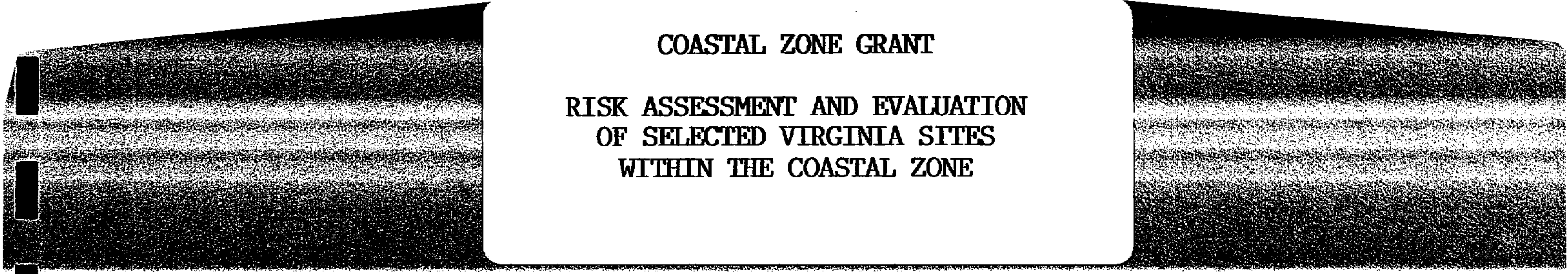

COASTAL ZONE GRANT

RISK ASSESSMENT AND EVALUATION OF SELECTED VIRGINIA SITES WITHIN THE COASTAL ZONE

FINAL REPORT

Risk Assessment and Evaluation of Selected Virginia Sites Within the Coastal Zone

(SE-VDWM-4222-89)

Submitted to

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by

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Risk Assessment and Evaluation of Selected Virginia Sites Within a Coastal Zone

FINAL REPORT

I. SUMMARY OF PROJECT GOALS

From the inception of this program, the participants from the Center for Risk Management of Engineering Systems have assumed two major goals for the project.

First, there were three specific sites that we were to investigate and, based upon our risk assessment, we were to give guidance to the Department of Waste Management on how to proceed with these sites. Specifically, the sites were the Suffolk Chemical Company near Suffolk, Alliance Chemical near Haynesville, and the former Republic Creosoting Company (now McLean Construction) located near Chesapeake, Virginia.

Second, we were to develop a systematic approach that could be used by the limited staff of the Department of Waste Management to organize information, make decisions, and plan strategies in dealing with the many other non-NPL sites in Virginia.

II. EVALUATION OF SUFFOLK CHEMICAL SITE

A. SUMMARY OF PERCEIVED PROBLEMS

The Department of Waste Management summarized the potential problems at this site as follows:

> The Suffolk Chemical Company has been operating an industrial chemical distribution center on this site in Suffolk, Virginia, since 1970. Liquids known to be commonly handled include solvents such as methyl ethyl ketone, 1,1,1-trichloroethane, and acetone, as well as numerous acids and bases. The site contains a clay-lined lagoon which receives rinse wastes and storm run-off and an area where solvents are dispensed. These areas would be the main location of contaminants. Sampling of on-site monitoring wells in 1986 detected significant levels of inorganics, such as lead, arsenic, and cadmium, and organics, most of which are solvents. No soil samples have been taken.
>
> The site is located near sensitive habitats. It is within one mile of the Great Dismal Swamp National Wildlife Refuge and extensive wetlands associated with the Nansemond River and Shingle Creek, both of which flow into Lake Meade, which is used as a public water supply. Shingle creek flows within 200 yards of the facility and receives shallow groundwater moving from the site. There are some shallow wells within a quarter mile of the site.
>
> Monitoring wells on site which tap into the shallow groundwater system were found to contain levels of lead and cadmium that are above Maximum Contaminant Levels established under the Safe Drinking Water Act. Arsenic, a probable human carcinogen, was also present in the samples. Numerous organics were detected in the monitoring well samples, including various benzene derivatives and a number of carcinogens, including bis (2-chloroethyl) ether and n-nitrosodimethylamine, compounds used as solvents in various industrial processes.

B. SUMMARY OF FIELD SURVEY AND SAMPLING DATA

As a result of the evaluation of previous data collected and our site visit at Suffolk Chemicals (December, 1988), we identified four major areas of concern and developed a sampling plan to investigate each area. This plan was implemented on our second visit to this site (February, 1989). The four areas are:

1. The lagoon sludge: No data established the status of the lagoon as either hazardous waste or as a potential source of groundwater contamination. The sampling involved carefully digging down to the lagoon liner and removing samples of the liner sludge. Analysis was for both EP TOX metals and for total metals as well as several other inorganic species.

2. The groundwater monitoring wells: Previous analyses of the wells were irregular, with several analytical discrepancies. Re-examination of these wells was also necessary to provide statistical support for modeling efforts.

Only three wells could be sampled. Well #3 (furthest upstream) was below surface water level, making sampling impossible. The other three wells, numbers 1,2, and 4, were all analyzed for Primary Drinking Water metals, several targeted inorganics, and acid-base/neutral extractable organics (GC/MS).

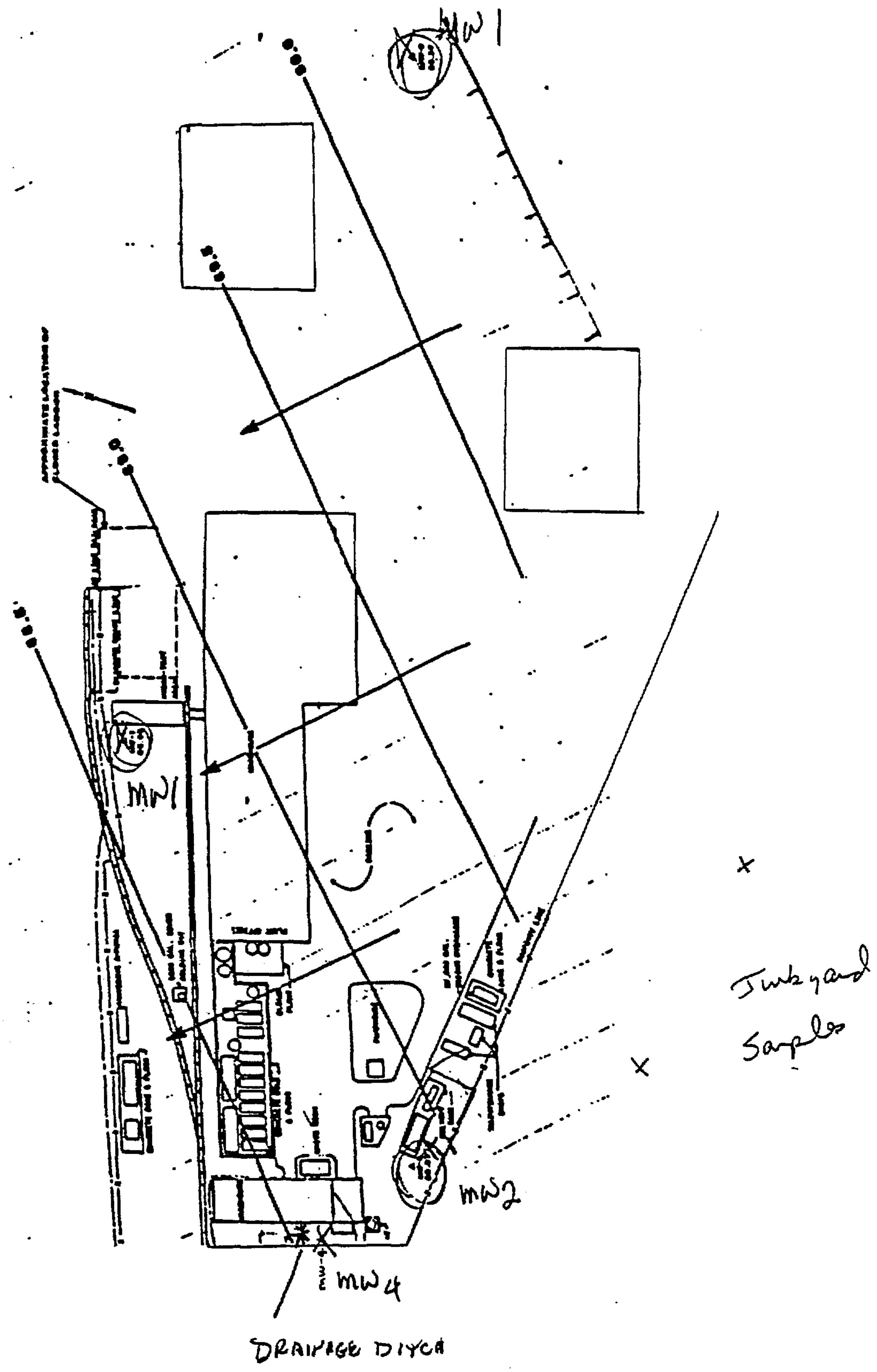
Preliminary assessment of the results shows well #2 to have the greatest inorganic contamination, low pH, high chloride, nitrates, and sulfates, as well as trace amounts of 4-chloro-3-methylphenol, 12,4-trichlorobenzene, and butyl benzyl phthalate. (Phthalates are used as plasticizers and under different solvent conditions, or acid environments, etc., they could have leached from the PVC well casings.) Well #2 is approximately 20 feet away from the sulfuric acid tank (probably the source of the low pH and sulfates observed).

Well #4 is unique, showing relatively high levels of copper, zinc, and chromium. Well #4 also showed 20 to 60 ppb levels of bis(2-ethylhexyl) phthalate and Poly Aromatic Hydrocarbons. (Since these are commonly found in fuel oils, they may be a result of run-off from the nearby parking lot.) (Note: Well #4 was partially filled in with sludge and bailing the well out only made the sludge contamination worse.)

3. The neighboring junkyard: Previous data at well #2 showed moderate levels of specific metals. Since this well is directly downstream from what had been an automobile junkyard, we wanted to test this as a source for metals. There was much debris and metal on the ground, making it necessary for us to insure that the junkyard was not contributing to the site's groundwater contamination. Two samples were taken of the soil. EP TOX analysis was performed.

4. Surface water run-off from behind the drum washing area:

FIGURE # 3 SITE MAP - SUFFOLK CHEMICALS



The drums are recycled, which requires washing them. An evaluation of the run-off in this area of high contamination potential was necessary to insure the washing station was not causing any contamination. There is a drainage ditch behind the washing station. Sludge from this area was collected and analyzed.

C. ANALYTICAL RESULTS

The analytical data is summarized in Tables 1-12. Locations of samples are shown in Fig. 3. New data are given in Appendix 1. Each type of sample will be discussed below.

1. Soils

Two suspected contaminated areas were the lagoon sludge and the junkyard. The results were not remarkable for most chemicals tested, except for slightly elevated levels of copper and zinc. Note that the levels of total metals (Table 1) and sulfate are higher in the lagoon than in the soils near the junkyard (Table 3). However, the EPTOX results more realistically represent the leachate into the groundwater; these results show a very low level of contamination (Table 2). Samples from the junkyard show no leakage: this result is consistent with the fact that it was cleaned up.

2. Surface Water

The surface run-off from the drum washing is likely to contaminate the surrounding area. The drainage ditch behind the drum washing area was analyzed; the results were not remarkable (Tables 4-5).

3. Groundwater

Analysis of well samples has been performed twice: once in 1986 (LES) and again in 1989 (Havens Laboratory). These results are displayed in Tables 6-12. High levels of chloride, ammonia, sulfuric acid, and total organic carbon were detected in the 1986 study. An assessment of the 1989 study shows that well #2 has the highest inorganic contamination, low pH, high chloride, nitrate, and sulfate, as well as trace amounts of 4-chloro 3-methylphenol, 1,2,4 -trichlorobenzene and butyl benzyl phthalate. Well #4 is unique, showing relatively high levels of copper, zinc, and chromium, Poly Aromatic Hydrocarbons and bis(2-ethylhexyl) phthalate. Well #1 was not remarkable. Well #2 showed high levels of sulfates and low pH.

D. INTERPRETATION AND MODELING

Available data for the site was evaluated. Evaluation of the soil and surface water data have yielded no conclusive results. High levels of sulfate, chloride, nitrate, copper, zinc, and some organics were found in the groundwater. These contaminants are prevalent in the uppermost aquifer, which is not used for drinking water purposes.

The contamination of groundwater at Suffolk is serious but the contaminants themselves are not highly toxic. The top aquifer is not utilized for drinking water purposes (LES, 1986). However, the middle aquifer supplies drinking water (LES, 1986) and the chances of these chemicals reaching aquifer from the top cannot be excluded. Data collected at present is inadequate to predict the migration of contaminants to the middle aquifer from the top aquifer. In order to estimate migration to the middle aquifer and eventually to drinking water wells, data will need to be collected concerning the thickness of the confining layer between the two aquifers, the hydraulic conductivities of the confining layer and the middle aquifer, and the potentiometric surface of the middle aquifer.

The potential for on-site groundwater contaminants to migrate to the nearby Shingle Creek was predicted utilizing two computer ground water models. Several modeling systems were investigated and these two were chosen based on their problem solving ability, their in-group familiarity, and availability.

The first is a widely used but somewhat complex model, method of characteristics (MOC) model developed at the U.S. Geological Survey (Konikow and Bredehoeft, 1978). MOC can handle anisotropic and heterogeneous media and non-point sources, and can account for unsteady flow. This model was used (Scherer, 1989) for simulating the migration of contaminants to Shingle Creek. Many simplifying assumptions (e.g., steady-state flow, constant hydraulic gradient, location, and leakage rate of sources assumed) had to be made to run the program. Utilizing worst case defaults, it was found that less than 2% of the contaminants reached Shingles Creek in 10 years.

The second model is an analytical solution for the migration of contaminants from a point source (CONMIG; Walton, 1989). This model assumes steady-state flow and allows for multiple point sources. This model, although simpler to use, does not allow for probabilistic elements which are necessary for risk analysis. Thus the basic equation used in this model was utilized for deriving a distribution function for the concentration at any point from the source, given the distribution function of the source concentration. Appendix

4 describes these derivations and the application to the Suffolk problem.

Parameters required for the model are given in Appendix 4 were estimated as shown in Table 13. Assume that at well #2 a sulfuric acid source is located which injects 100,000 gallons of sulfuric acid at the present time. The concentration of the acid has a distribution function which must be assessed. In the absence of appropriate data, the distribution can be assumed to be of a triangular form (Kelton and Law, 1982):

$$F_{C_o}(C_o) \begin{cases} = 0 & \text{when } C_o \leq \alpha \\ = (C_o-\alpha)^2/[(\beta-\alpha)(\tau-\alpha)] & \text{when } \alpha \leq C_o \leq \tau \\ = 1 - (\beta-C_o)^2/[(\beta-\alpha)(\beta-\tau)] & \text{when } \tau \leq C_o \leq \beta \\ = 1 & \text{when } C_o > \beta \end{cases}$$

$[\alpha, \beta]$ = interval in which c is believed to lie

τ = mode; the most likely value

From Equation (4) the distribution function for the concentration at Shingle Creek, which is 600 ft away (distance estimated from the U.S.G.S. 7.5 minute topographic map), is given by:

$$F_C(C) \begin{cases} = 0 & \text{when } C \leq \alpha f \\ = (C/f-\alpha)^2/[(\beta-\alpha)(\tau-\alpha)] & \text{when } \alpha f \leq C \leq \tau f \\ = 1 - (\beta-C/f)^2/[(\beta-\alpha)(\beta-\tau)] & \text{when } \tau f \leq C \leq \beta f \\ = 1 & \text{when } C > \beta f \end{cases}$$

It is assumed that α=500 mg/L, β=3000 mg/L and τ=2000 mg/L. Graphs of the input and output concentrations are shown in Figures 1 and 2. From Figure 2 it becomes clear that the chance of the concentration at the Creek exceeding 60 mg/L is negligible.

E. CONCLUSIONS

Based on the available data, the following statements about the Suffolk site can be made:

(1) Soil contamination of the junk yard and the drainage ditch behind the tank washing building was not significant, but because of the number of samples taken and sampling conditions, the posibility of contamination cannot be completely ruled out.

(2) High levels of sulfate, chloride, nitrate, copper, and zinc are present in some wells at groundwater level. In particular, well #2 contains about 2000 mg/L of sulfate.

These chemicals could reach the drinking water system by migrating to the Yorktown Aquifer.

(3) The models indicate that the possibility of groundwater contaminants reaching Shingle Creek during the next 20 years is low, but cannot be ruled out. Specifically, if a 100,000-gallon spill of sulfuric acid occurs near well #2, whose concentration is described by a distribution functions shown in Figure 1, the distribution of concentration of the acid in Shingle Creek after 20 years will be as shown in Figure 2. For example, if concentration near well #2 is 2000 mg/l, the concentration near Shingle Creek will be 35 mg/L after 20 years.

(4) High metal concentration found in well #2 is likely due to an automobile salvage yard located adjacent to the property. This area has been cleaned up and there was no evidence of metals contamination of the surface soils taken from the former junkyard off the Suffolk property.

(5) Metals concentrations in well #2 were much lower in the samples analyzed. It therefore appears that the metals contamination problem was suitably remedied by the clean up of the junkyard.

F. RECOMMENDATIONS

1. Although sulphate has been removed from the list of hazardous chemicals, there might be significant quantities of ammonium sulphate in the wells, since ammonia and sulphate levels are high. Leakage from the filler hoses from the sulfuric acid tank (as well as other tanks) needs to be stopped by installing a drip pad.

2. Two of the four wells need repair. Well #3 needs to be evaluated to remove the possibility of surface water contamination. Well #4 has been partially filled in and needs to be repaired.

3. Regular monitoring of pH and several common inorganics (sulphate, nitrate, ammonia, and chloride) needs to be performed.

4. Although the chemicals can migrate to the middle aquifer, we do not expect this to happen because of the intervening layer. However, investigation needs to be done to confirm that the intervening layer is not leaking. Sampling of wells withdrawing water from the middle aquifer can also be used to check the quality.

Figure 1: CDF for Concentration of Sulfuric Acid at Well #2

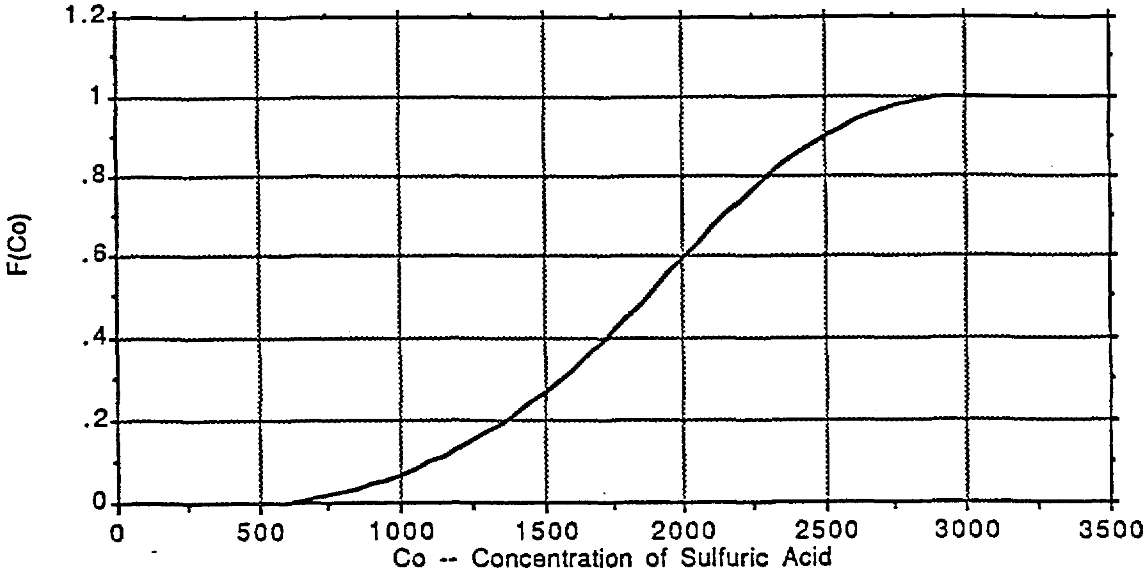


Figure 2: CDF Function of Sulfuric Acid at Shingles Creek (after 20 years)

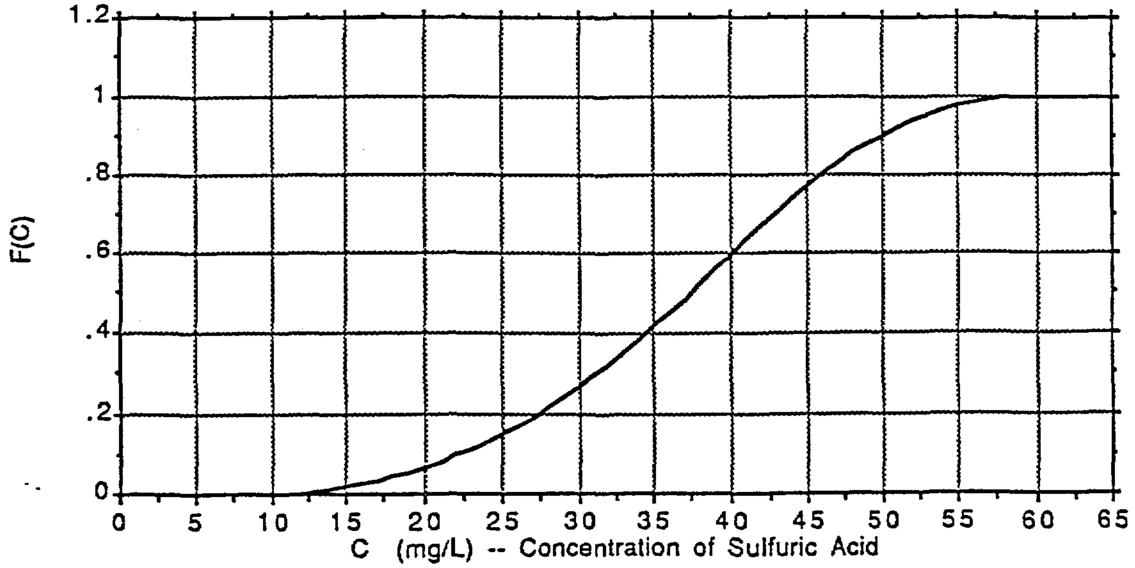


Table 1: Total Metals in the Soil (mg/L)

Chemical	Lagoon	Standard
Arsenic	<0.5	0.05
Barium	<10	1.0
Cadmium	1.4	0.010
Chromium	840	0.05
Copper	200	N/A
Lead	240	0.02
Mercury	<0.05	0.002
Selenium	<0.5	0.01
Silver	<1	0.05
Zinc	0.74	N/A

Table 2: EPTOX Metals in the Soil (mg/L)

Chemical	Lagoon	Junkyard		Standard
		#1	#2	
Arsenic	<0.002	<0.002	<0.002	0.05
Barium	<0.2	<0.2	<0.2	1.0
Cadmium	<0.01	<0.01	<0.01	0.010
Chromium	<0.1	<0.1	<0.1	0.05
Copper	<0.04	<0.04	<0.09	N/A
Lead	<0.1	<0.1	<0.1	0.02
Mercury	<0.0001	<0.0001	<0.0001	0.002
Selenium	<0.002	<0.002	<0.002	0.01
Silver	<0.03	<0.03	<0.03	0.05
Zinc	0.12	0.05	0.78	N/A

Table 3: Inorganics in the Soil (mg/kg)

Chemical	Lagoon	Junkyard	
		#1	#2
Ammonia (as N)	<0.8	<0.8	<0.8
Chloride	0.014	0.014	0.005
Nitrate (as N)	0.8	<0.1	<0.1
Sulfate	640.0	60.0	40.0

Table 4: Drainage Ditch EPTOX Metals Analysis (mg/L)

Chemical	Concentration	Standard
Arsenic	<0.002	0.05
Barium	<0.2	1.0
Cadmium	<0.01	0.010
Chromium	<0.1	0.05
Copper	<0.04	N/A
Lead	<0.1	0.02
Mercury	<0.0001	0.002
Selenium	<0.002	0.01
Silver	<0.03	0.05
Zinc	0.13	N/A

Table 5: Drainage Ditch Inorganic Analysis (mg/Kg)

Chemical	Concentration
Ammonia (as N)	<0.8
Chloride	0.014
Nitrate (as N)	5.2
Sulfate	60.0

Table 6: Inorganics (LES, Jan., 13, 1986)
(Unless otherwise stated, all parameters are in mg/L. NT = not tested, N/A = not applicable.)

Chemical	Well#1	Well#2	Well#3	Well#4
Alkalinity	458.0	832	NT	NT
Ammonia	10.97	8.04	NT	NT
Chloride	293.7	1043	NT	NT
Total Dissolved Solids	1103	4072	NT	NT
Nitrate	<0.01	0.40	NT	NT
pH	7.1 @ 10 C	6.3 @ 10 C	NT	NT
Chromium, dissolved	<0.04	<0.04	NT	NT
Mercury, dissolved	<0.001	<0.001	NT	NT
Copper, dissolved	<0.01	<0.01	NT	NT
Lead, dissolved	0.09	0.21	NT	NT
Zinc, dissolved	0.06	0.11	NT	NT
Arsenic, dissolved	0.015	0.039	NT	NT
Barium, dissolved	<0.01	0.15	NT	NT
Cadmium, dissolved	0.023	0.023	NT	NT
Volatile Organics	<0.010	<0.010	NT	NT
Total Organic carbon	NT	NT	NT	NT
Cyanide	NT	NT	NT	NT
Sulfate	NT	NT	NT	NT

Table 7: Inorganics (LES, May 13, 1986)
(Unless otherwise stated, all parameters are in mg/L. NT = not tested, N/A = not applicable.)

Chemical	Well#1	Well#2	Well#3	Well#4
Alkalinity	389.9	894.6	2310.5	502.2
Ammonia	9.18	11.5	2.52	3.56
Chloride	372.0	1203	11.3	398.3
Total Dissolved Solids	737	4750	2250	1537
Nitrate	<0.003	0.022	<0.003	0.023
pH	6.4 @ 26 C	4.7 @ 27 C	11.0 @ 27	5.3 @ 26 C
Chromium, dissolved	<0.04	<0.04	<0.08	<0.04
Mercury, dissolved	<0.001	<0.001	<0.001	<0.001
Copper, dissolved	0.02	0.03	0.13	0.02
Lead, dissolved	0.09	0.21	0.37	0.32
Zinc, dissolved	0.08	0.11	0.09	0.10
Arsenic, dissolved	0.007	0.023	0.006	0.005
Barium, dissolved	0.67	<0.01	<0.01	3.88
Cadmium, dissolved	<0.007	0.029	0.011	<0.007
Volatile Organics	NT	NT	NT	NT
Total Organic carbon	41.8	757.1	54.5	281.9
Cyanide	NT	NT	NT	NT
Sulfate	89.96	987.74	23.59	13.28

Table 8: Organics (LES, Jan. 13, 1986)
(Unless otherwise noted, all the parameters are in mg/L.
ND = not detected, NT = not tested).

Chemical	Well Number 1	2	3	4
1,2 Dichlorobenzene	ND	ND	NT	NT
1,3 Dichlorobenzene	ND	ND	NT	NT
1,4 Dichlorobenzene	ND	ND	NT	NT
bis (2-chloroethyl) ether	0.021	0.027	NT	NT
hexachlorethane	ND	0.123	NT	NT
hexachlorobenzene	ND	ND		
n-nitrosodi-n-propylamine	ND	0.041	NT	NT
bis (2-ethylhexyl) phthalate	ND	0.027	NT	NT
n-nitroeodimethylamine	ND	ND	NT	NT
bis (2-chloroisopropyl) ether	ND	ND	NT	NT
nitrobenzene	ND	ND	NT	NT
1,2,4-Trichlorobenzene	ND	ND	NT	NT
hexachlorocyclpentadiene	ND	ND	NT	NT
2-chloronaphthalene	ND	ND	NT	NT
acenaphthene	ND	ND	NT	NT
dibutyl phthalate	ND	ND	NT	NT

Table 9: Organics (LES, May 6, 1986)
(Unless otherwise noted, all the parameters are in mg/L.
ND = not detected, NT = not tested).

Chemical	Well Number 1	2	3	4
1,2 Dichlrobenzene	ND	0.044	0.026	0.018
1,3 Dichlorobenzene	ND	ND	ND	0.023
1,4 Dichlrobenzene	0.015	0.014	ND	ND
bis (2-chloroethyl) ether	ND	0.126	ND	ND
hexachlroethane	ND	0.978	ND	ND
hexachlorobenzene	ND	ND	0.011	ND
n-nitrosodi-n-propylamine	ND	0.190	ND	0.011
bis (2-ethylhexyl) phthalate	0.032	0.018	ND	ND
n-nitroeodimethylamine	0.053	ND	0.012	ND
bis (2-chlroisopropyl) ether	ND	0.109	0.015	0.464
nitrobenzene	ND	0.199	ND	ND
1,2,4-Trichlrobenzene	ND	0.015	ND	0.011
hexachlorocyclpentadiene	ND	0.018	ND	ND
2-chloronaphtalene	ND	0.016	ND	ND
acenaphthene	ND	0.035	ND	ND
dibutyl phthalate	ND	0.011	ND	ND

Table 10: Total Metals (Havens Laboratory, 2/22/89) (mg/L)

Chemical	Well#1	Well#2a	Well#2b	Well#4b	Standard
Arsenic	<0.002	<0.002	<0.002	<0.002	0.05
Barium	<0.2	<0.2	<0.2	<0.2	1.0
Cadmium	<0.01	<0.01	<0.01	<0.01	0.010
Chromium	<0.1	0.2	0.1	0.5	0.05
Copper	<0.04	<0.04	<0.04	0.14	N/A
Lead	<0.1	<0.1	<0.1	0.1	0.02
Mercury	<0.0001	<0.0001	<0.0001	<0.0001	0.002
Selenium	<0.002	<0.002	<0.002	<0.002	0.01
Silver	<0.03	<0.03	<0.03	<0.03	0.05
Zink	0.13	0.06	<0.08	0.75	N/A

Table 11: Inorganic Analysis (Havens Laboratory, 2/22/89) (mg/L)

Chemical	Well#1	Well#2a	Well#2b	Well#4b
Alkalinity (as CaCo3)	350	370	350	330
Ammonia (as N)	9.9	83	96	4.2
Chloride	210.0	585.0	615.0	448.0
Solids, total dissolved	1120	4670	5130	1640
Nitrate (as N)	0.525	4.550	3.300	0.700
pH	6.4	5.0	5.0	5.9
Sulfate	120.0	1900.0	2100.0	105.0
Cyanide	<0.01	<0.01	<0.01	<0.01
Conductivity (umho/cm)	1400	3300	3300	1700

Table 12: Organic Analysis (Havens Laboratory, 2/22/89) (mg/L) (samples were extracted by EPA method 3510, analyzed by EPA method 8270, GC/MS using a DB-1 Col. ND = none detected).

Chemical	Well#1	Well#2a	Well#4b
4-chloro 3-methylphenol	ND	0.023	ND
1,2,4-trichlorobenzene	ND	0.009	0.034
acenaphthelene	ND	ND	0.027
fluorene	ND	ND	0.008
fluoranthene	ND	ND	0.060
pyrene	ND	ND	0.039
butyl benzyl phthalate	ND	0.044	ND
bis(2-ethylhexyl)phthalate	ND	ND	0.116

Table 13: Risk Analysis Parameter Values

Parameter	Value	Remarks
Hydraulic conductivity, K	15 ft/day	conservative
Effective porosity, n	0.3	conservative
Hydraulic gradient , dh/dx	0.002 ft/ft	conservative (LES, 1986)
Aquifer thickness, m	30 ft	average
Long. dispersivity, A	10 ft	subjective estimate
Trans. dispersivity, A	2 ft	subjective estimate
seepage velocity, v	0.1 ft/day	computed
volume injected, v	100,000 gal.	conservative
Retardation factor, R	1	conservative (no retardation)
Half life, h	infinity	conservative (no decay)

III. EVALUATION OF ALLIANCE FERTILIZER COMPANY SITE

A. SUMMARY OF PERCEIVED PROBLEM

The Department of Waste Management summarized the potential problems at this site:

The Alliance Fertilizer site, located in Richmond County near Haynesville, has been in operation since 1977. The parent company is Alliance Agronomics Inc. of Mechanicsville, Virginia. Fertilizer is blended on-site and herbicides and pesticides are added during this process. The site is the source of nutrients and several herbicides that are leaching into the shallow groundwater and moving into nearby surface waters. Pesticides, including toxaphene and dieldrin, were detected in soil samples.

The shallow aquifer in the nearby area is utilized as a drinking water source for private residences. A nearby town obtains its water from a deeper aquifer in the area. The herbicides atrazine, alachlor, metolachlor, and dicamba have been detected in significant concentrations in the shallow aquifer. Several of them are possible human carcinogens. Nitrate is also present at levels that could present a human health hazard. One well has already been abandoned due to contamination. A nearby spring is also contaminated with nutrients and herbicides at concentrations that are toxic to some freshwater organisms. This spring eventually drains into the Rappahannock River, approximately three miles downstream.

B. SUMMARY OF FIELD SURVEY AND SAMPLING PLAN

Our sampling and analysis had several basic goals:

1. To test the possibility of a "hot spot" at the left front of the Alliance property as a potential source of the contamination of the Davis well on the neighboring property.
2. To remeasure all monitoring wells and the Davis well. To check concentration of previously identified problems and look for other possible problems.
3. To examine the spring to determine current level of contamination and potential sources of loading.

4. To examine drainage ditches for organic pollutants in an attempt to evaluate source of contamination in front of property (possibly leading to Davis well contamination).

Initial sampling at the Haynesville site occurred on May 24, 1989, and samples were taken in three categories:

1. Surface water at the head of Purcell Springs, behind the Alliance site.

2. Well water from all four on-site monitoring wells and the Davis property well.

3. Three soil samples, two from drainage ditches at the front and the right side and one from the driveway at a "hot spot" (approx. 2′ deep) where an earlier spill was suspected.

4. To locate the "hot spot", we used a HNU PI 101 gas analyzer hooked up to a KV soil gas probe. The soil gas was drawn by a 0.5 l/m pump from approximately 18-20" of depth. The area of the left front part of the property was laid out in a 4-part grid and the analysis conducted at each corner, with two samples taken from the middle of the grids. No hot spots were identified. One sample had a reading between 1.5 and 2 ppm, so a core sample was taken and analyzed.

Water samples were analyzed for pH, conductivity, TDS, PO_4, NO_3, and priority pollutants (acid/base-neutral extractables only). Soil samples were analyzed for only acid/base-neutral extractable priority pollutants.

Preliminary stream modeling of Purcell Spring indicated that the results of the previous sampling showed a great drop-off in concentration from sampling location #1 to #2. This, along with our earlier inspection of the spring, suggested that the stream was not running during sampling; therefore, our efforts to identify the loading location were invalid.

Therefore, a second sampling of Purcell Spring was deemed necessary and accomplished on a rainy day when the stream was running. We were also able to get several loading samples from behind Alliance and the Davis property.

C. ANALYTICAL RESULTS

The locations of samples are identified in Figures 4-6. Figure 7 is a site map showing the monitoring well locations, relative grade of the property, locations of other wells to the site, and the area of the suspected "Hot Spot". Analytical data are summarized in Tables 14-36 (the data collected for this study are included in Appendix 1). Each type of sample is reviewed below:

1. Soils

Soil samples were tested twice: once in February, 1988, by the Virginia State Water Control Board and then by Havens Laboratory in 1989. Both times, the samples were tested for pesticides and herbicides (atrazine, metolachlor, alachlor and dicamba in 1988; alachlor and metolachlor in 1989) but generally these compounds were not detected (see Table 14). The three samples taken during this study (form drainage ditches and the front of the site) did not contain detectable levels. The owner indicated the possibility of a hot spot in the left front of the property. This was analyzed using soil gas analysis and no contamination was found.

2. Surface water

The following surface water bodies have been tested for contamination: the holding pond, Purcell Spring, and the stream which runs from the site into Totuskey Creek.

Holding Pond: The 1986 samples (Tables 15-16) showed high levels of chloride, TKN, ammonia, nitrate, sulphate, atrazine, lasso and dual. No further analysis was conducted because Alliance does not have a discharge permit nor do they discharge from this pond to the stream. This was not perceived as a problem.

Purcell Spring: High levels of ammonia, nitrate, and sulphate were detected in '77 and '81 samples (Table 17). The 1986 samples showed a drop in the nitrate and ammonia level. The 1981 samples showed high levels of alachlor, metolachlor, and atrazine (Table 18) and metals (Table 19). The high levels of these chemicals are possibly due to the run-off from Alliance and nearby fields. Purcell Spring continues as a stream behind Alliance.

Stream: The stream near Alliance was sampled thrice: in 1981, 1988, and 1989 (see Tables 20-24). There is a discrepancy in the location of stations in 1981 and 1988 (as noted in the correspondence with Keith Fowler of the State Water Control Board in Appendix 2 with the Field Visit Reports) and it is difficult to decipher the relative locations of stations in

1981. High levels of nitrate, ammonia, alachlor, metolachlor, and atrazine were recorded at Station no. 3 (which probably is the same as station no. 1 of 1988) in the 1981 study (Tables 21-22). Station no. 4 also showed high levels of those chemicals. In the 1988 study, there was a high level of Nitrate (29.9 mg/L) at station no.1. Levels of alachlor, metolachlor, and atrazine were significantly less compared to those of 1981. It was not clear from the 1981 and 1988 data where these contaminants were coming from, hence additional nitrate samples were taken by Havens Laboratory on June 21, 1989, on a rainy day (Table 19).

Figure 9 shows a plot of nitrate concentration along the stream. From the 1988 data it becomes clear that there is a sudden drop-off after the initial sample location and then the concentration remains constant. However, the 1989 data shows an initial drop-off and then a sudden rise. This is probably due to a washload which comes from the drainage ditch near the hog lot (see Figures 4 and 5 for the locations of the stations for '88 and '89 respectively); a concentration level of 14.0 mg/L measured in that ditch confirms this hypothesis. Another source is at the mouth of Purcell Spring (Station no. 1). From the run-off samples at the back of Alliance property (maximum concentration of 2.26 mg/L), it appears that the high concentration of nitrate at station number 1 in 1988 is not due to surface run-off from Alliance. It may be because of groundwater seepage or because of evaporation, which had concentrated the nitrate in the standing water where station no. 1 was located.

3. Groundwater

Of the four residential wells (Haynie, King, Lawrence Davis, and Davis), only the Davis well showed significant levels of contamination (Tables 25-28). High levels of nitrate, chloride, sulphate, metolachlor, alachlor, dicamba, atrazine and some heavy metals have been detected since 1977. Figure 10 shows a plot of nitrate and chloride concentration in the well as a function of time. As can be seen, there is a rise in the contaminants from 1977 to 1986 from 20 mg/L to 60 mg/L and then a drop in 1989 to 12 mg/L.

Figure 11 shows a plot of nitrate concentration in the four monitoring wells. As can be seen, the nitrate concentration is quite high in the wells from August 1986 to September 1987, with well no. 4 showing the highest concentration. Samples taken by Havens Laboratory in May 1989 showed very low levels of nitrate in the four wells. The results for inorganic contaminants in the four monitoring wells are summarized in Tables 29-32.

The four monitoring wells also show high levels of metolachlor, alchlor, dicamba, and atrazine (summarized in Tables 33-36).

D. INTERPRETATION AND MODELING

Examination of our second sampling results of the Purcell Spring indicates that much of the nitrate contamination is from the hog lot at the back of the Davis property. High levels of nitrate at the head of the spring do not infulence other results of the spring, because the spring only runs when it rains. There is a pond at the head location (station no. 1) that evaporates and concentrates what probably were low levels into many times higher levels.

Surface examination, which included soil gas analysis in search of the hypothesized "hot spot," did not indicate any significant contamination. Interpretation of the plotted nitrate concentrations in the monitoring wells may indicate a peak in the contamination in midyear 1987 and a drop-off since. For this to be a viable hypothesis, further sampling of the monitoring wells will be needed to establish the trend.

There is considerable uncertainty concerning the source of the nitrate (NO_3^-) and other contamination in the Davis well. The "hot spot" near the buildings (in the front of the Alliance property) was ruled out because no contamination was detected. However, in case the source of contamination was on the Alliance property, we have modeled the possible migration of contaminants to this well from any source on the Alliance property. Two computer models for solving solute transport problems were used to assess the potential for contamination of the Davis well due to activities at Alliance Fertilizer: CONMIG and MOC. CONMIG (Walton, 1989) is a simple analytical solution for the advection-dispersion equation for point-source pollution. The Method of Characteristics (MOC) code (Konikow and Bredehoeft, 1978) is a numerical model which couples the groundwater flow equation with the solute-transport equation. The models are independent of the actual chemical contaminant. We have used nitrate as a model compound.

Data requirements for the models include estimates of aquifer characteristics such as porosity, thickness, flow velocity, transmissivity, head values, longitudinal and transverse dispersivities, location of the contamination source, and injection rate and concentration of the contaminant of interest. Both models are also capable of modeling simplified chemical reactions by incorporating sorption and/or decay constants.

The Groundwater Management Plan prepared for Alliance Fertilizer provides estimates for aquifer thickness (100 feet), flow velocity (3.5 - 10ft/yr), and transmissivities (0.000521 - 0.0490 ft$_2$/s). There is some question as to the validity of the flow velocities quoted in the report. A conservatively large value (40 ft/yr) was used in the simulations. Transmissivities were determined by slug tests and showed considerable variability. A reasonably conservative value of 0.02 ft^2/s was used. A typical porosity for unconsolidated sand deposits was employed (0.3). In order to be conservative, large values for dispersivities, contaminant injection rate, and an initial nitrate concentration of 1000 mg/L were used at the source. Using these values, a steady-state nitrate concentration of approximately 11 mg/L is attained in the Davis well after about 14 years (Figure 12). Large nitrtate concentrations can be attained if smaller velocities are used. This allows greater spreading of the plume in a lateral direction because the containment is not allowed to migrate away from the source as rapidly. On the other hand, the amount of time for the plume to reach the Davis well greatly increases. For example, if a nitrate concentration of approximately 20 mg/L reached in the Davis well using a velocity of 1ft/yr is considered, a steady-state nitrate concentration in the Davis well greater than 100 mg/L is attained after 100 years. (At 50 years, the concentration is less than 10mg/L.)

The MOC code was used for simulations in which the Davis well was pumped at a rate of 1000 gallons/day with a constant concentration of nitrate at the source of 500 mg/L. Steady state was reached in less than 15 years with a nitrate concentration of approximately 46 mg/L in the Davis well (Figure 13).

Assumptions inherent in these simulations include: (1) the aquifer is homogeneous and isotropic (i.e., constant hydraulic conductivity); (2) the aquifer thickness is constant; (3) the contaminant is well-mixed throughout the aquifer; (4) the velocity is constant; and (5) contamination loading and concentration is constant.

With respect to nitrate concentrations in the Davis well, the most important variables in the models are transverse dispersivity, injection rate, and concentration of nitrate at the source, so extremely conservative values were selected. Dispersivities are poorly understood in a physical sense and are typically used as fitting parameters. A longitudinal dispersivity of 100 feet is near the uppermost limit typically used by hydrogeologists and the ratio of longitudinal to transverse dispersivity of five used in the simulations is smaller than values suggested by experts (Anderson, 1979). The result is that the dispersivity values used in these simulations represent a worst-case scenario with respect to spreading of the plume. For example, if a transverse dispersivity of 10 feet is used in the CONMIG simulation, the steady-state nitrate concentration in the Davis well is approximately halved. Other parameters may also be important. The role of pore velocity was discussed above. If aquifer thickness and/or porosity are significantly less than the values used, then nitrate concentrations could be significantly higher because the contaminant is diluted in a smaller volume of water.

It is apparent from the use of very conservative data and assumptions in the models that Alliance Fertilizer is probably not the source of nitrate contamination to the Davis well (and other contaminants as well). Additional evidence support this conclusion. The considerable variability in the measured nitrate values suggests that contamination is not primarily due to migration of groundwater from a source more than 400 feet away. This behavior is more likely due to surface water entering the well. If this hypothesis is correct, the contamination may be from the Davis form itself (note that a ditch separates the Alliance site from the Davis well) and would limit the possibility of surface water contamination from Alliance. In addition, nitrate is typically a reactive species in shallow aquifers, and a considerable amount would be expected to decay during groundwater migration.

E. CONCLUSIONS

1. Levels of ammonia, nitrate, and sulphates were high in the surface water samples taken at Purcell Spring, probably due to the run-off from nearby fields. Samples examined by Havens Laboratory for nitrate concentrations, do not indicate that run-off from this site is contributing to the spring contamination problem.

2. The soil sample analysis (both soil gas and solid) do not indicate any contamination.

3. A massive spill with concentrations of 1000 parts per million in the soil would be unlikely to be able to contaminate the Davis Well at the identified levels (It may be a contributing factor). Models of these types do not take into consideration specific molecular characteristics, like hydrophobicity, ionic strength, etc. They treat all contaminants as similar agents. There are differences between organics and inorganics migration/transportation mechanisms (the oil industry is spending fortunes evaluating these conditions) in terms of adsorption/asbsorption partition coefficients and many other liquid medium interactions.

4. It is unlikely that Davis well is contaminated from the

Figure 4: Location of Stream Sampling Stations
(1988; Keith Fowler, SWCB)
(see Table 18 for concentrations)

Figure 5: Location of Stream Sampling Stations
(1989, Havens Laboratory)
(see Table 19 for concentrations)

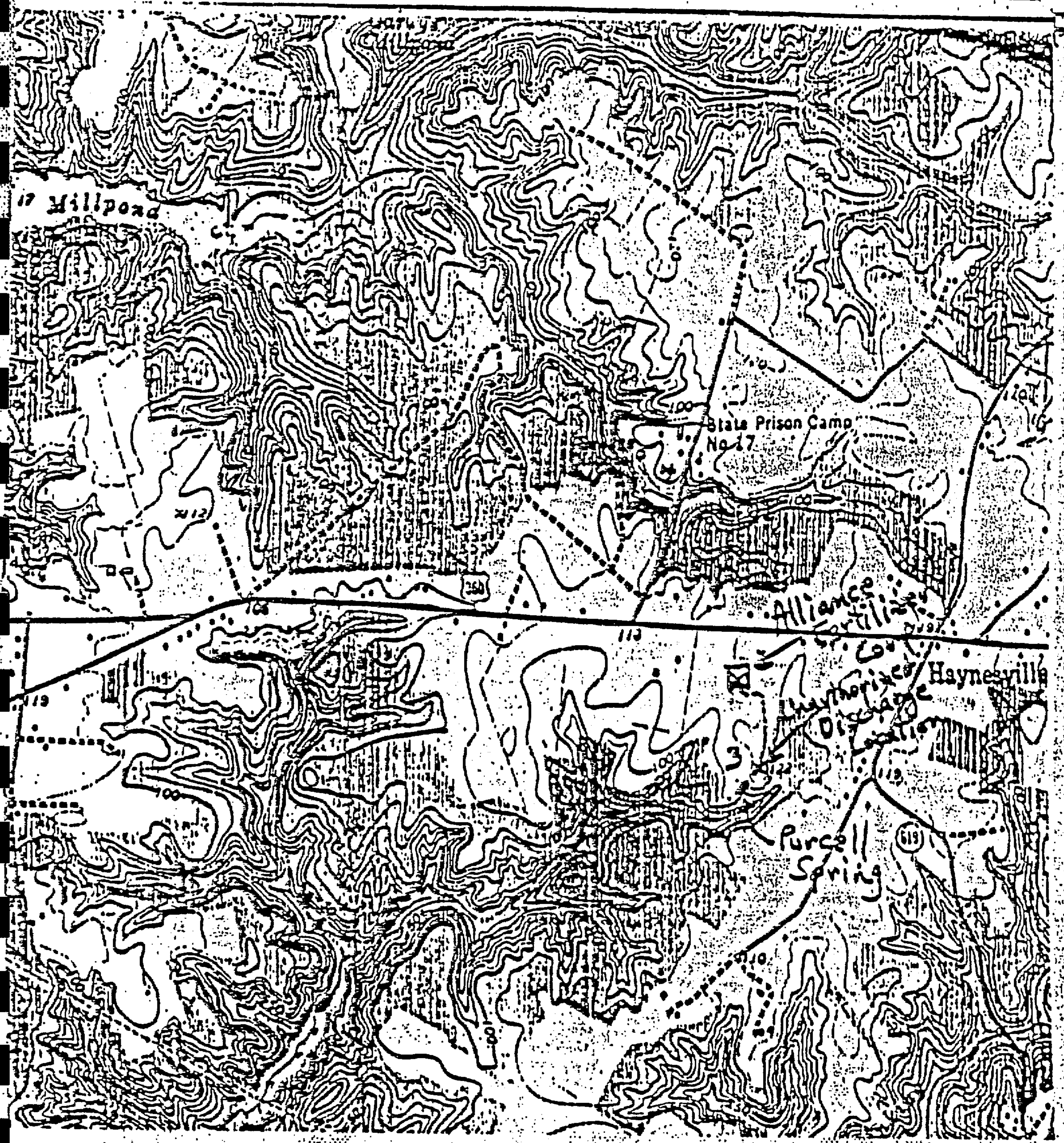


Figure 6: Location of Stream Sampling Stations
(1981, SWCB). (see Table 15 & 16)

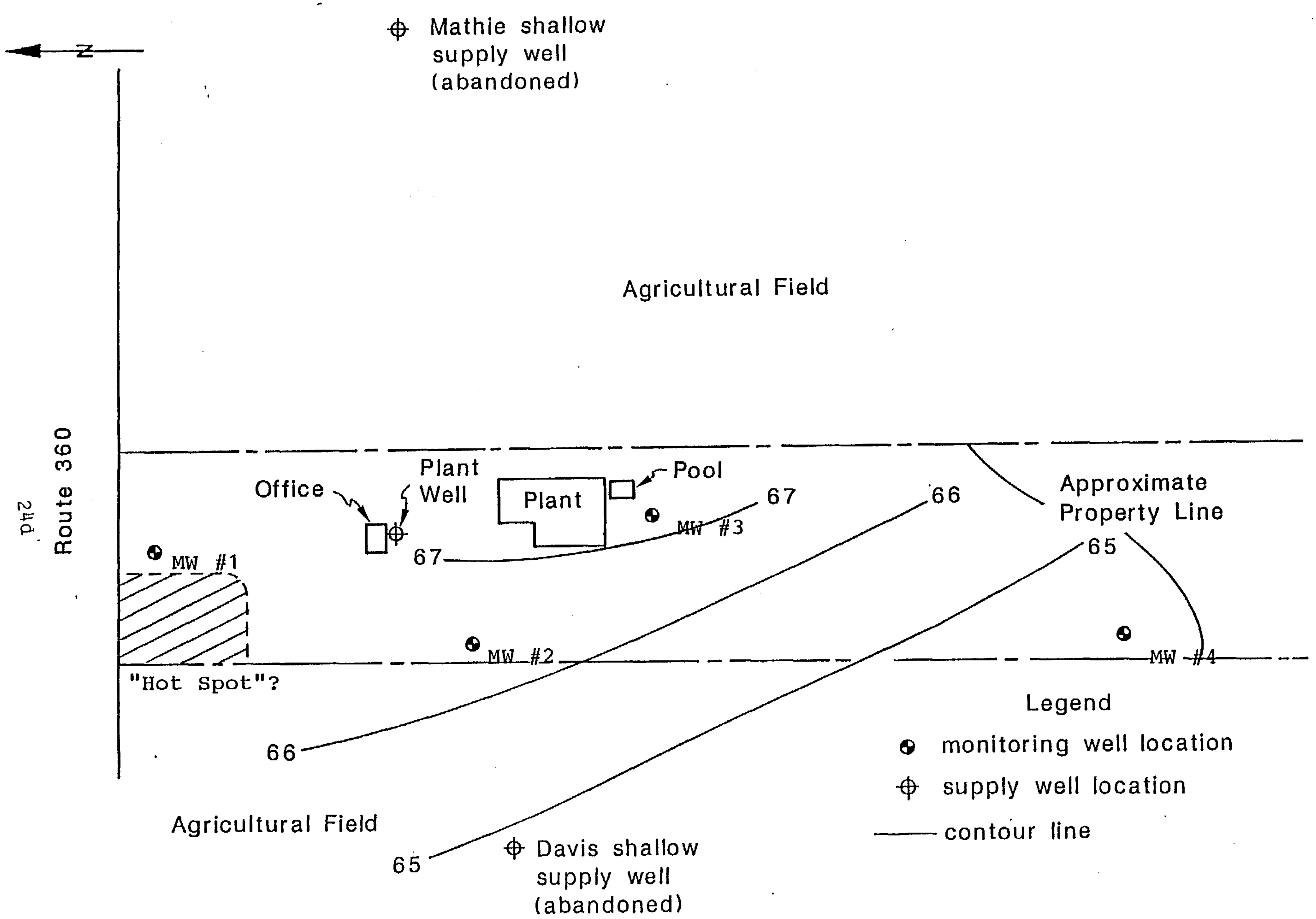


Figure 7: Alliance Fertilizer - Haynesville, Virginia

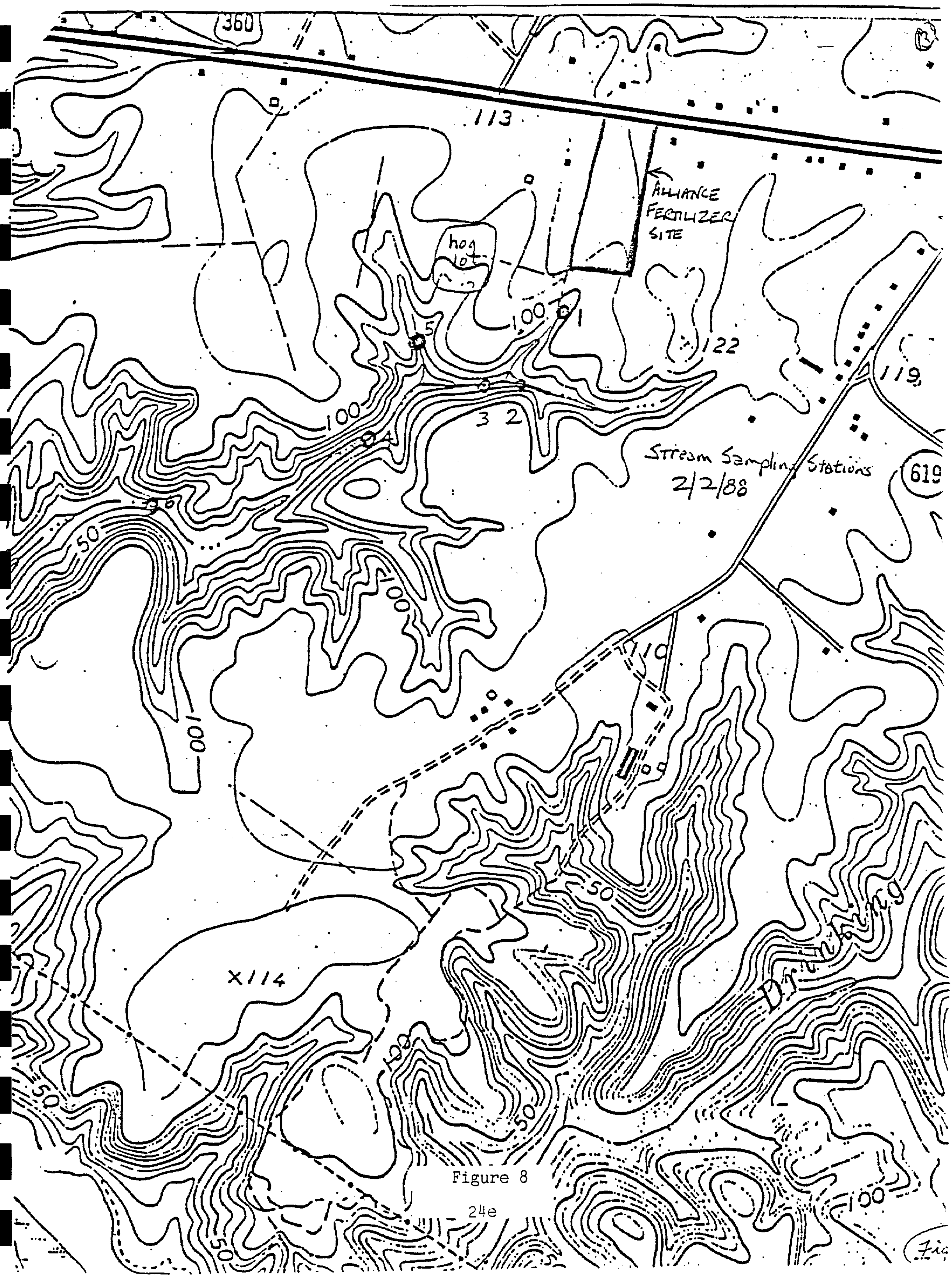

360
113
Alliance Fertilizer Site
hog lot
100
5
1
122
119
3
2
4
6
100
Stream Sampling Stations 2/2/88
619
50
100
100
110
50
X114
50
100
50
50
100
50
5

Figure 8

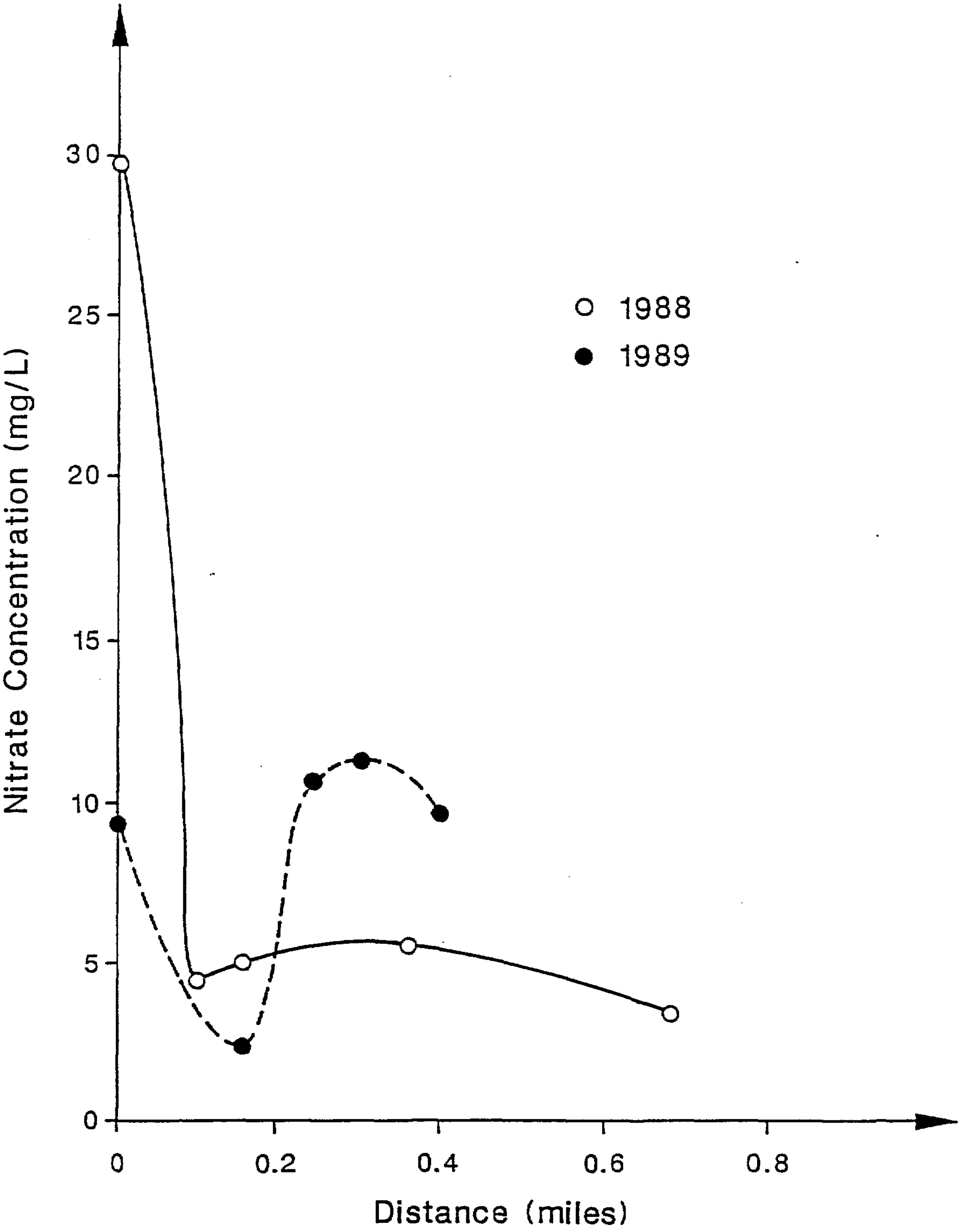


Figure 9: Nitrate in the stream near Alliance

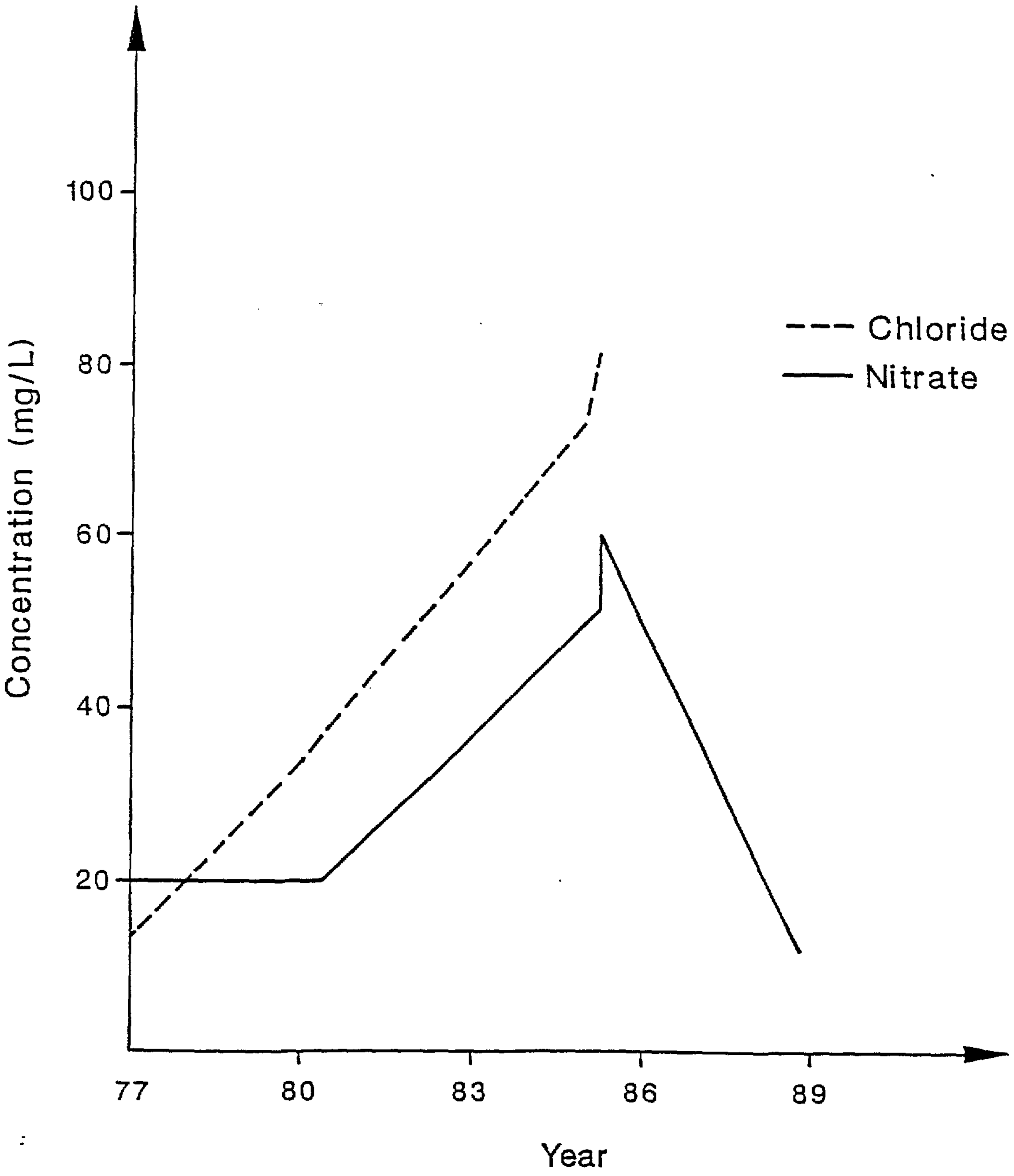


Figure 10: Concentration of chemicals in the Davis Well

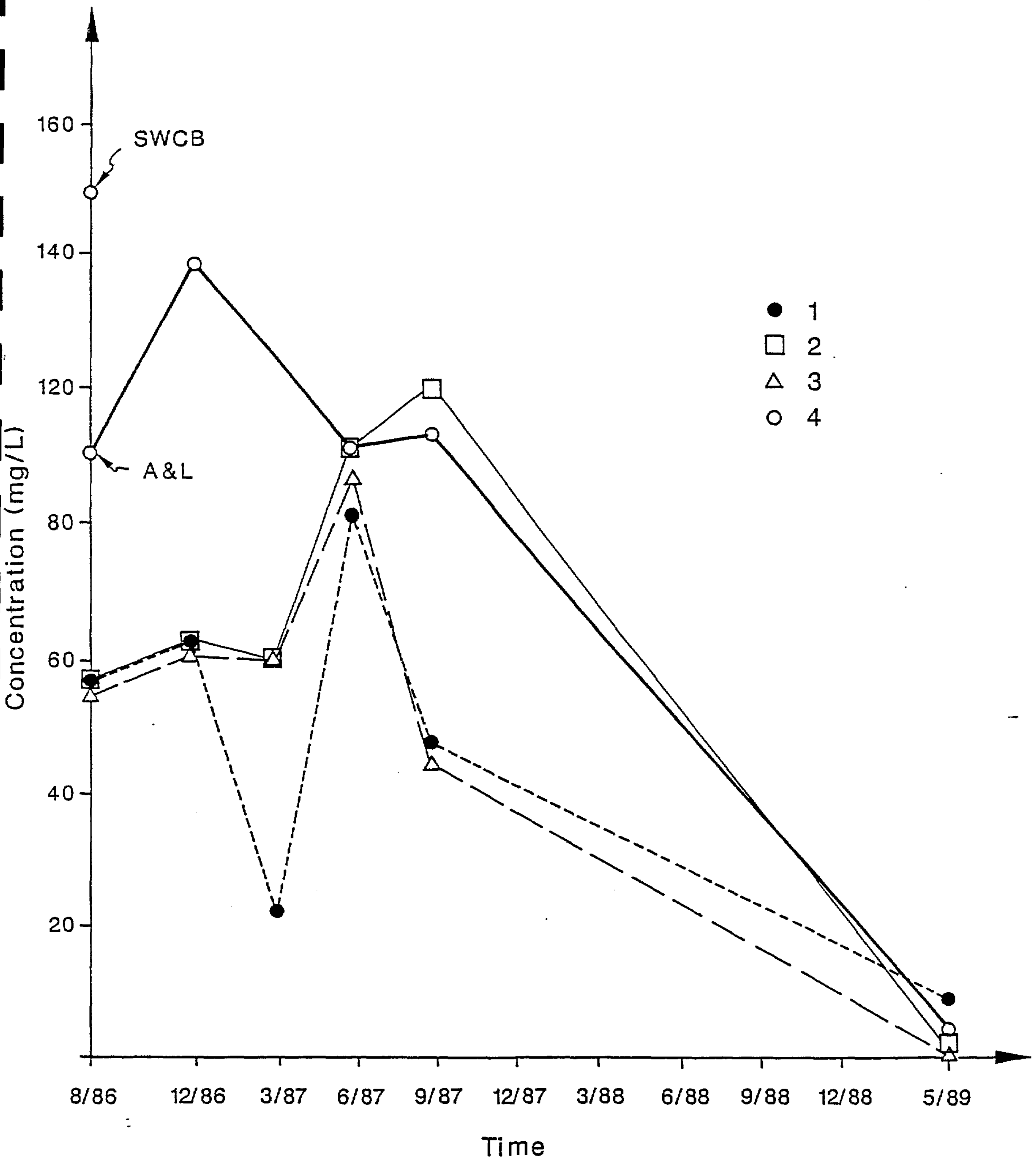


Figure 11: Concentration of nitrate in monotoring wells.

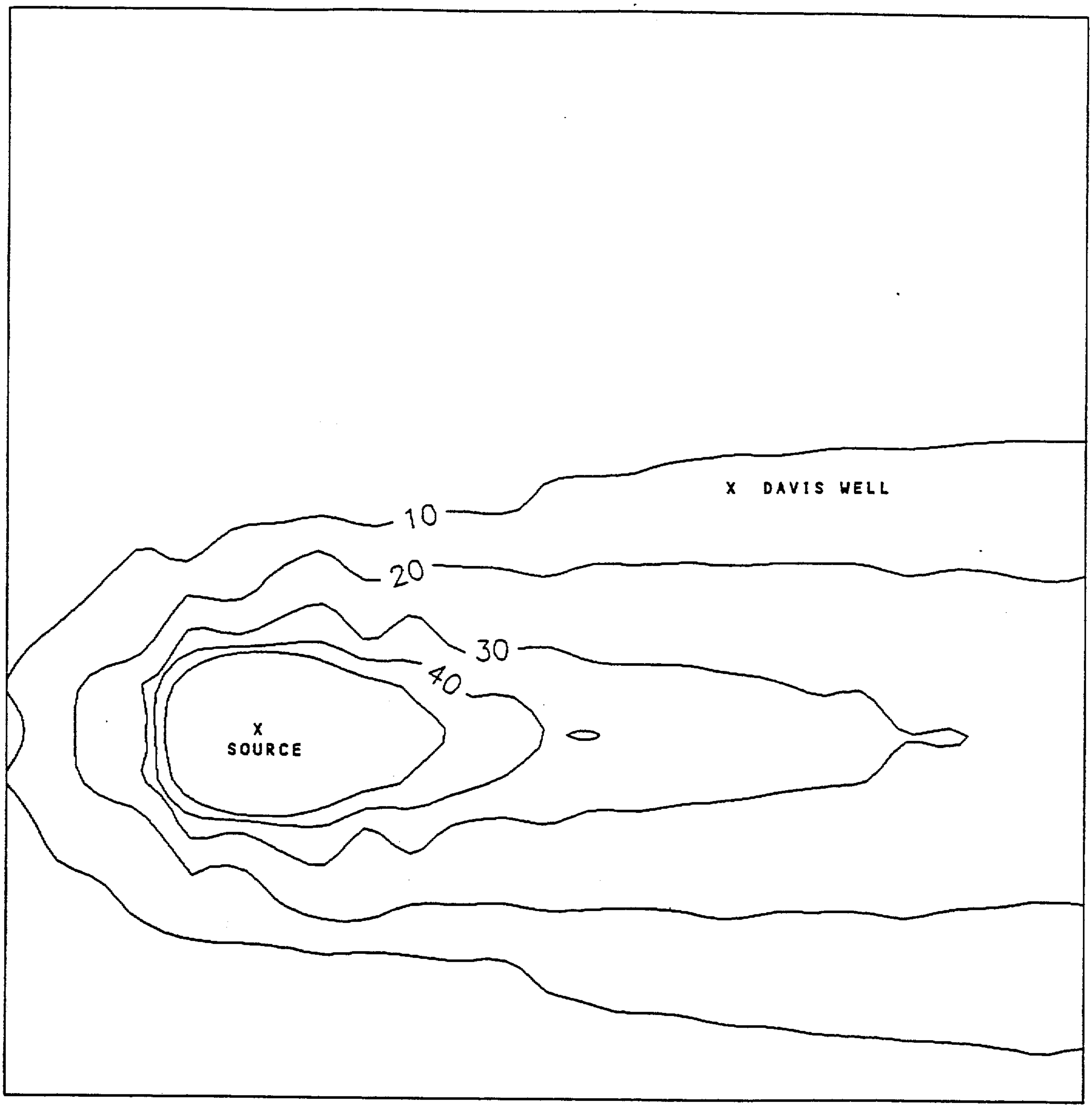


Figure 12: CONMIG results for NO_3 - migration from the Alliance site. Contours are in mg/L NO_3.

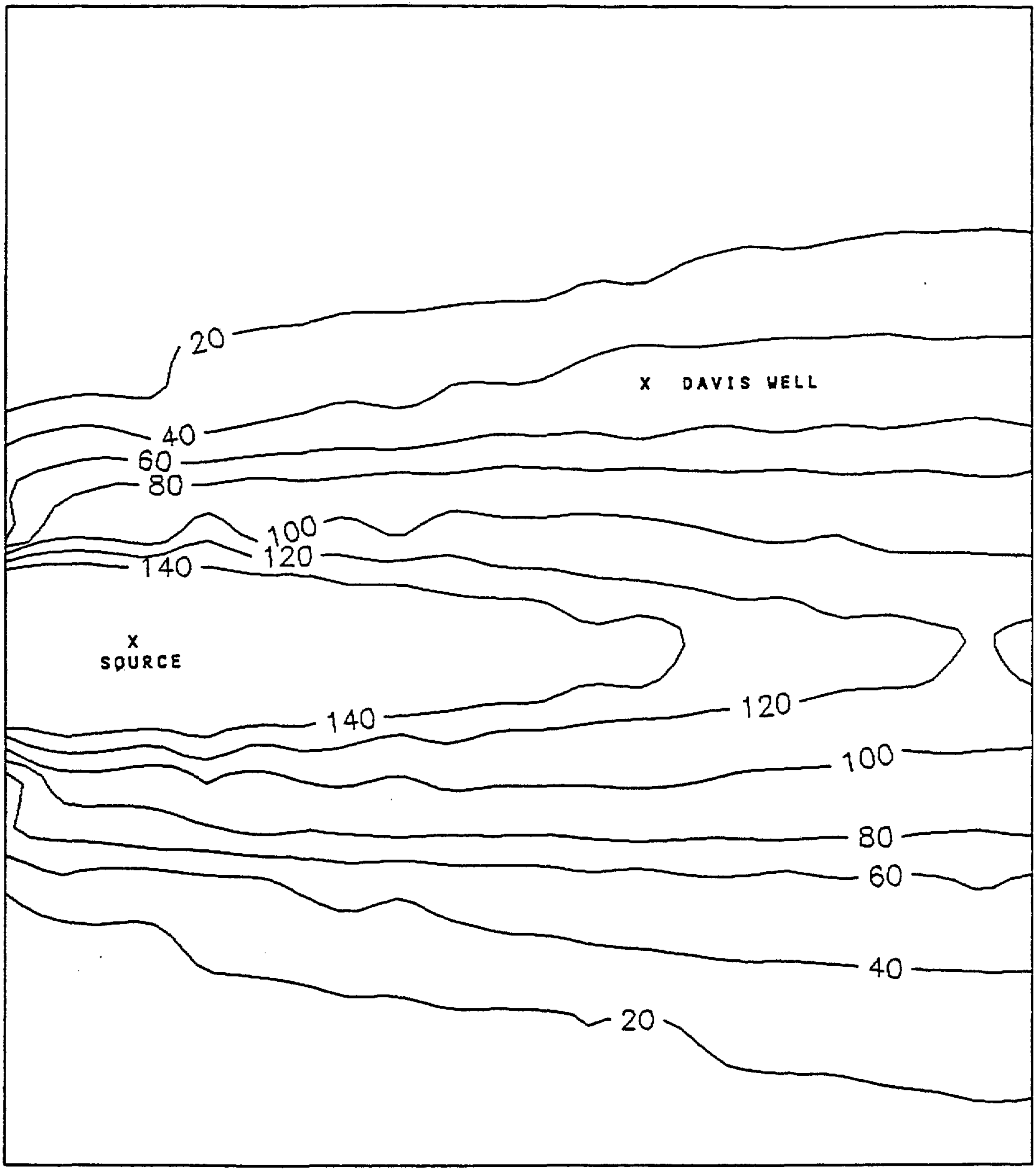


Figure 13: MOC results for NO_3 - migration from the Alliance site. Contours are in mg/L NO_3.

front part of the site. It is possible that it was contaminated in the past because of contamination in the Davis property.

F. RECOMMENDATIONS

1. The holding pond should not be discharged into the stream.

2. An ongoing monitoring program of the wells should be implemented.

Table 14: Soil Samples at Alliance (1-7 VSWCB, 2/2/88),
(8-10 HLI 5/89)
(ND** = not detected)

Chemical(ppm)	Station Number* 1	2	3	4	5	6	7	8	9	10
Atrazine	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Metolachlor	ND	ND	0.59	ND	ND	0.04	ND	ND	ND	ND
Alachlor	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dicamba	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Pesticides	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND

* STATIONS:

1: Agricultural field east of Alliance
2: Agricultural field west of Alliance
3: East of drainage ditch
4: Front lot of route 360
5: Near pond (?)
6: Dirt lot in back of Alliance
7: Former discharge location in back of Alliance
8: Drainage ditch in east of property
9: Drainage ditch in front of property
10: Hot spot source, left front of property

** Detection limits: Atrazine, Metolachlor, Alachlor,
Pesticides - 0.02 ppm
Dicamba - 0.01 ppm

Table 15: Holding Pond (4/7/86, VSWCB)
(Inorganics, mg/L)

Chemical	Concentration
pH	8.8
Conductance (umho/cm)	255
Diss. Solids	15,828
Chloride	4,000
TKN	4,000
Ammonia (as N)	2,900
Nitrate	786.5
Nitrite	1.0
Sulphate	144

Table 16: Holding Pond (4/7/86, VSWCB)
(Pesticide, ug/L)

Chemical	Surface	Mid
Atrazine	14,600	9,708
Lasso	3,900	2,934
Dual	14,700	11,400

Table 17: Purcell Spring (12/6/77 - 4/7/86, VSWCB)
(Inorganics, mg/L, NT = not tested)

Chemical	12/6/77	4/14/81	7/22/81	7/30/81	4/7/86
pH	5.7	4.9	4.9	5.6	4.8
Conductance	NT	NT	NT	NT	504
Total Solids	119	NT	NT	NT	NT
Volatile	62	NT	NT	NT	NT
Fixed	57	NT	NT	NT	NT
Susp. sol.	9	NT	NT	NT	NT
Diss. Sol.	NT	NT	NT	NT	219
Chloride	15	NT	NT	NT	4.0
TKN	<0.1	175.0	96-102.5	160.0	21.0
T. Phos.	<0.1	0.2	NT	0.1	NT
O. Phos.	<0.01	0.1	NT	0.04	NT
Ammonia (as N)	<0.1	160.0	96-102.5	137.5	19.0
Nitrate	2.3	200.0	105.0	175.0	27.45
Nitrite	0.01	0.37	0.33	0.44	0.05
Sulphate	28	NT	NT	NT	32.8

Table 18: Purcell Spring (4/14/81 - 7/30/81, VSWCB)
(Pesticides, ug/L)

Chemical	4/14/81	7/22/81	7/30/81
Alachlor	16	44	23
Metolachlor	49	166	87
Atrazine	54	121	15

Table 19: Purcell Spring (4/14/81 - 7/22/81, VSWCB)
(Metals, ug/L)

Metal	4/14/81	7/22/81
Arsenic	4	3
Cadmium	<10	<10
Chromium	<10	<10
Copper	<10	<10
Iron	NT	210
Lead	<2	2
Magnesium	NT	15,700
Manganese	NT	2,900
Mercury	<0.3	<0.3
Nickel	<100	10
Potassium	NT	14,600
Zinc	130	40

Table 20: Totuskey Creek Tributary Sampling (Inorganics, VSWCB, 7/30/81)
(Concentrations are in mg/L)

	Station Number*					
Chemical	1	2	3	4	5	6
pH	6.4	5.8	5.6	6.6	6.2	6.3
Alkalinity	7	4	19	19	7	10
TKN	0.9	0.5	160.0	31.0	1.0	0.9
T. Phos	0.1	0.1	0.1	0.3	0.1	0.2
O. Phos	0.08	0.05	0.04	0.29	0.04	0.18
Ammonia	0.6	<0.1	137.5	30.0	0.9	0.6
Nitrate	3.9	0.7	175.0	5.1	4.4	2.5
Nitrite	0.05	<0.1	0.44	0.39	0.05	0.02

* See Figure for location of the stations.

Table 21: Totuskey Creek Tributary Sampling (Organics, VSWCB, 7/30/81)
(Concentrations are in ug/L. ND = not detected, detection level is 0.1 ug/L. NT = not tested.)

	Station Number*					
Chemical	1	2	3	4	5	6
Alachlor	0.14	0.19	23.0	4.0	0.2	0.04
Metolachlor	1.0	0.08	87.0	40.0	1.6	ND

Trifluralin	NT	0.26	NT	NT	NT	NT
Atrazine	ND	ND	15.0	24.0	1.3	ND

* See Figure for location of the stations.

Table 22: Totuskey Creek Sampling (Inorganics, 2/2/88, VSWCB) (Concentrations are in mg/L. NT = not tested, ND = not detected.)

	Station Number*					
Chemical	1	2	3	4	5	6
pH	4.4	5.9	5.8	6.0	6.2	6.1
Alkalinity	NT	NT	NT	3.2	5.0	3.2
Acidity	46	5	7	5	3	2
Dissolved solids, total	217	67	70	73	50	40
TKN	14.0	0.4	0.4	0.3	0.5	4.5
Total Phosphorous	0.2	0.1-	0.1-	0.1-	0.1-	0.1-
Ortho Phosphorous	0.01-	0.01-	0.01-	0.01	0.03	0.01
Ammonia	4.0	0.04-	0.07	0.05	0.04	0.05
Nitrate	29.9	4.5	5.5	5.5	4.0	3.5
Nitrite	0.08	0.01-	0.01-	0.01-	0.01-	0.01-
Conductivity (umho/cm)	469	154	116	145	88.6	107

* See Figure for the location of stations.

Table 23: Totuskey Creek Sampling (Organics, 2/2/88, VSWCB) (Concentrations are in ug/L. NT = not tested, ND = not detected.)

	Station Numbers*					
Chemical	1	2	3	4	5	6
2,4-D	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3
Linucon	<1.0	<1.0	<1.0	<1.0	<0.1	<1.0
Alachlor	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Metolachlor	5.2	<0.1	<0.1	<0.1	<0.1	<0.1
Atrazine	1.0	<0.2	<0.2	<0.2	<0.2	<0.2
Picamba	<6.0(?)	<0.1	<0.1	<0.1	<0.1	<0.1

* See Figure for location of stations.

Table 24: Totuskey Creek Tributary Sampling for Nitrate (Havens Lab., 6/21/89)

Station*	Concentraion (mg/L)
1. Top of Purcell Spring	9.20
2. Branch # 3	3.30
3. Branch # 2	2.28
4. Foamy spot 100 ft past 5	11.2
5. Connect for 6	10.8
6. Run-off ditch behind hog lot	14.0
7. Old Stream	9.92
8. run-off ditch into Purcell spr.	0.51
9. Back Center, Alliance Property	0.51
10. Behind dike, Alliance Property	2.26

* See Figure for the location of stations

Table 25: Davis Well Inorganic Sampling (12/6/77 - 3/13/86)
(Units are mg/L unless otherwise stated. NT=not tested.)

Chemical	12/6/77 VSWCB	4/14/81 VSWCB	3/13/86 RCHD
Nitrate	20.0	20.0	51.0
Chloride	14	36	75.1
Sulphate	15	18	33.2
Total Solids	231	272	550
Volatile	147	165	288
Fixed	84	107	262
TKN	<0.1	0.2	0.9
T.Phos	<0.1	<0.1	<0.01
O.Phos	<0.01	0.01	<0.05
Ammonia (as N)	<0.1	<0.1	0.7
Nitrite	<0.01	<0.01	0.05
BOD	1	NT	NT
TOC	2	4	NT
Fluoride	NT	<0.1	<0.1
Halo. Hydrocarbon (ug/L)	NT	<0.1	<1.0
Arom. Hydrocarbon (ug/L)	NT	NT	<1.0
PH	5.8	5.7	6.7
Alkalinity	NT	NT	NT
Conductance (umho/cm)	NT	NT	728.2

Table 26: Davis Well Inorganic Sampling (3/31/86 - 5/24/89)
(Units are mg/L unless otherwise stated. NT=not tested.)

Chemical	3/31/86 RCHD	4/23/86 RCHD	2/2/88 VSWCB	5/24/89 Hav. Lab
Nitrate	52.5	60.0	32.5	12.1
Chloride	NT	81.4	NT	NT
Sulphate	NT	NT	NT	NT
Total Solids	NT	541	351	678
Volatile	NT	274	NT	NT
Fixed	NT	267	NT	NT
TKN	NT	INT	<0.1	NT
T.Phos	NT	0.1	<0.1	0.074
O.Phos	NT	0.01	0.01	NT
Ammonia (as N)	NT	1.2	<0.04	NT
Nitrite	NT	0.04	0.01	NT
BOD	NT	NT	NT	NT
TOC	NT	NT	NT	NT
Fluoride	NT	<0.1	NT	NT
PH	NT	6.35	6.5	6.5
Conductance (umho/cm)	NT	NT	31	640

Table 27: Davis Well Pesticide Sampling (4/14/81 - 6/18/89)
(Concentration in ug/L. NT=not tested.)

Pesticide	4/14/81 VSWCB	3/13/86 RCHD	4/23/86 RCHD	6/18/89 Hav. L
Metolachlor	<0.1	58	98	<0.1
Alachlor	<0.1	3.8	7.4	<0.1
Dicamba	<0.1	6.1	13	<0.1
Atrazine	<0.1	28	38	<0.1
Endrin	NT	<0.04	<0.04	<0.08
Lindane	NT	<0.1	<0.1	<0.1
Methoxychlor	NT	<0.2	<0.2	<0.2
Toxaphene	NT	<0.5	<0.5	<0.5
2,4-D	NT	<0.1	<1.0	<1.0
2,4,5-TP	NT	<0.1	<1.0	<1.0
Paraquat	NT	NT	<5.0	NT
Oryzalin	NT	NT	<1.0	NT
Carbofuran	NT	NT	<2.0	NT
Disulfoton	NT	NT	<0.5	NT

Table 28: **Davis Well Metals Sampling** (RCHD, 3/13/86)

Metal	Concentration (mg/L)
Arsenic	0.001
Barium	0.31
Cadmium	0.003
Chromium	0.0017
Lead	0.003
Mercury	<0.0003
Selenium	<0.001
Aluminium	0.07
Calcium	48.0
Iron	0.32
Magnesium	34.4
Manganese	0.37
Strontium	0.42
Zinc	0.05
Copper	0.11
Potassium	14.5
Sodium	<35.2
Nickel	<0.01
Boron	0.01
Calcium Hardness	119.9
Magnesium hardness	141.5
Ca/Mg hardness	261.0
Total hardness	264.0
Antimony	<0.0005

Table 29: Monitoring Well No. 1 Sampling Results (Inorganics)
(Concentrations are in mg/L. NT = not tested.)

Chemical	8/86 SWCB	8/86 A&L	12/86 A&L	3/87 A&L	6/87 A&L	9/87 A&L	5/89 Hav. L
Nitrate	57.48	50	63	22	81	48	9.0
Ammonia	0.2	3	NT	NT	NT	NT	NT
TKN	3.9	NT	NT	NT	NT	NT	NT
T. Phos	4.0	NT	NT	NT	NT	NT	0.004
O. Phos	0.03	0.46	NT	NT	NT	NT	NT
Diss. Sol.	603	420	470	225	300	380	290
Nitrite	0.02	NT	NT	NT	NT	NT	NT
pH	4.9	NT	4.3	4.9	4.1	4.5	6.7
Conduct. (umho/cm)	574	NT	NT	NT	NT	NT	420
Alkalinity	0.3	NT	NT	NT	NT	NT	NT
Acidity	20	NT	NT	NT	NT	NT	NT

Table 30: **Monitoring Well No. 2 Sampling Results** (Inorganics)
(Concentrations are in mg/L, NT = not tested.)

Chemical	8/86 SWCB	8/86 A&L	12/86 A&L	3/87 A&L	6/87 A&L	9/87 A&L	5/89 Hav. L
Nitrate	57.42	49	63	60	91	99	1.78
Ammonia	5.0	7	NT	NT	NT	NT	NT
TKN	5.0	NT	NT	NT	NT	NT	NT
T. Phos	8.0	NT	NT	NT	NT	NT	0.218
O. Phos	0.02	0.30	NT	NT	NT	NT	NT
Diss. Sol.	590	450	470	700	416	760	999
Nitrite	0.08	NT	NT	NT	NT	NT	NT
pH	4.4	NT	4.3	4.9	4.1	4.5	6.7
Conduct. (umho/cm)	652	NT	NT	NT	NT	NT	420
Acidity	110	NT	NT	NT	NT	NT	NT

Table 31: **Monitoring Well No. 3 Sampling Results** (Inorganics)
(Concentrations are in mg/L. NT = not tested. NC = not clear.)

Chemical	8/86 SWCB	8/86 A&L	12/86 A&L	3/87 A&L	6/87 A&L	9/87 A&L	5/89 Hav. L
Nitrate	53.73	48	61	61	86	45	0.26
Ammonia	35.0	88	NT	NT	NT	NT	NT
TKN	35.0	NT	NT	NT	NT	NT	NT
T. Phos	10.0	NT	NT	NT	NT	NT	0.120
O. Phos	0.05	0.20	NT	NT	NT	NT	NT
Diss. Sol.	651	760	770	1540	770	670	1880
Nitrite	0.02	NT	NT	NT	NT	NT	NT
pH	4.5	NT	5.8	4.0	4.1	4.3	6.0
Conduct. (umho/cm)	NC	NT	NT	NT	NT	NT	1900
Acidity	31	NT	NT	NT	NT	NT	NT

Table 32: Monitoring Well No. 4 Sampling Results (Inorganics)
(Concentrations are in mg/L. NT = not tested. NC = not clear.)

Chemical	8/86 SWCB	8/86 A&L	12/86 A&L	3/87 A&L	6/87 A&L	9/87 A&L	5/89 Hav. L
Nitrate	149.9	110	138	30(NC)	109	93	4.6
Ammonia	77.5	112	NT	NT	NT	NT	NT
TKN	85.0	NT	NT	NT	NT	NT	NT
T. Phos	28.0	NT	NT	NT	NT	NT	0.115
O. Phos	0.01	1.12	NT	NT	NT	NT	NT
Diss. Sol.	1202	1050	1400	680(NC)	830	1150	383
Nitrite	0.10	NT	NT	NT	NT	NT	NT
pH	4.6	NT	4.9	4.0	4.5	4.5	6.3
Conduct. (umho/cm)	1852	NT	NT	NT	NT	NT	420
Acidity	119	NT	NT	NT	NT	NT	NT

Table 33: Monitoring Well No. 1 Sampling Results (Organics)
(Concentrations are in ug/L. NT = not tested.)

Chemical	8/86 VSWCB	8/86 A&L	12/86 A&L	3/87 A&L	6/87 A&L	9/87 A&L	2/88 VSWCB	6/89 Hav. L
Metolachlor	125	104	61	22.4	30	86.3	90	16
Alachlor	1.7	1	NT	NT	NT	NT	1.7	2
Dicamba	8.6	4	NT	NT	NT	NT	62	<0.1
Atrazine	45	58	NT	NT	NT	NT	50	<0.1
2,4-D	NT	NT	NT	NT	NT	NT	0.5	<1.0
Linucon	NT	NT	NT	NT	NT	NT	21	NT

Table 34: Monitoring Well No. 2 Sampling Results (Organics)
(Concentrations are in ug/L. NT = not tested.)

Chemical	8/86 VSWCB	8/86 A&L	12/86 A&L	3/87 A&L	6/87 A&L	9/87 A&L	2/88 VSWCB	6/89 Hav. L
Metolachlor	8.9	3	5	3.3	5	9.3	7.1	<0.1
Alachlor	<0.1	<1	NT	NT	NT	NT	<0.1	<0.1
Dicamba	<0.05	<1	NT	NT	NT	NT	NT	<0.1
Atrazine	<1	1	1	1.4	3	3.9	1.8	<0.1
2,4-D	NT	NT	NT	NT	NT	NT	<0.3	<1.0
Linucon	NT	NT	NT	NT	NT	NT	<1.0	NT

Table 35: Monitoring Well No. 3 Sampling Results (Organics)
(Concentrations are in ug/L. NT = not tested.)

Chemical	8/86 VSWCB	8/86 A&L	12/86 A&L	3/87 A&L	6/87 A&L	9/87 A&L	2/88 VSWCB	6/89 Hav. L
Metolachlor	88	141	40	86.5	131	104.5	38	16
Alachlor	2.1	2	NT	NT	NT	NT	2.6	1
Dicamba	0.4	1	NT	NT	NT	NT	<0.1	<0.1
Atrazine	42	44	41	49.1	33	41.9	27	<0.1
2,4-D	NT	NT	NT	NT	NT	NT	<0.3	<1.0
Linucon	NT	NT	NT	NT	NT	NT	18	NT

Table 36: Monitoring Well No. 4 Sampling Results (Organics)
(Concentrations are in ug/L. NT = not tested.)

Chemical	8/86 VSWCB	8/86 A&L	12/86 A&L	3/87 A&L	6/87 A&L	9/87 A&L	2/88 VSWCB	6/89 Hav. L
Metolachlor	150	128	36	54.5	33	50.8	21	26
Alachlor	11.6	6	NT	NT	NT	NT	5.3	4
Dicamba	NC	2	NT	NT	NT	NT	<0.1	<0.1
Atrazine	60	60	37	21.3	18	28.2	18	<0.1
2,4-D	NT	NT	NT	NT	NT	NT	<0.3	<1.0
Linucon	NT	NT	NT	NT	NT	NT	5.7	NT

IV. EVALUATION OF REPUBLIC CREOSOTING (McLEAN CONSTRUCTION)

A. SUMMARY OF PERCEIVED PROBLEMS

The Department of Waste Management summarized the problems as follows:

The site, operated by Republic Creosoting Company from 1917-1972, is located in Chesapeake, Virginia, on the south branch of the Elizabeth River. During that time the property was owned by Reilly Tar and Chemical Corp. It is presently owned by McLean Contracting Company which uses it as a supply yard for their marine construction operations. The main activity at the site by Republic was creosote and tar treatment of wood. This also involved refining coal, tar, and creosote. Two open deteriorating tanks, which contain a sludge of nearly 100% polynuclear aromatic hydrocarbons (PNAs), remain on site. There is also a four-acre area of mulch which came from treated lumber shavings. The soils of this area are contaminated with PNAs up to 34%. Aqueous samples from a drainage ditch running through the mulch area contained significant amounts of lead, cadmium, cyanide, and mercury. Lead was also found in high concentrations in the soil near one of the sludge tanks.

The high levels of PNAs are a hazard if contacted. They are severe dermal irritants and can cause skin tumors. They are readily absorbed through the skin, where they exert toxic and/or carcinogenic effects. PNAs bind tightly to soil but they may be carried with it into the surrounding waters. In most organisms they are metabolized quickly, preventing bioaccumulation, but shellfish are an exception. Lead, cadmium, cyanide, and mercury are toxic to aquatic organisms at low concentrations. Samples were also taken from the drainage ditch, which empties into a marshy area adjacent to the Elizabeth River.

B. SUMMARY OF FIELD SURVEY AND SAMPLING PLAN

This site is expansive, the previous history is vague, and the new property owners may be daily contributing to the contamination problem. The original PAH problem is buried with 0 to 2 feet of sediment (potentially contaminated) dredged from the Elizabeth River, which makes source quantification much more difficult. We have defined five problem areas, based on our evaluation of existing data and our site visit. They are:

1. Quantitative assessment of the PAH source areas: Both the area where the creosote holding tanks were and the woodchip-mulched areas needed to be investigated as potential sources. Extensive soil gas analysis was planned to be used to outline contaminated areas, but high groundwater levels precluded our doing so. Coring was used to define depth and contamination levels. Targetted PAH analysis was done using FID/GC.

   Attempts were made to core out samples for PAH analysis. The mulch is covered with dredgings from the Elizabeth river, neither of these materials provides any support for coring. The samples were taken with the assistance of a backhoe. The water level was so high that sub-mulch samples were not practical to take, in place of them we took water samples from the holes dug by the backhoe. These samples were filtered and extracted and analyzed for PAH levels.

2. Groundwater: Little was known about the groundwater at this site, so modeling will not be reliable. PAH's are relatively insoluble and would not be readily transported but could migrate if high enough concentrations were present. There is also the question of other yet unidentified contaminants. Priority pollutant screens were therefore used to test several areas. The Elizabeth River borders one side of the property. Four wells, spaced evenly across the site, would give us insight into the groundwater contamination status. Because the aquifer is undefined here two additional wells off-site (opposite from the Elizabeth River) could help us establish base quantities and head values.

   Note: We requested drilling quotes from several firms for a class C well, 2" ID, PVC-cased. Verbal quotes were given to us: 60' to 80' wells would cost approximately $2,200 each, assuming no greater depth was necessary and no hard rock encountered. The costs could be less if the aquifer is encountered at shallower depths. We did not drill these wells in the present study as we did not have sufficient funds to complete the wells and the analysis program. As noted later, we think that this must be done to characterize the site.

3. Surface waters, drainage ditches, and the Elizabeth River: Sampling of the Elizabeth River upstream and downstream from the Republic site was conducted. In addition, run-off in the drainage ditches (both sides of the property) was sampled and analyzed. These samples were target-analyzed for PAH's, to determine the extent of PAH contamination, and screened for priority pollutants to see if there was anything else present (keeping in mind that PAH's are not readily soluble in

water).

4. Biological contamination from PAH's: PAH's readily accumulate in adipose tissues of animals and in plants. A measure of the extent of the contamination is to determine how much the PAH's have accumulated in local aquatic species, land animals, and plants. Collection of these biological specimens, to test whole body digestion and subsequent PAH analysis, should be very useful in this evaluation. Both grass and crab/fish samples were taken. Neither sets showed any evidence of PAH contamination.

5. McLean Construction as a source of contamination to the site: During our site visit, we observed that there were numerous empty 55-gallon drums on site, containing what appeared to be asbestos-containing materials and tons of dredged up sediment. We believe that these all need to be evaluated. The question we addressed is whether McLean Construction is adding to the problem? If so, what and how much?

C. ANALYTICAL RESULTS

Sampling locations are shown in Figure 14. Soil gas analysis (all of which were negative) were carried out at locations indicated by dot(˙). The water level being so high < 24" in some places did not allow us to successfully use soil gas analysis as a means of localizing the PAH contamination. No meaningful results were obtained.

Total metals analysis and EPTPOX metals analysis performed by Havens Laboratory shows very little contamination for many samples (see Tables 37-38 for results of the metals determinations and Table 39 reports on the PAH analysis). As a matter of fact, most metals are below the detection limits. However, in the areas where the mulch is buried, the contamination is very large.

Bulk asbestos analysis (Table 40 for results; Figure 14 for locations) was negative. Other fibers such as cellulose, fibrous glass, synthetics, and hair were detected.

D. INTERPRETATION AND MODELING

The mulch area is very contaminated with PAH's. At this time, no analytical data collected showed evidence that the PAH contamination has spread from the mulch area or is spreading. The toxicity of PAH's is well documented. The Elizabeth River has several sources of PAH contamination (one

REPUBLIC CREOSOTING (McLEAN CONSTRUCTION) SITE MAP

•: SOIL GAS ANALYSIS LOCATIONS ⊗ 4150

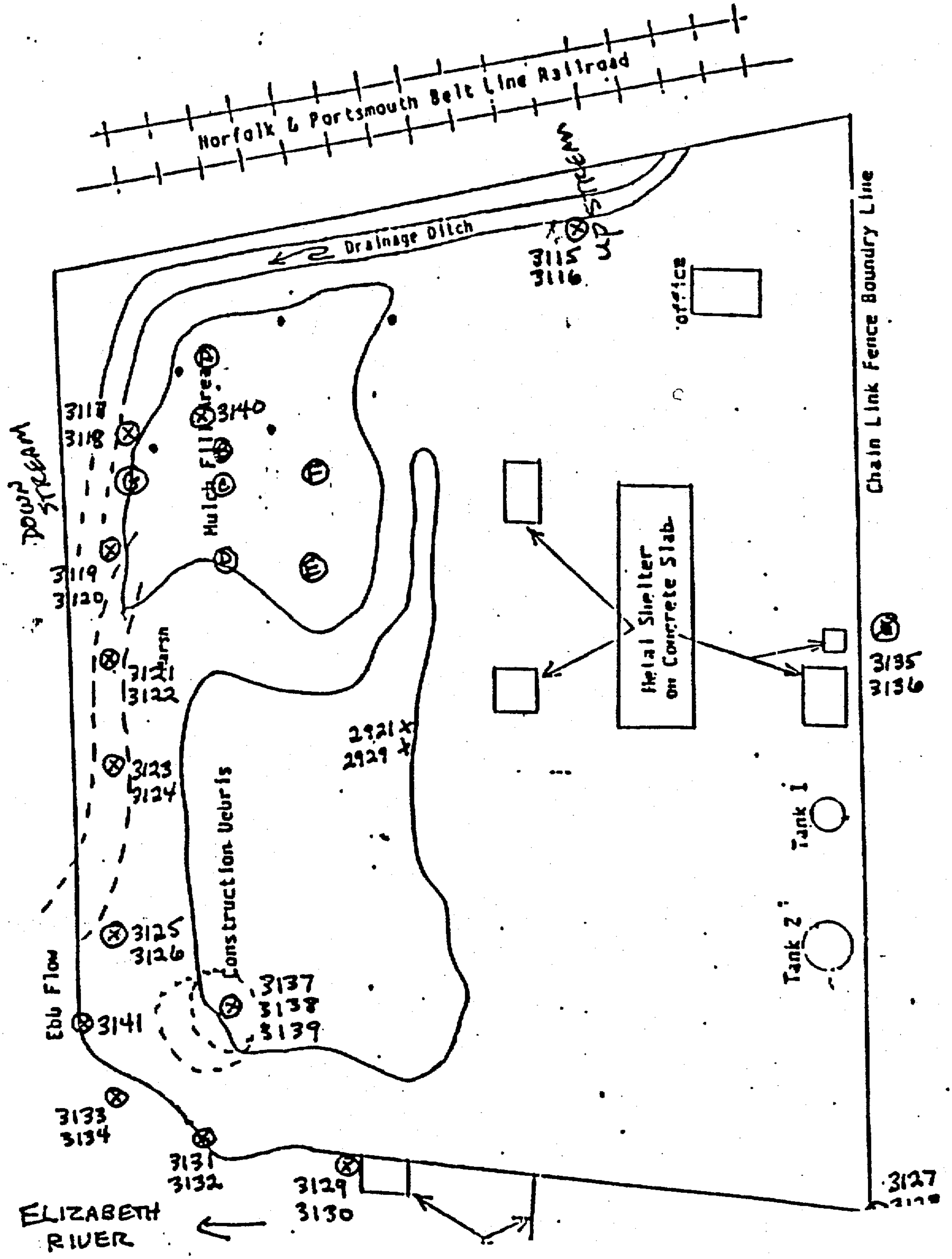


Table 37: Total Metal Analysis (Havens Laboratory, 8/11/89). Concentrations are in parts per million (mg/L). Locations of stations are shown in Figure 1.

Sample	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
3115	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
3117	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
3119	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
3121	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
3123	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
3125	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
3127	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
3129	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
3131	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
3133	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
3135	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0170	0.010	<0.001
4135	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	0.010	<0.001
4143	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	0.008	<0.001
4150	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001

Table 38: EP TOX Metals Analysis (Havens Laboratory, 8/11/89). Samples analyzed by EPA method 3010, EP Toxicity. Concentrations are in parts per million. Locations of stations are as shown in Figure 1.

Sample	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
4131	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	0.032	<0.001
4133	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
4137	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	0.010	<0.001
4139	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	0.026	<0.001
4141	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	0.007	<0.001
4145	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
4147	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	0.016	<0.001
4149	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	0.007	<0.001

Table 39: PAH Analytical Results (Havens Laboratory, 8/11/89).

HLI # (fld#)	Acenaphthene	Fluoranthene	Naphthalene	Pyrene	Benzo(a) Pyrene	Chrysene	Anthracene
74466 3116	-	-	-	-	-	-	-
74468 3118	-	-	-	-	-	-	-
74470 3120	-	-	-	-	-	-	-
74472 3122	-	-	-	-	-	-	-
74474 3124	-	-	-	-	-	-	-
74476 3126	-	-	-	-	-	-	-
74478 3128	-	-	-	-	-	-	-
74480 3130	-	-	-	-	-	-	-
74482 3132	-	-	-	-	-	-	-
74484 3134	-	-	-	-	-	-	-
74486 3136	-	-	-	-	-	-	-
74487-489 3137-39	-	-	-	-	-	-	-
74490 3140	-	-	-	-	-	-	-
74491 3141	-	-	-	-	-	-	-
74492 4130	-	-	-	-	-	-	600
74494 4132	9800	17500	500	11000	-	4200	160000
74496 4134	120	160	-	-	-	-	300
74498 4136	-	-	-	-	-	-	50
74500 4138	11200	32000	1200	16000	1500	4000	200500
74502 4140	7400	31000	-	15000	-	5800	185000
74504 4142	235	-	-	-	-	-	950
74506 4144	8900	25000	-	11000	-	-	110000
74508 4146	8700	10000	-	11000	-	-	95000
74510 4148	9600	10000	-	11000	-	-	85000

all results are in ppm
analysis by FID/GC

Table 40: Bulk Asbestos Analysis (Havens Laboratory, 8/11/89). Detection limits = 1%. ND = None detected; ACM = Asbestos Containing Material. Sample Locations are as in Figure 1.

Sample	% ACM & Type	% Other Fibers	% Other
2929	ND	5 cellulose 2 fibrous glass 15 synthetics 2 hair	76
2921	ND	2 cellulose 20 synthetics	78

V. FRAMEWORK FOR DECISION SUPPORT SYSTEM

This framework was designed to assist the Department of Waste Management (DWM) in performing evaluations of sites suspected of potential risks. The framework does not make decisions but is only a decision support approach. It will format data and provide simple or elaborate mechanisms of exposure evaluation, in an effort to allow the knowledgeable evaluator access to pertinent data (or to let him/her know that pertinent data is missing). This effort is not meant to replace CERCLA site evaluation protocols, but to parallel them. The Framework is as follows:

Phase 1 (Supported by the computer software ERIES):

1. COMPILATION OF DATA - Data can be acquired in many forms and types, at different times and locations, and from many sources. Data collected under different conditions using different procedures must be compared. Subjective and objective information is available. which makes examining the data difficult at best. This first part of the framework is basically an interactive program designed to format the data in a simple, uniform manner so that it can be more easily examined. It also will assist in insuring that all the available data is collected by helping define the pertinent data needed. The format should allow clerical staff to enter data.

   The data is compiled into two general groups: analytical data and site characteristics data. Either analytical data is target-selected or it can be collected generally, utilizing large unknown parameters (like priority pollutant analysis rather than selected chlorinated hydrocarbons). Site characterization data is necessary for exposure evaluation.

2. REVIEWING AND COMPARING DATA - This multicomponent section starts by defining a specific format for looking at data. Quantitative data can be displayed as a two-dimensional plot of multi-dimensional data and viewed as follows, for example:

```
-------------------------------------------------------------
 ANALYTE: Arochlor 1254   SAMPLE TYPE: Surface Water
              Plot of concentrations in ppm

            2  0.026    nd      0.005
    Times
            1  0.045    nd      0.018
             ---------------------------
                 1      2      3
                    Locations
-------------------------------------------------------------
```

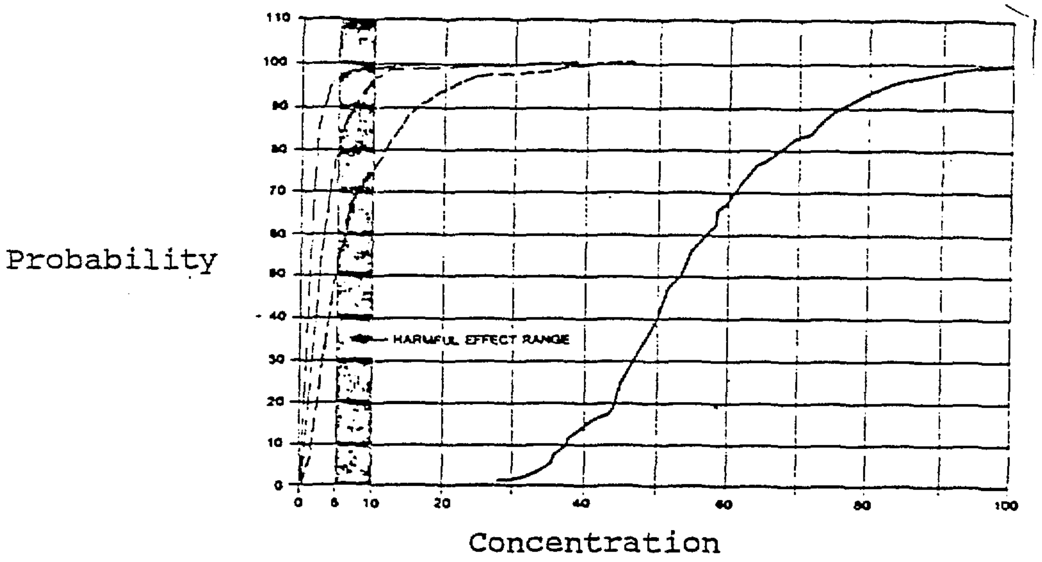
Qualitative data, both analytical and site-characteristic, will be in lists. At all times within this format, subjective statements on the quality of data can be entered. This can include the age, reliability of the data, etc., and should correspond to a 1-to-5 quality scale where 1 = good and 5 = bad. The review can be as simple as a list of compiled data (both analytical and characteristic) or comparisons of analytical data. Characteristic data is needed for modeling and exposure assessment. The ability to compare related data allows one to track trends (e.g., to determine if the concentration is going up or down at a specific location).

3. USE OF THE INITIAL DECISION TOOLS TO EVALUATE EXPOSURE - This is broken down into two basic groups of procedures:

   a) <u>Best case/worst case analysis</u> of contaminants at the sites. This is a powerful tool allowing one to predict the worst possible case and subsequently compare it to threshold values. In many cases the evaluation process may be terminated at this point, when the worst case does not exceed the minimum threshold. When minimal data has been collected and or when there are numerous gaps in characteristics data, creating larger uncertainties in the modeling and evaluation processes, exposure evaluation can still be estimated using this "Monte Carlo" analysis.

      This analysis program begins by making an estimate of the variables and assuming either a uniform or log-normal distribution. By making numerous calculation runs, randomly choosing the distributed variables using the low parameters and then the high parameters, one can generate a worst case/best case probability plot of distribution versus concentration. Subsequent insertion of TLV information on this plot allows one to judge the probability of whether the concentration has the potential to exceed the threshold values anywhere on the site.

Plot of Probability of Contamination versus Concentration of Contamination



b) <u>Simplified models</u> to assist in predicting movement and, eventually exposure. Simplified models do not require extensive site-characteristic data, which is often unavailable and always difficult to acquire. There are numerous models available. The data base support system program will have three specific simplified models built in to evaluate specific problems:

- Surface water models to evaluate both running and standing water bodies.
- A groundwater model to evaluate point source contamination (2-dimensional).
- A point source surface contaminants model to show effects on undefined aquifer systems (3-dimensional).

Phase 2 (Not included in the data base program, although we have used EPA's program called PCGEMS for this analysis.)

4. COMPLEX MODELING - The goals are to ensure the effective use of models for appropriate problems. It is necessary to define all quantitative inputs required by the program and to define the variability in default values and ranges as a function of output. Most complex models

VI. COMPUTER ASSISTED DECISION SUPPORT SYSTEM (ERIES)

ERIES, Environmental Risk Information and Evaluation System is a phase I (edition 1.0) program designed to provide maximum utility in support of the first half of the "Framework". ERIES is a knowledge based (KB) system. It rearranges multiple sets of data bases and compiles them into readily evaluatable formats of information. The comparison mode allows the user to look at trends, determine localization, and track concentrations with respect to both location and time.

ERIES is a menu driven, user friendly KB decision support system. A brief description of the program follows:

ERIES, Environmental Risk Information and Evaluation System

I. Title and Abstracts

These pages allow an evaluator the ability to screen sites. You can menu-select a site (by title or number) and then examine the following basic information.

Title Page - basic information about the site: name, address, contacts, etc.

Sources Page - an interactive listing of sources of information used to develop teh KB and those which are available.

Abstract - brief description of problem and notes on any litigation or pending regulatory action.

II. Knowledge Base Data Entry

This section is where entry of analytical and site characteristic data are made.

Analytical and Characteristic Data - includes five menu options:

1. Source surface data base
2. Surface water data base
3. Unsaturated zone data base
4. Groundwater data base
5. Analytical Reference data base

Source Surface Data Base

- How many sources have been identified?
- Source #1?
- Status of source? stopped, still contaminating?
- Analytes and data

III. Population Data Base

This section includes a brief description of the area including land usage and population density information as well as plant and animal species in the area.

IV. General Output

This section allows for a complete view of all collected data or any individual groups (e.g., groundwater only). This data is listed by groups and then subdivided by types. It also includes all locations and times.

V. Compare Data

With analytical results from several different sources at several different locations and times, it can be strategically important to view selected data in several formats. This portion of the program will do just that. It looks at analytical data and can view them two-dimensionally.

This sort program can display any analytical parameters from the source/surface, surface water, unsaturated zone, and ground water. It will ask user to define which paramenters to display. It will request you choose an analyte group, then a specific analyte. The program will then automatically generate a table allowing you to compare location versus date.

Great effort went into developing a readily expandable program. ERIES is capable of taking on many more tasks. The program will require initial installation and a user supporting document will be provided with the software.

APPENDIX 1

Actual Analytical Data for All Three Sites

Risk Assessment and Evaluation of Selected
Virginia Sites Within a Coastal Region

EP TOX METALS

Samples were analyzed by EPA Method 3010, EP Toxicity. Results are reported as concentration, parts per million (mg/L), in the sample extract.

ANALYTE	SPL# LAGOON HLI# 70511	JUNKYD1A 70513	JUNK1B 70515	MISC 70517
Arsenic	< 0.002	< 0.002	< 0.002	< 0.002
Barium	< 0.2	< 0.2	< 0.2	< 0.2
Cadmium	< 0.01	< 0.01	< 0.01	< 0.01
Chromium	< 0.1	< 0.1	< 0.1	< 0.1
Copper	< 0.04	< 0.04	0.09	< 0.04
Lead	< 0.1	< 0.1	< 0.1	< 0.1
Mercury	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Selenium	< 0.002	< 0.002	< 0.002	< 0.002
Silver	< 0.03	< 0.03	< 0.03	< 0.03
Zinc	0.12	0.05	0.78	0.13

INORGANIC ANALYSIS

Results expressed in parts per million (mg/L).

ANALYTE	SPL# Well#1 HLI# 70497	Well#2A 70500	Well#2B 70503	Well#4B 70509
Alkalinity (as $CaCO_3$)	350	370	350	330
Ammonia (as N)	9.9	83	96	4.2
Chloride	210.0	585.0	615.0	448.0
Solids, Total Dissolved	1120	4670	5130	1640
Nitrate (as N)	0.525	4.550	3.300	0.700
pH	6.4	5.0	5.0	5.9
Sulfate	120.0	1900.0	2100.0	105.0
Cyanide	< 0.01	< 0.01	< 0.01	< 0.01
Conductivity (umho/cm)	1400	3300	3300	1700

Results expressed in parts per million (mg/kg).

ANALYTE	SPL# 101 HLI# 70512	70514	70516	70518
Ammonia (as N)	< 0.8	< 0.8	< 0.8	< 0.8
Chloride	0.014	0.014	0.005	0.014
Nitrate (as N)	0.8	< 0.1	< 0.1	5.2
Sulfate	640.0	60.0	40.0	60.0

ORGANIC ANALYSIS

Samples were acid/ base-neutral extracted by EPA method 3510 and analyzed by EPA method 8270, GC/MS using a DB-1 Col.
note (-)= none detected

COMPOUND	SPL# Well#1	Well#2A	Well#4B
	HLI# 70498	70501	70510
4-chloro 3-methylphenol	-	0.023	-
1,2,4-trichlorobenzene	-	0.009	0.034
acenaphthelene	-	-	0.027
fluorene	-	-	0.008
fluoranthene	-	-	0.060
pyrene	-	-	0.039
butyl benzyl phthalate	-	0.044	-
bis(2-ethylhexyl)phthalate	-	-	0.116

1130 East Market Street, Charlottesville, VA 22901 (804) 293-6000

ANALYSIS REPORT

HLI REPORT # : RE-144-4
REPORT DATE : June 18, 1989
ACCOUNT # : 156
NAME : Center for Risk Assessment
COMPANY : UVA, School of Engineering & Applied Science
ADDRESS : Thornton Hall
Charlottesville, VA 22903
PHONE # : (804) 924-3954
PROJECT : Alliance Fertilizer
SAMPLING DATE : 5/24/89
SAMPLE TYPE : Well Waters and Soils

ANALYTE	Well#1	Well#1	Well#2	Well#3	Well#4	Creek	Davis
	73049	73055	73058	73061	73064	73067	73070
pH	6.7	6.5	6.5	6.0	6.3	6.2	6.5
Cond. (umho/cm)	420	430	1100	1900	420	410	640
TDS (mg/L)	290	288	999	1880	383	387	678
PO4-P, Total (mg/L)	0.004	0.002	0.218	0.120	0.115	0.112	0.074
NO3-N (mg/L)	9.0	8.8	1.78	0.26	4.6	4.7	12.1

ORGANIC_RESULTS

HLI#	DESC.	ANALYTE	CONC.
73051	Well #1	Alachlor	0.002
		Metolachlor	0.016
		DibutylPhthalate	0.028
73057	Well #2	Dibutylphthalate	0.010
73060	Well #3	Alachlor	0.001
		Metolachlor	0.016
		Dibutylphthalate	0.016
73063	Well #4	Alachlor	0.004
		Metolachlor	0.026
		Dibutylphthalate	0.016
73066	Creek	-	
73069	Davis Well	-	
73074	Side Ditch	-	
73075	Front Ditch	-	
73076	Side of Drive	-	

all results in ppm unless otherwise stated
Organic analysis-acid/base-neutral extract. by GC-MS

HAVENS LABORATORIES, INC.
1130 East Market Street, Charlottesville, VA 22901 (804) 293-6000

ANALYSIS REPORT

HLI REPORT # : RE-172-2
REPORT DATE : July 5, 1989
ACCOUNT # : 156
NAME : Center for Risk Assessment
COMPANY : UVA, School of Engineering & Applied Science
ADDRESS : Thornton Hall
Charlottesville, VA 22903
PHONE # : (804) 924-3954
PROJECT : Alliance Fertilizer
SAMPLING DATE : 6/21/89
SAMPLE TYPE : Runoff water

HLI #	DESCRIPTION	NO3-N (mg/L)
73667	3101, Behind Dike, Alliance property	2.26
73668	3102, Back center, Alliance property	0.51
73669	3103, Top of Purcell Spring	9.20
73670	3104, Run-off ditch into Purcell spring from Alliance-Davis property line	0.51
73671	3105, Run-off ditch behind hog lot	14.0
73672	3106, Connect for 3105	10.8
73673	3107, Foamy spot in creek 100' past 3106	11.2
73674	3108, Branch #2	2.28
73675	3109, Old stream	9.92
73676	3110, Branch #3	3.30

ANALYSIS REPORT

HLI REPORT # : RE-194-1
REPORT DATE : August 11, 1989
ACCOUNT # : 156
NAME : Center for Risk Assessment
COMPANY : UVA, School of Engineering & Applied Science
ADDRESS : Thornton Hall
Charlottesville, VA 22903
PHONE # : (804) 924-3954
PROJECT : Republic Creosote
SAMPLING DATE : 6/12/89
SAMPLE TYPE :

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TOTAL METALS
Concentrations are expressed in parts per million (mg/L).

HLI # (fld#)	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
74465 3115	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
74467 3117	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
74469 3119	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
74471 3121	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
74473 3123	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
74475 3125	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
74477 3127	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
74479 3129	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
74481 3131	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001
74483 3133	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001

HLI # (fld#)	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
74485 3135	<0.001	<0.001	<0.02	<0.001	0.017	<0.0002	0.010	<0.001
74497 4135	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	0.010	<0.001
74505 4143	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	0.008	<0.001
74512 4150	<0.001	<0.001	<0.02	<0.001	<0.002	<0.0002	<0.005	<0.001

EP TOX METALS

Samples were analyzed by EPA Method 3010, EP Toxicity. Results are expressed as concentration, in parts per million (mg/L), in the sample extract.

HLI #	Ag	As	Ba	Cd	Cr	Hg	Pb	Se
74493 4131	<0.001	<0.001	<0.02	0.002	<0.002	<0.0002	0.032	<0.001
74495 4133	<0.001	<0.001	<0.02	0.001	<0.002	<0.0002	<0.005	<0.001
74499 4137	<0.001	<0.001	<0.02	0.002	<0.002	<0.0002	0.010	<0.001
74501 4139	<0.001	<0.001	<0.02	0.003	<0.002	<0.0002	0.026	<0.001
74503 4141	<0.001	<0.001	<0.02	0.001	0.004	<0.0002	0.007	<0.001
74507 4145	<0.001	<0.001	<0.02	0.001	<0.002	<0.0002	<0.005	<0.001
74509 4147	<0.001	<0.001	<0.02	0.005	<0.002	<0.0002	0.016	<0.001
74511 4149	<0.001	<0.001	<0.02	0.001	<0.002	<0.0002	0.007	<0.001

BULK ASBESTOS ANALYSIS REPORT, EPA TEST METHOD 600/M4-82-020

REMARKS: Detection Limits = 1%. "-" = None Detected
ACM = Asbestos Containing Material

HLI #	FIELD SAMPLE # SAMPLE DESCRIPTION	% ACM & TYPE	% OTHER FIBERS	% OTHER
74513	2929,	-	5 cellulose 2 fibrous glass 15 synthetics 2 hair	76
74514	2921,	-	2 cellulose 20 synthetics	78

ANALYSIS REPORT

HLI REPORT # : RE-194-1.B
REPORT DATE : August 11, 1989
ACCOUNT # : 156
NAME : Center for Risk Assessment
COMPANY : UVA, School of Engineering & Applied Science
ADDRESS : Thornton Hall
Charlottesville, VA 22903
PHONE # : (804) 924-3954
PROJECT : Republic Creosote
SAMPLING DATE : 6/12/89
SAMPLE TYPE : PAH results

page 1 of 2

HLI # (fld#)	Acenaphthene	Fluoranthene	Naphthalene	Pyrene	Benzo(a) Pyrene	Chrysene	Anthracene
74466 3116	-	-	-	-	-	-	-
74468 3118	-	-	-	-	-	-	-
74470 3120	-	-	-	-	-	-	-
74472 3122	-	-	-	-	-	-	-
74474 3124	-	-	-	-	-	-	-
74476 3126	-	-	-	-	-	-	-
74478 3128	-	-	-	-	-	-	-
74480 3130	-	-	-	-	-	-	-
74482 3132	-	-	-	-	-	-	-
74484 3134	-	-	-	-	-	-	-
74486 3136	-	-	-	-	-	-	-

[redacted]LI # (fld#)	Acenaphthene	Fluoranthene	Naphthalene	Pyrene	Benzo(a) Pyrene	Chrysene	Anthracene
[redacted]74487-489 3137-39	-	-	-	-	-	-	-
[redacted]4490 3140	-	-	-	-	-	-	-
[redacted]4491 3141	-	-	-	-	-	-	-
[redacted]4492 130	-	-	-	-	-	-	600
[redacted]4494 132	9800	17500	500	11000	-	4200	160000
[redacted]4496 134	120	160	-	-	-	-	300
74498 [redacted]136	-	-	-	-	-	-	50
74500 [redacted]138	11200	32000	1200	16000	1500	4000	200500
74502 [redacted]140	7400	31000	-	15000	-	5800	185000
[redacted]74504 4142	235	-	-	-	-	-	950
[redacted]4506 4144	8900	25000	-	11000	-	-	110000
[redacted]4508 4146	8700	10000	-	11000	-	-	95000
[redacted]4510 4148	9600	10000	-	11000	-	-	85000

[redacted]ll results are in ppm
analysis by FID/GC

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

APPENDIX 2

Field Visit Reports

Risk Assessment and Evaluation of Selected Virginia Sites Within a Coastal Region

FIELD VISIT REPORTS

Suffolk Chemical field trip: February 1989

Team Leader - Mike Lockhart
Field Personnel - Sandra Neuse
Michele Sherer
Joey Romanoli

Sampling plan was developed to evaluate the following targeted potential problem areas:

- possibility that lagoon area could contaminate ground water
- possibility that lagoon sludge itself is a hazardous waste
- possibility that junk yard is contributing to groundwater contamination
- potential that surface run-off from drum washing area is a problem
- evaluate current state of groundwater
- evaluate any other problems that may appear

Sampling was conducted as represented in the analytical report. Analyses were performed using SW-846 and Standards Methods 14th Edition proceedural guides.

Several problems and observations were noted:

- the weather was overcast and raining throughout sampling procedures
- well #3 was under surface water and not able to be sampled
- well #4 had extensive silt and sediment at the 8′ mark
- groundwater level was approximately 10"
- the fill nozzle of the sulfuric acid tank extends out beyond the drip/leak protection
- no visible debris on junk yard lot
- wells #2 and #4 have extensive odor
- all wells bailed a minimum of five volumes before taking samples

Alliance Fertilizer field trip: May, 1989

Team Leader - Mike Lockhart
Field Personnel - Stan Havens
Therrell Hall
Karl Klein

Sampling was performed in two teams. Team 1 (Mike Lockhart and Karl Klein) sampled the following:

- front left corner of property for the presence of potential "hot spot" of pesticide/herbicide contamination
- collected 2x soil samples in drainage ditches to examine surface water contamination

Team 2 (Stan Havens and Therrell Hall) collected monitoring well, stream, and Davis well water samples.

Sampling was conducted as represented in the analytical report. SW-846 and Standard Methods prceedures were followed for the analysis.

Several problems and observations were noted:

- the weather was overcast.
- the entire region of the front left corner of the property was soil gas analyzed using a KVA soil gas probe and a HNU PID analyzer. Only one sample showed any deflection above background. A soil sample was taken for priority pollutant analysis at this location. Samples were taken at 18 to 24 inches depth.
- Purcell Spring was not running, the level of water was low.

Alliance Fertilizer field trip #2:   June 5,1989

Team Leader - Mike Lockhart
Field Personnel - John Martin

Preliminary modeling of the source loading of Purcell Spring showed a potential source of sampling error. That being, it was hypothesized that the stream was originally sampled in pooled areas - not running. Data from previous reports and our most recent data supported this conclusion. This result makes determining the loading source impossible. We needed to sample Purcell Spring after a period of rain to evaluate loading sources.

The secretary at Alliance called us and let us know when it was raining in Haynesville. We conducted sampling at several locations along the stream and tributaries and at several potential loading (run-off) locations.

Observations:
- raining and hot
- high suspended solids content

Republic Creosoting (McLean Construction) field trip: June 12,1989

Team Leader - Michael Lockhart
Field Personnel - Stan Havens
John Martin
Jim Smith
Clint Butts
Carla Gauss

NOTE: Mr Glen Metzler, with the Virginia Department of Waste Management, assisted in the field trip and sampling.

Sampling was performed in three teams:

Team #1 (Mike Lockhart, Jim Smith) evaluated and sampled the following:

- soil gas analysis of mulch area to localize area of highest PAH contamination
- surface debris evaluation to see if any new problems may exist

Team #2 (John Martin, Clint Butts, Carla Gauss) sampled the following:

- all surface water and river samples
- fish, crab, and grass samples

Team #3 (Stan Havens, Glen Metzler) sampled the following:

- core sampling of mulch area
- surface soil sample drainage area

Sampling was conducted as represented in the analytical report. SW-846 and Standards Methods proceedures were followed for all analyses.

Several problems and observations were noted:

- weather was cloudy
- it rained hard for the second half of the field trip
- coring through the mulch area was not a realistic approach. The mulch was too soft and irregular.
- the on-site foreman offered us the use of a backhoe and we dug holes to varying levels (and sampled) using it. We will probably need to dig down the base soil in the same fashion when installing monitoring wells.
- there are dozens of drums and tanks with varying contents scattered throughout the site.
- there are several areas where there appears to be asbestos-like insulation on pieces of scrap
- samples #3135 and #3136 were taken from the adjoining property with permission
- sample #4150 was taken across the railroad tracks on the other side of the road in front of the property in a drainage ditch

REPUBLIC CREOSOTING (McLEAN CONST.)
Field Trip to Analysis Report Correlation Table

HLI#	Field#	Code	Description	Analysis
74465	3115	-	water	metals
74466	3116	-	water	PAH
74467	3117	-	water	metals
74468	3118	-	water	PAH
74469	3119	-	water	metals
74470	3120	-	water	PAH
74471	3121	-	water	metals
74472	3122	-	water	PAH
74473	3123	-	water	metals
74474	3124	-	water	PAH
74475	3125	-	water	metals
74476	3126	-	water	PAH
74477	3127	-	water	metals
74478	3128	-	water	PAH
74479	3129	-	water	metals
74480	3130	-	water	PAH
74481	3131	-	water	metals
74482	3132	-	water	PAH
74483	3133	-	water	metals
74484	3134	-	water	PAH
74485	3135	-	water	metals
74486	3136	-	water	PAH
74487	3137	-	grass	PAH
74488	3138	-	grass	PAH
74489	3139	-	grass	PAH
74490	3140	-	fish	PAH
74491	3141	-	crab	PAH
74492	4130	hole a	6" surface	organic
74493	4131	hole a	6" surface	met
74494	4132	hole a	3' wood shavings	organic
74495	4133	hole a	3' wood shavings	met
74496	4134	hole a	5' ground water	organic
74497	4135	hole a	5' ground water	met
74498	4136	hole b	2" surface	organic
74499	4137	hole b	2" surface	met
74500	4138	hole c	wood shavings	organic
74501	4139	hole c	wood shavings	met
74502	4140	hole d	3' wood shavings	organic
74503	4141	hole d	3' wood shavings	met
74504	4142	hole d	5' ground water	organic
74505	4143	hole d	5' ground water	met
74506	4144	hole e	wood shavings	organic
74507	4145	hole e	wood shavings	met
74508	4146	hole f	wood shavings	organic
74509	4147	hole f	wood shavings	met
74510	4147	hole g	surface soil	organic
74511	4148	hole g	surface soil	met
74512	4149	-	drainage ditch	organic
74513	2929	-	pipe wrap	asbestos
74514	2921	-	pipe wrap	asbestos

CORRESPONDENCES

Enclosed at the end of APPENDIX 2 are copies of several correspondences we had with others pertaining to these sites.

July 9, 1989

TO: Mr. David Siedle, McLean Construction

FROM: Michael Lockhart, Field Operations, Systems
Engineering, University of Virginia (804)924-0960

SUBJECT: Field Evaluations and Sampling at McLean Construction
Site - General Overview

This site is expansive, the previous history is vague, and the property may contain other problems contributing to the contamination problems. The original PAH problem is buried in 0 to 2 feet of sediment (potentially contaminated) dredged from the Elizabeth River. This is going to make source quantification much more difficult. We have defined five problem areas based on our evaluation of existing data and our site visit. They are:

1. Quantitative Assessment of the PAH Source Area(s): Both the area where the creosote holding tanks and the wood chip land applied area(s) were need to be investigated as sources. Extensive soil gas analysis will be used to outline areas and coring will be used to define depth and contamination levels.

2. Ground Water: Little is known about the ground water at this site, so modeling is not going to be reliable. PAH's are relatively insoluble and will not be readily transported, but could migrate if high concentrations are present. There is also the question of other yet unidentified contaminents. Priority Pollutant screens are needed. Due to cost restrictions, ground water monitering will not be performed at this time.

3. Surface Waters, Drainage Ditches, and the Elizabeth River: Sampling of the Elizabeth River upstream and downstream from the Republic site will be conducted. In addition, run off in the drainage ditches (both sides of the property) will be sampled and analyzed. These samples will be target analyzed for PAH's to determine the extent of PAH contamination and screened for Priority Pollutants to see if there are other contaminents present (keeping in mind that PAH's are not readily soluble in water).

4. Biological Contamination For PAH's: PAH's readily accumulate in plants and in adipose tissues of animals. A measure of the extent of the contamination to date is the determination of the concentration of the PAH's which have accumulated in local aquatic species, land animals, and plants. Collection of these biological specimens, whole body digestions, and subsequent PAH analysis will be very useful in this evaluation.

5. Other Sources of Contamination to the Site: During our site visit we observed that there were numerous empty(?) 55 gallon drums on the site and what appeared to be Asbestos-Containing-Materials on several pieces of equipment as well as tons of dredged sediment. These all need to be evaluated. The overall question will be to evaluate the current state of the site.

The following generalized sampling plan has been devised to address the above problems:

1. a) Use soil gas analyzer to outline areas of PAH contamination.

   b) Take soil samples (up to six feet in depth) to quantify the PAH contamination. This will include up to 50 PAH and 5 Priority Pollutant samples.

2. No groundwater testing at this time.

3. Analyze runoff for Priority Pollutants (6-10) and PAH's (15-20).

4. a) Collect ten soil samples from targeted locations. Analyze for PAH's and metals.

   b) Collect foliage samples from each of these ten locations and analyze for PAH's.

   c) Collect two to four animal/fish samples from both zones A and B and analyze for PAH's (sampling zones A and B are along the Elizabeth River on th upstream/downstream portions of the property).

5. a) Inspect surface debris for asbestos and take samples as needed.

   b) Take samples of the containers and other possible sources of contamination (unknown at this time).

   c) Take several random samples of dredgings.

We will be prepared to take up to:

100 - soil/water PAH samples

25 - Priority Pollutant samples (acid/base-neutral extractables)

35 - metal samples (for total and EP toxicity metals)

25 - other related inorganic and general samples

Alliance Agronomics, Inc.
6526 Mechanicsville Turnpike
Mechanicsville, Virginia 23111
(804) 730-2900

April 6, 1989

Dr. Ralph O. Allen
University of Virginia
Chemistry Building
McCormick Road
Charlottesville, VA 22901

Dear Dr. Allen:

Enclosed is the groundwater management plan prepared by Environmental Technologies in 1988 for our Haynesville site. I have also included the changes and an addendum to the plan.

The crop history of the fields adjacent to our site has been difficult to determine. There are three fields that your group asked about--two to the west and one to the east of our site. We are unable to reconstruct the crop history or the crop protection chemicals used on the two fields to the west of us. These fields are owned by Mr. Wilson I. Davis and are located in front of and behind his home. I believe he rents out these fields to someone in the community.

The 20-acre field to the east of us was farmed by Mr. Douglas Lewis before 1987. In 1987, 1988, and 1989, I believe Mr. George Self farmed it.

Year	Crop	Chemical	Normal Rate
1982	Corn	Dual (Metolachlor)	1 1/4 pint/A
		Aatrex (Atrazine)	3 pints/A
		Toxaphene	1 quart/A
1983	Wheat	Banvel (Dicamba)	1/4 pint/A
		2,4-D	3/4 pint/A
	Beans	Dual	1 1/4 pint/A
		Lorox	1 lb/A
1984	Corn	Same as 1982	Same as 1982
1985	Wheat	Same as 1983	Same as 1983
	Beans	Same as 1983	Same as 1983

Year	Crop	Chemical	Normal Rate
1986	Corn	Dual Aatrex	1 1/4 pint/A 3 pints/A
1987	Wheat	Unknown	?
	Beans	Dual Lorox	1 1/4 pints/A 1 lb/A
1988	Corn	Same as 1986	Same as 1986
1989	Wheat	Unknown	?

I hope this information is beneficial. I am sorry for the delay in getting this to you.

Yours truly,

Waddy Garrett

G. Waddy Garrett
President

bjw

cc: Mr. Glen Metzler

1801603

COMMONWEALTH of VIRGINIA

STATE WATER CONTROL BOARD

2111 Hamilton Street

Richard N. Burton
Executive Director

Post Office Box 11143
Richmond, Virginia 23230-1143
(804) 367-0056

Please reply to: Tidewater Region — Kilmarnock Office
P. O. Box 669
Church Street
Kilmarnock, Virginia 22482-0669
(804) 435-3181

January 12, 1988

Mr. Mahesh P. Shah
Center for Risk Management
of Engineering Systems
Applied Math Building, Room 103
University of Virginia
Charlottesville, VA 22901

Re: Alliance Fertilizer
Haynesville VA

Dear Mr. Shah:

In response to your letter, attached is an enlarged map showing the exact stream sampling locations for the 2/2/88 study. Also attached is a copy of the file map for the 7/30/81 stream sampling stations. Since I was not present during that sampling, the attached map is the best I can provide. The 7/81 samples were collected by T. L. Switzer, who is no longer with this agency. Please note that Mr. Switzer's labeling of the "Unauthorized Discharge Location" and "Purcell Spring" (Station 3) is incorrect. The unauthorized discharge was into Purcell Spring, which is identified as Station 1 on my 2/88 map. I assume that his remaining stations are correctly labeled, and that his Station 4 corresponds with my Station 4, and his Station 5 is slightly downstream of my Station 6.

Please contact David Gussman at (804) 367-6763 if you have further questions regarding this facility.

Sincerely,

BKF

B. Keith Fowler
Environmental Specialist

cc: David Gussman

APPENDIX 3

Monte Carlo Estimation Procedure

Risk Assessment and Evaluation of Selected
Virginia Sites Within a Coastal Region

As mentioned earlier in this report, it is often difficult to accurately predict the interaction of the various factors that govern the transport of chemical contaminants in the environment. Because many of these factors have a probabilistic distribution (such as wind direction and speed, rainfall over a given period, and rate of groundwater flow), it is impossible to provide precise deterministic basis for analyzing the fate of chemicals released into ecological systems. For this reason, a model used to analyze contamination needs to have a probabilistic component if the decisionmaker wishes to analyze anything other than the expected exposure to contamination.

Such a model needs to have, at its heart, random numbers generated according to known probability distributions that can then be used in analytic equations governing chemical transport and decay. The use of such a model is known as Monte Carlo simulation because of the association between probability distributions and games of chance.

As an aid to understanding the usefulness of such a simulation, we should consider the problem facing current deterministic models. For example, in the surface water model for riverine systems in PCGEMS[1] asks, in the environment input file, for the average levels of:

- Oxidant Radical Concentration
- Rainfall (per month)
- Cloudiness (on a scale of 0.0 [clear] to 10.0 [full cover])
- Ozone in the Atmosphere
- Relative Humidity
- Atmospheric Turbidity

It then uses these average levels of environmental factors to calculate chemical breakdown from such things as photolysis and organic adsorption. Over a long period of time with the system in steady state, you would certainly expect to see results similar to those predicted by this model. However, these expected values do not provide a single clue as to the variability of chemical concentration. It can easily be seen that each of the environmental characteristics listed (and there are many others not included in this list) can vary over a relatively wide range on any given day, and each has a 50% chance of being above or below the mean given in the input file, although none of this variability is taken into account by the program itself. The effect of combining the differences from the mean of each of the input

---

[1] This refers to EXAMS-II (Exposure Analysis Modeling System), developed by the Environmental Protection Agency for use in PCGEMS (Personal Computer Version of the Graphical Exposure Modeling System) as a tool to analyze the expected concentrations of chemicals introduced into surface water environments.

characteristics will alter the concentration of a chemical over time, although the mean concentration will remain about the same. The greater the variance that each of the input parameters has, the greater the variance will be in chemical concentrations; conversely, in temperature regions with only small deviations from average weather conditions, there will be only a small variation from the mean chemical concentration.

The point of a Monte Carlo simulation, then, is to find probability distributions for the input characteristics. The model input is then taken as a set of random variables from these distributions. The variables interact according to the equations governing transport and decay already established in the model's code and the result is a system for determining the distribution of the chemical concentration. To begin with, one run is made with input numbers taken from the random variables (for rainfall and relative humidity, etc.). The output from the model is a level of concentration. Taking another run of the model with another set of numbers from the same distributions will give a different level of concentration. A number of successive runs will give data that represent the distribution of chemical exposure, which can be used for an analysis of variation, or extreme event analysis, or a number of other useful techniques that cannot be performed with an expected value alone.

The crucial aspect of this method is the importance of the input probability distributions. The more accurately they can be found, the better the results from the simulation. Fortunately, much of the data can be found in geological and weather reports made by outside agencies. Unfortunately, the distribution of chemical release from the source itself is unknown and must be determined for the input. Often the source itself is indeterminate and must be estimated; making measurements can be extremely costly and time-consuming (particularly for groundwater contamination). With only a few measurements of source concentrations, it is difficult to find the actual distribution of chemical release--although it can (and should) be estimated, for example with a triangular distribution.

This is where the advice of experts and research in other fields can be valuable. If studies of similar chemicals reveal a tendency towards one type of release distribution and the data taken from the actual site agrees well with that, then that type of distribution should be used. Similar reasoning follows for using the advice of technical experts; if an expert can determine a particular type of distribution for some chemical release and give a valid supporting argument, that distribution is a strong possibility for use in the input parameters.

On the down side of the Monte Carlo technique is the argument that it requires a great deal of computer time. This is often true when modeling an annual cycle of chemical contamination--after all, the more runs that are made, the better the results will be. However, initial groundwork on the PCGEMS models running on a 20 MHz 80386 computer (with the required 80387 math coprocessor) shows running time for an annual surface water model expected value analysis to be under a minute. Such speed certainly opens up the possibility of a great many runs if some method can be derived for automating the update of the input file based on the required probability distributions.

If other, less complex, models can be found to approximate chemical transport with fewer inputs, then the same reasoning can be used to adapt them to this type of simulation in order to provide the decisionmaker with a useful distribution of chemical contamination.

APPENDIX 4

Model Used for Alliance and Suffolk Sites

Risk Assessment and Evaluation of Selected
Virginia Sites Within a Coastal Region

Model for Risk Analysis

The common two-dimensional equation governing contaminant migration in uniform one-directional flow from a slug point source without adsorption and radioactive decay is (Hunt, 1983; Walton, 1989):

$$C = f(x,y,v_c,v_s,m,n,A_L,A_T,t)C_0 \qquad (1)$$

where $f(\ ) = 1.064\text{x}10^{-2} v_c \exp-\{[(x-v_s t)^2/4A_L v_s t] + y^2/(4A_L v_s t)\}/[mnv_s(A_L A_T)^{1/2} t]$

C_0 = difference between solute concentration injected into aquifer and native solute concentration in mg/L

C = change in aquifer solute concentration due to solute injection in mg/L

x,y = cartesian coordinates of monitoring wells in feet

m = aquifer thickness in feet

v_c = volume of injected mass in gallons

v_s = seepage velocity without adsorption in feet/day = $(K/n)dh/dx$

K = hydraulic conductivity in feet/day

A_L = longitudinal dispersivity without adsorption in feet

A_T = transverse dispersivity without adsorption in feet

To account for adsorption A_L, A_T, v_s , and C are divided by a retardation factor defined as (Marsily, 1986; Walton, 1989):

$$R_d = 1 + [(D_{bs}/n_p)K_d] \qquad (2)$$

where

R_d = retardation factor

D_{bs} = bulk density of dry aquifer skeleton in g/cm

n_p = aquifer actual porosity

K_d = distribution coefficient

Radioactive decay is simulated as (Marsily, 1986):

$$C_r = Ce^{-Zt} \qquad (3)$$

$Z = 0.693/h_1$

C_r = concentration of solute with radioactive decay in mg/L

C = concentration of solute without radioactive decay in mg/L

t = time after radioactive decay started in days

h_1 = half-life of substance in days

Derivation of Distribution Function

The initial concentration, C_0 can be treated as a random variable (because of uncertainty in our knowledge about its value) with a distribution function $F_C(c_0)$. Let $F_C(c)$ represent the distribution function of C. Then

$$\begin{aligned} F_C(c) &= P(C < c) \\ &= P(fc_0 < c) \\ &= P(C_0 < c/f) \\ &= F_C(c/f) \end{aligned} \tag{4}$$

Application

The above model was applied to the Suffolk problem. Parameters required for the model were estimated as shown in Table 1 of this Appendix. Assume that a sulfuric acid source is located at Well no. 2, which injects 100,000 gallons of sulfuric acid at present, with a concentration whose distribution function is to be assessed. In absence of appropriate data, the distribution can be assumed to be of a triangular form (Kelton and Law, 1982):

$$F_{Co}(C_o) \begin{cases} = 0 & \text{when } C_o \le \alpha \\ = (C_o-\alpha)^2/[(\beta-\alpha)(\tau-\alpha)] & \text{when } \alpha \le C_o \le \tau \\ = 1 - (\beta-C_o)^2/[(\beta-\alpha)(\beta-\tau)] & \text{when } \tau \le C_o \le \beta \\ = 1 & \text{when } C_o > \beta \end{cases}$$

$[\alpha,\beta]$ = interval in which c is believed to lie
τ = mode; the most likely value

From Equation (4) the distribution function for the concentration at Shingles Creek, which is 600 ft away (distance estimated from the U.S.G.S. 7.5 minute topographic map) is given by:

$$F_C(C) \begin{cases} = 0 & \text{when } C \le \alpha f \\ = (C/f-\alpha)^2/[(\beta-\alpha)(\tau-\alpha)] & \text{when } \alpha f \le C \le \tau f \\ = 1 - (\beta-C/f)^2/[(\beta-\alpha)(\beta-\tau)] & \text{when } \tau f \le C \le \beta f \\ = 1 & \text{when } C > \beta f \end{cases}$$

It is assumed that α=500 mg/L, β=3000 mg/L and τ=2000 mg/L. Graphs of the input and output concentrations are shown in Figures 1 and 2. From Figure 2 it becomes clear that the chance of the concentration at the Creek exceeding 60 mg/L is negligible.

Table 1: Risk Analysis Parameter Values

Parameter	Value	Remarks
Hydraulic conductivity, K	15 ft/day	conservative
Effective porosity, n_p	0.3	conservative
Hydraulic gradient , dh/dx	0.002 ft/ft	conservative (LES, 1986)
Aquifer thickness, m	30 ft	average
Long. dispersivity, A_L	10 ft	subjective estimate
Trans. dispersivity, A_T	2 ft	subjective estimate
seepage velocity, v_s	0.1 ft/day	computed
volume injected, v_c	100,000 gal.	conservative
Retardation factor, R_d	1	conservative (no retardation)
Half life, h_1	infinity	conservative (no decay)

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APPENDIX 5

Role of Risk Assessment in Site Evaluation

Risk Assessment and Evaluation of Selected Virginia Sites Within a Coastal Region

As in any project involving risk analysis, there must first be a process of site characterization for each area being investigated. This characterization of the problem is necessarily an important aspect of any successful risk analysis. In the case of chemical release into the environment, this phase of the study involves answering four questions in detail:

1. What are the conditions of exposure?
2. What are the adverse effects resulting from exposure?
3. What is the relationship between exposure and effect?
4. What is the overall risk?

The first problem, that of defining the conditions of exposure, is often the most difficult one for ecological systems. The overall goal is to determine who (or what, in the case of wildlife) will be exposed to chemical releases from the site in question--and in what amounts for how long. The problem faced in addressing these questions is the inherent difficulty in determining the ultimate fate of chemicals released into the environment. Given that it is impossible to accurately predict and analyze all of the factors in an ecological system, we must use estimates and averages in determining chemical transport: an average windspeed or aquifer flow, an average pH level in the soil, or an estimated annual rainfall. It is because of the uncertainty inherent here that we must be aware of the variability in possible exposure levels as well as the average amounts of exposure.

This difficulty in establishing analytic relationships between the various factors in a chemical transport mechanism often makes it necessary to turn to computer simulation in order to derive a distribution for exposure. A Monte Carlo simulation (of which more will be said later) can be particularly useful in this regard--especially since it is often difficult even to accurately determine the source of chemical releases.

Another topic to be addressed is the method of chemical transportation. Is it an atmospheric pollutant, or does it contaminate groundwater? Will it continuously evaporate or does it only break down in direct sunlight? Much of this information can be obtained in laboratory experiments on the chemicals being analyzed, but often measurements on-site reveal the predominant mode of chemical movement, as the varying concentrations between surface water, groundwater, the atmosphere, and the soil can all be measured to some degree. The extent of biological absorption is more difficult to discover--it is often impossible to measure chemical concentrations in wildlife without killing the animals in question. Biological absorption, then, must often be estimated from properties of the chemical itself. Indirect exposure is a necessary consideration in addition to the hazard of direct exposure. As an example, consider chemical waste dumped into rivers leading to oyster beds. People may never swim in that water, but they can potentially be poisoned by eating enough of the oysters. Indeed, this is a primary source of concern for certain types of chemical releases and may thus indicate where attention should be focused in studying contamination.

Once we have identified what is being released into the environment, how it is being transported, and who (or what) is being exposed to it, we must define the adverse effects that result. Will the chemical cause cancer? Can it alter human or animal genetic patterns? Will it physiologically damage the exposed population? These are important questions in analyzing the risk of exposure; presumably, this type of information is available for the chemicals being studied. That is, the sites in question are being investigated because they are potential sources of chemicals that are known to have adverse effects on the environment. If the effects of the chemicals being released are not known, then determining these effects should be a primary focus of this phase of study.

The nature of the chemical also comes into play here. Does the chemical gradually decay once in the body, or do successive doses build up, possibly to lethal levels? If the substance is chemically stable in the environment, populations could be subject to a low level of exposure over a long period; in other instances there could be a brief exposure of a large magnitude. Different types of exposure can lead to vastly different effects. There is also the problem of delayed effects. There may be a long time between initial exposure and the manifestation of adverse effects as, over time, the chemical builds up or works its insidious change in the human population. Just because there is no indication of a health hazard at a site presently does not necessarily mean that no hazard exists.

The third step is, logically, to relate exposure with adverse effects. Obviously a small dose of a chemical will not be as dangerous as a large dose; however it is necessary to ascertain whether chemical releases are within reasonable amounts. At this point some kind of relationship between an amount of exposure and an amount of adverse effect needs to derived in order to determine the overall consequences of environmental release. The possibility that some of the exposed population may be more susceptible than the average must be considered. People with special allergies may have a far greater reaction to an introduced substance than others; what may be a "safe" level in one person could conceivably be lethal in another. In any event, if such data is not available for chemicals being released at the sites under scrutiny, studies should be made to determine these effects.

The interaction between different populations must be considered as well. In any ecosystem there is a delicate balance in the food chain; a chemical that only affects speckled trout can still indirectly affect all the animals that feed on or depend on speckled trout for their existence. Thus, while it may be impossible to test all of the animal or plant species that may be exposed to a certain contaminant, an indication of adverse effects in even one species must be carefully considered.

It is entirely possible that a chemical can be found to have little or no effect on the environment even in the maximum concentrations found at the source. Although this may be the case, the prospect of multiple sources should be evaluated. For example, a factory may be discharging waste into a stream at what are thought to be reasonable levels. If, however, there are fields downstream with pesticide runoff, the chemical toxicity can be pushed to a dangerous level. While there may be nothing that can be done about the pesticide, cleaning up the factory's discharge may be warranted, to protect the environment.

The final problem in site characterization is estimating the risk, both to individuals and to society as a whole. It is here that the various effects studied earlier are compared, to ascertain which are the most undesirable, which affect the most people or greatest area, and which pose the greatest threat to the natural order of things. This process of evaluating risk can often become the political one of judging the acceptability of risk--but that is not its purpose. It should only provide a framework within which decisionmakers can determine what presents the greatest hazard and is thus in greatest need of correction. It is in combining the risks found in studying various sites that decisionmakers can determine which ones are in the greatest need of attention.

The primary reference for this appendix was:

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