TIBBETTS ROAD SITE
Barrington, New Hampshire

Feasibility Study Report

Appendices

Prepared For: U.S. Environmental Protection Agency
Region I
90 Canal Street
Boston, Massachusetts 02114

Prepared By: CDM Federal Programs Corporation
98 North Washington Street
Boston, Massachusetts 02114

June 1992

LIST OF APPENDICES

APPENDIX A

Ground Water Extraction System

This appendix contains a discussion and computations for conceptual design of a system for extraction of contaminated ground water from the overburden and weathered bedrock.

Appendix A

Ground Water Extraction System Considerations

The purpose of this appendix is to present the basis for selection of a design flow for evaluation of remedial alternatives in the Feasibility Study.

The description of the ground water regime at the Tibbetts Road Site is based on a systematic review and analysis of existing data. It is recognized that certain additional data will be necessary — primarily to provide a proper basis for remedial design. However, the following description is based on a practical working knowledge of the origin, occurrence and movement of ground water at and adjacent to the Site.

The process of designing an extraction and recharge system for treatment of the Site's contaminated ground water necessitates an estimate of how the ground water regime operates under natural conditions. Such an estimate depends on certain assumptions and the employment of averages that are less than precise figures. However, given the historic wide variation in rainfall/precipitation variance from average conditions, variability of an estimate of a conceptual regime is just as likely to be the result of natural causes as from any imprecision of the figures used in development of the estimate.

Basic Factors Influencing the Ground Water Regime

The Site and the adjacent area is not a part of a defined drainage basin as it is elevated from the surrounding area. Consequently, ground water movement is radially away from the Site and is entirely dependent upon the direct, site-specific, infiltration of rainfall/precipitation for replenishment. Ground water level and movement varies with the seasons. During the growing season, ground water replenishment is reduced as the bulk of the rainfall is taken up by the growing trees and other plants. Ground water movement from the site is complex as it occurs in poorly connected or separate systems in both the unconsolidated overburden material and in the underlying bedrock.

Climate

The climate of the Barrington area was discussed with Anthony Federer of the University of New Hampshire (Durham) (Telecom. Oct. 1991). In this area the growing season is just short of 5 months--starting about the first or second week of May and extending to about the end of September. Water levels have been measured periodically at the Site during these months (see Table A-1). Also, the continuous water level record maintained at the Site showed a relatively uniform high level during the winter months through early May; then dropping during the summer and starting to rise in October-November.

Studies of evapotranspiration conducted by the University of New Hampshire show variation between different forest covers and soils. The following general values were considered appropriate for analysis of Site conditions as they are similar to those currently present at the Site:

- evapotranspiration would most likely fall between 500 mm/year (19.7-in) for fully deciduous forest cover and 650 mm/year (25.6) for fully conifer forest cover (a composite value of 550 mm or 21.65-in is used in later calculations).

- with such cover, winter rains not lost to overland flow would infiltrate the ground (with minimal evapotranspiration loss because the forest is mostly deciduous) as it is not expected that the frost layer is fully continuous.

TABLE A-1

Available Data - Water Level Measurements from top of Well Casing - Various Dates

Well No.	10/8/90 (feet)	5/6/91 (feet)	6/5/91 (feet)	7/5/91 (feet)	Change from 10/90 to 5/91 (feet)	Change from 5/91 to 6/91 (feet)	Change from 5/91 to 7/91 (feet)	Intake depth (feet)
37D	11.7	4.4	7.8	10.7	+7.3	-3.4	-6.3	15.4-25.4
52S	11.9	---	7.8	10.7	---	---	---	6.5-11.5
57S	11.2	3.2	---	9.6	+8.0	---	-6.4	9.0-19.0
70S	---	---	6.9	10.2	---	---	---	8.0-13.0
71S	---	---	8.3	11.1	---	---	---	12.0-17.0
72S	---	---	6.7	9.9	---	---	---	7.5-12.5
74S	---	3.5	6.6	9.3	---	-3.1	-5.8	13.0-18.0
77S	---	3.7	6.6	9.2	---	-2.9	-5.5	10.0-15.0
75R	---	---	7.4	10.2	---	---	---	21.0-26.0
2R	29.6	15.2	---	27.2	+14.4	---	-12.0	?-350
35R	10.2	3.9	6.6	9.6	+6.3	-2.7	-5.7	29.0-82
59R	20.6	14.7	---	20.8	+5.9	---	-6.1	59.0-203.5
61R	28.5	15.8	---	26.9	+12.7	---	-11.1	70.0-203.5
67R	20.3	13.2	---	19.5	+7.1	---	-6.3	80.0-163.8
69R	15.1	8.3	11.2	14.4	+6.8	-2.9	-6.1	37.0-57.0
76R	---	4.8	---	15.9	---	---	-11.1	38.0-252.0

Note: The ground surface is normally 2.2 to 2.5 ft. below the top of the well casing.
Source: RI Section 3.0

- the evapotranspiration during the 5 growing months would comprise about 80 percent of the total annual amount.

A rainfall/precipitation record is maintained by the University (7 miles southeasterly of the Site). The basic data from this record show the following:

Precipitation Record Years	Average Annual (Inches)	Low Year 1985 (Inches)	High Year 1983 (Inches)	Avg. Month (Inches)	Low Month June/July (Inches)	High Month November (Inches)
1980-1990	-	29.98	56.14	-	-	-
1951-1980	43.2	-	-	3.60	3.00	4.70

The above figures indicate that rainfall/precipitation is *highly* variable annually as well as monthly.

Origin of Ground Water and Infiltration

Ground water levels depicted in the RI show that these levels, like the topography, are mounded at and in the immediate vicinity of the Site. The origin of the ground water is from the direct infiltration of the rainfall/precipitation that falls on the area. Of the total amount of such precipitation, previously quoted as an average annual amount of 43.2-in/year, only a portion becomes ground water. Approximately 80 percent of the anticipated annual evapotranspiration is expected to occur during the 5 months of the growing season. The amount of rainfall/precipitation that is added to the ground water during the different seasons is based on figures previously presented for the various Site conditions that influence and control the ground water regime. The movement of ground water into and out of the unconsolidated overburden at and adjacent to the Site is as estimated in the following calculations.

Ground Water Loss from Unconsolidated Overburden - 5 Summer Months

- Average rainfall 5 summer months = 5 mo. × 3.6-in/month = 18.00-in
- Evapotranspiration 5 summer months = 80% of 21.65 in ave./yr = 17.32-in

Infiltration to ground water (no surface run off in the growing season) = 0.68-in

- Ground water level gain 10/90 to 5/91 = 7.3 ft for 37D should also be representative of the ground water volume drained during the prior or following growing season. This drainage (specific yield) only amounts to 10 percent,* or less, of the volume of soil and water in the interval of level change.

	Specific Yield	
	10%	9%
- Volume to be drained at 10% = 0.73 ft. & at 9% = 0.657 ft. or:	8.76-in	7.88-in
- Added volume from infiltration (per above) for the five summer months =	0.68-in	0.68-in
Total 5 mo. ground water loss from overburden =	9.44-in	8.56-in
and: per month	1.89-in	1.71-in

* Silty sand would have a porosity of 35 to 40 percent but only 10 percent, or less, would drain in 150 days with the rest retained as soil moisture according to Johnson, A.J.; 1967, Compilation of Specific Yield - Geological Water Supply Paper 1662-D, U.S.G.S.

Drainage Hydraulic Gradient from Well Pairs

	Ground Water Elev. 10/8/90 (feet)	Ground Water Elev. 6/5/91 (feet)	
52S	315.9	320.0	
69 R	311.8	315.7	
diff.	4.1	4.3	(hydraulic gradient)

While the above only represents one well pair, and soils characteristics vary as do soil depths to rock, the difference in the hydraulic gradient between one season and another is small. As a result, the overburden drainage rate for summer conditions is also applied to winter conditions.

Review of Winter Drainage and Water Level Recovery

	Specific Yield	
	10%	9%
- Rainfall/Precipitation: 7 mo. × 3.6-in/mo. =	25.20-in	25.20-in
Less Evapotranspiration (20% if 21.65-in)	4.33-in	4.33-in
Remainder	20.87-in	20.87-in
Less overburden drainage (same as summer monthly × 7 mo.) 1.89-in/mo & 1.71-in/mo. × 7 mo. =	13.23-in	11.97-in
Available for Water Level Recovery	7.64-in	8.90-in
Translated to Water Level Rise (÷ by 10 & 9% respectively)	76.4-in or 6.4-ft	98.89-in or 8.2-ft

From the foregoing it appears reasonable to adopt a figure of 1.8 - in./mo. ± 5% average monthly overburden ground water loss (drainage) from the area of interest. This loss results in approximately a 7.3 ft. loss in the elevation of the ground water when vegetative growth absorbs nearly all of the precipitation and a corresponding rise when precipitation exceeds the ability of the ground water regime to move the amount of infiltration out of the area during the remainder of the year.

An area of 222,000 sq. ft.* (5.1 acres) is contemplated as a potential capture (extraction) area for remediation. As noted above the amount of ground water added to such an area would be seasonally variable; however, the drainage from it, under natural conditions, is expected to be relatively uniform. The average drainage rate, under natural conditions, is estimated to be 5.77 gpm. The computation for this estimate is as follows: 222,000 sq/ft. (1.8-in/12) 7.48 gal/ft^3/43,200 min/mo. = 5.77 gpm.

Soils/Overburden

Soils to a depth of about 3.5 ft. are described in the 1973 U.S. Department of Agriculture publication, *Soil Survey of Stafford County, New Hampshire.* This description indicates that the first 20 inches of surface material consists of a fine sandy loam and that a poorly permeable grayish-brown sandy loam pan layer may be present at a depth of 22 to 41 inches. The current and prior studies of the Site have employed different methods in an attempt to establish values of the soil hydraulic conductivity at and adjacent to the Site. The summary by EPA/ERB, (1986) states that an estimated value for horizontal permeability in the upper till is 16.1gpd/ft^2. More recent testing indicates that the upper till over the central and eastern portion of the site (wells 70S, 71S, 72S and 73S) is more likely to be an order of magnitude less than the 16.1gpd/ft^2 figure. While the results show a wide range of values, it would be expected that the soil horizontal hydraulic conductivity would, in general, correspond to the following:

Depth Interval (feet)	Site Generally (gpd/ft^2)	Tibbetts Rd. Side (westerly) (gpd/ft^2)	80ft. off-Site (easterly) (gpd/ft^2)
7 - 12	± 1.5	---	± 15
12 - 16	± 0.5	5 to 15	---
16 - 20	> 0.5	± 2.5	± 1

The above leaves in question the low value of 0.09 gpd/ft^2 for a 8 to 13 ft depth (well 70S in the easterly corner of the Site) and the 27.7 gpd/ft^2 value for a 5 to 7 ft. depth at well 62S (80 ft. off-Site-northwesterly). Also, all of the above figures, with the exception of the one for

* The area from Tibbetts Road easterly through to the well 35R location.

62S are the results of in situ testing of installed monitoring wells. The results from such tests are a measure of horizontal permeability/hydraulic conductivity (see RI Section 3.0).

An examination of the drop in ground water levels (2.9 ft.) in wells 37D and 52S from 6/5/91 to 7/5/91, as reported in Table A-1, presents an opportunity to estimate the vertical permeability of the Site's soils. During this period it is anticipated that all rainfall is utilized by the vegetative cover in the form of evapotranspiration. Also, it is anticipated that the vegetative cover will have no extractive effect on the ground water at levels from 6 to 8 feet below the surface. The 2.9 ft. drop translates to a vertical gravity drainage of 0.29 ft. of water over 30 days (specific capacity of 10% assumed - see note under Origin of Ground water) or a vertical hydraulic conductivity of 0.075 gpd/ft^2. This figure is approximately an order of magnitude less than figures quoted for horizontal hydraulic conductivity of the lower till (quoted at 0.7gpd/ft^2 in EPA/ERB, 1986). An order of magnitude difference, or more, is commonly encountered and must be considered as being reasonable.

Bedrock Ground Water

The ground water in the bedrock must be accepted as existing in at least two systems. An examination of Table A-1 shows wells 2R, 61R and 76R with approximately a 5 ft greater seasonal difference in elevation than other rock wells. An examination of the concentrations of total volatile organic contaminants in the bedrock (Table A-20 of the RI) shows that only at wells 69R and 75R do analytical results exceed 1,000 parts per billion (ppb). Both of the wells are completed in the highly fractured/weathered portion of the bedrock. No pumping tests were conducted at either of those wells. However, a pumping test was conducted at well 35R (R4) which is 90 ft. northeasterly of well 69R. Figures D5, D6 and Table D3 from EPA/ERB, 1986 are reproduced and included for ease of reference. A review of Figure D5, a semi-log plot of drawdown during the test indicates no boundary conditions were present. However, the test only extended for a 60 minute period and the presence of boundary conditions would be expected to be manifested only in an extended pumping period. The recovery plot, D6, indicates an aquifer of limited extent with no recharge with pumping lowering the static water level; if not permanently, at least for an extended time. This condition is reflected by the plot showing a residual drawdown of 1.5 ft. at the point where the t/t^1 ratio is 1.

Seasonal ground water levels in those two wells were:

	5/6/91 Elev. (feet)	7/5/91 Elev. (feet)	Seasonal Difference (feet)
Well 35R	317.4	311.7	5.7
Well 69R	318.6	312.5	6.1
Elev. difference	1.2 ft.	0.8 ft.	

For well 75R only the 7/5/91 elevation of 319.1 ft. was recorded. This elevation is anticipated to be generally representative of the highest elevation of the ground water mound in the highly fractured/weathered bedrock in the growing season. During the winter season the elevation is estimated to be about 6 to 7 feet higher and closely approximate a level of the ground water in the adjacent overburden soil.

Seasonal elevation changes of the ground water which occur in both the overburden and bedrock indicate that the source of bedrock recharge is the overburden; however, the difference in elevation is an indication of the low vertical permeability of the overburden and a slow rate of recharge. The pumping test results for 35R, which are indicative of no recharge and limited extent, also pose problems for any proposed pumping scheme for remediating contamination in the highly fractured/weathered bedrock.

<u>Summary</u>

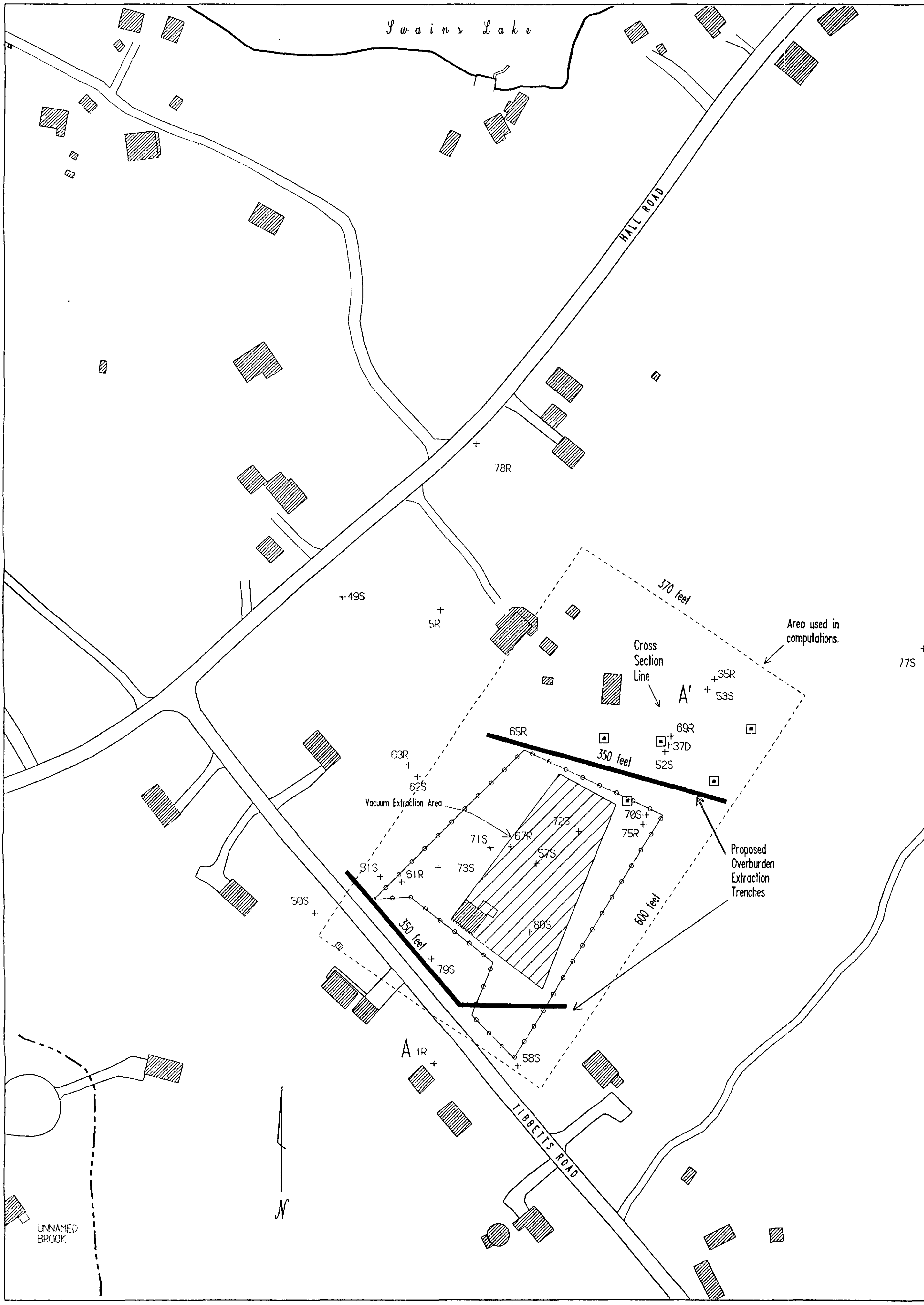
An area of 5.1 acres (600 ft. × 370 ft.) (222,000 sq. ft.) (generally encompassing the area of exceedance of MCLs) was adopted for consideration of institution of a remedial action scheme. Computations based on seasonal changes of ground water levels indicate that the vertical and horizontal outflow from the Site's topographic high amounts to about 1.8-in. of water per month or a total of 5.77 gpm over 5.1 acres.

A remedial action that utilized a technique to spread extracted and treated water over the Site could not be operated efficiently in the winter and would not prevent continued potential migration of contaminants from the Site. The bedrock aquifer exists as separate systems with the most plausible remedial action being to extract and treat from the contaminated upper highly fractured/weathered bedrock and discharge treated water to the lower (deeper) less contaminated bedrock aquifer.

A single pumping test of a well in the upper bedrock aquifer indicates that the aquifer is of limited extent and probably could not sustain pumping even at a 5 gpm rate from a single well. The overall bedrock system is complex and resists truly definitive estimates of extraction rates that would be appropriate for long term operation of a remedial system. With the small flow rates involved it is probably not important to establish an operational extraction rate. As a part of a predesign activity 5 or 6 weathered bedrock wells in the well 75R/69R area should be properly spaced and tested. It is expected that 3 or 4 new wells would be utilized as low rate extraction wells and the others, together with existing wells, utilized for monitoring purposes.

As a part of the remediation the installation of collection trenches to intercept outflow of the area from horizontal overburden flow is proposed. The variability of soil permeability makes an estimation of the volume so intercepted uncertain other than to express that it would be a minimal amount and unlikely to regularly exceed 1 gpm.

Tentative locations for the wells and trenches for a remedial action extraction system are as shown on the attached Figure A-1. The design extraction rate selected for use in the analysis of alternatives is 5 gpm. This may also be represented as a range of 3 to 10 gpm and must be refined later based on further work in the weathered bedrock. The northern extraction trench may be reduced in size or eliminated, depending on the effectiveness of the weathered bedrock wells.



+ Monitoring Well with MCL Exceedance

⊡ Proposed Weathered Bedrock Monitoring/Extraction Well

Scale 1 : 1,440

100 0 100 200 feet

Figure A-1

CONCEPTUAL EXTRACTION SYSTEM PLAN

TIBBETTS ROAD, BARRINGTON, NH

Source base map: Eastern Topographics, June 19, 1990

REFERENCES

(1) EPA.
Basics of Pump-and-Treat Ground-Water Remediation Technology.
EPA/600/8-90/003, March 1990.

(2) EPA.
Subsurface Contamination Reference Guide
EPA/540/2-90/011

(3) Federer, Anthony, Telecom. Oct. 1990, University of New Hampshire, Durham.

(4) Prepared by EPA/ERB
"Geohydrological Investigations, Tibbetts Road Site"
Barrington, NH
February 5, 1986

(5) U.S. Department of Agriculture Soil Conservation Service, March 1973, Soil Survey of Stafford County, New Hampshire.

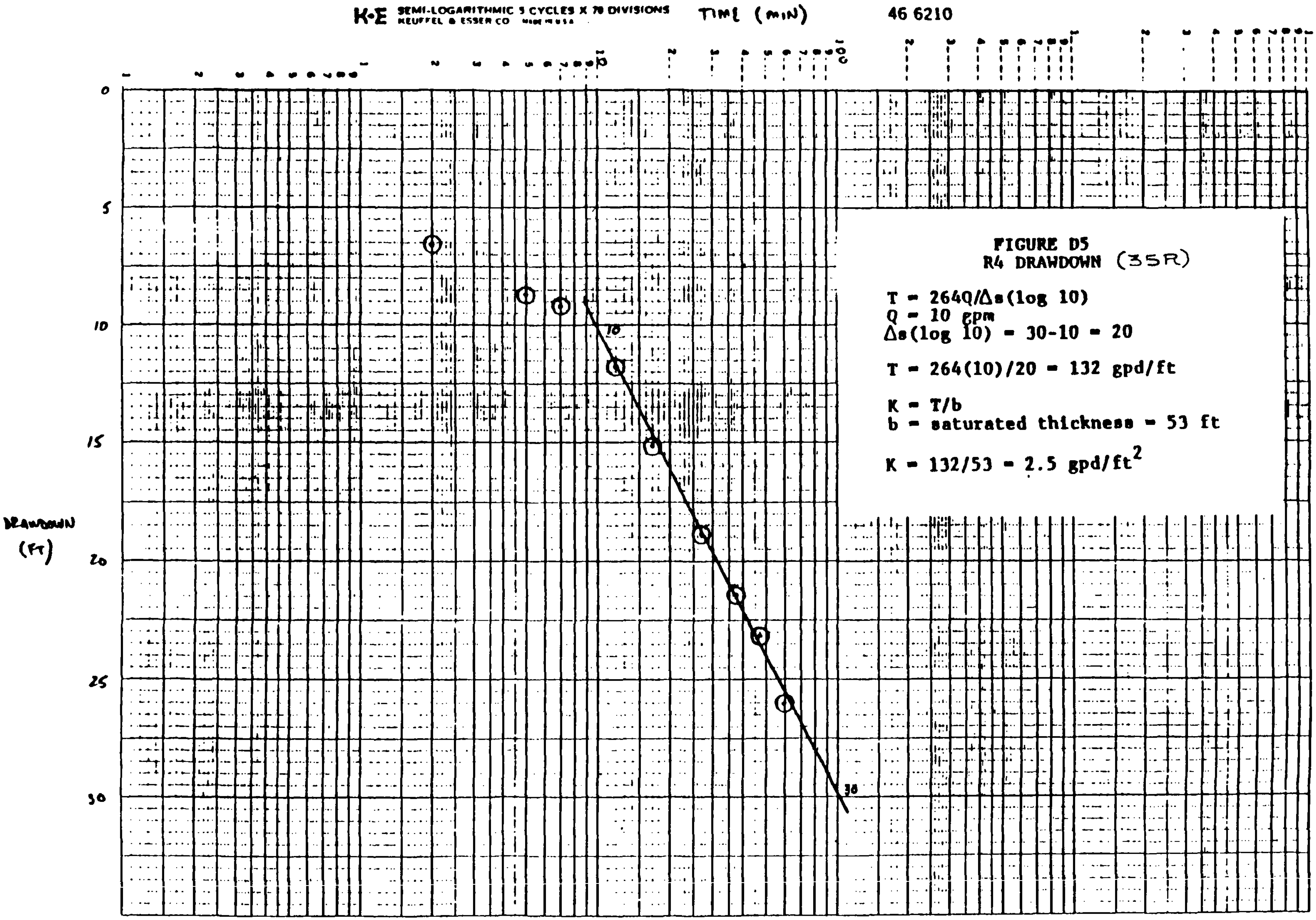


FIGURE D5
R4 DRAWDOWN (35R)

$T = 264Q/\Delta s(\log 10)$
$Q = 10$ gpm
$\Delta s(\log 10) = 30-10 = 20$

$T = 264(10)/20 = 132$ gpd/ft

$K = T/b$
b = saturated thickness = 53 ft

$K = 132/53 = 2.5$ gpd/ft^2

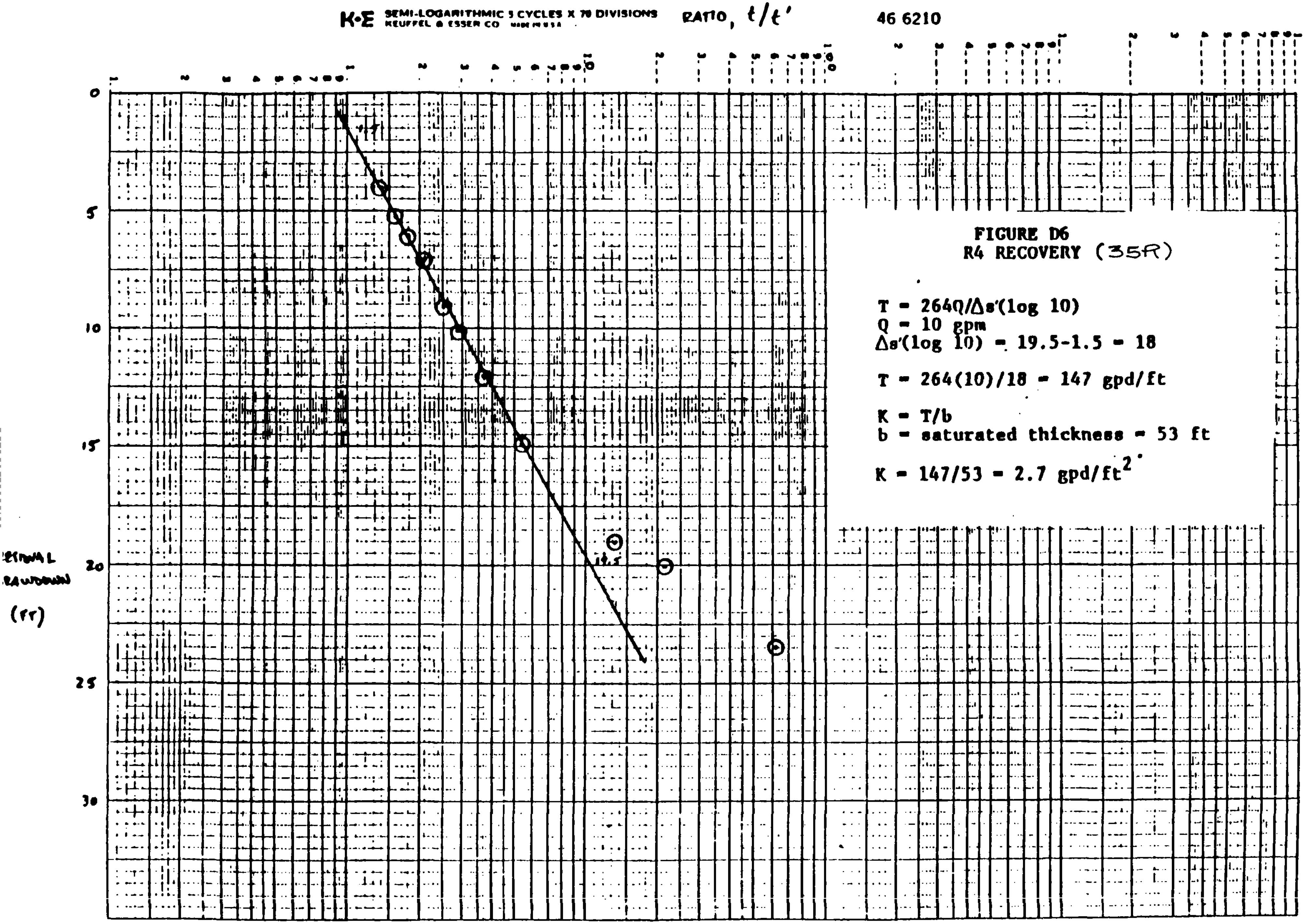


FIGURE D6
R4 RECOVERY (35R)

T = 264Q/Δs'(log 10)
Q = 10 gpm
Δs'(log 10) = 19.5-1.5 = 18

T = 264(10)/18 = 147 gpd/ft

K = T/b
b = saturated thickness = 53 ft

K = 147/53 = 2.7 gpd/ft^2

TABLE D3
ROCK WELL R4 (35R)
TIME-DRAWDOWN/RECOVERY DATA

DRAWDOWN DATA		RECOVERY DATA			
t (min)	s (ft)	t (min)	t' (min)	t/t'	s' (ft)
		62	1	62.0	23.00
2	6.60	64	3	21.3	20.11
5	8.70	66	5	13.2	19.02
7	9.20	75	14	5.4	15.01
12	11.80	84	23	3.7	12.08
17	15.10	94	33	2.9	10.08
27	18.80	102	41	2.5	9.08
37	21.40	117	56	2.1	7.11
47	23.11	135	74	1.8	6.09
60	26.04	170	109	1.6	5.25
		207	146	1.4	4.02

APPENDIX B

Shallow Aquifer
Flushing Calculations

(This appendix presents calculations that show the estimated time in years required for natural flushing of TCE in the shallow aquifer to a concentration equal to the MCL. A comparison of actual vs. calculated flushing rates for Benzene and TCE is also shown.)

The following tables summarize the parameters used and the results obtained from a flushing model used to determine the cleanup times to reduce the contaminant concentrations in the overburden and weathered bedrock aquifers to below the maximum contaminant level (MCL) for trichlorethylene (TCE) and benzene. Cleanup times were calculated for three areas within the overburden corresponding to the two proposed trench areas (Areas B and C) and the central portion of the site (Area A), and the area of weathered bedrock.

Input Parameters	**Overburden Areas**			**Weathered Bedrock Area**
	A	B	C	
Porosity, n	0.15	0.15	0.15	0.1
Soil Density, γ (kg/l)	2.0	2.0	2.0	2.2
Fractional Organic Carbon, f_{oc}	0.13%	0.13%	0.13%	0.10%
Saturated Thickness of Aquifer (ft)	15	15	15	35
Area of Contamination (ft^2)	32,000	32,000	82,000	75,000
Plume Volume (ft^3)	480,000	480,000	1,230,000	2,625,000
Pumping Rates: Natural Infiltration (gpm) Trenches/Wells (gpm)	 0.46* 0.8**	 0.46* 0.8**	 1.1* 2.0**	 1.9† 4.0††
Initial TCE Concentration (ppb)	7800	300	53	650
Initial Benzene Concentration (ppb)	590	1100	140	4000
TCE and Benzene MCL/Cleanup Goal (ppb)	5	5	5	5

CLEANUP TIMES IN YEARS REQUIRED TO MEET MCLS

	Overburden Areas			**Weathered Bedrock Area**
	A	B	C	
TCE: Natural Attenuation * Pumping	 41.1 23.6	 22.8 13.1	 14.7 8.1	 30.2 14.4
Benzene: Natural Attenuation * Pumping	 16.0 9.2	 18.3 10.5	 12.2 6.7	 24.2 11.5

* Due to 12" infiltration contacting contaminated zones.
** Due to 21" infiltration, which may include need for limited (summer) recharge.
† Due to 21" infiltration.
†† Average operation may be less.

Scale 1 : 1,440 100 0 100 200 feet

Figure B-1

PRECIPITATION, INFILTRATION AREAS IN OVERBURDEN FOR FLUSHING CALCULATIONS

TIBBETTS ROAD, BARRINGTON, NH

Source base map: Eastern Topographics, June 19, 1990

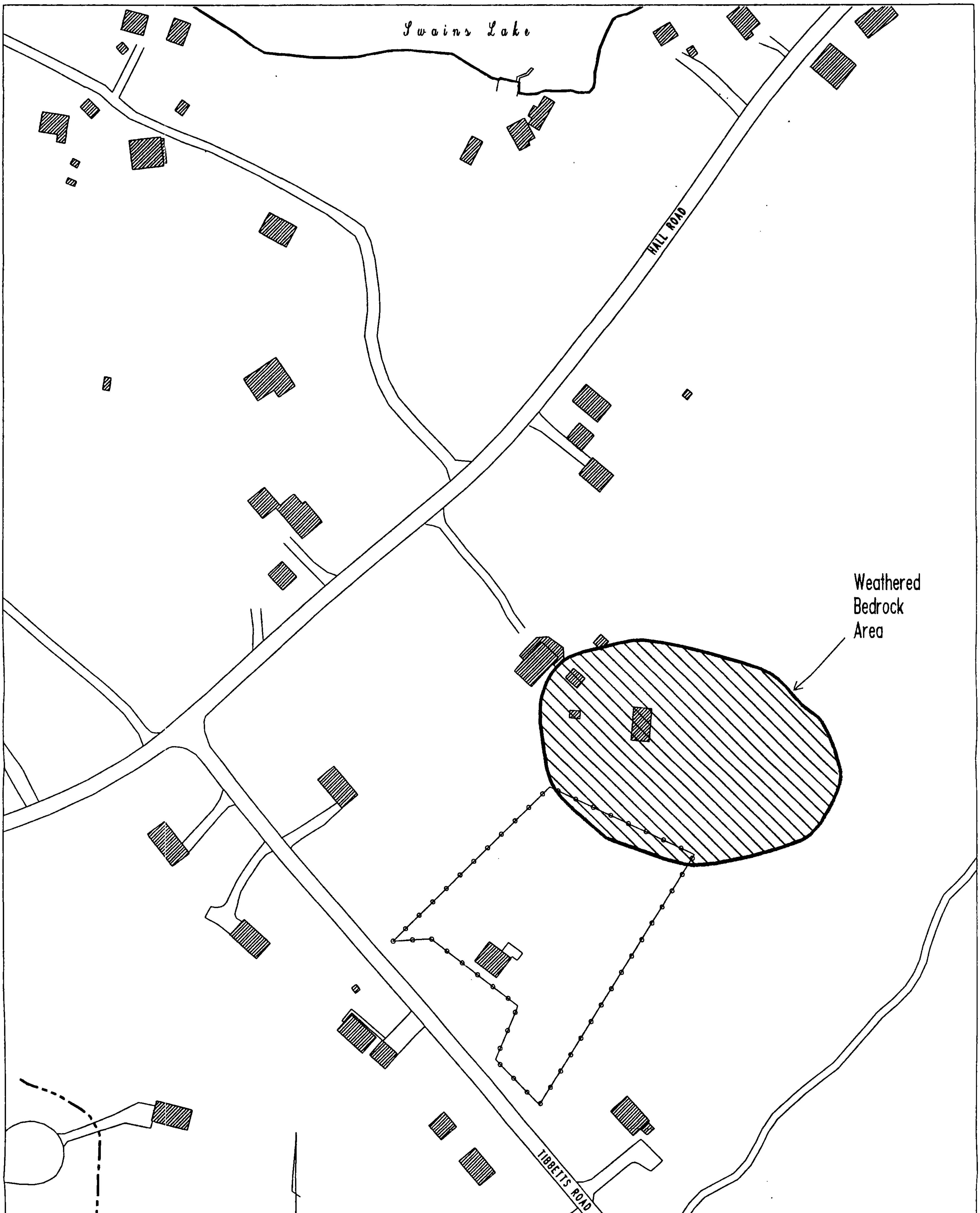


Figure B-2

PRECIPITATION, INFILTRATION AREA IN WEATHERED BEDROCK FOR FLUSHING CALCULATIONS

TIBBETTS ROAD, BARRINGTON, NH

Scale 1 : 1,440

100 0 100 200 feet

Source base map: Eastern Topographics, June 19, 1990

CDM Federal Programs Corp. Rough Groundwater Flushing Report for TRICHLOROETHENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 480000 cubic feet
Pump rate: 0.46 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: TRICHLOROETHENE
Koc (Organic carbon partition coefficient): 126 liters per kg
Kd (Distribution coefficient): 0.1638 liters per kg
Maximum Contamination Level: 5.0 micrograms per liter
Initial concentration in gw: 7800.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	22279.92	Conc =	7800.00
Flush #	1.00	Mass =	14479.92	Conc =	5069.29
Flush #	2.00	Mass =	9410.63	Conc =	3294.58
Flush #	3.00	Mass =	6116.05	Conc =	2141.18
Flush #	4.00	Mass =	3974.88	Conc =	1391.57
Flush #	5.00	Mass =	2583.31	Conc =	904.39
Flush #	6.00	Mass =	1678.92	Conc =	587.77
Flush #	7.00	Mass =	1091.14	Conc =	382.00
Flush #	8.00	Mass =	709.14	Conc =	248.26
Flush #	9.00	Mass =	460.88	Conc =	161.35
Flush #	10.00	Mass =	299.53	Conc =	104.86
Flush #	11.00	Mass =	194.67	Conc =	68.15
Flush #	12.00	Mass =	126.52	Conc =	44.29
Flush #	13.00	Mass =	82.22	Conc =	28.79
Flush #	14.00	Mass =	53.44	Conc =	18.71
Flush #	15.00	Mass =	34.73	Conc =	12.16
Flush #	16.00	Mass =	22.57	Conc =	7.90
Flush #	17.00	Mass =	14.67	Conc =	5.14
Flush #	18.00	Mass =	9.53	Conc =	3.34

Number of flush volumes required: 18.00
Final concentration in groundwater: 3.34 micrograms per liter
Time to cleanup: 41.08 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report for TRICHLOROETHENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 480000 cubic feet
Pump rate: 0.80 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: TRICHLOROETHENE
Koc (Organic carbon partition coefficient): 126 liters per kg
Kd (Distribution coefficient): 0.1638 liters per kg
Maximum Contamination Level: 5.0 micrograms per liter
Initial concentration in gw: 7800.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	22279.92	Conc =	7800.00
Flush #	1.00	Mass =	14479.92	Conc =	5069.29
Flush #	2.00	Mass =	9410.63	Conc =	3294.58
Flush #	3.00	Mass =	6116.05	Conc =	2141.18
Flush #	4.00	Mass =	3974.88	Conc =	1391.57
Flush #	5.00	Mass =	2583.31	Conc =	904.39
Flush #	6.00	Mass =	1678.92	Conc =	587.77
Flush #	7.00	Mass =	1091.14	Conc =	382.00
Flush #	8.00	Mass =	709.14	Conc =	248.26
Flush #	9.00	Mass =	460.88	Conc =	161.35
Flush #	10.00	Mass =	299.53	Conc =	104.86
Flush #	11.00	Mass =	194.67	Conc =	68.15
Flush #	12.00	Mass =	126.52	Conc =	44.29
Flush #	13.00	Mass =	82.22	Conc =	28.79
Flush #	14.00	Mass =	53.44	Conc =	18.71
Flush #	15.00	Mass =	34.73	Conc =	12.16
Flush #	16.00	Mass =	22.57	Conc =	7.90
Flush #	17.00	Mass =	14.67	Conc =	5.14
Flush #	18.00	Mass =	9.53	Conc =	3.34

Number of flush volumes required: 18.00
Final concentration in groundwater: 3.34 micrograms per liter
Time to cleanup: 23.62 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report
for BENZENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 480000 cubic feet
Pump rate: 0.46 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: BENZENE
Koc (Organic carbon partition coefficient): 64 liters per kg
Kd (Distribution coefficient): 0.0832 liters per kg
Maximum Contamination Level: 5 micrograms per liter
Initial concentration in gw: 590.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	1146.33	Conc =	590.00
Flush #	1.00	Mass =	556.33	Conc =	286.34
Flush #	2.00	Mass =	270.00	Conc =	138.96
Flush #	3.00	Mass =	131.03	Conc =	67.44
Flush #	4.00	Mass =	63.59	Conc =	32.73
Flush #	5.00	Mass =	30.86	Conc =	15.88
Flush #	6.00	Mass =	14.98	Conc =	7.71
Flush #	7.00	Mass =	7.27	Conc =	3.74

Number of flush volumes required: 7.00
Final concentration in groundwater: 3.74 micrograms per liter
Time to cleanup: 15.97 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report for BENZENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 480000 cubic feet
Pump rate: 0.80 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: BENZENE
Koc (Organic carbon partition coefficient): 64 liters per kg
Kd (Distribution coefficient): 0.0832 liters per kg
Maximum Contamination Level: 5 micrograms per liter
Initial concentration in gw: 590.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	1146.33	Conc =	590.00
Flush #	1.00	Mass =	556.33	Conc =	286.34
Flush #	2.00	Mass =	270.00	Conc =	138.96
Flush #	3.00	Mass =	131.03	Conc =	67.44
Flush #	4.00	Mass =	63.59	Conc =	32.73
Flush #	5.00	Mass =	30.86	Conc =	15.88
Flush #	6.00	Mass =	14.98	Conc =	7.71
Flush #	7.00	Mass =	7.27	Conc =	3.74

Number of flush volumes required: 7.00
Final concentration in groundwater: 3.74 micrograms per liter
Time to cleanup: 9.19 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report for TRICHLOROETHENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 480000 cubic feet
Pump rate: 0.46 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: TRICHLOROETHENE
Koc (Organic carbon partition coefficient): 126 liters per kg
Kd (Distribution coefficient): 0.1638 liters per kg
Maximum Contamination Level: 5.0 micrograms per liter
Initial concentration in gw: 300.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	856.92	Conc =	300.00
Flush #	1.00	Mass =	556.92	Conc =	194.97
Flush #	2.00	Mass =	361.95	Conc =	126.71
Flush #	3.00	Mass =	235.23	Conc =	82.35
Flush #	4.00	Mass =	152.88	Conc =	53.52
Flush #	5.00	Mass =	99.36	Conc =	34.78
Flush #	6.00	Mass =	64.57	Conc =	22.61
Flush #	7.00	Mass =	41.97	Conc =	14.69
Flush #	8.00	Mass =	27.27	Conc =	9.55
Flush #	9.00	Mass =	17.73	Conc =	6.21
Flush #	10.00	Mass =	11.52	Conc =	4.03

Number of flush volumes required: 10.00
Final concentration in groundwater: 4.03 micrograms per liter
Time to cleanup: 22.82 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report
for TRICHLOROETHENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 480000 cubic feet
Pump rate: 0.80 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: TRICHLOROETHENE
Koc (Organic carbon partition coefficient): 126 liters per kg
Kd (Distribution coefficient): 0.1638 liters per kg
Maximum Contamination Level: 5.0 micrograms per liter
Initial concentration in gw: 300.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	856.92	Conc =	300.00
Flush #	1.00	Mass =	556.92	Conc =	194.97
Flush #	2.00	Mass =	361.95	Conc =	126.71
Flush #	3.00	Mass =	235.23	Conc =	82.35
Flush #	4.00	Mass =	152.88	Conc =	53.52
Flush #	5.00	Mass =	99.36	Conc =	34.78
Flush #	6.00	Mass =	64.57	Conc =	22.61
Flush #	7.00	Mass =	41.97	Conc =	14.69
Flush #	8.00	Mass =	27.27	Conc =	9.55
Flush #	9.00	Mass =	17.73	Conc =	6.21
Flush #	10.00	Mass =	11.52	Conc =	4.03

Number of flush volumes required: 10.00
Final concentration in groundwater: 4.03 micrograms per liter
Time to cleanup: 13.12 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report
for BENZENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 480000 cubic feet
Pump rate: 0.46 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: BENZENE
Koc (Organic carbon partition coefficient): 64 liters per kg
Kd (Distribution coefficient): 0.0832 liters per kg
Maximum Contamination Level: 5 micrograms per liter
Initial concentration in gw: 1100.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	2137.23	Conc =	1100.00
Flush #	1.00	Mass =	1037.23	Conc =	533.85
Flush #	2.00	Mass =	503.38	Conc =	259.08
Flush #	3.00	Mass =	244.30	Conc =	125.74
Flush #	4.00	Mass =	118.56	Conc =	61.02
Flush #	5.00	Mass =	57.54	Conc =	29.61
Flush #	6.00	Mass =	27.92	Conc =	14.37
Flush #	7.00	Mass =	13.55	Conc =	6.98
Flush #	8.00	Mass =	6.58	Conc =	3.39

Number of flush volumes required: 8.00
Final concentration in groundwater: 3.39 micrograms per liter
Time to cleanup: 18.26 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report for BENZENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 480000 cubic feet
Pump rate: 0.80 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: BENZENE
Koc (Organic carbon partition coefficient): 64 liters per kg
Kd (Distribution coefficient): 0.0832 liters per kg
Maximum Contamination Level: 5 micrograms per liter
Initial concentration in gw: 1100.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	2137.23	Conc =	1100.00
Flush #	1.00	Mass =	1037.23	Conc =	533.85
Flush #	2.00	Mass =	503.38	Conc =	259.08
Flush #	3.00	Mass =	244.30	Conc =	125.74
Flush #	4.00	Mass =	118.56	Conc =	61.02
Flush #	5.00	Mass =	57.54	Conc =	29.61
Flush #	6.00	Mass =	27.92	Conc =	14.37
Flush #	7.00	Mass =	13.55	Conc =	6.98
Flush #	8.00	Mass =	6.58	Conc =	3.39

Number of flush volumes required: 8.00
Final concentration in groundwater: 3.39 micrograms per liter
Time to cleanup: 10.50 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report for TRICHLOROETHENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 1230000 cubic feet
Pump rate: 1.10 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: TRICHLOROETHENE
Koc (Organic carbon partition coefficient): 126 liters per kg
Kd (Distribution coefficient): 0.1638 liters per kg
Maximum Contamination Level: 5.0 micrograms per liter
Initial concentration in gw: 53.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	151.39	Conc =	53.00
Flush #	1.00	Mass =	98.39	Conc =	34.45
Flush #	2.00	Mass =	63.94	Conc =	22.39
Flush #	3.00	Mass =	41.56	Conc =	14.55
Flush #	4.00	Mass =	27.01	Conc =	9.46
Flush #	5.00	Mass =	17.55	Conc =	6.15
Flush #	6.00	Mass =	11.41	Conc =	3.99

Number of flush volumes required: 6.00
Final concentration in groundwater: 3.99 micrograms per liter
Time to cleanup: 14.67 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report
for TRICHLOROETHENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 1230000 cubic feet
Pump rate: 2.00 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: TRICHLOROETHENE
Koc (Organic carbon partition coefficient): 126 liters per kg
Kd (Distribution coefficient): 0.1638 liters per kg
Maximum Contamination Level: 5.0 micrograms per liter
Initial concentration in gw: 53.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	151.39	Conc =	53.00
Flush #	1.00	Mass =	98.39	Conc =	34.45
Flush #	2.00	Mass =	63.94	Conc =	22.39
Flush #	3.00	Mass =	41.56	Conc =	14.55
Flush #	4.00	Mass =	27.01	Conc =	9.46
Flush #	5.00	Mass =	17.55	Conc =	6.15
Flush #	6.00	Mass =	11.41	Conc =	3.99

Number of flush volumes required: 6.00
Final concentration in groundwater: 3.99 micrograms per liter
Time to cleanup: 8.07 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report
for BENZENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 1230000 cubic feet
Pump rate: 1.10 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: BENZENE
Koc (Organic carbon partition coefficient): 64 liters per kg
Kd (Distribution coefficient): 0.0832 liters per kg
Maximum Contamination Level: 5 micrograms per liter
Initial concentration in gw: 140.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	272.01	Conc =	140.00
Flush #	1.00	Mass =	132.01	Conc =	67.94
Flush #	2.00	Mass =	64.07	Conc =	32.97
Flush #	3.00	Mass =	31.09	Conc =	16.00
Flush #	4.00	Mass =	15.09	Conc =	7.77
Flush #	5.00	Mass =	7.32	Conc =	3.77

Number of flush volumes required: 5.00
Final concentration in groundwater: 3.77 micrograms per liter
Time to cleanup: 12.23 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report for BENZENE

PARAMETERS USED

Porosity: 0.15
Density: 2.00 kilograms per liter
Plume volume: 1230000 cubic feet
Pump rate: 2.00 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1300%

Contaminant: BENZENE
Koc (Organic carbon partition coefficient): 64 liters per kg
Kd (Distribution coefficient): 0.0832 liters per kg
Maximum Contamination Level: 5 micrograms per liter
Initial concentration in gw: 140.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	272.01	Conc =	140.00
Flush #	1.00	Mass =	132.01	Conc =	67.94
Flush #	2.00	Mass =	64.07	Conc =	32.97
Flush #	3.00	Mass =	31.09	Conc =	16.00
Flush #	4.00	Mass =	15.09	Conc =	7.77
Flush #	5.00	Mass =	7.32	Conc =	3.77

Number of flush volumes required: 5.00
Final concentration in groundwater: 3.77 micrograms per liter
Time to cleanup: 6.72 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report
for TRICHLOROETHENE

PARAMETERS USED

Porosity: 0.10
Density: 2.20 kilograms per liter
Plume volume: 2625000 cubic feet
Pump rate: 1.90 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1000%

Contaminant: TRICHLOROETHENE
Koc (Organic carbon partition coefficient): 126 liters per kg
Kd (Distribution coefficient): 0.1260 liters per kg
Maximum Contamination Level: 5.0 micrograms per liter
Initial concentration in gw: 650.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	2271.62	Conc =	650.00
Flush #	1.00	Mass =	1621.62	Conc =	464.01
Flush #	2.00	Mass =	1157.61	Conc =	331.24
Flush #	3.00	Mass =	826.37	Conc =	236.46
Flush #	4.00	Mass =	589.91	Conc =	168.80
Flush #	5.00	Mass =	421.12	Conc =	120.50
Flush #	6.00	Mass =	300.62	Conc =	86.02
Flush #	7.00	Mass =	214.60	Conc =	61.41
Flush #	8.00	Mass =	153.19	Conc =	43.83
Flush #	9.00	Mass =	109.36	Conc =	31.29
Flush #	10.00	Mass =	78.07	Conc =	22.34
Flush #	11.00	Mass =	55.73	Conc =	15.95
Flush #	12.00	Mass =	39.78	Conc =	11.38
Flush #	13.00	Mass =	28.40	Conc =	8.13
Flush #	14.00	Mass =	20.27	Conc =	5.80
Flush #	15.00	Mass =	14.47	Conc =	4.14

Number of flush volumes required: 15.00
Final concentration in groundwater: 4.14 micrograms per liter
Time to cleanup: 30.21 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report
for TRICHLOROETHENE

PARAMETERS USED

Porosity: 0.10
Density: 2.20 kilograms per liter
Plume volume: 2625000 cubic feet
Pump rate: 4.00 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1000%

Contaminant: TRICHLOROETHENE
Koc (Organic carbon partition coefficient): 126 liters per kg
Kd (Distribution coefficient): 0.1260 liters per kg
Maximum Contamination Level: 5.0 micrograms per liter
Initial concentration in gw: 650.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	2271.62	Conc =	650.00
Flush #	1.00	Mass =	1621.62	Conc =	464.01
Flush #	2.00	Mass =	1157.61	Conc =	331.24
Flush #	3.00	Mass =	826.37	Conc =	236.46
Flush #	4.00	Mass =	589.91	Conc =	168.80
Flush #	5.00	Mass =	421.12	Conc =	120.50
Flush #	6.00	Mass =	300.62	Conc =	86.02
Flush #	7.00	Mass =	214.60	Conc =	61.41
Flush #	8.00	Mass =	153.19	Conc =	43.83
Flush #	9.00	Mass =	109.36	Conc =	31.29
Flush #	10.00	Mass =	78.07	Conc =	22.34
Flush #	11.00	Mass =	55.73	Conc =	15.95
Flush #	12.00	Mass =	39.78	Conc =	11.38
Flush #	13.00	Mass =	28.40	Conc =	8.13
Flush #	14.00	Mass =	20.27	Conc =	5.80
Flush #	15.00	Mass =	14.47	Conc =	4.14

Number of flush volumes required: 15.00
Final concentration in groundwater: 4.14 micrograms per liter
Time to cleanup: 14.35 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report
for BENZENE

PARAMETERS USED

Porosity: 0.10
Density: 2.20 kilograms per liter
Plume volume: 2625000 cubic feet
Pump rate: 1.90 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1000%

Contaminant: BENZENE
Koc (Organic carbon partition coefficient): 64 liters per kg
Kd (Distribution coefficient): 0.0640 liters per kg
Maximum Contamination Level: 5 micrograms per liter
Initial concentration in gw: 4000.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	9068.80	Conc =	4000.00
Flush #	1.00	Mass =	5068.80	Conc =	2235.71
Flush #	2.00	Mass =	2833.09	Conc =	1249.60
Flush #	3.00	Mass =	1583.49	Conc =	698.43
Flush #	4.00	Mass =	885.06	Conc =	390.37
Flush #	5.00	Mass =	494.68	Conc =	218.19
Flush #	6.00	Mass =	276.49	Conc =	121.95
Flush #	7.00	Mass =	154.54	Conc =	68.16
Flush #	8.00	Mass =	86.38	Conc =	38.10
Flush #	9.00	Mass =	48.28	Conc =	21.29
Flush #	10.00	Mass =	26.98	Conc =	11.90
Flush #	11.00	Mass =	15.08	Conc =	6.65
Flush #	12.00	Mass =	8.43	Conc =	3.72

Number of flush volumes required: 12.00
Final concentration in groundwater: 3.72 micrograms per liter
Time to cleanup: 24.17 years

CDM Federal Programs Corp. Rough Groundwater Flushing Report for BENZENE

PARAMETERS USED

Porosity: 0.10
Density: 2.20 kilograms per liter
Plume volume: 2625000 cubic feet
Pump rate: 4.00 gallons per minute
100.00% of contaminated liquid replaced each iteration
Foc (percent organic carbon in soil): 0.1000%

Contaminant: BENZENE
Koc (Organic carbon partition coefficient): 64 liters per kg
Kd (Distribution coefficient): 0.0640 liters per kg
Maximum Contamination Level: 5 micrograms per liter
Initial concentration in gw: 4000.0 micrograms per liter

'Mass' refers to total mass of contaminant in a volume containing one liter of groundwater. 'Conc' is mass in 1 liter of gw. Both are given in micrograms.

Flush #	0.00	Mass =	9068.80	Conc =	4000.00
Flush #	1.00	Mass =	5068.80	Conc =	2235.71
Flush #	2.00	Mass =	2833.09	Conc =	1249.60
Flush #	3.00	Mass =	1583.49	Conc =	698.43
Flush #	4.00	Mass =	885.06	Conc =	390.37
Flush #	5.00	Mass =	494.68	Conc =	218.19
Flush #	6.00	Mass =	276.49	Conc =	121.95
Flush #	7.00	Mass =	154.54	Conc =	68.16
Flush #	8.00	Mass =	86.38	Conc =	38.10
Flush #	9.00	Mass =	48.28	Conc =	21.29
Flush #	10.00	Mass =	26.98	Conc =	11.90
Flush #	11.00	Mass =	15.08	Conc =	6.65
Flush #	12.00	Mass =	8.43	Conc =	3.72

Number of flush volumes required: 12.00
Final concentration in groundwater: 3.72 micrograms per liter
Time to cleanup: 11.48 years

The following tables summarize the parameters used and the results obtained from a flushing model used to determine the cleanup times to reduce the arsenic concentration in the overburden and aquifer to below the maximum contaminant level (MCL). Cleanup times were calculated for three areas within the overburden corresponding to the two proposed trench areas (Areas B and C) and the central portion of the site (Area A).

Input Parameters	**Overburden Areas**		
	A	B	C
Porosity, n	0.15	0.15	0.15
Saturated Thickness of Aquifer, h (ft)	15	15	15
Area of Contamination, A (ft^2)	32,000	32,000	82,000
Volume of Contaminated Water, V_w [million gallons (MG)]	0.54	0.54	1.38
Retardation Factor, R	2	2	2
Flow Rates, Q (MG/yr.):			
Natural Infiltration *	0.24	0.24	0.61
Ground Water Extraction **	0.42	0.42	1.1
Initial Arsenic Concentration, C_o (ppb)	97	150	185
Arsenic MCL/Cleanup Goal, C(t) (ppb)	50	50	50

CLEANUP TIMES IN YEARS REQUIRED TO MEET ARSENIC MCL

	Overburden Areas		
	A	B	C
Natural Attenuation *	3.0	4.9	5.9
Ground Water Extraction**	1.7	2.8	3.3

* Due to 12" infiltration contacting contaminated zones.

** Due to 21" infiltration, which may include need for limited (summer) recharge.

Objective: Determine the time required to reach the MCL of 50 ppb for Arsenic in the three overburden areas A, B, C (see Fig. B-1) based on natural attenuation and based on extraction of the contaminated groundwater.

Method: Use the "Mixing Tank" approach described by Bob Schreiber of CDM (see Calcs dated May 26, 1992):

$$C(t) = C_o e^{-\left(\frac{Qt}{nAhR}\right)}$$

$$\ln \frac{C(t)}{C_o} = -\frac{Qt}{nAhR}$$

$$\therefore \; t = -\frac{nAhR}{Q} \ln \frac{C(t)}{C_o}$$

where:
- t = cleanup time
- n = porosity
- A = Area of Contaminated Plume
- h = Saturated thickness of Plume
- R = Retardation Factor (Use 2 - WORST CASE)
- Q = Flow Rate
- $C(t)$ = Maximum Contaminant Level (50 ppb)
- C_o = Initial Contaminant Concentration

In the above equation, nAh = the volume of contaminated groundwater (V_w).

Thus, $$t = \frac{-V_w R}{Q} \ln \frac{C(t)}{C_o}$$

Area A

Parameters Used: $n = 0.15$; $A = 32{,}000\ ft^2$; $h = 15\ ft$

$V_W = 0.54$ Million Gallons (MG)

Based on an infiltration rate of 12 inches/year:

$$Q = 32{,}000\ ft^2 \times \frac{12\ in/yr}{12\ in/ft} \times \left(7.48 \times 10^{-6}\ \frac{MG}{ft^3}\right)$$

$$Q = 0.24\ MG/YR.\ \text{(Natural Attenuation)}$$

Based on an infiltration rate of 21 inches/yr. and a groundwater extraction system:

$$Q = 32{,}000 \times \frac{21}{12} \times 7.48 \times 10^{-6}$$

$$= 0.42\ MG/YR.$$

$C_0 = 97$ ppb (at Well 57S)

CLEANUP TIME

$$t = \frac{-V_W R}{Q} \ln\left(\frac{C(t)}{C_0}\right)$$

Natural Attenuation:

$$t = \frac{-(0.54\ MG)(2)}{0.24\ \frac{MG}{YR}} \ln\left(\frac{50\ ppb}{97\ ppb}\right)$$

$t = 3.0$ years

Groundwater Extraction:

$$t = \frac{-(0.54)(2)}{0.42} \ln \frac{50}{97}$$

$t = 1.7$ yrs.

AREA B

Parameters Used: $n = 0.15$; $A = 32{,}000\ ft^2$; $h = 15\ ft.$

$V_W = 0.54$ MG

Natural Attenuation @ 12"/yr.

$Q = 0.24$ MG/yr.

Groundwater Extraction @ 21"/yr.

$Q = 0.42$ MG/yr.

$C_0 = 150$ ppb (@ Well 52S)

CLEANUP TIME:

Natural Attenuation:

$$t = -\frac{0.54\,(2)}{0.24} \ln \frac{50}{150}$$

$t = 4.9$ yrs.

Groundwater Extraction:

$$t = \frac{-0.54\,(2)}{0.42} \ln \frac{50}{150}$$

$t = 2.8$ yrs.

AREA C

Parameters Used: $n = 0.15$; $A = 82{,}000\ ft^2$; $h = 15\ ft$

$V_w = 1.38$ MG

Natural Attenuation @ 12"/yr:

$Q = 0.61$ MG/yr.

Groundwater Extraction @ 21"/yr:

$Q = 1.1$ MG/yr.

$C_0 = 185$ ppb (@ Well 50 S)

CLEANUP TIME:

Natural Attenuation:

$$t = \frac{-1.38(2)}{0.61} \ln \frac{50}{185}$$

$t = 5.9$ yrs.

Groundwater Extraction:

$$t = \frac{-1.38(2)}{1.1} \ln \frac{50}{185}$$

$t = 3.3$ yrs.

CAMP DRESSER & McKEE

CLIENT EPA/ARCS
PROJECT TIBBETTS RD.
DETAIL
JOB NO.
DATE CHECKED 5-26-92
CHECKED BY SDHenderson
COMPUTED BY SCHREIBER
DATE 5/26/92
PAGE NO. 1/7

OBJECTIVES: ESTIMATE TIME TO REACH MCL FOR ARSENIC IN PLUME AT WELL 505 AREA.

THIS SET OF NOTES PROVIDES INFO. ON AN ESTIMATE OF TIME-TO-MCL.

SEE ALSO THE SWANSON-SCHREIBER 5/22/92 MTG. NOTES (1 PAGE), AND ATTACHED COPIES OF LYMAN, ET AL. BOOK PAGES.

ALSO NOTE THE REFS. TO VOLS I, II, + III OF CDM'S 10/91 DRAFT R.I. RPT.

BOTTOM LINE:

- MCL COULD BE REACHED WITHIN A YEAR OF 0.5 GPM PUMPING.
- DISPERSION COULD CAUSE THIS TIME TO BE EXTENDED.
- A GEOCHEMISTRY EVALUATION SHOULD BE PERFORMED — TO ESTIMATE ADSORPTION CHARACS. OF As IN THIS GEOLOGY - MORE RETARDATION COULD EXTEND TIME-TO-MCL SIGNIFICANTLY.

ASSUMPTIONS ~~[illegible]~~

- PUMPING OF ARSENIC PLUME = 0.5 GPM = 0.26 $\frac{MG}{yr}$ = 35,157 ft^3/yr

- AREA OF PLUME ≈ 1.5" × 0.8" @ 1" : 120'
  BASED ON FIG. 5-6 OF 10/91 DRAFT R.I. RPT. VOL. III

  $$A = (1.5 \times 120)(0.8 \times 120) = 17{,}280\ ft^2$$

- DEPTH OF PLUME :
  - BASED ON FIG. 3-7 OF DRAFT R.I. RPT (10/91) VOL. III.
  - PLUME IS ONLY IN "BROWN SANDY TILL."
  - DEPTH @ 50S ≈ 0.4" @ 1" : 20'

    $$h = 0.4 \times 20 = 8\ ft$$

- VOLUME OF WATER IN PLUME :

  $$V_w = n A h = (n)(17{,}280\ ft^2 \times 8\ ft)$$

  $$= (n)(138{,}240\ ft^3) \approx (n)(1\ MG)$$

- POROSITY : ASSUME IT RANGES FROM 10% TO 40%.

- RETARDATION :
  - VOCs BENZENE + TCE HAVE MOVED ABOUT 20 FT/YEAR — p. 5-13, 3rd ¶, R.I. RPT 10/91 VOL. III
  - ASSUMING VOCs WERE DUMPED AT SAME TIME AS ARSENIC, IT APPEARS THAT ARSENIC HAS MOVED AT SAME RATE AS BENZENE AND TCE.
  - THUS, MOST LIKELY RETARDATION ESTIMATE SHOULD BE LOW, TOWARDS 1.

CAMP DRESSER & McKEE CLIENT EPA/ARCS JOB NO. COMPUTED BY SCHREIBER
PROJECT TIBBETS RD. DATE CHECKED DATE 5/26/92
DETAIL CHECKED BY PAGE NO. 3/7

ASSUMPTIONS (CONT'D)

- RETARDATION (CONT'D):
  - BASED ON LYMAN, ET AL — SEE ATTACHED XEROX PAGES — AND ON DISCUSSIONS WITH MIKE MILLER + WARREN LYMAN:
    - ARSENIC CAN EXIST IN MANY CHEMICAL FORMS.
    - VARIOUS FACTORS (pH, REDOX, ETC.) CAN INFLUENCE ITS FORM AND ADSORPTION CONSIDERABLY.
    - RETARDATION IS THEREFORE HARD TO PREDICT.
    - ARSENIC IS TYPICALLY AN ANION IN GROUNDWATER.
    - MORE TIME WOULD BE NEEDED TO ANALYZE THE GEOCHEMISTRY AT THE SITE.
    - FIG. 2.12-6 ON p. 2.12-37 OF LYMAN ET AL CAN BE USED.

      ALSO, SECTION 3.1.1, p. 3-2 OF DRAFT R.I. RPT VOL. I — INDICATES SANDY, LOAM SOILS.

      THIS INDICATES "HIGH MOBILITY" — FURTHER BACKING UP LOW RETARDATION ASSUMPTION.
  - BOTTOM LINE — AS A "MOST LIKELY" CASE, ASSUME LITTLE RETARDATION.

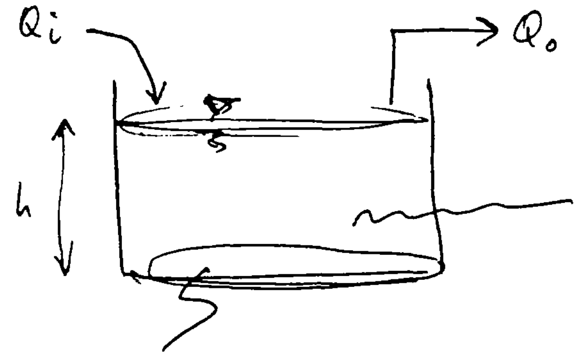
    AS A "WORST CASE," R MAY BE 2 OR SO.

- INITIAL CONC. AT START OF PUMPING: 139 µg/L

  BASED ON DRAFT R.I. RPT VOL. II TABLE 4-24.
- TARGET CONC.: MCL = 50 µg/L

METHOD

DERIVE "MIXING TANK" EQUATIONS



A = AREA
Vw = VOL. OF WATER
Vy = VOL. YIELDED

$$Q = Q_o = Q_i$$

$$V_w = nV \; ; \; V_y = S_y V$$

~~ASSUME V_w ... V_y ... V~~

$$V = Ah$$

$$V_w = nAh$$

$$M(t) = c(t) \cdot V_w$$

$$\Delta M = -Q \cdot c(t) \cdot \Delta t$$

$$\Delta M = -\Delta c \cdot V_w$$

$$\Delta c \cdot V_w = -Q \cdot c(t) \cdot \Delta t$$

$$V_w \cdot dc = -Q \cdot c(t) \cdot dt$$

$$\frac{dc}{c(t)} = -\frac{Q}{V_w}\,dt = -\frac{Q}{nAh}\,dt$$

$$\int_{c_o}^{c(t)} \frac{dc}{c} = \int_0^t -\frac{Q}{nAh}\,dt$$

$$\ln(c)\Big|_{c=c_o}^{c=c(t)} = -\frac{Q}{nAh}t\Big|_0^t$$

$$\left[\ln(c(t)) - \ln(c_o)\right] = -\frac{Q}{nAh}t$$

METHOD/EQUATIONS (CONT'D)

$$\ln\left[\frac{c(t)}{C_0}\right] = -\frac{Q}{nAh}t$$

$$e^{-\left(\frac{Q}{nAh}\right)t} = \frac{c(t)}{C_0}$$

$$c(t) = C_0 e^{-\left(\frac{Q}{nAh}\right)t}$$

THIS EQN. IS FOR NON-RETARDED SPECIES.

FOR RETARDED CONTAMINANTS, MODIFY THE VOLUME BY DEFINING AN "EFFECTIVE VOLUME":

$$V_R = V_w \cdot R$$

THUS, MIXING TANK EQN BECOMES:

$$c(t) = C_0 e^{-\left(\frac{Q}{nAhR}\right)t}$$

MAJOR ASSUMPTIONS OF THIS METHOD

- PLUME IS FULLY MIXED.
- DISPERSION DURING PUMP + TREAT IS LIMITED.
- RETARDATION MODELS INSTANTANEOUS EQUILIBRIUM OF PARTITIONING.
- RETARDATION SHOULD BE RANGED ACROSS LIKELY VALUES.
- WATER VOLUME IS DEFINED BY POROSITY "n" — THIS SHOULD BE RANGED FROM SPECIFIC YIELD TO TOTAL POROSITY.

ANALYSIS

- PREPARE A TABLE AND SHOW A RANGE OF POSSIBLE RESULTS. CIRCLE THE "MORE LIKELY" RESULT.
- TWO RANGED VARIABLES ARE:
  - R ≡ RETARDATION: 1 – 2; 1 MORE LIKELY
  - n ≡ POROSITY: 10% – 40%; 20% MORE LIKELY.
- USE OTHER ASSUMPTIONS LISTED ELSEWHERE.
- ANALYSIS EQN. BASED ON "MIXING TANK" APPROACH:

$$c(t) = C_o e^{-(Q/nAhR)t}$$

$$C_o = 139\ \mu g/L$$

$$Q = 0.26\ MG/yr$$

$$Ah = 1\ MG$$

$$c(t) = 50\ \mu g/L$$

$$(50\ \mu g/L) = [139\ \mu g/L]\, e^{-\left[\frac{0.26\ MG/yr}{(n)(1\ MG)(R)}\right](t)}$$

$$0.36 = e^{-\left[\left(\frac{1}{nR}\right)\left(\frac{0.26t}{yr}\right)\right]}$$

$$\ln(0.36) = -\left(\frac{1}{nR}\right)\left(\frac{0.26t}{yr}\right)$$

TIME TO REACH MCL ⟶ $t = -(nR)\left(\frac{yr}{0.26}\right)\left[\ln(0.36)\right]$

$$t = (3.88\ years) \times (nR)$$

CAMP DRESSER & McKEE

CLIENT	EPA/ARCS	JOB NO.		COMPUTED BY	SCHREIBER
PROJECT	TIBBETTS RD.	DATE CHECKED		DATE	5/26/92
DETAIL		CHECKED BY		PAGE NO.	7/7

RESULTS

EST'D NO. OF YEARS, AND MONTHS TO REACH ARSENIC MCL

	RETARDATION FACTOR	
POROSITY	1	2
10%	5 MOS.	10 MOS.
20%	10 MOS.	1 YR, 8 MOS.
30%	1 YR, 3 MOS.	2 YRS, 6 MOS.
40%	1 YR, 8 MOS.	3 YRS, 4 MOS.

CHECK CALCULATION

$$c(t) = c_0 e^{-(Q/nAhR)t}$$

t = 3 YRS, 4 MOS. = 1,216.75 DAYS

c_0 = 139 μg/L

Q = 0.5 GPM = 720 gals/day = 96 cfd

A = 17,280 ft^2

h = 8 ft

n = 40% = 0.4

R = 2

$$c(t) = (139) e^{-[(96)/(0.4 \cdot 17,280 \cdot 8 \cdot 2)] 1,216}$$

$$c(t) = (139) e^{-1.06} = (139)(0.35)$$

$c(t)$ = 48.16 μg/L ✓ ≈ MCL

CAMP DRESSER & McKEE | CLIENT EPA/ARCS | JOB NO. | COMPUTED BY SCHREIBER
PROJECT TIBBETTS RD | DATE CHECKED | DATE 5/22/92
DETAIL SWANSON – SCHREIBER | CHECKED BY | PAGE NO. 1/1

4710-4-FS1-FSRT

ARSENIC

- DON'T KNOW D/G EXTENT.
- TILL OVER BR.
- DOWNWARD GRADIENT
- MCL = 50 µg/L
- BACKGROUND = 10 µg/L
- SOURCE HISTORY:
  - '84-'85 EPA ON SITE.
  - ~~EP~~ PRP ON SITE FOR A LONG TIME
  - NO As IN SOILS.
  - COULD HAVE BEEN DUMPED AS A LIQUID, OR DISSOLVED FROM SOIL BY BIO ACTIVITY OR DUMPED W/ACID.
  - BEST GUESS IS THAT As RELEASED IN 1984, BECAUSE PRP DUMPED VOAs THEN TO COVER UP.

    VOAs SHOW A SLUG, GOING PAST 50 + 51 WELLS.

- TRENCH DESIGN:
  - ~~SATURATION POINT~~
  - ASSUME THAT TRENCH WILL GET VOLUME HYDRAULICALLY.
  - ENTIRE SYSTEM IS 5 GPM.

    TRENCH ~ 1 GPM.
  - ASSUME 0.5 GPM FOR As PLUME.

- As RETARDATION:
  - CHECK W/MIKE MILLER + WARREN LYMAN.

ENVIRONMENTAL INORGANIC CHEMISTRY

Properties, Processes, and Estimation Methods

Edited by

Itamar Bodek, Ph.D., Arthur D. Little, Inc.

Warren J. Lyman, Ph.D., Arthur D. Little, Inc.

William F. Reehl, Arthur D. Little, Inc.

David H. Rosenblatt, Ph.D., U.S. Army Biomedical Research and Development Laboratory

SETAC Special Publications Series

Series Editors

Barbara T. Walton,

Oak Ridge National Laboratory

Richard Ashley Conway,

Union Carbide Corporation

PERGAMON PRESS

New York • Oxford • Beijing • Frankfurt

São Paulo • Sydney • Tokyo • Toronto

7.2 ARSENIC (As)

7.2.1 Occurrence and Uses

In its natural state, arsenic is usually associated with sulfide ores. Over 100 minerals and ores contain arsenic. The principal arsenic-bearing minerals include: arsenopyrite (FeAsS), niccolite (NiAsS), cobaltite (CoAsS), tennantite ($Cu_{12}As_4S_{13}$), enargite (Cu_3AsS_4), and native arsenic [5]. The principal arsenic compounds produced are arsenic trioxide (As_2O_3) and arsenic metal, from which other compounds are made. About 70% of all arsenic used is in pesticides, principally the following:

- Monosodium methanearsenate (MSMA) — $HAsO_3CH_3Na$
- Disodium methanearsenate (DSMA) — $Na_2AsO_3CH_3$
- Arsenic acid — H_3AsO_4
- Dimethylarsinic acid (cacodylic acid) — $(CH_3)_2AsO_2H$

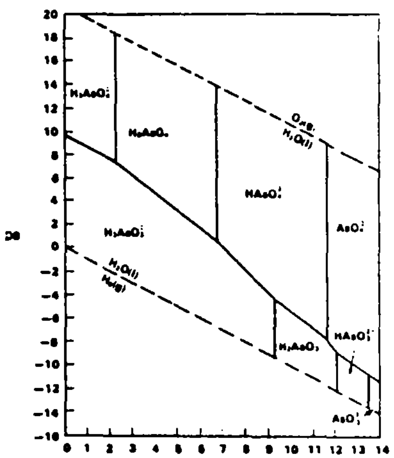
Other uses of arsenic and arsenic compounds are in wood preservatives, glass manufacture, alloys, electronics, catalysts, feed additives, and veterinary chemicals [23].

There are many arsenic forms of environmental significance, including arsenious acids (H_3AsO_3, $H_2AsO_3^-$, $HAsO_3^{-2}$), arsenic acids (H_3AsO_4, $H_2AsO_4^-$, $HAsO_4^{-2}$), arsenites, arsenates, methylarsenic acid ($H_2AsO_3CH_3$), dimethylarsinic acid ($(CH_3)_2AsO_2H$), arsine (AsH_3), dimethylarsine ($HAs(CH_3)_2$) and trimethylarsine ($As(CH_3)_3$). These forms illustrate the various oxidation states that arsenic commonly exhibits (−III, 0, III, V) and the resulting complexity of its chemistry in the environment.

7.2.2 Speciation Reactions in Water

Arsenic(V) chemistry resembles that of phosphorus(V). In aqueous systems, it exhibits anionic behavior. In aerobic waters, arsenic acid predominates only at extremely low pH (<2); within a pH range of 2 to 11, it is replaced by $H_2AsO_4^-$ and $HAsO_4^{-2}$. Arsenious acid appears at low pH and under mildly reduced conditions, but is replaced by $H_2AsO_3^-$ as the pH increases. Only when the pH exceeds 12 does $HAsO_3^{-2}$ appear. At low pH in the presence of sulfide, $HAsS_2$ can form; arsine, arsine derivatives and arsenic metal can occur under extreme reducing conditions [24]. Figure 7.2-1 shows the speciation of arsenic under varying pH and redox conditions. Figures 7.2-2 and -3 show the composition of arsenic in aerobic and reduced systems, respectively.

Since it forms anions in solution, arsenic does not form complexes with simple anions like Cl^- and SO_4^{-2}, as do cationic metals. Rather, anionic arsenic complexes behave like ligands in water. Arsenic forms bonds with organic sulfur, nitrogen and carbon. Arsenic (+III) reacts with sulfur and sulfhydryl groups such as cystine, organic dithiols, proteins and enzymes, but it does not react with amine groups or organics with reduced nitrogen constituents. On the other hand, arsenic (+V) reacts with



Source: *Rai et al [22] (Copyright 1984. Electric Power Research Institute Reprinted with permission.)*

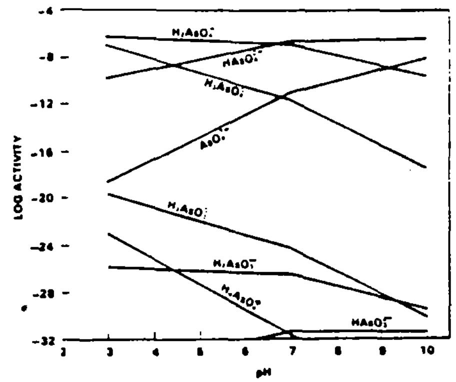
FIGURE 7.2-1 The pe-pH Diagram for Arsenic in Water at 25°C

reduced nitrogen groups such as amines but not sulfhydryl groups. Carbon forms organoarsenicals with both the trivalent and pentavalent forms [23]. The complexation of arsenic (+III and +V) by dissolved organic matter in natural environments prevents sorption and coprecipitation with solid-phase organics and inorganics; essentially, it increases the mobility of arsenic in aquatic systems and in the soil [5].

7.2.3 Solubility/Precipitation

The behavior of arsenic as a ligand suggests that the presence of metal cations could result in precipitation of arsenates and arsenites. Wagemann [25] studied barium, chromium, iron and calcium at typical freshwater concentrations as possible factors controlling the concentration level of total dissolved arsenic in solution. He postulated that at typical freshwater concentrations. Ba is the most likely controlling metal. Figure 7.2-4 shows the theoretical conditions for the precipitation of $Ba_3(AsO_4)_2$.

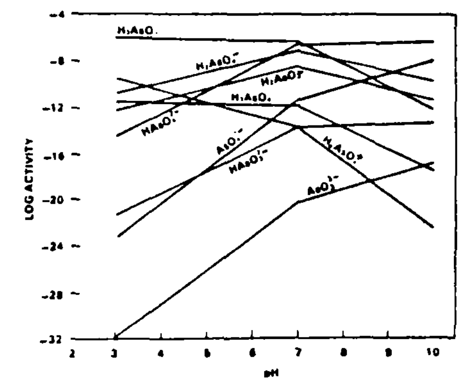
AsS and or As_2S_3 may form in very anoxic environments where sulfur is present [8]. Some authors [5,8,22] suggest that $FeAsO_4$ may control As levels at high redox



Total concentration of soluble As assumed to be 10^{-6} M

Source: *Rai et al [22] (Copyright 1984 Electric Power Research Institute. Reprinted with permission.)*

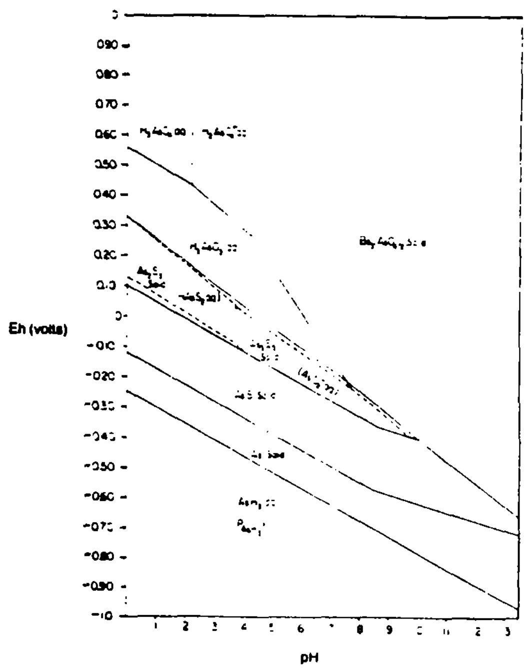
FIGURE 7.2-2 Activities of As Aqueous Species Under Aerobic Conditions (pe + pH = 16)



Total concentration of soluble As assumed to be 10^{-6} M.

Source: *Rai et al [22] (Copyright 1984. Electric Power Research Institute. Reprinted with permission.)*

FIGURE 7.2-3 Activities of As Aqueous Species Under Reduced Conditions (pe + pH = 7)



Source: Wagemann [25] (Copyright 1978, Pergamon Press Inc. Reprinted with permission.)

FIGURE 7.2-4 Fields of Stability for Important Arsenic Species at 25°C and 1 Atm in the Presence of 10^{-5} M Total Arsenic, 10^{-3} M Total Sulfur and 2.2×10^{-7} M Total Barium

(pe>12.5) and acidic pH (pH<2.3). $Pb_3(AsO_4)_2$ and $Mn_3(AsO_4)_2$ have also been suggested as possible solids in natural environments [14], but it has not been established whether the mechanism is precipitation or sorption onto solid surfaces.

The precipitation of arsenic depends largely on redox potential and pH. However, the presence of other minerals is also important: co-precipitation of arsenic with sulfides and iron oxides is a significant removal mechanism for arsenic in aqueous systems, as described below.

7.2.4 Sorption on Soils and Sediments

Arsenic is strongly sorbed onto soils and sediments, and sorption is one of the principal means by which arsenic is removed from solution. The process actually comprises three mechanisms: (1) specific adsorption onto Fe and Al hydrous oxides, clays, and carbonates; (2) co-precipitation with Fe oxides; and (3) isomorphic substitution of arsenic with phosphorus in minerals [24]. Co-precipitation with hydrous Fe oxides is probably the most common mechanism under most environmental conditions [5]. Ferguson and Gavis [5,8] state that co-precipitation with manganese oxides can also occur.

Each of the arsenic species possesses different chemical properties that affect its sorption behavior. In anaerobic sediments, Holm *et al.* [16,22] reported that arsenate is more strongly sorbed than methylarsenic acid. Cacodylic acid (dimethylarsinic acid) is less strongly sorbed than arsenate or methylarsenic acid. Wauchope [27] found that the same order applied in aerobic sediments.

Ferguson and Anderson [7] stated that the sorption of arsenate on iron and aluminum hydroxide followed the Langmuir isotherm, while arsenite was less strongly sorbed on the same materials and seemed to vary linearly with concentration. Iron oxide surfaces are positively charged at particular pH conditions, and arsenate and arsenite may be sorbed as negatively charged ions. Gulens, Champ and Jackson [12] speculated that both As(V) and As(III) anions form complexes with Fe(III) in solution; the difference in As(V) and As(III) sorption could then be explained by the greater solubility of the Fe(III)-As(III) complex. Whatever the mechanism, As(III) appears to be less strongly sorbed than As(V).

The factors affecting arsenic sorption on soils and sediments include redox conditions, pH, the presence of certain competing anions and complexing ions, salinity, clay content, and hydrous oxide content. Sorbed As(V) in sediments may be remobilized if conditions become sufficiently reduced for As(III) to form. Arsenic also appears to be more mobile under alkaline conditions. The maximum sorption of As(V) on kaolinite and montmorillonite is at pH 5 [9]. The sorption of As(III) increases beyond this pH; at pH 8, more As(III) is sorbed than As(V). Gupta and Chen [13] showed that sorption of As(III) onto alumina, bauxite and carbon decreases at pH values above 9, while for As(V), the decrease occurs when the pH is above 7. Similar pH dependencies have been shown for sorption on Al and Fe oxides [1,21].

The rate and extent of arsenic sorption onto alumina, bauxite and carbon decreases with increased salinity [13]. The presence of other ions also affects arsenic sorption, because they compete for sorption sites or complex with arsenic. Because of its similarity to arsenate, phosphate competes strongly with arsenate on iron oxides, soils and sediments [4,15,16,18]. The anions that have little or no effect include Cl^- and SO_4^{-2} [17,18]. Organics that complex with arsenic presumably would increase arsenic mobility and decrease its sorption.

The literature provides sorption constants for arsenic either as a particular arsenic species or for total arsenic sorption onto various sorbents, soils and sediments. Different types of sorption constants are also reported: sorption capacities at equilibrium, Freundlich constants, Langmuir constants, and sorption for specific experimental conditions. A brief summary of each kind of constant as measured for arsenic is given below. The reader is encouraged to refer to the original documents for details on experimental conditions, because values vary greatly depending on the particular conditions of each measurement.

Fuller [10,11] found the mobility of arsenic in clay soils to be low to moderate but much higher for loamy and sandy soils (6-10 cm/day for loamy sand). Using leachates of varying concentrations from landfills and soils, Arthur D. Little, Inc. [3] measured sorption capacity by means of batch tests, as shown in Table 7.2-1.

TABLE 7.2-1

Sorption Capacity for Total Arsenic at Equilibrium for Soils

Soil Type	Solution Conc. at Equilibrium (ppb)	Sorption Capacity (μg total As/g soil)
Alluvial material	< 0.2-420	1.1-215
Residual soil	< 0.2-225	1.1-28.9
Silty fine sand with little clay	0.4-483	1.0-252
Gravelly, well-graded silty sand	14-477	1.0-121
Brown, clayey sand	2.2-495	1.0-80
Fine sand	10-514	1.1-7.9

Source: Arthur D. Little, Inc. [3].

Elkhatib *et al.* [6] reported values for arsenic (III) sorption by various soils in West Virginia. Freundlich isotherms were used to model the sorption for Lily (fine loamy siliceous), Chavies (coarse loamy mixed), and Upshur (fine mixed) soils. The results are shown in Table 7.2-2.

Sorption of arsenic(V) has been described by the Langmuir isotherm. For kaolinite and montmorillonite, A_m was reported [9] to be 7.19 and 9.9 μmol/g respectively, and the corresponding K_L values were 3.54 and 3.57 (log M^{-1}).[1] For soils, A_m (total) was reported by Wangan *et al.* [26][1] to vary between 3.31 and 4.47.

TABLE 7.2-2

Freundlich Isotherm Constants[a] for Some West Virginia Soils

Soil Type	Lily		Chavies		Gilpin		Pope		Upshur	
Horizon	A	Bt	A	Bt	A	Bt	A	Bw	A	Bt
K_F	28.3	22.7	77.4	93.8	30.2	18.2	63.8	102.0	33.6	21.6
1/N	0.389	0.428	0.437	0.460	0.674	0.958	0.671	0.669	0.646	0.636

a. K_F, 1/N = Freundlich constants for $S = K_F C^{1/N}$, where S = mg As (III)/kg and C = mg As (III)/liter.

Source: Elkhatib *et al.* [6]

Wauchope and McDowell [28] measured sorption, S (μmol/g), for various arsenic species onto sediments from five lakes and one creek in the Mississippi River alluvial flood plain. Their results are shown in Table 7.2-3.

TABLE 7.2-3

Sorption (S) of Arsenic Species Onto Sediments After Two Hours

	Arsenate $H_2AsO_4^-$		Methanearsonate $HAsO_3CH_3^-$		Cacodylate $HAsO_2(CH_3)_2$	
Sorbate Conc. (μM)	0.37	3.87	0.36	3.63	0.40	3.90
Sorption[a] (μmol/g)	−0.023-0.063	0.36-0.71	−0.008-0.067	−0.018-0.68	−0.011-0.081	0.017-0.48

a. Negative values indicate desorption from the sediments.

Source: Wauchope and McDowell [28]

1. A_m = Langmuir sorption maximum, μmol/g; K_L = Langmuir constant, log M^{-1}. A_m (total) is the sum of A_m(i) when more than one type of site, i, is present

7.2.5 Biotransformation

The biological cycling of arsenic in the environment is described in section 2.15, which deals with the microbial transformation of inorganic pollutants. Methylation of arsenic is important because of the extremely toxic products that result. Also, this process transfers arsenic from sediments back to the water column in aquatic systems, increasing arsenic mobility in the environment. Biotransformation of arsenic can produce highly volatile compounds such as arsine (AsH_3), dimethylarsine ($HAs(CH_3)_2$) and trimethylarsine ($As(CH_3)_3$).

The processes and conditions involved in arsenic cycling in water were illustrated in section 2.15 (Figure 2.15-3). This cycle has been found to occur in both freshwater and saltwater systems [2,5,8]. The dominant processes in the arsenic cycle of an environmental system is determined by the environmental conditions (aerated or reduced, pH, microbial population, etc.) in the system.

7.2.6 Volatilization

In extremely anoxic environments, arsine may be produced. Methylation of arsenic can also result in highly volatile methylated arsine derivatives. Arsine is probably rapidly oxidized under aerobic conditions or in the atmosphere [5,19,20], but dimethylarsine and trimethylarsine may be more persistent because of their lower rates of oxidation [5].

7.2.7 Literature Cited

1. Anderson, M.A., J.F. Ferguson and J. Gavis, "Arsenate Adsorption on Amorphous Aluminum Hydroxides," *J. Colloid and Interface Sci.*, **54**, 391-99 (1976).

2. Andreae, M.O., "Distribution and Speciation of Arsenic in Natural Waters and Some Marine Algae," *Deep Sea Research*, **25**, 391-402 (1978).

3. Arthur D. Little, Inc., *Full-Scale Field Evaluation of Waste Disposal from Coal-Fired Electric Generating Plants. Appendix F (Part 4)*, EPA Contract No. 68-02-3167, Final Report to U.S. EPA, Office of Research and Development, Washington, D.C. (1984).

4. Barrow, N.J., "On the Displacement of Adsorbed Anions from Soil: II. Displacement of Phosphate by Arsenate," *Soil Sci.*, **117**, 28-33 (1974), as cited by Rai *et al.* [22].

5. Callahan, M., M. Slimak, N. Gabel, I. May, C. Fowler, J. Freed, P. Jennings, R. Durfee, F. Whitmore, B. Maestri, W. Mabey, B. Holt and C. Gould, *Water-Related Environmental Fate of 129 Priority Pollutants. Volume I: Introduction and Technical Background, Metals and Inorganics, Pesticides and PCBs*, EPA-440/4-79-029a, EPA Contracts 68-01-3852 and 68-01-3867, Office of Water Planning and Standards, U.S. Environmental Protection Agency, Washington, D.C. (1979).

6. Elkhatib, E.A., O.L. Bennett and R.J. Wright, "Arsenite Sorption and Desorption in Soils," *Soil Sci. Soc. Am. J.*, **48**, 1025-30 (1984).

7. Ferguson, J.F. and M.A. Anderson, "Chemical Forms of Arsenic in Water Supplies and Their Removal," in *Chemistry of Water Supply, Treatment, and Distribution*, A.J. Rubin (ed.), Ann Arbor Science Publishers, Ann Arbor, Mich. 137-58 (1974).

8. Ferguson, J.F. and J. Gavis, "A Review of the Arsenic Cycle in Natural Waters," *Water Res.*, **6**, 1259-74 (1972).

9. Frost, R.R. and R.A. Griffin, "Effect of pH on Adsorption of Arsenic and Selenium from Landfill Leachate by Clay Minerals," *Soil Sci. Soc. Am. J.*, **41**, 53-57 (1977), as cited by Rai *et al.* [22].

10. Fuller, W.H., *Investigation of Landfill Leachate Pollutant Attenuation by Soils*, EPA 600/2-78-158, NTIS PB 286 995, Municipal Env. Res. Lab., Cincinnati, Ohio (1978).

11. Fuller, W.H., *Movement of Selected Metals, Asbestos, and Cyanide in Soil: Applications to Waste Disposal Problems*, EPA 600 2-77-020, PB 266 905, Municipal Environmental Research Laboratory, Cincinnati, Ohio (1977).

12. Gulens, J., D.R. Champ, and R.E. Jackson, "Influence of Redox Environments on the Mobility of Arsenic in Ground Water," in *Chemical Modeling in Aqueous Systems*, E.A. Jenne (ed.), American Chemical Society, Washington, DC, 81-95 (1979).

13. Gupta, S.K. and K.Y. Chen, "Arsenic Removal by Adsorption," *J. Water Pollut. Control Fed.*, **50**, 493-506 (1978).

14. Hess, R.E. and R.W. Blanchar, "Dissolution of Arsenic from Waterlogged and Aerated Soils," *Soil Sci. Soc. Am. J.*, **41**, 861-65 (1977).

15. Hingston, F.J., A.M. Posner and J.P. Quirk, "Competitive Adsorption of Negatively Charged Ligands on Oxide Surfaces," *Disc. Faraday Soc.*, **52**, 234-342 (1971), as cited by Rai *et al.* [22].

16. Holm, T.R., M.A. Anderson, D.G. Iverson, and R.S. Stanforth, "Heterogeneous Interactions of Arsenic in Aquatic Systems," in *Chemical Modeling in Aqueous Systems*, E.A. Jenne (ed.), Symposium Series 93, American Chemical Society, Washington, D.C., 711-36 (1979), as cited by Rai *et al.* [22].

17. Leckie, J.O., M.M. Benjamin, K. Hayes, G. Kaufman and S. Altman, *Adsorption/Coprecipitation of Trace Elements from Water with Iron Oxyhydroxide*, EPRI-RP-910, Electric Power Research Institute, Palo Alto, Calif. (1980), as cited by Rai *et al.* [22].

18. Livesey, N.T. and P.M. Huang, "Adsorption of Arsenate by Soil and Its Relation to Chemical Properties and Anions," *Soil Sci.*, **131**, 88-94 (1981), as cited by Rai *et al.* [22].

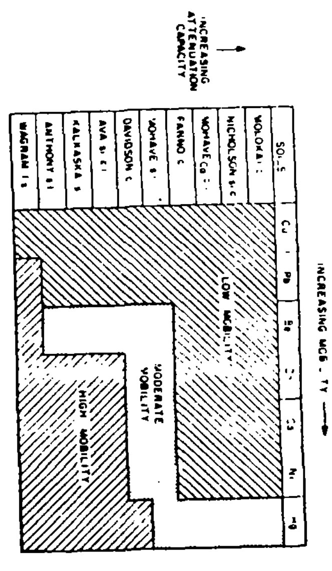
19. Parris, G.E. and F.E. Brinckman, "Reactions which Relate to the Environmental Mobility of Arsenic and Antimony: I. Quarternization of Trimethylarsine and Trimethylstibine," *J. Org. Chem.*, **40**, 3801-03 (1975), as cited by Callahan *et al.* [5].

TABLE 2.12-9

Empirical Parameters for Calculating the Propagation Velocity of Zinc by Equation 19

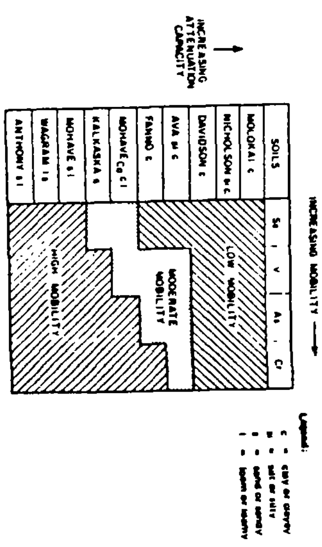
Parameter	[Zn]ps/[Zn]i 0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
a	0.0210	0.0173	0.0161	0.0149	0.0136	0.0111	0.00954	0 00803	0.00487
b	0.000657	0.000591	0.000570	0.000550	0.000526	0.000482	0 000466	0 000443	0 000398
c	2 784	2 747	2 697	2 660	2 637	2 638	2 660	2 648	2 698
d	0 00373	0 00336	0.00324	0.00310	0 00288	0 00255	0 00254	0 00236	0 00211
e	− 15.38	− 14.92	− 14 86	− 14 72	− 14 75	14 57	14.76	14 96	15 82
f	82 37	80 25	79 18	78 42	77 79	77 12	76 71	76.57	78 93
g	67.11	60 90	58.93	56 97	54 66	51 12	51 03	49 37	46 16
h	− 188.2	167 5	− 162.1	156 3	− 148.2	− 135 9	− 137 1	− 132.3	− 122 0
i	− 6 44	− 5 88	− 5.68	− 5.48	− 5 27	− 4.92	− 4.82	− 4.61	− 4 22
r^2	0 841	0 844	0.846	0 848	0 847	0 848	0 848	0 848	0 846

Source: Amoozegar-Fard, Fuller and Warrick [2] *(Copyright 1984, Reprinted with permission.)*



Source: Fuller [10]

FIGURE 2.12-5 Relative Mobility of Cation-Forming Elements in Soils



Source: Fuller [10]

FIGURE 2.12-6 Relative Mobility of Anion-Forming Elements in Soils

TABLE 2.12-4

Distribution Coefficients for Some Metals

Metal	Sorbent	Sorbate Conc. (M)	Electrolyte Identity	Electrolyte Conc. (M)	pH	K_d (ml/g)
Ba	River sediment	$10^{-4.0}$	Seawater	~0.7	8	530
	River sediment	$10^{-6.4}$	River water	—	—	2,800
Cd	Montmorillonite (Na-form)	$10^{-6} - 10^{-7}$	$NaNO_3$ + NaOAc	1.0 0.01	5.0	8
				1.0 0.01	6.5	100
				0.01 0.01	5.0	210
				0.01 0.01	6.5	800
Cu	Bentonite (Ca-form)	$0-10^{-4.2}$	Seawater	~0.7	8	43
	Kaolinite	Trace	Humic acid added	0 μg/l	6.4	43
				0.5 μg/l	6.4	3.2
				1.0 μg/l	6.4	2.6
				71.5 μg/l	6.4	2.2
	$Fe_2O_3 \cdot H_2O$(am)	$10^{-6.5}$	Seawater	~0.7	8	7,000
	MnO_2(hydrous)	$0-10^{-6.5}$	Seawater	~0.7	8	7,300
Mn	Fe oxide(hydrous)	$10^{-7.8} - 10^{-6.8}$	Seawater	~0.7	8	20,000
Hg	$Fe_2O_3 \cdot H_2O$(am)	2.5×10^{-6}	$NaNO_3$	1.0	4.5	58,200
					5.95	2,550,000
	Bentonite	10^{-6}	$Ca(NO_3)_2$	0.01	6.7	408,000
					7.9	179,000
					8.9	118,000
Ni	Montmorillonite	$10^{-6.5}$	Seawater	~0.7	8	200
	Fe oxide(hydrous)	$10^{-6.5}$	Seawater	~0.7	8	100,000
Zn	δ-MnO_2	10^{-6}-10^{-4}	Seawater	~0.7	8	800,000

Definitions:

$S = K_d C$

where S = mass sorbed at equilibrium per mass of sorbent (μmol/g)

K_d = distribution coefficient (ml/g)

C = sorbate concentration in solution at equilibrium (μmol/ml)

Source: Data (from various sources) adapted from Rai et al. [34]

TABLE 2.12-5

Langmuir Constants for Some Metals

Metal	Sorbent	Sorbate Conc. (M)	Electrolyte Identity	Electrolyte Conc. (M)	pH	Constants A_m (μmol/g)	Constants K_L (log M^{-1})
As	Hydroxide $Al(OH)_3$ (am)	As(V)	—	—	5	1,600	5.08
					6	1,487	5.17
					7	1,179	5.24
					8	538	5.12
					8.5	681	4.85
					9	501	4.82
	Oxyhydroxide, $Fe_2O_3 \cdot H_2O$(am)	As(III) as AsO_2^- 10^{-7} 10^{-5}	$NaNO_3$	1.0	4.0	457	5.98
					5.7	490	6.26
					7.0	513	6.36
					8.8	417	6.18
	Montmorillonite	10^{-4} - 10^{-3} As(V) + 10^{-4} - 10^{-3} As(III)	Leachate	—	5	9.9[a]	3.57[a]
Ba	MnO_2 (hydrous)	10^{-5} 10^{-3}	$NaClO_4$	0.01	5	2,050	4.6
Cd	Montmorillonite (Na-form)	$10^{-6.9} - 10^{-4}$	$NaClO_4$	0.01	6.5-7	0.5	7.7
				0.03	6.5-7	0.4	7.2
				0.05	6.5-7	0.4	6.8
				0.17	6.5-7	0.2	6.9
				1.0	6.5-7	0.3	6.7
	River sediment	$10^{-6.7} - 10^{-3.8}$	—	—	~7.5	10-173	4.4-6.0
Cr	Kaolinite	10^{-4} - $10^{-2.2}$ Cr(VI)	Leachate	—	3	3.64	—
					4	2.5	—
					7	0.98	—
		$10^{-3.3} - 10^{-1.8}$ Cr(III)	Leachate	—	3	96.3	—
					4	283	—

(Continued)

APPENDIX C

Cost Information

(This appendix contains cost computations and backup for the presentation of costs in Section 4)

CAMP DRESSER & McKEE CLIENT ____ JOB NO. ____ COMPUTED BY ____
PROJECT ____ DATE CHECKED 11/7/91 DATE ____
DETAIL ____ CHECKED BY [signature] PAGE NO. ____

CIVIL AND SITE RELATED.

COST ESTIMATE INFORMATION

CAMP DRESSER & McKEE CLIENT EPA JOB NO. 004 COMPUTED BY WRS
PROJECT Tibbetts Rd. DATE CHECKED 11/21/91 DATE 10/17/91
DETAIL FS Costs CHECKED BY [illegible] PAGE NO. (1.)

Cost Items for MM-2 (Note: MM-1, true No action, $0)

List various items & issues.

Demolition of house:

testing to prove not hazardous? - yes, for PCB's. disposal facility will need.

Knock down, cut up & haul away.

disposal cost at the landfill. - non haz.

Fencing: upgrade & maintain.

Rake, loam and seed site.

Remove debris, drums.

Monitoring: X number of Wells at specific time intervals.

VOA's / Semivolatiles / metals, could just use VOC's.

Use std laboratory price list.

Field crew at $50 / hour / person.

Based on text:

20 existing wells, assume monitoring plan already done.

VOC's - quarterly for two years.

semi annual for two more years

once a year thereafter.

Other issues: would state do some res. wells in the area as part of their overall approach? - exclude.

: deed restrictions? - include.

: public education programs - exclude cost

: cost of 5 year reviews? - exclude cost

Notes: Assume state does res. wells.
VOA's are adequate for tracking.

(1) Demolition of House

- tests for PCB's
  say 10 tests @ $150 each. = $1,500
  time to plan for, collect, and analyze samples, write report.
  200 hrs @ $50/hr = $10,000

  $11,500

- Demolition activity / Haul out. $20,000
- Cut up & Load into roll-offs, leave foundation as is. $5,000
- Disposal Cost @ $30/cubic yard.
  20'×30'×20' × 5% / 27 = 22.2 C.Y. $700
  (not hazardous.)

$37,200

(say $40,000 for removal.)

CAMP DRESSER & McKEE CLIENT ____ JOB NO. ____ COMPUTED BY ____
PROJECT ____ DATE CHECKED 11/21/91 DATE ____
DETAIL ____ CHECKED BY [illegible] PAGE NO. 3

(2) Site Aesthetics/Security

Fencing Repairs & upgrade. L.S.	$ 2,000	
Rake, loam, & seed. 2 acres/$2,500/acre.	$ 5,000	
RI/prior waste removal / 15 drums @ $300 each	~~$ 4,500~~	use pg 5 Calculation = ~~$20,000~~ $27,000
	$ ~~11,500~~ → ~~$12,000~~	WRS 2/10/92
	$ ~~29,000~~	
	$ 34,000	

~~(3)~~ Monitoring

Sample 20 wells
3 persons/1 week
120 hours x $50/hour = $ 6,000 / per event.

Sample/Analysis Cost. (VOA'S)
$205/sample X 20 wells. QC samples, etc. = $4,100 ~~00~~ 410 / per event

Report Prep, record keeping/reviews. = $ 2,000 / per event

$12,500 / per event. → $13,000

(3) ~~(4)~~ Preparation of Deed Restrictions
estimate 10 properties: @ $500 each — $ 5,000
(no cost or payment to owners.)

(Annual/Semiannual Site Inspections Under Monitoring Above.)

ALTERNATE WATER SUPPLY COSTS (A Portion of MM-2.)

• Issue is the cost of upgrading and operation and maintenance of the water supply.

Upgrading:

Based on conversations with the district, it appears that there is a problem with clogging of the filters. WRS discussed this with a district representative (Boucher) via telecom. The clogging occurs in a geotextile which separates the rock from the sand in the 2 - 70'x30' gravity slow sand filters? The geotextile is nonwoven and clogs? "Someone" had estimated replacement cost at about $100,000.

- It appears that two options are available:
  - (1) – geotextile replacement - possibly with a woven fabric.
  - (2) – complete filter replacement.

- Cost Factors for upgrading of the filters:
  - Study of the problem:
  - Report on finds and recommendations:
  - Specifications and procurement of contractor.
  - Modifications:
    - removal of sand, stone & fabric.
    - replace fabric and sand.
    - replace piping.

- Startup and shakedown of filters.
- Monitoring of operation for 6 months/or more.

Study of Problem / Report.

Review Plans. (20 hrs)
Discuss operation w/ district. (5 hrs.)
Observe operations,
Sampling & analysis in field. } 20 hrs.

Report of Results and Recommendations -(30 hrs.)

[75 hrs. @ $70/hr. = $5,250]

- Estimate L.S. of $10,000; including sampling & analysis

Develop Procurement Documents.

Specifications & Drawings, Computations -(200 hrs.)
Procurement activities - (40 hrs.)

[240 hrs @ $60/hr. = $14,400]

- Estimate L.S. of $16,000.

Removal and Replacement of Filter Components.

- Remove and stage sand, stone & fabric.
- Disposed of stone.
- Fresh sand & stone, new fabric.

30'x70' = 2,100 S.F. x 2 = 4,200 S.F.

Rough estimate: 4,200 S.F. x 3' / 27 = 467 C.Y.

Consider Excav, backfill compact by hand costs.

Means 1991 Data - 5th Edition.

Pg. 36

heavy soil / $19.50/C.Y.
hand tamp - 6" layers. $10.40/C.Y.

$29.90/C.Y.

AMP DRESSER & McKEE CLIENT______ JOB NO.______ COMPUTED BY WRS
PROJECT______ DATE CHECKED______ DATE 2/6/92
DETAIL______ CHECKED BY______ PAGE NO. (7)

Filter fabric.

Polypropylene $1.65/S.Y. plus 50% surcharge for small area

(pg. 47 - pavement base price.)

Stone: $30/C.Y. X 467 C.Y. = $14,010.

Fabric: $\frac{4,200}{9}$ x $2.50/s.y. = $1,167.

$15,177.

With opening, excavation, piping mods.
& cleanup a good rough figure is $25,000 to $30,000.

say $30,000

Startup, shakedown & monitoring.
estimate L.S. of $10,000.

Total of above: $66,000

(After consideration of above, decided to estimate more thorough upgrade.)

WRS 4/15/92 JAP 6/5/92

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY ______
PROJECT ______ DATE CHECKED ______ DATE ______
DETAIL ______ CHECKED BY ______ PAGE NO. ______

WATER TREATMENT SYSTEM UPGRADING

3/23/92

Comp. R. Stoops
Check W. Swanson.

(MM-2)

TIBBETTS ROAD SITE

SYSTEM REPLACEMENT COST SUMMARY

Building	$ 70,000
Package Treatment Plant	100,000
Sludge Drying Bed	25,000
Yard Work & Piping	10,000
Subtotal	$205,000
Engineering, Contingency &Administration @ 35%	$ 72,000
Total	$277,000

- Designed for 50 homes

- Treatment Provided by Two 50 gpm packaged units

- Use existing finished water storage and pressure system and existing chlorine and hydroxide system.

TECHNOLOGY SALES ASSOCIATES, Inc.

INSTRUMENTATION • CHEMICAL FEED • CONTROLS • BUTTERFLY AND BALL VALVES • PROCESS EQUIPMENT

HARLAN A. BARTLETT
PAUL S. SEIBERT, JR., P.E.
WAYNE C. FISCHER
ASSOCIATES
MICHAEL J. BRILLON
DARCY A. COLANERI
RICHARD F. KRAMER

TRI-TOWN PROFESSIONAL BUILDING
8 WILKINS DRIVE SUITE 210
PLAINVILLE, MA 02762

(508) 695-6070
FAX (508) 699-7617

TELEFAX TRANSMITTAL COVER SHEET

DATE: 3/20/92

TO: CDM

FAX #: 617-621-2565

ATTN: Bob Stoops

SUBJECT: Barrington, NH. / CPC Microfloc

PAGES: 6 TO FOLLOW

MESSAGE: Dear Bob,

Enclosed is info on the Trimite System. The 2TM50A would include two TM50A Tanks and offer the redundancy you desire. Please call with any questions.

REGARDS,

IF ANY OF THE ABOVE PAGES ARE NOT RECEIVED, PLEASE CALL US AT (508) 695-6070. THANK YOU.

OUR FAX NO. IS: (508) 699-7617.

TRI-MITE™ UTILIZES TRIDENT® TEC COST-EFFICIENT WATER TREATMEN

TRI-MITE™ IS COMPACT AND COMPLETE

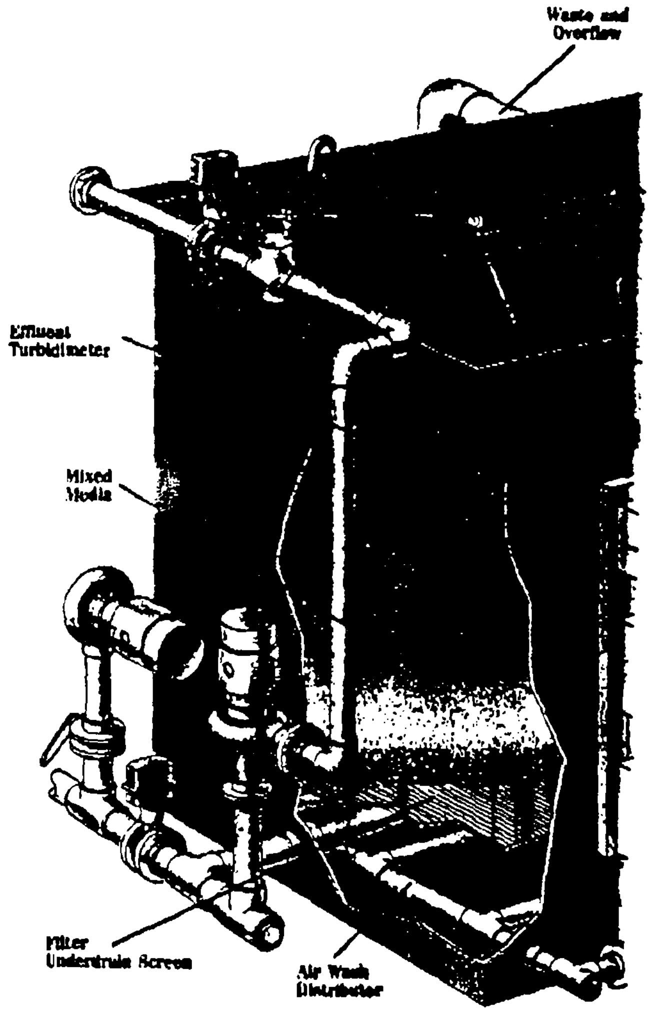
The Tri-Mite™ from CPC Engineering is a complete, factory-built water treatment plant. Tri-Mite, the smallest in *Microfloc Products' Trident® family of* treatment systems, combines the innovative flocculation/clarification technology of the Adsorption Clarifier™ with solid-state controls and the proven Microfloc Mixed Media filtration process. The result is a prepackaged plant that can meet both municipal and industrial standards for process and drinking water at a fraction of the cost and total land area required by conventional systems. Available in five sizes, one Tri-Mite unit can process flows ranging from 50 gpm to 350 gpm.

Benefits of the patented* Tri-Mite system include:

- Superior water quality
- Minimal space requirements
- Excellent process reliability
- Easy, affordable installation
- Low maintenance
- Simple operation

Unlike many other water treatment systems, Tri-Mite equipment is shipped fully assembled for easier, less costly installation. In addition, all but the two largest models are shipped with the Adsorption Clarifier media and Mixed Media already in place, further speeding installation and minimizing expense.

*Note: Proprietary Tri-Mite technology is protected under U.S. patents #4547286, #4608181, #4743382.



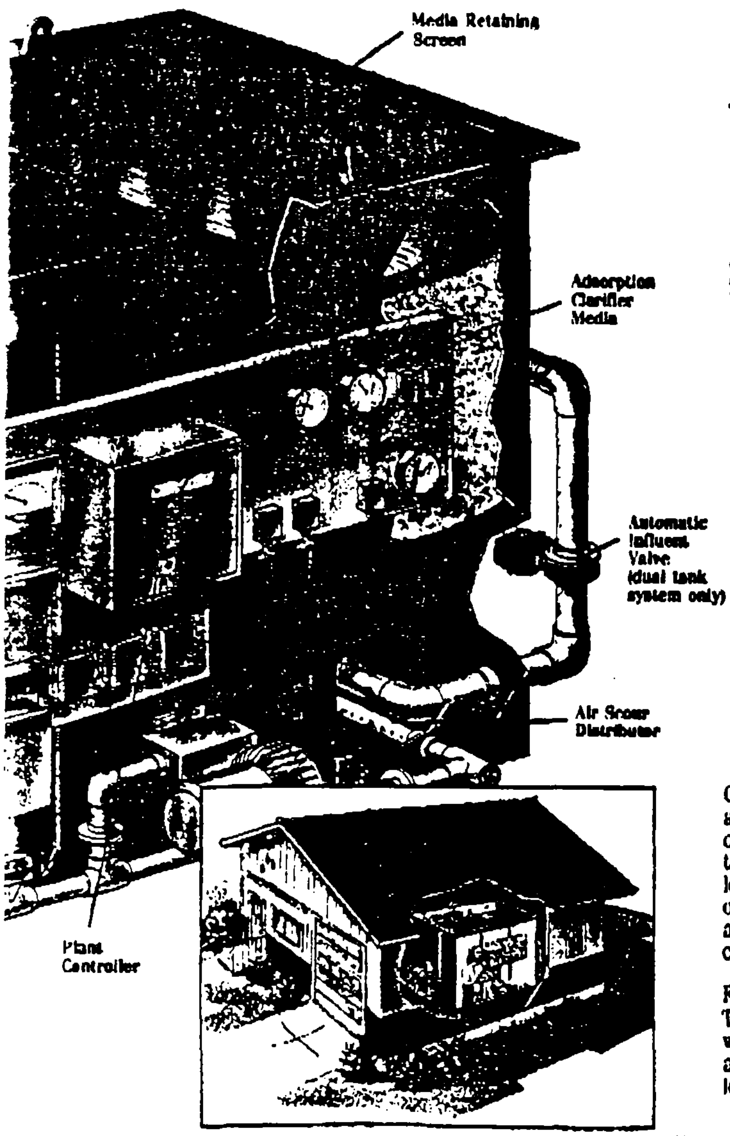
Actual models may vary slightly from artist's rendering shown.

TRI-MITE™ PRODUCES HIGH-QUALITY POTABLE OR PROCESS WATER

Tri-Mite water systems are ideal for small-scale industrial and municipal water treatment of surface water and groundwater supplies. Industrial uses include potable and process water production and reverse osmosis pretreatment. Municipal uses include treating drinking water in small communities, park and recreation areas and resorts.

The Trident process utilized by the Tri-Mite system can remove turbidity, color, iron, manganese, taste and odor. The system also removes many illness-causing microorganisms, such as *Giardia lamblia* and *Cryptosporidium*. The combination of the Adsorption Clarifier and the Mixed Media filter removes virtually all particulate contaminants and can routinely produce finished water with turbidity of 0.1-0.3 NTU.

INOLOGY TO PROVIDE RELIABLE, T IN LOW-CAPACITY APPLICATIONS



This cutaway illustration shows the compact size of a Tri-Mite unit within a correspondingly compact plant building. Efficient land use can result in significant capital cost savings.

TRI-MITE™ MODELS AND OPTIONS

Model	Nominal Capacity
TM-50A	50 gpm (72,000 GPD)
TM-75A	75 gpm (108,000 GPD)
TM-100A	100 gpm (144,000 GPD)
TM-175A	175 gpm (252,000 GPD)
TM-350A	350 gpm (504,000 GPD)

Note: Tri-Mite is designed for a one or two-unit configuration. The second unit of a two-unit system shares controls, backwash pump and air blower with the first unit.

Optional Equipment:

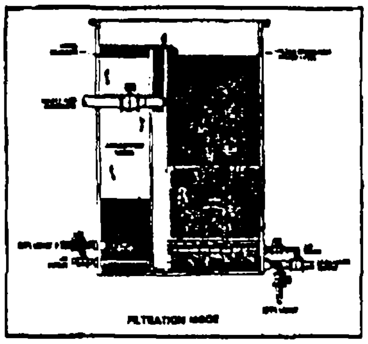
- Filter-to-waste valve and controls for use after filter backwash.
- Influent static mixer where additional mixing is required.
- Additional chemical feed systems as required.
- Streaming current monitor coagulation control.

CONVENIENT FINANCING IS AVAILABLE

CPC Engineering has made special arrangements for municipalities or other governmental units that choose to make their Tri-Mite acquisitions with lease/purchase financing. A simple, one-page form is all that is required for a quote, and the entire financing process will usually take less than a week.

For more information on acquiring a Tri-Mite with lease/purchase financing, which can offer cost and convenience advantages over bond issues and bank loans, call CPC Engineering.

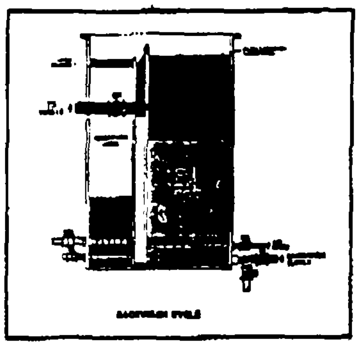
HOW TRI-MITE™ WORKS



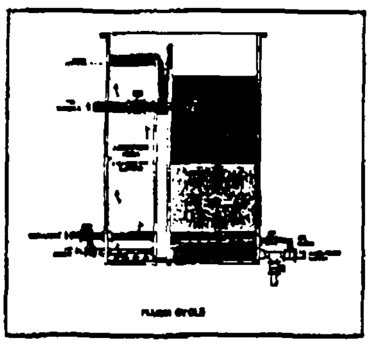
After chemical dosing, raw water enters the plant and flows upward through the Adsorption Clarifier. This innovative solids separation device contains granular, buoyant media that trap and remove the coagulated particles. Contact flocculation and clarification occur as the coagulated particles move through the media and are adsorbed onto the surfaces of the media and previously trapped solids. The Adsorption Clarifier provides stable, high-rate pretreatment and sends well-conditioned water to the Mixed Media filter. At this stage, up to 95% of turbidity has already been removed.

The Mixed Media filter polishes the flow to create excellent finished water quality. The filter uses a careful combination of materials to produce a filter bed that hydraulically grades from coarse to fine in the direction of filter flow. This allows true depth filtration and increased solids storage at high filter rates designed to match the efficiency of the Adsorption Clarifier. The result is consistent, high-quality effluent.

Proper coagulation is also essential for good water treatment, yet its control is seldom included as a process component, especially in low-capacity systems. The Tri-Mite utilizes a solid-state controller to facilitate coagulation control. The controller continuously receives an effluent turbidity signal and compares it to the operator-selected effluent setpoint quality. If the actual effluent turbidity is above or below deadband (the acceptable range around turbidity setpoint), the controller directs an appropriate change in the primary coagulant dosage rate.



HOW TRI-MITE™ SIMPLIFIES PLANT OPERATION AND MAINTENANCE



The patented Tri-Mite water system incorporates a number of elements which minimize operation and maintenance requirements. Painted carbon steel tankage, fully automatic controls and a compact design all reduce the amount of time and attention required to maintain and operate the system. (Stainless steel or aluminum tankage is also available.)

In addition, the Tri-Mite water system uses a simplified, two-step cleaning process. The Adsorption Clarifier is cleaned by injecting diffused air into the bottom of the clarifier. The air reduces the adsorption media's buoyancy, causing immediate expansion and scouring. Raw water continues to enter the clarifier, and the accumulated solids are flushed to waste.

The Mixed Media filter is backwashed by reversing the flow. In the three smallest Tri-Mite models, filter media is directly retained by an underdrain screen.

The two largest models, TM-175A and TM-350A, are each equipped with a PVC pipe lateral underdrain system and media support gravel. All Tri-Mite systems include air-enhanced backwash.

The filter wash cycles are accomplished automatically and are coordinated with interlocking controls. The control system can also automatically initiate a backwash when the effluent reaches a given turbidity level. Should the backwash fail to lower effluent turbidity to an acceptable level, the control system can shut the plant down automatically and initiate an alarm.

CALL CPC ENGINEERING FOR COMPLETE ANSWERS TO YOUR WATER TREATMENT PROBLEMS

To learn more about the Tri-Mite or our other Microfloc water treatment technologies, call (508) 347-7344. We can provide a complete, cost-effective approach to your water treatment.

microfloc.
PRODUCTS
CPC Engineering Corporation
P.O. Box 36, 441 Main Street
Sturbridge, MA 01566
(508) 347-7344
FAX: (508) 347-8156/(508) 347-7049

TRI-MITE™ SPECIFICATIONS

GENERAL

Under this section of the specifications, the contractor shall furnish and install a completely integrated, factory-built water treatment plant similar and equal to TRI-MITE™, Model TM-_____ manufactured by CPC Engineering Corporation, P.O. Box 36, Sturbridge, MA 01566. The equipment shall be suitable for indoor installation and have a nominal capacity of _____ gpm. The equipment shall be hydraulically and electrically tested prior to shipment.

The plant supplied shall be simple to operate and maintain. All major plant functions shall be automated. The plant shall operate at the nominal rate, shutting down automatically as required to backwash the filter and clean the Adsorption Clarifier™ chamber. The plant shall accommodate the introduction of floc-forming chemicals. Coagulant and polymer shall be added to the influent.

The treatment plant shall include chemical treatment, Adsorption Clarification™, Mixed Media filtration, automatic process valves and controls, an air scour blower and automatic coagulation control.

The equipment, controls, and piping shall be suitable to accommodate future addition of a second unit of the same size. Unit number 1 shall contain the blower, backwash pump, programmable controller, coagulant controller and effluent turbidimeter which will be common to both units. These components will not have to be supplied as part of the second unit, if one is installed.

All equipment specified in this section shall be provided by one manufacturer to ensure a properly designed system. The manufacturer's experience must include at least 600 million gallons per day of installed high-rate filtration capacity in operation for at least five years.

The contractor shall pay royalty or license fees for use of patented devices or systems and shall protect the Owner from patent infringement litigation thereon.

Suppliers other than the above named company wishing to quote on equipment in this section shall make a pre-bid submittal 30 days prior to bid. This bid shall include process and design capabilities as evidenced by extended pilot studies of installations, and maintenance of a highly qualified quality control and service organization. Written approval to quote must be obtained from the engineer at least 15 days prior to bid opening and will only be recognized by addendum.

TREATMENT PROCESS

Chemical Treatment. The chemical feed systems shall include three separate metering pumps, each independently adjustable to feed coagulant, polymer, and a third chemical. Each feeder shall include a suction hose, strainer, chemical-resistant tank, and mixer.

Automatic Chemical Control. Controls shall be provided to automate the primary coagulation dosage. Filter effluent turbidity shall be monitored and compared to an operator-adjustable setpoint. Coagulant dosage shall be adjusted automatically to bring the effluent turbidity to the setpoint. The unit shall have an adjustable deadband to minimize dosage overshoot. Dosage adjustments shall be proportional to the deviation from the setpoint. The unit will be contained within the main control panel.

Adsorption Clarifier™. The Adsorption Clarifier™ shall have a total area of _____ square feet. Adsorption clarification shall be accomplished using granular adsorption media specifically manufactured for use in water treatment. The media shall be designed to optimize the removal of coagulated particles with a minimum of headloss development. The material shall be of a type that has been demonstrated to achieve this performance in more than 100 full-scale installations. The clean bed headloss through the Adsorption Clarifier™ shall be less than 18 inches at a 10 gpm/sq. ft. upflow rate.

The adsorption media shall be of specific gravity less than 1.0, so as to be buoyant, and shall be easily fluidized with application of diffused air.

The adsorption media shall be retained by a corrosion-resistant assembly that allows free passage of water, but contains the granular adsorption media particles. The retainer shall be accessible and removable from the top of the tank.

The Adsorption Clarifier™ shall be equipped with an air scour system consisting of a fixed distribution grid. The air distribution laterals shall be constructed of corrosion-resistant material. The compartment shall be provided with a screened outlet to permit draining of water without loss of adsorption media.

Filtration. The total filter area shall be _____ square feet. The effluent system shall include a pump and a level-responsive valve arranged so that the plant effluent matches the flow entering the plant. The filter shall be equipped with auxiliary air scour to enhance the backwash efficiency. The filter media shall be a 30 inch deep Mixed Media bed composed of three materials, each of different size and specific gravity, providing uniform void gradation from coarse to fine in the direction of flow. The top of the bed shall consist of material of approximately 1.2 mm particle size and the bottom of approximately 0.3 mm particle size. The materials shall be carefully designed and selected by the treatment plant manufacturer.

The TM-50A, TM-75A, and TM-100A shall have filter materials retained directly on a Johnson stainless steel channel-rod screen so as to eliminate the need for support gravel.

The TM-175A and TM-350A will be provided with media support gravel designed for the PVC pipe lateral underdrain system. Filter materials for TM-175A and TM-350A shall be shipped in bags for installation.

Low Pressure Air Supply. Low pressure air for scouring of the Adsorption Clarifier™ and Mixed Media filtration materials shall be supplied by a two-stage regenerative type blower with a cast aluminum alloy impeller and blower housing. The unit shall be dynamically balanced, have a close coupled ODP motor and include intake and exhaust silencers. Bearings shall be double sealed and permanently lubricated.

Plant Construction. The major components shall be of the size and configuration shown on the plans. The tankage outside walls shall be fabricated of _____ _____ suitably braced and supported. In no case shall a single wall separate filtered water and unfiltered water. The double bulkhead shall be provided with free drainage.

The arrangement of treatment modules, auxiliary devices and supporting equipment shall provide ready access for maintenance.

Surface Preparation. Oil, grease, dirt, rust, millscale and foreign matter shall be removed from the interior tankage surface by a method defined by Steel Structures Painting Council Spec SSPC-SP10 and exterior by Spec SSPC-SP6. Tankage interior and exterior shall receive at the factory two coats of high build epoxy finish protective coating, to a thickness of 7 to 11 mils, suitable for potable water service. Tank bottom shall be bare, for placement into a mastic base pad coating. (Aluminum and stainless steel tankage shall have a matte exterior finish produced by sandblasting and shall not be painted.)

Plant Process Valves. Automatic valves with motor actuators shall be provided for process valves. Valves 2" and smaller shall be ball type with bronze body, brass ball and Teflon®[1] seats. Valves 2½" and larger shall be wafer butterfly valves with aluminum bronze disc, Buna N seat and stem seals, and iron body.

Motor actuators shall have 120V, 60 Hz supply, NEMA 4 enclosure.

A manual wafer-type butterfly valve, complete with operating lever, shall be provided for backwash rate setting.

Automatic valves shall be provided for effluent, Adsorption Clarifier™ scour, filter scour, backwash inlet, waste, and filter drain-down.

An optional filter to waste valve can also be provided.

Plant influent flow shall be adjustable by a manual rate set valve. Plant effluent flow shall be maintained by a level-responsive control valve.

Automatic influent valves shall be provided on dual unit installations.

Plant Control. The treatment plant valve sequencing and coagulant dosage adjustment shall be executed by a solid-state programmable logic controller. The controls shall be completely assembled and mounted in a NEMA 12 enclosure. The control panel shall provide for automatically starting and stopping the plant raw water pumps and chemical feed pumps, based on clearwell level or manual override.

The control system shall provide means for automatically initiating cleaning of the Adsorption Clarifier™ by elapsed time or a preset, but adjustable, pressure sensor. Manual initiate shall also be provided. The control system shall include an interlock so that only one Adsorption Clarifier™ can be cleaned at a time in dual tank systems. During the flush cycle, collected solids shall be removed by proper sequencing of valves and blower. Return to service shall be automatic.

The control system shall provide means for automatically initiating backwash of the Mixed Media filter by a preset, but adjustable, filter headloss sensor or elapsed time. Manual initiate shall also be provided. The control system shall include an interlock so that only one filter can backwash at a time in dual tank systems. When a Mixed Media backwash cycle is initiated, the Adsorption Clarifier™ is flushed first, immediately followed by a filter backwash. The control system shall automatically sequence valves and pumps during the backwash cycle. Return to service shall be automatic.

The control system will also automatically initiate a backwash on effluent high turbidity and will shut the plant down and initiate and alarm should the backwash fail to substantially reduce effluent turbidity after an operator selected time delay setting.

Pumps. The treatment plant manufacturer shall provide factory-installed effluent and backwash pumps. Pumps shall be centrifugal, end suction, close coupled with ODP Motor. (See Technical Data Sheet.)

Electrical Equipment. The power supply to load center shall be __________ (See Technical Data Sheet.)

Pump and blower motors shall be open drip-proof construction with 40°C rise rating. Motor starters shall be housed in NEMA 1 enclosures and are factory installed and wired.

Preassembly. TM-50A, TM-75A and TM-100A units will be entirely factory preassembled with both clarifying and filter media installed. Installation requirements will include proper location of the unit on the jobsite base pad and completion of electrical and piping connections to and from the unit.

The TM-175A and TM-350A installation requirements will include proper location of the unit on the base pad and completion of electrical and piping connections to and from the unit, as well as field installation of clarifier media, filter media and support gravel.

Plant Start-up and Operator Training. The treatment plant manufacturer shall provide _____ days of plant start-up and operator training. Training shall be conducted by a factory-trained serviceman employed by the manufacturer.

An additional ____ day(s) of technical direction shall be provided for media placement in TM-175A and TM-350A units.

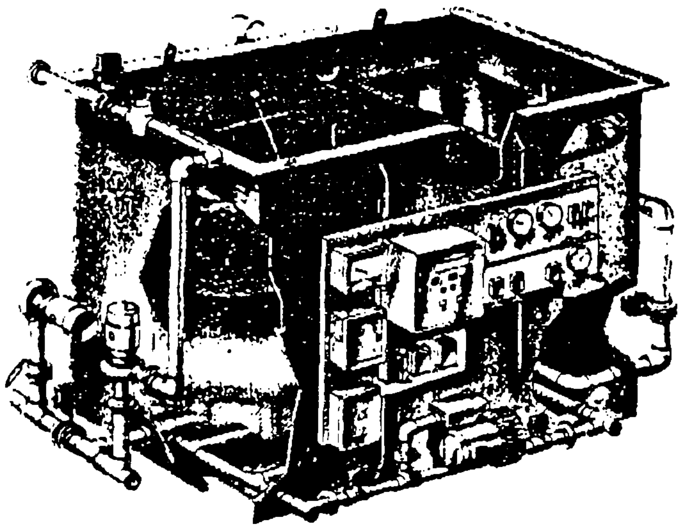
Operator's Manual. The treatment plant manufacturer shall furnish three Owners Manuals which shall provide complete instructions for installation, start-up, operation and maintenance.

[1] Teflon is a registered trademark of Dupont Corp.

microfloc PRODUCTS

CPC Engineering Corporation
P.O. Box 36, 441 Main Street
Sturbridge, MA 01566
(508) 347-7344
FAX: (508) 347-8159/(508) 347-7049

KS8.90-2



TRI-MITE™ TECHNICAL DATA SHEET

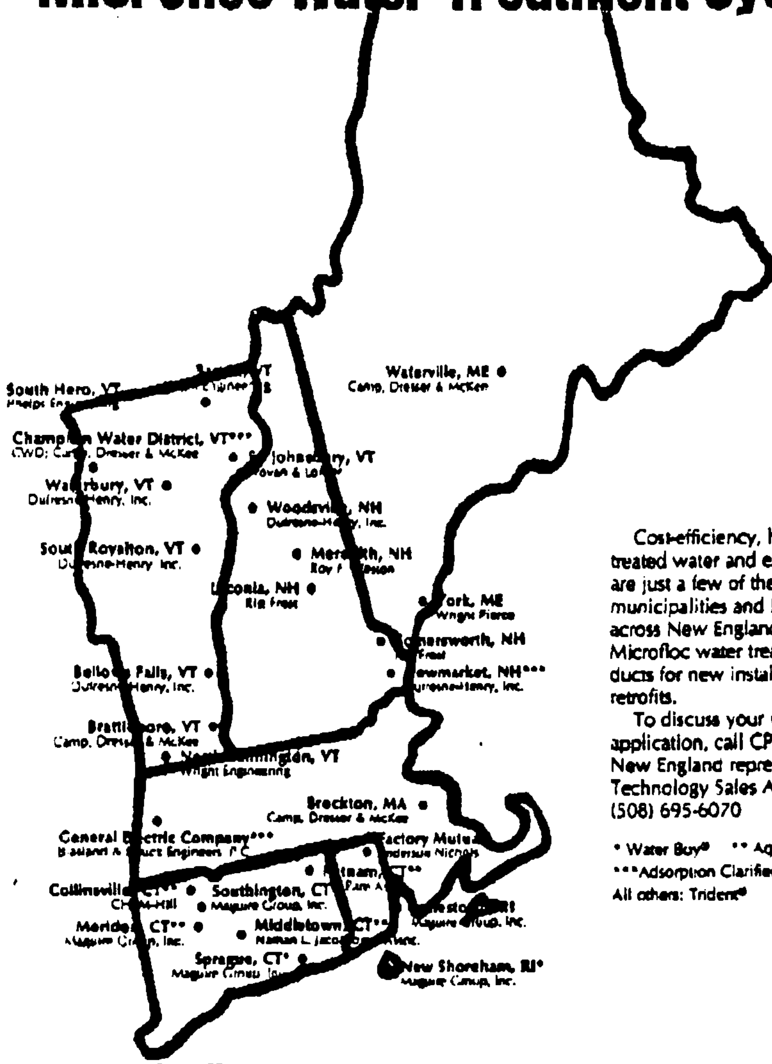
PARAMETERS		UNITS		TM-50A	TM-75A	TM-100A	TM-175A	TM-350A
Influent Flow Rate		GPM (GPD)		50 (72,000)	75 (108,000)	100 (144,000)	175 (252,000)	350 (504,000)
Shipping Dimensions		Length (ft)		8'-4"	9'-3"	10'-11"	12'-6"	22'-6"
		Width (ft)		6'-10"	5'-2"	8'-0"	10'-4"	10'-10"
		Height (ft)		3'-0"	9'-1"	8'-11"	9'-4"	9'-4"
Tank Dimensions		Length (ft)		4'-7"	6'-3"	8'-6"	10'-6"	19'-2"
		Width (ft)		2'-5"	4'-1"	4'-1"	9'-11"	8'-11"
		Height (ft)		7'-6"	7'-6"	7'-4"	7'-6"	7'-6"
Weights		Shipping (lbs.)		6,000	9,000	12,000	21,000	42,000
		Operating (lbs.)		10,500	16,000	21,000	37,000	74,000
Base Pad Design		Pounds/ft²		575	575	575	575	575
Backwash Holding Tank Volume		Gallons		2,600	3,300	5,200	9,100	18,200
Overhead Clearance		Minimum (ft)		2'-0"	2'-0"	2'-6"	2'-6"	2'-6"
Pipe Connections		Influent (in.)		2	2½	3	4	6
		Effluent (in.)		2	2½	3	4	6
		Backwash (in.)		3	4	4	6	8
		Waste/Overflow (in.)		4	6	6	8	10
Adsorption Clarifier®		Total Area (ft²)		5.0	7.5	10.0	17.5	35.0
		Upflow Rate (gpm/ft²)		10	10	10	10	10
Mixed Media Filter		Total Area (ft²)		10.0	15.0	20.0	35.0	70.0
		Rate (gpm/ft²)		5	5	5	5	5
		Backwash Rate (gpm/ft²)		15	15	15	15	15
Total Volume per Wash Cycle (Notes 1 & 2)		Adsorption Clarifier (gal.)		400	600	500	1,400	2,800
		Mixed Media (gal.)		900	1,350	1,800	3,150	6,300
Process Components	Pumps	Effluent		50 gpm, 1 hp	75 gpm, 1½ hp	100 gpm, 3 hp	175 gpm, 5 hp	350 gpm, 10 hp
		Backwash		150 gpm, 3 hp	270 gpm, 5 hp	360 gpm, 7½ hp	525 gpm, 10 hp	1,000 gpm, 25 hp
	Blower	Horsepower		3	3	7.5	7.5	7.5
	Controls	Solid State		Automatic	Automatic	Automatic	Automatic	Automatic
	Chemical Feed	Coagulant System		50 gal. tank	100 gal. tank	100 gal. tank	200 gal. tank	400 gal. tank
				60 gpd pump	108 gpd pump	108 gpd pump	240 gpd pump	480 gpd pump
				¼ hp mixer	¼ hp mixer	¼ hp mixer	½ hp mixer	½ hp mixer
		Polyelectrolyte System		50 gal. tank	50 gal. tank	50 gal. tank	100 gal. tank	200 gal. tank
				60 gpd pump	60 gpd pump	60 gpd pump	108 gpd pump	240 gpd pump
				¼ hp mixer	¼ hp mixer	¼ hp mixer	¼ hp mixer	¼ hp mixer
		Other Chemical System		50 gal. tank	50 gal. tank	50 gal. tank	100 gal. tank	200 gal. tank
				28 gpd pump	38 gpd pump	38 gpd pump	108 gpd pump	240 gpd pump
				¼ hp mixer	¼ hp mixer	¼ hp mixer	¼ hp mixer	¼ hp mixer
Electrical		Load Center		120/240V, 60 Hz, 1Ø, 3 wire, 50A	120/240V, 60 Hz, 1Ø, 3 wire, 70A	120/208V, 60 Hz 3Ø, 4 wire, 70A	120/208V, 60 Hz 3Ø, 4 wire, 100A	120/208V, 60 Hz 3Ø, 4 wire, 150A

NOTES:

1. Mixed Media backwash rate shown above is 15 gpm/ft² as required at [illegible]°F. Required rate varies linearly with temperature from 10 gpm/ft² at 32°F to 18 gpm/ft² at 78°F. Wash volumes indicated above are based on a 6-minute backwash duration.
2. The Adsorption Clarifier® is normally washed (using influent water) one or more times between Mixed Media backwashes, as well as in sequence with a Mixed Media backwash. The waste holding system should be sized to handle a total of two complete wash volumes from each compartment. The Adsorption Clarifier wash volume indicated above is based on an 8-minute total water flush.
3. The influent pumping system should provide a range of 25-35 ft. at the plant inlet.
4. Available materials of tank construction include painted carbon steel, aluminum or 304SS. Process piping is PVC.
5. The second unit in a two-tank configuration shares the controls, effluent turbidimeter, backwash pump, air blower and chemical feed systems from the first unit.
6. Standard start-up and operator training requirements are 3 days in one trip to the jobsite for the TM-50A, TM-75A and TM-100A models. TM-175A and TM-350A standard start-up and operator training requirements are 4 days in one trip to the jobsite. Add one additional day for two unit configurations.

KS8.98-2

Some Points In Favor Of Microfloc Water Treatment Systems.



Cost-efficiency, high-quality treated water and easy operation are just a few of the reasons that municipalities and businesses all across New England have selected Microfloc water treatment products for new installations and retrofits.

To discuss your water treatment application, call CPC Engineering's New England representative, Technology Sales Associates, at (508) 695-6070

* Water Boy® ** Aquarius®
***Adsorption Clarifier® only
All others: Trident®

microfloc
— PRODUCTS —

CPC Engineering Corporation
P.O. Box 36 · 441 Main Street
Sturbridge, MA 01566
Phone: (508) 347-7344
Fax: (508) 347-7049

Technology Sales Associates, Inc.
Tri-Town Professional Building
6 Wilkins Drive, Suite 210
Plainville, MA 02762
(508) 695-6070

As seen in "Journal," New England Water Works Association.

AMP DRESSER & McKEE	CLIENT Barrington NH	JOB NO. 4710-Y-RFI	COMPUTED BY RAS		
	PROJECT WTP	DATE CHECKED 3/23/92	DATE 3/21/92		
	DETAIL Sizing	CHECKED BY WRS	PAGE NO. 1		

50 Homes

From MA Sanitary Reg's : (WATER USE 115 gal/day per bedroom)

Assume: 3 bedrooms per house

50 × 3 × 115 = 17250 gpd ✓

(500% 600% peak factor)

peak hour demand:

From Clark Viessman & Hammer
Third Addition p. 166

Graph for peak water usage: 50 units
2 house/Acres
100,000 gpd
INST.

100 000 gpd = 69 gpm ✓

∴ SELECT TWO 50 gpm packaged UNITS TO Serve as redundancy for Average use and to meet periodic peak usage. ✓

Assume:

A. USE EXISTING Finished water storage & pressure system

USE Existing Chlorine & Hydroxide System.

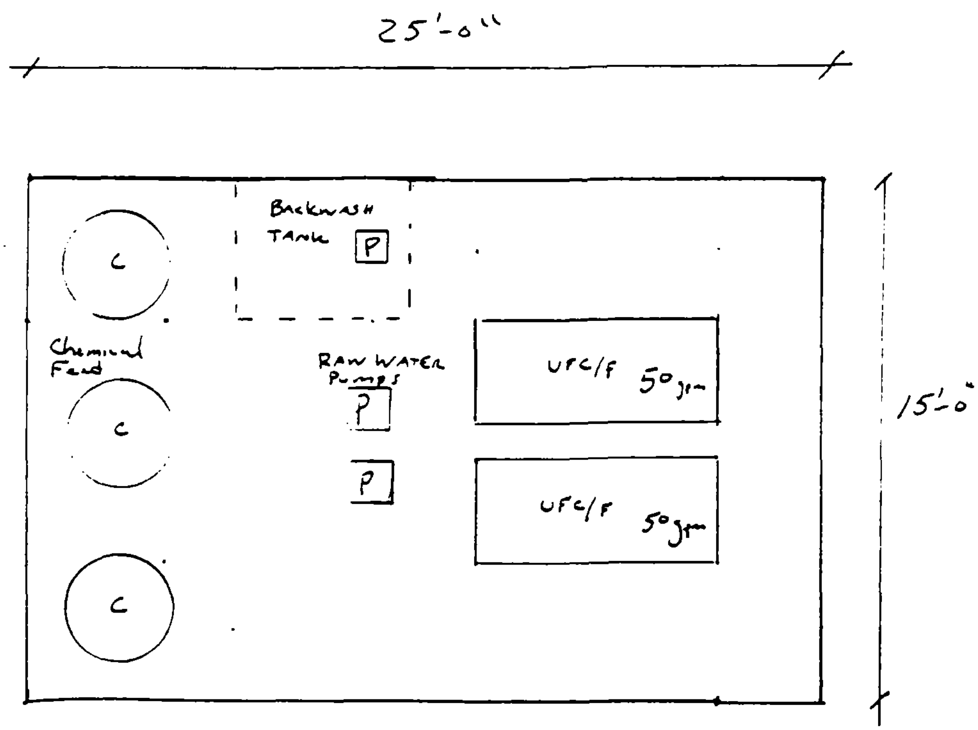
Costs

Modify or create drying bed for solids

$25,000

packaged plant cost assume ② Microfloc or similar UFC/F

$90,000 (Carbon Steel) — $128,000 (Stainless Steel) SAY $100,000



Small Package Building: 25 × 15 = 375 sq. ft

@ $180/sf = $67,500 SAY: $70,000

Cost Summary

Building	$ 70,000
Package plant	$ 100,000
drying Bed	$ 25,000
Misc. Yard work & piping Tie in to Exist System	$ 10,000
	$ 205,000 ✓
+ Engineering & Contingency ~~30%~~ 35%	~~61,500~~ 72,000 DMK 6/10/92
	$ ~~266,500~~ 277,000 DMK 6/4/92

AMP DRESSER & McKEE CLIENT ________ JOB NO. ________ COMPUTED BY WRS
PROJECT ________ DATE CHECKED ________ DATE 2/6/92
DETAIL ________ CHECKED BY ________ PAGE NO. (4.)

Annual O&M

Budget for next year is $15,000 not including labor.

10 to 12 hours/week for labor.

say 12 hours/wk x 52 weeks x $50/hour = $31,200/yr.

Total: $46,200/yr.

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY ______
PROJECT ______ DATE CHECKED 11/21/91 DATE ______
DETAIL ______ CHECKED BY [signature] PAGE NO. (4)

Alternative MM-2

LIMITED ACTION ALTERNATIVE

ITEMS	CAPITAL	O&M	NOTES
(1) DEMOLITION AND REMOVAL OF HOUSE	$40,000		Tested but not hazardous.
(2) SITE SECURITY GENERAL CLEANUP	~~$12,000~~ ~~$27,000~~ $34,000 WRS 2/7/92		(using pg 5 calculation for DRUMMED WASTE DISPOSAL).
(3) PREPARATION OF DEED RESTRICTIONS	$5,000		
MONITORING OF GROUND WATER		$13,000 per event.	4 times for two years = $52,000 2 times for two years = $26,000 Annual thereafter: $13,000 Must use 10% discount rate:
WATER SYSTEM UPGRADE	$66,000 WRS 2/7/92	$46,000	
ADD: ENGINEERING @ 15%	$10,500		
ADMIN @ 5%	3,500		
Add ~~20%~~ 15% contingency:	$ ~~11,000~~ 10,500		
Capital	$ ~~96,500~~ $ ~~68,000~~ $169,500 WRS 2/7/92		
O&M		$ ~~13,000~~ 59,000/yr. WRS 2/7/92	

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY ______
PROJECT ______ DATE CHECKED 11/21/91 DATE ______
DETAIL ______ CHECKED BY [signature] PAGE NO. (5)

Consider Incinerator Ash / RI waste (for Item #2 above)

Ash 12 drums: Carbon 3 drums.

Sampling & analysis @ $1,000 each — $12,000
(dioxin tests on ~~some/~~ 12 ~~not all~~ ash drums.)

Removal: ~~dump @ onsite~~
~~remove 6 @ $1,000 each~~
Off-site disposal @ $1,000 each — $ ~~6,000~~ 12,000

$ ~~18,000~~ 24,000
w/ reports, etc
say $ ~~20,000~~ 27,000

WRS 2/10/92

COST ITEMS FOR CONSIDERATION MM-3 plus.

Groundwater monitoring.

Well installation.

Trench installation.

Observation well installation.

Connection pipes to treatment units.

Storage/equalization tank.

Air stripper

Carbon Adsorption

UV/O3 Unit

Discharge piping

Building, w/ HVAC & Plumbing

Instrumentation & Controls

Process Piping.

Bench Scale Tests.

Need to secure & restrict site per MM-2.

May need to provide a new fence.

CAMP DRESSER & McKEE CLIENT EPA | JOB NO. 7710-004 | COMPUTED BY WRS
PROJECT Tibbetts Rd. | DATE CHECKED 11/21/91 | DATE 10/22/91
DETAIL Trench/Well System | CHECKED BY [illegible] | PAGE NO. (1.)

Compute Costs of Extraction System
Based on F.S. Appendix A
Work by R. Preble.

~~(MM-4A, etc.)~~
(MM-5, 6 & 7) WRS 4/15/92 JAB 6/5/92

Extraction System Details

(1) Trenches

2 - 350 ft. = 700 ft.

- fill depth @ some 15 to 20 ft.
- to be conservative, preliminary cost of the trench system can be 20 ft. deep along the entire length.

Cost Factors

- soil sampling & analysis.
  estimate need 70 samples for VOA's along trench lines (would be part of design cost)
- excavate and temporarily stockpile soil.
- trench dewatering / treat water in plant (already constructed)
- placement of filter fabric and drainage net.
- placement of crushed (filter) stone base.
- placement of "under drain" pipe.
- complete placement of crushed stone.
- backfill trench with excavated soil.
- remove excess spoil to on-site recharge area.
- place manholes, pumps, controls and force mains to treatment buildings.
- Connect to control panels & start system.
- water from trench would be run thru the treatment system.
- use sheet piling for trench stabilization and dewatering following excavation.

(2) Wells

Consider 5 extraction wells
approximately 40 feet in depth.
These would be placed in weathered rock
in the area of 75R - 69R.

Cost Factors

- well drilling and development.
- pump and control placement.
- placement of lines to treatment units.

(3) Operating Costs

Manpower. (part of an operator) say 20 hrs./month.
Maintenance. (parts, repairs)
Electric Power. (use a 30' lift)

x $50/hr
$1000
x12
$12,000/yr
manpower -
add to
treatment
eq. costs.

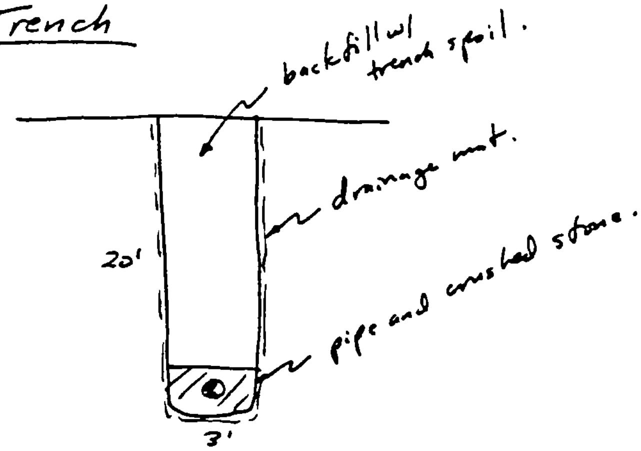
Recharge Area

(1) 100 ft. x 100 ft:

6 trenches, 4 to 5 feet deep, 100 ft. long.
~600 ft. total

Cost

Trench



Excavation : $\frac{700' \times 20' \times 3'}{27}$ = 1,556 C.Y.

Crushed Stone : $\frac{3' \times 1.5' \times 700'}{27}$ = 117 C.Y.

Fabric/Net : $\frac{43' \times 700'}{9}$ = 3,344 S.Y.

Pipe : 700'

Manholes : One at each end, one center - total 6 each.

Pumps (2) : 1 to 2 gpm each.

Feed Pipes : 400', 4-5' deep trench.

Means Cost Data for 1991 10th Edition Site Work Cost Data

Pipe placement including O&P : (pg. 70)
6" ϕ
CORR. plastic tubing : $1.80/L.F.
End Caps. : $8.80 each
Coupler : $8.80 each

Manholes. (pg. 71)
Concrete cast in place 4'x4' 8' deep : $1,525
over 8' deep : $135/ft.
Precast 4' I.D. 8' deep : $940
over 8' deep : $125/ft.

Drainage geotextiles:
Fabric/adverse conditions: $1.65/S.Y.
Soil drainage mat on vertical wall:
(0.44" thick)
adverse conditions. $16.20/S.Y.

Drainage material: 3/4" crushed stone: $17.65/C.Y.
adverse conditions

Dewatering (pg. 25)
2" diaphragram pump. : $100/day

Trench Excavation (pg. 34)
14'-20' deep. : $3.54/C.Y.
Backfill & Compact. (pg. 35) : $1.56/C.Y.
(Front End Loader - min. haul)

Excavating/utility trench common earth. (pg. 35) : $0.62/L.F.
6" wide/60" deep

For collection pipe. (pg. 65)
use water distri: system price. 2" ϕ : $4.01/L.F.

Sheet piling (Steel) (p26) $9.20/S.F.
20 ft deep pull + SALVAGE but reuse
10 times so deduct SALVAGE value + scrap.

On-Site hauling of excavated material (to stockpile or cover) $4.00/cy
(pg 35)

Price Pipes and Manholes

6"ϕ pipe placement

700' X $1.80/L.F. = $1,260

End caps. 4 each @ $8.80 = 35

Couplers 40 each @ $8.80 = 352

Manholes.

2 cast in place (for pumps) @ 20'

2 each [$1,525 + (12' X $195/ft)] = $7,730

4 precast (for observation/cleanout)

4 [$940 + (12 X $125/ft)] = $9,760

2"ϕ lines to treatment.

400' X $4.63/L.F. (0.62 + 4.01) = $1,852

Price Drainage Material.

Drainage Mat

$16.20/S.Y. X 3,344 S.Y. = $54,173

Crushed Stone

$17.65/C.Y. X 117 C.Y. = $2,065

Subtotal $77,227

(carry forward 77,227)

Price
Trench Dewatering & Backfill

Dewatering

$100/day x 40 days = $4,000

Trench excavation & Backfill
(3.54+1.56)
$5.10/C.Y. x 1,556 C.Y. = $7,936

Total: $89,163

Surcharge for H&S considerations/material handling (20%) $17,833

SubTotal: $106,996

round to: $107,000

Add Pumps & Mechanical/Controls.

L.S. $10,000

sub. Total $117,000

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY ______
PROJECT ______ DATE CHECKED ______ DATE 11/21/91
DETAIL ______ CHECKED BY ______ PAGE NO. 6a

Steel Sheet Piling

20 ft deep, pull + savage but use 10 times so take No salvage value.

700 ft long x 20 ft deep x 2 sides = 28,000 S.F.

28000 ÷ 10 = 2800 S.F. of piles needed.

Means p307: price w/o Salvage is 364.77/ton vs. 543.52/ton w/ Salvage.

∴ $\frac{364.77}{543.52} \approx$ 2/3 of S.F. price For No Salvage.
(Drive + Extract)

∴ pg 26 price is $9.20 / SF. w/ Salvage

so 9.20 x 2/3 x 28,000 = $172,592

plus cost of piles @
$715/ton x $\frac{ton}{74\ S.F.}$ x 2800 SF. x 1.1 = 29,760

Total = $202,352
say $205,000

On-Site Hauling

$\frac{700 \times 20 \times 3\text{ ft wide}}{27}$ = 1556
x $4/cy
$6225 x 2 (1 to Stockpile, 1 to backfill) = $12,450

say $13,000

Balance Carried From Pg 6 = 117,000
Steel Sheet Piles = 205,000
On-Site Hauling = 13,000

Sub total = $335,000

Balance Carried Fwd = $335,000

Cost
Wells.

5 wells @ ~~40'~~ 60' = ~~200'~~ 300' total drilling.
@ $150/ft = $ ~~30,000~~ 45,000

Pumps & Controls L.S. $ 10,000 WRS 2/10/92

wells Sub Total $ ~~40,000~~ 55,000

Collection System total = $ ~~375,000~~ 390,000

Cost
Recharge Area

Cost @ trench system 60" deep.
(600 ft. total)

Use costs from collection trench.

6" ⌀ pipe placement
600' X $1.80/L.F. = $1,080
couplers & caps. 30 each @ $8.80 each. = 264

Precast Manholes
2 each at 8'±
$940 X 2 = = $1,880

Crushed Stone
$\frac{2' \times 3' \times 600'}{27} \times \$17.65/c.y.$ = $2,353

Subtotal: $ 5,577

CAMP DRESSER & McKEE CLIENT ____ JOB NO. ____ COMPUTED BY WRS
PROJECT ____ DATE CHECKED 11/21/91 DATE ____
DETAIL ____ CHECKED BY [illegible] PAGE NO. (82)

(carried forward) $5,577

Excavation and Backfill

$\frac{5' \times 2' \times 600'}{27} \times \$5.10/C.Y.$ = $1,133

This System only included in Alternative MM-7. Refer to Injection Well Cost Estimate for MM-7. JAP 6/9/92

~~THIS SYSTEM NOT INCLUDED IN ALTERNATIVES~~ ~~WRS 2/3/92~~

Sub-total $6,710

Surcharge for H&S, Materials Handling (20%) $1,342

Total: $8,052

round to: $10,000

Summary Construction Cost

Extraction Trenches : ~~$117,000~~ $335,000
Extraction Wells : ~~40,000~~ 55,000
} ~~375,000~~ $390,000 WRS 2/3/92
Recharge Area : ~~10,000~~

~~$167,000~~
~~$385,000~~

Need to Compute annual O&M. - Combine with Treatment.

Inspection and maintenance.

Power for pumping.

Parts, etc. add $1,000/year.

Time 240 hours @ $50/hr ~~$4,000~~ $12,000/year.

Power: Extraction 7 units @ 1/6 HP

Cost: $\frac{7}{6}$ HP × 0.746 $\frac{KW}{HP}$ × 8760 hours/yr × $0.10/KWH = $762.41/yr.

Total $5,762.41/yr.

round to $6,000/yr.

Clearing + Grubbing Costs

Means pg 23

estimate based on 2 acres total to be cleared + grubbed

Clearing @ $8475/acre x 2 = $16,950
grub @ 4525/acre x 2 = 9,050

$ 26,000

Mobilization / Demobilization Costs

@ $10/mi per equipment item

Assume 50 miles one way = 100 miles R.T.

equipment needed:

4 dump trucks
2 dozer/loaders
2 backhoes
1 pile driver
1 scraper

10 items x 1.5 (contingency) = 15 equipment items

15 x $10/mi x 100 miles = $15,000

Temporary Utilities + Facilities

Two office Trailers @ $200/mo x 24 mos.	=	$ 9,600
Trailer freight in/out @ $500/1 way x 2 x 2	=	2,000
Portable johns + service 3 req'd @ $100/month x 3 x 24	=	7,200
Power for 2 trailers @ $100/mo ea x 24	=	4,800
Install power + phones		2,000
phone service $100/mo x 24	=	2,400
		$ 28,000

On-Site Vapor Containment Building

assume 1000 ft² bldg @ $12/S.F.
plus installation cost
Sprung Instant Structures or equal
No foundation

$12 x 1000 x 2 (installation) = $ 24,000

(Add This item to Cost of Treatment Facilities Bldg)

TREATMENT PROCESS EQUIPMENT

COST ESTIMATE INFORMATION

CAMP DRESSER & McKEE CLIENT USEPA JOB NO. COMPUTED BY K. Murphy
PROJECT TIBBETTS ROAD DATE CHECKED 11/22/91 DATE 11/1/91
DETAIL COST ESTIMATE CHECKED BY MWK. PAGE NO. (1)

CAPITAL COSTS FOR UV OXIDATION

ITEM	AMOUNT	
EQUALIZATION TANK	$ 1700	
LAMELLA GRAVITY SETTLER	$ 31,200	
FILTER PRESS	$ 13,000	
COLLECTION TANK	$ 1700	
UV OXIDATION SYSTEM	$ 77,500	
SLUDGE HOLDING TANKS	$ 3600	
PUMPS / COMPRESSOR	$ 10,600	
PROCESS BUILDING CONSTRUCTION	$ 151,000	
~~SITE WORK~~	~~$ 72,000~~	included elsewhere.
	Σ ~~362,300~~ 290,300	

(Note: $314,300 w/$24,000 additional to accomodate VES.)

WRS GAO 6/5/92

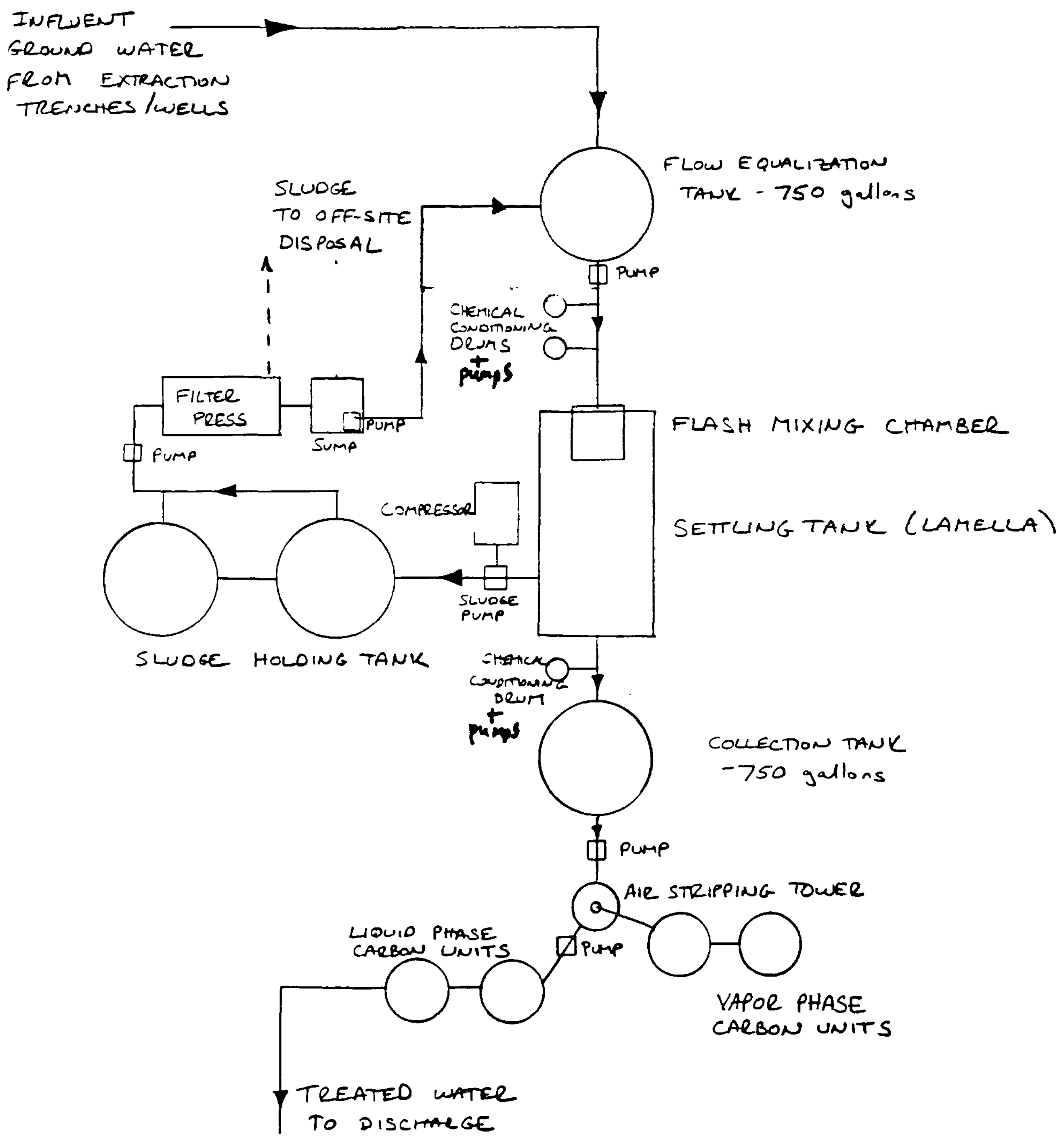
CAPITAL COST FOR AIR STRIPPING / CARBON

ITEM	AMOUNT
EQUALIZATION TANK	$ 1700
LAMELLA GRAVITY SETTLER	$ 31,200
FILTER PRESS	13,000
COLLECTION TANK	$ 1700
AIR STRIPPER	$ 22,000
CARBON TREATMENT UNITS	
VAPOR PHASE	$ 3600
LIQUID PHASE	$ 3000
SLUDGE HOLDING TANKS	$ 3600
PUMPS / COMPRESSOR	$ 11,200
PROCESS BUILDING CONSTRUCTION	$ 151,000
~~SITE WORK~~	~~$ 72,000~~ included elsewhere.
	$ ~~314,000~~ 242,000

(Note: $266,000 w/ $24,000 additional to accomodate VES)

WRS [initials] 6/5/92

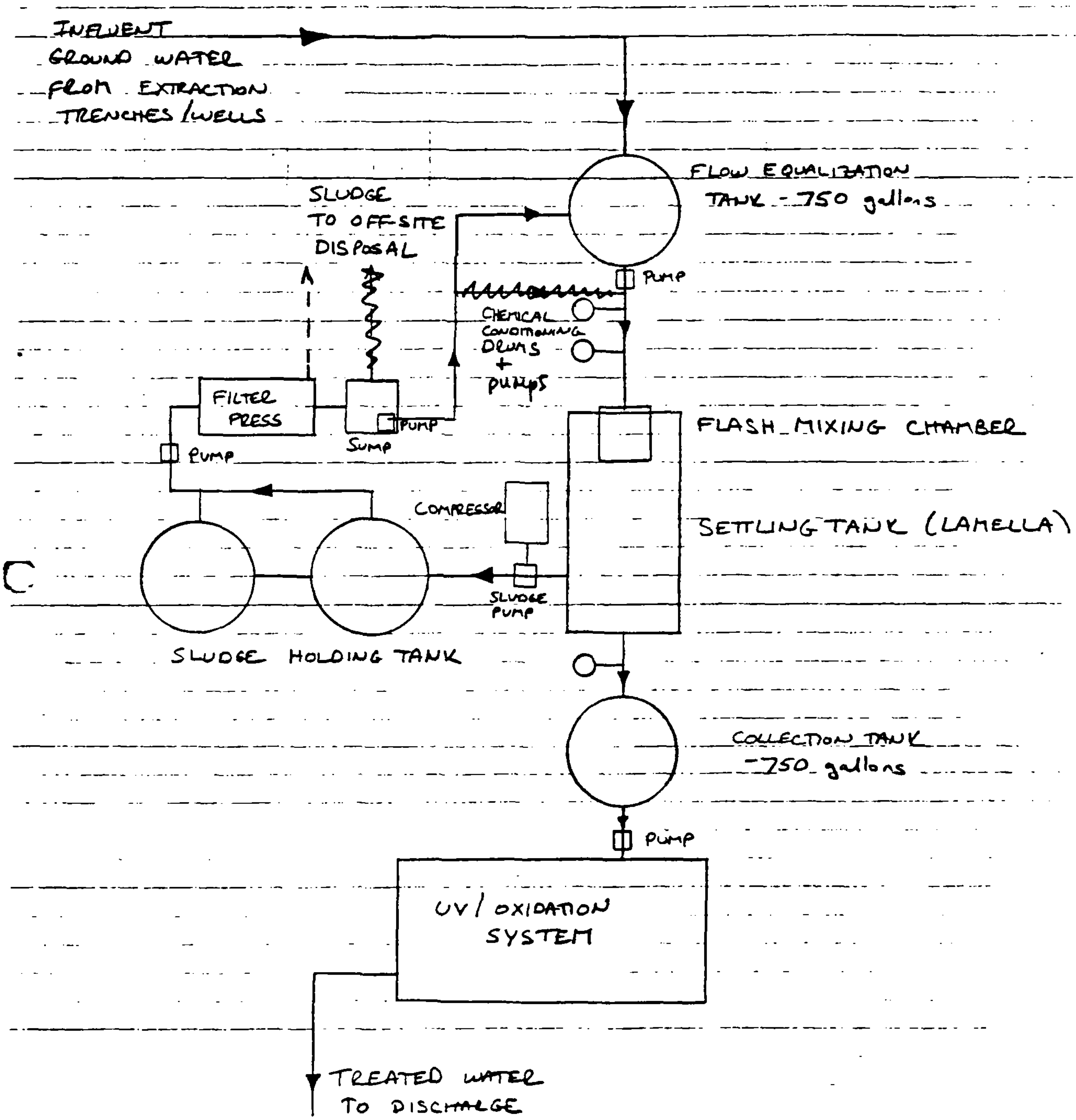
AIR STRIPPING SYSTEM



APPROXIMATE BUILDING DIMENTIONS REQUIRED 35 x 40'

CAMP DRESSER & McKEE	CLIENT USEPA	JOB NO.	COMPUTED BY K. MURPHY
	PROJECT TIBBETTS ROAD	DATE CHECKED 11/21/91	DATE 11/13/91
	DETAIL TREATMENT SCHEMATIC	CHECKED BY [illegible]	PAGE NO. 4

UV OXIDATION SYSTEM



APPROXIMATE BUILDING DIMENTIONS REQUIRED 35 x ~~35~~ 40'

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS RD
DETAIL COST ESTIMATE

JOB NO.
DATE CHECKED 11/22/91
CHECKED BY [signature]

COMPUTED BY K. MURPHY
DATE 10/22
PAGE NO. 1

EQUALIZATION TANK

CONTINUOUS SYSTEM AT 5 GPM

$$5 \frac{gal}{min} \times \frac{60 min}{hr} \times 1 hr = 300 \text{ gal tank}$$

FROM MASSACHUSETTS ENGINEERING CO.
773-7777
USE 750 gal capacity tank (steel tank with protective coating)
for additional capacity for a more flexible operation
48" Diameter
96" Height

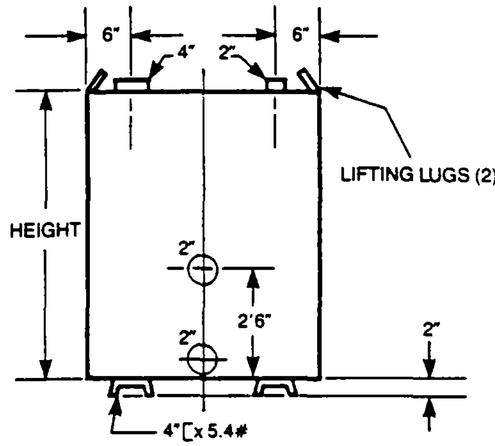
COST = $ 1400
plus Shipping $ 100
plus installation $ 150 / $ 1650

cone bottom tank see spec on following page

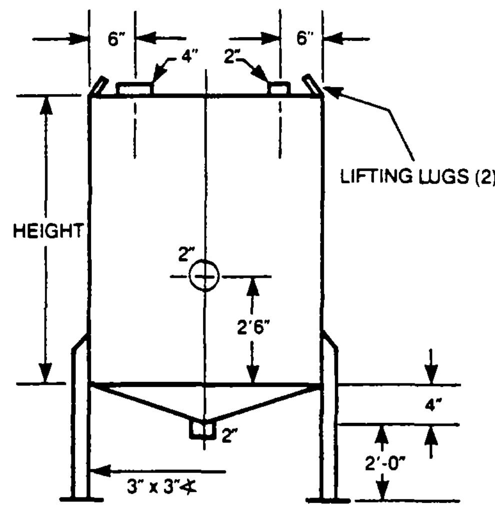
vertical jumbo drums

[illegible]	[illegible]	[illegible]	[illegible]
JVD-1	510	48"	64"
JVD-2	750	48"	96"
JVD-3	1000	48"	128"
JVD-4	1020	64"	74"
JVD-5	1500	64"	108"
JVD-6	2000	64"	144"
JVD-7	1250	72"	72"
JVD-8	1700	72"	96"
JVD-9	2100	72"	120"
JVD-10	2500	72"	144"
JVD-11	2950	72"	168"
JVD-12	2050	96"	66"
JVD-13	3000	96"	96"
JVD-14	4100	96"	132"
JVD-15	5000	96"	162"

**Other capacities are available*



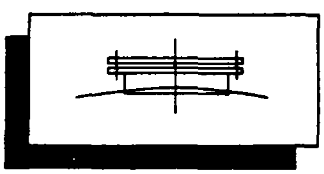
[illegible]	[illegible]	[illegible]	[illegible]
48"	10.4	7.8	93.6
64"	18.6	13.9	166.8
72"	23.5	17.6	211.2
96"	41.8	31.3	375.6



Accessory Items

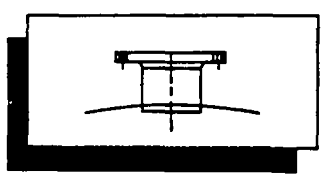
A complete line of accessories is offered including manholes, valves, fittings, pumps, flanges, and ladders. Special protective coatings inside and outside are also available.

Manholes



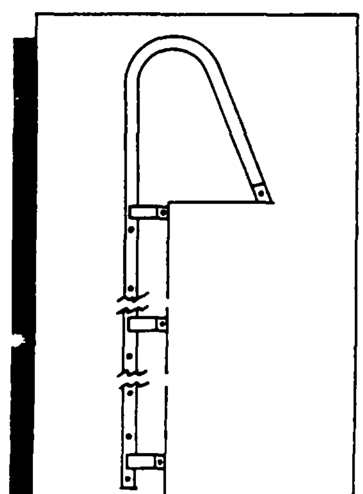
Sizes:
16"
18"
20"
24"

Flanges—150#



Sizes:
4"
6"
8"
11"
12"

Ladders



Massachusetts Engineering Co. INC.

AVON INDUSTRIAL PARK
AVON, MA 02322
1-617-580-0550 Boston–773-7777
1-800-343-0788 (outside Mass)

CAMP DRESSER & McKEE CLIENT USEPA JOB NO. ______ COMPUTED BY K. MURPHY
PROJECT TIPPETTS RD DATE CHECKED 11/22/91 DATE 10/22/91
DETAIL COST ESTIMATE CHECKED BY [signature] PAGE NO. 2

FURNISH AND INSTALL LAMELLA GRAVITY SETTLER UNIT FOR IRON REMOVAL

DESIGN FLOW : 5 gpm
IRON CONC. : 230 ppm

Price Quote from Joe Wurzel
New England Sales, Inc.
Marshfield, MA
834-7994

Model 11248 RLF up to 10 gpm

Lamella Tank	$ 18,000
Floc + Rapid Mix Tanks	$ 6,200
Installation Cost	$ 7,000
	$31,200

Epoxy painted - carbon steel tank
FRP plates

CAMP DRESSER & McKEE CLIENT USEPA JOB NO. ____ COMPUTED BY K. MURPHY
PROJECT TIBBETTS ROAD DATE CHECKED 11/22/91 DATE 10/22/91
DETAIL COST ESTIMATE CHECKED BY MWK PAGE NO. 1

IRON REMOVAL AND IRON SLUDGE PROCESSING EQUIPMENT

DESIGN CRITERIA:

Influent Iron Concentration : 230 mg/l [Peak conc. detected in 1990/91]

Flow Rate : 5 gpm = 0.0072 MGD = Q

SLUDGE QUANTITY ESTIMATE (lbs/day)

$S = 8.34\ Q\ (2.9\ Fe + SS + A)$

S = sludge produced (lbs/day)
Fe = Iron concentration in gw (mg/l)
SS = Suspended solids (mg/l) [assume negligible]
A = Additional Chemicals Added (mg/l)
Q = flow (MGD)

$S = 8.34\ (0.0072)\ [2.9\ (230) + 0 + 5]$

S = 40 lbs/day

- 1-2% solids sludge predicted from a Lamella Gravity Settler
- 40 lbs/day of sludge solids at an estimated 1.5% solids concentration expected from an inclined plate settler (lamella), results in sludge quantity of:

$\frac{40\ lbs/day}{0.015} = 2690$ lbs/day of 1.5% sludge

Assuming sludge weighs 62.4 lbs/ft³

$V = \frac{W_s}{\%\ solids\ \gamma} = \frac{40\ lb/day}{(0.015)(62.4\ lb/ft^3)} = 43\ ft^3/day$ of sludge produced

= 322 gal/day

FILTER PRESS can produce 30% solids (based on vendor information)

$\frac{40\ lbs/day}{(0.30)(62.4\ lbs/ft^3)} = 2\ ft^3/day = 15\ gal/day$

FOR 50 mg/l Iron

S = 10 lb/day   1.5%   638 lbs/day = 76 gal/day

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT DEECTS LD
DETAIL

JOB NO.
DATE CHECKED 4/22/91
CHECKED BY [illegible]

COMPUTED BY K MURPHY
DATE 12/22/91
PAGE NO. 2

FILTER PRESS VOLUME

$$\text{Filter Press Volume } (ft^3) = \frac{\text{Total Volume of Product Feed per cycle in gallons} \times \text{\% solids Concentration of Product Feed}}{2.89}$$

$$\frac{40 \text{ lbs/day}}{(0.015)(62.4 \text{ lb/ft}^3)} = 43 \text{ ft}^3\text{/day} = 320 \text{ gal/day} \times 7 \text{ day/wk}$$

$= 2,238$ gal/wk of sludge to dewater

assume 40 hr work week

56 gal/hr or ~ 450 gal / 8-hr shift

$$\text{Filter Press Volume} = \frac{450 \text{ gal/day} \times 0.015}{2.89} \simeq 2.5 \text{ ft}^3\text{/day}$$

MINIMUM

CAMP DRESSER & McKEE CLIENT USEPA	JOB NO.	COMPUTED BY K. MURPHY
PROJECT TIBBETTS RD	DATE CHECKED 11/22/91	DATE 12/02/91
DETAIL COST ESTIMATE	CHECKED BY [signature]	PAGE NO. 3

COLLECTION TANK / PUMP CHAMBER

510 gallon capacity tank

MASSACHUSETTS ENGINEERING CO.

COST = $1500

[SEE EQUALIZATION TANK COST]

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS RD
DETAIL COST ESTIMATE
JOB NO.
DATE CHECKED 11/22/91
CHECKED BY [illegible]
COMPUTED BY K. MURPHY
DATE 10/23/91
PAGE NO. 1

SLUDGE PROCESSING EQUIPMENT (OPTIONAL)

FILTER PRESS FOR

40 lbs/day solids (2690 lbs/day of 1.5% sludge or 43 ft³/day)

Price quote from Joe Wurzel, New England Sales)
470 mm Filter Press
= $ 10,000

Installation Cost = $ 3000

$ 13,000

SLUDGE STORAGE

- 76 gal/day (1.5% sludge) @ 52 ppm iron
- 322 gal/day (1.5% sludge) @ 230 ppm iron

for 2-10 day storage = 750 gal

Use 2 750 gallon tanks (cone bottom)

Need greater slope on cone

MASSACHUSETTS ENGINEERING CO.
Price Quote

$ 1400/each

4' Diameter
8' Height

SHIPPING COST $ 100/ea
INSTALLATION COST $ 200/ea

$ 1700/ea $ 3400 for 2 tanks

AIR STRIPPER UNIT

Design Flow = 5 gpm

Vendor: R.E. Wright Associates, Inc. 1-800-944-5515 David Brown
Chuck Culpin

Capital cost = $ 22,000
for ST-1 includes installation costs
(also see attached)

Operation + Maintenance for Air Stripper
$ 2000/yr routine maintenance
$ 1500/yr to replace packing material
$ 3500/yr

USE OF VAPOR PHASE CARBON FOR OFF-GASES

$ 3600 capital
$ 22,500/yr (see O+M backup)

USE OF LIQUID PHASE CARBON

$ 3000 capital

$ ~~45,000~~/yr (see O+M backup)
24,000

CAPITAL = $28,600
O+M = $ ~~41,000~~ 50,000

~~Present worth (30, 10%) = 28,600 + 41,000 (9.427)~~
~~= $ 415, 110~~

~~Total Present worth for carbon use = $415,000~~

Submitted by: ____

AIR STRIPPING TOWERS

Required Data for Pricing

Date Submitted: 10/30/91 Date Needed: 10/31/91

Budgetary? X Yes __ No

Competitive Bid? __ Yes __ No Bid Date: ________

Company Name: CDM Inc.

Address: Ten Cambridge Center Cambridge MA 02142

Phone: (617) 252-8000 Contact Person: Kathleen Murphy

Fax: (617) 621-2565 Project/Reference name: Tibbetts Road

GPM of liquid to be processed: 2-5 Water Temp.: 15 C ___ F

Number of sources of influent: 1

	GPM	TDH
Influent pump required:	___	___
Effluent pump required:	___	___

Electrical Power Available:

115 V	___	Single Phase
115/230 V	X	Single Phase
220 V	___	Three Phase
460 V	___	Three Phase

Explosion-proof components required? ___ Yes X No

Design electric circuit to control influent pump? ___ Yes ___ No

Local zoning restrictions (tower height): No

Condition of influent water: Iron-Max. 230 ppm Ave. 55 ppm

(Hardness, iron, suspended solids, etc.)

Shall off gases be regulated? X Yes ___ No

Type of regulation requested: X Carbon ___ Incineration ___ Other

Type of column material requested: ___ FRP ___ SS ___ Alum.

Winterization X Yes ___ No

General location of AST: N.H.

Special site conditions: Residential Neighborhood

Misc. notes and comments: Please provide: capital + O+M costs, Whether liquid phase carbon would be required to meet cleanup goals, and if flow was increased to 10 gpm how would that affect cost.

r.e. wright associates, inc.

Chemical	Influent Concentration ppb ug/l	Influent Concentration ppm mg/l	Effluent Requirement ppb ug/l	Effluent Requirement ppm mg/l	Effluent Requirement % Removal
Acetone					
cis Acetylenedichloride (1,2-DCE)					
trans Acetylenedichloride(1,2-DCE)					
Benzene					
Bromoform					
Bromodichloromethane					
Carbon Tetrachloride					
Chlorobenzene					
Chlorodibromomethane					
Chloroethane					
Chloroform (Trichloromethane)					
Chloromethane (Methyl Cloride)					
Dichlorodifluoromethane					
Ethyl Acetate					
Ethylidenechloride (1,1-Dichloroethane)					
Ethylenedichloride (1,2-Dichloroethane)					
Ethylbenzene					
Ethyl Toluene (3-)					
Ethyl Toluene (4- or p-)					
Methane					
Methylbromide					
Methylchloroform (1,1,1-Trichloroethane)					
Methylenechloride (Dichloromethane)					
Methylethylketone (MEK)					
Methylisobutylketone (MIBK)					
Napthalene					
Tetrachloroethylene (PCE)					
Toluene					
Trichloroethylene (TCE)					
Trichlorofluoromethane					
Trichlorotrifluoroethane (UNCON113)					
UCON-113					
Vinyl Chloride (Chloroethylene)					
Vinylidenechloride (1,1-Dichloroethylene)					
Vinyltrichloride (1,1,2-Trichloroethane)					
M Xylene					
O Xylene					
P Xylene					
Other (Specifiy)					

SEE ATTACHED

TIBBETTS ROAD, NH
GW CONCENTRATIONS

CONSTITUENT	MAX. CONC.(mg/l)	CLEANUP GOAL (mg/l)
Benzene	3.1	0.005
cis-1,2-dichloroethene	4 for UV	0.07
trans-1,2-dichloroethene	4 oxidation	0.1
Ethylbenzene	2.5	0.7 FOR CARBON
4-methyl-2-pentanone [MIBK]	10 ← 150 mg/l	* ← 90% removal
Tetrachloroethene	2.5	0.005 < 5 ppb
Toluene	12	1
1,1,1 Trichloroethane	0.22	0.2
Trichloroethene	7.8	0.005
Xylenes	18	10
Bis(2-ethylhexyl)phthalate	0.24	NA
2-Methylnaphthalene	0.04	NA
Naphthalene	0.455 < 1 ppb	* ← >90% removal
Arsenic	0.185	0.05
Chromium	0.514	0.1
Lead	0.22	0.05
Manganese	19.9	0.05
Nickel	0.40	0.1
Vanadium	0.55	NA
Iron	227	1

* = No MCL available, Please report estimated effluent concentrations.

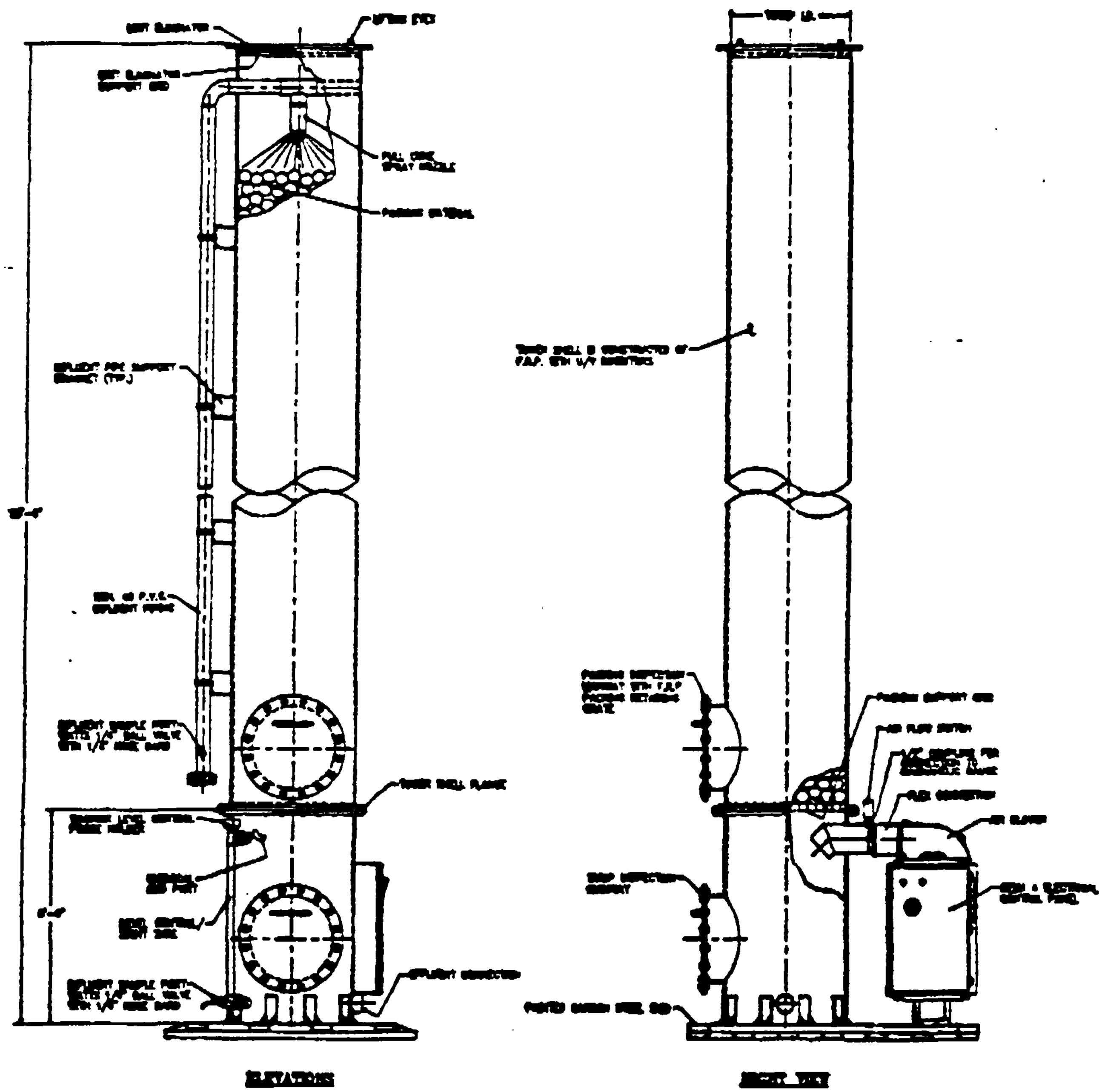
NA = Not Applicable, No Cleanup Goal Required

DESIGN FLOW: 5 GPM

No significant reduction of MIBK or Naphthalene using air stripping alone.

E.R.S. STANDARD EQUIPMENT

1, 2, AND 3 FT. DIA. AIR STRIPPING TOWERS



r.e. wright associates, inc.

ENVIRONMENTAL RESTORATION SYSTEMS GROUP

CORPORATE OFFICES

3240 SCHOOLHOUSE ROAD
MIDDLETOWN, PENNSYLVANIA 17057
TOLL FREE: 1-800-238-3320
IN PA. (717)944-5501
FAX. (717)944-4881

AIR STRIPPING TOWER

Specifications

- Fiberglass reinforced plastic (FRP) construction with U/V inhibitors
- Cast-aluminum spark-resistant blower with TEFC motor.
- Site tube with Warrick level controls/high level shutoff.
- Air flow switch and automatic shutoff for loss of air flow.
- Full-size NEMA 4 control panel.
- Allen Bradley electrical components.
- High efficiency, polypropylene, random-dumped packing.
- Scotfoam mist eliminator.
- Painted carbon steel skid.
- Chemical injection port for ease in cleaning the column.
- Two hand-ways for packing inspection and removal.
- Magnehelic gauge to measure pressure drop through packing.
- Stainless steel influent and effluent sampling ports.
- Flanged top, adaptable for off-gas treatment.
- Lifting lugs.

Unit Dimensions

Model	ST-1	ST-2	ST-3
Diameter	1 foot	2 feet	3 feet
Overall Height	25 feet	25 feet	25 feet
Packed Height	18 feet	18 feet	18 feet
Maximum Flow Rate	15 gpm	90 gpm	200 gpm
Blower	1/2 HP	1 HP	7 1/2 HP
Electrical Requirements	1/60/115/230	1/60/230	3/60/230/460
Optional Off-gas Treatment:			
Carbon	200 pounds	400 pounds	1,600 pounds

Available Options

- Off-gas treatment—includes duct from top of tower to carbon unit, appropriately sized duct heater, and one carbon unit.
- Pump controls for air stripping tower panel—includes motor starter with thermal overload protection and intrinsically safe water level controls.
- Explosion-proof NEMA 7 controls.
- Installation and maintenance contracts.
- Custom design systems up to 12 feet in diameter, including telemetry control options and pre- and/or post-treatment.

r.e. wright associates, inc.
environmental restoration systems

November 12, 1991

Ms. Kathy Murphy
CDM, Inc.
10 Cambridge Center
Cambridge, MA 02142

Re: Budgetary Price for a
5 gpm Air Stripping Tower
Project Reference Name; Tibbetts Road

Dear Ms. Murphy:

R. E. Wright Associates, Inc. (REWAI) is pleased to present the following budgetary price for the air stripping tower (AST) system described in this letter.

Design:

Minimum Influent Water Temperature - 59°F
Minimum Influent Water Flow Rate - 3 gpm
Maximum Influent Water Flow Rate - 5 gpm
Air/Water Ratio - 75:1
Air Flow - 50 CFM
Static Water Pressure Loses through System - 7 inches

Contaminants

Chemical	Maximum Influent (ppb)	Design Effluent (ppb)
Benzene	3,100	5
Cis-1,2-Dichloroethene	4,000	70
Trans-1,2-Dichloroethene	4,000	100
Ethylbenzene	2,500	700
Tetrachloroethene	2,500	5
Toluene	12,000	1,000
1,1,1-Trichloroethane	220	200
Trichloroethene	7,800	5
Total Xylenes	18,000	10,000

3240 schoolhouse road middletown, pa 17057-3595
toll free 800-238-3320, in pa (717)-944-5501 fax (717)-944-4551

Other Chemicals (Estimated Effluent Level Only)

4-Methyl-2-Pentanone	10,000	10,000[2]
Naphthalene	455	455[2]
2-Methylnaphthalene	240	NA
Bisphthalate	40	NA

Inorganics[3]

Arsenic	185
Chromium	514
Lead	220
Manganese	19,900
Nickel	400
Vanadium	550
Iron[1]	227,000

[1]The AST system's packing and liquid phase carbon will foul causing excessive maintenance if the manganese and iron present in the influent water is not removed, by pretreatment.

[2]4-Methyl-2 Pentanene and naphthalene will not air strip using the proposed design. However, the liquid phase carbon will remove this chemical, but the effluent level will vary from 100 percent at start-up of carbon and steadily fall from that point.

[3]This budgetary proposal does not include provision for the removal of the inorganics listed. A pre-treatment system will be required for removal of the inorganics.

AST System:

One (1) AST one foot (1') in diameter by twenty-five feet (25') in overall height. The tower will be manufactured from fiberglass reinforced plastic (FRP), chemical resistant isophthalic resin with U/V protection and designed for 100 mph wind loads and seismic zone 2 vibrational effects. The tower will be delivered as fully assembled as possible and equipped with the following:

- o Vapor exhaust cap.
- o Three-inch (3") diameter flanged duct (connecting the tower to the air phase carbon unit).
- o Tower mounted duct supports.
- o Mesh type mist eliminator with support.
- o Tower mounted influent pipe supports.
- o Flanged tower top.
- o Flanged tower sump.
- o Packing support plate.
- o A packing bed depth of eighteen feet (18') of polypropylene packing.

- o Air inlet.
- o Lifting lugs.
- o Base ring/hold down lugs.
- o Influent spray nozzle.
- o Painted carbon steel system skid.

Nozzles:

- o One-inch (1") influent nozzle (NPT) with internal tower piping.
- o One and one-half (1.5") effluent nozzle flanged.
- o Three (3) eight-inch (8") diameter manways.
- o Two-inch (2") NPT drain with plug.
- o Instrumentation nozzles.
- o Two (2) sample ports.
- o Chemical addition port.

Fluid Handling Equipment:

- o One (1) effluent pump, 1/60/230 volt, 1/2 Hp TEFC motor, to produce 5 gpm at 50 TDH.
- o System piping one-inch (1"), PVC Schedule 40.

Electrical Equipment and Instrumentation

- o One (1) Nema 4 electrical enclosure to operate one (1) blower and two (2) pumps and wired for a 1/60/230 volt power supply.
- o Tower sump level controls.
- o Air flow switch.
- o Pressure gauge.

Mechanical Equipment

- o One (1) air blower, 1/60/230 volt, 1/2 Hp TEFC motor, equipped with a flexible connector, stand and weather cover.
- o 0.5 KW duct heater.

Vapor Phase Carbon

Two (2) carbon units with 400 pounds of virgin carbon.

Liquid Phase Carbon

Two (2) carbon units with 330 pounds of virgin carbon.

Approximate carbon usage:

Vapor Phase - .7 pounds/hour
Liquid Phase - .6 pounds/hour ?

Budgetary Prices; FOB Point of Manufacture.

AST System....................................$22,000.00
Vapor Phase Carbon Units ($900/ea.),...........$ 3,600.00
Liquid Phase Carbon Units ($1,500/ea.)...........$ 3,000.00

Total Budgetary Price..................................$28,600.00

If you have any questions or need further assistance, please feel free to contact me.

Very truly yours,

R. E. WRIGHT ASSOCIATES, INC.

Thomas J. Hanlon
Chief Cost Estimator

TJH:df

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS RD
DETAIL COST ESTIMATE
JOB NO.
DATE CHECKED 11/22/91
CHECKED BY [illegible]
COMPUTED BY K MURPHY
DATE 10/22/91
PAGE NO. 1

UV/OXIDATION SYSTEM

Design flow : 5 gpm

PEROXIDATION SYSTEM   UV H_2O_2 oxidant

ULTROX   UV, H_2O_2, O^3 oxidant

ULTROX Capital Cost $ 75,930

O+M $ 1.21/1000 gallons

5 gpm = 2.6 x10⁶ gallons/yr

$ 3200/yr

PEROXIDATION SYSTEMS - Vendor Quotes Model SSB30

Capital cost	$ 70,000
Installation Start-up + Training	$ 7500
	$ 77,500

O + M

Replacement	=	$ 315/yr
H_2O_2	=	$ 1600/yr
Electricity	=	$ 900/yr
		$ 2815/yr

MINIMUM FLOW REQUIRED FOR UNIT = 10 gpm
PRETREATMENT REQUIREMENTS
< 1 ppm iron influent

Capital = $77,500
O+M = $2815/yr   ~~Present worth (10%, 30) $26,537~~

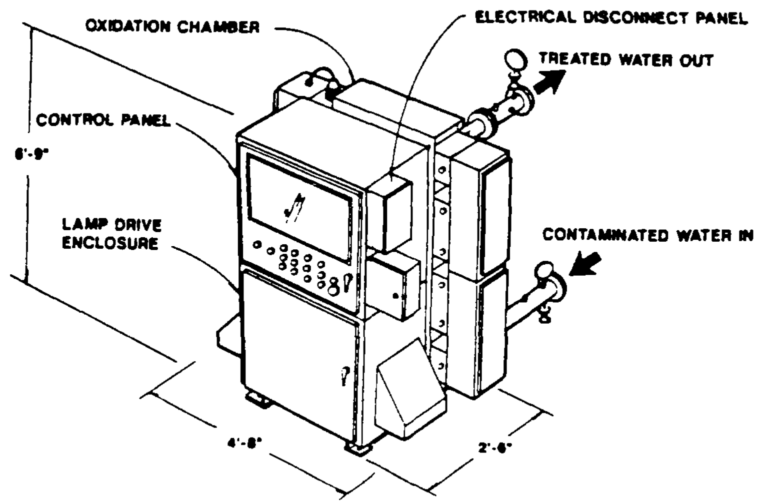
~~= $ 104,037~~

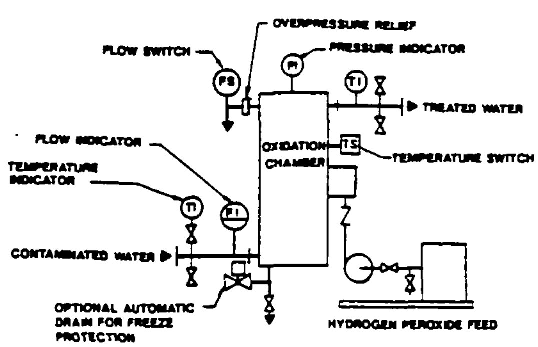
~~TOTAL Present Worth for UV oxidation = $ 104,000~~

perox-pure™
ORGANIC DESTRUCTION PROCESS

MODULAR TREATMENT SYSTEMS

MODEL SSB-30





SPECIFICATIONS	Model SSB-30	
Flow Rate: Maximum	60 gpm	100 gpm
Connections:	150# Flange	150# Flange
Inlet:	1 1/2"	2"
Outlet:	2"	2"
Power Supply:	3 pH/60Hz/480V, 30KW, 40 Amps	
Electrical Encl.:	NEMA 3R	
Material - Wetted Parts:	316 SS, Quartz, Fluoroelastomers, TFE	
External Parts:	Enameled Steel	
Weight - Shipping:	1500 lbs.	
Operating:	2000 lbs.	

The perox-pure™ chemical oxidation system consists of modular equipment designed to treat water contaminated by dissolved organic materials. Bench-scale process evaluations will determine the oxidation time necessary for the treatment level desired and whether pretreatment of the water is necessary. Full-scale oxidation chamber size and the number of lamps are then selected.

The oxidation chamber contains horizontally mounted lamps in quartz sleeves with fluoroelastomer seals. Indicators are provided to monitor performance of each lamp. Safety features include shop-wired and tested control panels interlocked with temperature and flow switches to shut off power at preset conditions.

The perox-pure™ system and its components are covered by numerous issued and pending patents.

Peroxidation Systems Inc.
5151 E. Broadway, Suite 600 Tucson, Arizona 85711 602-790-8383 FAX 602-790-8008

CAMP DRESSER & McKEE CLIENT USEPA | JOB NO. | COMPUTED BY K. MURPHY
PROJECT TIBBETTS ROAD | DATE CHECKED 11/22/91 | DATE 11/5/91
DETAIL COST ESTIMATE | CHECKED BY [signature] | PAGE NO. 2

PUMPS / COMPRESSOR

Pumps Required :		No.
Centrifugal Pumps - discharge to lamella		1
discharge to air stripper or UV unit		1
discharge to carbon		1

$ 500 / ea — 3 for air stripping/carbon

$ 1500 (3) $ 1000 (2) — 2 for UV oxidation or carbon

Sludge Pumps [Air Diaphram Pump] - discharge to sludge storage — 1
discharge to filter press — 1
— 2

$ 1400/ea

$ 2800 (2)

Submersible pump - discharge from sump to lamella — 1

$ 1000 /ea

$ 1000 (1)

Chemical feed pumps — 3

$ 1000 /ea

$ 3000 (3)

Compressor - $ 1000

TOTAL [air stripping /carbon] $ 9300 plus 20% installation cost — $ 11,160

TOTAL [UV OXIDATION or carbon] $ 8800 plus 20% installation cost — $ 10,560

CAMP DRESSER & McKEE CLIENT USEPA | JOB NO. | COMPUTED BY K MURPHY
PROJECT TIBBETTS ROAD | DATE CHECKED 11/22/91 | DATE 10/22/91
DETAIL COST ESTIMATE | CHECKED BY [signature] | PAGE NO. 3

PROCESS BUILDING

Building Dimensions 35' x 35' = 1225 ft^2

ITEMS	HARTWELL RD Wellfield WTP (3717 ft^2)	x 0.33	Revised Cost
Earthwork	$ 6000		2000
Concrete	$ 78 000		25,700
Masonry	$ 67000		22,100
Steel and Iron	$ 40000		13,200
Carpentry	$ 3000		1000
Weather Protection	$ 12000		4000
Doors + windows	$ 12000		4000
Finishes	$ 16000		5300
Instrumentation + Controls	$ 40000		13,200
Conveyance	$ 3000		1000
Mechanical	$ 162 000		53,400
Electrical	$ 42,000		13,800
	$ 431,000		$ 158,700

USE $ 160,000) NOT used see next page.

SITE WORK

Demolition and Removal of House $ 40,000

General Cleanup and Site Security $ 32,000

$ 72,000

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS ROAD
DETAIL COST ESTIMATE
JOB NO.
DATE CHECKED 11/22/91
CHECKED BY [signature]
COMPUTED BY K. Murphy
DATE 11/7/91
PAGE NO. 4

Alternative Process Building

Use Prefab Building

vendor: Dutton + Garfield distributer of
Butler Buildings Steve Webster (603) 425-2600
or (508) 374-4511

would be 35' x 40' Building SBF Height options, 10, 12, 14, 16'

\$ 45-50/ft² including excavation, laying concrete floor, delivery

\$ 70,000 For Building

Plus

Instrumentation + controls	\$ 13,200
Conveyance	\$ 1000
Mechanical	\$ 53,400
Electrical	\$ 13,800
	\$ 151,000

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS ROAD
DETAIL COST ESTIMATE O+M
JOB NO.
DATE CHECKED 11/22/91
CHECKED BY AMK
COMPUTED BY K. MURPHY
DATE 11/5/91
PAGE NO. 5

Operation and Maintenance Cost
FOR UV OXIDATION

ITEM	COST /yr
POWER	
Pumping	$ 4440
Equipment	$ 900
HVAC + Electric	$ 5775
CHEMICAL COSTS	
Metals Removal	$ 6320
UV Oxidation	$ 1600
LABOR	$ 60,000
SOLIDS DISPOSAL	$ 3610
EQUIPMENT MAINTENANCE + REPAIR	$ 1245 ?
	$ 83,390/yr

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS ROAD
DETAIL COST ESTIMATE O+M
JOB NO.
DATE CHECKED 11/22/91
CHECKED BY [signature]
COMPUTED BY K. MURPHY
DATE 11/5/91
PAGE NO. 6

POWER FOR UV OXIDATION

PUMPING:

Centrifical Pumps	2 x 1 HP	= 2 HP
2 Air Diaphram Pumps + Compressor		4 HP
Submersible Sump Pump		1 HP
Chemical Feed Pump	3 x ½ HP	1.5 HP
	Subtotal	8.5 HP
1 HP = 0.746 kw		6.3 kw

No correction for cycled operation.

6.3 kw x 24 hrs/day x 365 day/yr x $0.08/kwh

= $ 4440/yr

EQUIPMENT: $ 900/yr

HVAC + Electricity

Use Hartwell Road feasibility study multiplied by 0.33 for building reduction

$ 17,500 x 0.33 = $ 5775/yr

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS ROAD
DETAIL COST ESTIMATE O+M
JOB NO.
DATE CHECKED 11/22/91
CHECKED BY [illegible]
COMPUTED BY C MURPHY
DATE 11/5/91
PAGE NO. 7

CHEMICAL COSTS

Metals Removal - FROM GLASSBOROUGH, NJ DESIGN COSTS

NaOH

For 34 gpm + 12 mg/l iron
610 gal/month of 25% NaOH

For 5 gpm + 50 mg/l iron
375 gal/month of 25% NaOH

\$ 1.20 gal 25% NaOH

\$ 450/month — \$ 5400/yr

Polymer - Calgon - POL-E-Z-675 anionic polymer High MW Low Charge Density

6.6×10^{-4} gal/hr for 34 gpm

9.7×10^{-5} gal/hr for 5 gpm

5 gallon = \$ 90 + shipping — \$ 100/yr

Sulfuric Acid

0.0071 gal/min 25% H_2SO_4 for 34 gpm
0.001 gal/min
550 gal/yr

\$ 1.50 gal — \$ 820/yr

\$ 6320/yr

UV OXIDATION

H_2O_2 (quote by Peroxidation Systems) — \$ 1600/yr

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS ROAD
DETAIL COST ESTIMATE O+M

JOB NO.
DATE CHECKED 11/22/91
CHECKED BY [signature]

COMPUTED BY K. Murphy
DATE 11/5/91
PAGE NO. 8

LABOR

ASSUMING 8 Hr work Day
7 days a week
1 person

2912 Man Hours /yr
at $ 20/hr

$ 60,000/yr

EQUIPMENT MAINTENANCE + REPAIR

For UV Oxidation $ 315/yr ?

For Remaining Operations
%1.5 of remaining equipment capital costs
0.015 x $ 61,300 $ 930 /yr

$ 1245 /yr

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS ROAD
DETAIL COST ESTIMATE
O+M
JOB NO.
DATE CHECKED 11/22/91
CHECKED BY [signature]
COMPUTED BY K. MURPHY
DATE 10/30/91
PAGE NO. 9

If sludge cake is disposed of as hazardous waste the cost is \$500 / ton (price quote from Keefe Environmental Services site Dec. 89 - Clean Harbors Quote)

assume 1 cy ≈ 1 ton of sludge

For 1.5% sludge (230 ppm Fe)

43 ft³/day = 1.6 cy/day ≅ 1.6 ton/day x \$500/ton x 365 day/yr

= \$290,648 /yr

For 30% sludge (230 ppm Fe)

2 ft³/day = 0.074 cy/day ≅ 0.074 ton/day x \$500/ton x 365 day/yr

= \$13,518 /yr

For 30% sludge (50 ppm Fe)

0.5 ft³/day = 0.020 cy/day ≅ 0.020 ton/day x \$500/ton x 365 day/yr

= \$3,610 /yr

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY ______
PROJECT ______ DATE CHECKED 11/22/91 DATE ______
DETAIL ______ CHECKED BY AMK PAGE NO. 10

SAMPLING AND ANALYSIS COSTS

$ 250 / sample Priority Pollutant Metals
$ 205 / sample Priority Pollutant VOA (GC/MS)
$ 475 / sample Priority Pollutant Semi-VOAs (GC/MS)

Effluent Sampling once a month
Metals and VOAs every month
ABNs every other month

$ 455 x 12 = 5,460
$ 475 x 6 = 2850

$ 8310 / yr

Use treatment plant labor for all but surface water Discharge option (NPDES)

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS ROAD
DETAIL COST ESTIMATE
O+M
JOB NO.
DATE CHECKED 11/22/91
CHECKED BY MUK
COMPUTED BY IC Murphy
DATE 11/7/91
PAGE NO. 1

OPERATION AND MAINTENANCE COST
FOR AIR STRIPPING

ITEM	COST / yr
POWER	
PUMPING	$ 5260
HVAC + Electric	$ 5775
CHEMICAL COST	
Metals Removal	$ 6320
CARBON USAGE	
VAPOR PHASE	$ 22,500
LIQUID PHASE	$ 24,000
LABOR	$ 60,000
SOLIDS DISPOSAL	$ 3610
EQUIPMENT MAINTENANCE + REPAIR	$ 4535

TOTAL $ 132,000 /yr

CAMP DRESSER & McKEE CLIENT USEPA | JOB NO. | COMPUTED BY K. Murphy
PROJECT TIBBETTS ROAD | DATE CHECKED 11/22/91 | DATE 11/7/91
DETAIL COST ESTIMATE | CHECKED BY [illegible] | PAGE NO. 2

O+M

POWER FOR AIR STRIPPING

PUMPING

AIR STRIPPER BLOWER		½ HP
Centrifical Pumps	3 x 1 HP	= 3 HP
2 Air Diaphram Pumps + Compressor		4 HP
Submersible Sump Pump		1 HP
Chemical Feed Pump	3 x ½ HP	1.5 HP
		10 HP
		= 7.5 KW

No correction for cycled operation.

7.5 KW x 24 Hr/day x 365 day/yr x $0.08/KWh = $5260

HVAC + ELECTRICITY

Use Hartwell Road Feasibility Study Multiplied by 0.33 for building reduction

$17,500 x 0.33 = $5775

CAMP DRESSER & McKEE	CLIENT USEPA	JOB NO.		COMPUTED BY K. MURPHY	
	PROJECT TIBBETTS ROAD	DATE CHECKED 4/22/91		DATE 11/13/91	
	DETAIL COST ESTIMATE O + M costs	CHECKED BY MWK		PAGE NO 3	

CARBON USAGE FOR AIR STRIPPING ALTERNATIVE
USING INFORMATION PROVIDED BY R.E. Wright

VABOR PHASE CARBON

Two (2) units used in series with 400 pounds of carbon

Carbon usage ≈ 0.7 lb/hr = 17 lb/day

Change unit every 24 days

Regenerate 15 units per year.
$1000 each for regeneration costs
+500 for shipping

$1500/unit x 15 units = $22,500/yr

LIQUID PHASE CARBON

Two (2) units used in series with 330 pounds of carbon

Carbon usage ≈ 0.6 lb/hr = 14½ lb/day

Change unit every 23 days

Regenerate 16 units per year
$1000 each for regeneration costs
+500 for shipping

$1500/unit x 16 units = $24,000

CAMP DRESSER & McKEE CLIENT USEPA
PROJECT TIBBETTS RD
DETAIL COST ESTIMATE O+M

JOB NO.
DATE CHECKED 11/22/91
CHECKED BY [signature]

COMPUTED BY K. Murphy
DATE 11/18/91
PAGE NO. 4

EQUIPMENT MAINTENANCE + REPAIR FOR AIR STRIPPING / CARBON TREATMENT

$ 2000 /yr — routine maintenance for air stripper
$ 1500 /yr — to replace packing material

$ 3500 /yr for air stripper

For Remaining Operations
% 1.5 of remaining equipment capital costs

0.015 x 69,000 = $ 1,035 /yr

$ 4535 /yr

CAMP DRESSER & McKEE CLIENT EPA JOB NO. 7710-004. COMPUTED BY WRS
PROJECT Tibbetts Rd. DATE CHECKED 11/21/91 DATE 10/31/91
DETAIL Remediation CHECKED BY MMC PAGE NO. (1)

~~MM-4(+)~~ (MM-5, MM-6, MM-7) WRS 4/15/92 GAP 6/5/92

Vacuum Extraction Assessment in the Area of ~~Suspected NAPLs~~. High Concentration

Area to be considered:

North end of site up to 37D/69R group: (WELLS 80S/57S plus 2 other locations)

~~Consider vacuum extraction in an area about 100 feet long by 30 feet wide, the long direction being on a line from 70S to 69R. This areal extent could potentially handle any NAPLS which may subsequently be discovered in this general location.~~

Extraction wells - dual purpose - air/water.

~~An air collection/vapor collection pipe would be placed in a trench approximately 100 feet long and air collected for treatment with activated carbon, or treat @ catalytic incinerator or UV/ox. unit.~~ WRS 2/9/92

The in-situ vapor extraction system would include the following components:

(1) Skid-Mounted Vapor Extraction System

(2) ~~Extraction trench or~~ extraction wells.

(3) Space in treatment building.

~~(4) Vapor Phase Carbon Units (disposal also). or catalytic incineration w/ UV/oxidation unit.~~ MMC

(4) Vapor Phase Carbon Units (disposal also). or catalytic incineration w/ UV/oxidation unit.

Assumes water table has been depressed by the pump & treat system.

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY WRS
PROJECT ______ DATE CHECKED 11/21/91 DATE 10/31/91
DETAIL ______ CHECKED BY [illegible] PAGE NO. 2.

(1) Vapor Extraction System.
Blower / Controls / ETC.

Volume to be treated:

$$\frac{30' \times 100' \times 20'}{27} = \underline{2,200 \text{ C.Y.}}$$

Skid-Mounted Unit for this volume is approximately: \$20,000 (rough L.S. estimate based on similar F.S.)	L.S.	\$20,000
(2) Carbon Units (including disposal of spent carbon) (rough L.S. estimate based on similar F.S.) (assumes 1 year of operation)	L.S.	\$30,000
(3) Additional Building Space: 60 S.F. X \$50/S.F.		\$3,000
(4) Piping + Wiring L.S.		\$2,000

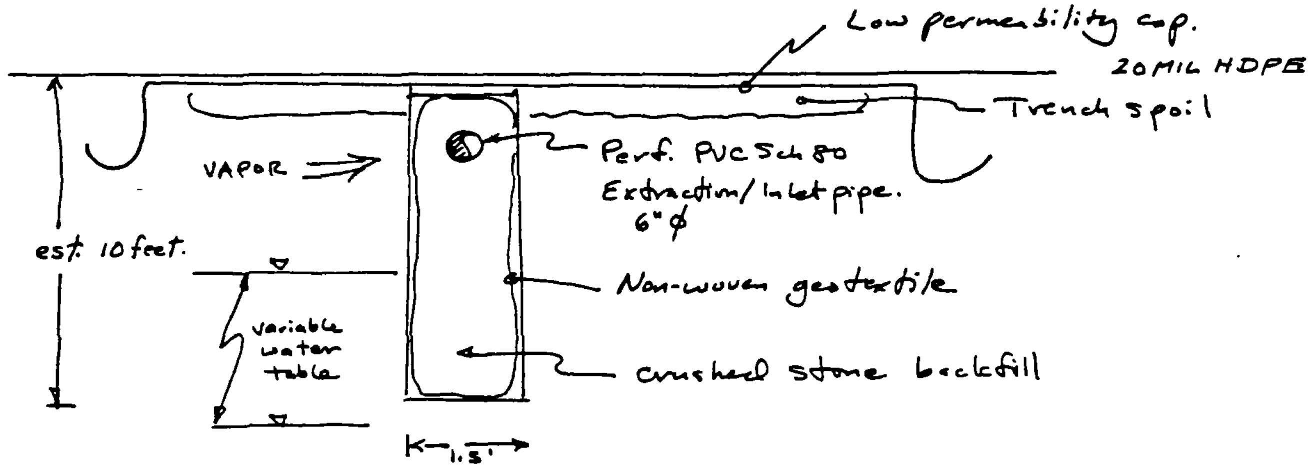
Subtotal: \$55,000

CAMP DRESSER & McKEE CLIENT
PROJECT
DETAIL

JOB NO.
DATE CHECKED 11/21/91
CHECKED BY [signature]

COMPUTED BY WCS
DATE 10/31/91
PAGE NO. (3.)

(4) Trench System (Concept Sketch)



Estimate Quantities

PVC Pipe - 100' extraction
100' to housing.

HDPE

$$\frac{100' \times 30'}{9} = 333 \text{ S.Y.}$$

Geotextile

$$\frac{26' \times 100'}{9} = 289 \text{ S.Y.}$$

Trench Volume

$$\frac{10' \times 1.5' \times 100'}{27} = 56 \text{ C.Y.}$$ $\times 2$ for slope trench sides

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY WKS
PROJECT ______ DATE CHECKED 11/21/91 DATE 10/31/91
DETAIL ______ CHECKED BY mwc PAGE NO. 4

Cost Trench System.

PVC Pipe Cost:

Means, (pg. 70) 6"ø $1.80/ft.
Site work Cost Data.
say $2.00/ft to
include fittings, etc.: $200.

Trench Excavation
(pg. 34) 56 C.Y. round up to
~~70~~ 112 C.Y. @ $4.50/C.Y. = $ ~~315.~~ 504

Crushed Stone. $30/C.Y. x 70 C.Y. = $2,100.
(used pavement price)
(pg. 38)

HDPE. use $2.00/SY. x 333 S.Y. = $ 666

Fabric.
Drainage Mat on vertical wall
(adverse cond. terms) $16.20/SY.
pg. 69 x 289 S.Y. = $4,682

Subtotal: $ 7,963
Add 30% for haz. conditions: $ 2,389

Total: $ 10,352

Capital Sub Total pg. 4: $ 65,352
~~round to $ 65,400~~

sub total ~~say~~ say $ 66,000

CAMP DRESSER & McKEE CLIENT EPA | JOB NO. 004-1L60 | COMPUTED BY WRS
PROJECT Tibbetts Rd. | DATE CHECKED ______ | DATE 2/6/92
DETAIL Cost - VES | CHECKED BY ______ | PAGE NO. (1)

Revise Vacuum Extraction (VES) System Cost.

Cost System of 4 wells instead of a trench.

Well sizing

Consider total depth of 30', allowing penetration of the harder lower till. 6"φ/12"φ

Dual withdrawal system w/ both a small submersible pump and an air extraction system line. Cap/ Access Port for inspection, maintenance, and pump pulling.
Trench w/ air and water lines to building.
Use nominal 100' length of lines.

Mean's 1991 5th Edition. pg. 75

Price for gravel pack well
8"φ, 40' deep w/ gravel & casing - complete
@ $24 / L.F.

1/2 HP submersible pump. $505.

pg. 74

2"φ line @ $2.87/L.F.

trench excavation.
@ $4.50 / C.Y.

$$\frac{1' \times 5' \times 1.5 \text{ (side slope)} \times 100'}{27} = 28 \text{ C.Y.}$$

Well footage:	30ft. x 4 wells x $24/L.F.	= $2,880
	4 pumps x $505	= $2,020
	4 trenches 28 c.y. x 4 x $4.50/c.y.	= $504
	2-2"ϕ lines 800' x $2.89/L.F.	= $2,312
		$7716
	add 30% for haz. work x1.3 = (10,031)	
		$10,031
		Say $10,000

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY GMK
PROJECT ______ DATE CHECKED ______ DATE 11/21/91
DETAIL ______ CHECKED BY ______ PAGE NO. 4a

Balance : ~~$66,000~~
pg 4 $65,000 WRS 2/3/92

On-Site Hauling of Excavated material
@ $4/c.y. x 112 cy = $448

Add for overliner (vapor barrier) and
plumbing + blower to treat excavated soil

- $2/sy x 500 SF x $\frac{sy}{9SF}$ = $110
- Pipe $200
- Blower $1000
- Carbon (1st) 2500
  w/ disposal included

$3,810 $3,810

TOTAL ~~$70258~~
$69,258 WRS 2/3/92

Capital Total say $70,000

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY WNS
PROJECT ______ DATE CHECKED 11/21/91 DATE 10/31/97
DETAIL ______ CHECKED BY [illegible] PAGE NO. 5

Operation and Maintenance Costs

System Operator @ 20 hrs/week
20 x $50/hr. x 52 weeks = ~~$52,000~~

may be able to combine
w/ rest of plant.
Therefore, cut to 10 hrs/wk = $26,000

Power.
1/4 HP blower
$1/4$ HP x 0.746 kWH/HP x 8760 hrs x $0.10/kWH = $163

Equipment Maintenance, parts, etc.: L.S. $2,000

Monitoring of air in & out of carbon: (L.S.) $5,000
(laboratory costs - 20 samples @ $250 each)

Condensate & Particulate disposal:
one drum every two weeks
$300/drum x 26 = $7,800
(may be able to run thru
other treatment units.)

Total: $40,963

CAMP DRESSER & McKEE | CLIENT | JOB NO. | COMPUTED BY WRS
PROJECT | DATE CHECKED | DATE 4/13/92
DETAIL | CHECKED BY | PAGE NO. —

OFF-SITE RECHARGE BED

(MM-5)

Off-Site Recharge Bed Considerations

Objective is to provide a recharge bed for 5gpm flow. This recharge bed is expected to be placed where conditions will be similar to those recorded at Well 57S and other overburden wells, i.e. high seasonal g.w. levels.

Referencing A. Bernhart - Treatment and Disposal of Waste Water from Homes by Soil Infiltration and Evapo-transpiration.

200 U.S. gallons requires an evapobed of 1,700 S.F. pg. 48.

1,440 gallons per day (1 gpm) requires: $\frac{1440}{200} \times 1,700 = 12,240$ S.F.

@ 5 gpm, 12,240 S.F. X 5 = 61,200 S.F.

(from fig 2-17 seepage rate 0.27 to 0.38 gal/s.F./day. - Bernhart.)
(loom-clay-silt)

from 57S "draindown" curve - 0.075 ft/day when water is seasonally high.

@ n=0.1 , 0.06 gal/s.F./day.)

@ 0.1 ft/day, 0.075 gal/s.F./day.)
(draindown at high end of curve)

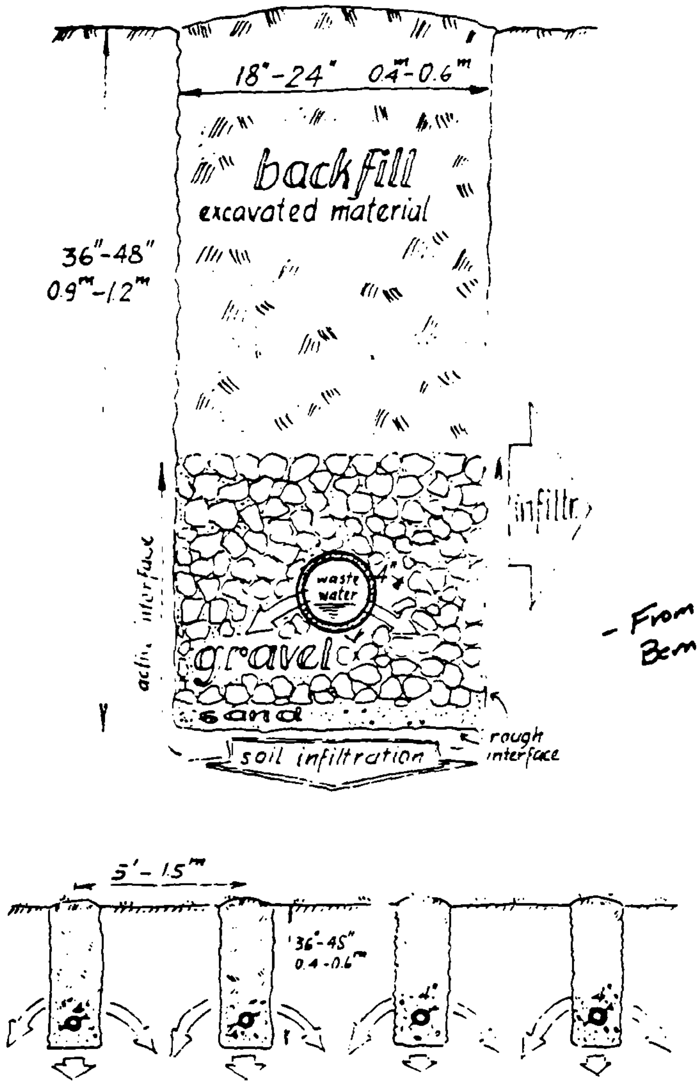
@ 0.075 gal/s.F./day

7,200 gal/day requires 96,000 S.F.

Size @ 100,000 S.F. > 61,200 S.F.

Other factors: - how much "border" needed.

- elevated sand mound approach; maximize E-T.
- trench design.
- actual soil conditions will vary.



- From Bernhart -

Figure 2-12
Anaerobic seepage trenches, the conventional construction method, using deep trenches with excavated material used as backfill. Since the lower parts of the trenches are frequently innundated, hydraulic pressure is exerted onto the sidewalls of the trenches, - so that these areas become active interface areas for wastewater infiltration.

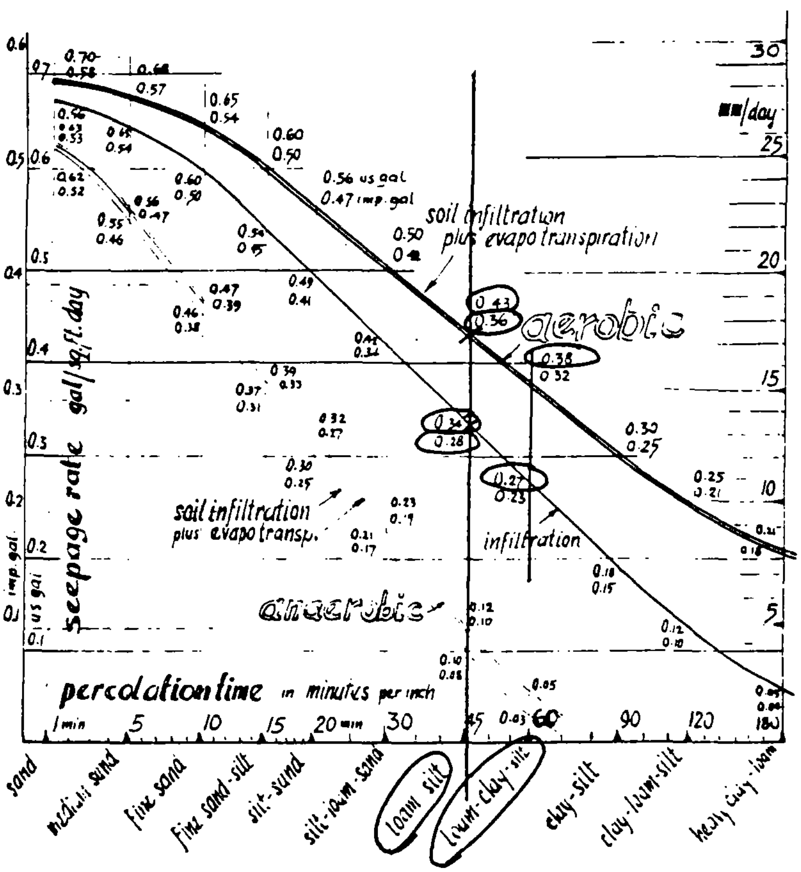
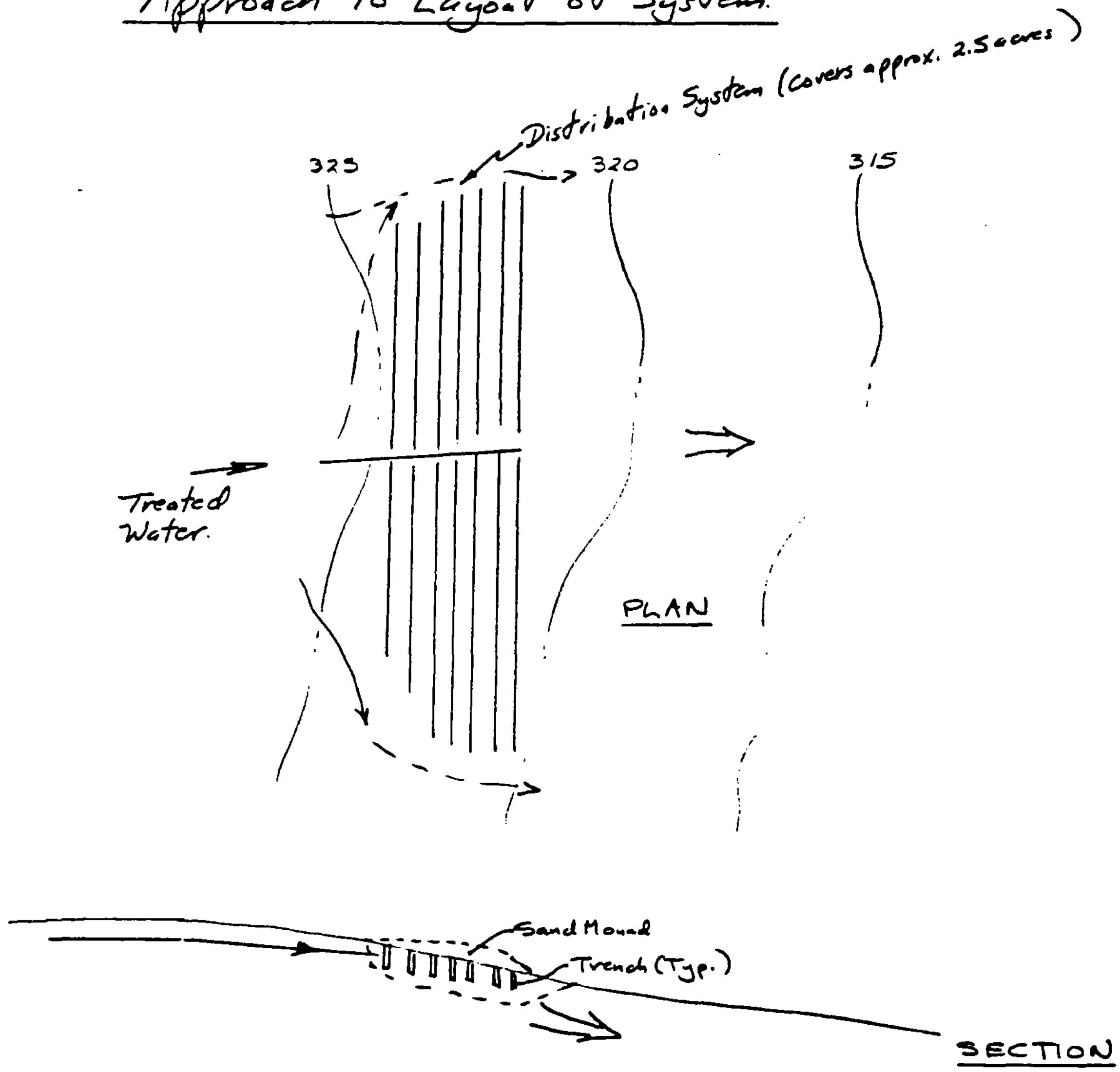


Figure 2-17
Seepage rates are the sum of soil infiltration s_i and evapotranspiration s_e, in gal per sq ft day and in mm per day;
- for various types of soils,
- for aerobic and for anaerobic microbial conditions,
- for well planted, humped seepage beds.

- From Bernhart. -

CAMP DRESSER & McKEE	CLIENT EPA	JOB NO. 7710-004	COMPUTED BY WRS
	PROJECT Tibbetts	DATE CHECKED	DATE 9/14/92
	DETAIL Off-Site Recharge	CHECKED BY	PAGE NO. 2

Approach to Layout of System.



Other considerations

- Basic infiltration area: 100,000 S.F.
- Possible dimension: 200 ft. by 500 ft. across contours of the land.
- Consider 100 ft. buffer: Total Land Area to be purchased.

  400 ft. by 700 ft.

  280,000 S.F. or about 7 acres.
- Consider a chain link fence around the basic 200 ft. by 500 ft. area; 1400 L.F. w/ 2 gates.

- Feed line from Site: unknown location - use 2,000 ft.

  ϕ of lines: "feed" line: 6" ϕ
  distribution pipe: 4" ϕ
  space distribution pipe @ ~20' o/c
  total pipe length:
  500' X 10 lines = 5,000'

- Sand Fill: "average" of 2 ft. over the area

  $$\frac{2\,ft. \times 200\,ft \times 500\,ft.}{27\,cu.ft/cu.yd.} = 7{,}400 \text{ cubic yards.}$$

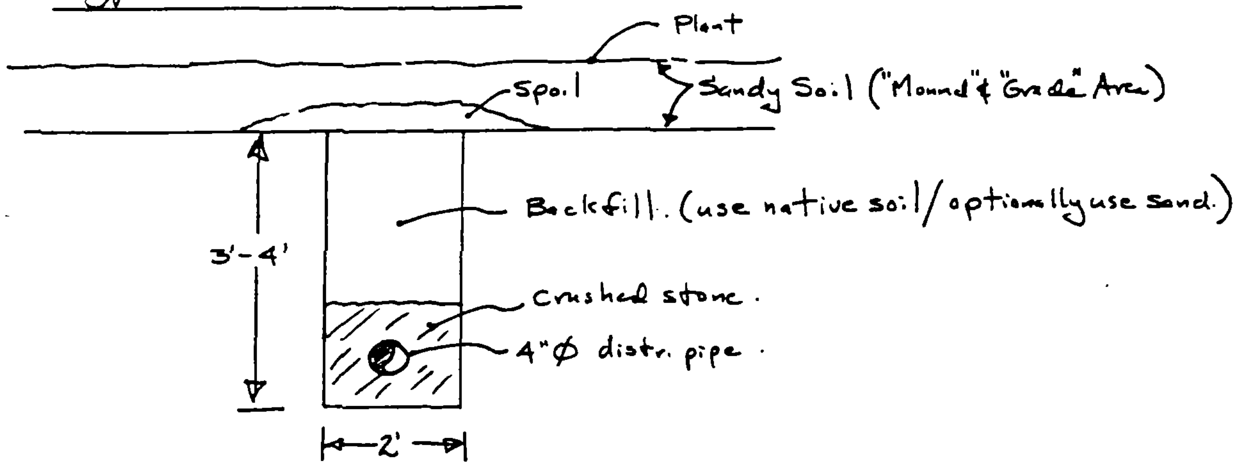
- Manholes: say 6 each. in recharge area for observation.
- Operations: Mow planted area every two weeks April - Sept.

  Observe water levels.

CAMP DRESSER & McKEE

CLIENT: EPA
PROJECT: Tibbetts Rd.
DETAIL: Off-Site Recharge.
JOB NO.: 7710-004
DATE CHECKED:
CHECKED BY:
COMPUTED BY: WRS
DATE: 4/14/92
PAGE NO.: 4

Typical Trench Section



Excavation for trenches: $\frac{2' \times 4' \times 5000'}{27}$ = 1,480 Cu. yds.

- increase to 1,800 to cover other grading & drainage work

Crushed Stone: $\frac{2' \times 1.5' \times 5000'}{27}$ = 560 Cu. yds.

- round to 600 Cu. yds.

Will need "tees" & "plugs", manholes & covers.

tees - 10 each ±.
plugs - 20 each ±.

CAMP DRESSER & McKEE	CLIENT	JOB NO.	COMPUTED BY WRS
	PROJECT	DATE CHECKED	DATE 4/15/92.
	DETAIL	CHECKED BY	PAGE NO. (5.)

① Land Taking:

Estimate 7 acres @ $10,000/acre = $70,000

Easements, etc. (est. L.S. @ $10k) = $10,000

Clearing & Grubbing

4 acres: $13,000/ac. = $52,000

(Means pg. 23 (see also pg 9 above 11/21/91)

(See collection trench & on-site recharge comps. for unit costs.)

② Feed Pipe @ 2,000 ft.

6"ϕ pipe placement

2,000' @ $1.80/L.F. = $3,600

Couplers 100 @ $8.80 each = $ 880

Manholes 4 precast for observation, etc.

4 @ $940 each = $3,760

(8' deep.)

Bedding Sand.

2'X2'X2,000'/27 ≅ 300 C.Y. X $30.00 C.Y. = $9,000

Trench Excavation & Backfill.

3'X6'X2000'/27 ≅ 1,300 C.Y. X $5.10/C.Y. = $6,630

subtotal: $155,870

CAMP DRESSER & McKEE	CLIENT	JOB NO.	COMPUTED BY wes
	PROJECT	DATE CHECKED	DATE 4/15/92
	DETAIL	CHECKED BY	PAGE NO. (6.)

(3) Distribution System / Recharge Bed.

Distribution Pipe @ 5,000 ft.

5,000' @ $1.60 / L.F.	= $8,000
tees & couplers 250 @ $8.80 each.	= $2,200
Manholes. 6 precast for observation, etc.	
6 @ $940 each (8' deep)	= $5,640

Crushed Stone

560 C.Y. @ $17.65 / C.Y. + 40 C.Y. @ $17.65 / C.Y. (misc.)	= $10,590

Excavation & Backfill

1,800 C.Y. @ $5.10 / C.Y.	= $9,180

Sand Fill (for mound, uniform - screened) (possibly washed & blended.)

7,400 C.Y. @ $30.00 / C.Y. (select fill: $6.45, haul $19.45, say $30 total) (20 mi)	= $222,000

Loam & Seed

4 acres @ $2,500 / acre	= $10,000

Chain Link Fence.

1,400 L.F. @ 6' @ $8.45 / L.F.	= $11,830
2 gates @ $170 each	= $340
subtotal:	$279,780
Total pg. 5 & 6	$435,650
say $440,000.	

For O&M of System:

Mowing, check on system, etc. :

10 hrs/wk X 26 wks X $50/hr. — $13,000./yr.

Misc. parts, etc. — $ 2,000/yr.

Total $15,000/yr.

CAMP DRESSER & McKEE | CLIENT ______ | JOB NO. ______ | COMPUTED BY ______
PROJECT ______ | DATE CHECKED ______ | DATE ______
DETAIL ______ | CHECKED BY ______ | PAGE NO. ______

SURFACE WATER DISCHARGE
COST ESTIMATE.

(MM-6)

COMPUTE COSTS OF SURFACE WATER DISCHARGE SYSTEM (MM-~~5~~ 6)

WRS 4/15/92
GAP 6/9/92

System Components

Discharge Line: 1,800 feet - 6-inch ϕ gravity flow.

Pumping Station: duplex package unit at 10 gpm maximum design flow.

Force Main: 2-inch ϕ - 2,200 feet

Discharge Line: 1,400 feet - 6 inch ϕ gravity flow.

Manholes: 6 each.

Use an average trench depth of 8 ft. for the discharge line.

Use a depth of 4 or 5 ft. for the force main or pressure line.

Consider some repaving: ~~500~~ 1600 feet on gravity / ~~300~~ 1400 feet on F.M..

Cost Discharge Lines (Means Site Work Cost Data 1991 10th Ed.)

Reinforced Plastic Pipe, 6" ϕ (pg. 74):		:	\$14.65/L.F. (includes O&P)
Excavation and backfill:	Bedding	:	2.24/L.F.
Trench 6 to 10 feet deep	excavate	:	\$4.50/C.Y.
(pg. 34)	backfill	:	\$1.56/C.Y.
	tamping	:	\$2.75/C.Y. } \$8.81/c.
Pavement (bituminous concrete 4" thick) (pg. 38)		:	\$36/S.Y.

Manholes:

Precast 8' deep (4' ID) (pg 71)	:	\$940 each.
Covers. 24"x24" opening	:	\$485 each.
		\$1,425

Pipe: 3,200ft. x $14.65/L.F. = $46,880
Bedding: 2.24/L.F x 3200 = 7,200
Trench:
$\frac{8' \text{deep} \times 3' \text{wide} \times 3{,}200' \text{long}}{27}$ ($8.81/C.Y.) = $25,060

Pavement:
$\frac{5' \times 1600'}{9}$ (~~500'~~) ($36/S.Y.) = ~~$10,000~~ $32,000

Manholes: 6 each x $1,425 each = $8,550

gravity Line subtotal: ~~$90,490~~ $119,690

Cost Force Main/ Pressure Discharge

PVC pipe: 2"φ $4.01/ft.
(water distribution - pg. 65)

Bedding: $1.30/LF

Excavation and backfill
Trench. 4'-6' deep.
(pg. 34)

excavate: $4.00/C.Y.
backfill: $1.56/C.Y.
tamping: $2.75/C.Y.
$8.31/C.Y.

Pipe: 2,200 (~~1,400~~) ft. x $4.01/L.F = ~~$5,614~~ $8,822

Trench: $\frac{5' \text{deep} \times 2' \text{wide} \times 2{,}200' \text{long}}{27}$ (~~1400'~~) ($8.81/C.Y.) = ~~$4,309~~ $7,180

Bedding: $1.30 x 2200' = $2,860

Pavement: (~~same as above~~) = ~~$10,000~~ $22,000
$\frac{5' \times 1100'}{9}$ ($36/SY)

force main subtotal: ~~$19,923~~ $40,862

Package Pumping Station: L.S. with installation $40,000

~~force main subtotal~~ ~~$120,412~~ ~~$80,862~~

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY Dmk
PROJECT ______ DATE CHECKED ______ DATE 11/21/91
DETAIL ______ CHECKED BY ______ PAGE NO. 3a

gravity line subtotal: $ 119,690

- ADD consideration for traffic control and traffic access while working in Hall Road (@ 20%) = 23,938

- ADD consideration for working in contaminated soils near site L.S. = 10,000

$ 153,628

Say $ 154,000

force main subtotal 40,862

- ADD consideration for traffic control and traffic access while working in Hall Road (@ 20%) = 8,172

49,034

say $ 49,000

Package Pump Station (from pg 2) L.S. = $ 40,000
w/ installation

Total: $243,000

WRS
gAP 6/5/92

gravity Line carried forward: # ~~120,413~~ 119,690
Force MAIN carried forward: 80,862

Add consideration of working in contaminated soils near site. L.S. # 10,000

Sub Total # ~~130,413~~
210,552

round to: # ~~130,000~~ # 210,000

ADD Consideration for traffic control AND traffic Access while working in Hall Road (@20%) = 42,000

252,000

Need to compute annual O&M. - Combine w/ treatment

Inspection and maintenance.
Power for package unit.

Misc. items/parts #1,000/yr.
Inspection and maintenance
80 hours @ #50/hr = # 4,000

Power:
1/4 HP X 0.746 KW/HP x 8760 hours/yr x #0.10/KWH = #163.37/yr.

Total: 5,163.37/yr.
round to #5,200/yr.

ADD for Labor related to collecting samples for monitoring (NPDES permit)
@ #1000/mo x 12 Mo/yr = # 12,000/yr

Monitoring (additional double process monitoring): add $ 8,310

Total: $ 30,510

WRS
GAO 6/5/92

CAMP DRESSER & McKEE

CLIENT		JOB NO.		COMPUTED BY	
PROJECT		DATE CHECKED		DATE	
DETAIL		CHECKED BY		PAGE NO.	

INJECTION WELL COST ESTIMATE.

3/19/92

Comps. R. Preble
Check W. Swanson.

(MM-7)

TIBBETTS ROAD

Injection Wells

A program for providing injection wells for disposal of treated water would preferably include two wells so a backup is available if the operating well requires servicing. The concept includes utilizing the existing 6-in. monitoring well designated 76R. The location of a second well is proposed to be near the intersection of the woods road leading to the above-existing well and Tibbetts Road. The budget estimate herein includes the cost of providing a search for a second injection well to cover the contingency that the first new well would not exhibit adequate capacity.

A drilled well diameter of 6 inches is proposed with an anticipated depth of 400 feet. If adequate capacity is not met at this depth, the installation of a second well is proposed rather than extending the depth.

Well completion would include a connection to the well casing for attachment of the discharge piping from the treatment facility, valving to isolate the well during operation, well venting, access for measurement of water level to monitor well condition, vandal-proof caps and protective posts to serve during construction and later snow plowing, etc.

Low yield might prompt hydrofracing of one well to improve yield. Operation for 300 feet of bedrock would be to separate the well into 6 hydrofrac zones or separate pressurized operation for best production improvement potential.

Connection Piping To Injection Wells

Extending down from the treatment location to a new well just southwest of the Treadwell property and then along the woods road to the existing well would amount to some 1,400 feet. Possibly, work in protective Level C would be required within the site boundaries.

<u>Budget</u>

An estimate of cost for the above-described system has been prepared which would necessitate a budget amount for the contractual amount of $70,000 which would including utilizing 3 wells (including 2 new ones). If one new well proved sufficient, a savings of approximately $10,000 would be expected.

TIBBETTS ROAD
INJECTION WELL BUDGET

Wells - (2 new wells - if 1 new well budget $10,000 less)

1.	Mobilization and on-site moves for drilling equipment		$ 1,500
2.	Drilling for casing and surface seal (incl. materials)	100 ft. x $40 =	4,000
3.	Bedrock 6-in. drilling	600 ft. x $12 =	7,200
4.	Well development		1,200
5.	Pumping test and well ratings (initial testing @ 24 hrs. each well)		4,800
6.	Hydrofrac operation to improve production - 1 well at $5,000		5,000
7.	Rating of hydrofraced well (6 hrs.)		800
8.	Well completion items - 3 wells		6,000
		SUBTOTAL	$30,500

Connecting Piping to Treatment Facility

1.	1,400 feet of 4-inch PVC buried 5 ft. connecting pipe @ $20/ft.		$28,000
2.	Level "C" surcharge for ± 12% of pipeline length 160 ft. x $10/ft.		1,600
3.	Miscellaneous (driveway crossing/surface restoration)		3,400
		SUBTOTAL	$33,000

TOTAL	$63,500
CONTRACT TOTAL(1)	$70,000

NOTE: (1) If completed under a general contract, add 15% or approximately $4,600 to the $30,500 well work effort. Round contract total to $70,000.

CAMP DRESSER & McKEE CLIENT ______ JOB NO. ______ COMPUTED BY WRCS
PROJECT ______ DATE CHECKED 11/21/91 DATE ______
DETAIL ______ CHECKED BY [illegible] PAGE NO. 7.

Balance Carried Fwd = $ ~~335,000~~

Cost
Wells.

5 wells @ ~~40'~~ 60' = ~~200'~~ 300' total drilling.
@ $150/ft = $ ~~30,000~~ 45,000

Pumps & Controls L.S. $ 10,000

Wells Sub Total $ ~~40,000~~ 55,000

Collection System total = $ ~~375,000~~ 390,000

JAP 6/9/92

WRS 2/10/92

Cost
Recharge Area

Cost @ trench system 60" deep.
(600 ft. total)

Use costs from collection trench.

6" ϕ pipe placement
600' X $1.80/L.F. = $1,080
Couplers & caps. 30 each @ $8.80 each. = 264

Precast Manholes
2 each at 8' ±
$940 X 2 = = $1,880

Crushed stone
$\frac{2' \times 3' \times 600'}{27} \times \$17.65/\text{c.y.}$ = $2,353

subtotal: $ 5,577

(carried forward) $5,577

Excavation and Backfill

$\frac{5' \times 2' \times 600'}{27} \times \$5.10/\text{c.y.} =$ $1,153

Subtotal $6,710

Surcharge for H&S, Materials Handling (20%) $1,342

Total: $8,052

round to: $10,000 ✓

This System added to alternative MM-7 only [initials] 6/10/92

THIS SYSTEM NOT INCLUDED IN ALTERNATIVES WRS 2/19/92

JAB 6/9/92

Summary Construction Cost

Extraction Trenches :	$ 335,000 ~~$ 117,000~~	$ 390,000 ~~$ 375,000~~	WRS 2/?/92
Extraction Wells :	55,000 ~~40,000~~		
Recharge Area :	~~10,000~~		
	~~$ 167,000~~ ~~$ 385,000~~		

Need to Compute annual O&M. - Combine with Treatment.

Inspection and maintenance

Power for pumping.

Parts, etc. add $1,000 / year.

Time 240 ~~80~~ hours @ $50/hr $ 12,000 ~~4000~~ /year.

Power: Extraction 7 units @ 1/6 HP

Cost: $\frac{7}{6}$ HP × 0.746 $\frac{\text{kW}}{\text{HP}}$ × 8760 hours/yr × $0.10/KWH = $762.41/yr.

Total $5,762.41/yr.

round to $6,000/yr.

CAMP DRESSER & McKEE

CLIENT ______ JOB NO. ______ COMPUTED BY ______

PROJECT ______ DATE CHECKED ______ DATE ______

DETAIL ______ CHECKED BY ______ PAGE NO. ______

OFF-SITE DISCHARGE TO POTW

MM-8 (See Section 3.0).

CAMP DRESSER & McKEE CLIENT EPA JOB NO. 7710-004 COMPUTED BY WRS
PROJECT Tibbetts Rd. DATE CHECKED 11/4/91 DATE 10/23/91
DETAIL Costs CHECKED BY [illegible] PAGE NO. 1

COMPUTE COSTS OF POTW DISPOSAL SYSTEM
~~(MM-8)~~ 7

MM-8
Not considered
in final Alts.
WRS 4/15/92
GAP 6/5/92

Use a flow of 5gpm or 7,200 gpd.

Disposal cost at POTW at $50 /1000 gallons.
This is the DOVER POTW price for drop off
out of Town Sewage.

At $50/1,000 gallons X 7,200 gpd X 365 days/year

= $131,400 /year.

(may be able to negotiate
better price based on "weak"
strength of water.)
(if cost of treatment is 50% hydraulic then: $65,700/year.)

Cost of hauling to POTW.

use: 5,000 gallons / truck

7,200 gallons/ day

2 trips/ day & a storage tank;
or two trucks.

(round trip distance estimated at 24 miles.)

System could be as follows:

36,000 gallon storage tank ~~(or second truck)~~ (part of plant cost.)

5,000 gallon truck.

O+M for 1 driver. @ $30,000/yr. (includes O.H./fringe)

Truck - Means data P-16 (016 420 6300)

Trailer "Rental" Rate of $1,925 month covering vehicle
repairs, etc.

X 12 = $23,100 /year.

30 ton Truck rental rate of $2950/mo
(Means pg 15) X 12 = $35,400 /yr

CAMP DRESSER & McKEE CLIENT		JOB NO.		COMPUTED BY	WRS
PROJECT		DATE CHECKED	11/21/91	DATE	10/29/91
DETAIL		CHECKED BY	[illegible]	PAGE NO.	(2)

O&M:

Fuel at 5 mpg: @ $1.00/gallon.

2 trips x 24 miles, 48 miles/day / 5 mpg x $1.00 = $9.60/day

x 365 days = $3,504/yr.

Sub. Total: $56,604/yr.

Total Annual Cost $188,004/yr.

round to: $188,000/yr.

Storage/Transfer System:

Provide 5-day storage in 2 - 18,000 gallon tanks.

assume tanks are winterized, or they could be installed inside the building

- Foundation 20,000
- 2 tanks, 18,000 gals @ $2.0/gal = 72,000
- assume winterization @ $10,000/tank = 20,000

$112,000

Duplex transfer pumping system ≈ $12,000

APPENDIX D

Development of Ground Water Cleanup Goals

Appendix D

Development of Ground Water Cleanup Goals

The purpose of this appendix is to present the logic for the development of preliminary cleanup goals for ground water. The results of the risk assessment computations for the ground water ingestion pathway are presented in summary form in Tables D-1 and D-2. Table D-1 summarizes the potential carcinogenic risks for ground water ingestion, and is based on Section 6.0 of the RI (Tables 6-17 and 6-18). Six chemicals of concern have computed carcinogenic risks. Table D-2 summarizes the potential noncarcinogenic risks for groundwater ingestion and is based on Section 6.0 of the RI (Tables 6-19 and 6-20). Nine chemicals of concern have noncarcinogenic risks, expressed as hazard indices, exceeding 1.

Table D-1
Potential Carcinogenic Risks from Ground Water Ingestion

Chemical of Concern	Chemical-Specific Carcinogenic Risk Average Concentrations		Chemical-Specific Carcinogenic Risk Maximum Concentrations	
	Shallow Wells	Deep Wells	Shallow Wells	Deep Wells
benzene	3.22×10^{-5}	1.13×10^{-4}	3.73×10^{-4}	1.05×10^{-3}
styrene	—	4.91×10^{-6}	—	1.16×10^{-4}
tetrachloroethene	9.49×10^{-5}	1.61×10^{-5}	1.49×10^{-3}	1.49×10^{-4}
trichloroethene	4.30×10^{-5}	9.40×10^{-6}	1.00×10^{-3}	8.37×10^{-5}
bis(2-ethylhexyl)phthalate	9.83×10^{-7}	2.29×10^{-6}	1.64×10^{-6}	3.93×10^{-5}
arsenic	1.00×10^{-3}	6.14×10^{-4}	3.79×10^{-3}	1.09×10^{-3}

Source: Tables 6-17 and 6-18 of the Remedial Investigation.

Table D-2
Potential Noncarcinogenic Risks from Ground Water Ingestion, with Hazard Indices Exceeding 1

Chemical of Concern	Average Concentrations		Maximum Concentrations	
	Shallow Wells	Deep Wells	Shallow Wells	Deep Wells
1,2-dichloroethene (total)	—	—	11.00	3.01
4-methyl-2-pentanone	—	—	5.48	3.01
tetrachloroethene	—	—	6.85	—
toluene	—	—	1.64	—
naphthalene	—	—	3.12	—
arsenic	1.34	—	5.07	1.45
chromium	—	—	1.93	2.82

Table D-2 (continued)
Potential Noncarcinogenic Risks from Ground Water Ingestion, with Hazard Indices Exceeding 1

Chemical of Concern	Average Concentrations		Maximum Concentrations	
	Shallow Wells	Deep Wells	Shallow Wells	Deep Wells
manganese	1.64	1.34	5.45	3.12
vanadium	—	—	—	1.69

Source: Tables 6-19 and 6-20 of the Remedial Investigation.

Potential Carcinogens

Five of the chemicals of concern, which are potentially carcinogenic, including benzene, styrene, tetrachloroethene, trichloroethene, and arsenic, have promulgated maximum contaminant levels (MCLs). However, the MCL for arsenic is currently under review. In addition, the MCL for styrene is based on noncarcinogenic effects. An MCL has been proposed for bis(2-ethylhexyl)phthalate. Generally, final and proposed MCLs are appropriate cleanup goals to be considered for the contaminated groundwater at the Site. The five potentially carcinogenic chemicals of concern with MCLs are:

Chemical	MCL (ug/L)
benzene	5
styrene	100
tetrachloroethene	5
trichloroethene	5
arsenic	50
bis (2-ethylhexyl) phthalate	4 (proposed)

Noncarcinogens

A number of noncarcinogenic chemicals of concern for site groundwater have final MCLs, including cis- and trans-1,2-dichloroethene, ethylbenzene, toluene, 1,1,1-trichloroethane, xylenes, and chromium. In addition, an MCL has been proposed for nickel, and an action level based on noncarcinogenic effects has been issued for lead. These MCLs, proposed MCLs and action level can serve as cleanup goals and are:

Chemical	MCL (ug/L)
cis-1,2-dichloroethene	70
trans-1,2-dichloroethene	100
ethylbenzene	700
toluene	100
1,1,1-trichloroethane	200
xylenes	10,000

Chemical	MCL (ug/L)
chromium (total)	100
lead	15 (Action level)
nickel	100 (proposed)

For several of the contaminants of concern for groundwater at the Tibbetts Road Site, including 4-methyl-2-pentanone, 2-methylnaphthalene, naphthalene, manganese and vanadium, no MCL, proposed MCL or action level is available. Therefore, risk-based cleanup levels for these five contaminants were derived based on a hazard index of 1.0 for each toxicity endpoint, exposure assumptions for the ingestion of groundwater, and EPA reference doses (RfDs). Table D-3 presents the development of the risk-based cleanup goals for these contaminants.

Table D-3
Development of Risk-based Cleanup Goals for Noncarcinogenic Chemicals of Concern with No Available MCLs

Chemical of Concern	Target Hazard Index (unitless)	Oral Reference Dose (Rfd)[1] (mg/kg/day)	Effect of Concern	Exposure Factor[3] (L/kg/day)	Risk-based Cleanup Goal[4] (mg/L)
4-methyl-2-pentanone (synonym methyl isobutyl ketone)	1.0	5E-02	Liver/kidney	2.74E-02	1.825
2-methylnaphthalene	0.5	4E-02[2]	Decreased Body Weight Gain	2.74E-02	0.73
Naphthalene	0.5	4E-02	Decreased Body Weight Gain	2.74E-02	0.73
Manganese	1.0	1.4E-01	No Effect	2.74E-02	5.11
Vanadium	1.0	7E-03	None Observed	2.74E-02	0.256

Notes:

1 RfDs obtained from EPA's Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST), 1992.

2 The RfD for naphthalene was used for 2-methylnaphthalene, as a RfD was not available.

3 Exposure Factor of 2.74E-02 L/kg/day = 2 liters of water/day x 350 days ingestion/365 day per year x 1/70 kg/body weight.

4 Risk-based Cleanup Goal (mg/L) = RfD (mg/kg/day)/Exposure Factor (L/kg/day).

Potential cleanup levels for contaminants found in groundwater at the Tibbetts Road Site are summarized in Table D-4.

Table D-4
Potential Cleanup Levels for
Contaminants Found in Groundwater at the Tibbetts Road Site

Chemical of Concern	Preliminary Cleanup Goal (in ug/L)	Basis (MCL or Risk Based, if no MCL available)
Volatile Organic Compounds (VOCs)		
Benzene	5	MCL
cis-1,2-dichloroethene	70	MCL
trans-1,2-dichloroethene	100	MCL
Ethylbenzene	700	MCL
4-methyl-2-pentanone	1,830	Risk
Styrene	100	MCL
Tetrachloroethene	5	MCL
Toluene	1,000	MCL
Trichloroethene	5	MCL
1,1,1-Trichloroethane	200	MCL
Xylenes	10,000	MCL
Semivolatile Organic Compounds (SVOCs)		
Bis(2-ethylhexyl)phthalate	4	Proposed MCL

**Table D-4 (Continued)
Potential Cleanup Levels for
Contaminants Found in Groundwater at the Tibbetts Road Site**

Chemical of Concern	Preliminary Cleanup Goal (in ug/L)	Basis (MCL or Risk Based, if no MCL available)
2-methylnaphthalene	730	Risk
Naphthalene	730	Risk
Metals		
Arsenic	50	MCL
Chromium	100	MCL
Lead	15	Action Level
Manganese	5,110	Risk
Nickel	100	Proposed MCL
Vanadium	256	Risk