)
Pumping Rate	33 gpm

TABLE A-5
(Continued)

H. Sludge Storage Container	
Number	Two (2)
Type	Dempster Boxes
I. Lime Feed Facilities	
Storage Bin	
Number	One (1)
Detention Time	30 days at average, 20 days at maximum
Dimensions	12' diameter x 40' high
Capacity	3,160 cu.ft. or 71 tons CaO
Material of Construction	Epoxy coated steel
Lime Slaker	
Number	Two (2)
Rate	1,000 - 2,000 lbs/hr
Lime Slurry Make-up Tank	
Number	One (1)
Capacity	4,000 gals.
Detention Time	Four (4) hours
Dimensions	9' diameter x 11' high
Solution Strength	5%
Control	Tank level control on dilution water and slaker feed rate
Material of Construction	Steel
Mixer	
Number	One (1)
Capacity	5 HP
Lime Slurry Recirculation Pump	
Number	Two (2) (one stand-by)
Type	Centrifugal circulating pump
Capacity	100 gpm
Material of Construction	Abrasion resistent
J. Post Neutralization Tank	
Purpose	To adjust pH of wastewater to 8.0 -
Number	One (1)
Detention Time	10 minutes
Dimensions	21' x 21' x 12' deep (10' SWD)
Mixer	One (1) at 15 HP
Material of Construction	Reinforced concrete

TABLE A-5
(Continued)

K. Sulfuric Acid Feed Facilities

Storage Tank	
Capacity	3,500 gallons
Dimensions	7' diameter x 12' long
Concentration of Stored Acid	98% H_2SO_4
Material of Construction	Steel
Feed Pump	
Number	Two (2)
Type	Metering Pump
Capacity	0-30 gph
Control	Automatic

L. Polymer Feed Facilities

Day Tank	
Number	Two (2)
Capacity	3,000 gallons each
Detention Time	24 hours each
Mixer	Two (2) at 2 HP
Feed Pump	
Number	Two (2) at 1 HP
Capacity	0-100 gph
Concentration of Polymer (Dow A-23) Solution	0.2%

M. Control Building

Number	One (1)
Size	2,400 sq.ft.

TABLE A-6

Llangollen Landfill
New Castle County, Delaware

SUMMARY OF CAPITAL COSTS
GROUNDWATER LIME TREATMENT SYSTEM

Process Units	Installed Cost, 1973 $
Wastewater Lift Station	$ 68,800
Oxidation/ Equalization	178,000
Chemical Feed Systems	84,400
Flash Mix Systems	21,000
Flocculation-Clarifiers (2), including Sludge Station	208,000
Post Neutralization	25,100
Sludge Dewatering, Including Sludge Holding Tank	138,400
Electrical Substation (600 KVA)	11,300
MAJOR SYSTEMS SUB-TOTAL	$ 735,000
Yard & Mechanical Piping @ 15% of Major Systems	$ 110,200
Electrical & Instrumentation @ 12% of Major Systems	88,100
Site Work @ 5% of Major Systems	36,700
SUB-TOTAL	$ 970,000
Buildings - 3,000 ft.^{2}	$ 90,000
TOTAL CONSTRUCTION COST	$1,060,000
+ Construction Contingency and Engineering	191,000
TOTAL CAPITAL COST	$1,251,000

TABLE A-7

Llangollen Landfill
New Castle County, Delaware

SUMMARY OF DIRECT OPERATING COSTS
GROUNDWATER LIME TREATMENT SYSTEM

Operating Cost	1973 Dollars
Labor	
Operating - 2 men @ $5.00/hour	$ 87,600
Supervision - 10%	8,800
Utilities, Average Usage	
Electrical HP @ $131/KW/year (1.5¢/KWH)	15,600
Maintenance	
3% of $ 970,000	29,100
Chemicals, Average Usage	
Sulfuric Acid - 1,780 lbs/day @$40/ton	13,000
Lime (CaO) - 4,733 lbs/day @ $20/ton	17,300
Polyelectrolyte - 33.4 lbs/day @ $1.50/lb	18,300
Sludge Disposal	
16 yd^3/day @ 3/yd^3	17,500
TOTAL DIRECT OPERATING COST	$ 207,200

APPENDIX B

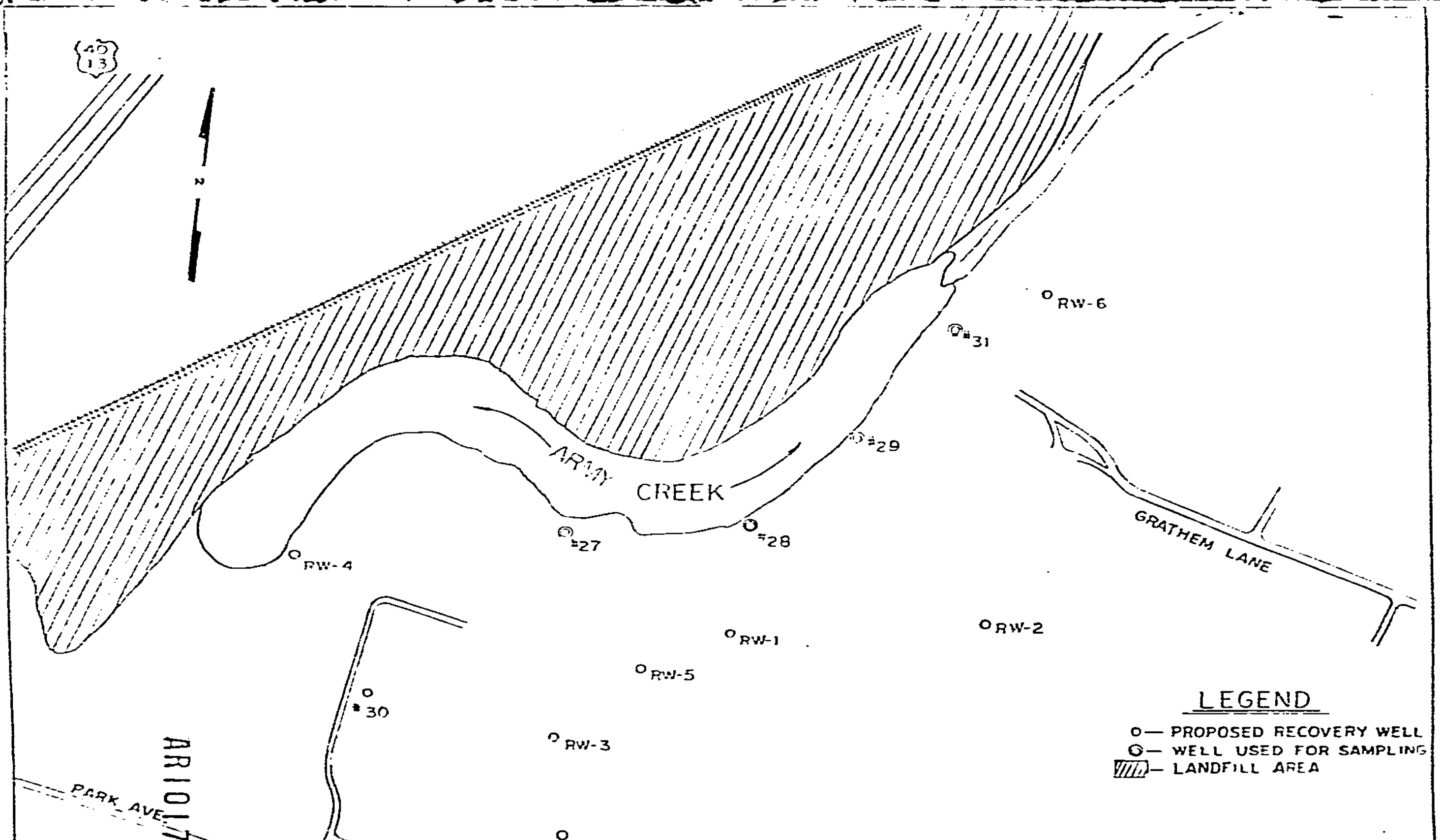

FIGURE B-1

LANDFILL SITE AND PROPOSED RECOVERY WELLS

LLANGOLLEN LANDFILL, NEW CASTLE COUNT E.

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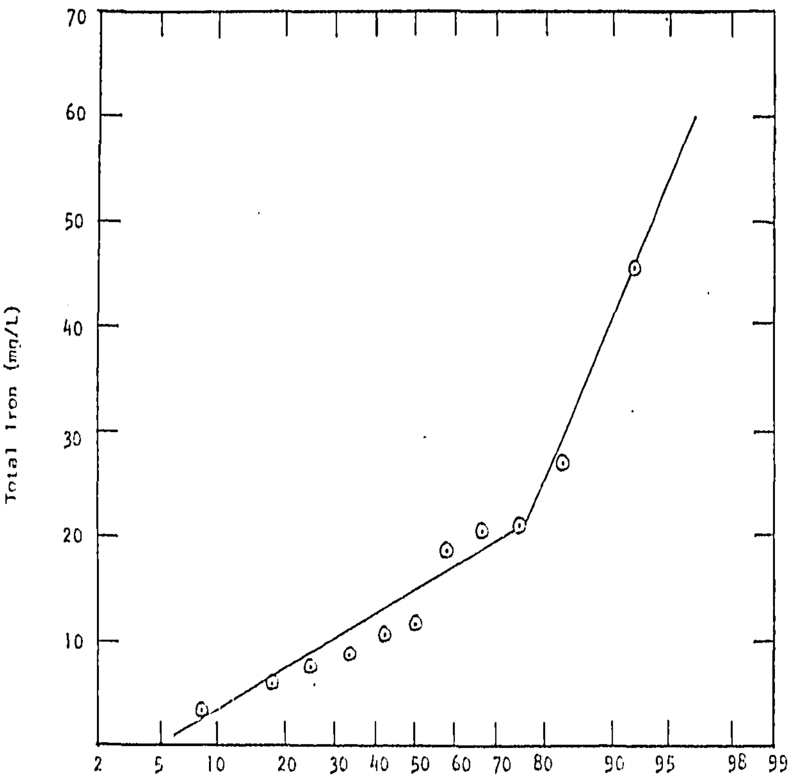
New Castle County, Delaware

Total Iron Concentration in Raw Ground Water



Probability-of-Occurrence, % of the time ordinate value is less than or equal to the graph value.

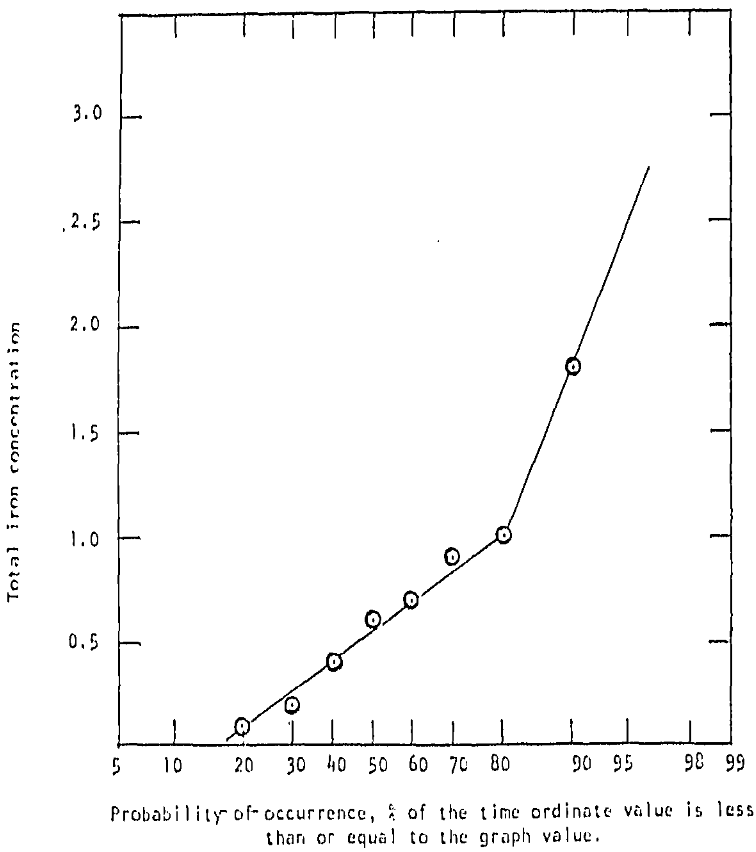
AR101787

ROY F. WESTON, INC. WILMETTE ILLINOIS	DRAWN SCH	SCALE None	DWG.NO. B-2 [illegible]
	DATE 11/9/73	W.O.NO. 463-11	

New Castle County, Delaware

Total Iron Concentration After Treatment

With Lime to pH = 9.0



AR101788

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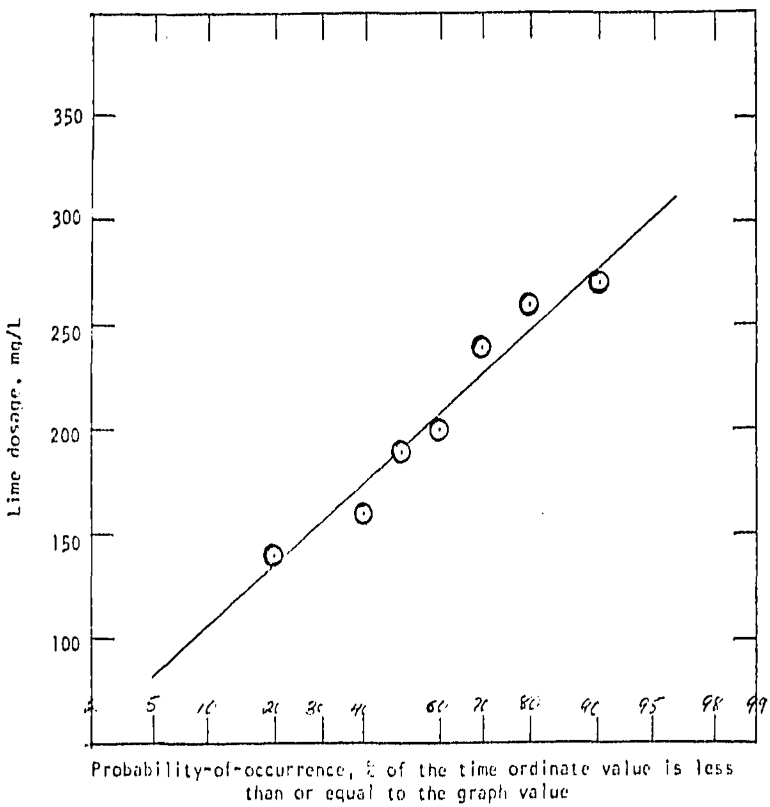
	DATE 11/9/73	W.O. NO. 403-11	

New Castle County, Delaware

Lime Requirement to Raise pH to 9.0



AR101789

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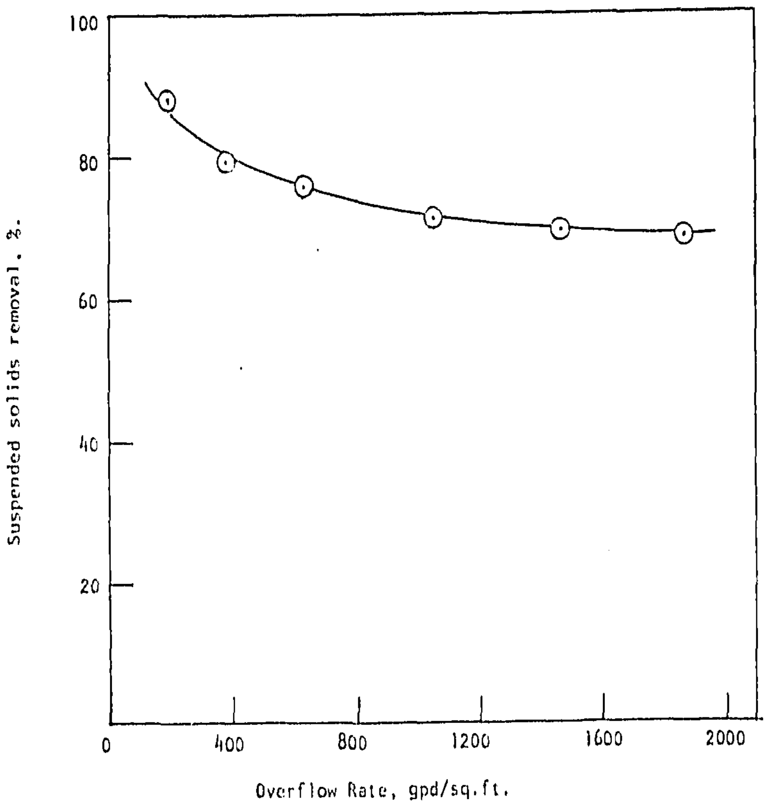
WILMETTE ILLINOIS	SCH	None	[illegible]
	DATE 11/9/73	W.O.NO. 463-11	

New Castle County, Delaware

Clarifier Overflow Rate vs. Suspended Solids Removal



AR101790

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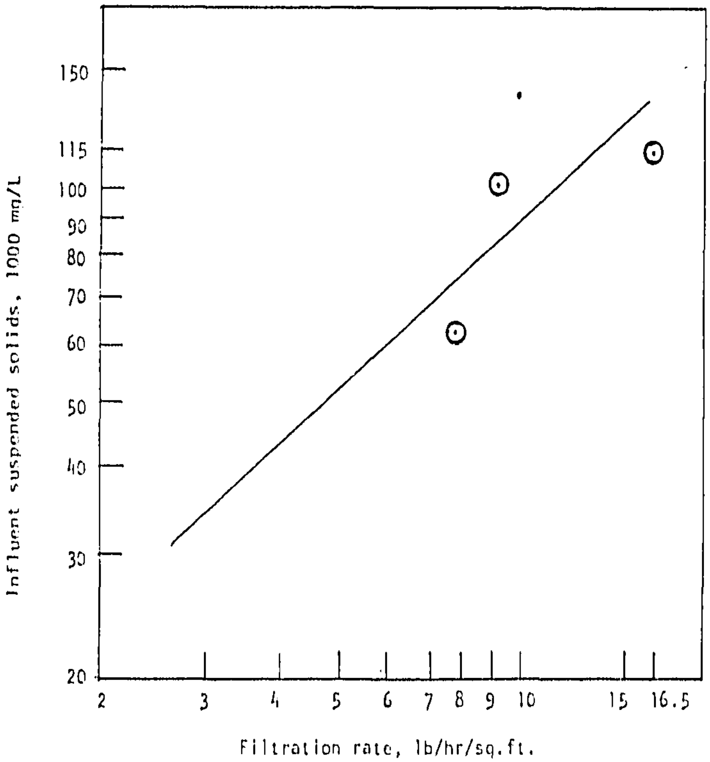
	DATE 11/9/73	W.O.NO. 463-11	

New Castle County, Delaware

Filtration Rate vs. Influent Suspended Solids



AR101791

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	DATE 11/9/73	W.O. NO. 463-11	

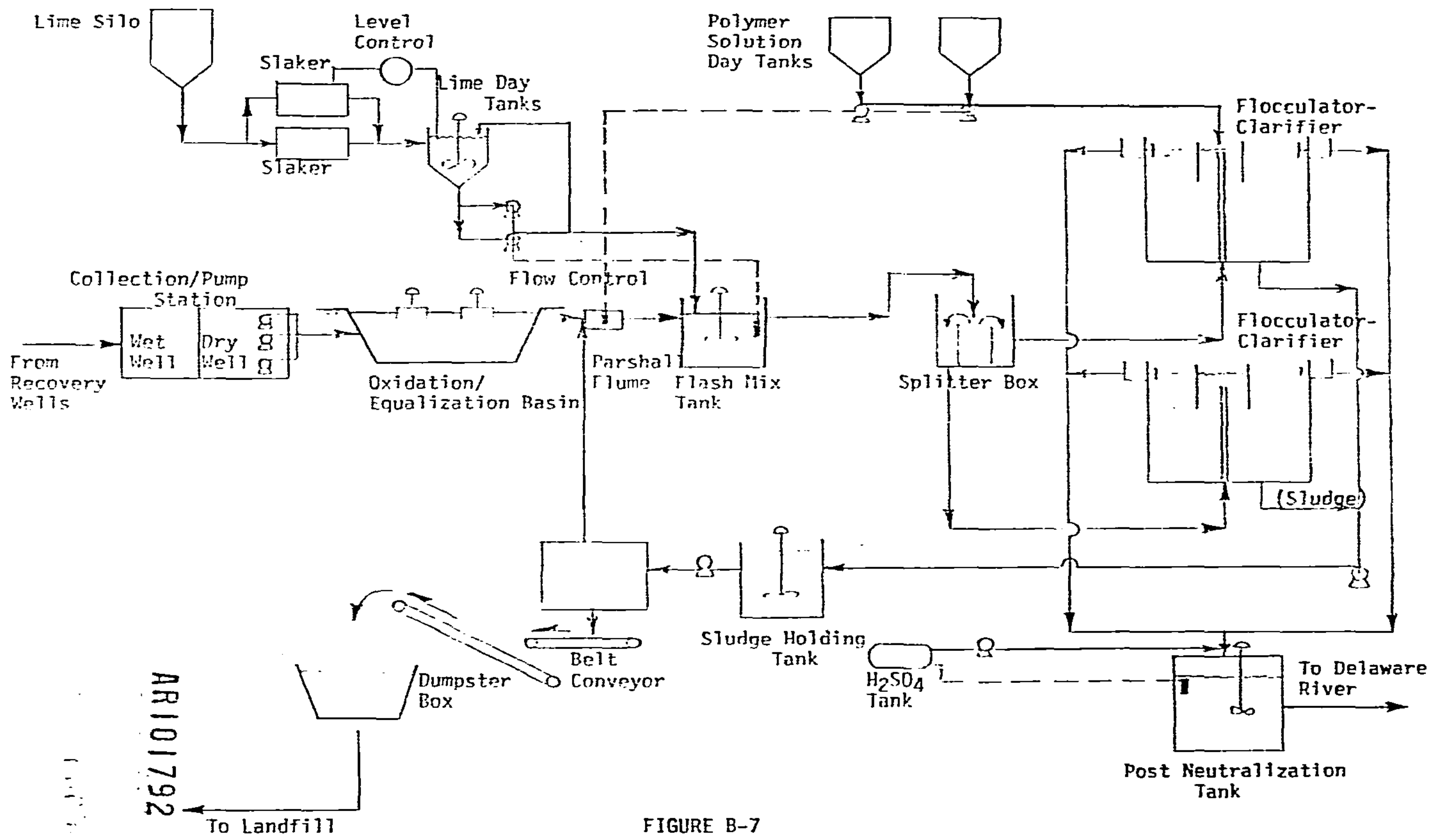


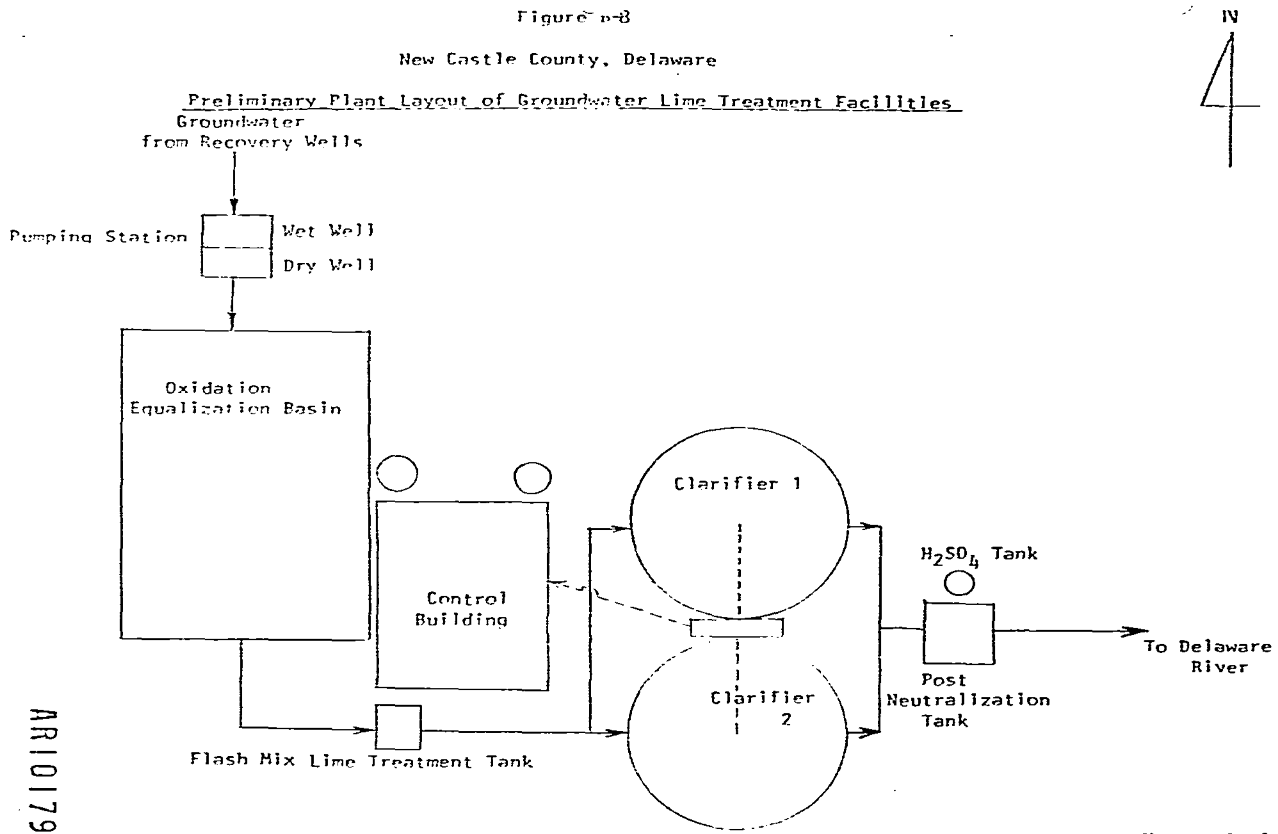
FIGURE B-7

Wastewater Treatment Sche tic Process Flow Diagram

Figure n-8

New Castle County, Delaware

Preliminary Plant Layout of Groundwater Lime Treatment Facilities



Not to Scale

Drawn: SCH
Date: 11/6/73
W.O.No: 463-11

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APPENDIX F

Treatment of Contaminated Ground Water
(Gravity Settling)

Llangollen Landfill
New Castle County, Delaware

Amir A. Metry, Ph.D., P.E.
Project Engineer

Walter R. Niessen, P.E.
Project Manager

January 1974

Prepared by:

ROY F. WESTON, INC.
ENVIRONMENTAL SCIENTISTS AND ENGINEERS
Lewis Lane
West Chester, Pennsylvania

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LIST OF FIGURES AND ILLUSTRATIONS

SUMMARY

Llangollen Landfill, in New Castle County, Delaware, is a potential source of contamination of ground water in that area. The contaminated zone of the underlying aquifer is spreading toward the Delaware River. Recovery wells with an estimated flow of 4.0 mgd from the aquifer are planned to prevent further spreading of this contaminated zone, and most are already in operation. Figure 1 shows location of recovery wells and the landfill. Previous studies by Roy F. Weston, Inc. indicated that the contaminated ground water was amenable to physical-chemical treatment for reduction of dissolved metals (primarily iron). Also, Weston was retained to develop a conceptual design for the required metals-removal treatment plant. The treatment facilities would require approximately $1,[illegible] for construction and approximately $200,000 annual operating cost. After preliminary review and evaluation by New Castle County Engineers, Weston was asked to submit an evaluation of the feasibility of gravity settling of iron, and of the impact on water quality and the overall project costs of such a simplification of the proposed treatment facility.

Laboratory testing, on one composite sample of recovery-well water, indicated that it is technically feasible to reduce the iron in the plant effluent to the 2.0 mg/L level, as set by the proposed regulation for discharge in Delaware streams. However, a lime addition back-up system may be needed in the future. The proposed facilities would consist of: a) an aeration basin to oxidize ferrous iron to ferric iron; b) two settling basins for removal of ferric iron and suspended solids; and c) two sludge holding basins for thickening and storage of sludge. Sludge removal would be via a mobile hydraulic dredge once or twice every year. Sludge holding facilities would have an estimated life of 10 years.

It is recommended that further verification of design parameters be performed in the laboratory, using multiple composite samples for all recovery wells, prior to engineering design and construction of the facilities. A 10-acre site would be selected on the basis of its location and hydrogeologic characteristics. Engineering design of pipeline and booster pumping station, if needed, would follow final selection of the site for treatment facilities.

Total capital cost is estimated at $660,000 and annual operating costs are estimated at $105,000. However, these cost figures do not include the effluent pumping station or the effluent discharge pipeline to the Delaware River.

INTRODUCTION AND BACKGROUND

The Landfill

The Llangollen Landfill site, a county-wide solid waste disposal site near New Castle, Delaware, operated by the New Castle County Department of Public Works from approximately 1960-1968, is shown in Figure 1. The total area of landfill operation was approximately sixty acres. The landfill is approximately 4,400 feet long, 250 to 900 feet wide, and approximately 30 feet thick, and contains an estimated 3 million cubic yards of municipal and industrial refuse material.

Hydrogeology of the Landfill Area

The sand in the Llangollen area, of the Pleistocene Columbia Formation, consists of alluvial deposits which are predominantly medium to coarse sand, with gravel. This formation forms nearly continuous surficial cover up to 60 feet in thickness. The base of this formation ranges about 10 feet above to 20 feet below mean sea level in the vicinity of the landfill. The underlying Potomac Formation consists of stream-deposited unconsolidated sands, silts, and clays of Lower Cretaceous Age. The sand units are channel-shaped, with extensive interbedded lenses of clay and silt which accumulated on ancient floodplains and estuaries. The Potomac Formation dips toward the southeast at approximately 40 to 140 feet per mile (uppermost and lowermost beds respectively) in the study area.

Hydrogeologically, the general coarse Columbia deposits serve as an infiltration and recharge gallery for the Potomac sands. Ground water in the Potomac sands becomes confined (artesian) beneath relatively impermeable beds of clay and silt as it travels seaward down deep in the formation. The approximate thickness of the Potomac confining units immediately beneath the Columbia sands ranges from 10 to 30 feet. Immediately beneath the landfill, these clay and silt deposits are shallow, thin, or absent (in the southeast corner of the fill).

Leachate Generation

When ground water, infiltrating surface water, or a combination of both moves through the landfill's solid wastes, it produces a complex solution of dissolved and suspended material (leachate).

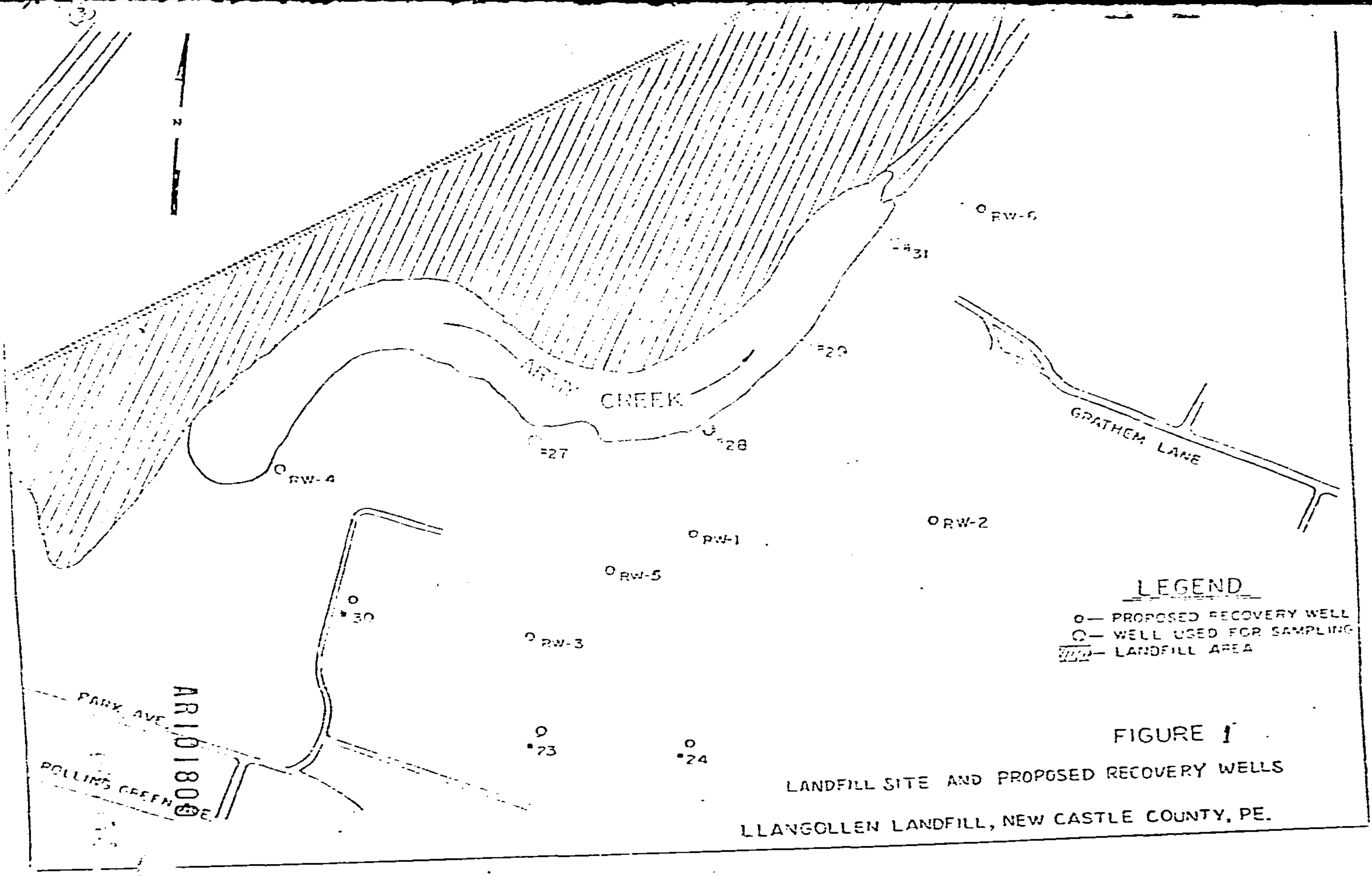

FIGURE 1

LANDFILL SITE AND PROPOSED RECOVERY WELLS

LLANGOLLEN LANDFILL, NEW CASTLE COUNTY, PE.

High levels of ground-water infiltration and surface-water infiltration, as well as absence of confining layers at some locations beneath the landfill, are prime causes of substantial leakage of leachate from the Llangollen landfill into the Potomac aquifer.

Ground-water Quality Problem

Scarcity of potable water in New Castle County has made conservation of such valuable resources essential. Pollution of a major aquifer (i.e., the Potomac aquifer) by leachate from the Llangollen landfill will result in loss of a major supply of high-quality potable water unless corrective measures are taken to halt the progress of contaminants through the aquifer towards the water supplier. Recovery wells for the purpose of withdrawing the contaminated portion of the aquifer have already been installed for this purpose, and most of them are already pumping. Currently, the recovered contaminated ground water is discharged directly to the Army Creek Pond, and finally reaches the Delaware River. The major objection, by regulatory agencies, to discharging the recovered ground water without treatment is the relatively high iron content, which averages [illegible] mg/L. The Delaware State Department of Natural Resources (Division of Environmental Control) has recently proposed a new regulation on effluent discharge into the State Rivers. This proposed regulation includes a limit of 2.0 mg/L of total iron in any effluent to be discharged into the state waters. Such requirements dictate the need for a treatment facility for recovered ground water prior to its discharge in the Delaware River or any of its tributaries, e.g., Army Creek.

Treatment Requirements

This investigation is based on the assumption that iron removal is the primary target of the treatment facilities. However, incidental removal of metals, suspended solids, and color would also be achieved in the settling basins. Laboratory-scale settling, by gravity, was found to be capable of reducing iron concentration below the allowable limit of 2.0 mg/L. Gravity precipitation of aerated ground water is expected to meet, on the average, the criterion for discharge in the State waters. However, a back-up system consisting of continuous or manual lime feeding may be required to insure performance of settling lagoons under adverse ground-water conditions, such as low pH. Such a back-up system should be considered only if, after construction of the facilities, the effluent from the settling basins exceeds the allowable discharge limits on iron.

AR101801

WASTEWATER TREATABILITY

In a previous report by Roy F. Weston, Inc. to New Castle County[1], a concept design for removal of iron from contaminated ground water was presented. Treatability studies in that report confirmed that iron could be removed efficiently using lime precipitation. However, as an alternative approach to lime treatment, upon the request of New Castle County, a composite sample of the recovery wells that are already in operation was tested for treatability without the aid of lime.

The composite sample was aerated for one hour and then left to settle by gravity. The composite sample contained 40 mg/L of total iron and 41 mg/L of suspended solids, and had a pH of 6.7. Suspended solids and total iron in the supernatant were determined and plotted in Figure 1. Interpretation of laboratory data indicated that an overflow rate of 45 gpd per sq ft is adequate for reducing iron concentration to approximately 2.0 mg/L and for reducing suspended solids in the supernatant to about 5.0 mg/L. However, a scale-up factor of 3.0 is used to account for actual performance in the settling basin and to allow for turbulence, short circuiting, and inlet-outlet losses. This scale-up factor makes the design overflow rate 15 gpd/sq ft.

The laboratory sample showed good settling characteristics and a distinct interface between supernatant and settled sludge. Such good results are expected as long as the ground water is on the alkaline side, which is expected to be true in most cases most of the time. However, a simplified scheme for adding lime to the recovered ground water may be needed as a back-up system in case gravity settling does not meet the effluent requirements for discharge to the Delaware River. This report does not include a design for such a back-up system, because the decision regarding such a system should be deferred until the facilities are constructed and actual performance data are evaluated. Addition of lime treatment prior to the aeration basin should be evaluated if the gravity system (without lime) fails to meet the effluent quality requirements. Lime treatment facilities, as an "add-on" feature, may be operated on a continuous basis or, if lime is needed only occasionally, a manual feed of lime at a known rate to the aeration basin may prove to be practical.

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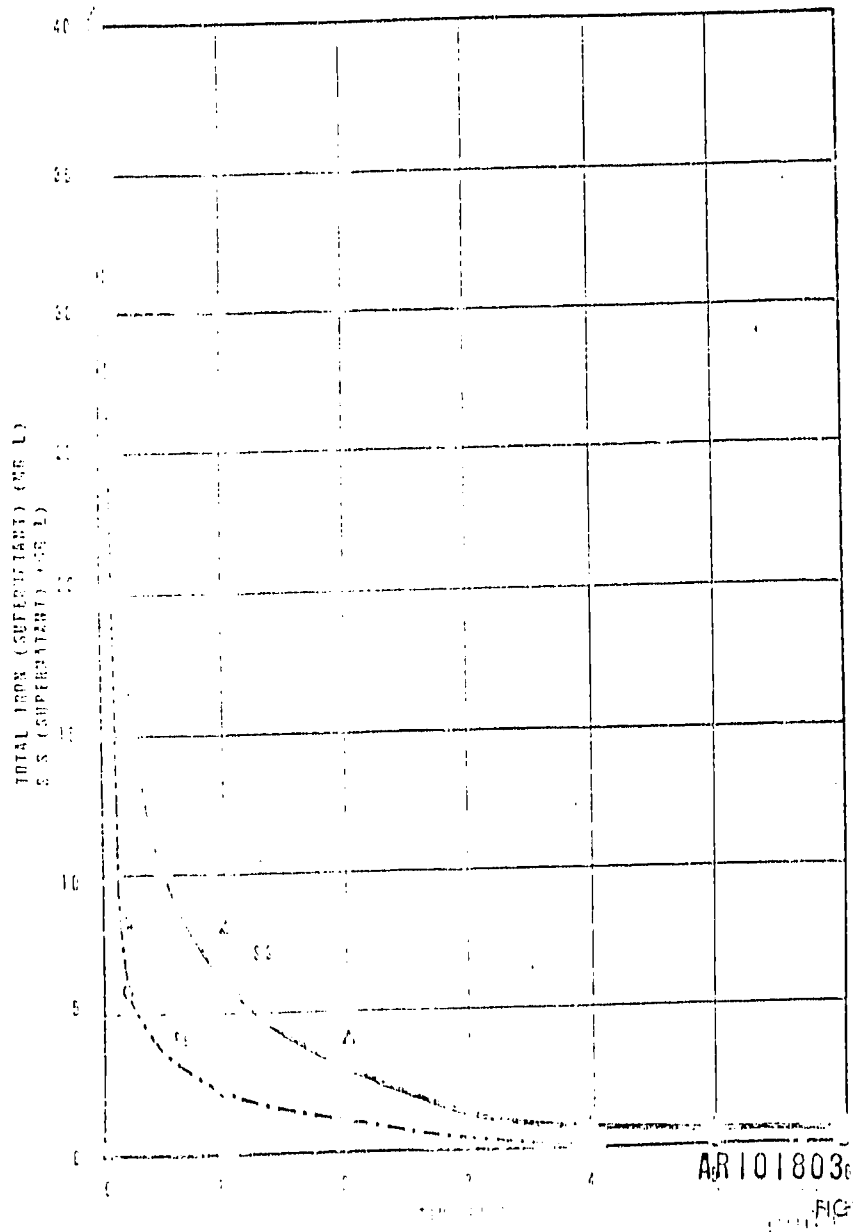
[1]"Conceptual Design Report, Lime Treatment of Groundwater", Llangollen Landfill, New Castle County, Delaware, November 1973.

AR101802

LLANGOLLEN SANITARY LANDFILL
NEW CASTLE COUNTY, DELAWARE

SUSPENDED SOLIDS AND TOTAL IRON IN SUPERNATANT



AR101803

FIGURE 2

ROY F. WESTON, INC.

It should be mentioned here that the concept design presented in the following section is based on the testing of one composite sample. This design is preliminary and is presented for the purpose of assessing the concept of treating the contaminated ground water without aid of chemicals. However, before the engineering design phase, it is recommended that a laboratory confirmation on design parameters be performed using several samples. Also, sludge solids content prior to and after thickening should be determined; this should be done after all the recovery wells are operating, to get a true composite that reflects the combined characteristics of the recovered ground water.

DESCRIPTION OF THE PROPOSED TREATMENT FACILITIES

Figure 3 is a plot plan and flow diagram for the proposed treatment facilities. Ground water will be pumped from the recovery wells at an average rate of 3.0 mgd (and at a maximum rate of 4.0 mgd at the peak demand on ground water at the summer months). Recovered water from all the operating wells will be combined in one force main and pumped to an aeration basin. The aeration basin will be an earthen basin lined with clay, which is locally available at the site vicinity. The aeration basin will be sized to aerate the maximum rate of flow for two hours and will have two mechanical surface aerators. Aeration of laboratory samples was shown to be effective in oxidizing ferrous iron to ferric iron, as shown in Figure 2. One hour of aeration was sufficient in the laboratory, but prior experience has indicated that a more suitable detention time for full-scale operating facilities is approximately two hours. Ferrous iron is oxidized to ferric iron as shown in the following simplified chemical reaction:

$$4\ Fe^{++} + 3O_2 + 6\ H_2O \qquad 4\ Fe(OH)_3$$

In order to provide sufficient oxygen for completion of this reaction, approximately 50 percent excess oxygen should be supplied via the mechanical aerators. For a flow of 4.0 mgd at a maximum iron concentration of 60 mg/L (assumed to be all in the ferrous state), the stoichiometric quantity of oxygen required to drive this reaction to completion is approximately 38 pounds per hour. Consequently, an oxygen at a rate of 57 lbs/hour should be supplied via the mechanical aerator.

The aeration (oxidation) basin will be equipped with two 25-HP floating surface aerators, which would be capable of transferring approximately 80 lbs O_2/hr. Thus, the oxygen transfer capability will be more than adequate to supply the oxygen required for oxidation of ferrous iron. However, such large aerators are needed to keep the recovered water completely mixed in the aeration basin and to prevent the suspended solids from precipitating in the basin.

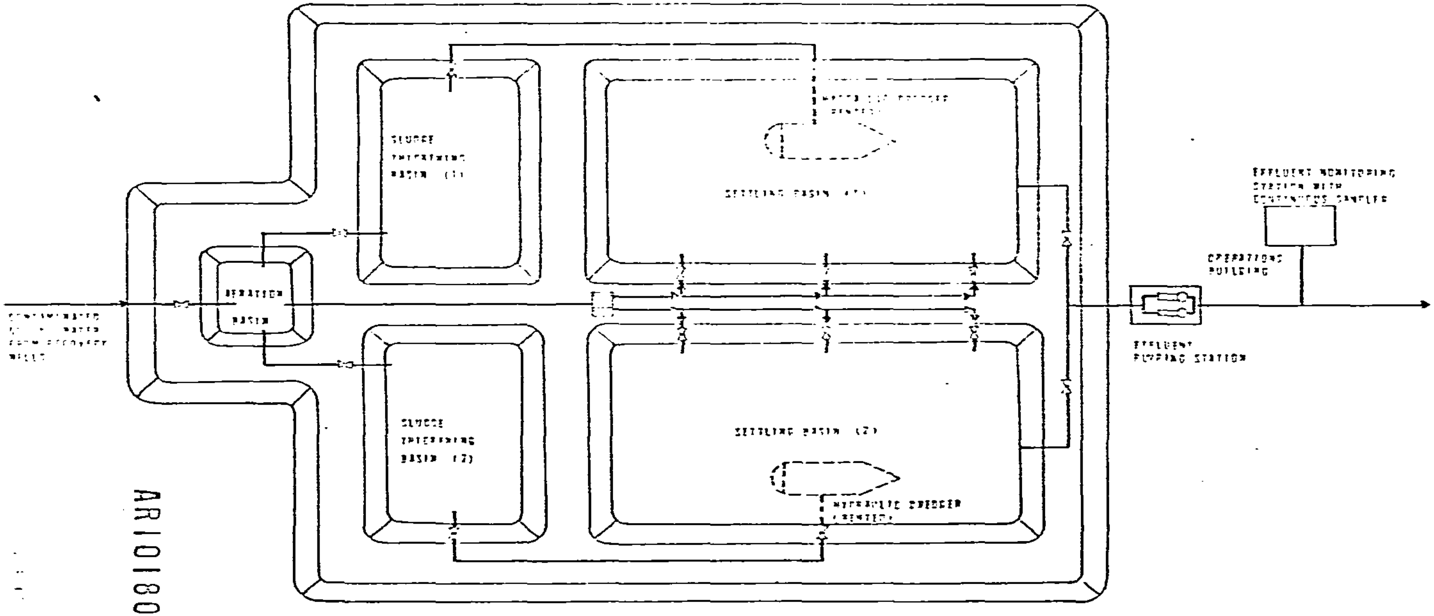
After aeration, the flow will be divided in a splitter box and will flow by gravity to two settling lagoons. The settling lagoons will be sized on the basis of an average flow rate of 3.0 mgd and an overflow rate of 15 gpd/sq ft; therefore, the required overall lagoon area is 4.6 acres. Each of the two lagoons will have a surface area of 2.3 acres and an 6-ft side water depth, with 2 ft of freeboard.

LLANGOLLEN SANITARY LANDFILL

NEW CASTLE COUNTY, DELAWARE

PRELIMINARY FLOW DIAGRAM

LEACHATE-GROUND WATER TREATMENT SYSTEM



AR101806

FIGURE 3

ROY F. WESTON, INC

The proportions of the lagoon are not fixed at this stage of the design, to allow for flexibility in selection of a suitable site. Selection of the site will be based on the overall area requirements and on its location, topography, and hydrogeologic characteristics. The settling lagoons will be earthen basins with clay lining. The lagoons will be constructed by excavation of part of the lagoon depth and by using the excavation materials for building the dikes around the lagoon. Basic physical requirements of the site for the settling lagoons are as follows:

1. Adequate overall area (approximately 10 acres).

2. Approximately level topography.

3. Location on as direct a line as possible between the recovery wells and the point of discharge on the Delaware River (this is to minimize the pipeline and right-of-way costs).

4. Favorable hydrogeologic characteristics, in order to minimize the potential for ground-water contamination resulting from leakage of the settling basins or of the sludge lagoons. The perfect site would be underlain by clay at a few feet below the surface and would not have a high water table. If clay is not present near the surface, the basin would have to be lined with clay, transported from its nearest source, and the maximum high water table should be at least ten feet below surface.

Suspended solids will be allowed to settle in the settling basins, forming sludge on the bottom of these basins. No laboratory data have been obtained for the solids content in the settled sludge. However, based on our previous study on lime treatability, the solids content is expected to be about 3 percent. Furthermore it is expected that sludge will thicken at the bottom of the basins and that its solids content will substantially increase. However, for lack of verification, a conservative solids content of 3 percent is used for estimating the rate of sludge build-up in the basins. Based on this assumption, it is estimated that the lower two feet of the basins would need to be dredged approximately once every 8 months. In actual operation, the dredging of the sludge (2 feet on the bottom of the basins) may be as infrequent as once a year.

Sludge will be dredged, as frequently as needed, via a mobile hydraulic dredger. The hydraulic dredge will float on the water surface and pump out the bottom layer of the basin. This method generally consists of using a rotating cutterhead of the dredge to break-up any compacted sludge, which is then pumped through a floating suction line to the edge of the basin where a stationary pipeline carries it to sludge thickening basins. A mobile dredge would discharge an average of 30 cu yds per hour (thus, approximately 250 hours to dredge one of the two settling basins). Hydraulic dredging would not disrupt operation of the basin. However, if other methods of dredging are utilized, the flow should be diverted to one basin while the second is being dredged.

Sludge will be allowed to thicken in two sludge holding basins, and the supernatant will be returned to the aeration basin and mixed with the incoming recovery water for further treatment in the settling facilities. The sludge holding basins are designed for an estimated life of approximately 10 years. However, if the recovery scheme continues for more than 10 years, additional basins could be constructed, or the thickened sludge could be removed from the basins by means of a clam shell and hauled away by dump trucks for final disposal in an adequate disposal site. The two sludge holding basins will also be earthen basin construction with clay lining. Each basin will have an effective surface area of 0.9 acres and a side water depth of [illegible] feet plus 2 feet of freeboard.

The effluent from the settling basins will be disposed of in the Delaware River just below the Army Creek Tidal Gate. It is not possible at this time to determine the configuration of the effluent line from the settling basins to the final point of disposal, because of the lack of knowledge of the exact location of the treatment facility. However, after selection of a suitable site, it will be possible to design this pipeline and, if needed, a booster pumping station. The need of an effluent pumping station will be dictated by the location of the treatment facility and the general topography of the site relative to the final discharge point. It should be emphasized here that the estimated capital costs and operating costs do not reflect the cost of either the effluent pipeline nor a booster pumping station.

A small building or a trailer will be needed for effluent sampling and water quality monitoring as well as for office space and facilities for the plant operators. The same trailer could be also used for housing the electrical control systems and miscellaneous small equipment.

SUMMARY OF DESIGN BASIS
AND MAJOR UNIT SIZES

Design Basis

A. Recovered Ground-Water Characteristics

1. Total Expected Flow, mgd

Average	3.00
Maximum	4.00

2. Influent Suspended Solids, Average — 60 mg/L

3. Influent Iron, Average — 40 mg/L

4. Influent Copper — <0.05 mg/L

5. Influent Silver — <0.05 mg/L

6. Influent pH, Range — 6.5 - 7.5

B. Effluent Criteria for Iron

Proposed Criteria by Delaware State Department of Natural Resources, Division of Environmental Control — 2.0 mg/L

C. Recommended Treatment

Aerate recovered ground water to convert ferrous iron to ferric iron. Settle aerated influent to precipitate iron. Hydraulically dredge settling basins, and thicken the sludge in a sludge basin.

D. Expected Concentration and Loadings -- Treated Groundwater

	mg/L	lbs/day (Average Flow)
1. Suspended Solids	2.0	500
2. Iron	2.0	50
3. Copper	<0.05	
4. Silver	<0.05	
5. pH	6.0-8.0	

E. Expected Sludge Production

From Settling Basins 3,125 lbs/day dry solids

Major Unit Sizes

A. Aeration Basin

Number	One
Function	To convert ferrous iron to ferric iron
Surface Area (mid depth)	0.13 acres
Depth	8' SWD + 2' Freeboard
Capacity	33,400 gal (4,500 cu ft)
Detention Time	Two hours
Aerators	Two 25-HP Surface Floating Aerators
Construction	Earthen basin with clay lining

B. Settling Basins

Number	Two
Function	Gravity precipitation of ferric iron and suspended solids
Surface Area (mid depth)	2.3 acres, each (4.6 total area)
Depth	8' SWD + 2' FB
Overflow Rate	15 gpd/sq ft
Computed Detention Time based on Average Flow	4 days
Capacity, total	12 million gallons
Construction	Earthen basin with clay lining

C. Sludge Thickening Basins

Number	Two
Function	To thicken and store sludge dredged from settling basins
Surface Area (mid depth)	0.9 acres, each (1.8 acres total area)
Depth	8' SWD + 2' Freeboard
Capacity, total	4.7 million gallons
Approximate Sludge Storage Life	10 years

AR101810

D. Dredging Equipment

Mobile Hydraulic Dredging Equipment	To be rented as needed
Frequency of Dredging of Settling Basins	Every 8-12 months

E. Effluent Pipeline and Booster Pumping Station

Not covered in this report

Llangollen Landfill
New Castle County, Delaware

Iron Removal Facility

SUMMARY OF CAPITAL COSTS

Earth Work (Cut, Fill and Haul Excess)	$325,000
Clay Lining of Basins*	96,000
Mechanical Aerators (Two at 25 HP)	23,000
Access Roads	16,000
Major Systems Sub-Total	$460,000
Yard and Mechanical Piping at 15% of Major System	69,000
Yard Electrical Work	8,000
Electrical Sub-station	10,000
Building (1,000 sq ft) or Trailer	27,000
Total Construction Cost	$574,000
Construction Contingency	86,000
Total Capital Cost	$660,000

*Cost of other Lining Material

Asphalt Lining	$122,000
Rubber Lining	340,000
Plastic Lining	150,000

**Capital cost does not include land purchase, pipeline, booster pumping station, or engineering costs.

Llangollen Landfill
New Castle County, Delaware

Iron Removal Facility
January 1974 Dollars

SUMMARY OF OPERATING COSTS

Labor	
Operating (3 men* at $5.00/hr)	$ 31,200
Supervision at 10%	3,200
Utilities, Average Usage	
Electrical 50 HP at $131/KW/year	4,900
Maintenance	
Hydraulic Dredging	59,000
Piping at 2%	1,400
Electrical at 4%	800
Mechanical Equipment at 6%	1,400
Structures at 1%	3,100
Total Operating Cost	$105,000

*1 man/shift, 2 shifts/day, 7 days/wk
Three operators required.

APPENDIX A

State of Delaware Effluent Limitations

<u>Effluent Limitations Based on a Practicable Level of Pollutant Removal Technology.</u> Effluent limitations imposed under this section shall be expressed in terms of average daily loadings, and maximum daily loadings or instantaneous maximum concentrations.

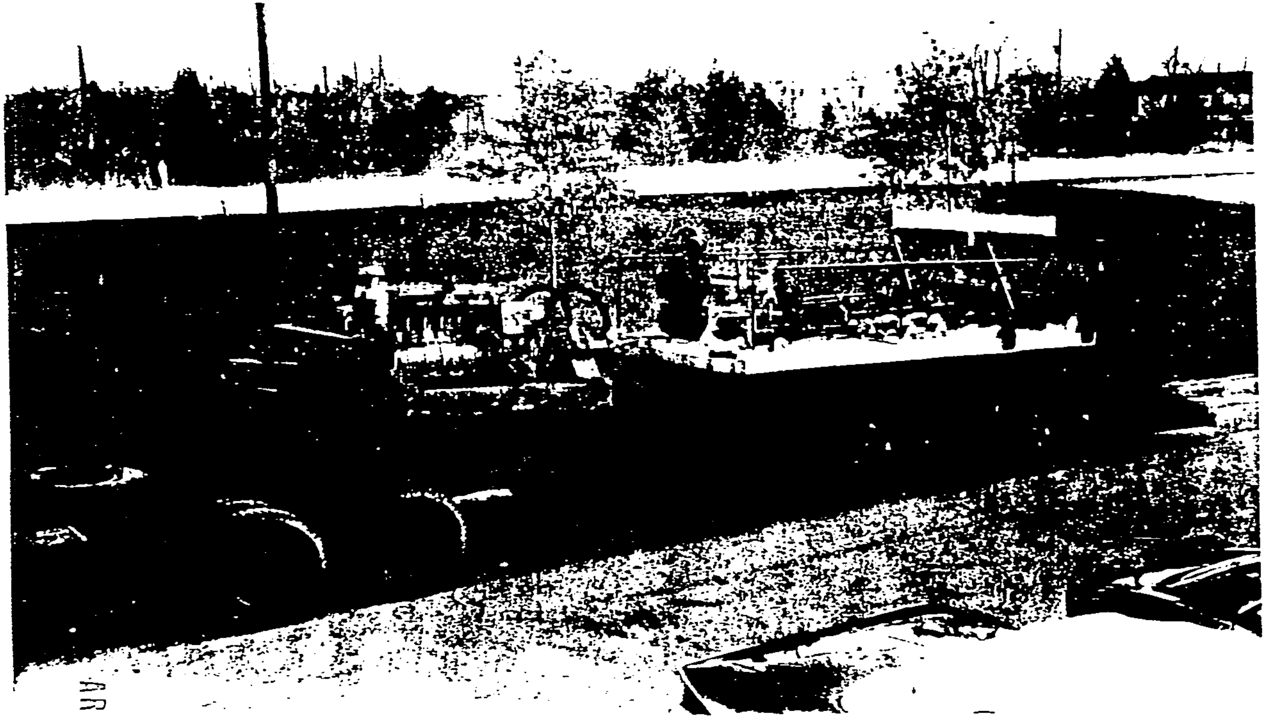
a. Waste water flows containing <u>added</u> pollutants which are subject to limitation shall be segregated from flows not subject to limitation to the maximum practicable extent.

b. Wastewater flows containing <u>added</u> pollutants shall be at least treated so as not to exceed the following limitations for the listed parameters:

(1)	BOD_5	30 mg/L
(2)	Suspended Solids	30 mg/L
(3)	Cadmium	0.150 mg/L
(4)	Chromium (total)	0.150 mg/L
(5)	Lead	0.150 mg/L
(6)	Mercury	0.005 mg/L
(7)	Copper	1.0 mg/L
(8)	Iron (total)	2.0 mg/L
(9)	Nickel	1.0 mg/L
(10)	Selenium	0.020 mg/L
(11)	Silver	0.10 mg/L
(12)	Zinc	1.0 mg/L
(13)	Cyanide	0.050 mg/L
(14)	Fluoride	1.5 mg/L
(15)	Oil & Grease	10.0 mg/L
(16)	Phenolics	1.0 mg/L

The concentration levels imposed herein shall be utilized to establish average daily loading limitations. Measurements to determine compliance with the above requirements shall be taken at a point after treatment as designated by the Department.

cus des d d a s all in fe mall met ro act and highly manuverable, it can be easily t orted by tractor-trailer to any point. Draft of only 8½" allows 5' overhead clearance. Controls and cutter are fully hydraulic.



M O B I L E   D R E D G E   # 1 5

Size: 8' x 12½' x 6' **Pump Size:** 6" x 6" **Engines:** Diesel
Draft: 8½" **Max. Dredging Depth:** 21' **Cutter Head:** Heavy-duty cast steel
Manuverability: Performs 360 degree turn in 18' channel

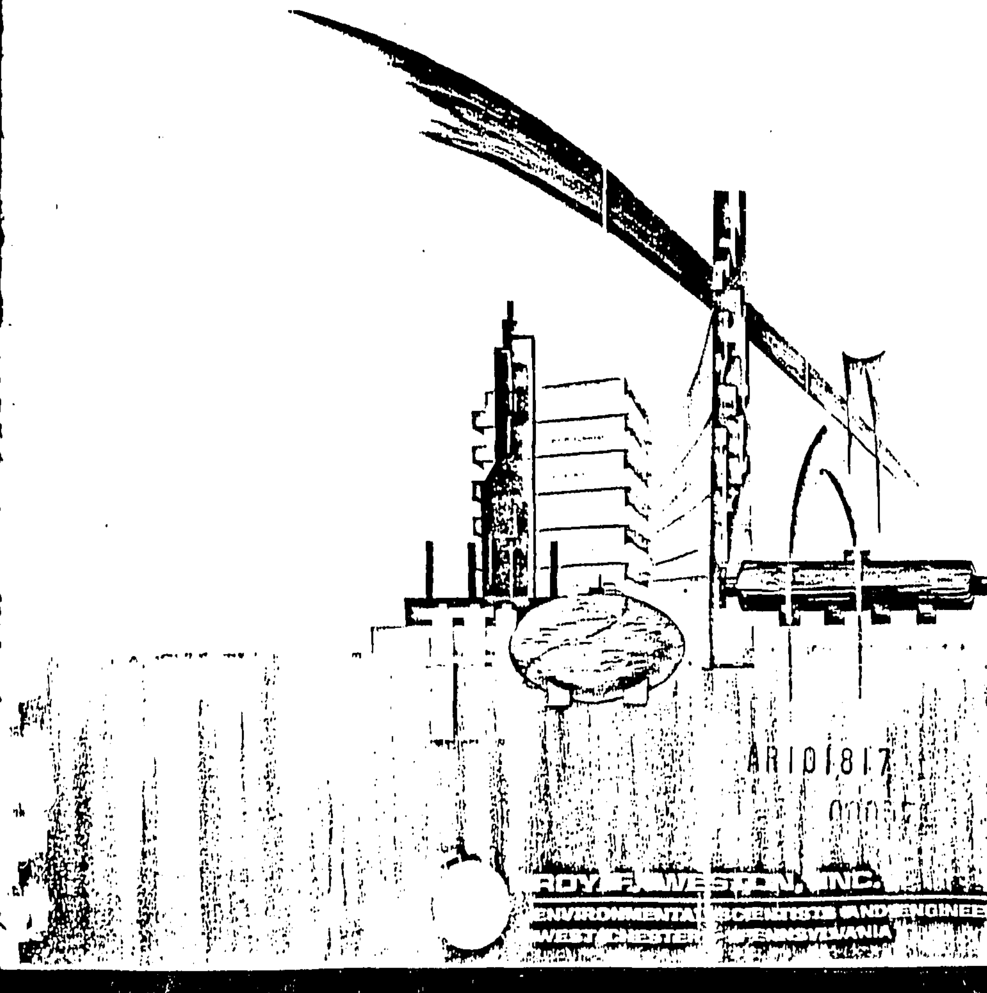
MOBILE DREDGING & PUMPING COMPANY - 344 POTTSTOWN RD. - EXTON, PA 19341 - (215) 363-6677

APPENDIX G

PRELIMINARY FEASIBILITY STUDY

LEACHATE CONTROL STRATEGIES FOR LLANGOLLEN LANDFILL

NEW CASTLE COUNTY, DELAWARE



Preliminary Feasibility Study

Leachate Control Strategies for
Llangollen Landfill

New Castle County, Delaware

Walter R. Niessen

Walter R. Niessen, P.E.
Project Manager

9 May 1974

Prepared by
Roy F. Weston, Inc.
Environmental
Scientists and Engineers
West Chester, Pennsylvania

W.O. 463-15

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(continued)

PROJECT PARTICIPANTS

The following members of the staff of Roy F. Weston, Inc. have participated in the planning and execution of this project and the preparation of this report.

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P. J. Marks Manager, Laboratory Services	Pollution Control Concept Department
E. M. Smith, P.E. Senior Project Engineer	Pollution Control Concept Department
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M. A. Apgar Environmental Geologist	econENVIRONomics Department
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J. R. Adams Technical Editor	Pollution Control Concept Department

LIST OF TABLES

LIST OF FIGURES AND PLATES

SUMMARY

Leachate from the Llangollen Landfill, New Castle County, Delaware, is causing contamination of an important source of potable groundwater. Roy F. Weston, Inc. was retained to evaluate the following promising control alternatives:

- Hydrogeologic isolation of the landfill.
- Removal of the Llangollen refuse material, with final disposal to a new incinerator, another landfill, or to the ocean.

This investigation concluded that it is uncertain whether the hydrogeologic isolation of the leachate would be effective enough to restore the aquifer to its previous purity. Hydrogeologic isolation would also require the operation of pumping and treatment facilities for indefinite but prolonged periods.

Removal of the Llangollen refuse and its final disposal would provide an absolute solution in a relatively short period. Locating a new incinerator at Llangollen for disposal of the old refuse as well as new refuse is compatible with the County's Master Plan and offers cost benefits with respect to transportation. However, uncertainty remains as to the technical feasibility of certain types of incinerators.

Removal of the Llangollen refuse and its disposal to another landfill or to the ocean would provide an absolute solution in a relatively short time; however, the uncertainty of political and environmental acceptability remains.

The cost of hydrogeologic control is in the same range as incineration; costs for hauling and landfill or ocean disposal are slightly less than incineration.

This report makes the following recommendations:

1. Implement a limited program of hydrogeologic controls to minimize the present leachate migration.

2. Investigate the feasibility of "haul and dump" alternatives.

3. Initiate a detailed concept evaluation of alternative methods of incineration.

General

The Llangollen Landfill is situated approximately two miles southwest of the City of New Castle in New Castle County, Delaware. (See Figure 1.)

Previous studies conducted by Roy F. Weston, Inc. (under contract to New Castle County) have shown that the leachate from the Llangollen Landfill has caused major contamination of an important source of potable groundwater. Efforts to recover leachate contamination already in the aquifer are currently underway; however, elimination of future contamination will require measures directed at controlling the generation of leachate at the landfill itself.

In November 1973, New Castle County authorized Weston to investigate the feasibility of different alternatives for eliminating leachate from the Llangollen Landfill. The major objective of this study was to recommend which route should be followed to assure minimum adverse effects to the groundwater supplies.

From a number of alternatives, Weston identified two routes which offered promise: isolation and removal. Isolation of the landfill by hydrogeologic means would leave the Llangollen Landfill intact, but would reduce the migration of leachate to the aquifer. Removal of the refuse presently within the landfill would curtail leachate at its source, but would require ultimate disposal via incineration, landfilling in a more suitable site, or ocean dumping.

Scope and Objectives

This report is intended to discuss in detail the landfill characteristics and physical setting and to evaluate the alternatives by which leachate generation from the landfill can be minimized and controlled so that use of the presently-impaired aquifer can be restored to fuller use in the future.

The alternatives considered for eliminating the leachate potential from the Llangollen Landfill are the following:

- Hydrogeologic isolation of the landfill by reducing infiltrating waters both from precipitation and from the Pleistocene Aquifer.

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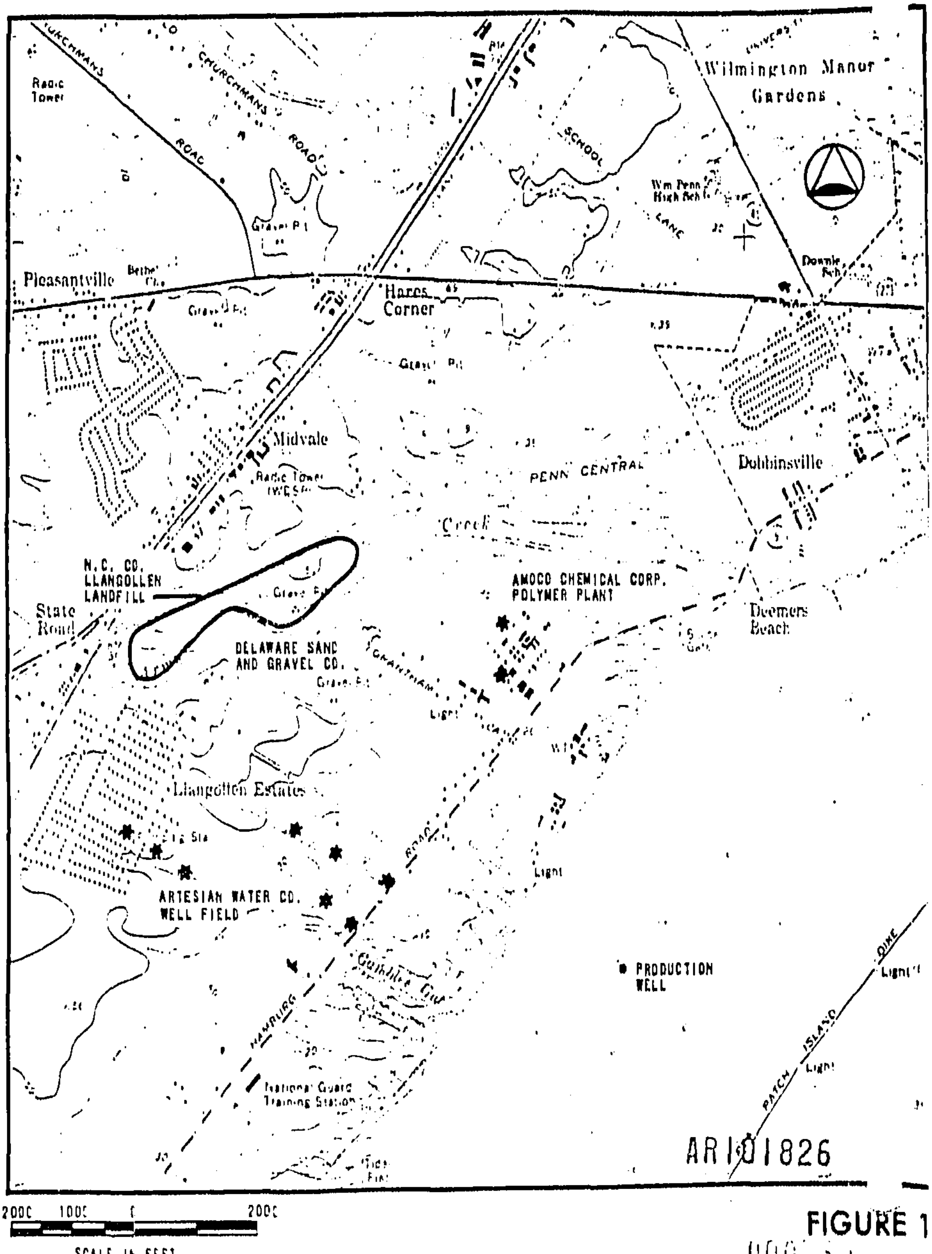
NEW CASTLE COUNTY, DELAWARE
LLANGOLLEN LANDFILL
LOCATION MAP



AR101826

FIGURE 1

ROY F. WESTON, INC.

- Removal of the Llangollen refuse and final disposal via a conventional or advanced incinerator.

- Removal of the Llangollen refuse and final disposal in another sanitary landfill or in the ocean.

Investigative Approach

Weston's approach to the systematic evaluation was based on the following steps:

- Problem identification.

  - History of the Llangollen Landfill.
  - Physical setting of the landfill.
  - Landfill construction.
  - Groundwater infiltration.
  - Water entry to the landfill.

- Investigation of Hydrogeologic Control for Leachate Control.

  - Reduction of precipitation infiltration.
  - Interception of groundwater.
  - Collection of leachate inside the landfill.
  - Recirculation of leachate.

- Investigation of Incineration Processes for Ultimate Disposal of Llangollen Refuse.

  - Compatibility with New Castle County's solid waste management plans.
  - Technical evaluation of the incineration of Llangollen refuse.

- Economic Evaluation of Alternatives.

AR101827

History of Llangollen Landfill

The Llangollen Landfill was constructed in a worked-out sand and gravel pit between 1960 and 1968. It is approximately 4,400 feet long and 200 to 900 feet wide, and covers approximately 56 acres. The average refuse-thickness is about 25 feet. It is estimated that Llangollen Landfill contains more than 2,000,000 cubic yards of municipal and industrial refuse material. Figure 2 shows the elevation of the floor and the landfill, and Figure 3 shows the refuse thickness.

Physical Setting of the Landfill

The sand excavated from the present landfill site was part of the Columbia Formation, a Pleistocene stream deposit which consists predominantly of medium to coarse sand with gravel beds. In the Llangollen area, this sand forms a nearly continuous surficial cover, ranging from 10 to 60 feet in thickness. The base of the formation ranges from about 10 feet above to 20 feet below the mean sea level in the vicinity of the landfill.

The underlying Potomac Formation consists of stream-deposited unconsolidated sands, silts, and clays of Lower Cretaceous Age. The formation is approximately 600 feet thick in the vicinity of the landfill and rests on a seaward-dipping bedrock surface. Potomac sand units are generally channel shaped, though often laterally-extensive lenticular clay and silt deposits are interbedded with thin lenses and thick blankets of clay and silt which accumulated on ancient floodplains and estuaries. The Potomac Formation thickens and dips towards the southeast at approximately 40 to 140 feet per mile (uppermost and lowermost beds, respectively) in the study area.

Hydrologically, the generally coarse Columbia deposits serve as an infiltration and recharge gallery for the Potomac sands. Groundwater in the Potomac sand becomes confined (artesian) beneath the relatively impermeable beds of clay and silt as it travels seaward, down dip in the formation. Figure 4 shows the elevation of the top of the Potomac clay in the vicinity of the landfill. Immediately beneath the landfill these clay and silt deposits are thin and locally sandy or absent, especially on the eastern half.

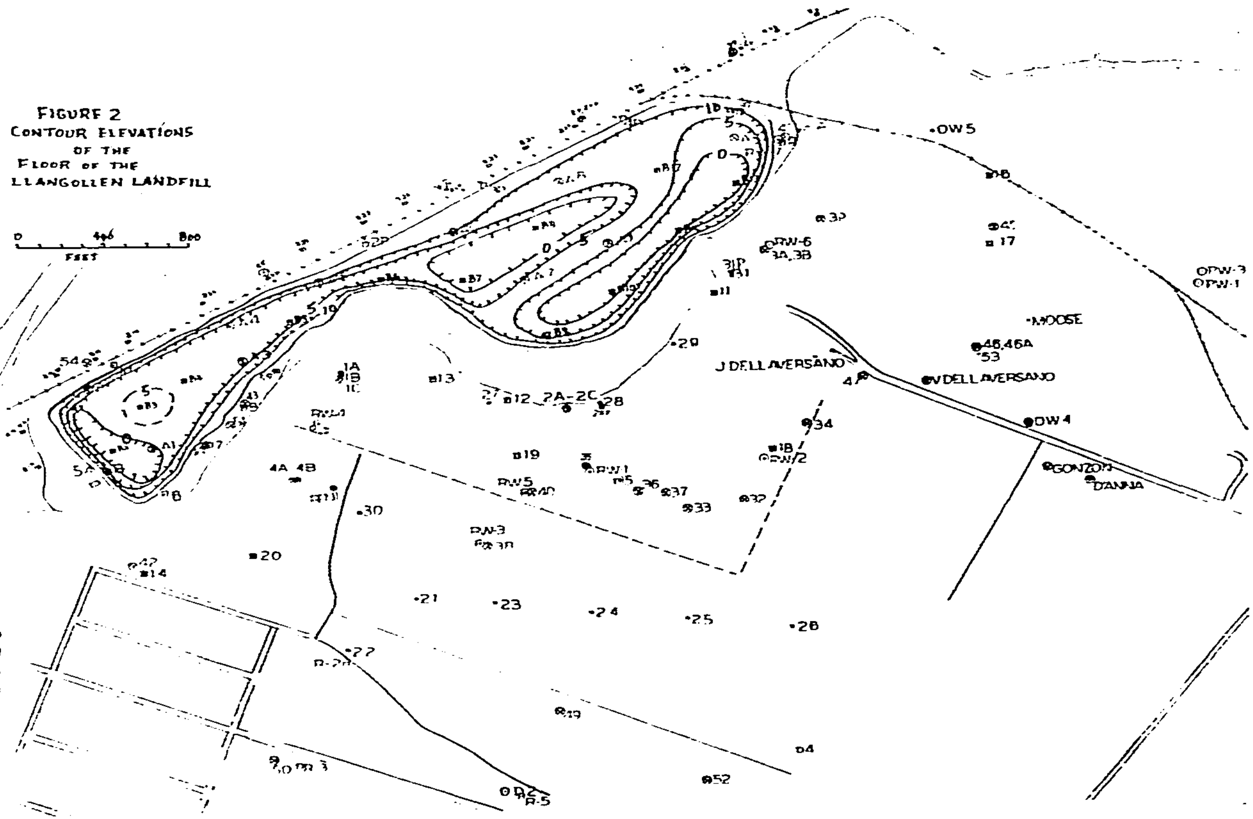


FIGURE 2
CONTOUR ELEVATIONS
OF THE
FLOOR OF THE
LLANGOLLEN LANDFILL

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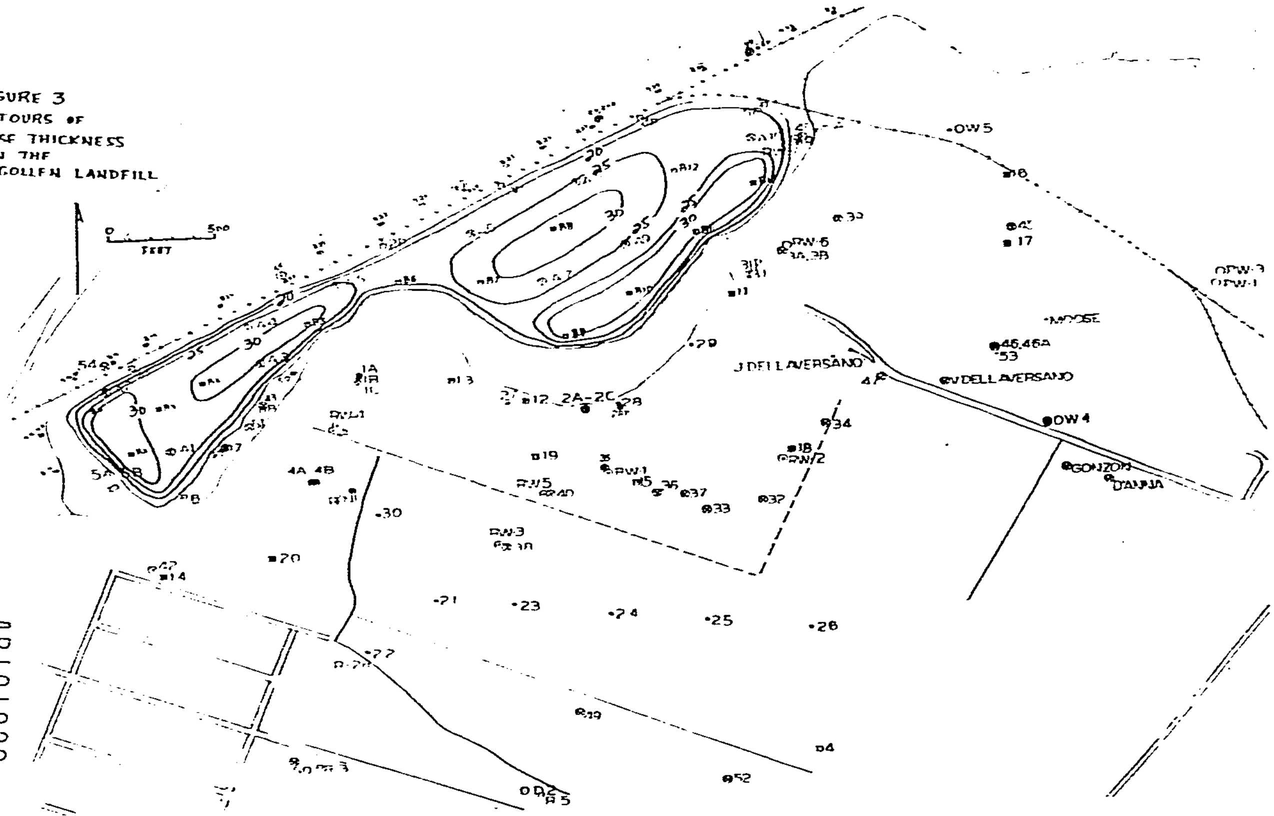

FIGURE 3
CONTOURS OF
REFUSE THICKNESS
IN THE
LLANGOLLEN LANDFILL

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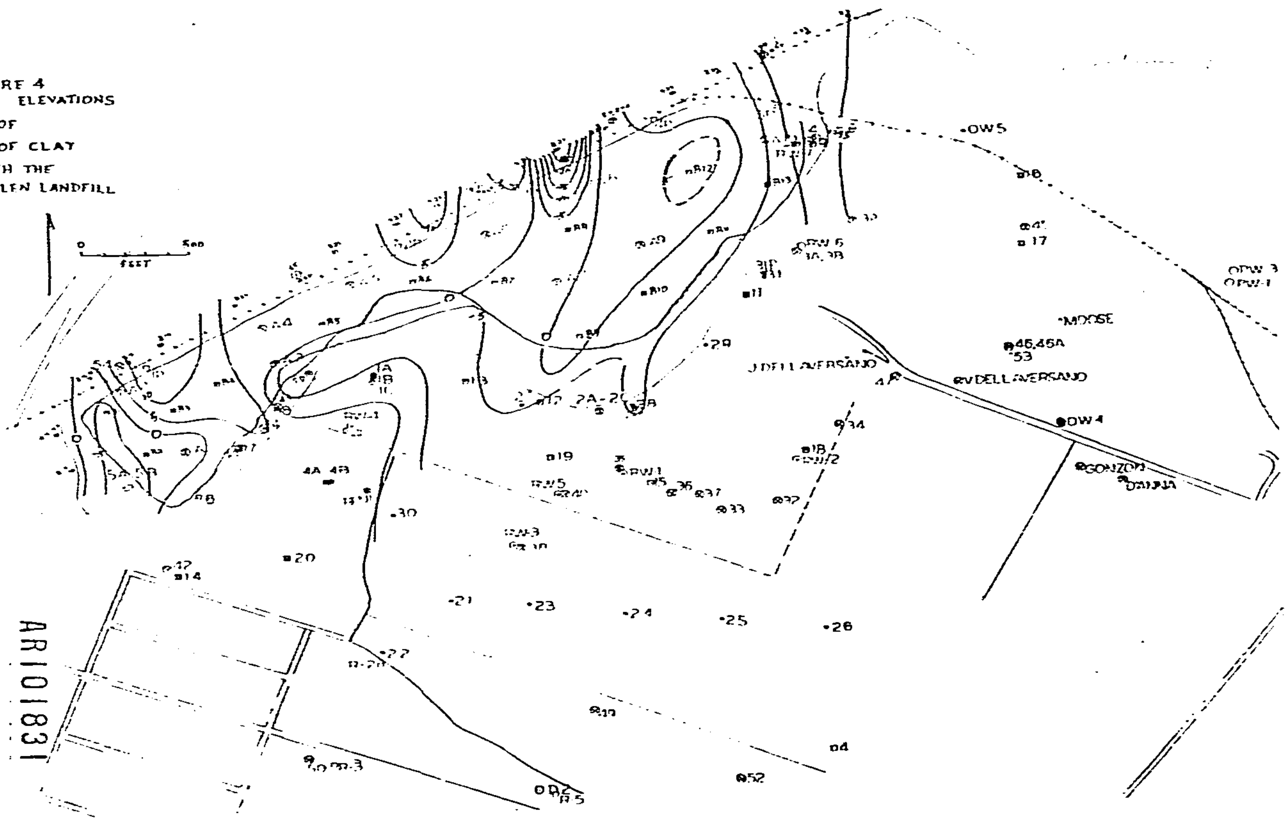
FIGURE 4
CONTOUR ELEVATIONS
OF
TOP OF CLAY
BENEATH THE
LLANGOLLEN LANDFILL



Landfill Construction

The gravel pit in which the Llangollen Landfill is constructed was excavated with a dragline down to a "hard zone", generally an iron-cemented conglomerate, which marked the base of the Columbia or red Potomac clay. Massive clay deposits were probably not removed during the sand and gravel operation, because clay would have had a deleterious effect on the aggregate quality of the sand and would have interfered with the sand washing plant process.

The gravel pit, however, was excavated well below the water table. Aerial photographs taken in the late 1950's and early 1960's show large pools of standing water on the floor of the sand pit. In places where the Potomac clay was thin or absent, the excavation may have been continued into Potomac sand. Excavation into Potomac sand has been observed locally in the Wilson Contracting Company's gravel pit northeast of the landfill.

Refuse placement, compaction, and covering operations at the Llangollen Landfill were carried out by the gravel pit operators, Saienni Brothers, using some of the quarry equipment already on the site. Refuse burial was started at the eastern end and generally proceeded back toward the pit entrance on the west, as shown in Figure 5. All types of wastes, including liquid waste chemicals and oils, were dumped at the site. The existing ponds were filled with refuse, and compaction of the refuse was generally poor. When the water table dropped in the early 1960's, the refuse already in place or in process of being buried in the eastern end of the landfill became unsaturated.

All intermittent cover material was obtained within the pit from residual sand, tailing piles, and siltation basin deposits. As time progressed, cover material and landfill space became critically depleted; this situation encouraged deeper excavation, especially on the western end of the pit. This excavation removed some, and in a few places maybe all, of the confining clay on top of the Potomac sands. This practice probably created direct access routes for the leachate from the landfill to enter the Potomac sands in places where routes may not otherwise have existed. However, the lithology of the upper part of the Potomac Formation near the landfill (as illustrated in Plate 1) is so variable that it is probable that at least some natural sand channels in the Potomac were in direct contact with the overlying Columbia sands.

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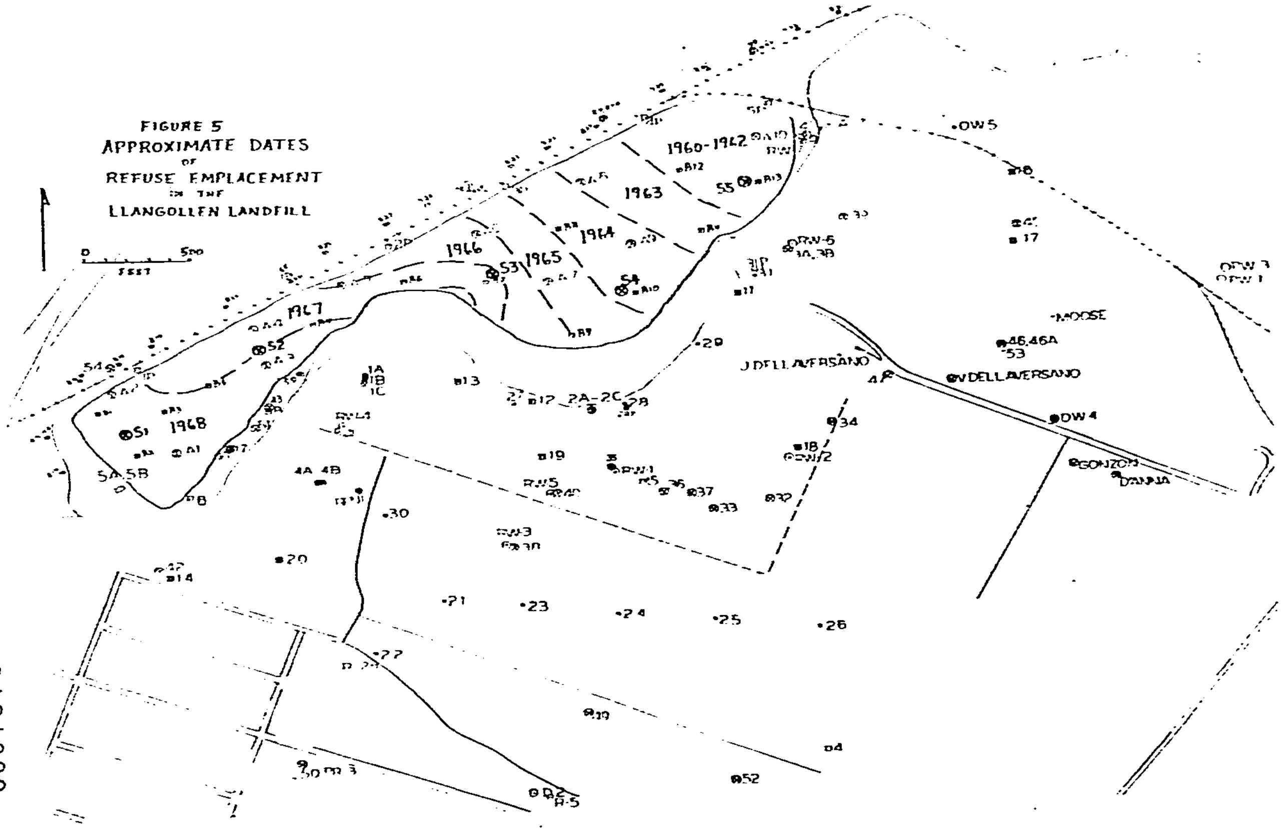
FIGURE 5
APPROXIMATE DATES
OF
REFUSE EMPLACEMENT
IN THE
LLANGOLLEN LANDFILL



The initiation of heavier pumping from the Potomac Aquifer by the Amoco Chemical Corporation (to the east) and the Artesian Water Company (south of the landfill) in the early 1960's lowered the local water table especially south and west of the landfill where Potomac clay is generally thin or absent, thus demonstrating the direct connection between the Columbia and Potomac sands. A water table elevation approximately ten feet higher than the present one is evidenced by water strand lines on some of the older walls of the Delaware Sand and Gravel Pit just south of the Llangollen Landfill.

Water Entry to the Landfill

Water which now enters the landfill originates in two ways:

1. Direct precipitation on and infiltration through the landfill surface.

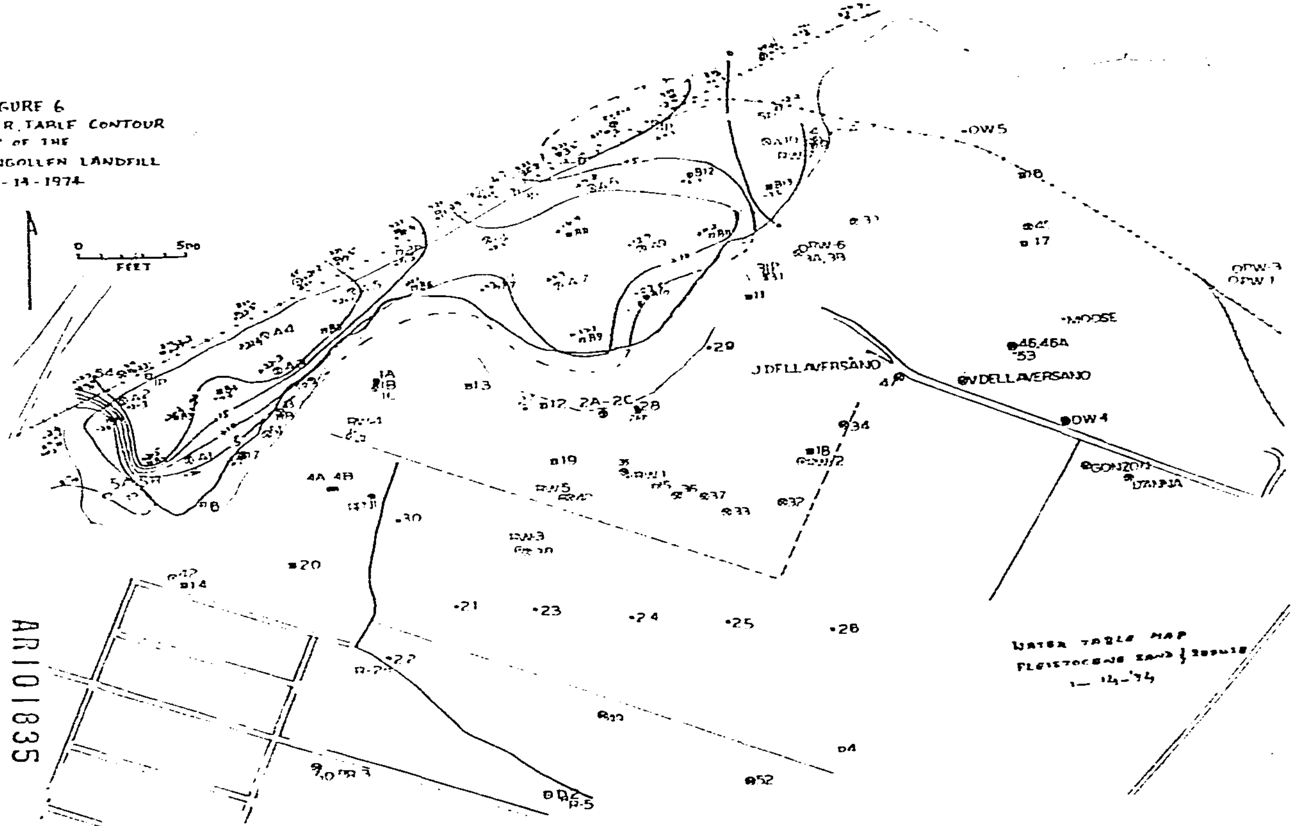
2. As lateral groundwater movement into the saturated lower portion of the landfill.

The water leaches dissolved organic and inorganic chemicals as it percolates through the refuse. The resulting highly-polluted solution is called "leachate". Although any landfill located in the humid temperate climate, as prevailing in northern Delaware, will produce leachate, the high rates of both surface and groundwater infiltration to the Llangollen Landfill have greatly magnified the rate of leachate production there.

Elimination of the Llangollen Landfill as a pollutant source will require stopping all water addition to the landfill, or -- if this is not possible -- minimizing the inflow and collecting leachate either in or beneath the landfill. To this end, a more detailed description of the magnitude and location of water infiltration sources follows.

Analysis of water inflow to the landfill is best done by dividing the landfill into two sections, as shown in the water table map (Figure 6). Section 1, the western section (760,000 square feet), receives both surface water and ground water inflow, and has a generally continuous clay floor of relatively low permeability. As a result, the zone of

FIGURE 6
WATER TABLE CONTOUR
MAP OF THE
LLANGOLLEN LANDFILL
1-14-1974



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saturation in this section of the landfill is thick (Figure 7), and some of the leachate seeps out on the surface along the western and southern margins of the landfill.

Section 2, the eastern and older portion of the landfill (1,350,000 square feet), now receives water only via infiltration of direct precipitation. The contact between the Columbia and Potomac Formations is often quite permeable in the vicinity of the eastern part of the landfill. Here the Potomac clay deposits are relatively thin, sandy, or absent. Water in the Columbia sands moves downward to the Potomac Aquifer rather than laterally to the landfill. In addition, the Columbia sands have been excavated northeast and south of the landfill, and the elevations there and in the marsh to the east is lower than that of the landfill surface and, in places, lower than much of the Llangollen Landfill floor. The result is that the refuse is less saturated, and major leachate seeps are not visible at the surface.

Precipitation Infiltration

The surface of the landfill is pocketed with depressions resulting from the differential subsidence of the refuse. These depressions prevent stormwater runoff from the landfill. The landfill cover is generally sandy and quite permeable. However, deposits of clay have accreted in the topographic depressions so that stormwater which runs off the inter-depression areas ponds in the depressions rather than running off the landfill. These ponds slowly infiltrate to the landfill or evaporate. Because of these conditions, at least 50 percent of the precipitation which falls directly onto the landfill surface infiltrates through the landfill cover and percolates through the refuse.

The annual precipitation in the Llangollen vicinity averages 44 inches per year. Assuming 50 percent of this precipitation infiltrates to the landfill, the average input is 10.6 million gallons per year (29,000 gallons per day) to Section 1, and 18.6 million gallons per year (51,000 gallons per day) to Section 2.

This input is very sporadic; sometimes there is none for months, especially during the warmer summer months. But 50-percent infiltration from a single one-inch rain storm can add more than 660,000 gallons of water to the refuse in less than a day! When precipitation does occur, the infiltration amount from any given storm is highly variable and depends

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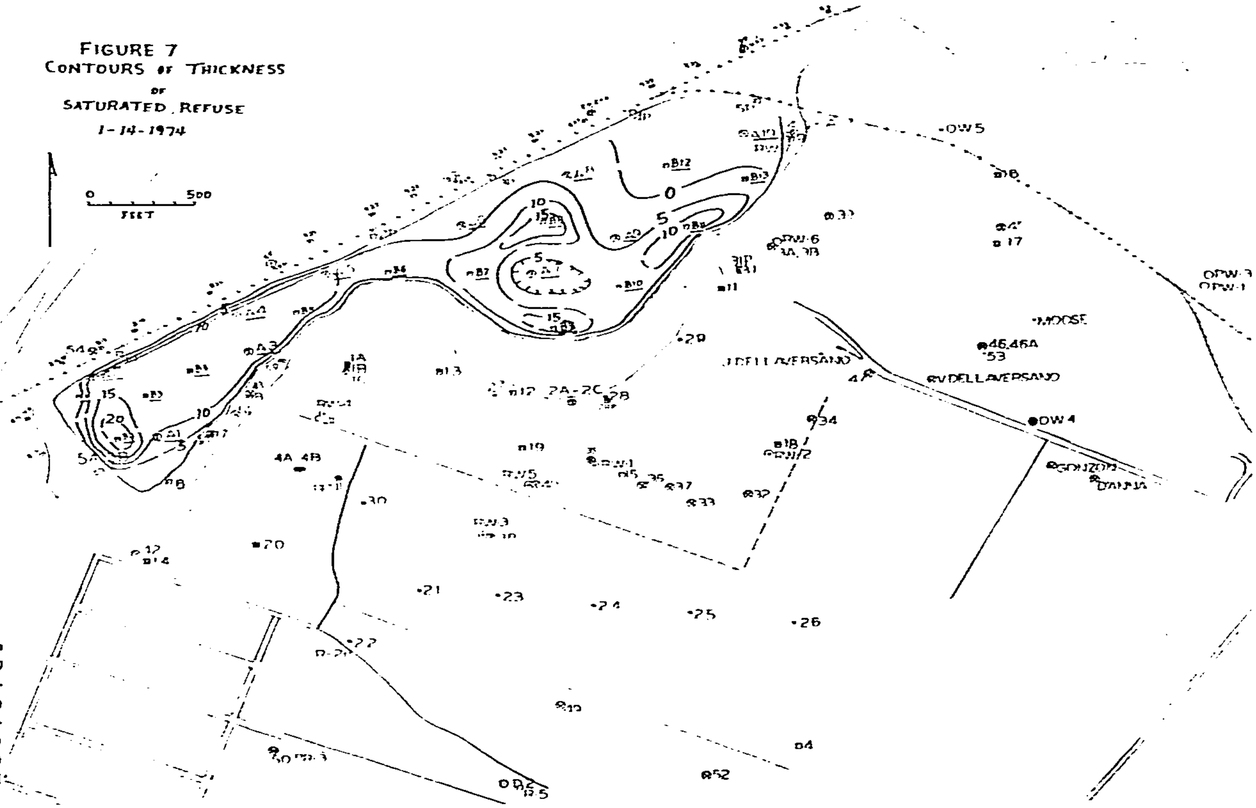
FIGURE 7
CONTOURS OF THICKNESS
OF
SATURATED REFUSE
1-14-1974



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upon the storm intensity and duration, form of precipitation, temperature, plant cover characteristics, season, and original soil moisture conditions.

Groundwater Infiltration

Figure 6 shows a water table map for the landfill and the immediate surrounding area made from data collected on 7 December 1973. The contours on the map are drawn through points of equal groundwater elevations. Groundwater flow occurs perpendicular to the contours from higher to lower elevations.

The figure shows that lateral groundwater infiltration to the landfill is occurring on the northwestern margin of the landfill, i.e., in Section I. Here the water-table configuration is similar to the topographic surface contours. The rate of groundwater flow is a function of the cross-sectional saturated area perpendicular to the direction of groundwater movement, the permeability of the materials through which the groundwater is moving, and the hydrologic gradient along the direction of groundwater flow. Using approximate measurements of the cross-sectional area and hydrologic gradient and making an estimate of the permeability of the materials, total groundwater inflow to the refuse is estimated at between 100,000 and 200,000 gallons per day. A reasonable estimate of the average groundwater inflow rate is 120,000 gallons per day. The groundwater inflow rate, although dependent upon precipitation as it affects the hydrologic gradient and saturated thickness of the earth materials, is relatively steady and continuous, especially when compared to the precipitation inflow.

Precipitation Infiltration Reduction

If the landfill surface is re-graded and covered with material suitable to retard infiltration yet support a plant cover, up to 80 percent and possibly more of the direct precipitation on the landfill surface can be prevented from infiltrating to the refuse. Such a result can be obtained by one of several methods. These are:

1. Re-grading the landfill and covering it with a heavy loam soil material. The final grade plan would be designed to conduct precipitation from the landfill as surface runoff. This would be done either by means of smooth even slopes or by crenulating the landfill surface and constructing lined runoff channels. The flat surface would probably be most advantageous for future land use while the crenulated surface would probably be more efficient in conducting water off the landfill.

2. Re-grading and covering the landfill surface as above and injecting an asphalt membrane beneath the soil cover to retard vertical percolation of moisture which has infiltrated the soil cover. This holds moisture within the root zone of the plant cover and permits the plants to transpire away more of the water. This procedure has been tested on the 4-to 6-acre landfill of the University of Delaware in Newark with reportedly favorable results.

3. Synthetic covers could be utilized but would be costly, would require more maintenance, and would prevent vegetation growth and limit reuse of the property.

Reduction of the amount of direct precipitation which infiltrates the landfill to 20 percent would mean that an average of 32,000 gpd of water (22 gpm) would enter the refuse. As explained previously, input would not be uniformly distributed through time, because precipitation events are sporadic. When plant cover is active (late spring to early fall), the evaporation rate is higher and the soils are generally drier. More infiltration would occur during the cooler months.

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Interception of Groundwater Inflow

Groundwater inflow to the landfill through the Pleistocene sand can be reduced by one or a combination of the following methods:

1. A well-point system.
2. A series of larger diameter wells, each equipped with submersible pumps.
3. A perforated drain pipe.
4. A gravity-run recharge well system screened in both the Columbia and Pleistocene sands.
5. Excavation of the Pleistocene sand, resulting in groundwater interception and drainage through a surface conduit around the landfill.

Well Points

A well-point system would consist of a series of small-diameter (1-1½") galvanized pipes with short (3') screens and drive points attached to their bottoms. These points could be jetted to the top of the Potomac clay along a 2,000-foot line from boring B14 eastward to B24. The individual well points would be connected to a suction header. Water would be pumped from the well points by suction lift through a pump located at the eastern end of the header. The top of each well point (at the header) would have to be no less than 27 feet above the top of the pumping level or water would not be raised. In the situation where maximum dewatering is desired -- not only to prevent groundwater inflow, but to reduce the water table in the landfill -- the distance from the suction header connection to the top of the well-point screen would have to be less than 27 feet.

If the well points were placed in the same line as completed soil borings north of the landfill, excavation of a trench approximately 1,000 feet long, averaging about 10 feet deep, but up to 20 feet in the middle section, would be required. The trench would have to be a minimum of 5 feet wide at the bottom and would require shoring to prevent sidewall collapse. However, if the well points could be located along the PRR railroad cut (where the elevation is less), little or no shoring would be required.

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Each well point would create its own cone of depression in the water table. These pumping cones would have to interfere mutually, to the extent that the water table between the well points would be lowered sufficiently so that no water moved between them towards the landfill. To do this, a maximum spacing of 50 feet (i.e., a minimum of 40 well points) would be required. Lowering of the water table would increase the rate of groundwater movement towards the well points, but this flow should not exceed 250,000 gallons per day, and will probably be only half of that amount.

Water table lowering at the well-point network would also reverse the direction of the water table gradient between the landfill and the well-point systems. As a result, highly contaminated water in the landfill would be induced to move to the well points. Perhaps after the volume of leachate stored in the landfill is reduced by outflow to the well points and by vertical seepage through the landfill floor, the well-point system would no longer be contaminated. If the well-point discharge became contaminated by drainage from the landfill, the quality of the recovered water should improve by dilution as the reservoir of leachate in the landfill is depleted. At worst, the quality of the water pumped from the well points after maximum lowering of water levels in the landfill should be better than that pumped from the contaminant recovery wells operating in the Potomac Formation. Thus, the well-point discharge could be piped, if necessary, to the treatment facility being designed for water from the Potomac contaminant recovery wells. The volume of water from the well-point intercept system should not exceed 5 percent of the 4 mgd total design flow rate of the wastewater treatment facility; thus, this volume could be easily handled.

If the water quality from the well-point network were acceptable for direct surface discharge without treatment, it could be pumped to the Army Creek marsh past the eastern end of the landfill. This will prevent any return seepage to the landfill from the creek.

The well-point system alone will not dewater the entire landfill, because the Potomac clay surface atop which the well points will be completed is everywhere above sea level, while parts of the landfill floor -- especially on the far western end -- are below sea level. However, the well-point system should be capable of stopping virtually all of the groundwater inflow to the refuse.

Drilled Interceptor Wells

A line of 4- to 6-inch wells drilled to the base of the Columbia Formation north of the landfill could be used to intercept part of the groundwater moving into the refuse. The wells would each be equipped with a submersible pump. Again, drawdown interference between wells would have to be sufficient to prevent water from passing through the line of wells to the landfill. Higher pumping rates from the wells than possible from the well points might reduce the number required to intercept refuse-bound groundwater. However, the limited available drawdown (less than 20 feet) in the area to be dewatered would preclude pumping large quantities of water from a single well. Also, nearly complete dewatering of the Columbia sand would require well spacings almost as close as those of the well-point system.

The individual wells would cost 3 to 5 times that of a single well point. However, the submersible pumps would not be as restricted in their depth of operation as the suction lift (maximum 27 feet) system utilized with the well-point installation. Thus, if expensive excavation were required for part of the well-point system, or if interception of part of the water in the Columbia sand prior to its reaching the well-point system were desired, several drilled wells could be economically employed in the project.

Perforated Drain

A perforated drain pipe could be constructed to intercept all water flowing through the Columbia sand into the northern part of the landfill and to desaturate the sand north of the landfill. This pipe would be installed in an excavation conducted to an elevation corresponding to the lowest Columbia sand channel. Where the Potomac clay surface topography fluctuates, the pipe would actually be situated in the top of the clay surface.

The collector pipe (8-inch diameter) would be underlined and surrounded by clean gravel designed to act as a water-transmitting filter media to keep the slots in the pipe from becoming clogged with fine soil particles. The remainder of the trench would be back filled with the material removed during the excavation.

The pipe would be slightly sloped (1 percent) to collector sumps equipped with submersible pumps to remove the water

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(estimated at 230,000 gpd maximum). The discharged water would be conducted by a surface pipeline to the Army Creek marsh east of the landfill. This collector system would permit uniform and slightly greater lowering of the water table adjacent to the refuse as compared to that accomplished by a series of wells which must everywhere be screened in the sand above the Potomac clay.

The perforated drain would be approximately 2,500 feet long and would extend from the vicinity of Well 56 westward to the edge of the landfill. The excavation depth would range from 20 to 40 feet and would average about 30 feet. Well points would be required to dewater the proposed drain section so that the excavation would stand open with a minimum of shoring.

Unfortunately, the excavation operation (involving dewatering and/or shoring) would be quite expensive. Another major disadvantage is that, if the pipeline became clogged or broken, it would be inaccessible for repair and would have to be entirely reconstructed.

Collection of Water Inside the Landfill

Some water will enter the refuse and stand in it regardless of attempts to intercept inflow and to drain the landfill by external controls. The water on the refuse floor will slowly seep into the Potomac Aquifer unless it is collected. However, in those places where much water is standing, it does so because the relatively low permeability of the landfill floor acts as a barrier to vertical movement. This low permeability is usually due to the presence of clay beneath the landfill. However, a bacterial slime formed during refuse decomposition further reduces the vertical permeability.

Much of the standing leachate could be collected by drains constructed inside the landfill. These drains would consist of perforated plastic pipe surrounded with clean gravel. The collector pipes would be slightly inclined (minimum 0.5 percent slope) toward a central sump consisting of a standpipe. Each standpipe would be equipped with a small (1/4 or 1/3 hp) submersible pump.

If the present groundwater inflow rate to the refuse could be cut 90 percent and the surface water inflow reduced to 20 percent of the direct precipitation, then total water inflow would average 44,000 gpd (30 gpm). Several small pumps could easily handle this volume of leachate.

The drain lines could be laid in a grid over the entire landfill floor or in a concentric fashion from sumps located in positions where the landfill floor is suspected to be a collecting spot for leachate. This latter approach to the problem would undoubtedly be less costly, because it would require much less excavation and material. Sumps with radiating arms should be located in areas of suspected leachate leakage. These areas generally conform with places where the depth of the base of the refuse due to deeper excavation is below sea level.

Water pumped from the leachate sumps in the landfill will be highly contaminated, although relatively small in volume. This water could be fed directly into the discharge pipe to the wastewater treatment facility constructed to handle contaminants recovered from the Potomac Formation. Alternatively, the recovered leachate could be recirculated into the landfill, but, as will be explained in the next section, this is unwise. Once the contaminants have been intercepted prior to entering the Potomac Aquifer, they should be treated and disposed of.

Although the internal collector system appears necessary to minimize leakage of contaminants to the Potomac Aquifer, its construction should be sequenced to follow that of the wellpoint system. This will allow the impact of the external dewatering system to be assessed separately and will permit design of the internal collectors based on the resultant lowered water levels on the landfill.

Recirculation of Water to Speed Chemical Stability

Attempts to isolate the landfill from all water inputs have several shortcomings:

1. Some water will enter the landfill regardless of the external controls.

2. The system requires continual maintenance and operating costs.

3. The operation has no apparent time limit after which the landfill will be chemically stable.

The last point is the most bothersome and has led to investigation of alternative schemes which would stabilize the refuse in some definite time frame. Additives which would

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fuse or chemically stabilize the refuse do not exist. Therefore, the only apparent solution is to purposely add water, perhaps enriched with nutrients, to the landfill to speed decomposition of the refuse and to leach away all the soluble chemical byproducts. Such a procedure derives added appeal because the landfill would not then need to be covered right away -- an operation which will be expensive. However, considerable re-grading would be necessary in any event to eliminate ponding and to prevent recycled water from running off the site.

Spray Irrigation of Leachate

Spray irrigation of treated domestic sewage and industrial wastewaters has been demonstrated to be an effective means of waste treatment. The treatment processes include aeration while spraying, bacterial decomposition in the upper soil layers, chemical adsorption on soil particles, and chemical uptake by plants.

Unfortunately, spray irrigation of leachate would have several major difficulties or potential difficulties including:

1. Airborne odors.

2. Possible chemical toxicity to plants.

3. Clogging of surface soil pores and plant stomata by iron and manganese precipitates from the oxidized leachate.

4. Clogging of surface soil pores by a slime derived from the highly organic chemical loading in the leachate.

The highly concentrated nature of the leachate would require it to be sprayed on the landfill at rates considerably lower than the 2-inch per week guideline for treated domestic wastewater on permeable soils. If the leachate were recycled by spreading through infiltration galleries on the landfill surface, clogging of these galleries by aerated leachate precipitates would still be a problem.

Addition of water to the landfill would generate larger volumes of contaminated water; some of it would inevitably leak through the landfill floor to the Potomac Aquifer. Also

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water addition would raise the zone of saturation in the landfill, causing outflow of leachate to the Columbia sand north of the landfill by local reversal of the water table gradient, and the Army Creek as seeps along the western, southern, and perhaps eastern margins of the landfill.

Thus, water addition can be expected to increase the volume of polluted water to be contended with -- at least for some time. This last element -- time -- is at the crux of the water addition program; here the most critical question arises. How long will it take to stabilize the refuse, or will water circulation have any beneficial impact at all?

One landfill study (Dobson, 1964)[1] concluded that refuse decomposition in a landfill occurs most rapidly at a moisture content between 50 and 60 percent. Above and below this point, bacterial activity is generally slower. Examination of refuse samples excavated from the Llangollen Landfill has shown the moisture content to range from 40 to 70 percent. Thus, refuse decomposition might be proceeding just as quickly now as if water were to be purposely added to the landfill. Even if the refuse were desaturated, the field capacity of the refuse (the amount of water which would be held after gravity drainage) would be above 50 percent moisture. The result of adding water may simply get more products of partial decomposition into solution, thus adding to the water pollution problem.

Another landfill study (Apgar and Langmuir, 1971)[2] showed that the concentration of contaminants in leachate from an eight-year old landfill cell that had been constantly saturated with water was often higher than that of a nearby unsaturated two-year old landfill cell. Weston's own experience with water leaching through a 40-foot thick landfill in the midwest has indicated that no confident prediction can be made of the time when the landfill will not produce contaminants.

Thus, with no assurance that recycling water into the landfill will appreciably speed up the achievement of chemical stability of the buried refuse, and considering the other problems which are discussed above -- the most troublesome of which is the production of large volumes of leachate -- such a program should not be initiated.

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[1] Dobson, A.S., "Microbial Decomposition Investigations in Sanitary Landfills", Ph.D. Thesis, Department of Civil Engineering, West Virginia University, 1964.

[2] Apgar, M.A. and D. Langmuir, "Ground-Water Pollution Potential of a Landfill Above the Water Table", Ground Water, Vol. 9, No. 6, 1971.

Compatibility of a New Incinerator with New Castle County's Plans

While the most pressing solid waste problem in New Castle County is abatement of leachate movement in and away from the Llangollen Landfill, it is important to evaluate any potential solution in the context of the total solid waste management services planned (at least for the next 20 years) by New Castle County. The significance of this consideration is well recognized by the County, particularly in view of present efforts to develop a Solid Waste Management Plan. Weston has been, and is, assessing the impact of any Llangollen solution on long-term solid waste service needs in the County.

An incinerator at the Llangollen Landfill would serve the following dual purpose:

1. Burning "in-place" refuse at the landfill, thus providing a sound, confident solution to leachate production.

2. Simultaneously processing fresh refuse from selected portions of the County (Phase I).

Fresh refuse acceptance would have a step-increase upon completion of the Llangollen reclamation (Phase II). Phase II operations would thus automatically parallel the increasing waste generation resulting from growth of the County's population and economy.

Compatibility of a Llangollen Incinerator with long-term solid waste management in New Castle County must consider the following:

1. The incinerator's effect on the Pigeon Point Recycle Plant.

2. The availability of sufficient refuse following the removal of the refuse at the Llangollen Landfill.

3. The incinerator's effect on New Castle County's expenditures for solid waste management.

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Solid Waste Quantity

All three considerations involve determination of solid waste quantities, sources, and distribution. New Castle County and the City of Wilmington supplied recent population and employment data, including projections to 1955, from which projected waste quantities to be generated were determined. The residential waste generation rate for 1973 (2.61 pounds per capita per day) was determined from weighing records at the Pigeon Point Landfill. One-way travel times between selected points in the County were supplied by the Department of Highways and Transportation.

Current and projected population and employment figures are presented in Table 1. The scope of this study allowed an employment-sector breakdown into two groups: Manufacturing, and Commercial/Industrial Services/Community Services (C/IS/CS). This level, at minimum, is necessary since our records indicate that each employee in the manufacturing group generates approximately three times as much waste as an employee in the C/IS/CS group.

The application of generation rates per employee to associated employment within a group or a specific firm identified by its Standard Classification Code (SIC) enable the determination of total waste generation. Generation rates used for New Castle County are based on detailed survey results from a county in the northeastern United States of similar size and physical characteristics. Table 2 indicates that total waste generation is expected at least to double between 1970 and 1995, while the population increases by 80 percent.

Fourteen currently-operated and two recently-closed landfills are listed in Table 3. Nine of the existing sites are owned and operated by manufacturing corporations and accept internal manufacturing waste on-site; three are privately owned, and accept employment-related wastes; and two are publicly held. Existing State records do not include life expectancies or degree of conformance with sanitary landfill operating procedures. On-site surveys and interviews are necessary to evaluate the degree to which existing facilities will contribute to total disposal requirements for the County, both now and in the future. The trend has been for increased direct participation and closer monitoring of private waste disposal facilities by public agencies to the extent that privately-operated businesses, especially manufacturing corporations, are looking to their local government for disposal services.

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Table 1

New Castle County Population and Employment[1]

	1970			1985[2]			1995		
	Wilmington	Remaining County	County Total	Wilmington	Remaining County	County Total	Wilmington	Remaining County	County Total
Population	79,441	305,470	384,911	98,370	518,760	617,130	101,000	590,950	691,950
Employment-Sector:									
Manufacturing	16,427	36,939	53,366	21,189	64,561	85,750	21,851[3]	69,961	91,812
Commercial/Industrial Services/Community Services	45,761	55,476	101,237	65,813	106,718	172,531	68,599[3]	118,161	186,760
Total Employment	62,188	92,415	154,603	87,002	171,279	258,281	90,450	188,122	278,572

1 Source: New Castle County Planning Department, City of Wilmington Planning Department

2 Employment based on Roy F. Weston, Inc. analysis; 1985 employment assumed to directly proportional to population change.

3 Employment division between two sectors based on County Planning data and Roy F. Weston, Inc. analysis.

Table 2

New Castle County Solid Waste Generation

Tons Per Year X1000

Waste Type	1970 Wilmington	1970 Remaining County	1970 County Total	1985 Wilmington	1985 Remaining County	1985 County Total	1995 Wilmington	1995 Remaining County	1995 County Total
Residential[1]	38	145	183	61	321	382	72	423	495
Manufacturing[2]	58	129	187	74	227	301	77	245	322
Commercial/Industrial Services/Community Services[3]	60	74	134	87	141	228	91	156	247
TOTAL	156	348	504	222	689	911	240	824	1064

[1] 1970 generation rate of 2.61 pounds per capita per year based on 1973 County figures; projections from 1970 assume a 2 percent non-compounded annual increase in generation rate.

[2] Constant generation rate of 3.51 tons per employee per year.

[3] Constant generation rate of 1.32 tons per employee per year.

Table 3

New Castle County
Landfill Inventory

Ownership	Location	Major Waste Type Accepted
Private:		
Abex Corp.	On Site	Internal Manufacturing
Container Corporation	On Site	Internal Manufacturing
Delmarva Power and Light	On Site (Edgemore)	Internal (fly ash)
Diamond Shamrock Chemical Co.	On Site	Internal Manufacturing (Calcium sulfate sludge, PVC resin)
duPont	On Site (Newport)	Internal Manufacturing
FMC	On Site	Internal Manufacturing
Getty Oil Co.	On Site	Internal Manufacturing (ash)
Pyrites Corp.	On Site	Internal Manufacturing
Wilmington Fiber Speciality	On Site	Internal Manufacturing
Delaware Sands and Gravel Co.	Newport	Employment-related
Harvey Knotts (closed)	Newport	All (especially Town of Newport & GM Assembly Plant Waste)
Micuccio Brothers	South of Canal and West of Hwy. 13	Employment-related
Weaver's Pole Line Construction, Inc.	Delaware City	Employment-related (especially polypropelene waste from Amoco, Inc.)
Public:		
Marine Terminal - City of Wilmington	Port of Wilmington	Demolition and Construction
New Castle County - Pigeon Point	Adjacent to intersection of Christina and Delaware Rivers	All (primarily residential)
New Castle County's Tybouts (closed)		All

The Pigeon Point Recycle Plant, with funding provided through an EPA grant, is expected to begin construction after negotiations are completed, according to the State of Delaware. This demonstration plant will have a maximum-rated capacity of 1,200 tons per day and a six-day weekly operation. Figure 8 illustrates that, by 1977 (earliest date for Pigeon Point Recycle Plant and Llangollen Incinerator openings), an estimated 2,200 tons per day (tpd) will be generated, or 1,000 tpd in excess of the capacity of the Pigeon Point facility. A 1,000-tpd incinerator at Llangollen, processing equal weight-quantities of fresh refuse and reclaimed waste from Llangollen Landfill, could accommodate one-half, or 500 tpd, of the excess refuse generated. The balance (500 tpd) could be disposed of in privately-operated facilities meeting State and County Regulations or could be landfilled directly by the County.

By 1987, the 1,500,000 tons of reclaimed refuse from the Llangollen Landfill will have been processed, allowing the Llangollen Incinerator to accept 1,000 tpd of fresh refuse. Pigeon Point and Llangollen Incinerator will then collectively provide disposal capacity for 2,200 tpd, while estimated generation will reach 3,000 tpd. Maximum waste generation less disposal capacity of the two facilities occurs in 1986 and 2000, and is equal to approximately 1,300 tpd.

Solid Waste Distribution and Transportation Costs

The savings in transportation costs afforded with two facilities instead of one will be part of the Llangollen Incinerator's effect on New Castle County's expenditures for solid waste management expenditures. To determine transportation cost differences, 1985 wastes were allocated to 10 planning districts (as defined by the County and the City of Wilmington), with the New Castle planning district divided into a north and south section and with the Middleton/Odessa/Townsend area south of the canal divided into three sections. In all, 14 sources were used in the analysis. (See Figure 9.)

Twelve test cases were studied: six for all waste (residential, manufacturing, and C/IS/CS) and six for residential waste. The methodology employed is that of Weston's "Solid Waste Allocation Model" (SWAM), a sophisticated computer program for striking the least costly balance among the variables of cost for hauling and cost for disposal. (The skeletal amounts of data available and the time constraints of this project precluded actual application of the SWAM model however.)

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NEW CASTLE COUNTY
SOLID WASTE GENERATION

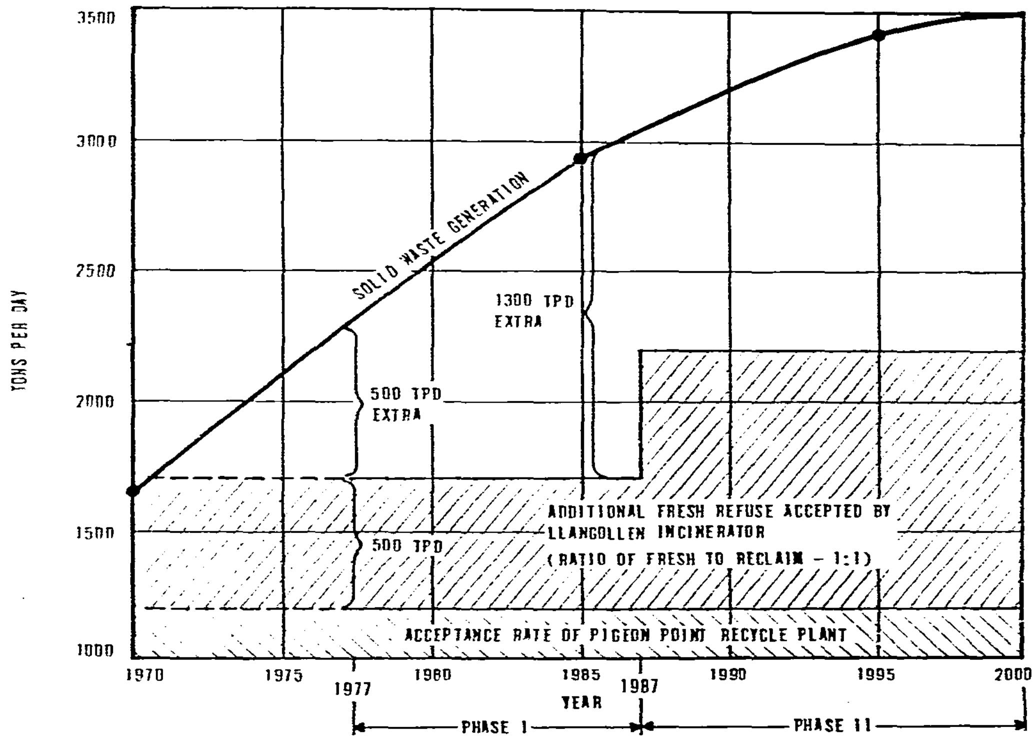

FIGURE 8

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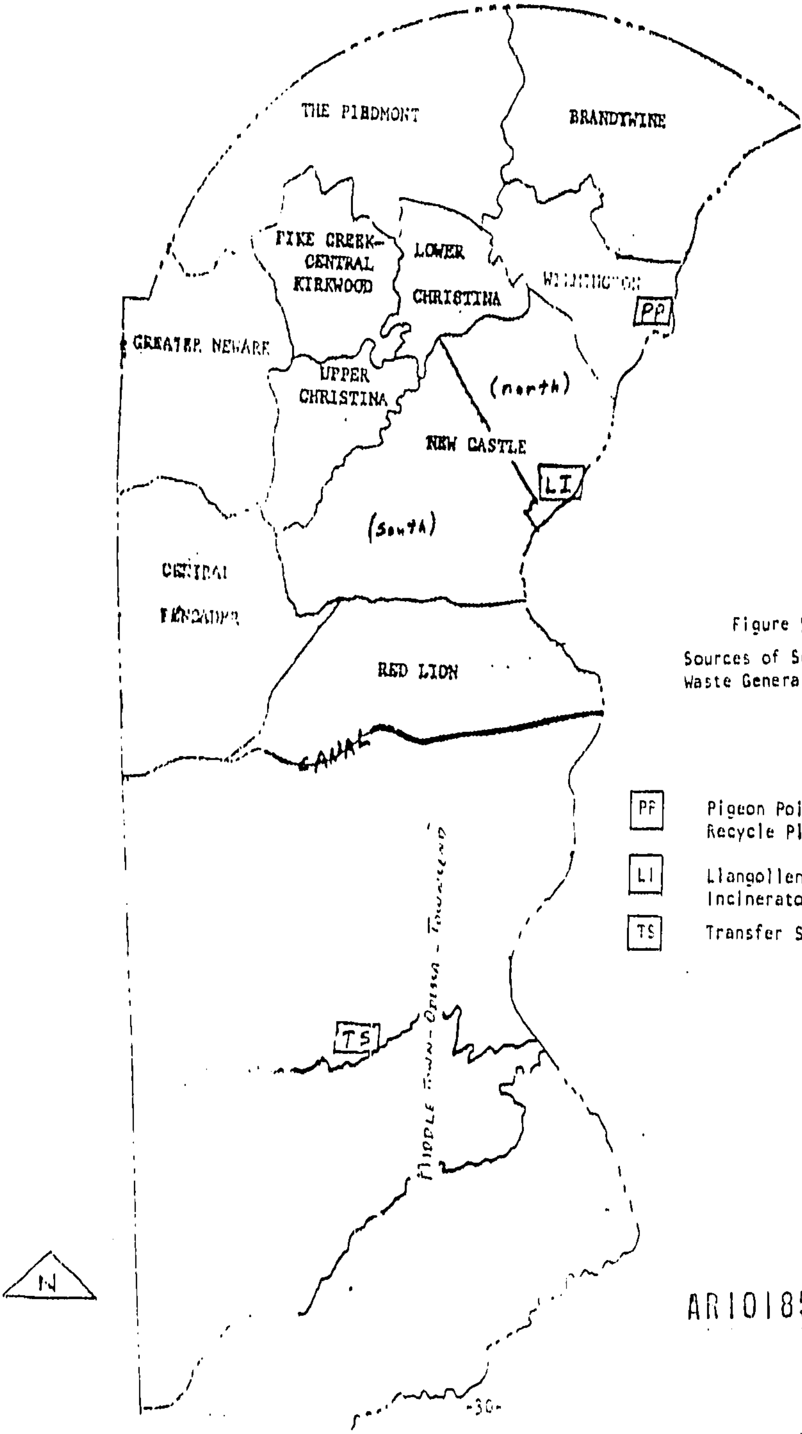

Figure 9

Sources of Solid Waste Generation

PP	Pigeon Point Recycle Plant
LI	Llangollen Incinerator
TS	Transfer Station

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- Direct Haul Alternatives:

  1. Pigeon Point Recycle Plant - Transporting the waste from all sources directly to the Pigeon Point Recycle Plant.

  2. Llangollen Incinerator - Transporting the waste from all sources directly to the Llangollen Incinerator.

  3. Optimal - Each source's waste is transported to the processing facility (either Pigeon Point or Llangollen) that will minimize total transportation costs.

- Transfer Station Alternatives:

  4. Pigeon Point Recycle Plant - Same as Alternative 1 with the addition of a transfer station located near Odessa to receive waste from those sources chosen on the basis of minimizing transportation costs.

  5. Llangollen Incinerator - Same as Alternative 2 with the addition of the transfer station.

  6. Optimal - Each source's waste is transported either to the transfer station or to one of the two final processing facilities so that total transportation costs are minimized; same as Alternative 3 with the addition of the transfer station.

A unit haul cost of $4.40/ton-hr/trip (based on a 24-cu yd, rear-loading packer truck with a 3-man crew) was used for the packer trucks; $0.80/ton-hr/trip (based on a 50-cu yd trailer with a 1-man crew) was used for the transfer trailer vehicle. Round-trip travel times between sources and processing sites were developed from State Highway Department records. Results of the analysis, presented in Table 4, indicate that Alternative 3 (Direct Haul, Optimal) results in a 12-percent savings in total transportation costs over Alternative 1 (Direct Haul, Pigeon Point) when considering all waste. Furthermore, adding the transfer station results in additional savings in all comparable alternatives. Alternative 6 (Transfer Station, Optimal) results in a $380,000 annual savings over Alternative 4 (Transfer Station, Pigeon Point), equivalent to approximately $0.86 per ton sent directly to the Llangollen Incinerator.

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TABLE 4

New Castle County Annual Transportation Cost ($X1000) - 1985

Type	Direct Haul Alternatives (1) Pigeon Pt. Recycle Plant $	(2) Llangollen Incinerator $	(3) Optimal $	% Less than Pigeon Pt. Alternative (1)	Transfer Station Alternatives[3] (near Odessa) (4) Pigeon Pt. Recycle Plant	(5) Llangollen Incinerator	(6) Optimal $	% less than Pigeon Pt. Alternatives (4)	(1)
All Solid Waste	3,590	3,530	3,150[1]	12	3,400	3,400	3,020[4]	11%	16%
Residential Solid Waste	1,550	1,470	1,300[2]	16	1,470	1,420	1,250[5]	15%	19%

[1] 444,000 tons per year (TPY) were sent directly to Pigeon Point Recycle Plant and 467,000 TPY were sent directly to Llangollen Incinerator.

[2] 160,000 TPY were sent directly to Pigeon Point and 222,000 were sent directly to Llangollen.

[3] All waste sources south of canal were sent to transfer station; all other sources were optimally allocated; includes cost of transfer station processing at $1.50 per ton plus savings in collection costs.

[4] Allocation: 444,000 TPY directly to Pigeon Point; 441,000 TPY directly to Llangollen; 26,000 TPY to transfer station then to Llangollen.

[5] Allocation: 160,000 TPY directly to Pigeon Point; 212,000 TPY directly to Llangollen. 10,000 TPY to transfer station then to Llangollen.

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While the County is not currently responsible for collection of any waste, future policy may involve more direct participatice from the County. In any event, the reduced haul time will enable the collection agencies to reduce their user charges to customers (or, perhaps, postpone their unit-charge increases) to the net benefit of County residents and establishments.

Summary

In conclusion, there is a reasonably good indication that an incinerator at Llangollen would be compatible with long-term solid waste disposal needs in New Castle County. It is even reasonable to say that an incinerator will contribute positively to transportation economics and to residents' convenience. While the degree to which private disposal facilities will assist in meeting future needs is uncertain, we can be assured that a significant portion of C/IS/CS solid waste will continue to be collected together with residential waste, thereby increasing the waste disposal capacity expected to be provided by the County. More County-specific information and investigation are needed, however, to instill confidence in the decision-making process.

Landfill Refuse Incineration

Excavation and incineration of refuse is one means of removing the source of leachate from the Llangollen Landfill. The refuse in the landfill was expected to be high in moisture and in noncombustible content (due to the cover material). There were no data available in the literature that would assist us in determining the feasibility of incineration; therefore, arrangements were made to obtain samples so that the quantity of water, inerts, and combustible material in the landfilled refuse could be determined.

Additional information needed included the bulk density of the refuse in place and after removal from the landfill, and also the bulk density of the residue after combustion. Another desirable data element was the degree of organic degradation (loss in combustible content) that had taken place since placement of the refuse in the landfill as determined in terms of the net Btu/lb of combustible material on a dry, ash-free basis.

Refuse Incineration

The sampling and analytical program was the first step required to evaluate the feasibility of incineration. Table 5 presents the results of the sampling and analytical program. Figure 10 indicates the location of sample points in the landfill.

The bulk density reported in Table 5 is in place; from our observations and experience, we estimate that the bulk density will decrease by approximately 15 to 20 percent following excavation.

The heating value reported was subjected to a verification procedure based on the reduction of the Btu value to a moisture and ash free (MAF) basis. Comparison of the refuse characteristics on the MAF basis, however, showed such a great variability that it was concluded that the samples (only 1 gram of material) used for heat content determinations could not be considered representative. However, visual inspection of the refuse showed that very little degradation had taken place. Thus, raw refuse MAF heat content was felt to be an acceptable estimate of the landfilled refuse characteristics. If the incineration route were selected however, the combustion tests should be repeated to obtain adequate data.

The moisture, residue, and combustible characteristics (taken with kilogram quantities of refuse) were reviewed, and the values are considered believable. Since the summation

$$H_2O + Ash + Combustible = 100$$

if the values for H_2O and ash "feel good", then the value for combustible is acceptable.

From the results obtained in this limited sampling program, it was evident that most of the samples were too wet to be burned in conventional incineration equipment. This conclusion is apparent from the data presentation of Figure 11. Only three samples fell within the self-burning or autogenous zone of conventional incinerator operation (defined as refuse which at 150-percent excess air exhibits a flame temperature in excess of 1,200°F). The boundary of the autogenous zone shown in Figure 11 is not totally believable because the basis for the autogenous zone reported is not clear from the literature reference (Hotti, G., "Montreal Incinerator Is Two-Fold Innovator", Power, January 1968).

Table 5

Llangollen Landfill Refuse Combustion Characteristics

Depth	Characteristics	Sample Site 1	2	3	4	5
A 0-5 ft	1. Bulk Density, lbs/cu yd	965	670	695	850	973
	2. Percent H_2O	42.5	49.7	45.2	-	67.3
	3. Percent Residue	23.4	5.8	20.2	-	15.8
	4. Percent Combustible	34.1	44.5	34.6	-	16.9
	5. Btu/lb (dry free residue)	3,811	8,025	6,073	-	5,673
B 6-10 ft	1. Bulk Density, lbs/cu yd	1,220	615	745	900	1,044
	2. Percent H_2O	55.9	54.7	64.1	-	48.3
	3. Percent Residue	38.6	5.6	7.4	-	35.0
	4. Percent Combustible	5.5	39.7	28.5	-	16.7
	5. Btu/lb (dry free residue)	4,177	4,666	4,854	-	3,246
C 11-15 ft	1. Bulk Density, lbs/cu yd	1,280	650	915	944	1,791
	2. Percent H_2O	50.7	62.5	59.6	-	58.5
	3. Percent Residue	13.7	4.8	22.3	-	27.7
	4. Percent Combustible	35.6	32.7	18.1	-	13.8
	5. Btu/lb (dry free residue)	10,238	6,632	3,405	-	3,115
D 16-20 ft	1. Bulk Density, lbs/cu yd	1,840	905	1,150	789	1,880
	2. Percent H_2O	48.3	76.7	62.8	-	35.1
	3. Percent Residue	46.0	2.2	15.6	-	44.7
	4. Percent Combustible	5.7	21.1	21.6	-	20.2
	5. Btu/lb (dry free residue)	1,650	7,705	5,434	-	1,145
E 21-25 ft	1. Bulk Density, lbs/cu yd	-	-	1,175	990	-
	2. Percent H_2O	-	-	69.4	-	-
	3. Percent Residue	-	-	6.7	-	-
	4. Percent Combustible	-	-	23.9	-	-
	5. Btu/lb (dry free residue)	-	-	6,794	-	-
F 26-30 ft	1. Bulk Density, lbs/cu yd	-	-	1,100	-	-
	2. Percent H_2O	-	-	60.7	-	-
	3. Percent Residue	-	-	23.3	-	-
	4. Percent Combustible	-	-	16.0	-	-
	5. Btu/lb (dry free residue)	-	-	4,[illegible]	-	-

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LLANGOLLEN LANDFILL

SAMPLE POINTS

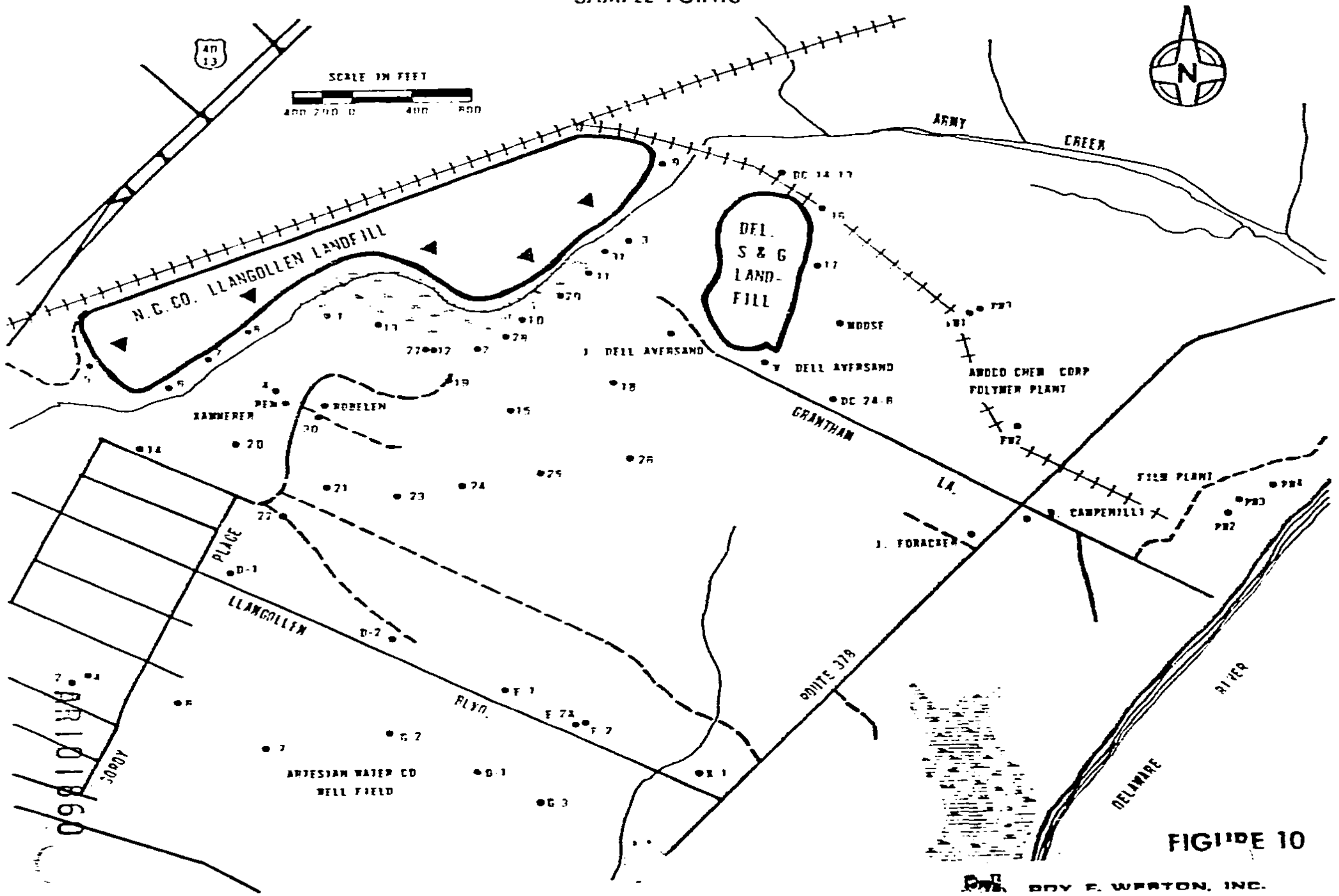

FIGURE 10

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NEW CASTLE COUNTY, DELAWARE
LLANGOLLEN LANDFILL
REFUSE COMPOSITION - COMBUSTION DIAGRAM

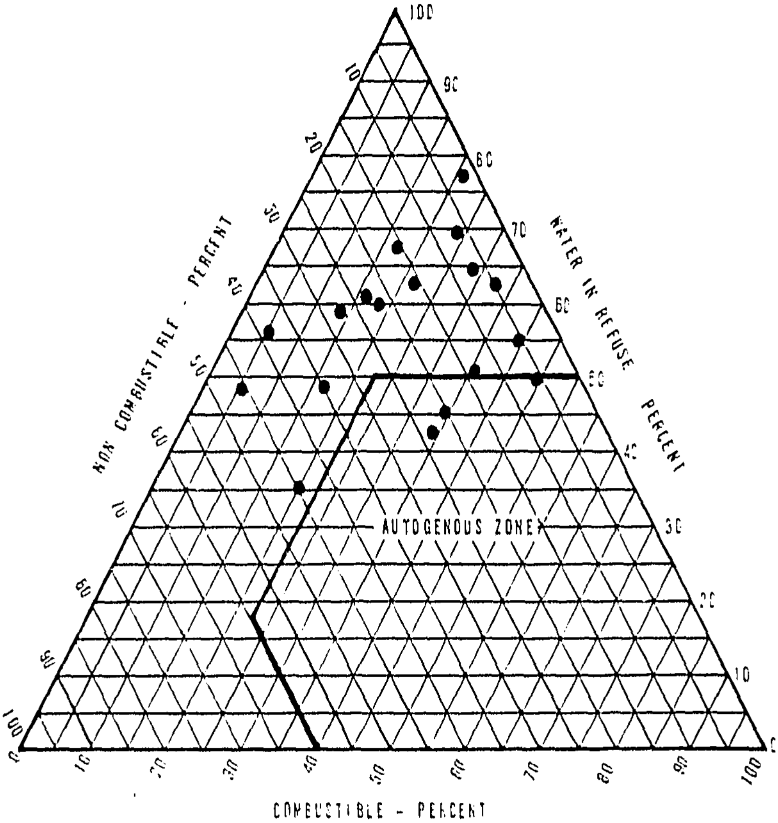

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FIGURE 11

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Because the basis for Figure 11 was unknown, we proceeded to derive a heat balance for a conventional refractory wall incinerator so as to better assess the combustibility of the Llangollen refuse. The first step in this program was to establish heating values for the refuse. Figure 12 is based upon a series of test reports prepared by the Office of Solid Waste Management Programs (OSWMP) of the Federal EPA. The data from their reports indicates that the heating value of fresh refuse on a moisture and ash free basis ranged from 7,920 to 9,800 Btu/lb, with an average of 8,960 Btu/lb. Therefore, Figure 12 relates the heating value of the refuse (as received) to the percentage of combustibles or inerts in the refuse.

Figure 13 relates the moisture and residue to a variable we can control in operation: the amount of excess air to maintain a furnace exit temperature of 1,600°F. Note that a dotted line at 80-percent excess air (1.8 times the theoretical combustion air) is plotted. This value represents the approximate minimum excess air that has been achieved on steam generating incinerators and, therefore, constitutes a possible minimum for a refractory wall furnace. In accordance with this curve, if the residue quantity is approximately 20 percent, the maximum water that can be present in the refuse is 52 percent at 80 percent excess air.

Figure 13 confirmed the data presented in Figure 11 wherein it is shown that the bulk of the refuse to be removed from the landfill is too wet to burn well by itself. The moisture content of the Llangollen refuse varied from 42.5 to 76.5 percent and averaged 56 percent.

It was thus concluded that an auxiliary fuel would be necessary in order to dry the material to a theoretically combustible state. As fresh refuse was known to be available in the County, the use of fossil fuels was ruled out as a source of auxiliary heat.

Fresh refuse can vary in moisture content from approximately 20 to 50 percent depending upon the season of the year, weather conditions, domestic storage practices, and other factors generally beyond the control of the County. The moisture content of fresh refuse can also be affected by the collection practice; for instance, the County might dictate that all refuse be placed in plastic bags which would shield the refuse from the effects of inclement weather. However,

NEW CASTLE COUNTY, DELAWARE
LLANGOLLEN LANDFILL

REFUSE HEATING VALUE AS RECEIVED
(EPA-OSWMP OPEN FILE REPORTS)

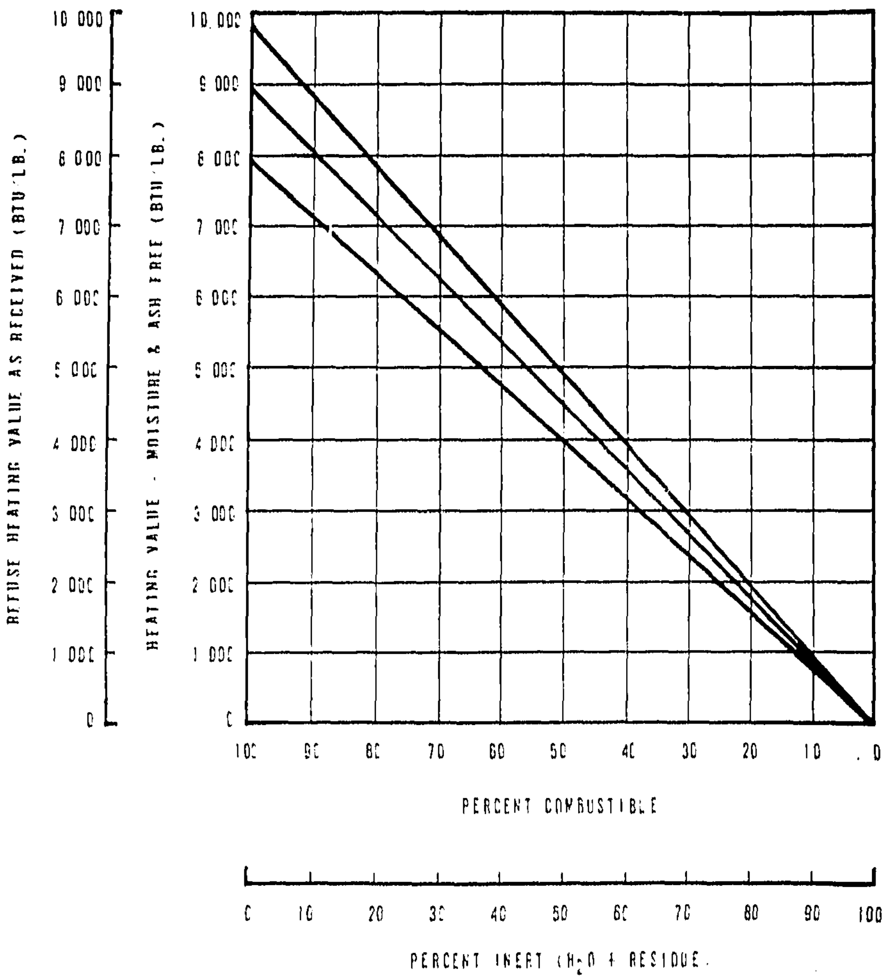

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FIGURE 12

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NEW CASTLE COUNTY, DELAWARE
LLANGOLLEN LANDFILL

REFUSE COMBUSTION
REFRACTORY FURNACE

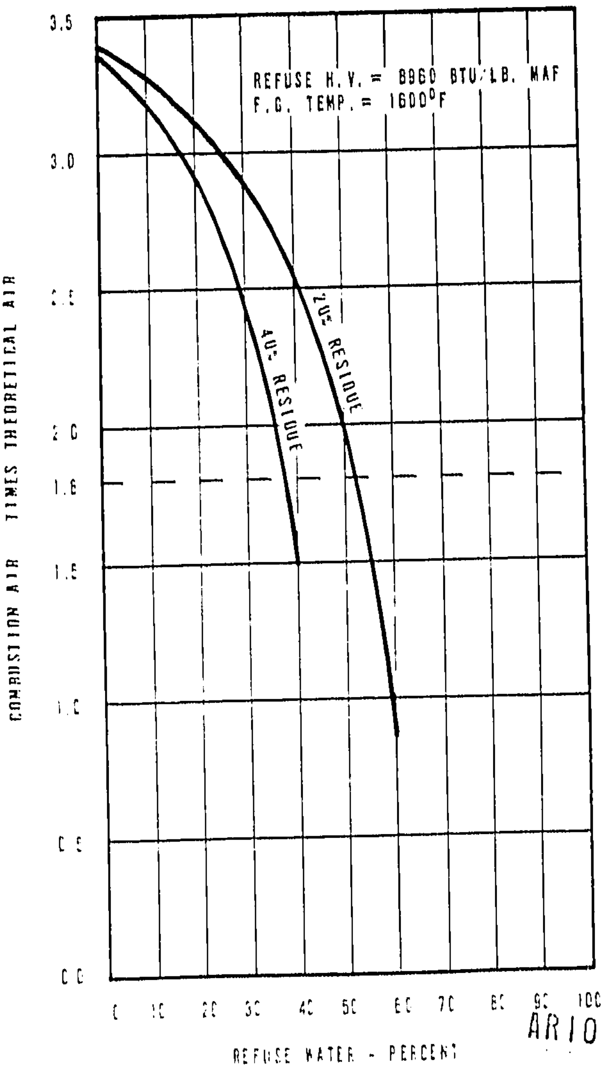

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FIGURE 3

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for purposes of this feasibility review, an average value of 26-percent moisture was selected, and various blends of reclaim and fresh refuse were tried before arriving at a one-to-one mixture of fresh and reclaimed refuse. The one-to-one blend would exhibit average properties as follows:

Proximate Analysis	Landfill Refuse Average	Fresh Refuse Average	Mixed Refuse 1:1
Percent Water	56 (0)*	28 (0)	42 (0)
Percent Residue	19 (43)	21 (29)	20 (34)
Percent Combustible	25 (57)	51 (71)	38 (66)
Btu/lb	2,250	4,600	3,400

*Figures in parenthesis are on dry basis.

With a one-to-one mix of reclaimed and fresh refuse, the mixture is theoretically combustible in a conventional incinerator. Some calculations were made in an effort to use the waste heat from the incinerator as a means of drying the reclaimed refuse. To avoid odor emission problems, the criteria was set that the drier vent gases must pass through the furnace high temperature zone before being exhausted. The practicality of this was judged poor because the degree of drying that could be achieved was minimal, and there are several major technical problems involved in mixing a large quantity of hot gases with a large quantity of drier exhaust gases (needed to insure that odorous gases do not pass unburned through the combustion zone of the incinerator). Therefore, this concept was abandoned as a practical means of controlling refuse moisture content.

The theoretical mixture of average raw and average reclaimed refuse yeilding a combustible mixture must be tempered by the fact that both the raw and reclaimed refuse will vary in moisture and inert composition with time; therefore the calculations show only the average conditions, and operation of the facility would have to compensate for daily variations in the quality of the refuse to be burned.

Another problem exists in that good mixing of the reclaimed and raw refuse must be accomplished in order to insure complete combustion in an incinerator furnace. It was judged that the only means of achieving a satisfactory mixture of the two components was to feed both the reclaimed and raw refuse to a shredder and blend before charging the furnace.

With a one-to-one mixture and assuming a time span of 10 years to totally dispose of the Llangollen refuse, a 1,000-ton/day incinerator would be required. Assuming that some of the cover material could be segregated and not charged into the incinerator, the time span might be as short as 8 years or as long as 12 years depending upon the quality (heat and moisture content) of reclaim and raw refuse actually received at the incinerator site.

Conventional Incineration

Conventional incinerators may be of the refractory-wall or steam-generating types. In both cases the typical practice is to burn the refuse as received on grates. Burning on grates is typically called mass burning, and a rather deep fuel bed is maintained over the grate surface, with air being introduced under the grate and passing through the refuse as the refuse is being burned. So-called "conventional incineration" is a well-proven technology (not always properly applied in the design of the facility) but, even with an excellent design, the operating personnel must learn to cope with the variable nature of raw refuse as received.

Mass burning incinerators are occasionally plagued with the problem of receiving and trying to burn wet raw refuse. Because the problem does not exist all of the time, there are few, if any, incinerators that are adequately designed to cope with the wet refuse problem. The practices of incinerator operators in attempting to cope with wet refuse have been surveyed by Stevenson ("Burning Wet Refuse", Proceedings and Discussions of the 1972 National Incinerator Conference, ASME). Operator practice includes reducing the furnace charge rate and the depth of the fuel bed, physically agitating the fuel bed, and the use of auxiliary fuel to maintain adequate furnace temperatures. Systems have been designed so that an auxiliary fuel such as heavy oil can be introduced into the refuse as it is fed to the furnace, and some designers recommend that the underfire air be pre-heated.

It is also possible to burn the refuse in suspension. This is now being done in St. Louis, Missouri (the only U.S. unit) in a utility boiler. However, 80 to 90 percent of the heat at the St. Louis plant is being provided by the combustion of a conventional fossil fuel (coal). Suspension burning was not considered a viable means of disposing of the Llangollen refuse since the procedure requires two-stage shredding (a costly operation) and the use of fossil fuels to insure stable and complete combustion.

Shredding of the refuse prior to feeding the furnace has not been typical practice in incinerator design. One such installation exists on the North American Continent, however, in Hamilton, Ontario. In this unit, the refuse is fed to the furnace by means of an air-swept spreader stoker, and the refuse burns on a traveling grate. In a spreader stoker unit, some of the drying and combustion takes place in suspension as it is being blown onto the grate. The balance of combustion takes place on the grate surface itself. The Hamilton installation has experienced problems with material handling and shredding but, reportedly, burning of the shredded raw refuse is not a problem.

No one from the Weston organization or the County has seen the Hamilton, Ontario installation. (Sutin, G.L., "Solid Waste Reduction Unit Promises to be a Better Mouse Trap", Public Works, February, 1969.) We understand, however, that there are several mass burning incinerators handling shredded refuse in the vicinity of Paris, France and one under construction in Beirut, Lebanon.

While a mixture of fresh and reclaimed refuse is theoretically autogenous, we examined the means by which the reclaimed and fresh refuse could be mixed to ensure adequate combustion on a mass burning grate. We concluded that it would be impractical to alternate grapple loads of wet and dry material and that we could not accomplish a satisfactory mixing of the two materials by any commercially available mixing device. This latter consideration involves the heterogeneity of the refuse as received and the impracticality of blending large masses of dry and wet material. We concluded that the material should be subdivided by means of a coarse shredder and then further blended before being discharged to a pit where some interchange of moisture could take place prior to firing. In attempting to feed two streams of refuse to a shredder, control problems should be anticipated as should clogging problems in the shredder due to the presence of wet material.

We would anticipate that the shredding operation, the materials handling problems, and the firing and burning problems would require further investigation although, at this point, we conclude that a conventional mass burning spreader-stoker incinerator with modifications can be adapted and used to dispose of the Llangollen Landfill material in combination with raw refuse from daily collections in New Castle County.

The residue from a conventional incinerator based on a one-to-one mix of raw and reclaimed refuse will be approximately 0.7 lb of residue per 2 lbs of feed to the furnace (0.7 lb of residue for every pound of Llangollen refuse burned). As it is unreasonable to assume total burn out of the refuse, the residue from the furnace must be properly landfilled as the ultimate disposal method.

The concept of energy recovery was considered in evaluating different incineration processes for disposal of Llangollen refuse. Aside from the technical feasibility of recovering heat from the incinerated refuse, other important factors are the following:

1. Cost of a steam-generating incinerator or fuel gas-converting incinerator versus a conventional refractory furnace incinerator: Preliminary cost evaluation indicated that steam-generating and fuel-gas converters are cost competitive with conventional refractory furnace incinerators.

2. Availability of a market for recovered steam and/or fuel-gas: A preliminary evaluation of the amount and condition of steam that could be generated in a steam-generating incinerator and consultation with AMOCO technical staff indicate that AMOCO could use (and pay for) all the steam generated at the proposed incinerator. The overall quantity and quality of steam generated at AMOCO boilers would allow the utilization of the steam generated at the proposed incinerator even on an interrupted basis. The same investigative approach was conducted to determine the marketability of selling low Btu fuel gas generated in a gas-converting incinerator (such as Purox by Union Carbide). It was found that AMOCO could fire such fuel gas in their boilers in conjunction with oil and pay for the fuel value of this gas.

If the Llangollen Incinerator were to be of a steam-generating type, fireside tube wastage must be investigated (and is being intensively investigated by a number of organizations and

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individuals). Evidence to date indicates that as long as steam pressures are not too high the corrosion problems that have been encountered are controllable. Since AMOCO has a need for a large quantity of low-pressure steam, this would seem to be the indicated conventional incineration route to follow as steam generating incinerators are capable of operating at lower excess air rates, and exportable steam has a dollar recovery value.

Recent experience with steam-generating incinerators indicates that they are no more expensive and possibly less expensive than refractory incinerators, and the steam generated could be used to operate incinerator auxiliaries and to heat the underfire air which is one of the recommended procedures for combustion of wet refuse.

Therefore, if a conventional type incinerator is the indicated incineration system to be implemented, we suggest that, while further investigation is necessary, the steam-generating type is the most feasible selection given the conditions outlined.

Other Incinerator Approaches

In addition to the conventional incineration concepts discussed above, several new systems are now under development or in prototype use that have merit and should be investigated as alternative on-site processing methods.

Union Carbide Purox System

Union Carbide has operated a 5-ton per day (tpd) pilot unit since 1970 in their Tarrytown, New York Technical Center. A 200-tpd system is under construction at their South Charleston, West Virginia Plant with a forecast 31 March 1974 start-up date. The South Charleston prototype system will burn municipal refuse from the surrounding community. Union Carbide advises that they have four plants that they expect to build, pending successful operation of the South Charleston facility.

The Purox system uses pure oxygen (98 to 99 percent) to burn a portion of the refuse to generate high (2,800-3,000°F) temperatures in the lower regions of the furnace. The products of the process are a black sand residue and a low Btu fuel gas that can be exported and burned in boilers reportedly with only minor changes to the users' burner system.

Because the Purox system uses oxygen (rather than air) as the oxidizing medium, energy utilization to heat the nitrogen present in air can be used to compensate for a high moisture content in the refuse feed. Union Carbide has stated that they can handle raw or shredded refuse with up to 60-percent moisture present. At the higher moisture refuse feed, oxygen consumption increases and the fuel value of the off-gas is lowered, but the off-gas is still useful as a boiler fuel. The off-gases from the Purox system are largely particulate-free carbon monoxide and hydrogen and, because the fuel gas is exported, the only air pollution emission from the system, if any, would exist at the boiler plant using the fuel gas. Present expectations, however, are that the fuel gas would be non-polluting, the equivalent of natural gas.

Union Carbide has indicated that a five-to-two ratio of reclaimed to raw refuse should yield 4 million Btu's per ton of mixed waste feed in exportable fuel gas. They state that they do not believe shredding or intensive mixing of the reclaimed and raw refuse is necessary, but, pending operation of the South Charleston prototype installation and further investigation, we feel that the shredding and mixing of the refuse should be considered a possible processing step until adequate evidence exists to the contrary.

The technical attractiveness of this alternative is based upon the following:

1. The potential to eliminate the shredding process as a pre-processing step.

2. The residue is a black glass sand; limited tests indicate it to be inert (not leachable) and might be used as an aggregate in the construction of County bituminous paved roads.

3. The potential to produce a nitrogen by-product. AMOCO presently uses an inert gas atmosphere in their operation; thus manufacture of a second salable product would be indicated if such would improve oxygen manufacturing economics.

4. The capital cost of the oxygen plant can be eliminated if Linde, Airco, or another firm could be persuaded to develop a merchant gas production facility in the area.

While this would reduce the initial capital investment of the system to the County, it would increase the operational cost of the system because the purchased oxygen would have to be produced as a commercial venture and sold to the County at a profit.

5. The five-to-two mix minimizes the amount of fresh refuse that would be necessary for destruction of the Llangollen material. This minimizes the demand for fresh refuse (possibly more compatible with New Castle County Solid Waste Management Plans).

6. Air pollution is essentially zero with this system since the fuel gas is clean and exported to be burned in existing boilers. The fuel gas produced is expected to be less polluting than the present residual oil fuel used by AMOCO and would be of beneficial usage in light of current fossil fuel energy concerns.

Some disadvantages of the Purox system are:

1. The process has not been proven on a commercial scale, but the 200-tpd plant is presently in its startup mode.

2. The process requires construction and operation of an oxygen plant in addition to the incinerator unless merchant gas production for the area can be encouraged.

3. Shredding of refuse may prove to be required.

Fluid-Bed Incineration

Copeland Systems, Inc. is promoting the incineration of municipal refuse in a fluid-bed reactor. This process requires shredding of the refuse and separation of ferrous metals before feeding the shredded materials to a fluid-bed unit. Heat recovery (steam generation) is possible with such units and can be economically advantageous. The fluid-bed unit is capable of handling wetter refuse than conventional incineration because the design requires a minimal amount of excess air. In sludge incinerator practice, the fluid-bed units have a demonstrated capability of burning sewage sludge with approximately 40-percent excess air. Referring to Figure 13, at

40-percent excess air, a one-to-one raw to landfill refuse ratio (55-percent moisture, 20-percent residue) could be satisfactorily burned.

The fluid-bed systems require a fossil fuel for startup and control of furnace temperatures but, when the refuse being fired is autogenous under the conditions of operation, a minimal amount of fossil fuel is required. Wet scrubbers are typically used on fluid-bed units as the means of air pollution control; most of the inerts will pass out of the reactor in the gas stream and will be collected in the scrubbing system. Those inerts that remain in the bed can be drained from the bed periodically and will be largely sterile. The leachability characteristics of such residue is not known.

A preliminary quotation has been requested from Copeland for a 500-tpd plant. Copeland has indicated that they would be willing to build and operate the facility on a contract basis. The conditions for such a contract disposal option would require that the County sign a long-term contract for solid waste disposal on an acceptance fee base (with suitable escalation clauses). Disposal of the wastewater and ash would be a County responsibility. Assuming the County would provide the land, AMOCO would have to sign a long-term contract for steam on an interruptable basis. The Copeland representative also indicated that facility size could be larger to accomodate a larger proportion of New Castle County Solid Waste than that necessary to eliminate the landfill leachate source.

The technical risk of such a system should be investigated if the County plans to own and operate its own fluid-bed incinerator. Even if the County chooses the contract disposal route, the technical risk should still be investigated. If the system fails to perform as advertised, the County would be left with a groundwater pollution problem from Llangollen even though the County would not be financially liable for the fluid-bed system costs.

Black Clawson Hydrodisposal System

Little published data is available concerning this system. Weston personnel inspected the Office of Solid Waste Management Program's funded prototype plant in Franklin, Ohio; however, the Black Clawson product manager has been unwilling to provide basic information about the system. We include this option for consideration because fresh refuse need not be blended with the reclaim in order to destroy the Llangollen Landfill material. Also, since the process includes breakdown of the feed refuse in a water-filled hydropulper, the naturally high-moisture content of the landfilled material has no adverse effects on cost or on processing technology.

The Black Clawson system is a recycle system with ferrous and non-ferrous metals recovery, glass recovery, and paper fiber recovery. Since one might assume that much of the cellulose fiber in the landfill has undergone some degradation however, we would not anticipate that useful fiber products could be obtained from Llangollen. The residue from the operation is dewatered and burned in a fluid-bed reactor similar to the Copeland System. The economics of the Black Clawson system may well depend upon the fiber reclamation portion of the flowsheet but, at least for the period of time that it takes to dispose of the Llangollen refuse, there is little reason to believe that fiber recovery is a viable option. The degradation that probably has taken place in the landfill may well have destroyed the value of the fiber for recycle purposes. The Franklin system is based upon 50-percent reclamation of the paper which constitutes one of the largest fractions of raw municipal refuse.

We have been told by the developers of the system that initial problems with the hydropulper had been solved by modification of the machine. We are also told that, because of the presence of large amounts of paper fiber, the dewatering press prior to burning in the fluid bed reactor is a relatively simple operation, considerably less complex than the dewatering of a sewage sludge.

Summary of Incineration Alternatives

Of the incinerator systems considered, all may require shredding of the refuse (Union Carbide feels that their Purox process may not require the shredding step).

Resource recovery concepts are considered as a major factor in evaluating and selecting the type of incinerator for final disposal of Llangollen refuse. Preliminary evaluation of marketing potential of steam or low Btu fuel gas is favorable due to the needs of the AMOCO manufacturing plant. AMOCO could use more than twice the low-pressure steam or heat value of fuel gas that could be produced in the proposed incinerator. At this capacity, it would be convenient to sell all the steam or fuel gas produced at the incinerator to AMOCO as an auxiliary source of energy. Selling steam or fuel gas to an industrial user at its fuel dollar value will produce a revenue that would help offset the total annual cost of the proposed incinerator.

At this level of investigation, we believe we have identified 4 potentially usable incinerator concepts which should be considered further for technical and economic feasibility.

With each of these systems, we would contemplate receiving reclaimed and fresh material in storage bins equipped with drains connected to the County wastewater treatment plant. The material would be reclaimed from these storage bins by bridge cranes and charged either to the furnace or to the shredding equipment. The interim storage of the material reclaimed from the Llangollen Landfill is an indicated step because we suspect that some excess water will drain from this material. No credit for this drainage has been taken, however, in evaluating the options.

The Purox option yields a residue which is minimal in bulk and weight and which might be suitable for beneficial use. The fluid-bed option would rank next in terms of residue disposal problems, and some portion of this material may be useful as an aggregate. Finally, conventional incineration will yield residue with the least desirable characteristics in terms of organics present and the highest bulk and weight of the four systems evaluated at this point.

This investigation of incinerator options has been devoted largely to the ultimate solution of the Llangollen leachate problem. We suggest that, if the incinerator option is selected for further consideration, its impact on New Castle County's overall solid waste management practices be further evaluated prior to committing the design criteria.

ECONOMIC ANALYSIS OF ALTERNATIVES

General Considerations

In the previous section, the different alternatives were evaluated on the basis of their technical merits and limitations. It was shown that hydrogeologic controls for isolating the landfill lack certainty in the degree of leachate control and would require pumping of groundwater for an indifinite but probably long time period (greater than 20 years). The incineration concept provides an absolute solution in a finite duration, but uncertainty remains as to the technical feasibility of certain systems. The concept of hauling and disposal at another site offers an absolute solution to the Llangollen Landfill problem. However, uncertainty remains as to environmental and political acceptability.

In this section, an economic analysis for different alternatives is performed. In order to have a common base for comparison, the costs are discounted to their present worth. The following assumptions are made in this analysis:

1. Interest Rate = 6 percent
2. Life of hydrogeologic controls = 30 years
3. Life of incinerators = 25 years
4. Life of treatment plant = 25 years
5. Revenue from steam sales = $1.00/1,000 lbs of steam
6. Revenue from fuel gas sales = $1.00 per million Btu

Tables 6 through 10 list capital cost, operating costs, and present worth for each alternative. Table 11 summarizes the elements of costs for different phases of the project (i.e., during and after disposal of Llangollen refuse).

Table 6

Economic Analysis of Hydrogeologic Controls

Capital Costs	
Phase I	
Dewatering the Pleistocene	$ 400,000
Regrade and Cover Surface	500,000
Recovery Wells Re-Location	200,000
Recovery Wells Treatment Facilities	660,000
Electrical System	150,000
Pipe Line to Delaware River	250,000
Sub-Total Phase I	$ 2,160,000
Phase II	
Infiltration Galleries in Landfill	$ 1,900,000
Physical/Chemical Treatment Plant	300,000
Sub-Total Phase II	$ 2,200,000
Total Hydrogeologic Controls	$ 4,360,000
Operating Costs	
Operating Costs, Phase I	$ 320,000
Operating Phase	280,000
Sub-Total	$ 600,000
Amortization Cost/Year	$ 316,800
Total Annual Costs	$ 916,800
Present Worth of Hydrogeologic Controls	$15,300,000

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Table 7

Economic Analysis of Purox System
Without Shredding

Capital Cost	
Incinerator Facility	$13,500,000
Hydrogeologic Controls	1,300,000
Total Capital Cost	$14,800,000
Annual Cost	
Incinerator	$ 11.50/ton*
Excavation of Refuse	$ 400,000/year
Hydrogeologic Controls	$ 184,000/year
Fuel Gas Revenue	$ 600,000/year
Present Worth of Purox System Without Shredding	$12,600,000

*This figure includes Amortization Cost.

Table 8

Economic Analysis of Purox System
With Shredding

Capital Cost	
Incinerator Facility	$13,500,000
Refuse Shredder	2,800,000
Hydrogeologic Controls	1,300,000
Total Capital Cost	$17,600,000
Annual Cost	
Incinerator	$ 11.50/ton*
Shredder	$ 4.00/ton*
Excavation of Refuse	$ 400,000/year
Hydrogeologic Controls	$ 184,000/year
Fuel Gas Revenue	$ 600,000/year
Present Worth of Purox System with Shredding	$16,300,000

*This figures includes Amortization Cost.

Table 9

Economic Analysis of Steam Generating Incinerator

Capital Cost	
Incinerator Facilities	$22,500,000
Refuse Shredder	4,000,000
Total Incinerator Capital Cost	$26,500,000
Amortization Cost	7.03/ton
Hydrogeologic Controls	$ 1,300,000
Operating Costs	
Incinerator	$ 6.08/ton
Refuse Shredder	$ 2.14/ton
Excavation of Refuse and Disposal of Residue	$ 485,000
Hydrogeologic Controls	$ 184,000
Steam Revenue	$ 600,000
Present Worth of Steam Incinerator	$16,700,000

Table 10

Economic Analysis of Excavation and Hauling Llangollen Refuse

Excavation, Haul and Ocean Dumping*	
Excavate Llangollen Refuse	$ 3,500,000
Structural and Environmental Controls	1,500,000
Hauling and Barging	5,000,000
Total Cost	$10,000,000
Excavation, Hauling and Disposal in Another New Castle County Landfill**	
Excavate Llangollen Refuse	$ 3,500,000
Hauling Cost (10 miles)	1,500,000
Structural and Environmental Controls	1,500,000
Gate Charge at New Landfill	3,000,000
Total Cost	$ 9,500,000

*It is not likely that EPA would grant New Castle County a permit to ocean dump Llangollen Refuse.

**Viability of this alternative is dependent on the availability of enough capacity in an existing landfill.

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Table 11

Summary of Capital and Operating Costs for Llangollen Landfill Removal Alternatives

System	Element of Cost	Capital Cost ($)	Cost per Ton ($): Llangollen Refuse	Fresh Refuse	Total Annual Cost $/Year (Including Amortization): Llangollen Refuse (0-6 years)	Fresh Refuse (0-6 years)	Mixed Refuse (0-6 years)	Fresh Refuse 700 tpd (9-25 years)
Purox System without Shredding (700 tpd)	Incinerator	$13,500,000	$11.50	$11.50				
	Hydrogeologic Controls and Excavation	1,300,000	4.50	-				
	Subtotal	$14,800,000	$16.00	$11.50				
	Less Fuel Gas Credit		-4.00	-7.00				
	Total		$12.00	$ 4.50	$1,800,000 (500 tpd)	$ 270,000 (200 tpd)	$2,070,000 (700 tpd)	$1,350,000 (700 tpd)
Purox System with Shredding (700 tpd)	Incinerator	$13,500,000	$11.50	$11.50				
	Shredder	2,800,000	4.00	4.00				
	Hydrogeologic Controls and Excavation	1,300,000	4.50	-				
	Subtotal	$17,600,000	$20.00	$15.50				
	Less Fuel Gas Credit		-4.00	-7.00				
	Total		$16.00	$ 8.50	$2,400,000 (500 tpd)	$ 510,000 (200 tpd)	$2,910,000 (700 tpd)	$1,785,000 (700 tpd)
Steam Generation at an Incinerator (1,000 tpd)	Incinerator	[illegible]	[illegible]	[illegible]				
	Shredder	[illegible]	3.30	3.30				
	Hydrogeologic Controls and Excavation	[illegible]	4.50	-				
	Subtotal	[illegible]	[illegible]	[illegible]				
	Less Steam Credit		-4.00	[illegible]				
	Total		[illegible]	[illegible]	$2,362,500 (500 tpd)	[illegible] (500 tpd)	[illegible]	[illegible]
Removal and Disposal in Another Landfill	Excavation	[illegible]	[illegible]					
	Hauling, [illegible]	[illegible]	[illegible]					
	Structure and Environmental Controls	[illegible]	[illegible]					
	Gate Charge	[illegible]	[illegible]					
	Total	[illegible]	[illegible]					

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Hydrogeologic Controls

Hydrogeologic controls are divided into two phases. Phase I is the attempt to hydrogeologically isolate the landfill by reducing precipitation and groundwater entry into the landfill. Phase I will include relocation of recovery wells closer to the landfill, treatment plant construction, and a pipeline to the Delaware River. Phase II will include collection of the concentrated leachate accumulated on the bottom of the landfill. This phase would involve construction of infiltration galleries and a physical/chemical treatment plant for the collected leachates.

Total capital costs for Phase I plus Phase II is estimated to be $4,360,000. This capital cost is amortized over 30 years at 6-percent interest rate yielding an amortization and cost of $316,800 per year. Annual operating and maintenance costs for Phases I and II are estimated at $600,000. Total annual cost is estimated to be $890,000. Present worth of this total annual cost for an indefinite period (over 50 years) is estimated to be $15,300,000. (See Table 6.)

Purox System without Shredding

Capital cost of a 700-tpd Purox system without a shredder is estimated to be $13,500,000 plus a cost of $1,300,000 for the hydrogeologic program that must be conducted during the process of excavation and incineration of the Llangollen refuse. (See Table 7.)

Amortization of the incinerator capital cost including operating costs results in a cost of $11.50 per ton of refuse processed at this facility. In addition, $4.50 per ton for excavation of refuse, disposal of residue, and hydrogeologic controls is added to the cost per ton, which becomes $16.00.

Credit of fuel gas rates is estimated at $4.00 per ton of Llangollen refuse and $7.00 per ton of fresh refuse. The total net cost per ton becomes $12.00 per ton of Llangollen refuse and $4.50 per ton of fresh refuse.

For the purpose of comparing and evaluating this alternative versus other alternatives, the cost of removal and disposal of Llangollen refuse (500-tpd for 8 years) is discounted and espressed in present worth. The present worth of the costs related to Llangollen refuse is estimated to be $12,600,000.

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Purox System with Shredding

Similar analysis of a Purox system with shredding is shown in Table 8. Costs per ton are the same as the previous alternative, except an additional $4.00 per ton is added for shredding refuse. Present worth of this alternative (based on 500 tpd for 8 years at $16.00 per ton) is estimated to be $16,300,000.

Steam Generating Incinerator

Economic analysis of a 1,000 tpd steam generating incinerator with shredder indicates that the total capital costs will be $26,500,000 plus $1,300,000 for hydrogeologic controls. (See Table 9.)

The total cost per ton of Llangollen refuse is estimated to be $19.75; however substracting $4.00 for steam sales will result in a net cost of $15.75 per ton. The present worth of this alternative (500 tpd for 8 years) is estimated to be $16,700,000.

Excavation and Hauling

Excavation and hauling to another landfill (10 miles away) would require an investment of $9,500,000. Excavation, hauling, and ocean dumping would require $10,000,000 of capital costs. (See Table 10.)

Discussion

The above alternatives can be ranked according to their capital cost requirements:

1.	Hydrogeologic Controls	$ 4,360,000
2.	Excavation and Hauling to another Landfill	$ 9,500,000
3.	Excavation, Hauling and Ocean Dumping	$10,000,000
4.	Purox System without Shredding	$14,800,000
5.	Purox System with Shredding	$17,600,000
6.	Steam Generating Incinerator	$27,800,000

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It should be emphasized here that the costs of hydrogeologic controls and hauling refuse to a landfill or to the ocean are 100 percent attributable to disposal of the Llangollen refuse. On the other hand, only a portion of capital cost of the different incineration processes is attributable to disposal of the Llangollen refuse, because these facilities will have an estimated life of 25 years, while only part of their capacity will be used to dispose of the Llangollen refuse for the first 8 years of their life. In addition, revenue is expected due to sale of steam or fuel gas from these systems.

Better evaluation of these alternative can be achieved by ranking the alternatives according to the present worth of those costs associated with disposal of Llangollen refuse:

1.	Excavation and Hauling to Another Landfill	$ 9,500,000
2.	Excavation, Hauling and Ocean Dumping	$10,000,000
3.	Purox System without Shredding	$12,600,000
4.	Hydrogeologic Controls	$15,300,000
5.	Purox System with Shredding	$16,300,000
6.	Steam Generating Incinerator	$16,700,000

From this ayalysis, it can be concluded that the least cost method is to dispose of the Llangollen refuse by excavation and hauling to another landfill location or to the ocean for dumping. However, there will be political and environmental opposition to such an approach. Both incineration and hydrogeologic controls are in the same range of present worth.

The decision between hydrogeologic isolation versus removal and incineration will be on the basis of their respective effectiveness of leachate control and restoring the Potomac Aquifer to its' normal production.

Conclusions

1. Hydrogeological Control

   a. Uncertainty remains as to degree of leachate control.

   b. Cost of control is competitive, but not commanding.

   c. Pumping and treatment is required for an indefinite but prolonged period.

   d. Aquifer restoration to unimpeded use is uncertain.

2. Incineration Control

   a. Uncertainty remains as to technical feasibility, but this can be resolved.

   b. Cost of control is competitive, but not commanding, and high investment will be involved.

   c. Provides an absolute solution and is finite in duration.

   d. Appears compatible with the master plan and is cost effective with respect to transportation.

3. Haul - Dump Control

   a. Uncertainty remains as to environmental acceptability (ocean dump) and landfill acceptability (Pidgeon Point).

   b. Lowest net cost.

   c. Provides an absolute solution in a relatively short time period.

Recommendations

1. Implement a limited hydrogeological control program to minimize leaching in the near-term.

2. Initiate immediate investigation of haul-dump (ocean and Pidgeon Point) options.

3. Initiate detailed concept evaluation of incineration options.

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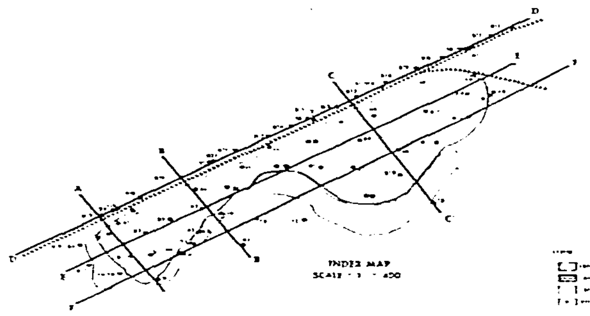
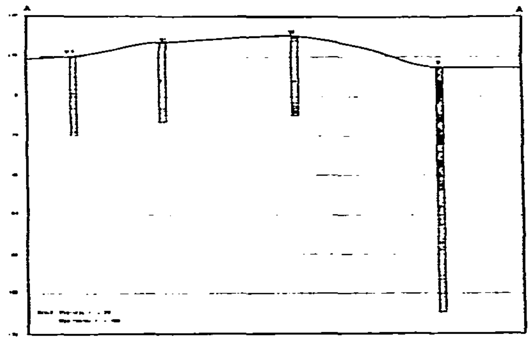
APPENDIX A

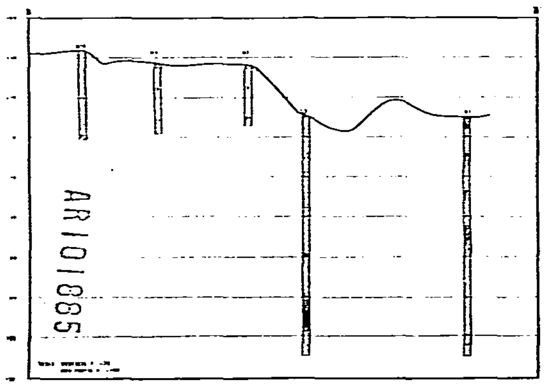
LLANGOLLEN LANDFILL
NEW CASTLE COUNTY, DELAWARE

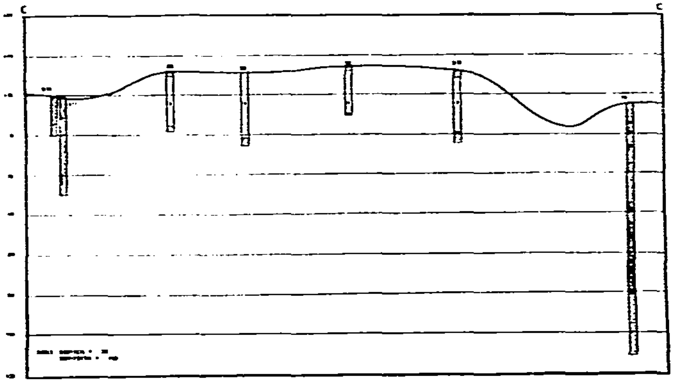
LONGITUDINAL & LATERAL CROSS SECTIONS OF THE LLANGOLLEN LANDFILL

PLATE 1









ROY F. WESTON, INC.

APPENDIX H

NEW CASTLE COUNTY

LLANGOLLEN LANDFILL REHABILITATION PROJECT

Concept Engineering Report

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E. BIOLOGICAL ASSESSMENT OF ARMY CREEK

- Introduction
- Methods
- Results

F. LANDFILL RELOCATION: Two Million Yards of Buried Refuse Moved (Reprint For Solid Waste Management, RRJ, Oct. 1975).

Project Participants

New Castle County Department of Public Works

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I. EXECUTIVE SUMMARY

Background

The Llangollen Landfill is about two miles southwest of the City of New Castle Delaware. The landfill was constructed in a worked-out sand and gravel pit between 1960 and 1968. It covers approximately 55 acres and contains approximately two million cubic yards (about 1 million tons) of mixed municipal, commercial and industrial solid wastes.

Previous investigations by Roy F. Weston, Inc. (Weston) under contract to the New Castle County Department of Public Works (the County) have shown that contaminants (leachate) from the landfill are polluting the groundwater in the area.

By pumping 3 to 5 million gallons per day of groundwater during the past three years the county has been able to retard pollutants migration toward major well fields in the area. However, even with heavy pumping, pollutants are threatening groundwater quality and uses.

Furthermore, it is expected that leachate will continue to migrate from the Llangollen Landfill towards major groundwater users in the area. The quality and availability of groundwater resources will continue to degrade in a region where a water deficit has been forecast.

Several alternatives for ultimate abatement of groundwater contamination have been evaluated. These include: hydrogeologic isolation of the landfill, incineration of Llangollen refuse, ocean disposal, transport to and processing in Pigeon Point Landfill and rehabilitation (reconstruction) of the Llangollen Landfill.)

Summary of these alternatives and their costs is included in Section II of this report.

<u>Recommended Concept:</u>

Rehabilitation (reconstruction) of the Llangollen landfill was recommended for implementation because it offers: technical feasibility, cost effectiveness, control of groundwater contamination, minimal operating effort and cost, finite duration for construction and restoring groundwater quality, net saving over any other alternative, and finished areas suitable for recreational uses.

The Llangollen Landfill rehabilitation, or reconstruction, plan consists of:

(1) Preparation and lining of a new landfill area adjacent to the present site (Delaware sand and gravel pit);

(2) Transfer of refuse to the prepared area;

(3) Placement and compaction of the refuse in the new area;

(4) Collection and treatment of leachate;

(5) Management of surface and subsurface waters; and

(6) Rehabilitation of the old site and finishing of the new site into a high-quality recreational area.

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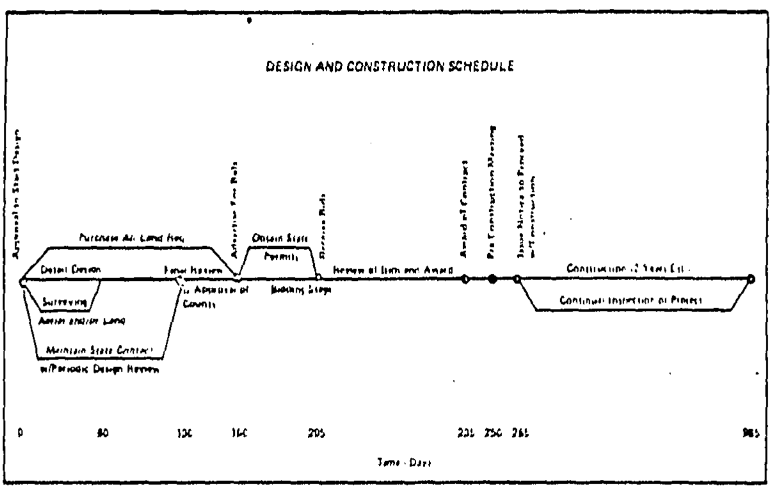
Figure 1.1

SCHEDULE



Benefits of the recommended concept include: technical feasibility, cost effectiveness, control of ground water pollution, relatively short time for completion, net savings to taxpayers over other alternatives and rendering the finished areas suitable for beneficial uses.

Basis of selection of the rehabilitation concept are discussed in Section III and IV. Detailed presentation of the concept is included in Section [illegible]. Environmental limitations and controls related to the rehabilitation project are discussed in Sections V and VIII. Alternatives for completed landfill reuse are developed in Section [illegible]. Conclusions and recommendations for project implementation are listed in Section X.

Initial and Continuing Costs

Direct and indirect costs related to relocation of the Llangollen Landfill are presented in Section IX. Initial cost of the proposed plan is estimated as $6 million plus $1 million for contingencies and engineering and legal and administrative costs, and $200,000 per year for (an additional 5 years) for pollutants recovery, leachate treatment and landfill maintenance.

Program Implementation

It is recommended that the county review this report, request funds for the rehabilitation project, authorize the engineering design, acquire a new site, and submit a permit application to the Delaware DNR. Figure 1.1 is a schedule of design and construction of the rehabilitation program.

II. INTRODUCTION

Background

The Llangollen Landfill, shown in Figure 2.1, is located two miles southwest of the City of New Castle, Delaware. The landfill was constructed in a worked-out sand and gravel pit between 1960 and 1968. It is approximately 4,400 feet long and 200 to 900 feet wide, and covers approximately 55 acres; average refuse thickness is about 25 ft. It is estimated that the landfill contains about two million cubic yards (approximately one million tons) of refuse.

Previous studies by Roy F. Weston, Inc., under contract to New Castle County, have shown that the leachate from the Llangollen landfill has caused contamination of an important source of potable groundwater (the Potomac aquifer) in the vicinity of the landfill. Efforts to recover leachate contamination already in the aquifer are already underway; Figure 2.2 shows location of major recovery wells and status of pollutant migration in the Potomac aquifer.

By pumping 3-5 million gallons per day of groundwater, the county has been able to retard pollutant migration towards major well fields in the area (Artesian Water Company and AMOCO Chemical Corporation). However, even with this heavy pumping, pollutants are still threatening groundwater quality and usability in the area. Furthermore, continued pumping wastes large volumes of groundwater and inhibits the use of needed potable water resources.

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NEW CASTLE COUNTY, DELAWARE
LLANGOLLEN LANDFILL
LOCATION MAP

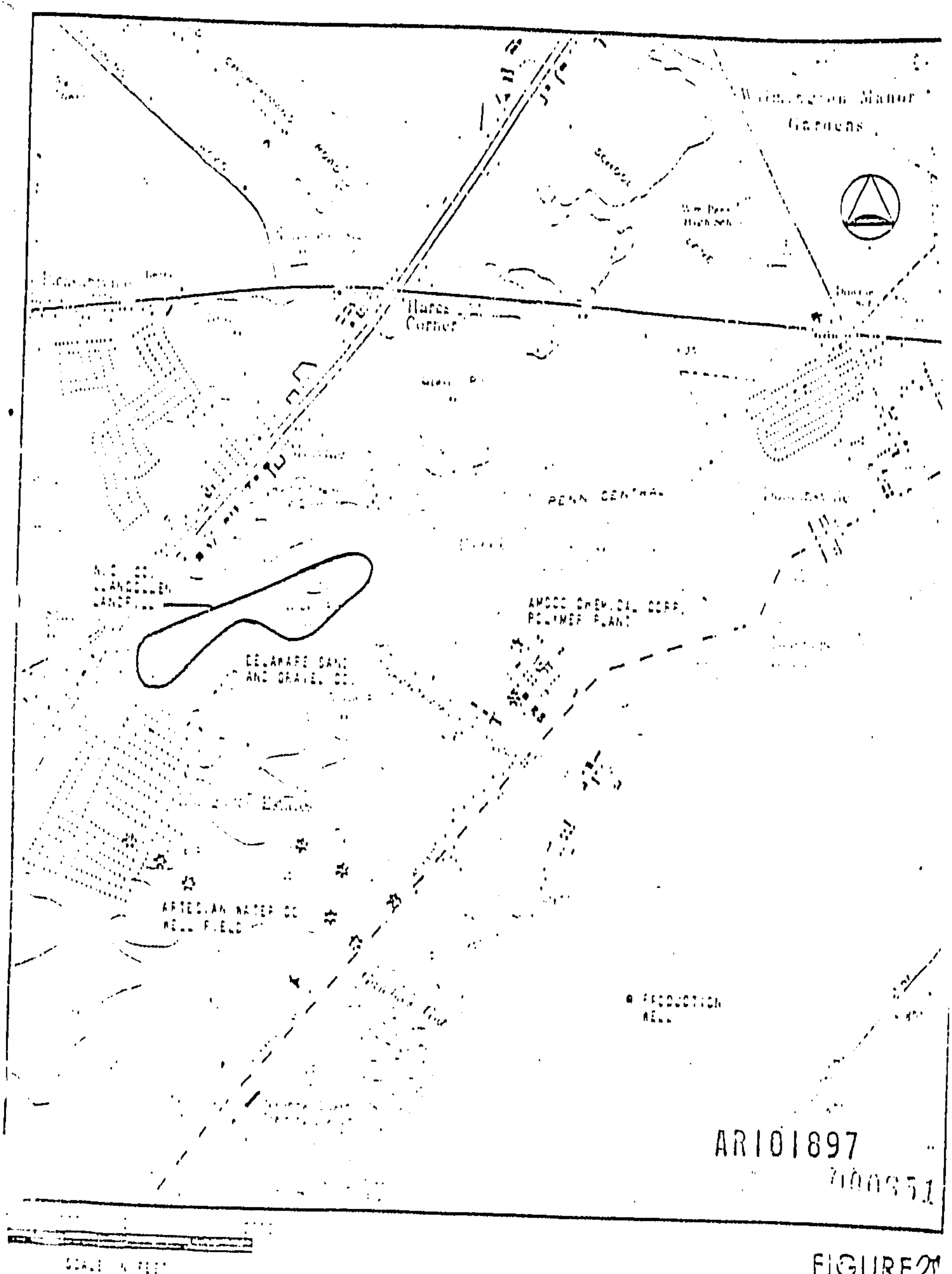
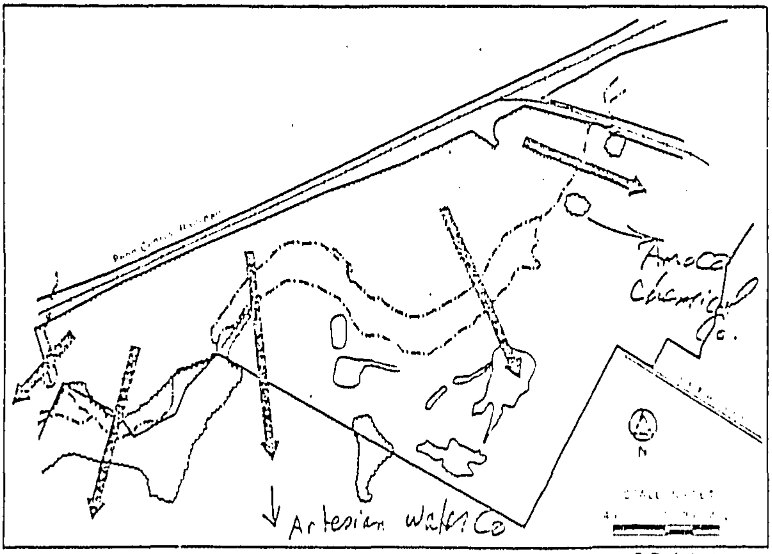


FIGURE 2

ROY F. WESTON, INC.

FIGURE 2.2



Plot plan of the Llangollen Landfill and the study area, showing direction of leachate migration and contamination potential.

Problem Definition

The Llangollen landfill was constructed in a worked-out sand and gravel pit. The sand excavated from that pit was part of the Columbia formation. The underlying Potomac formation consists of stream-deposited unconsolidated sands, silts and clays. Previous hydrogeologic study, by Weston, indicated that immediately beneath the landfill, clays and silt deposits are thin and locally sandy or absent, which creates channels for leachate migration into the Potomac aquifer.

The initiation of heavier pumping from the Potomac aquifer by AMOCO Chemical Corporation (to the east) and by the Artesian Water Company (south of the landfill) in the early 1960's lowered the local water table, especially south and west of the landfill, where Potomac clay is generally thin or absent, thus demonstrating the direct connection between the Columbia and Potomac sands. This connection facilitates migration of leachate from the landfill into the Potomac aquifer, which is the source of potable water supplies in the area.

As illustrated in Figure 2.3, causes of leachate formation and migration can be summarized as follows:

1. Excessive infiltration, due to inadequate landfill cover and final grades and lack of vegetation. These factors result in low runoff and/or low evapotranspiration loss from the landfill cover and, therefore, higher infiltration into refuse, which is responsible for generating approximately 30 million gallons of leachate per year.

2. Lateral infiltration, from the Pleistocene aquifer. This infiltration takes place due to the absence of confining materials and due to high water table conditions (approximately 10 feet above the bottom of the landfill. It is estimated that lateral groundwater infiltration into the landfill is responsible for ~~over~~ approximately 85 million gallons of leachate per year.

3. Absence of confining layers (clays) or other means of leachate interception (liners or galleries) is responsible for migration of leachate from the landfill into the Pleistocene aquifers. The contamination of this aquifer does not create a threat to water supplies in the area, since all pumping is from the Potomac aquifer. However, contaminants could further migrate into the Potomac aquifer.

4. Absence of confining layers (clays) or other means of leachate interception at the bottom of the landfill is responsible for leachate migration from the landfill into the Potomac aquifer, which is the major source of potable water in this part of New Castle County.

Hydrogeologic and engineering investigations indicate that the leachate migration from the Llangollen landfill into the Potomac aquifer, towards major water users in the area, will continue unless positive means of control are implemented. The quality and availability of groundwater resources will continue to degrade in this region where a water deficit has been forecast.

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Pollution Control Alternatives

Weston has evaluated for New Castle County several alternatives for ultimate abatement of the ground water pollution and aesthetics problems of the Llangollen Landfill.

1. Hydrogeologic Solution for the Landfill - The hydrogeologic program would include measures for reducing precipitation infiltration, measures for reducing lateral infiltration of subsurface waters, and measures for recovery of contaminated ground waters. Such a program has several disadvantages: (a) incomplete stoppage of leachate migration into ground water; (b) need for continued pumping of ground water for an indefinite period (over 50 years); (c) waste of large quantities of ground water (5 million gallons/day); (d) high total cost.

2. Incineration of Llangollen Refuse - By mixing mined old refuse with fresh refuse (to reduce moisture content), the material now in the landfill can be burned. Steam or fuel gas can be recovered. Several systems have been evaluated including steam-generating, Purox, and Torrax incinerators. Disadvantages of the incineration concept are: (a) incompatibility with the State of Delaware Solid Waste Management Plan; (b) uncertainty of steam or fuel gas markets in the landfill area; (c) high total cost.

3. Excavation of Llangollen Refuse and Disposal in the Atlantic Ocean -

This can be achieved by excavation of Llangollen refuse, truck and barge hauling, and, finally, ocean dumping. This procedure is not acceptable to the Environmental Protection Agency (EPA) unless other feasible alternatives for abating the pollution problem do not exist (which is not the case).

4. Excavation of Llangollen Refuse and Processing at the Pigeon Point Landfill - This procedure would place unacceptable demands on the remaining capacity of the Pigeon Point Landfill, and would result in several adverse environmental impacts due to transfer of the refuse from Llangollen to Pigeon Point. Further, major technical problems and hazards are expected in the processing of the Llangollen refuse.

5. Rehabilitation (Reconstruction of Llangollen Landfill) - This alternative offers a positive means for stopping pollutant migration from the landfill into ground water and for rehabilitation of the aquifer. This concept is discussed in more detail in following sections.

Summary of these alternatives is listed in Table 1.1.

Table 1.1

Summary of Pollution Control Alternatives

	Alternative	Initial Cost/Duration $ Millions	Continuing Cost/Duration $/Year
1.	Hydrogeologic Isolation[(1)] of Landfill through Continuous Pumping and Interception of Groundwaters	4.4, over 1 year	900,000/yr., for indefinite period of time (over 50 yrs.)
2.	Incineration of Llangollen[(2)] Refuse with Other Fresh Refuse	14 to 18, over 3 years	600,000/yr., for 10 years.
3.	Excavation and Hauling to[(3)] Ocean	10, over 2 years	200,000/yr., for 5 years.
4.	Excavation and Hauling to[(4)] Another Landfill (Pigeon Point)	9.5 over 2 years	200,000/yr., for 5 years.
5.	Rehabilitation (Reconstruction) of Llangollen Landfill	7, over 2 years	200,000/yr., for 5 years.

(1) Does not provide positive means for stopping pollutant migration into ground water.

(2) Not compatible with Delaware Solid Waste Management Plan.

(3) Not acceptable to the Environmental Protection Agency.

(4) Results in unacceptable demands on remaining Pigeon Point Landfill capacity.

Scope and Objectives

The objective of this study was to develop a concept for abating the groundwater pollution and related problems that resulted from leachate migration from the Llangollen Landfill. The New Castle County and Weston technical staff realized that the public interest can best be served by prompt action to put an end to continuing groundwater pollution and achieve the following objectives:

- Protecting and restoring the quality of the county's water resources,
- Providing private, industrial, and municipal users with required quantities of potable water,
- Putting a time limit on the indefinite recovery program and its associated cost to the county,
- Net savings, in the long run, to taxpayers over rehabilitation of groundwater supplies if no controls are implemented.

The criteria for developing an acceptable rehabilitation plan for the Llangollen Landfill include:

- Improving and maintaining groundwater and surface water quality,
- Cost-effectiveness,
- Practicality and ease of implementation,
- Political and public acceptability,
- Regulatory agency acceptability, and
- Rendering a beneficial use for the reconstructed landfill.

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Organization of the Study

The project has been a truly multi-disciplined one; to achieve the study goals and objectives, the Weston project team included: environmental engineers, civil engineers, hydrogeologists, planners and economists. Section III of this report covers the development of the basic landfill rehabilitation scheme. Section IV and Appendix A cover evaluation of alternatives landfill rehabilitation and selection of the optimum plan. Section V summarizes the pre-concept evaluation and development of hydrogeologic and design parameters for the recommended rehabilitation plan. The concept engineering is developed and summarized in Section VI. Alternatives for completed landfill reuse are discussed in Section VII. Environmental controls necessary for a successful rehabilitation plan are presented in Section VIII. Preliminary cost estimates of the recommended plan are summarized in Section IX. Conclusions and recommendations are included in Section X.

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III. BASIC REHABILITATION CONCEPT

The basic rehabilitation concept considered in this study consists of removal of refuse and replacing it in a controlled landfill as means of abating the subsurface water pollution by leachates from the Llangollen Landfill.

General Considerations

The rehabilitation, or reconstruction, scheme of the Llangollen Landfill consists of the following tasks: 1) Removal of refuse from the existing site, 2) Preparation and lining landfill areas, 3) Transfer of refuse to prepared areas, 4) Placement, compaction, covering and finishing new areas, 5) Collection and treatment of leachate and 6) Management of surface and subsurface waters.

The landfill rehabilitation can be achieved by several approaches; 1) Reconstruction of Llangollen Landfill itself, 2) Removal of portions of refuse from Llangollen and disposal in another location (e.g. Pigeon Point), and 3) Removal of refuse and placement in a specially designed and constructed area contiguous to the Llangollen Landfill Site.

An acceptable rehabilitation plan should meet the following objectives: 1) Improving and maintaining subsurface and surface water quality, 2) Cost-Effectiveness, 3) Practicality, 4) Political and Public acceptability, 5) Regulatory agencies acceptability, and 6) Beneficial use for the reconstructed landfill.

Existing Conditions

In order to develop rehabilitation concepts, the existing conditions in Llangollen Landfill and their relationship to contamination of the groundwaters were investigated. Leachate generation and migration into subsurface waters can be attributed to the following factors:

- Excessive infiltration into refuse layers due to the lack of adequate cover, vegetation, final grade and drainage devices.

- Lateral infiltration from the Pleistocene aquifer into the landfill due to absence of confining layers or diversion devices at the landfill site and due to high water table.

- Portions of leachate migrate from the Pleistocene aquifer due to absence of confining layers or means of leachate interception at the landfill.

- The remainder of leachate migrates from the bottom of the landfill into the Potomac Aquifer due to the absence of confining layers or means of leachate containment and collection at the landfill.

The net result of the existing conditions at the Llangollen Landfill is escape of significant amounts of leachate and contamination of groundwaters at the area, which is threatening municipal, domestic and industrial water supplies of the area.

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Requirements for Rehabilitation

As illustrated in Figure 3.1, several engineering and environmental requirements for rehabilitation of the landfill have to be met; these include:

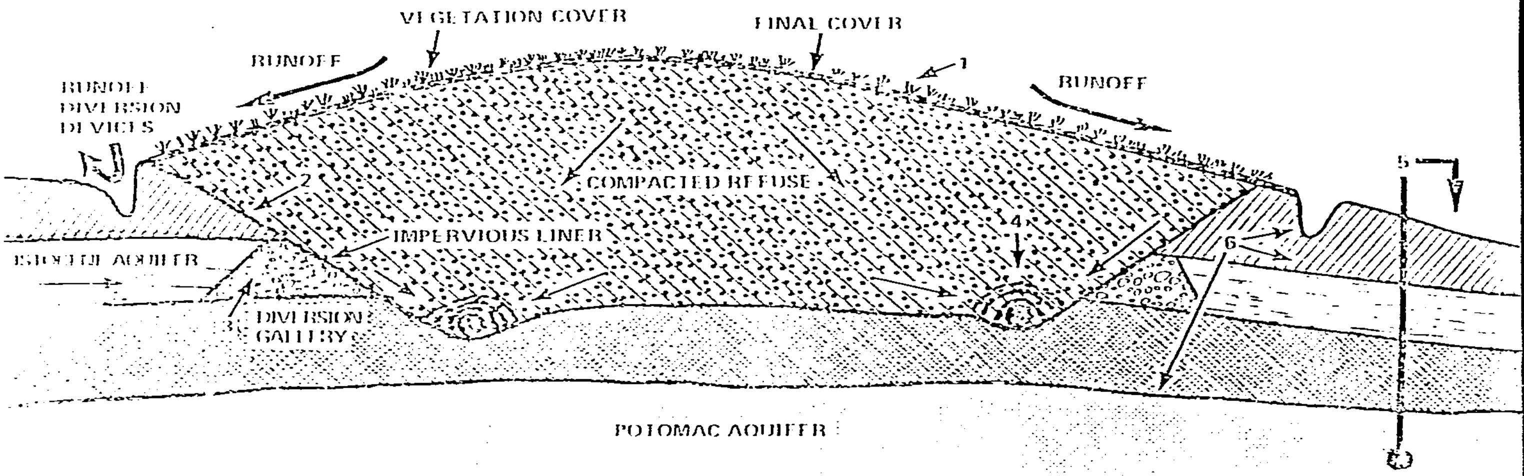
Provisions for Minimizing Infiltration, and consequently leachate generation, potential. This can be achieved by using; a) soil cover material with low permeability, b) special techniques for reducing infiltration such as subsoil asphalt injection, c) adequate final grades (3 - 35%) that maximizes runoff away from the site, d) construction of drainage devices and e) proper vegetation cover (e.g. Reed Canary Grass) to maximize evapotranspiration or combination of these measures.

Containment of Leachate within the landfill is necessary, since it is unrealistic to expect complete elimination of rain and subsurface water infiltration into the landfill. An impervious liner should be utilized as means for separating refuse from subsurface waters and for leachate interceptions and collection.

Diversion of Shallow Groundwaters will be needed in order to relieve hydrostatic pressures on the liner. Any significant pressures due to subsurface waters may result in unbalanced forces on the liner and cause lifting or even rupture. Subsurface waters should be intercepted and directed to a path of least resistance (e.g. infiltration galleries, away from the landfill.) Also, as an added protection, leachate should be allowed to accumulate to several feet on top of the liner to counteract any hydrostatic pressures.

Figure

RECONSTRUCTED LANDFILL



LEACHATE CONTROLS

1 MINIMIZING INFILTRATION BY FINAL COVER, VEGETATION COVER AND PROPER GRADING

2 CONTAIN LEACHATE WITHIN LANDFILL BY LINING SIDES AND BOTTOM WITH IMPERVIOUS LINER

3 DIVERT SHALLOW GROUNDWATERS TO RELIEVE PRESSURES ON SIDES

4 COLLECT AND TREAT LEACHATE (DISPOSE IN SEWER)

5 CONTINUE REHABILITATION OF THE POTOMAC AQUIFER

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Leachate Collection and Treatment will be achieved by placing a layer of sand and perforated pipes on top of the liner to drain leachate from the landfill into sump(s) equipped with pumps that discharge the leachate into the sewer interceptor. Leachate will be discharged directly or after receiving pretreatment, if required, to the municipal sewer and will receive adequate treatment at the municipal wastewater treatment facility.

Rehabilitation of the Potomac Aquifer by recovery of contaminants through continuing pumping the recovery wells during the landfill reconstruction program. The pumping program may be continued for several years (5-7) until the groundwater quality reaches acceptable limits.

Monitoring Surface and Subsurface Water Quality is a key step for successful program. Monitoring wells will be constructed as a part of the program. Samples from these wells as well as from recovery wells and other discharge points should be frequently analyzed (every 1-2 weeks) during the construction phases and at a less frequent basis (1-3 months) after completion of the rehabilitation program. Sampling should continue for several years after completion of construction, to determine the effectiveness of the rehabilitation program and the need for continuing operation of recovery wells.

IV. ALTERNATIVES FOR LANDFILL REHABILITATION

Listing of Alternatives

Four alternative plans were developed for the rehabilitation of the Llangollen Landfill utilizing the criteria listed in Section III, Basic Rehabilitation.

<u>Alternative Plan A</u> consists of transportation of an initial quantity of refuse to the Pigeon Point Facility for processing and disposal, with utilization of the rehabilitated Llangollen site for disposal of the remaining refuse.

<u>Alternative Plan B</u> consists of transportation of an initial quantity of refuse to a prepared site at the Delaware Sand and Gravel Pit (DS & G) with utilization of the rehabilitated Llangollen Landfill for disposal of the remaining refuse.

<u>Alternative Plan C</u> consists of transportation of an initial quantity of refuse to a temporary storage site at the opposite end of Llangollen with utilization of the rehabilitated Llangollen as the site for disposal of all refuse.

<u>Alternative Plan D</u> consists of preparing the DS & G Pit (plus some additional adjacent land) as a landfill site for the Llangollen refuse.

Technical evaluation of the four alternative plans (pros and cons) and economic analysis are included in Appendix A.

Recommended Alternative

The recommended alternative is Alternative Plan D, Excavation of Llangollen Landfill With Transport of the Refuse to a Prepared DS & G Pit for Landfilling. Alternative Plan D is cost-effective, technically sound, utilizes the best available technology, is the most economically attractive, possesses more positive and less negative aspects than any other plan, and satisfies the major prerequisite that it stop pollutant migration into the ground waters of the area within a finite time period. The major advantage this plan has over the other plans is the visibility of the DS & G Pit. This visibility will enable the county to prepare a tight bid package and contractors to make a firm bid because they can formulate manpower, material, and equipment requirements and schedules for the rehabilitation and landfilling portions of the plan on the basis of what he has seen and measured as he inspects the site. This type of visibility is not available for the alternative plans which utilize Llangollen as the primary landfill site.

A detailed description of the rehabilitation concept is presented in the following section.

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SECTION V SUMMARY OF PRE-CONCEPT EVALUATION

Refuse Characterization

In January, 1974 five pits were excavated in the Llangollen Landfill in order to evaluate refuse characteristics in the entire landfill. Table 5.1 is a summary of the characteristics of the refuse excavated at the five sites. Figure __ is a graph which shows the relationship of increasing bulk density with depth of the refuse for the same five pits. The bulk density of the Llangollen refuse varies from 650 lbs. per cubic yard for unsaturated surface refuse to over 1800 lbs. per cubic yard for saturated refuse at depth.

With a variable (5 to 20 ft.) saturated thickness, approximately 563,000 cubic yards of the total 1.98 million cubic yards of contained refuse in the landfill are saturated. While the volume of the saturated refuse will not appreciably increase due to unloading during landfill excavation, the unsaturated refuse or approximately 1.42 million cubic yards will expand. The total volume expansion will be approximately 15% after excavation; therefore, the total volume of the excavated refuse may be as much as 2.20 million cubic yards.

Site Selection Criteria and Recommended Location

The following criteria were considered in selecting the new site:

1. A new site must have a capacity to accept more than 2 million yd^3 of refuse.

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2. The new site should be located as close to the present landfill as possible and be readily available and accessible.

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3. The new site must provide adequate thickness of low permeability material between the pit bottom and the top of the Potomac aquifer.

4. The new site should not be located in an area in which refuse deposition below standing water would be required.

5. The new site should be located in an area where the seasonal fluctuations of the water table would have no adverse effect on a liner.

6. If possible, the new site should be located in a relatively isolated area thus providing visual and areal separation between the site and developed areas.

In view of the proximity to the present site, two borrow pits were considered: The Wilson pit to the north and the Delaware Sand and Gravel pit (D S & G, owned by Dell Aversano to the south of the Llangollen Landfill. Evaluation of the two sites on the basis of the above criteria indicated that the DS & G pit should be the primary site for the following reasons: 1) Whereas the Wilson pit is zoned and is being developed as an industrial park, the DS & G pit is presently used as an unlined, uncovered landfill, 2) Access to the Wilson pit would necessarily require crossing the Pennsylvania railroad tracks and the DS & G pit will not, 3) A large number of borings, observation wells and recovery wells, constructed in the area indicate that the thickness of clays and other confining materials separating the Potomac aquifer from the overlying Columbia sands increase to the southeast of the present Llangollen Landfill, 4) The DS & G pit has a thicker layer of confining material between the bottom of the pit and the top of the Potomac aquifer. Clay thickness decreases rapidly to the northwest and the underlying aquifer is close to the land surface. Also, field geologic investigations indicate that clays and sands of the Potomac Formation crop out in parts of the Wilson pit. Absence of clays between the Potomac Sands and the bottom of the refuse in parts of the existing Llangollen Landfill has caused and perhaps accelerated migration of leachate from the refuse to the Potomac sands, 5) Available water level data indicate that the seasonal fluctuation of the water table would have minimum effect on a liner in the DS & G pit, 6) The bottom of the existing Llangollen Landfill is below the water table and as much as 60 million gallons of highly contaminated water (leachate) may drain from the saturated portion of the refuse. Placement of a liner will require lowering the water table several feet below the pit and the liner cushion. Although heavy pumpage can lower the water table during construction, the liner is likely to float due to hydrostatic pressure when the pumps are off, 7) The DS & G pit does have areas where water is standing and in places the floor of the pit is below the water table. However, these areas can be easily dried by pumps and backfilled with existing nearby spoils material. The water level in one pond is maintained by damming Army Creek. The removal of this dam would lower the water level in the Dell Aversano pit, 8) The two sites are almost equally spaced from developed areas, ~~and 9)~~ Based on preliminary evaluation the following nearby areas were considered environmentally unsuitable.

a) Two large gravel pits located around Route 273, adjacent to the Triangle Mall.

b) A tract of land new Dobbinsville.

d) A tract of land near the Delaware National Guard Armory on Route 9.

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Site Limitations and Recommended Controls

In the Llangollen landfill there are at least two distinct areas where the Potomac red clay has been removed, probably during the site's operation as a sand pit. At these points, the underlying Potomac aquifer is in direct hydraulic contact with the saturated refuse. The result is that transport of contaminated water is proceeding directly into the Potomac aquifer and being incorporated into the flow pattern of the Potomac ground water. If utilization of this site were to be considered, additional liner security at these points will be necessary; for example, the areas which are not underlain by a Potomac confining layer would require additions of either additional liner material or suitable clay backfill. In the Wilson gravel pit to the north of the Llangollen Landfill it is felt that because the base of the pit is already at the top of the Potomac Formation, it is not recommended that this pit be used because additional protection material would probably be required in a larger area. In the DS & G pit there still remains, for the most cases, at least five to 10 feet of Columbia sand overlying the Potomac Formation.

Important site controls that will be employed area: 1) the southern confining wall of the DS & G pit will be sloped to a sufficient degree as to be able to accept a liner, 2) large standing bodies of water in the DS & G pit will be backfilled. As part of an overall grading operation during preparation of the site, most of these items will be accomplished. Sufficient fill material remains in the Delaware Sand & Gravel pit in our estimation to enable the contractor to accomplish this. The south boundary wall of the

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pit varies between 30 and 40 feet in height and the side slopes are about 110° in most cases. In some local cases, the side slopes are almost vertical. Backfilling of select material or common borrow in order to realize a minimum of 2.5:1 (horizontal, vertical) grade will be necessary.

<u>Dewatering of Existing and Proposed Sites</u>

It is estimated that approximately 563,000 cubic yards of refuse are saturated. Water enters the landfill in two ways:

a. Infiltration through the landfill surface from direct precipitation.

b. Lateral movement of ground water into the saturated portion of the landfill.

The average annual precipitation in the Llangollen area is 44 inches. Although water addition to the landfill from precipitation is sporadic, it averages approximately 80,000 gpd (gallons per day). Average groundwater inflow by lateral movement is estimated to be 150,000 gpd. When a cell has been excavated, a single storm of one inch rainfall will, however, add approximately 27,000 gallons of water per acre of the excavated area. Depending upon the moisture-holding capacity and specific yield of refuse, the leachate drained from the saturated volume of the refuse could be as much as 60 million gallons.

Existing Site

Dewatering of the existing site will involve removal and disposal of highly contaminated water. Whereas treatment and disposal of the leachate would depend upon the degree of contamination, leachate removal will be accomplished by a combination of sumps, drains and pumping from excavated cells. The landfill will be divided into cells and a sump will be installed in each cell. The sumps will be constructed and operated such that each cell is dewatered as much as possible before excavation of the cell is started. Figure 5.1 shows a conceptual scheme of dewatering the existing Llangollen Landfill.

The leachate pumped from the sumps and excavated cells will re[illegible] ment. It is recommended that the leachate be piped to the municipal interceptor sewer for treatment at the Wilmington Sewage Treatment Plant. Although the regulatory agencies may not permit, short-term release of leachate Army Creek will be the most economical method of disposal during site excavation.

Proposed Site

Dewatering of the proposed site (DS & G) will be accomplished by a combination of the following methods:

1. Cleaning debris which is causing impoundment of water (Army Creek Dam) in the Army Creek.
2. Pumping Dell Aversano pond.
3. Pumping out any standing water in the DS & G pit.
4. Dewatering the upper sand in the DS & G pit.

Since the Army Creek impoundment is providing some treatment to the contaminated water pumped from recovery wells, the Army Creek dam will not be removed initially. The water standing in the DS & G pit will be pumped out using one or two large pumps. If the DS & G pit cannot be dewatered as long as the water level in the Army Creek is maintained at the present elevation, it will be necessary to remove the dam or intercept the ground water between the Army Creek pond and the designed landfill. The ground water can be intercepted by a battery of shallow wells. Dewatering of the upper sand is recommended through the DS & G pit in order to lower water table and to relieve pore pressure from the bottom of the liner. The upper sand will be dewatered by shallow wells.

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V-F Hydrogeologic Controls

Dewatering of the Llangollen Landfill will be continued until most of the refuse has been excavated. In addition to dewatering of the landfill, stormwater diversion berms will be needed both within and along the outer parameters of the excavated cell.

In order to utilize DS & G pit as a lined landfill, it will be necessary to replace all or some of those recovery wells presently located in the pit. The existing recovery and observation wells which will be buried under the refuse must be sealed. At least 16 and as many as 28 wells would require sealing. In that the recovery wells cannot be shutdown for an extended period, the replacement recovery wells must be installed and operating before the existing wells are sealed and the landfill site is prepared. The replacement recovery wells should be installed south and east of the DS & G pit Installation of the replacement recovery wells will require access, acquisition or right-of-way arrangements on property not owned by Dell Aversano. The wells will be constructed as double-cased wells. It is estimated that new wells would be required to replace the present RW-1, RW-2 and RW-4.

Under the existing conditions, surface runoff accumulates in the DS & G pit around and southeast of Observation Well 13. This area also drains to the Dell Aversano pond through a culvert located southeast of Well 27. Site preparation should include constructing berms for storm runoff diversion. In addition to dewatering the Delaware Sand and Gravel pond, it will be necessary to grade its bottom such that no surface water accumulates in it and there is several feet of less permeable material between the liner and the underlying sand.

V-6 Llangollen Pit Rehabilitation

The rehabilitation of the existing landfill site will include either backfilling with select material or allowing the site to remain as essentially a waterfilled pool. Backfilling the site with suitable materials to bring the bottom three to four feet above the water table would require a minimum of 700,000 cubic yards of material, compaction and grading.

It is recommended, therefore, that upon completion of refuse excavation and removal of leachate standing in the landfill, appropriate, less permeable material should be used to spread over the selected areas in the bottom of the excavated pit where natural clay has been removed.

After bottom preparation is completed, the berm that separates the present Army Creek impoundment and the landfill is broken and the excavation site allowed to contain with water. Thus, the present landfill becomes a pond and can be used for recreational purposes in time. This requires regrading the steep banks along the railroad tracks north of the landfill.

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SECTION VI

CONCEPT ENGINEERING

Design Basis

The concept design is based on excavating and moving 1,980,000 cubic yards (563,000 cubic yards of which are saturated) of refuse in an aesthetically pleasing and environmentally acceptable manner from the Llangollen Landfill to a new landfill at the Dell Aversano Site/Delaware Sand and Gravel Pit (DS & G) (includes a small tract of additional land adjoining the site). This plan meets the objective of removing the source of groundwater contamination at Llangollen and not creating any potential for pollution at the new landfill. The landfill at the new site will contain the entire 1,980,000 cubic yards of refuse in an environmentally sound manner utilizing the best available technology for preparation and operation of a landfill.

New Landfill Features:

- Fully lined with a synthetic impermeable liner
- Protective pads for top and bottom of liner
- Leachate collection and conveyance system
- Groundwater interception system
- Groundwater monitor wells
- Final and vegetation cover
- Gas control

See Figures 6-1 and 6-2.

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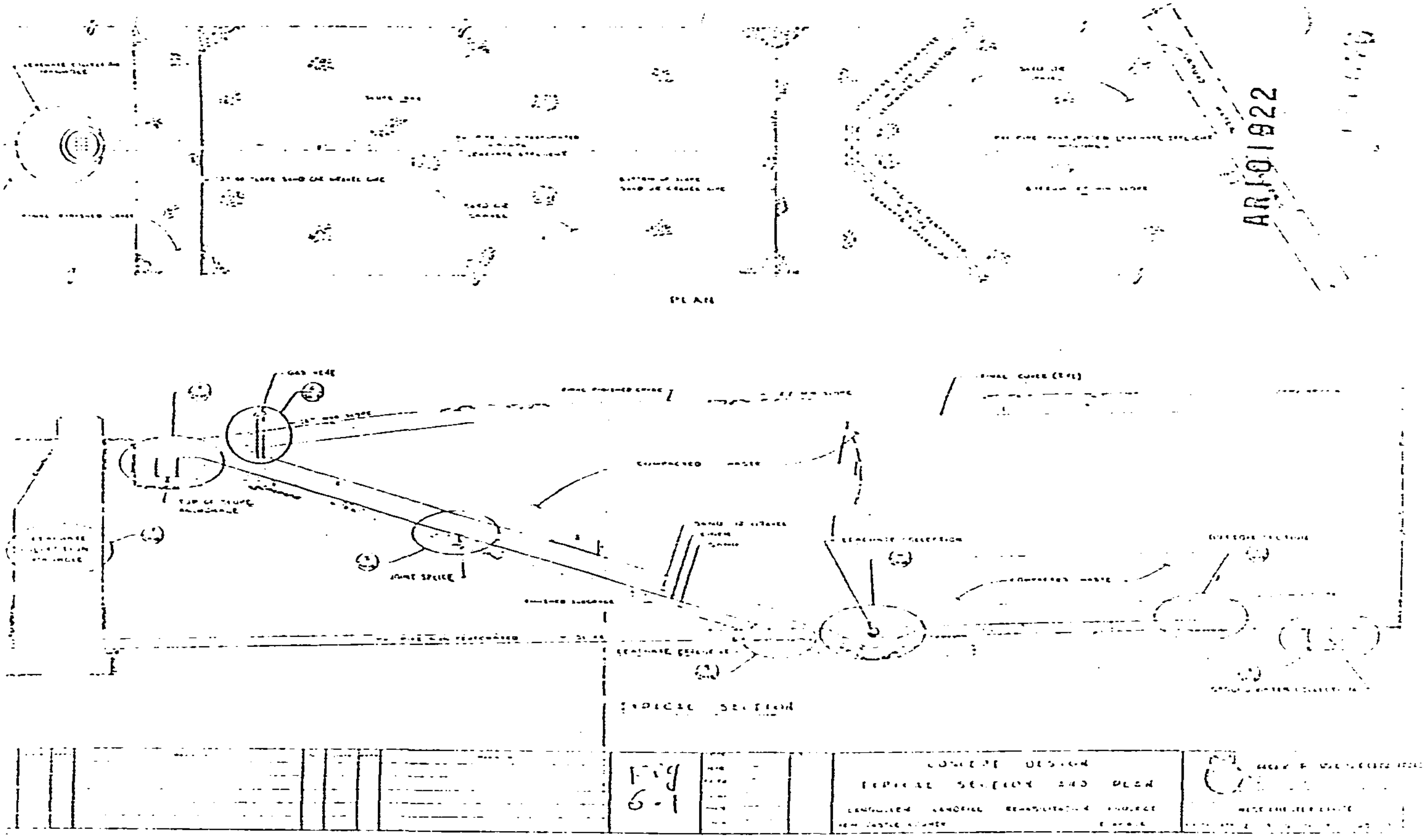

PLAN
TYPICAL SECTION
COMPACTED WASTE
JOINT SPLICE
CONCEPT DESIGN
TYPICAL SECTION AND PLAN
Fig 6-1
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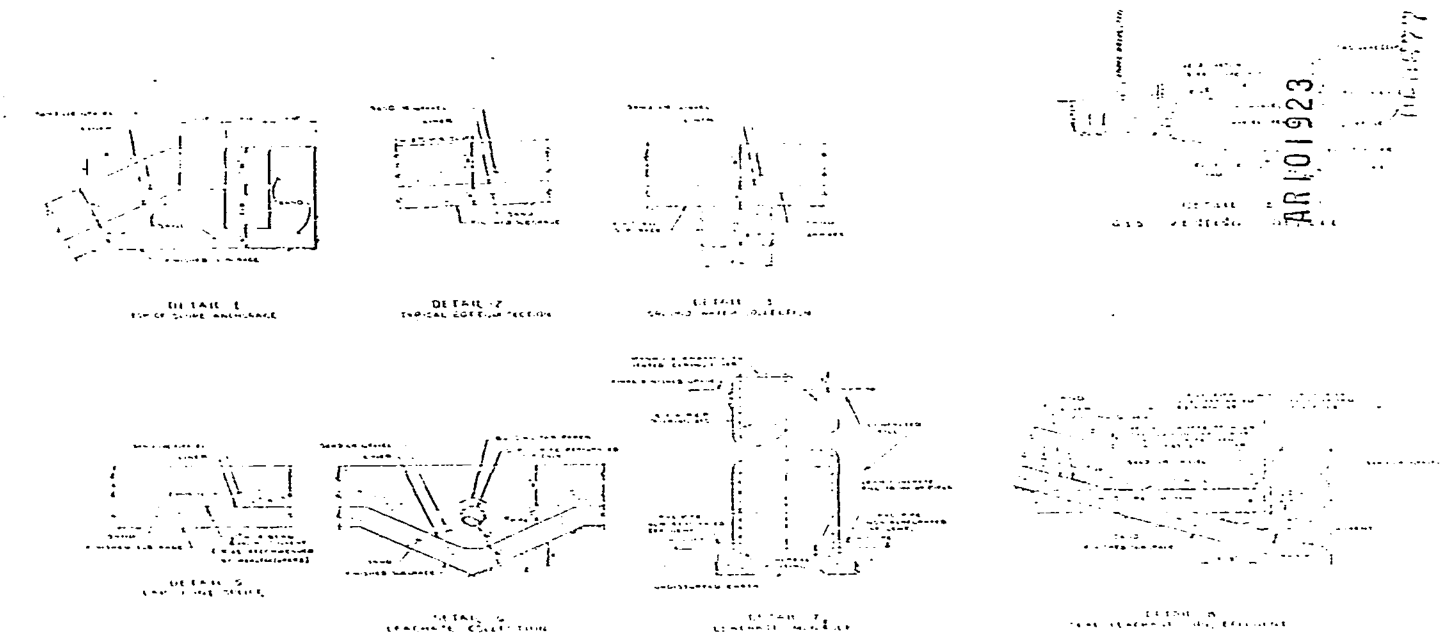

Fig 6.2

CONCEPT DESIGN
TYPICAL DETAILS

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Methods for Refuse Handling

The four types of refuse that will be encountered during the excavation of the Llangollen Landfill are the following:

- Unsaturated municipal and industrial refuse
- Saturated municipal and industrial refuse
- Bulky items
- Isolated packets of hazardous wastes (industrial sludges, waste oils, acidic/caustic wastes).

All of the refuse, with the exception of the hazardous wastes, will be handled by readily available, conventional heavy construction equipment (e.g. front-end loaders, crawler tractors, clamshells, draglines, road graders, and dump trucks). This plan was formulated with equipment of the following sizes: front-end loader, 2.75 to 5 cubic yard bucket; crawler tractor, gross weight 66,000 to 89,000 pounds; clamshells, 1 to 8 cubic yards; draglines, 1.5 to 5 cubic yards; and, dump trucks, 10 to 30 cubic yards.

This plan is feasible with much larger equipment such as reclaiming wheels and electric shovels found at strip mining operations and self-propelled earth movers (23 cubic yard scrapers) and large dump trucks (50 cubic yards) found at highway construction sites. If readily available and if the transportation and set-up costs are low, then this type of equipment would lower both the costs and time required for excavation.

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The majority of the refuse (1,420,000 cubic yards) is unsaturated. Excavation of this dry, compacted refuse is an operation similar to excavating earthen materials. Crawler tractors and front-end loaders will be used to excavate and load the dump trucks. See Figure 6-3. The remainder of the refuse (563,000 cubic yards) is saturated; as much of the water as possible will be removed by the dewatering procedures contained in Section V - SUMMARY OF PRE-CONCEPT EVALUATION.

During refuse mining leachate present in Llangollen Landfill will be controlled. Leachate quantities will be reduced by minimizing infiltration, both lateral groundwater inflow and surface stormwater, and vertical groundwater inflow, by interception utilizing channels and removal by pumping with release to natural drainage devices. Removal of concentrated leachate from the saturated layers of refuse will be accomplished by pumping at strategic locations as discussed in Section V - SUMMARY OF PRE-CONCEPT EVALUATION and releasing the leachate to the municipal sanitary sewer system.

During the landfill reconstruction, small volumes of leachate may be washed away by storm runoff. Most of these streams of contaminated runoff should be intercepted and recycled into the existing landfill or to the sewer. However, it is not realistic to expect that all contaminated runoff waters will be intercepted--some contaminated discharges will find their way into surface waters during the landfill reconstruction. Excavation of this refuse will be accomplished using either draglines or clamshells working from the top on a thin layer of unsaturated refuse. See Figure 6-H. Clamshells appear to be the more versatile piece of equipment in this type of operation. Bulky items (e.g. vehicles, tires, appliances, furniture, etc.) are handled by the crawler tractors/clamshells with an effort made to achieve size reduction in the handling process.

Once a packet of hazardous wastes has been identified special excavation and handling procedures (to be included in the final design package) will be initiated.

All of the refuse, with the exception of the hazardous wastes, will be loaded onto dump trucks. These vehicles then haul the refuse on a specially constructed road over Army Creek to the new site for landfilling.

Odor control will be necessary around the perimeter of the excavation site, at the open excavation face, and at the loading site for the dump trucks. Methods, equipment required, and equipment siting are contained in Section VIII, ENVIRONMENTAL CONTROLS.

<u>Site Preparation</u>

The new landfill, at the DS & G Site, will be prepared utilizing the best available technology in compliance with the Delaware Solid Waste Disposal Regulation (DSWDR). Site preparation will be accomplished in such a manner (maximum use of noise and dust abatement methods) as to have as little effect as possible on the general environment of the area surrounding the site.

The landfill will be prepared in sections as needed: the initial section will be at the east end approximately five acres in size, the other sections will progress to the west and be two to three acres in size. The final product will be a site that has been graded so that all leachate generated will flow (by gravity) through a collection system to the leachate sump(s) (possibly one sump, dependent upon a detailed survey, part of final design package). The site will be dewatered naturally by the removal of the dam across Army Creek or by lowering the water level in the impoundment. This is expected to lower the water table approximately two feet. The bottom will then be regraded and raised if necessary to meet the minimum three (3) feet required between the bottom of the refuse and the seasonal high water table by DSWDR. The detailed survey will generate the information required to calculate the quantities of fill required and the amount of spoil available to prepare the bottom. If there is not enough material available within the site, then some material will be excavated from the additional tract (10 acre minimum and 20 acres preferable) and placed on the bottom.

The final six inches of the prepared bottom will consist of sand and rounded materials (preferably spoil materials or previously unmined sand deposits) that forms a protective layer on which the liner rests. See Figure 6-1 and 6-2. This layer protects the liner from sharp projections, rock fragments, or boulders that might rupture the liner from below during landfilling operations. Incorporated into this pad will be the groundwater

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interception and diversion system which protects the liner from hydrostatic pressure. These materials will be placed using normal construction methods and equipment (e.g. dump trucks, front-end loaders, crawler tractors, and a road grader).

The side slopes of the DS & G site are approximately 1:1.1 (1 foot horizontal to 1.1 foot vertical), which exceeds the maximum allowable slope of 2.5:1 (2.5 feet horizontal to 1 foot vertical) on which synthetic impermeable liners may be placed (3:1 optimal). Material from the adjacent tract will be excavated and placed to rehabilitate the slopes. As material from the adjacent tract is excavated to provide rehabilitation material or cover material or stockpiled, the excavated slopes will not exceed the 2.5:1 maximum. Therefore, when the adjacent tract is prepared for landfilling, only the protective layer will be placed as required.

Next in the landfill preparation procedure is installation of the liner. The recommended liner system is a synthetic liner (e.g. hypalon, DuPont 3110, PVC, etc.;refer to Appendix A for detailed description of liners . This type of liner is delivered in rectangular panels that are rolled or folded into a transportable size. These panels have to be placed, unfolded or unrolled, and spread out to their full size. Once they are positioned, they are seamed together in the field and constitute the continuous landfill liner system. Caution must be used when working under windy conditions, and a crew of up to 10 men will be required to work the larger panels. All edges, whether final or temporary, will be anchored in order to keep the liner in place. (See Figures 6-1, 6-2, and 6-5).

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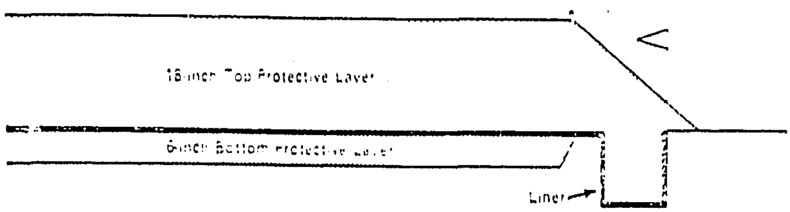
Figure ~~3.1~~ 6-5

Anchor for Leading Edge of Panel



The anchor system consists of placing the liner edge in a ditch (approximately one foot wide and one foot deep) and backfilling with earthen material; temporary anchors should be marked to facilitate relocation. All field seams are inspected to insure that they are of the utmost quality, and the liner itself is inspected for any rough spots, tears or holes. Any rough spots, tears or holes are patched, using patches of the liner material and the appropriate cement or fixative. Improper seams are reseamed. Installation and inspection of the liner are the most important steps in site preparation. The liner is the environmental safeguard and its integrity has to be assured.

After the liner has been placed, seamed, anchored, and inspected, the protective layer for the liner top is placed. This layer is composed of the same materials as the bottom layer, obtained from either stockpiled spoil materials or previously unmined sand deposits. This protective layer averages 18 inches in depth and serves two functions; first, as a protection against objects that are landfilled which might puncture the liner if placed directly upon it, and second as a transport media through which the leachate can flow to the leachate collection system (a grid of perforated PVC pipe). (See Figures 6-1 and 6-2). It is not recommended to drive or operate heavy construction equipment directly on the liner; therefore, placement of the top protective layer starts at one edge of the site, with placement and rough grading moving outward from there so that the equipment is always operating on the rough graded protective layer instead of the liner. After all mater[illegible] for

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a section, the leachate collection system is installed and the surface final graded. The section or area is now prepared for landfilling operations.

Monitor wells will be established to determine direction of groundwater flow and initial quality, and to periodically sample and determine the quality of the groundwater. Since the County has already established monitor and recovery wells in the area with extensive data available, it should be possible to use this data to determine the initial quality and direction of flow of the groundwater. Also, if their location is favorable, these wells might be designated as the official monitor wells. Figure 6-6 shows location of proposed monitoring points.

At this time, it is recommended that an access road be constructed from Llangollen Landfill across Army Creek to the new site. This road will have an all-weather surface and be capable of withstanding frequent traffic composed of heavy construction vehicles. Minimum width will be 22 feet which supports two-way traffic without congestion. Since this road crosses Army Creek, adequate culverts will be included so that runoff from a major storm (24 hour, 10 year) will drain without backup.

Landfill Operation

General

Landfill operations will be carried out in a scheduled, controlled manner adhering to the same aesthetic and environmental factors that influenced site preparation and in strict compliance with the DSWDR. Excavated refuse from the Llangollen Landfill will be transported to prepared areas and landfilled by the area method utilizing the best available technology. Cells and lifts will be delineated and schedules for landfilling operations formulated during final design. The resultant product will be a contiguous mass of well compacted refuse separated only by thin layers of daily cover. This operation provides a means of disposing of the Llangollen Landfill refuse, eliminating that source of pollution without creating any environmental hazards at the new site.

Transportation

All excavated refuse, with the exception of hazardous wastes (to be handled and landfilled separately), will be transported to the new site by dump trucks. Five (5) tons (10 cubic yards) is considered the minimum effective size and approximately 25 tons (50 cubic yards) the maximum effective size for this operation considering the mobility, short haul distance, and need to minimize congestion requirements. Transportation will be via a specially constructed, two-way traffic road that runs from the Llangollen Landfill across Army Creek to the DS & G Site. The road will have an all-weather surface (asphalt, gravel, etc.) and be designed and constructed to handle heavy loads of frequent occurrence. Since saturated refuse, resulting in seepage from the trucks, will be hauled over this road, provisions for the collection of runoff will be established. Throughout most of the operation dust control measures

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will be used and consist of all or some of the following: spraying problem areas with water; applying calcium chloride; and/or spraying areas with the necessary quantities of oil.

Unloading Areas

The scale of operation for this project is of sufficient magnitude to warrant multiple unloading areas. It is recommended that a minimum of three to four areas (one for each crawler tractor utilized) be established. (See Figure 6-7). This type of layout effectively eliminates most of the congestion in the landfilling areas and allows for smoother operations. All unloading areas will be designated by the landfill operations manager or his supervisors on a daily or as required basis. In order to effectively utilize the crawler tractor, the unloading area is not to be further than 30 feet from the working face. The area is to be large enough for the simultaneous arrival, unloading, and departure of more than one of the transportation vehicles.

Mixing of Excavated Wastes

Approximately 25 percent of the refuse is saturated; in order to achieve better compaction and uniformity of the landfilled material the dry wastes will be mixed in the unloading area with the saturated wastes. A mixing ratio in the range of 3:1 to 2:1 dry refuse to saturated refuse will be attained. This is possible since excavation of both materials will occur simultaneously after an initial start-up period, The mixing process is accomplished by the crawler tractor and is simply a procedure of pushing the loads together, with the mixing occurring as the refuse is pushed to the working face and placed.

Placement and Compaction

Placement and compaction of the refuse is by the area method utilizing crawler tractors (or other suitable means of compaction; i.e., sheepsfoot rollers, landfill compactors, etc.). The size of the working face of a cell is not to exceed what can be compacted and covered daily by the equipment. In general, the width should not exceed 100 feet for each crawler tractor. Refuse is spread and compacted in thin layers not to exceed a depth of two feet (compacted material). Maximum compaction is achieved by working the refuse up the slope of the working face and having the crawler tractor make multiple passes over the material.

Individual cells, composed of the compacted two-foot layers, will not exceed a total depth of 10 feet. A lift, by definition, is a layer of cells of common elevation. (See Figure 6-8). Final slope of the lifts is to be greater than two percent, but less than 25 percent to aid in limiting infiltration and erosion. Dust, odor, and vector control programs will be initiated as necessary as discussed in SECTION VIII - ENVIRONMENTAL CONTROLS.

A detailed plan designating location, sequence, and time is to be formulated as part of the final design package.

Daily Cover

At the end of each working day an earthen layer of six inches (compacted depth), is to be placed on the refuse landfilled that day. The earthen material shall be of such character that it can be compacted to minimize percolation of water through the cover, will not crack excessively when dry, and possesses no putrescible material or large objects. At the present, it is felt that sufficient cover material is contained on the additional tract of land that has to be purchased; if this is not the case then it will have to be brought to the site. All daily cover will be periodically inspected and any cracks, eroded or uneven areas will be repaired. Any area on which refuse will not be landfilled for one year will receive two feet of cover material. If cover material of the type described above is unavailable, depths required will be increased to obtain comparable properties.

Leachate Collection and Treatment

The new landfill is a controlled landfill; all leachate generated is contained within the landfill by the liner and cannot enter the surrounding soil and geologic formations, contaminating surface and groundwaters. The quantity of leachate generated is reduced by utilizing means to reduce stormwater infiltration into the landfill (final cover, proper grades, asphalt membrane and vegetation). The leachate is collected by a combination of the protective layer for the liner top and a grid of perforated pipes placed in that layer. Movement of the leachate is through this system to a leachate sump or sumps. From the

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sumps the leachate is released to the municipal sanitary sewer system for treatment at the municipal sewage treatment plant. The above means of leachate control represents the best available technology for municipal-type landfills. Projected flows of leachate are very small when compared to the daily treatment plant flow, much less than the five percent of plant daily flow that might cause plant operational problems. It is expected that pretreatment would be unnecessary, but that a surcharge will be levied against the landfill based on Biochemical Oxygen Demands (BOD) and Suspended Solids (SS) concentrations and the quantity of leachate released. The Department of Natural Resources and Environmental Control requires that leachate quantity and quality data be submitted to the Department when requested; therefore, complete records will be maintained.

Monitor Point Sampling

The monitor points established during site preparation will be maintained during and after landfill operations. Samples will be taken and analyzed, and data submitted to the Department on a quarterly basis.

Subsurface Water Management

Upon completion of the lined landfill, it will be necessary to continue contaminant recovery pumping for several years until contaminants are removed from the aquifer. During construction of the lined facility at the Delli-Aversano Site, a certain number of wells (maximum of 29) would possibly require sealing and abandoning. Since the continuation of pumping

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will be necessary, a plan of contaminant removal well installation will be enacted based upon staging operations of the landfill. Recovery wells will be drilled on a one-at-at-time basis as the need arises. The standard for cessation of pumping will be based upon water quality noted in passive observation wells. When the water quality in these wells approaches USPH standard limits, it will be recommended that recovery wells be shut off permanently. Recovered water will be pumped to Army Creek, thus allowing natural "recirculation" to occur. Shallow ground water, if intercepted, will be conducted along natural drainage paths to a stream discharge point and will not come in contact with leachate in the new landfill.

Limited Access

Access to the entire site (both Llangollen Landfill and DS & G Site) will be limited to employees and those persons specifically authorized access to the site; access by unauthorized vehicles or persons will be prohibited. Gates or barriers and fencing will be used to block all access roads to the site when operations are not being conducted in the area. Other means of limiting access to the area will be provided as necessary.

Communications

Telephone or radio communications will be available at or readily accessible to the site.

Fire Control

Necessary measures will be taken to prevent and extinguish fires; adequate equipment for minimizing fire hazards will be kept on-site.

Sanitary Facilities

Adequate sanitary facilities and shelter will be provided for the employees.

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Accident Prevention and Safety

An operation safety program will be established for the site. All employees will be familiar with this plan, and especially the emergency plan for handling accident victims. In order to minimize the hazards which might cause accidents, it is recommended that the following be included in the above safety program:

- Special attention should be directed towards control of landfill gases and fires.
- Any substances that are suspected to be of a corrosive, flammable or explosive nature should be segregated and handled separately.
- Refuse excavation, transport and placement equipment should be selected and operated in a manner that minimizes fire and explosion hazards.
- Operators should be protected by special clothing and special cabins in the landfill equipment.
- Alarm and first-aid equipment should be available at several points on-site.
- Frequent inspection and tight supervision are a key element in maintaining acceptable safety practices throughout the project.

Salvage and Scavenging

There will be no salvage or scavenging operations at the new site.

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Final Cover

All areas which are at final grade will receive a final cover of earthen material. This material will have the same properties as the daily cover and will be compacted to a minimum thickness of two feet. Final slopes will not be less than two percent or greater than 25 percent. All final cover will be seeded with the appropriate vegetative cover to reduce dust, infiltration, and erosion. The final cover will be maintained so that no cracks, eroded or flat areas are allowed to develop or remain. The final cover will be underlain by an asphaltic membrane to further minimize infiltration.

The final topographic features of the completed landfill site (both the Llangollen Landfill and the new site) will be developed in the final design. One concept is presented in SECTION VII - COMPLETED LANDFILL REUSE.

Erosion and Sedimentation Control

Until the new landfill is completed and the vegetative cover established, provisions for sedimentation and erosion control will be provided. New landfill areas will be designed in a manner that minimizes entry of run-off waters into active cells. Figure 6-8 illustrates means of runoff water diversion away from the working areas. Drainage devices consist, basically, of runoff diversion channels at the completed areas and diversion channels at the end of the prepared area. Collected runoff waters will then be diverted to natural surface water drainage streams.

Completed landfill areas will be designed in a manner that minimizes erosion and sedimentation problems. The following means of controls are recommended:

- Drainage channels, designed to handle the 25 yr./24 hour storm.
- Terracing steep slopes (over 20%) every 25 ft. of height.
- Construction of sedimentation ponds for silt removal from finished (and unvegetated) areas, at 0.6 inches per acre of disturbed area, until vegetation is established.
- Final cover will be placed on finished landfill areas, and vegetation cover will be established to minimize erosion of final cover.

The final design (based on final topographic features) will include these provisions; once the vegetative cover is established these provisions can be eliminated.

Gas Control

Lateral migration of decomposition gases is controlled by the liner with movement upward through the porous protective layer. Gases along the perimeter will be vented to the atmosphere through a series of pipes placed through the final cover, into the sand layer. A grid of vents will be installed over the entire surface of the landfill to aid in the venting of gases.

VII. COMPLETED LANDFILL REUSE

Alternatives of Reuse

Appendix D of this report includes a detailed discussion of alternative reuse plans for the rehabilitated Llangollen Landfill.

Four general objectives for landfill reuse were utilized as evaluation criteria: (a) maximizing site utility, (b) compatibility with land use plans and regulations, (c) assuring environmental control and (d) minimizing cost of implementation and annual operation.

Major alternatives for reuse evaluated include (a) recreational use (park with or without a lake, golf course or pitch and putt course), (b) cultural use, (c) industrial or residential use (industrial park, residential housing or new landfill on the old Llangollen site) and (d) "do nothing" alternative.

Technical and economic evaluation of the above alternatives favors site reuse for passive and active recreation, including lake and/or pond.

Site Development

Site development and related costs can be broken down into three categories:

- Site Preparation and Landscaping - Cost items would include trees/revegetation, rip-rap at the inlet and outlet of the lake, additional cover material as needed, etc. These items represent between 10 and 25 percent of the total investment.

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- Activities - Activities would include items such as trails, footbridge, picnic area, sports field, playfield, tennis complex, and perhaps a boat launch and swimming beach. Renovating the Grantham house in a historical context could also be considered. This category at cost would represent between 20 and 40 percent of the total capital expenditures for reuse.

- Support Facilities - This category encompasses items like roads, parking, maintenance building, utilities, litter baskets and signs. These costs represent between 35 and 55 percent of the total reuse investment.

Figure 7.1 is a Conceptual Reuse Plan of the entire site. As shown on the map, the total site of 102 acres would be divided into approximately 34 acres of lake and pond, and 68 acres of land.

Generally, activities associated with active use increase as one proceeds eastward on the site. This accommodates residents of Llangollen Estates as well as placing active use facilities adjacent to parking and the existing access road, Grantham Road. The nature area and playfields would be due north of Llangollen Estates. The sports fields, tennis complex and maintenance building would be north of the planned industrial use area. A wooded picnic area would provide a buffer between the predominantly active-use area to the east and the predominantly passive-use to the west. The picnic area would contain the only extensive wooded

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area not bordering the lake. This localizes the need for increased soil depth on the new site, thus minimizing the complexity of the landfill operation during the rehabilitation project.

A pedestrian and bicycle trail circumscribes the lake and pond, thus facilitating access to all points in the park. The land bordering the railroad tracks extends southward into the water areas at two points. The extended land area on the west forms the fish pond, and the one on the east breaks up the monotony of the northern slope. Together they add an aesthetically pleasing view to people south of the lake and encourage full utilization of the park. A grassy mound, located at the southeastern corner of the park, provides a visual barrier to neighboring industrial development while functioning as a "look-out" point for the entire park. Snow sledding in the winter would also be possible.

Implementation Strategy

(1) First and foremost is the design and acceptance of a reuse plan. This must be accomplished prior to design of the rehabilitation plan to assure economy in the entire program. (2) The sequence of the rehabilitation operation should proceed in a manner which will enable park development to occur over a period of time. (3) At the completion of rehabilitation, the slopes will have been seeded. Park development should begin with establishment of the lake and pond configurations, followed by revegetation and construction of the pedestrian and bicycle trail. (4) Active-use areas are better developed after revegetation has been firmly established and initial settling has subsided. (5) Building

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the boat launch (for small sailing craft) and the swimming beach would best be accomplished last, and after the lake and pond have reached equilibrium and are proven safe.

In summary, site reuse and its development could commence immediately after rehabilitation. Final development can occur at the discretion of the Department of Parks and Recreation and in accordance with the County's desires. Final development may extend into the fifth year or later after the completion of the rehabilitation project.

The ultimate result of reuse development will be an excellent park resource--one the County can be proud of owning and one the community and surrounding district can enjoy for years to come.

VIII ENVIRONMENTAL IMPACTS AND CONTROLS

General Requirements

It is most appropriate to call the Llangollen Landfill renabilitation an "environmental control program", since the sole reason for it is the abatement of groundwater contamination by landfill leachate. Consequently, high emphasis is placed on special environmental controls through the landfill rehabilitation program. Several environmental problems are envisioned during landfill construction phases: odor, leachate, contaminated runoff, fires, blowing litter, vectors, wildlife, operator safety, etc., are of major concern. This section of the report defines such problems and recommends remedies for their control.

The criteria for selecting various environmental controls was based on: economics, effectiveness, practicality, acceptability to the public and environmental agencies, and flexibility of operations. However, it is important to emphasize that most of these controls will not eliminate the problems, but will rather minimize their impact on the environment, local residents and construction personnel. It is expected that, even with the controls, some adverse impacts and inconveniences will result from relocation of the Llangollen refuse. However, with proper controls and public relations it is expected that local residents and environmental agencies will tolerate these temporary inconveniences, especially when they realize that the program will result in tremendous environmental and aesthetic benefits to the community.

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Odor and Nuisance Impacts and Control

An important environmental consideration in the Llangollen Landfill relocation is the control of malodor from partially decomposed refuse. A positive odor control program is necessary.

Additional environmental nuisance problems must also be considered. These include fugitive dust, rat and fire problems.

The odor problems that will be experienced during the landfill relocation are of such an extent that collection and venting the odors to control devices are not feasible. The cost for destruction of the malodors by adsorption, combustion or absorption would be unreasonably high. Additionally, it is not technically feasible to implement collection of the malodorous air volumes. Counteracting the malodors with chemicals is a technically and economically feasible odor control. Nearby residents should be protected by:

(1) Constructing a chemical screening system between the landfill and nearby residences.

(2) Spraying refuse with odor-modifying chemicals.

This type of odor control program has been successfully completed at the Buffalo, New York landfill. At this landfill, two million cubic yards of buried solid wastes were dug up and transported six miles to another landfill site. (See Appendix F)

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The chemical screening system is implemented by vaporizing odor-counteracting, aromatic chemicals through orifices in pipe which is laid around the landfill perimeter between the odorous sources and the residences. At Llangollen, approximately 4800 feet of pipe (stove pipe) would be necessary to implement the chemical screening between the landfill and nearby residences at Llangollen Estates and Wilton and the commercial and business establishments along Route 13 (see Figure 8.1). Twenty-four hour per day screening could be implemented.

In addition to the chemical screening system implemented at the Buffalo landfill, these systems have been installed at sewage treatment plants, mushroom composting operations and cattle feed lots--all malodorous operations.

In addition to the odor screening system, spraying the refuse with odor-abating chemicals is also proposed as an integral part of the positive odor control program. The landfill operating face should be sprayed with the water soluble odor abating aromatic chemical mixture. Only on-site experience can dictate the frequency of spraying the open face, however,

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this spraying should be conducted at the end of each working day. The excavated material should also be sprayed after the refuse has been loaded onto trucks. To further reduce odor potential all loads should be covered with a tarp after spraying. The roadway should also be periodically sprayed with the chemical solution. This will be necessary especially after wet refuse has been transported. The new landfill working area may also need to be sprayed occasionally. At the end of the working day, all truck beds and operating equipment should be sprayed with the odor-abating chemical solution.

A spray truck, of 1,000-2,000 gallons capacity, containing the odor-abating chemical solution, must be available for use as needed. It is possible that all loads may not need to be sprayed and that the working faces and the roadways may need spraying only intermittently.

Based upon previous experience, it has been estimated that as much as 60,000 pounds of odor-counteracting chemical may be necessary to spray onto the excavated material.

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It does not seem feasible to totally eliminate all malodors during the landfill relocation. Thus, Weston recommends several other measures:

1. The refuse in the new landfill must be completely covered with clean soil <u>each</u> evening.
2. The landfill relocation time should be reduced as much as possible, either by working both ends of the landfill simultaneously <u>or</u> by using more equipment to double the amount of refuse removed.
3. A public relations effort should be conducted among the nearby residents to explain the short-term inconveniences (i.e., malodors,) long-term improvements (i.e., elimination of water pollution, construction of a green area, etc.).

An adjunct environmental problem will be that of dust control. Fugitive dust caused by truck traffic and landfilling operations must be controlled. A spray truck should be provided--a separate truck from the odor control spray truck--in order that the roads and open ground areas may be sprayed. The main roadway between the landfills should be oiled and re-oiled at intervals to prevent fugitive dust emissions.

The second spray truck should also be utilized as fire-fighting equipment to douse small fires or contain larger fires until fire fighting equipment arrives at the landfill. It is possible that fires may occur, due to ignition of trapped methane gas from decomposition of garbage and/or the

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waste oils and chemicals that have been disposed of at the landfill. Provisions for fire-fighting equipment can readily be made with the spray trucks that will be at the landfill for odor and dust control.

We also recommend that all loading equipment have air-conditioned cabs for the operators to protect against possible fire hazards. Additionally, truck drivers and other personnel must not enter the working areas while excavation and loading is under way. This prohibition should be enforced, not only for fire protection but for general safety reasons.

It is expected that as the landfill is disturbed, rodents, especially rats, will be a problem. These rats will invade nearby residences if no rodent control program is implemented. Thus, it is necessary to conduct a positive rodent control program. A subcontractor who is in the rodent control business should be hired for the duration of the project.

ECOLOGICAL IMPACTS AND CONTROLS

Ecological Impacts

1. Short-term Biological Implications of relocation of the Llangollen landfill and development of lake on local biological habitats will, understandably, be adverse. Existing terrestrial flora and fauna will either be destroyed or displaced throughout the areas of the proposed new lake and landfill. Some disturbance of ecological systems adjoining the project area will also occur. Motile species such as small mammals, birds, reptiles and snakes may be able to migrate to surrounding woodlands and marshes to avoid construction impacts, but such action will generally meet with increased competition for space and food and, thus, reduced overall population levels.

Terrestrial communities will be adversely impacted by physical removal, changes in ground water levels during construction, and dust generation.

Aquatic communities within Army Creek and Pond will suffer negative impacts from construction of roads, erosion from the reopened landfill, degradation of water quality, noise, and dust. However, several valuable mitigating measures are available for the proposed project which would minimize or eliminate adverse biological effects.

2. Long-Term Ecological Implications for development of the new lake on the present Llangollen Landfill site will definitely be a benefit to the area's ecological communities.

long run. Army Pond is presently in an advanced state of eutrophication; water quality is poor; sedimentation rates are high; emergent vegetation covers the upper 25% of the pond; and thick, organic deposits render most of the benthic environment devoid of aquatic life.

Present aquatic species are limited to carp, turtles, and a few snakes (See: Biological Assessment of Army Creek, 8 December 1975, in Appendix E). The pond and downstream areas are obviously adversely impacted by leachate from the landfill, producing decreased species diversity and population abundance. If left in its present state, Army Pond would become a swampy marsh in five to ten years, soon to be followed by succession into a shrub-woodland habitat.

However, long-term ecological concepts of lake management must be considered so as to produce a viable recreational and sports fishing resource rather than a eutrophic, polluted waterbody similar to Army Pond.

Incoming water quality via Army Creek is poor; mitigation measures should be taken to reduce the impacts of high nitrate, phosphate, suspended solids levels, and biochemical oxygen demand on the proposed new lake. Furthermore, suspension of organic particles in the water column during landfill excavation and deposition of rich sediments from the present pond into the future lake must be avoided or minimized. Success of a balanced, ecologically diverse lake will depend on: minimizing adverse impacts on adjacent ecosystems, improvement of water quality entering the lake via Army Creek and ground water inflow, prevention of dumped or natural leachate entering the lake during developmental stages, prevention of organic mud from Army Pond entering the lake, establishment of shoreline-stabilizing vegetation, and stocking of sports fish.

Use of land presently occupied by the sand and gravel operation for the proposed new landfill will entail few adverse environmental impacts. Present lack of vegetation and wildlife over most of the site allows for little disturbance of indigenous biota. Lining of the new landfill with clay or plastic sheeting will prevent leachate from entering Army Creek or from contaminating nearby terrestrial habitats. Seeding and planting of the finished landfill will be necessary to provide renewed biological and recreational uses of the area.

B. Mitigating Measures

1. Water Quality

In order to maximize the life and biological productivity of the new lake, incoming water quality will have to be maintained at high levels. Nutrient-rich waters would accelerate growth of phytoplankton and rooted aquatic plants and thus speed up the aging and filling-in of the lake. Further, sports fish such as largemouth bass, sunfish, perch, walleye, catfish and others would not long be able to endure conditions as undesirable as those of Army Pond.

Water quality may be greatly aided by construction of one or more one-acre catch basins on Army Creek upstream of the lake. Such acti[illegible] suspended solids to settle and provide a mechanism of nutrient uptake by plankton and plants in these settling basins before such substances flow into the lake. Also, water presently in Army Pond, containing dilute pumped leachate and large concentrations of solids, must not be allowed to flow into the new lake. Rather, the pond should be drained via the existing stream and be allowed to empty into the Delaware River.

2. Sedimentation.

Suspended particles will, without question, enter the new lake via inflows, leaf detritus, stormwater runoff and in situ production of plankton and algae. However, it will be of great advantage to minimize the amount of sedimentation existing after completion of lake construction. This is important since sediments sequester and release nutrients and organic materials, thus promoting excessive plankton blooms and producing low levels of dissolved oxygen. Sedimentation can be minimized by: building check dams and catch basins upstream, drainage of Army Pond water away from the new lake, and removal of the thick organic deposits presently found in Army Pond before that area is tied into the new lake. Lack of removal of the one-to two-foot thick layer of organic detritus would have serious negative impacts on the future aquatic community of the lake. Further beneficial impacts on water quality and sedimentation will be provided by removal of the salt, sand, and cinder piles stockpiled by the Delaware Department of Highways along the western edge of the landfill, near Army Creek. Such substances will invariably be washed into the receiving stream during heavy rains.

3. Terrestrial Habitats.

Insofar as the newly developed facilities will consist of a lake with adjoining park, all possible efforts at minimizing damage to existing woodlands and vegetation should be exercised. Tree borders, small woodlands and fence rows should not be damaged during construction. Not only would existing woods around the existing landfill provide valuable aesthetic highlights to the lake and park, but such trees and shrubs will minimize erosion, improve bank stabilization, provide overhanging areas of shade for aquatic fauna, harbor many forms of birds and small mammals, and provide very significant natural seed sources for rapid revegetation of the area after completion of the project. Road construction between existing and future landfill areas should be conducted over grassy or marshy areas, avoiding the small woodlands of the site wherever possible.

Maintenance of existing vegetated areas will also be likely to aid in rodent (rat) control. Hawks and owls presently reside and hunt in the project area. Their activities may very likely increase significantly as the rodent population increases to make use of the newly-opened landfill.

4. Aquatic Habitats.

Draining and dredging of Army Pond will cause drastic reductions in or elimination of, present populations of fish, amphibians, reptiles, and invertebrates; and will affect those species (raccoons, birds, and snakes)

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feeding on the above. Such impact is unavoidable, but not considered of major consequence due to the stressed condition of the pond habitat as a result of leachate inflows. Many species will quickly find their way from Army Pond to early fragments of the new lake as the latter is dug and filled with water. Other species, notably fish and invertebrates, will recolonize the lake from populations existing upstream and downstream. Forage and sports fish (bass, sunfish, walleye, pickerel, catfish, and others) will, however, have to be imported and stocked, since these species either do not thrive in the small Army Creek or would not be expected to be able to migrate into the new lake from downstream. The fish-stocking program will have to be monitored to assess the types of fish best able to survive in the new lake and to develop breeding and shelter structures best suited to their needs. Selective planting or introduction of aquatic plants or emergent vegetation cover and habitat for the various fish and invertebrate species.

Section IX
Preliminary Cost Estimates

_sis of Cost Estimates

The cost estimates for the recommended alternative .e been prepared using base data obtained from e Weston estimating section which is valid for Llangollen area. The following costs are preliminary; al cost estimates will be prepared during rmulation of the bid package and the final esign. All unit costs for a category include the costs ociated with the materials and equipment apital, maintenance, and operating) utilized to repare or complete that activity.

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Capital and Construction Costs

Prepare Dell-Aversano site

a) Regrade bottom
266,000 yd² @ 0.45 $/yd² — $ 120,000

b) Rehabilitate side slopes
material available on site
142,000 yd³ @ 1.40 (in place) $/yd³ — 200,000

c) Groundwater provisions
20,000 linear feet of trench
2 ft by 2 ft filled with crushed stone
3,000 yd³ @ 6.50 $/yd³ — 20,000

d) Leachate collection
2 sumps @ 100,000 $/sump — 200,000

e) Liner
300,000 yd² @ 5.00 $/yd² (installed) 1,500,000

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f) Excavate additional tract
less material used for slope rehabilitation
260,000 yd³ @ 0.57 $/yd³ — 150,000

2. Excavate Llangollen

a) Dry refuse
1,417,000 yd³ @ 0.27 $/yd³ — $ 380,000

b) Saturated refuse
563,000 yd³ @ 0.87 $/yd³ — 490,000

Subtotal — $ 870,000

Transportation of excavated material
swell factor 15 percent
1,980,000 (1.15) yd³ @ 0.30 $/yd³ — $ 680,000

4. Landfill operations at new site
2,280,000 yd³ @ 0.51 $/yd³ — $ 1,160,000

5. Land cost
65 acres total (45 Dell Aversano and 20 additional tract) — $ 200,000

_. Llangollen site dewatering — $ 250,000

1. Odor control — $ 250,000

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_ Repair Llangollen bottom — $ 100,000
20,000 yd³ @ 5.00 $/yd³

9. Vegetative cover for all disturbed areas
70 acres @ 700 $/acre — $ 59,000

10. Miscellaneous (vector control, dust control, road, sewer surcharge, asphalt membrane) — $ 250,000

Subtotal — $ 6,000,000

11. Contingencies, Engineering, Legal and Administrative costs — $ 1,000,000

Continuing Operating Costs

Continuing operating costs consist of recovery well operation/maintenance, revegetation, landfill cover maintenance, sewer surcharge, etc..

Costs
5 years @ 200,000 $/year — $1,000,000

Total cost of the project over five year time period (majority of the expenditures occur within the first three years) — $ 8,000,000

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X CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Groundwater Quality in the vicinity of the Llangollen Landfill is degraded by leachate migrating from the landfill. In spite of the recovery programs leachate will continue to migrate towards major water users in this region, where a water deficit has been forecast.

2. Groundwater Pollution can best be controlled by removal of the source of contamination (Llangollen refuse) and by recovery of contaminants which are already in the Potomac aquifer by operating a battery of recovery wells at the vicinity of the existing site.

3. The Public Interest can best be served by prompt county action to put an end to the source of groundwater pollution. Such action will result in protecting and restoring the county's water resources meeting demands on potable water, and in net savings to taxpayers, in the long term, due to loss of groundwater supplies if no controls were implemented.

4. Alternatives of Source Control include hydrogeologic isolation of the landfill, incineration of Llangollen refuse, disposal of refuse in the Atlantic Ocean or in Pigeon Point landfill and rehabilitation (reconstruction of the Llangollen Landfill.

5. Technical and Economic Analysis of control alternatives favors control of groundwater contamination by removal of the Llangollen refuse and replacing it in a lined landfill, and by continuing the [illegible] until groundwater quality is restored to an acceptable level.

6. Technical and Economic Factors favor the Delaware Sand and Gravel Pit (DS & G), owned by Dell Aversano, as the new location for the Llangollen refuse.

7. Llangollen Landfill Rehabilitation plans consist of: preparation of a new site; transfer of refuse; placement, compaction and cover, collection and treatment of leachate; management of surface and subsurface waters; and rehabilitation of the Llangollen site and the new site to a high-quality recreational area.

8. Cost of The Recommended Plan is estimated as $6 million plus $1 million for contingencies and legal, engineering, and administrative costs, a $200,000 per year (for an additional five years) for pollutant recovery, leachate treatment and landfill maintenance.

9. Benefits of the Recommended Plan include: technical feasibility, cost effectiveness, control of groundwaters pollution, low operating effort and cost, relatively short time frame for completion, net savings to taxpayers over other alternatives and rendering the finished areas suitable for beneficial used (such as high-quality recreation).

10. Reuse Options for Finished Areas include converting the new landfill site into a park and the Llangollen site into a lake. Recreational facilities would include picnic areas, bicycle and hiking trails, a bathing beach and boating facility.

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11. <u>Environmental Controls</u> during the rehabilitation program include odor, dust rodent and fire control, management of surface and subsurface waters, collection and treatment of leachate, ecological controls.

12. <u>After Completion of the Rehabilitation Program</u>, the county will have to continue operating the recovery wells (for about 5 years), monitor groundwater quality, maintain the landfill surface by regrading and revegetation, and remove collected leachate in the municipal sewer.

<u>RECOMMENDATIONS</u>

1. <u>Review Concept Report</u>. It is recommended that the county review the concept report and communicate any comments to the Weston Project Team.

2. <u>Request Funds</u>. It is recommended that the county request funds for the rehabilitation project.

3. <u>Engineering Design</u>. It is recommended that the county authorize engineering design and bid package preparation for the rehabilitation project.

4. <u>Acquire New Site</u>. It is recommended that the county acquire land, as delineated in this report (by condemnation rights) for relocation of the Llangollen refuse.

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5. Permits. It is recommended that the county submit this report to the Delaware Department of Natural Resources, (DNR) for their review and "approval-in-concept" on the rehabilitation program. Official permit application can be submitted to DNR during the engineering design phase of this project.

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ALTERNATIVES FOR LANDFILL REHABILITATION

General

Four alternative plans were developed for the rehabilitation of Llangollen Landfill utilizing the basic considerations listed in Section III, BASIC REHABILITATION PLAN. Primary emphasis was placed on the plan being technically and economically feasible while providing a permanent solution to the aquifer contamination problem within a finite time period. The alternative plans were developed, evaluated in detail, and one plan recommended. The following subsections present the alternative plans, technical evaluations, economic evaluations, and the recommended plan.

Each of the four alternative plans is technically feasible and correct, utilizes the best available technology for landfill operations, and complies with the State of Delaware's regulations on solid waste disposal. However, within each alternative plan there are positive (pros) and negative (cons) aspects which are listed in this section.

Alternative Plan A (Transfer Portion of Refuse to Pigeon Point)

This plan consists of transportation of an initial quantity of refuse to the Pigeon Point Facility for disposal with utilization of a rehabilitated Llangollen as the landfill site for the remainder. See Figures 4-1 and 4-2. Landfill rehabilitation (reconstruction) will be achieved, under this plan, as follows:

- Excavate initial quantity of refuse (recommended starting point west end, surface area approximately 8 acres/volume 300,000 cubic yards) transport over the road to the Pigeon Point Facility.
- Prepare vacated area for landfilling operation (bottom and slope rehabilitation, ground water interception system, liner installation, and leachate collection system.
- Excavate additional Llangollen refuse and landfill in newly prepared area.
- As new areas become vacated, prepare as described above for future landfill operations.
- After the Llangollen refuse has been excavated and land-filled in a rehabilitated Llangollen, placement of final cover and means for minimizing infiltration (e.g., asphalt spraying).
- Establishment of vegetative cover (landscaping).
- Use as a recreational green area.

Positive Aspects (Pros)

- No additional land has to be acquired.
- All construction and landfilling activities at one site; any environmental controls required (i.e., ground water interception, leachate collection, odor, etc.) would be minimized in comparison to operating two sites.

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- Construction and rehabilitation procedures will not cause any change in the monitor and recovery well systems.
- This plan offers a definite solution to the aquifer contamination problem at Llangollen. Upon completion of the landfill, leachate can no longer enter the aquifer and the aquifer will be cleansed by natural infiltration over a period of time.
- Completed landfill will be a useful recreational green area for area and county residents.

Negative Aspects (cons)

- Hauling portion of refuse (15%) to the remote Pigeon Point Facility upsets the economies of scale due to the use of over-the-road haul vehicles and loss of a portion of Pigeon Point's available volume.
- Site dewatering process has to be complete and continual so bottom areas will be dry enough for rehabilitation. Excessive volumes of fill material will be purchased and placed to raise the bottom above the water table (360,000 cu. yds.).
- All side slopes have to be rehabilitated; photographs of the Llangollen pit before landfilling indicate slopes greatly exceed the recommended maximum of 2.5:1 (2.5 feet horizontal to 1 foot vertical). Large volumes of fill material (120,000 cu. yds.) will be purchased and placed to correct existing slopes.

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- Excavation and landfilling operations within the same site increase traffic congestion problems.
- Where the natural clay confining layer has been disrupted or removed double lining will be necessary.
- Cover material will be purchased (160,000 cu. yds.); none available on-site.
- Impossible to formulate a tight bid package and receive firm bids from contractors (bids will have to contain contingencies to compensate for the possibility of unforseen problems).

Cost Of Alternative Plan A

Site Preparation	$1,790,000
Landfill Liner and Leachate Collection	1,660,000
Refuse Excavation	870,000
Refuse Transport--Pigeon Point	830,000
Refuse Transport--Llangollen	580,000
Gate Charge--Pigeon Point	470,000
Refuse Placement, Compaction, Cover	1,040,000
Hydrogeologic Controls	250,000
Odor Control	250,000
Sealing Llangollen	100,000
Landfill Vegetative Cover	50,000
Miscellaneous	330,000
Subtotal	8,220,000
Contingencies, Engineering, Legal, and Administrative Costs	1,000,000
Continuing Costs	1,000,000
TOTAL	$10,220,000

Alternative Plan B: (Transfer Portion of Refuse to DS & G Pit)

Alternative Plan B - Transportation of an initial quantity of refuse to a prepared site at the Delaware Sand and Gravel Pit (DS & G) with utilization of a rehabilitated Llangollen as the landfill site for the remainder. See Figures A-3 and A-2. This concept will be achieved by the following steps:

- Acquire a portion of the DS & G Site (minimum of 15 acres).
- Prepare the site for landfilling operations (as described in Plan A).
- Excavate initial quantity of refuse at west end (approximately 8 acres/300,000 cubic yards), transport to DS & G Site.
- Prepare vacated area for landfilling operation (as described in Plan A).
- Excavate additional Llangollen refuse and landfill in newly prepared area.
- As new areas become vacated prepare them for future landfill operations.
- After all refuse has been excavated and landfilled in a rehabilitated Llangollen, placement of final cover, landscape and prepare for final use.

Positive Aspects (Pros)

- Having the majority of the construction activities [illegible]

- Economies of scale are realized.
- DS & G site is visible; this part of operation readily defined and evaluated.
- This plan offers a definite solution to the aquifer contamination problem at Llangollen.
- Completed landfill will be a useful recreational green area.

<u>Negative Aspects (Cont)</u>

- Have to acquire additional land (minimum of 15 acres).
- Dewatering process has to be complete and continual so bottom areas will be dry enough for rehabilitation.
- Side slopes at both Llangollen and DS & G site have to be rehabilitated; existing slopes exceed by far the recommended maximum of 2.5:1 (2.5 feet horizontal to 1 foot vertical); Fill material will be purchased to obtain required slopes (160,000 cu. yds.).
- Excavation and landfilling operations within the Llangollen site increases traffic congestion problems.
- Where the natural clay confining layer has been disrupted or removed at Llangollen double lining will be necessary.
- Cover material for both sites will be purchased (190,000 cu. yds.).
- Have to construct road network to DS & G Site.
- Final product two landfills (two ground water interception diversion system, two leachate collection and conveyance systems, etc.

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- Construction and landfilling will cause the removal, grouting, and relocation of some of the monitor and recovery wells.
- Impossible to formulate a tight bid package and receive firm bids from contractors. (Bids will have to contain contingencies to compensate for the possibility of unforeseen problems).

Cost of Alternative Plan B

Site Preparation--DS & G	$ 130,000
Site Preparation--Llangollen	1,790,000
Landfill Liner and Leachate Collection--DS & G	450,000
Landfill Liner and Leachate Collection--Llangollen	1,660,000
Refuse Excavation	870,000
Refuse Transport	680,000
Refuse Placement, Compaction, Cover	1,170,000
Hydrogeologic Controls	250,000
Odor Control	250,000
Sealing Llangollen	100,000
Landfill Vegetative Cover	70,000
Miscellaneous	380,000
Subtotal	$7,800,000
Contingencies, Engineering, Legal and Administrative Costs	1,000,000
Continuing Costs	1,000,000
TOTAL -	$9,800,000

Alternative Plan C. (Temporary Storage of Portion of Refuse)

Alternative Plan C - Transportation of an initial quantity of refuse to a temporary storage site at the opposite end of Llangollen with utilization of a rehabilitated Llangollen as the landfill site for all the refuse. See Figures A-4 and A-2.

- Excavate initial quantity of refuse, recommended starting point west end, (approximately 8 acres/300,000 cubic yards) transport to a temporary storage site at the opposite end (recommended east end), wastes stored in this fashion will be compacted and covered, and provisions provided for collection and treatment of surface runoff and drainage.
- Prepare vacated area for landfilling operation.
- Excavate additional Llangollen refuse and landfill in newly prepared area; also, landfill a portion of the stockpiled waste.
- As new areas become vacated prepare them for future landfill operations.
- After all refuse has been excavated and landfilled in a rehabilitated Llangollen, place final cover, landscape and prepare for final use.

Positive Aspects (Pros)

- No additional land has to be acquired.
- All construction and landfilling activities at AR104975

- Construction and rehabilitation procedures will not cause any changes in the monitor and recovery well systems.
- Do not have any hauling to a remote site.
- Full economies of scale are realized.
- This plan offers a definite solution to the aquifer contamination problem at Llangollen. Upon completion of the landfill, leachate can no longer enter the aquifer and the aquifer will be cleansed by natural infiltration over a period of time.
- Completed landfill will be a useful recreational green area for area and county residents.

Negative Aspects (Cons)

- Dewatering process has to be complete and continual so bottom areas will be dry enough for rehabilitation. Fill material (360,000 cu. yds.) will be purchased and placed to raise the bottom above the water table.
- Side slopes have to be rehabilitated; photographs of the Llangollen pit before landfilling indicate slopes exceed the recommended maximum of 2.5:1. Fill material (120,000 cu. yds.) will be purchased and placed to obtain the 2.5:1 slopes.
- Excavation and landfilling operations within the same site increase traffic congestion problems.
- Where the natural clay confining layer has been disrupted or removed at Llangollen double lining will be ne[illegible]

- Materials that are temporarily stockpiled are double handled.
- Stockpile an additional source of contaminated runoff and odors and will attract vectors, birds, and wildlife.
- Cover material will be purchased; (160,000 cu. yd.); none available on-site.
- Impossible to formulate a tight bid package and receive firm bids from contractors (bids will have to contain contingencies to compensate for the possibility of unforeseen problems).

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Cost of Alternative Plan C

Site Preparation	$1,790,000
Landfill Liner and Leachate Collection	1,660,000
Refuse Excavation	870,000
Refuse Transport	790,000
Refuse Placement, Compaction, Cover	1,170,000
Hydrogeologic Controls	250,000
Odor Control	250,000
Sealing Llangollen	100,000
Landfill Vegetative Cover	50,000
Miscellaneous	330,000
Subtotal	$7,260,000
Contingencies, Engineering, Legal, and Administrative Costs	1,000,000
Continuing Costs	1,000,000
TOTAL	$8,260,000

Alternative Plan D: (Transfer all refuse to DS & G Pit)

Alternative Plan D - Utilization of a prepared DS & G Pit (plus some additional, adjacent land) as a landfill site for the Llangollen refuse. See Figure A-5.

- Acquire the new site plus an additional tract of land adjacent to the site (minimum 10 acres).
- Prepare a portion of the DS & G Pit (bottom and slope rehabilitation, ground water interception system, liner installation, and leachate collection system) sufficiently large enough to allow the start of landfilling operations (5 acres).
- Excavate Llangollen refuse; transport to the new site for landfilling.
- Prepare additional areas of DS & G Pit as they are required.
- Upon completion of excavation operations at the Llangollen Landfill locate and correct areas where the naturally occurring protective clay layer has been removed or disrupted. This is to lower the infiltration rate and to allow build-up of water at the site while providing necessary quantities of recharge to the aquifers.
- When landfilling of Llangollen refuse is complete, place final cover and means of limiting infiltration.
- Establishment of vegetative cover (landscaping).
- Use new site as a green area.
- Use Llangollen site as a recreational area (water activities; i.e., sailing, canoeing, fishing, etc.).

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Positive Aspects (Cont.)

- DS & G Pit is close to Llangollen and readily accessible.
- Full economies of scale are realized.
- Degree of dewatering is only that necessary to remove refuse from Llangollen.
- Having excavation operations separated from the landfilling operations eliminates congestion.
- Land acquired in addition to the DS & G Pit (approximately 10 acres) will provide rehabilitation and cover material for the landfill site.
- This plan offers a definite solution to the aquifer contamination problem at Llangollen. Upon completion of the landfill at the prepared site the source of leachate at Llangollen will have been removed. At the new site leachate cannot enter the aquifer. Contaminated aquifers will be cleansed over a period of time by ground water recovery program.
- The new site when completed will be a useful recreational green area for area and county residents.
- The Llangollen site can become a lake for water recreation activities.
- The proposed site is exposed and visible (problem areas apparent) making it possible to formulate a comprehensive and detailed bid package and receive firm bids from contractors.

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Negative Aspects (Cons)

- Additional land (DS & G Pit plus a minimum of 10 acres from an adjacent property) must be acquired.
- Have to build road network.
- Requires removal, grouting, and relocation of many existing monitor and recovery wells.
- At Llangollen, where the natural clay confining layer has been disrupted or removed clay material will be placed to control infiltration rate so a lake will develop.
- Side slopes at the DS & G Pit have to be rehabilitated; they exceed the 2.5:1 (2.5 feet horizontal to 1 foot vertical) maximum recommended. Material will be transferred from the additional tract purchased and placed to obtain the desired slopes.

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Cost of Alternative Plan C

Site Preparation	$470,000
Landfill Liner and Leachate Collection	1,700,000
Refuse Excavation	800,000
Refuse Transport	680,000
Refuse Placement, Compaction, Cover	1,160,000
Hydrogeologic Controls	250,000
Odor Control	250,000
Sealing Llangollen	100,000
Landfill Vegetative Cover	50,000
Miscellaneous	460,000
Subtotal	$6,000,000
Contingencies, Engineering, Legal, and Administrative Costs	1,000,000
Continuing Costs	1,000,000
TOTAL	$8,000,000

Recommended Plan

The recommended alternative is Alternative Plan C, Excavation of Llangollen Landfill With Transport of the Refuse to a Prepared DS & G Pit for Landfilling. Alternative Plan C is cost-effective, technically sound, utilizes the best available technology, is the most economically attractive, possesses more positive and less negative aspects than any other plan, and satisfies the major prerequisite that it stop pollutant migration into the ground waters of the area within a finite time period. The major advantage this plan has over the other plans is the visibility of the DS & G Pit. This visibility will enable the county to prepare a tight bid package and contractors to make a firm bid because they can formulate manpower, material, and equipment requirements and schedules for the rehabilitation and landfilling portions of the plan on the basis of what he has seen and measured as he inspects the site. This type of visibility is not available for the alternative plans which utilize Llangollen as the primary landfill site.

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APPENDIX D

Completed Landfill Reuse

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APPENDIX D

COMPLETED LANDFILL REUSE

General Considerations

Introduction

Many landfill sites can be considered to have three active lives, each one useful but serving different economic sectors. For instance, many sites were initially sand and gravel operations supplying raw materials to the construction industry. After the completion of mineral excavation, the sites were converted into waste disposal facilities serving area residents and industries. The third life began by landscaping final slopes to provide for recreational activities for the surrounding area.

In the case of Llangollen, this three-life use will also materialize, the only exception being that a major correctional/renovation phase will occur prior to the third and final use.

Historically, site use after excavation for mineral has not been well planned, if planned at all. Landfill reuse is also seldom well planned. It is most important, however, to design and operate a landfill in accordance with a definite reuse design in order for maximum practical utility to be realized.

In fact, the task of evaluating reuse alternatives, selecting one, and preparing appropriate design drawings for the recommended reuse must be done prior to landfill design, with the landfill reuse defined in terms such as final topography, alternative locations for surface [illegible] controls, and required facilities (requiring stable foundations), landfill design and operation can proceed in an economical and efficient manner.

This section of the report addresses alternative concepts for reuse of the Llangollen area, which is composed of the Llangollen Landfill (47 acres) and the new site (approximately 55 acres). The new site is located adjacent and to the south of the Llangollen Landfill. Figure 7.1 identifies the Llangollen area and the surrounding vicinity.

<u>Reuse Objectives</u>

Four general objectives for landfill reuse are defined as follows:

<u>Maximize Site Utility</u>

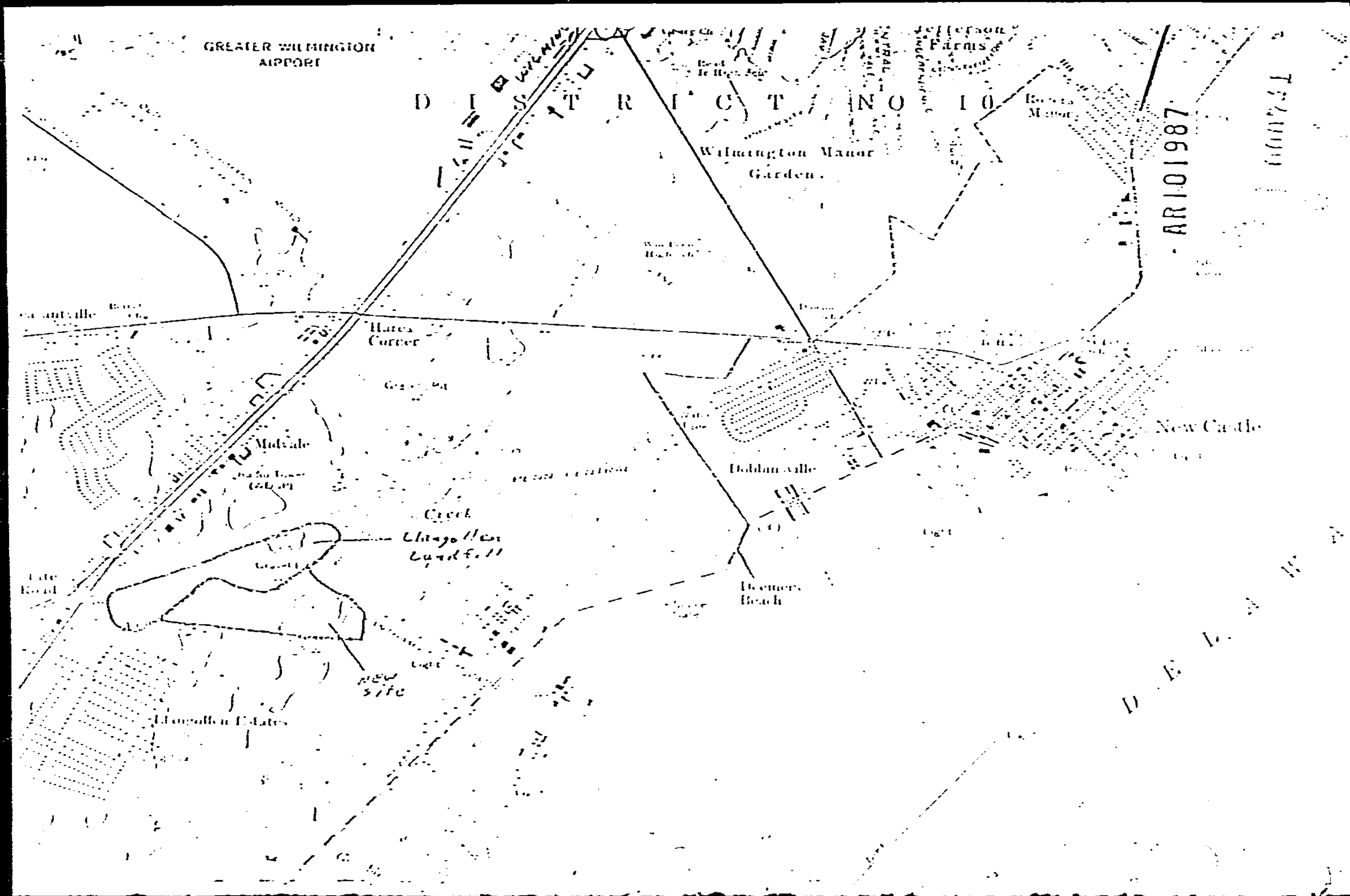
Ultimate reuse should be designed to maximize benefits to the user population, be it the surrounding residential community, the industrial community, or a combination of both.

<u>Compatible with Land Use and Regulations</u>

Site reuse should be compatible with existing land use in the area and offer complementary activities to land use plans in the area.

The relationship between the reuse plan and the following three key elements is important:

- Plans developed by New Castle County's Department of Parks and Recreation.


GREATER WILMINGTON AIRPORT
D I S T R I C T NO 10
Wilmington Manor Garden
Jefferson Farms
Hares Corner
Midvale
Creek
Chicago Ave Landfill
new site
Dobbinsville
Bremers Beach
New Castle
D E L A W

- Plans developed by New Castle County's Department of Planning.
- Impact on the Llangollen Estates residential development adjoining the site's southwest boundary.

In addition, existing zoning and subdivision regulations must conform to the ultimate use plan or be appropriately changed.

Assure Environmental Control

The Llangollen Landfill rehabilitation project will result in placing certain restrictions (location of structures, load bearing capacity, gas venting network, etc.) on the level of development for site reuse. This is true for any landfill project. The reuse alternative selected should be one which assures that the rehabilitation project will result in negligible environmental impact on the final use.

Conversely, the ultimate use should not in any way jeopardize maintaining environmental control of the rehabilitated area. In addition, the new site now functions as an aquifer recharge area. Maintenance of this quantity of recharged water should be incorporated into the reuse design.

Minimum Cost of Implementation and Annual Operation

The capital cost of converting the rehabilitated area into an ultimate use should be controlled within limits of assuring adequate site utility. Reuse implementation costs are assumed to include only surface preparation cost, since the final topography will be established by the rehabilitation program

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design. The net annual operating cost (expenses less any revenue) should also be controlled within practical limits.

General Advantages of the Site

There are several advantages to the site which make it attractive to most reuse alternatives:

- Close to a large user population (approximately 1000 people in Llangollen Estates.
  - the 1970 population of the New Castle-Upper Christiana Planning District was 61,541; the population is expected to more than double by 1985.
  - within 6.5 miles of Wilmington City limits
  - within 1.5 miles of New Castle city limits
- Close to major transportation arterials (U.S. Routes 13, 301, and 40 and State Highway 273 to the North and West) and good accessibility by all weather roads (State Highway 9 and Grantham Road to the South and East).
- No indication of significant air, water or noise pollution from activities in the surrounding area.
- All utility services are available and close.

Originally the site was to be developed by the New Castle County Department of Parks and Recreation (DPR), having been given to the DPR by the County. Once leachate contamination of ground water was confirmed, however, the New Castle County Department of Public Works (DPW) was responsibility of investigating and correcting the problem. Upon completion of the rehabilitation project, DPW responsibility will be reduced to monitoring water quantity and maintaining the environmental control system.

General Constraints of the Site

Some constraints do exist at the site which will influence ultimate reuse:

- Some settling will occur on the new site after landfilling is complete.
- Load bearing capabilities on the new site will be restricted. Any major structures will require pilings.
- The site is located adjacent to a wet lands area.
- The site, divided by Army Creek, is located in the flood plain. Final use design must adequately accommodate potential flood waters in order to protect adjacent land uses.
- The Llangollen Landfill and the new site have functioned as a major recharge area for the Artesian well fields. Filling in the new site will result in a groundwater recharge loss which should be compensated for in the reuse plan.
- The Llangollen area is located in the Greater Wilmington Airport crash hazard zone classification of limited crash hazard potential. This, however, should not significantly limit reuse considerations.

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5.2 Alternatives for Reuse

Alternatives for reuse are now briefly discussed and screened to two candidates for subsequent evaluation. Reuse categories have been broken down into recreational, cultural, industrial or residential, and do nothing.

Recreational Use

Major alternatives for recreational use are a:

- park with a lake
- park without a lake
- golf course or pitch and putt course

A park with a lake would consist of approximately 68 acres dedicated for active and passive recreational activities. These activities would be located on the southern section of the property. About 34 acres would become a lake, adjoining the southern bank of Army Creek and covering an area northward to the Penn Central railroad tracks.

The park without a lake option would be similar in function to the previous option except that no water-related aesthetics or activities would be available. Site development for reuse would require back-filling the rehabilitated (excavated) area to a depth above the seasonal high water table level. Both this option and the park with a lake option will be retained for evaluation in the following section.

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The third basic recreational use considered was creating a golf course or pitch and putt course. Preliminary analysis indicates that this alternative would result in underutilization of the site, be inconsistent with the recreational needs, and be less cost effective than the park alternatives. Golf courses require about 10 acres of land per hole. A property size of just over 100 acres would accommodate only a nine-hole golf course. Experience has shown that nine-hole courses are not attractive to the potential user population. Furthermore, pitch and putt courses are most successful when located adjacent to a full-sized 18 hole course.

New Castle County presently has two 18-hole golf courses: Greenhill Golf Course located on the northwestern city limits of Wilmington and Delcastle Golf Course located about six miles west of Wilmington. These appear to be accomodating the region's needs satisfactorily.
Costs associated with a 9-hole golf course would be for backfilling the old landfill site and development of the course. Backfilling 2,000,000 cubic yards to come back up to grade could cost as much as $6,000,000. Developing the golf course would add another $500,000 to $1,000,000 to the capital investment. In addition, operating and maintenance costs would be significantly higher than those associated with a park.

Cultural Use

Cultural use could provide for any one or a combination of activities like an indoor or outdoor theater, zoo (however, the county has an existing Brandywine Zoo), indoor and/or outdoor gardens. The [illegible] Brantner House could be renovated in the historical style appropriate for the period in which Colonel Grantham was a noted figure. This option would also complement the basic recreational uses discussed above.

Generally cultural facilities should be located in areas which have adjoining, compatible land uses and which are conveniently accessible to a large population (e.g., in or near a major city). More than 50 percent of the area bounding the Llangollen property is under existing or planned industrial use. This situation is not conducive to attracting a cultural use population.

Cultural centers typically serve a regional or larger service area. The location of the Llangollen site indicates that the best service size would be that defined by a district. For these reasons, plus the constraints imposed on structure foundations, it is felt that a reuse which is fundamentally culturally-oriented is not the most practical alternative.

Industrial or Residential Use

Extensive reuse alternatives considered were:

- industrial park
- residential housing
- new landfill on the old Llangollen site

Industrial land use needs in the vicinity of the Llangollen area are already well planned with sufficient land allocated for development. For example, a large tract of land (approximately 100 acres), AR101993

Llangollen area, has been dedicated to an industrial park. Development is currently underway.

Pilings would also be required at the new site prior to any facility construction. The old landfill site would also require backfilling to grade before any construction activity could commence.

Residential housing was also excluded from further consideration for many of the same reasons. In addition, the sand and gravel operation due east of the property may continue beyond the time for site reuse preparation. Such industrial activity would only jeopardize the market price and turnover rate of adjacent housing.

The final alternative considered for employing extensive use of the site was development of another landfill on the old landfill site. This alternative would involve:

- Grading and backfilling to a depth sufficient to cover the water table.
- Installing a leachate collection system and gas collection system.
- Landfilling with solid waste to a predetermined final grade.
- Preparing site for ultimate reuse.

The southern part of the property, of course, could be developed upon completion of rehabilitation and used while the new landfill operation was on-going.

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While this alternative is attractive from the standpoint of being an interim revenue generator with no severe traffic or land use impacts, three factors discredit this approach. First, it is imperative that the potential environment impact of the reuse application be minimized. Another landfill operation would compound water quality monitoring in the area. The rehabilitation project will be done in a manner to safeguard all water sources. However, there exists another landfill operation just east of the property which may be contributing to existing ground water contamination. With the existence of this adjoining private landfill, it is best to minimize the number of areas requiring close supervision.

Secondly, the new site is presently acting as a groundwater recharge area for the Artesian well field, as discussed earlier. If the entire Llangollen area were sealed (no vertical movement of precipitation into the ground water table), as would be the case with two landfills, then recharge efficiency would be significantly reduced.

Finally, insufficient cover material would be available for operating the new site. As much as 400,000 cubic yards would be needed at an approximate cost of $3.00 per cubic yard. For these reasons, the new landfill alternative was deemed inappropriate and will not be discussed in the following section.

<u>Do Nothing Alternative</u>

The "do nothing" alternative here means that the renovated site AR101995

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subjected only to landfill site closing procedures applicable in the State of Delaware. At a minimum, this would include application of final cover and seeding on the new site, and grading the excavated area to prevent danger to trespassers.

The only problem with this alternative is that it does not meet the objective of maximizing site utility. While this alone would not exclude the option, it must be compared with competing alternatives. Such comparative analysis indicates, that a much more favorable cost-benefit ratio would be realized if a park were developed.

D.3 Evaluation of Alternatives

In the preceding discussion of reuse alternatives, reuse objectives were imposed on each alternative. This resulted in excluding all alternatives except two: a park with a lake (Park with Lake) and a park without a lake (Park). These candidates are now evaluated and compared on the basis of fulfilling the reuse objectives.

Maximization of Site Utility

The similarity between the candidate reuse alternatives is evident. Both are outdoor parks with recreational facilities. The Park alternative would contain more land-oriented activities. However, the user population is not expected to overload the available land area or activities for either alternative.

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DEPARTMENT OF PARKS AND RECREATION
NEW CASTLE COUNTY, DELAWARE

PLANNING SERVICES 510-9

August 4, 1966

POLICY RE: COUNTY-WIDE PARKS AND RECREATION STANDARDS

SUMMARY OF RECOMMENDED STANDARDS FOR RECREATION FACILITIES IN NEW CASTLE COUNTY

RECOMMENDED RECREATION STANDARDS

...ility	Equipment	Optimum Size (Acres)	Acres per 1,000 Population	Population Served by Facility	Service Area
...ylot	Swings, slides, play sculptures, sand box, fence, and benches.	under 5	-	800	1/8-1/4 mile in high density area. Less in low-density rural areas.
...ighborhood ...	Totlot area, toilet, drinking water, area for passive recreation, swings, slides, tennis courts, field for football, baseball, etc. For elementary school-age children hard surface game area and landscaping.	5-30	2.5	12,000	1/2-1 miles (varies - dependent on population density).
...trict Park	Picnic tables, toilet, drinking water, shelter, walkways, and landscaping.	30-75	2.5	30,000	1-2 miles
...ional Park	Mostly those provided by nature with trails, picnic tables, camp sites, etc.	75-200	5	40,000	1/2 hour driving time.
...ervation	Camping facilities, picnic areas fishing, boating, and winter sport facilities.	over 200	15	-	1 hour driving time.

...rce: Advanced Planning Division, New Castle County Regional Planning Commission estimates. These were derived from standards published by the National Recreation Association, the Local Planning Administration and the American Society of Planning Officials, and modified to suit New Castle County.

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The specific recreational facilities planned are listed in the next section, Conceptual Reuse Plan. The basic difference in the activities would be additional passive use (nature areas, picnic areas, landscaping, open fields, etc.) for the Park alternative. Suffice to say that imposing this criteria on both alternatives does not lead to favoring one over the other.

7.3.2 <u>Compatibility with Land Use and Regulations</u>

<u>Relationship with Department of Parks and Recreation Plans</u>

Prior to the confirmation of a ground water contamination problem at the Llangollen Landfill, New Castle County assigned the County Department of Parks and Recreation (DPR) to plan and develop the site. At that time, and even now, the DPR recommends a district park with predominantly active use (tennis courts, baseball and football fields, basketball courts, etc.). Both candidate alternatives are basically consistent with DPR plans. Table 7.1 defines the recreational facility standards in New Castle County.

The original site was [illegible] acres. Combining the new site results in a total area of [illegible] acres. Even with this additional acreage, DPR indicated they would still prefer maximizing active land use. The reason for this position is that the two major nearby parks have or will have water-oriented uses. One park, Coventry Ridge - Lewden-Greene Park, is planned. Located about two miles northwest of the Llangollen area, it contains various active and passive recreational facilities (including a swimming pool complex) on a [illegible]-acre narrow plot. Classified as a regional park, its northern border ([illegible],000 feet) bounds the Christiana River. The plan calls for a tree line and forested nature study area to provide a buffer between the river and all recreational facilities. No swimming in the river is allowed but canoeing is possible

The other park, Ommelanden Farm, is located less than two miles south of the Llangollen area. The portion of the site southeast of State Route 9 (about 190 acres) is almost square in shape and is bounded on the southeast by the Delaware River. While no plans have been developed by DPR, preferences lean toward passive use (nature study area) and maybe a marina on the Delaware River. The portion of the site northwest of State Route 9 is much smaller (about 34 acres) and is intended to be developed for very active use.

The Llangollen area, however, with the acquisition of 55 more acres, will result in more land available for development than was first envisioned even with a lake. Therefore, it is believed that either alternative would be acceptable to DPR use intentions. The land area (about 68 acres) associated with the lake option would be within the district park size standards (30 - 75 acres), the classification originally intended.

<u>Relationship with Department of Planning Plans</u>

The proposed 1985 plan for the New Castle - Upper Christiana Planning District calls for a district park to be located at the Llangollen Landfill. The Planning Department indicates that the area where the new site will be acquired is proposed for industrial use (office research) on the west and for a resource protection area (stream valley, flood plain, marshland) on the east. The industrial use area (shown on the Planning Department's 1985 Land Use Map) is quite large (300 - 400 acres), however, so no land-use problem is expected as a result of the planned reuse of the Llangollen area.

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Impact on Llangollen Estates

The property's southwest boundary adjoins the Llangollen Estates single-family residential development, which is now complete. The price range of the homes (almost 300) is between $50,000 and $100,000. Either candidate reuse plan will provide an excellent neighborhood resource.

Regulations

While, at the time of this writing, it was not known whether the existing zoning and sub-division regulations were consistent with the reuse plan alternatives, no unusual problems are expected which would delay implementation of the reuse plan.

7.3.3 Assurance of Environmental Control

The impact of the rehabilitation project on either reuse alternative will be negligible. The gas collection and leachate collection and treatment systems will control any pollutants generated at the new site. Final slopes will be designed to both accommodate reuse and facilitate precipitation runoff. Recreational facilities and support structures will be located in areas where settlement will be minimal or non-existent.

Site reuse will be designed not to interfere with post-rehabilitation control procedures-- leachate collection and treatment or gas collection and disposition. However, site reuse can have a direct impact on the efficiency of recharge to the underground water table connected to the Artesian well field.

If the recharge must be maintained, then the Park with Lake Alternative would best accomplish this objective.

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If the entire property were brought up to the natural grade, as suggested

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in the Park Alternative, then special design elements would be required to foster recharge to the aquifer. Furthermore, precautions against localized flooding would have to be made, since the site is partially contained in a flood plain.

Minimize Cost of Implementation

The comparative cost of implementing various alternative plans is frequently the deciding factor of selection. This could very well be the case here, considering the two alternative reuse plans under question.

It is estimated that the Park with Lake Alternative would cost about $500,000, which would vary in accordance with the type and size of facilities and the overall style of development. The Park without Lake Alternative would cost considerably more, perhaps as much as $6 million more. The cost difference is almost entirely attributable to the need for backfilling the excavated hole, estimated at 2 million cubic yards at $3.00 per cubic yard. Some additional capital would be required for landscaping and providing additional activities on the land area which was designated a lake in the Park with Lake Alternative.

Assuming that site reuse will be conceptual similar to the two candidates discussed, then the DPR would be responsible for site reuse development and associated costs. The DPW would continue to pay for environmental control costs and to correct any major settlement problems.

D.4 Conceptual Reuse Plan

Description

The Park with Lake concept would provide for both passive and active recreation use, including a lake and/or pond. Site development and related expenditures can be broken down into three categories:

- Site Preparation and Landscaping - Cost items would include trees/revegetation, rip-rap at the inlet and outlet of the lake, additional cover material as needed, etc. These items represent between 10 and 25 percent of the total investment.
- Activities - Activities would include items such as trails, foot-bridge, picnic area, sportsfield, playfield, tennis complex, and perhaps a boat launch and swimming beach. Renovating the Grantham house in a historical context could also be considered. Activities would represent between 20 and 40 percent of the total capital expenditures for reuse.
- Support Facilities - This category encompasses items like roads, parking, maintenance building, utilities, litter baskets and signs. These costs represent between 35 and 55 percent of the total reuse investment.

Generally, activities associated with active use increase as one proceeds eastward on the site. This accommodates residents of Llangollen Estates as well as places active use facilities adjacent to parking and the existing access road, Grantham Road. The nature area and playfields would be due north of Llangollen Estates. The sportsfields, tennis complex and maintenance building would be north of the planned industrial use area. A wooded picnic area would provide a buffer between the predominantly active use area to the east and the predominantly passive use area to the west. The

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picnic area would contain the only extensive wooded area not bordering the lake. This localizes the need for increased soil depth on the new site, thus minimizing the complexity of the landfill operation during the rehabilitation phases.

A pedestrian and bicycle trail circumscribes the lake and pond, thus facilitating access to all points in the park. The land bordering the railroad tracks extends southward into the water areas at two points. The extended land area on the west forms the fish pond, and the one on the east breaks up the monotony of the northern slope. Together they add an aesthetically pleasing view to people south of the lake and encourage full utilization of the park. A grassy mound, located at the southeastern corner of the park, provides a visual barrier to neighboring industrial development while functioning as a "look-out" point for the entire park. Snow sledding in the winter would also be possible.

Implementation Strategy

First and foremost is the design and acceptance of a reuse plan. This must be accomplished prior to design of the rehabilitation plan to assure economy in the entire program. Drawing and documentation should fully identify interfacing requirements between the rehabilitation project and reuse development. These include suggested locations of the leachate treatment facilities and the gas venting system. Ground stability, post rehabilitation, should be identified in appropriate sections of the site. Any and all special refuse grades and fill depths should be identified; e.g., for areas requiring extra soil coverage (picnic area).

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The sequence of the rehabilitation operation should proceed in a manner which will enable park development to occur over a period of time. For instance, if rehabilitation operations commence in the western portion of the site, then the pond area can function as a retaining basin for upstream and upland area runoff during heavy precipitation periods. Discharge of water from the interim catch basis could be controlled to minimize rehabilitation operational problems. With proper sequencing, the playfield could also be developed early to provide early usage to the neighboring community.

At the completion of rehabilitation, the slopes will have been seeded. Park development at this time should begin with the establishment of the lake and pc configurations, followed by revegetation and construction of the pedestrian and bicycle trail. Active-use areas are better developed after revegetation has been firmly established and initial settling has subsided. Building the boat launch (for small sailing craft) and the swimming beach would best be accomplished last and after the lake and pond have reached equilibrium and are proven safe.

In summary, site reuse and its development could commence immediately after rehabilitation, if not before in the western area. Final development can occur at the discretion of the Department of Parks and Recreation and in accordance with the County's desires. Final development may extend into the fifth year or later after the completion of the rehabilitation project.

The ultimate result of reuse development will be an excellent park resource--one the County can be proud of owning and one the community and surrounding district can enjoy for years to come.

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