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United States Department of the Interior

OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

TAKE PRIDE IN AMERICA

ER 93/122

MAY 25 1993

Mr. Thomas C. Voltaggio, Chief
Hazardous Waste Management Division (3HW00)
Environmental Protection Agency, Region III
841 Chestnut Street
Philadelphia, PA 19107

Dear Mr. Voltaggio:

Pursuant to a request from your agency and in accordance with our Inter-agency Agreement, the Department of the Interior has prepared a Preliminary Natural Resources Survey (PNRS) for the Occidental Petroleum/Firestone Site located in Montgomery County, Pennsylvania.

In preparation for this report, we reviewed the Draft Remedial Investigation (RI) Report (March 1992), the Final RI Report (March 1993), the Draft Feasibility (FS) Study Report (June 1992), the Final FS Report (March 1993), and the April 1993 Proposed Remedial Action Plan (PRAP). The Fish and Wildlife Service (FWS) and Geological Survey Staff consulted relevant literature in the preparation of their technical analyses, which are consolidated and included as an enclosure.

Based upon our evaluation of the site information, we will inform our Solicitor that the potentially responsible parties (PRPs) must agree to take several specific actions during remediation to eliminate the threat to trust resources, that the PRPs will have to restore trustee resource habitats satisfactorily, and/or will have to provide adequate monetary compensation before the Department can satisfy its responsibilities under Section 122(j)(2) of CERCLA.

The Department's trust resources at the site include a variety of migratory bird species including waterfowl, wading birds, raptors and perching birds. These species are exposed to contaminated sediments found within the sedimentation pond and drainage swale, neither of which have been included in the proposed remedial action. The sediments contain polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenols (PCBs), dibenzofurans and mercury at concentrations that are injurious to migratory birds. As such, the Department recommends further sampling of the sediment pond and drainage swale to further define the extent of this contamination, and once this is completed, that contaminated sediments be removed in accordance with target levels equivalent to the maximum Schuylkill River background concentrations detected during the RI. Based upon the RI results, the target cleanup levels would be 5 mg/L for PAHs, 0 mg/L for dibenzofurans, 0 mg/L for PCBs and 0.4 mg/L for mercury.

The Department believes its concerns for trust resources in other areas of the site should be adequately addressed through implementation of the PRAP, provided the areas disturbed by remedial activities are restored for wildlife by seeding them with native grasses and herbs and managing the area with minimum disturbance. This action is best accomplished via preparation of a vegetation management plan that is coordinated with the FWS during remedial design.

Our Regional Environmental Officer, Don Henne, is available to discuss any of the issues mentioned herein or identified more fully in the enclosure. Mr. Henne may be contacted at the following address:

Office of Environmental Affairs
Custom House, Room 217
200 Chestnut Street
Philadelphia, PA 19106-2904
Phone (215) 597-5378

Should your Regional Counsel or attorneys from the U.S Department of Justice require our Official position on a covenant not to sue, please contact our Regional Solicitor, Anthony R. Conte. Mr. Conte can be reached at the following address:

Regional Solicitor
Northeast Region
Suite 612, One Gateway Center
Newton Corner, MA 02158
Phone (617) 527-3400

We look forward to resolving the Department's remaining concerns.

Sincerely,

Jonathan P. Deason
Director
Office of Environmental Affairs

Enclosure

cc:
Anthony Dappolone, Central PA Section,
Superfund Remedial Branch, EPA-III
Don Henne, REO/PHI

**Technical Analysis of the
Occidental Chemical/Firestone Superfund Site**

**Prepared by the
U.S. Department of the Interior**

**Fish and Wildlife Service
State College, PA**

**Geological Survey
Malvern, PA**

I. Background

Information in this report is based upon the March 1992 Draft Remedial Investigation Report (RI), including Appendices K and M; the March 1993 Final RI Report; the June 1992 Draft Feasibility Study Report (FS), including Appendix A; the March 1993 Final FS Report; and the April 1993 Proposed Remedial Action Plan. In addition, the Fish and Wildlife Service (FWS) has been involved in EPA Region III Biological Technical Assistance Group (BTAG) reviews of this site.

The Occidental Chemical Corporation site (Site) is 250 acres in size, located 1/2 mile southeast of Pottstown. The Site is located within a meander loop of the Schuylkill River, which surrounds the Site on three sides and forms the western, southern and eastern boundaries (see Figure 1). Much of the Site lies within the 100-year floodplain.

Prior to World War II, the Site was owned by Jacobs Aircraft Engine Company (JAEC), which manufactured aircraft engines. The Defense Plant Corporation purchased the Site from JAEC in 1942, although JAEC continued to operate and manufacture aircraft engines until late 1944. In 1945, Defense Plant Corporation leased the Site to Firestone Tire and Rubber, which subsequently purchased the Site in 1950. Firestone manufactured tires and polyvinyl chloride (PVC) resins at the Site. In 1980, Firestone sold the Site to Hooker Chemicals and Plastics Corporation, which later became the Occidental Chemical Corporation. Occidental continues to manufacture PVC resins at the Site today.

Past manufacturing operations at the Site have led to the release of hazardous substances at various locations (see Figure 2):

- A 17-acre solid waste landfill was operated on the Site from about 1942 through 1985. The landfill is 1,700 feet long, ranges in width from 360 to 650 feet, and is capped with an impermeable liner to prevent leachate production. The landfill was closed in 1985 in accordance with a Closure Plan approved by the Pennsylvania Department of Environmental Resources (DER). In the late 1970's, Firestone installed a ground water recovery system comprised of nine onsite process water wells which are continuously pumped. The bedrock ground water is pumped to the surface and is re-used during processing. The leachate control system continues to operate and controls the ground water flow towards the center of the Site. This pumping acts to contain the contaminant plumes.

- An unlined, 7-acre residual waste landfill is active and is being operated by Occidental. The landfill is located east of the closed landfill and is approximately 1,000 feet long by 300 feet wide. A sediment basin parallels the base of the landfill and carries all surface water to a drainage swale. The landfill and sediment basin are unlined.

- Four inactive unlined earthen lagoons, located within the 100-year floodplain of the Schuylkill River, were used for the storage of PVC sludge until DER ordered their closure in 1974. Each lagoon measures approximately 150 by 150 feet. The four lagoons are arranged in a square pattern and together cover an area of approximately 2.5 acres. The lagoons were operated in series, with the northernmost lagoons receiving the plant effluent. Sludge was first allowed to settle in concrete holding basins (still used today). Unpolymerized PVC solids settled to the bottom of the basins. The supernatant water was skimmed off and sent directly to the Pottstown sewage treatment plant. When a basin neared capacity (settled solids) the PVC sludge was diked to the northernmost lagoon. Sludge from the earthen lagoons had been periodically removed and placed in the landfill. These lagoons were not used after 1974.

  Sampling conducted during the RI revealed that three of the lagoons are underlain with a layer of coal fines. The coal fines evidently adsorbed contaminants released from the PVC wastes, preventing contamination of the underlying soils. Lagoon 1 lacks a coal fines layer, and a shallow layer of soils directly beneath this lagoon is contaminated.

- Two active lined lagoons currently hold PVC sludge, which is recycled into the manufacturing process and resold as low grade PVC product. The lagoons are located immediately northeast of the earthen lagoons; measure 165 feet by 330 feet and approximately 12.5 feet deep; and are lined with a synthetic liner to prevent migration of chemicals into the ground. The lagoons are currently operated under RCRA Interim Status and will be closed by 1994 in accordance with a RCRA Closure Plan. Based on ground water monitoring well data, the lined lagoons have not leaked.

- A handling area where trichloroethylene (TCE) spills over the years contaminated the soils and underlying ground water. In early 1984, approximately 898 tons of TCE-contaminated soils were removed in the TCE handling area. TCE concentrations in ground water in the TCE handling area ranged from 10 to 295 ug/L.

Additional areas of possible contamination include a large borrow area containing a mix of old field and vegetated wetland/open water habitats, and a forested wetland corridor between the site and the Schuylkill River.

II. Trust Resources

Anadromous fish (American shad) occurred historically in the Schuylkill River near the site, but the runs were eliminated by dams downstream. The Pennsylvania Fish Commission is proposing to restore American shad to the Schuylkill River. The catadromous American eel currently exists in the river.

A FWS biologist visited the Site on March 1, 1990. The diverse mix of forested wetlands, old field habitats, and the open water/emergent wetlands and mud flats of the borrow area (Figure 2) provide habitats for a variety of migratory bird species. We observed great blue herons and kestrels on the Site, and Canada geese and American mergansers on the Schuylkill River adjacent to the Site. Contractors for the RI observed great blue herons, mallards, turkey vultures, osprey, mourning doves, blue jays, crows, Carolina wrens, and song sparrows. Hundreds of other bird species could potentially use the habitats present on the Site. A risk assessment for ecological receptors determined that exposure to site-related contaminants at the existing concentrations would pose no risk to resident mammals or reptiles. Avian species that could potentially be at risk from high levels of contamination in the sediment pond and drainage swale (Figure 2), were not evaluated in the risk assessment.

III. Hydrologic Setting

The Site lies within a meander of the Schuylkill River, a major stream in southeast Pennsylvania that flows to the southeast and is confluent with the Delaware River. The area of the Site nearest the bend of the meander is a floodplain that is about 10 feet above the river surface. The land surface on the Site slopes from a high of 230 feet above sea level in the northwest to the floodplain at about 120 feet above sea level in the southeast. The Site is underlain by a bedrock aquifer.

Ground Water

The Site is underlain by the Brunswick Formation, which consists of interbedded shales, siltstones, and sandstones that are Triassic in age and are part of the Newark Basin. The sedimentary facies are discontinuous in all directions along the plane of bedding, forming lenses which grade into other facies; many of the lens-shaped beds can extend for thousands of feet along strike (Longwill and Wood, 1965). In the area of the Site, the beds dip about 12 degrees northwest, and beds do not appear continuous as discerned from geophysical and geologic logs. Two thin argillaceous beds are mapped near the center of the site; these beds were identified as Lockatong Formation in previous mapping (Longwill and Wood, 1965) but have been reinterpreted as argillaceous units within the Brunswick Shale (Lyttle and Epstein, 1987).

The Brunswick Formation forms a water-table aquifer near the surface and can be semi-confined at depth. The aquifer is recharged by precipitation and most recharge occurs in the winter and spring. Ground water flows through fractures (secondary porosity) in the rocks, although there may be some flow in pores (primary porosity) of sandstone units. In these types of Triassic rocks, hydraulic conductivity typically is greater along strike than in other directions; however, the hydraulic conductivity in fractures oriented in directions other than those of bedding can be as great or greater than that along strike. Aquifer tests conducted by BCM (1991) indicate that the sandstone units are more productive than the shale and siltstone units.

Under natural static (non-pumping) conditions, the direction of ground-water flow in the bedrock aquifer would be generally from the northwest toward the Schuylkill River. The Schuylkill River is a natural discharge zone for at at least some of the ground water; the shallow aquifer may be in good hydraulic connection locally with the Schuylkill River and deeper zones may flow to regional discharge zones further downstream. Because the Site lies within a meander ground water may flow under and parallel to the river in the some areas circumscribed by meanders. Some ground water can flow under the Schuylkill River because the river does not fully penetrate the aquifer and probably is only a partial discharge boundary.

Under the pumping conditions, drawdown apparently is greater along strike than downdip, as documented in aquifer tests by BCM (1991, 1993), reflecting differences in hydraulic conductivity. The cone of depression is an ellipse, with greater drawdown updip than downdip. Under pumping rates of 300 gal/min drawdown is sufficient to induce flow from the Schuylkill River into the aquifer, reversing the natural direction of flow. Drawdowns may extend under the river along strike.

In the Brunswick Formation, potentiometric heads were measured during the straddle-packer tests in wells on the Site (BCM, 1991). Vertical gradients between different zones in the wells indicate that groundwater flows vertically as well as horizontally. The wells can act as conduits to increase the degree of vertical connection between the semi-confined units. The direction of flow can be both up and down in a well depending on the distribution of zones in a well. Shallow zones typically have higher heads than deeper zones, resulting in downward flow, but some still deeper zones may have higher heads than intermediate zones, resulting in upward flow. For example, flowing wells occur in the Brunswick Formation across the river in Chester County (McManus, 1990).

The aquifer tests conducted using straddle packers (BCM, 1991) indicated little hydraulic connection between adjacent packed off zones. However, an aquifer such as the Brunswick Formation is difficult to characterize, especially with a few wells, because of the discontinuous facies and a complex network of interconnected fractures. Comparison of the geological and geophysical logs in the RI (BCM, 1993) suggests that while sandstone is more abundant at depth, well-defined beds are difficult to correlate between wells.

Surface Water

The surface drainage from the Site is to the Schuylkill River. No natural streams cross the Site, although there are two storm sewers that discharge to the river, and a drainage swale from the landfill crosses the floodplain (Figure 2). Sprogue Run flows near the northern border of the Site before joining the Schuylkill River downstream of the Site. The Schuylkill River is relatively large, with a drainage area of 1,147 square miles for the stream-measurement station on the Schuylkill River at Pottstown, just upstream of the Site; discharge of the Schuylkill River at Pottstown exceeded 468 cubic feet per second 90 percent of the time for the period of record (USGS, 1992). The southeastern area of the Site is in the 100-year floodplain of the Schuylkill River; 10-year floods are estimated to reach a land-surface elevation of 130 feet above sea level in the Site area (Federal Emergency Management Agency, 1980).

The Schuylkill River forms a series of sharp meanders for several miles downstream beginning with the meander that encompasses the Site. About 5 miles downstream of the Site there is a low-level dam (Vincent Dam) that was constructed in the 19th century for navigation; the dam traps significant quantities of sediment in the pool and is effective in limiting transport of trace metals and possibly organic substances (Yorke et al, 1985).

IV. Contamination

The EPA investigated the Site during 1985; TCE, vinyl chloride monomer (VCM), and trans-1,2-dichloroethylene (trans-1,2-DCE) were detected in elevated concentrations in ground water and based upon these findings as well as earlier characterization, the EPA ordered Occidental Chemical Corporation to conduct an RI in 1988.

Prior to 1988, TCE had been detected in water from deep production and shallow wells in bedrock during groundwater monitoring that Firestone began in 1979. Concentrations of TCE up to 14.5 miligrams per liter (mg/L) were measured in water from production wells in the period up to 1985. Other organic compounds detected in ground water include the volatile organic compounds (VOCs), VCM and trans-1,2-dichlorothelyene. During lagoon and landfill investigations in 1976, organic compounds and metals were identified in the sludge and sediment. Soil sampling showed that the soils near the TCE handling area contained up to 72.7 milligrams per kilogram (mg/kg) of TCE, which resulted in excavation and removal of 898 tons of soil. In 1985, EPA sampling of 4 bedrock monitoring wells and 2 production wells for VOCs, semi-volatile organic compounds (SVOCs), pesticides, metals and polychlorinated biphenyls (PCBs) indicated that TCE, VCM, and other VOCs, and the SVOC bis-(2-ethylhexyl)-phthalate were present in ground water but pesticides and PCBs were not; some metals such as aluminum, arsenic, and chromium were detected in ground water. The EPA 1985 investigation also identified TCE, PCE, trans-1,2-DCE, VCM, ethylbenzene, styrene, bis-(2-ethylhexyl)-phthalate, and other organic compounds in the sediments of the sedimentation pond and earthen lagoons (Figure 2).

The RI conducted by BCM began in 1990, and included assessments of the ground water, earthen lagoon and landfill areas, soil surveys near the TCE-handling area and elsewhere on Site, drainage to Schuylkill River, and the sediments and water in the Schuylkill. Contamination of ground water by TCE, trans-1,2-dichloroelthylene, styrene, VCM, and ethylbenzene was identified as the contamination of greatest concern. Concentrations of these five VOCs in ground water at the Site exceeded the EPA maximum contaminant levels (MCLs) for those compounds in drinking water.

Ground water is contaminated to depths as great as 582 feet, although concentrations of TCE and other VOCs generally are greatest within 200 feet of the surface near the TCE-handling area. In earlier investigations, the soil and shallow bedrock aquifer had been shown to be contaminated by TCE (monitoring wells were drilled to depths of 125 feet or less), but TCE was present in water from production wells that are as deep as 440 feet. In the RI, discrete zones to depths as great as 582 feet were sampled using packers in 10 additional deep bedrock monitoring wells drilled for the RI. Concentrations of TCE in ground water as great as 91 mg/L were measured from producing zones near 77 feet below land surface of one well (TB-3). Although greatest ground water concentrations of TCE were from zones in the upper 200 feet of the aquifer, TCE concentrations of 3 mg/L were measured in water from a zone 500 feet below land surface in a well (TB-1).

Samples for metals analysis were collected from the deepest zone in each well, and none of these samples contained concentrations of metals that exceeded the EPA MCLs for metals in drinking water. However, samples from these deep zones may not represent concentrations at shallower depths. The specific conductance (a measure of dissolved constituents) of the ground water in some of the shallow (less than 200 feet below land surface) zones that contain high concentrations of TCE ranged from 1,000 to 1,200 microSiemens per centimeter, about three times background; elevated concentrations of metals may be present in some of these shallower zones. Arsenic in concentrations greater than the MCL had been measured earlier in a sample from one well.

Water-quality data from the 10 monitoring wells drilled for the RI were used to describe a plume of organic-compound contamination in ground water (see Figure 3) (BCM, 1991 and 1993). The plume is roughly elliptical in shape, and is similar to the pattern of drawdown observed for the pumping tests (BCM, 1991, 1993). The updip well, nearest the river, was apparently free of organic contamination. All other wells contained water with some detectable concentrations of VOCs. The plume was defined under pumping conditions, and may not represent concentrations of organics in ground water under static conditions. The aquifer test and packer sampling were conducted while three of the deep plant production wells were pumping at rates of about 300 gal/min. The extent of contamination in the downdip direction is not well characterized. It is difficult to fully describe the extent of contamination using only 10 wells; specific fractures may carry more contamination than indicated by the estimated plume, which can be important in designing remediation or determining if migration off the Site occurs.

Biodegradation of organic compounds may be occurring in some areas of the ground-water contamination. Measurements of dissolved oxygen were distinctly lower in some of the packed intervals, suggesting a consumption of oxygen by biological processes. Evidence of TCE degradation is the presence of a breakdown product, trans-1,2-DCE, in the ground water. The FS report (1993) states that biodegradation is not a feasible remediation technique because of insufficient nutrients to support the process. A closer analysis of the data may indicate whether biodegradation of TCE or other compounds occurs, could occur, or should be considered.

The RI states that no contamination has moved off the Site in ground water, yet no samples were collected to verify this assumption. There are a few domestic wells very near the Site that were not accounted for in the RI (BCM, 1993). Residential wells across the river in Chester County are in use and some of these wells are along strike (to the northeast) and could be drawing some contaminated water from the Site under the river. Water-table maps suggests that the aquifer continues beneath the sharp bends in the river (McManus, 1990).

Away from the TCE-handling area, water samples from shallow wells in the overburden (weathered bedrock and soil) apparently do not contain consistently elevated concentrations of organic compounds and metals.

Sampling conducted during the RI revealed that sediments from the northern storm sewer outfall contained high concentrations of polycyclic aromatic hydrocarbons (PAHs) (up to 5.8 mg/L total), and sediments from the southern storm sewer outfall contained PAHs at up to 1.7 mg/L and phthalates up to 11 mg/L. Cadmium, chromium, copper, mercury and zinc concentrations were also slightly elevated in the northern storm sewer.

The drainage swale leading from the sedimentation pond contained PAHs in concentrations as high as 99 mg/L. Dibenzofurans were found in two samples, with the highest concentration 1.3 mg/L. Mercury was also identified in a number of samples, with a maximum of 3.1 mg/L recorded. PCBs were found at 0.74 mg/L in the one sample that was analyzed for these compounds.

As mentioned previously, the bedrock aquifer is contaminated with a variety of VOCs including TCE, trans-1,2-DCE, VCM, styrene, and ethylbenzene. The ground water beneath the Site is currently being pumped for use as process water for Occidental's operations. This pumping has prevented migration of contaminants from the bedrock groundwater off the Site, thus eliminating this potential pathway of contamination to the Schuylkill River. Nevertheless, a risk assessment was conducted assuming discharge of both the overburden aquifer and bedrock aquifer to the Schuylkill River, combined with potential contamination from Site runoff, and assuming complete mix with the entire river flow. The resulting projected river contaminant values were 4 to 8 orders of magnitude lower than chronic water quality criteria for the protection of aquatic life.

Unfortunately, this analysis failed to take into account current background Schuylkill River concentrations, which, according to sampling conducted during the RI, already approach or exceed aquatic life criteria for some metals. In addition, if ground water is discharging through the bed of the river, the concentration of contaminants in the interstitial pore water of the sediments could be high enough to cause toxic effects to benthic invertebrates. Although increased concentrations of some metals (copper, silver and zinc) were found in river water samples collected downstream of the Site, the small number of samples makes it impossible to conclusively link the results to Site contamination.

No contaminants of concern were found in sediments from open water areas in the borrow pits (Figure 2).

V. Pathways of Exposure

In the Brunswick Formation, ground water flow can be vertical and (or) horizontal. Because of vertical gradients and pumping of production wells, contamination is drawn down from the surface into deeper zones of the aquifer, resulting in cross-contamination of the aquifer. Deep, open, non-pumping wells can act as conduits for contaminant transport because of vertical gradients between different zones within a well. Recharge through contaminated soils and near surface materials in the unsaturated zone can contribute to ground-water contamination.

Ground-water flow may be greater parallel to strike than in other directions, because the aquifer is anisotropic and hydraulic conductivity commonly is greatest along strike in these types of rocks. The ellipsoidal pattern of drawdown reflects the spatial differences in permeability. Should pumping cease, contaminated ground water may flow to the river or under the river, especially along strike (northeast). Also, because the shallower zone of the aquifer is the most contaminated and probably has better hydraulic connection with the river than the deeper zones, the potential risk associated with transport offsite in these shallow zones may be greater than for the overall aquifer.

Additionally, because TCE, and some of the other organic contaminants are denser than water, TCE may sink and move along bedding in a down-dip direction. Such a pattern of transport was suggested for TCE movement in similar rocks in Gettysburg, PA (Figure 4) (Becher, 1989). TCE may penetrate the more porous sandstone units which appear to be more permeable than the siltstone and shale of the Brunswick Formation.

The earthen lagoon area and drainage swale lie on the 100-year floodplain; some of these areas lie within the 10-year floodplain. Metals and organic compounds present in the sediments and soils in this area could be transported offsite during flooding or in storm runoff.

VI. Proposed Remedial Action

The April 1993 Proposed Remedial Action Plan (EPA, 1993) identifies the selected remedial actions as additional ground water recovery and treatment by air stripping to remove VOCs. The treated ground water would then be used in the PVC production process, after which it would undergo additional treatment before discharge either to the Pottstown sewage treatment plant or the Schuylkill River. The earthen lagoons would be remediated by drying the PVC layers and landfilling the coal fines. The PVC layers will be marketed as reclaimed product. No other areas on the Site were found to be in need of remediation.

The proposed recovery wells are almost all less than 200 feet deep and will replace existing production wells. However, one proposed recovery well (RW-6) is planned to be completed at much greater depths and pumped at 100 gal/min. This well, to be drilled to 540 feet and cased down to 220 feet, will be open to the deep zone of contamination; pumping this well to collect contamination at depth may cause greater downward migration of contamination. Because zones in the Brunswick Formation are not completely confined, contaminants may be transported via vertical hydraulic connections that include other wells. However, if these wells are not pumped continuously, the natural gradient and other pumping wells may cause TCE to move off the Site in ground water.

VII. Concern for Injuries to Trust Resources

We are concerned about the potential risk to migratory birds such as songbirds, wading birds, and others, from ingesting contaminated sediments and water from the sediment pond and drainage swale. PAHs, mercury and dibenzofurans have all been implicated in avian embryotoxicity. In addition, the high concentrations of these compounds in the sediments of this drainage system will constitute a continuing source of contamination to the Schuylkill River long into the future unless they are removed. While past injuries to migratory birds exposed to this contamination have not been documented, the possibility exists.

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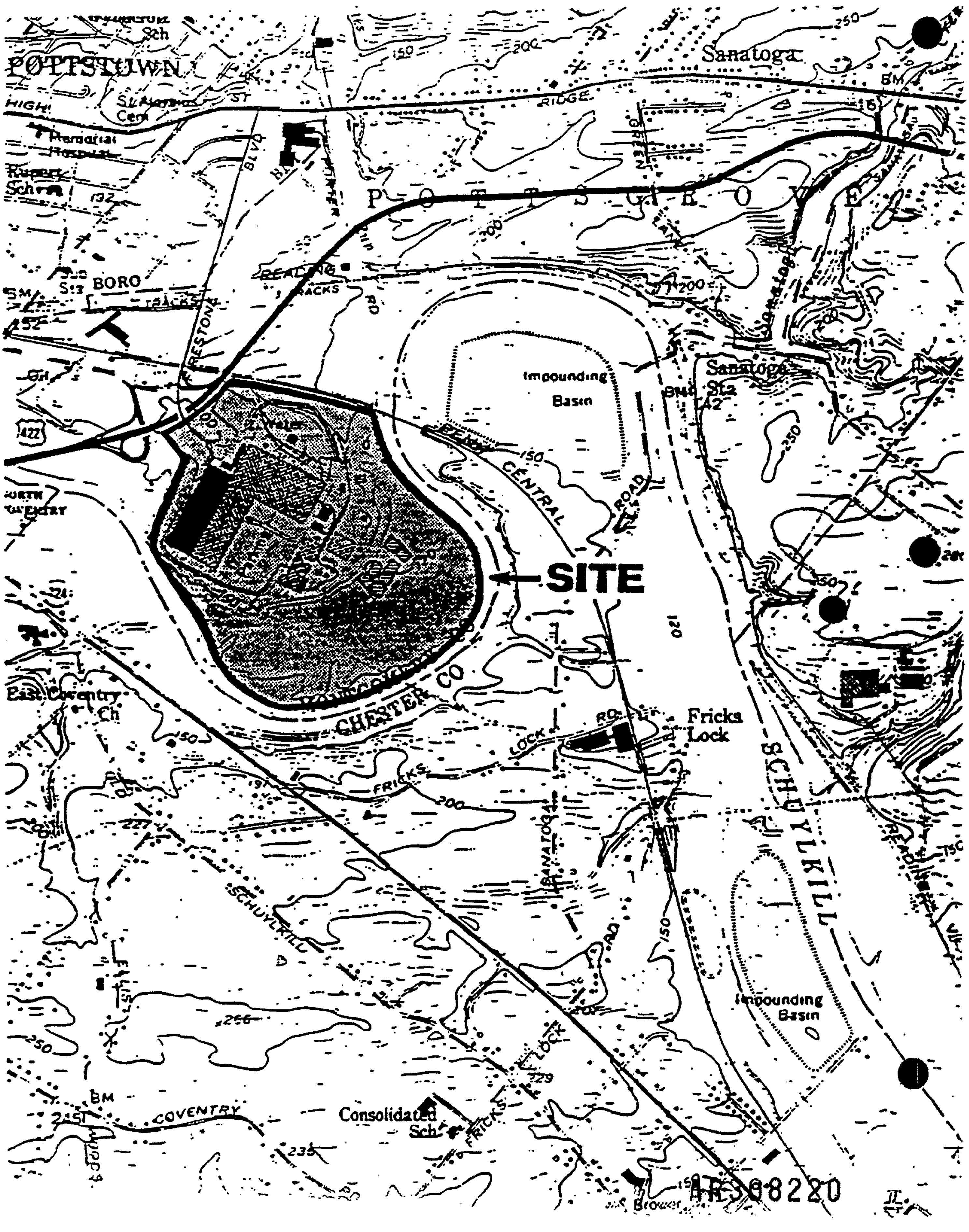
North

FIGURE 1

OCCIDENTAL



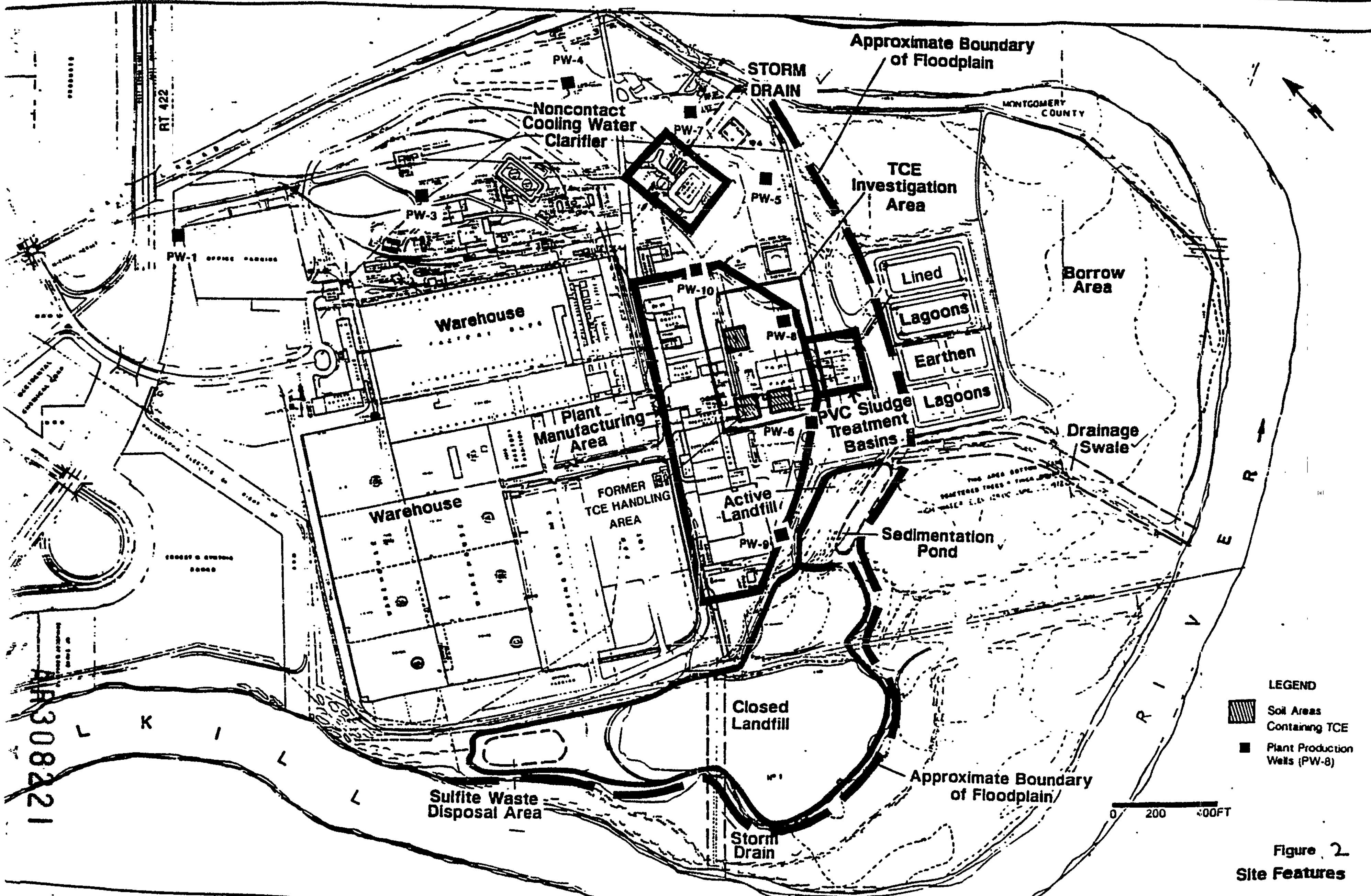
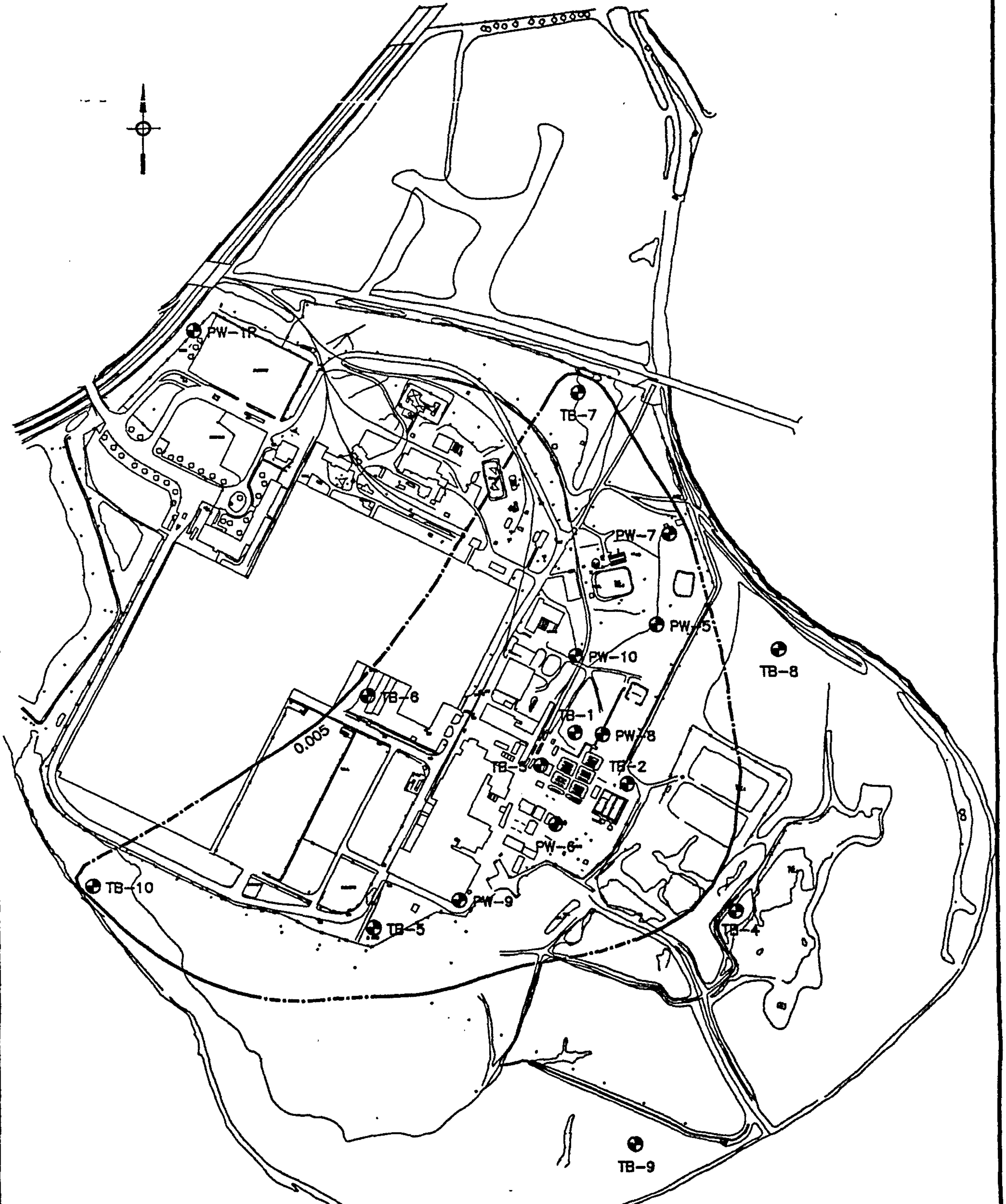


Figure 2
Site Features



LEGEND

⬤ TB-4	Reconnaissance Borehole Location
———	MDL (0.005 mg/l)
—·—·—	PRELIMINARY REMEDIATION GOAL (0.005 mg/l)

AR308222

400 0 200 400 800

Figure 3

Occidental Chemical Corporation

TCE
Isoconcentration
Contour Plot

Remedial Investigation

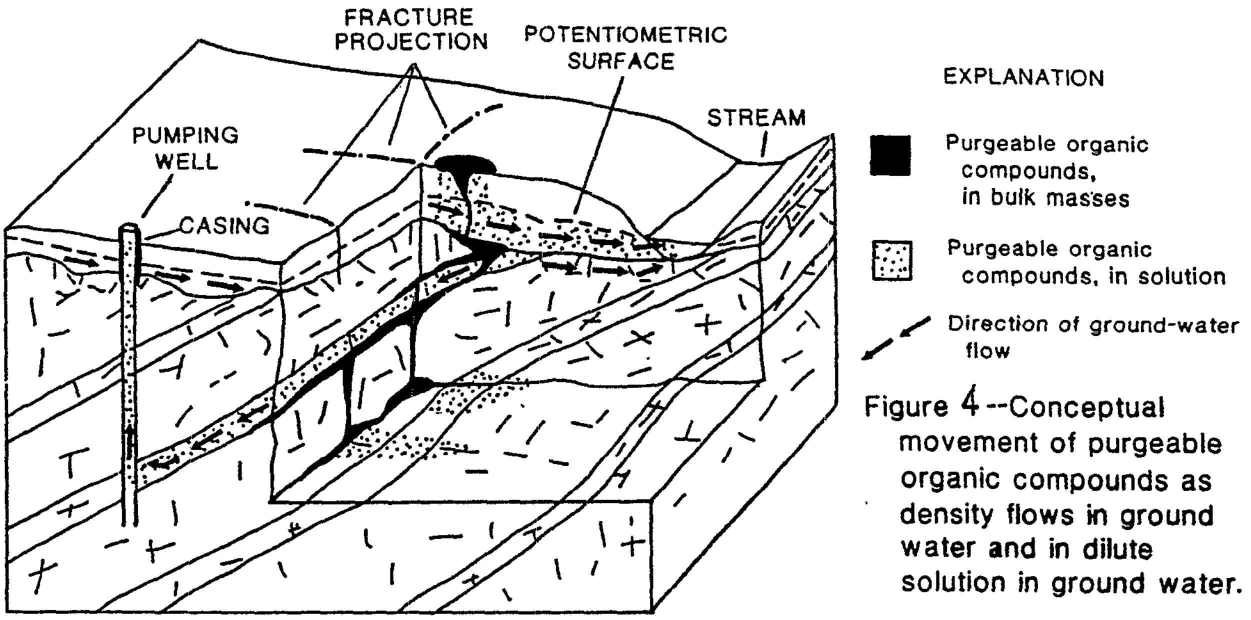


Figure 4--Conceptual movement of purgeable organic compounds as density flows in ground water and in dilute solution in ground water.

(From Becher, 1989)