1-1-1986

Contaminant hydrogeology of solvents, gasoline, and salt

Garrett, P.

Moreau, M.

Williams, J.

TRIP B-6

CONTAMINANT HYDROGEOLOGY OF SOLVENTS, GASOLINE AND SALT

Peter Garrett, Marcel Moreau, and John Williams
Department of Environmental Protection,
Augusta, Maine.

INTRODUCTION

In the last several years, there has been an enormous boost to the study of hydrogeology by the unfortunate need to investigate and clean up chemical spills of one sort or another. On this trip we will be seeing (as far as it is possible to see groundwater) the nature of three very different kinds of spills, and several new and old tools that can be used to further spill investigations. We will also discuss what can be done for unfortunate owners of wells in the paths of plumes, and what lies ahead in terms of prevention and cleanup.

HYDROCARBONS AS GROUNDWATER CONTAMINANTS

Hydrocarbons have been with us for decades. The chlorinated hydrocarbons are commonly known as **solvents** because of their property of dissolving oily materials (for which water's nickname as the universal solvent is not apt). Chlorinated hydrocarbons are the quintessential degreasers, plasticisers, and paint strippers. No doubt they have been improperly disposed of since they were first manufactured, but it was only in the '70s that leaks were discovered to be causing groundwater contamination.

Nowadays, that contamination is known to be nationwide and alarmingly ubiquitous: it may have been for years, but only since about 1980 have chemical analytical techniques been able to detect hydrocarbons down to the parts per billion range.

Chlorinated hydrocarbons are manufactured by substituting a chlorine atom for a hydrogen, somewhere in the chain or ring. This may be done at one location per molecule, as in (mono)chlorobenzene, or at several, as in trichloroethylene. The result is a compound which has a greater specific gravity than its non-chlorinated cousin.

Properties of common hydrocarbons, both chlorinated and not are given in the following table:

Table 1: Some Interesting Properties of Hydrocarbons

Hydrocarbon	solubility in water mg/l (=ppm) @ 20°C	specific gravity	recommended maximum contaminant level (ppb)	odor recog. threshold (mg/cu m)
chlorobenzene	500	1.11	60	1
1,1,1-trichloroethane	4400	1.35	200	400
trichloroethylene	1100	1.46	0	110
tetrachloroethylene	140	1.63	-	50
pentachlorophenol	14	1.98	220	?
2,3,7,8-TCDD (dioxin)	0.00002	-	-	-
benzene	1780	.88	0	0.5
toluene	515	.87	2000	1
xylene	175	.86-.88	440	<1

You will notice that hydrocarbons are far from being insoluble. Some are soluble in water in the parts per thousand range, though considered as a group, their solubilities vary over several orders of magnitude. Because of the extreme insolubility of some (especially dioxin) we can be thankful that they are unlikely to be groundwater contaminants (though they can and do adsorb to soil and sediment particles).

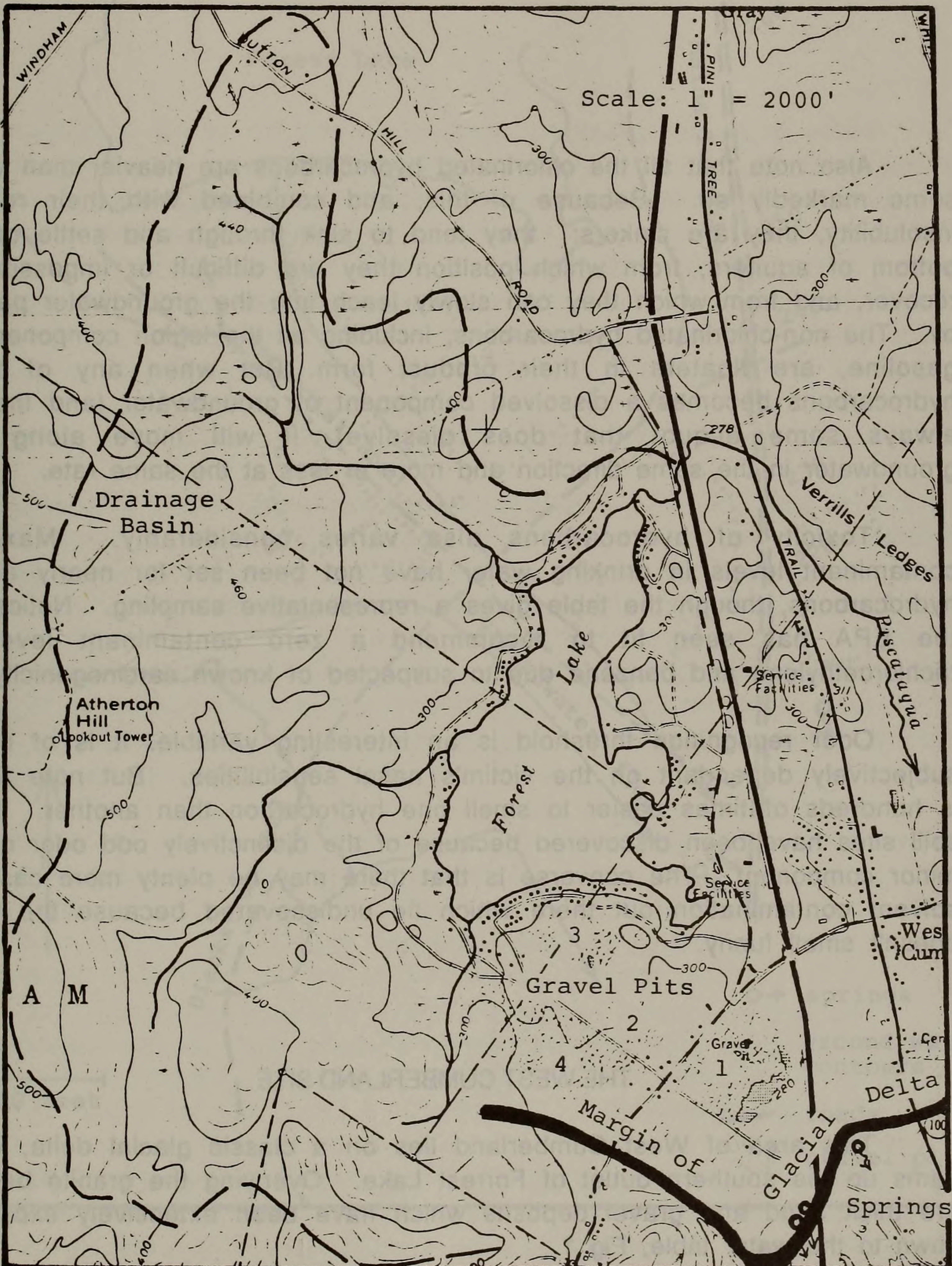


FIGURE 1. West Cumberland site with Forest Lake and its drainage basin dammed by glacial delta sands and gravels. (USGS 7½ minute Quadrangle: Cumberland Center).

Also note that all the chlorinated hydrocarbons are heavier than water, some markedly so. Because of this, and combined with their relative insolubility, they are sinkers: they tend to sink through and settle on the bottom of aquifers, from which position they are difficult or impossible to recover, and from which they can slowly leach into the groundwater passing by. The non-chlorinated hydrocarbons, including all the legion components of gasoline, are floaters in their product form. But when any of these hydrocarbons becomes a dissolved component of groundwater (and there is always some aliquot that does dissolve), it will move along with groundwater in the same direction and more or less at the same rate.

Toxicity of hydrocarbons also varies considerably. Maximum contaminant levels in drinking water have not been set for nearly all the hydrocarbons, though the table gives a representative sampling. Notice that the EPA has seen fit to recommend a zero contaminant level for trichloroethylene and benzene due to suspected or known carcinogenicity.

Odor recognition threshold is an interesting variable. It is of course subjectively dependant on the victim's nasal sensibilities. But note that it is hundreds of times easier to smell one hydrocarbon than another. Some spill sites have been discovered because of the distinctively odd odor of one minor component. The converse is that there may be plenty more cases of solvent contamination out there which lie undiscovered because the water doesn't smell funny.

THE WEST CUMBERLAND SITE

This area of West Cumberland lies on a classic glacial delta, which dams up the southern outlet of Forrest Lake. Overlying the granite bedrock are thick sand and gravel deposits which have been extensively excavated down to the water table, Fig 1.

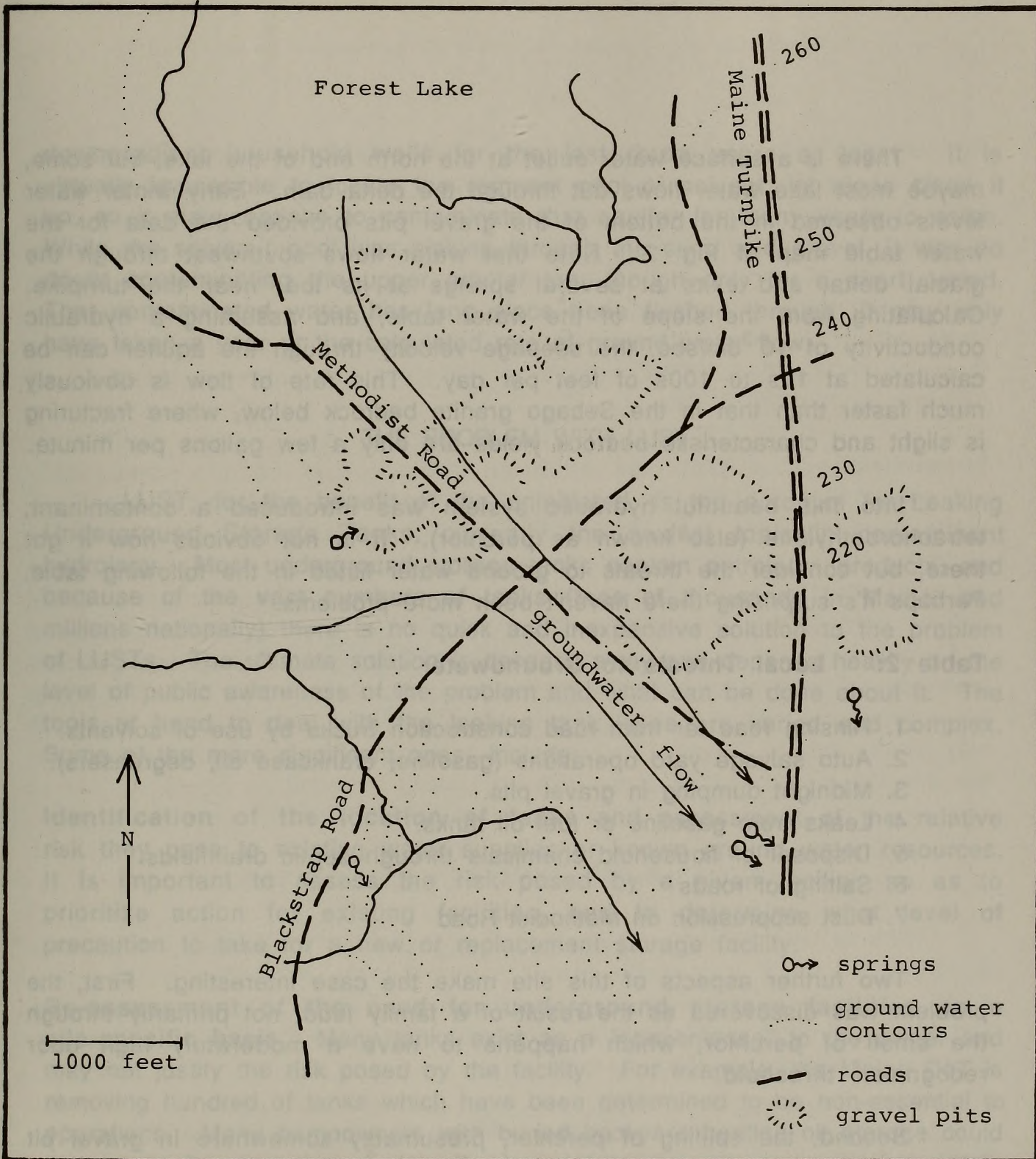


FIGURE 2. West Cumberland glacial delta with superimposed ground water contours. Flow is south-east, from the lake through the sand and gravel to the springs.

There is a surface water outlet at the north end of the lake, but some, maybe most lake water flows out through the delta dam. Early winter water levels observed in the bottom of the gravel pits provided the data for the water table map of Fig. 2. Note that water flows southwest through the glacial delta, and exits at several springs at its toe, near the turnpike. Calculating from the slope of the water table, and assuming a hydraulic conductivity of 10^{-2}cm/sec, the seepage velocity through the aquifer can be calculated at 10s to 100s of feet per day. This rate of flow is obviously much faster than that in the Sebago granite bedrock below, where fracturing is slight and characteristic bedrock yields are only a few gallons per minute.

Into this beautiful hydraulic system was introduced a contaminant, tetrachoroethylene (also known as perchlor). It is not obvious how it got there, but consider the threats to ground water listed in the following table. Perhaps it's surprising there haven't been more problems.

Table 2: Local Threats to Groundwater

1. Rinsing road tar from road construction trucks by use of solvents.
2. Auto salvage yard operations (gasoline, crankcase oil, degreasers).
3. Midnight dumping in gravel pits.
4. Leaks from gasoline or fuel oil tanks.
5. Disposal of household chemicals through septic drainfields.
6. Salting of roads
7. Dust suppression on Methodist Road

Two further aspects of this site make the case interesting. First, the problem was discovered as the result of a family feud, not primarily through the smell of perchlor, which happens to have a moderately high odor recognition threshold.

Second, the spilling of perchlor, presumably somewhere in gravel pit #4 may have taken place many years ago. It could have sunk through the sand and gravel to the top of the bedrock surface, where it continues to leach slowly into the bedrock aquifer giving the same levels of contamination in downgradient household wells for the last three years at least. It is virtually impossible to locate the remnant pool of solvent, let alone clean it up, so it may continue to contaminate that aquifer for many years to come. While the solven t pool was sinking through the sand and gravel, it was no doubt contaminating the upper aquifer too, though only for a short period. That contaminated water has long since been flushed through: it may only have taken a year at the calculated rate of ground water flow.

THE PROBLEM WITH LUST

LUST, for the benefit of the uninitiated, is the acronym for Leaking Underground Storage Tanks, currently the sexiest topic in contaminant hydrology. Most underground storage tanks contain petroleum products, and because of the vast numbers of tanks (tens of thousands in Maine, and millions nationally) there is no quick and inexpensive solution to the problem of LUSTs. The ultimate solution is decades away and depends heavily on the level of public awareness of the problem and what can be done about it. The tools at hand to deal with the leaking tank issue are varied and complex. Some of the more significant ones include:

Identification of the location of tanks and assessment of the relative risk they pose to existing water supplies or known ground water resources. It is important to assess the risk posed by a given facility, so as to prioritize action for existing facilities, and to determine what level of precaution to take for a new or replacement storage facility.

Re-assessment of the need for underground storage facilities on a site-specific basis. Many tanks exist as a "convenience" to the owner and may not justify the risk posed by the facility. For example, the Maine DoT is removing hundred of tanks which have been determined to be non-essential to operations. Many homeowners with buried backyard heating oil storage could just as easily store their fuel in the basement.

Implementation of state-of-the-art technology for new facilities. Corrosion has been a prime cause of storage facility failures in the past. Fiberglass and corrosion-protected steel tanks can effectively deal with corrosion. Double wall tanks and dual containment storage systems can prevent future ground water contamintaion by detecting problems before they affect the environment. Training and certification of the people who must install this new technology is also important. Old skills and practices must be refurbished so that the new technology is properly installed and performs according to plan.

Formulation of a plan for existing tanks. It is neither economically nor practicalbly feasible to replace all existing storage systems overnight. While assorted early leak detection tools are available, including inventory of tank contents, ground water monitoring wells, precision tank testing, and assorted electronic monitoring devices, no method is perfect, and every method only detects a leak after it has occurred. In many cases, especially in Maine's bedrock aquifers, even a very small leak can cause very significant problems. One strategy might be to replace tanks before they leak, but try to convince a tank owner that a storage facility must be replaced even though it may not be leaking — yet! To get an idea of the range of possible options on this one issue, take a look at an EPA worksheet, reprinted as Fig. 3.

SALT AS A GROUND WATER CONTAMINANT

Salt is very soluble. Salt water is also heavy, so it sinks through the aquifer: therefore it is more likely to contaminate drilled wells than dug wells. Also it is not very toxic except for sensitive folks (who perhaps should be drinking distilled water anyway). These things make salt a very different contaminant from hydrocarbons.

In the sixties, Maine relied on the spreading of pure salt for winter highway maintenance. This salt was stored under cover, so the storage wasn't a threat to groundwater, though the spreading was. In 1968, salt use on roads reached a peak of 100,000 tons per winter: contaminated roadside

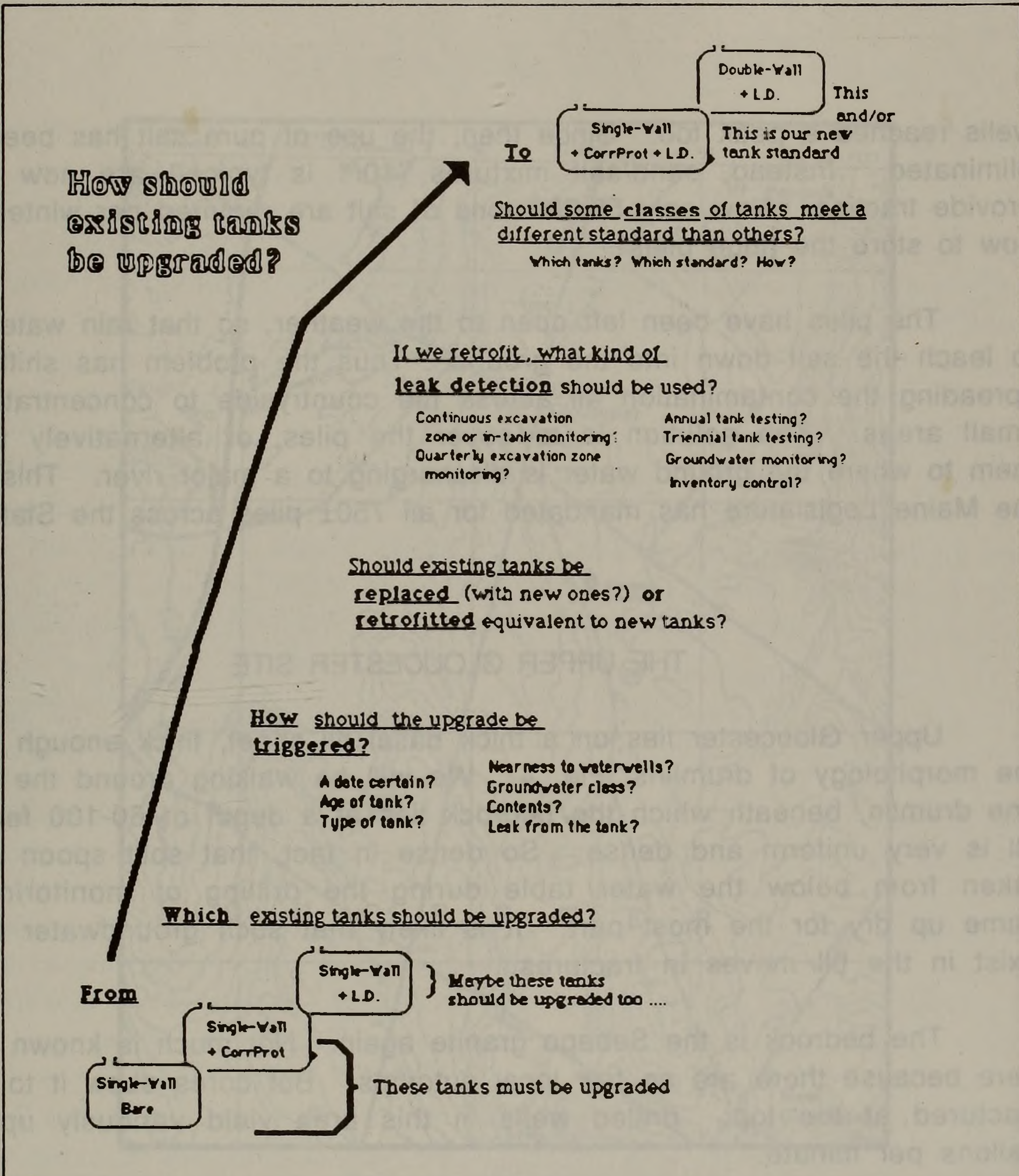


Figure 3. EPA worksheet dated 6/86, discussing what needs to be done about existing underground petroleum storage tanks.

wells reached a peak too. Since then, the use of pure salt has been nearly eliminated. Instead, sand/salt mixtures (10/1 is typical) are now used to provide traction. Now only 50,000 tons of salt are required per winter. But... how to store the huge piles?

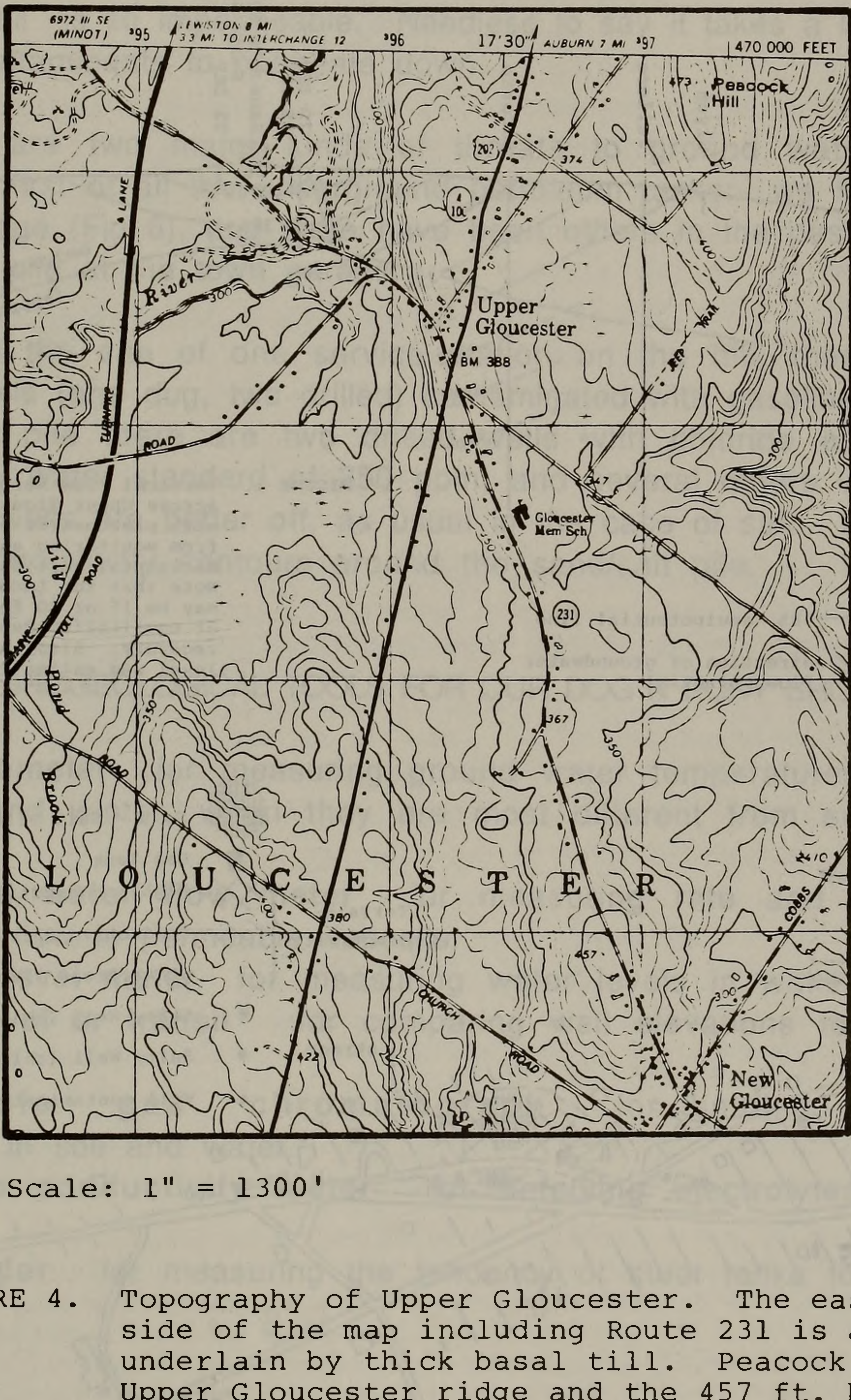
The piles have been left open to the weather, so that rain water is free to leach the salt down into the ground. Thus the problem has shifted from spreading the contamination all across the countryside to concentrating it in small areas. The solution is to cover the piles, or alternatively to move them to where the ground water is discharging to a major river. This is what the Maine Legislature has mandated for all 750± piles across the State.

THE UPPER GLOUCESTER SITE

Upper Gloucester lies on a thick basal till sheet, thick enough to show the morphology of drumlins, Fig. 4. We will be walking around the crest of one drumlin, beneath which the bedrock lies at a depth of 60-100 feet. The till is very uniform and dense. So dense in fact, that split spoon samples taken from below the water table during the drilling of monitoring wells came up dry for the most part: It is likely that such groundwater as does exist in the till moves in fractures.

The bedrock is the Sebago granite again. Not much is known about it here because there are so few local outcrops. But cores show it to be well fractured at the top: drilled wells in this area yield variously up to ten gallons per minute.

The water table in Upper Gloucester is up close to the ground surface, a fact which has allowed the development of dug wells throughout the village. But because Upper Gloucester is located on a hill top, the hydraulic gradient is predominantly downwards. This is shown schematically in Fig. 5. We will observe an astonishing 8-9 ft head difference over a 50 ft vertical spacing of monitoring well piezometers. This of course is only possible



Scale: 1" = 1300'

FIGURE 4. Topography of Upper Gloucester. The east side of the map including Route 231 is all underlain by thick basal till. Peacock Hill, Upper Gloucester ridge and the 457 ft. hill in New Gloucester are all interpreted as drumlin landforms.

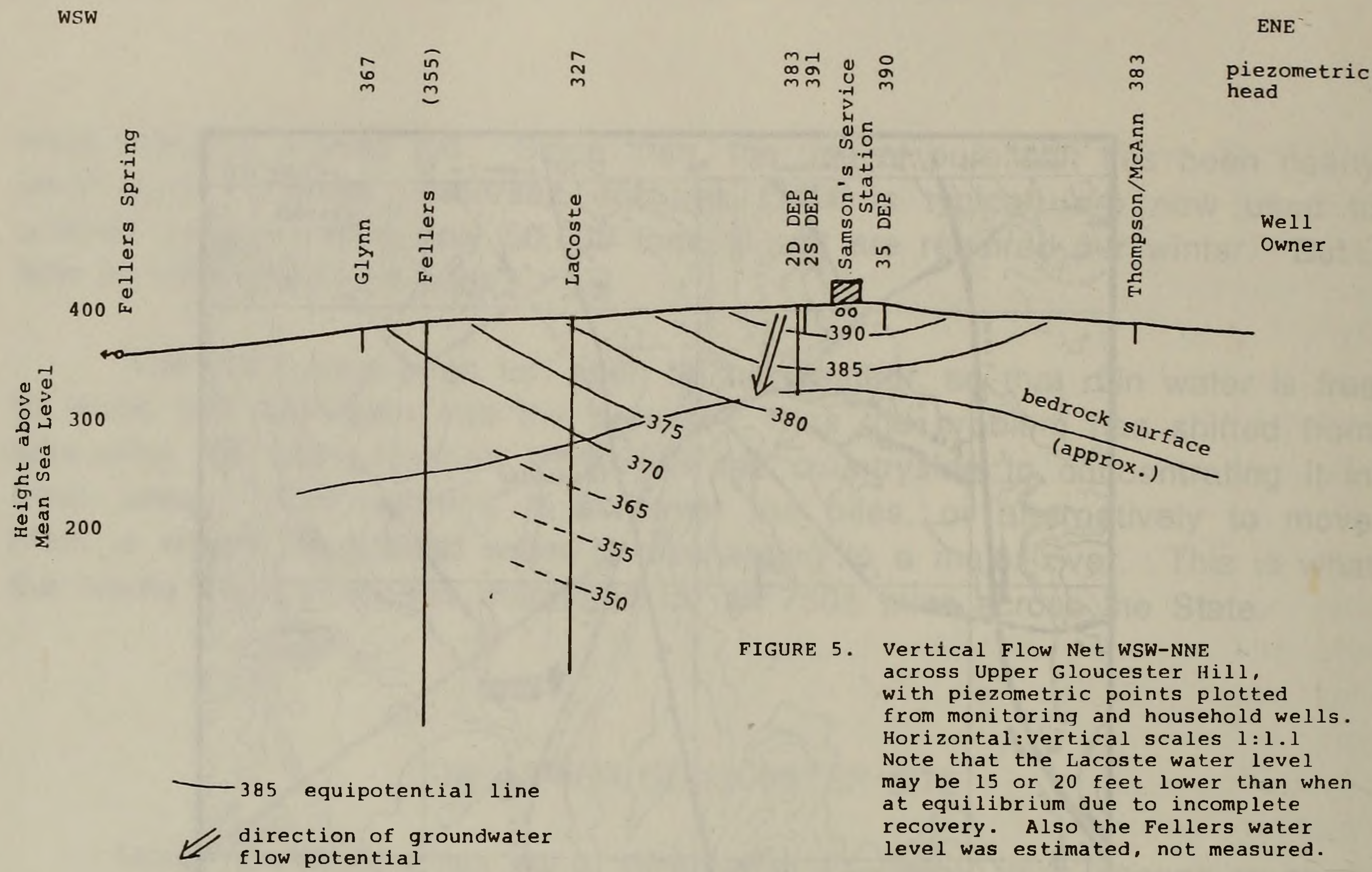


FIGURE 5. Vertical Flow Net WSW-NNE across Upper Gloucester Hill, with piezometric points plotted from monitoring and household wells. Horizontal:vertical scales 1:1.1 Note that the Lacoste water level may be 15 or 20 feet lower than when at equilibrium due to incomplete recovery. Also the Fellers water level was estimated, not measured.

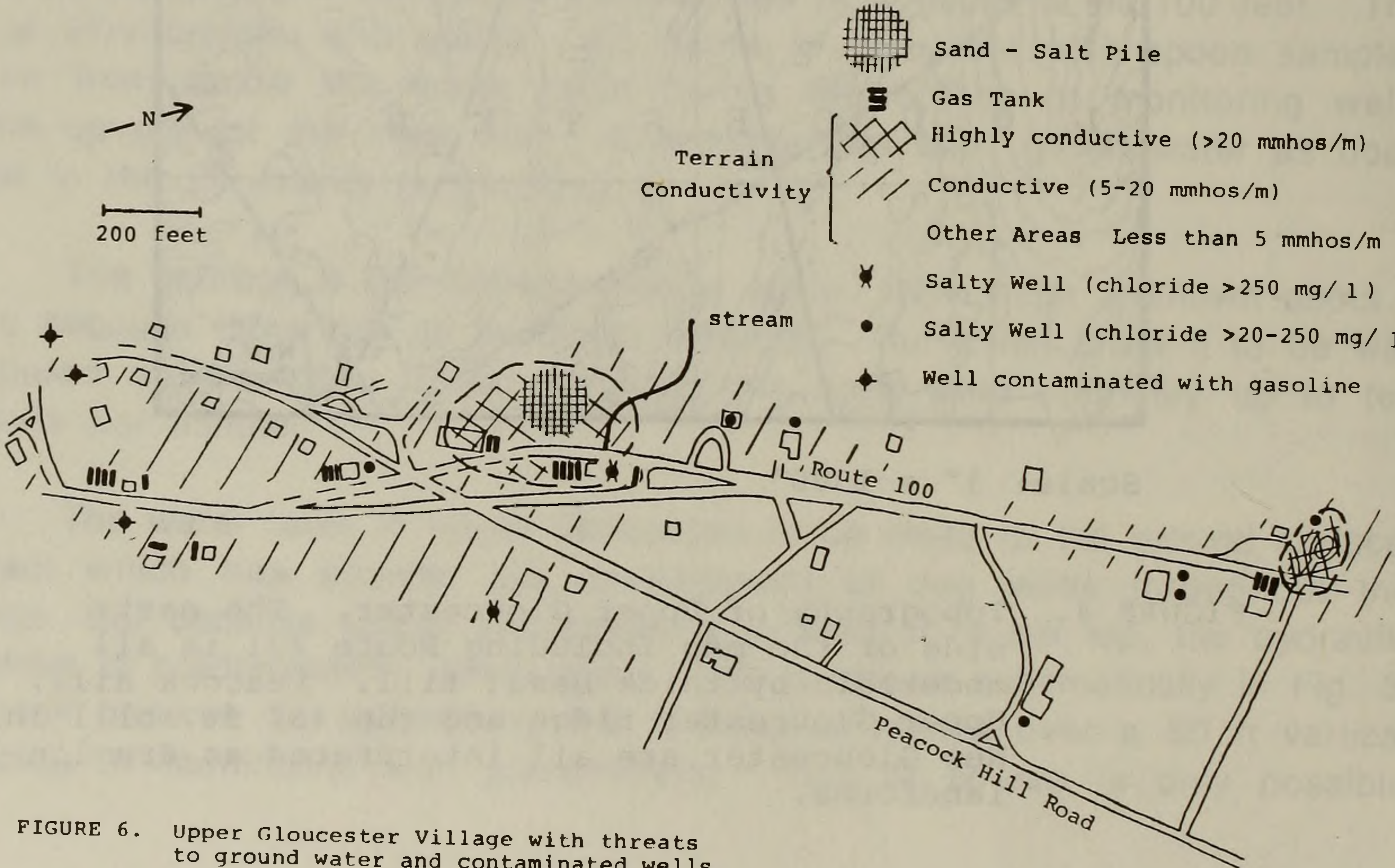


FIGURE 6. Upper Gloucester Village with threats to ground water and contaminated wells.

because the till is so impermeable. Needless to say it takes a long while for water and contaminants to permeate down.

There are two major kinds of threats to ground water in Upper Gloucester. First of all the underground petroleum tanks: we have counted 20 in the village (Fig 6), and there have been others in the past. Secondly, the sand/salt pile at the town garage.

Around the site of one service station on the hill, there are three household wells (one dug, two drilled) contaminated with gasoline. And near the sand/salt pile there are two drilled wells with chloride exceeding the State drinking water standard of 250 ppm, and several others with elevated levels. Dug wells are better off, as usual in the case of salt. Fig. 6 shows the terrain conductivity contours around the sand/salt pile.

HYDROGEOLOGICAL TOOLS FOR OUR DOG 'N PONY SHOW

Thermometer for measuring ground water temperatures, especially in summer and winter, when they are most different from surface water temperatures.

Ground water flow meter for measuring rate and direction of ground water flow in permeable deposits.

Water level meter for measuring water levels in wells.

Pop level or transit for comparing well elevations to a common datum.

Portable gas chromatograph for sniffing out volatile contaminants in soil and water.

Terrain conductivity meter for detecting electrolytes like salty water.

Voltmeter for measuring the tendency of steel tanks to corrode in soil.

REFERENCES

There aren't any, except in the files of the Maine Department of Environmental Protection. Contaminant hydrogeology is a rapidly evolving science. Even Freeze and Cherry's "Groundwater", published in 1979 makes no mention of chlorinated hydrocarbons as groundwater contaminants. So for further reading on the subject in general, we urge the perusal of current issues of Ground Water, the Ground Water Monitoring Review, and the proceedings of specialist conferences.

ITINERARY

take Maine Turnpike to Gray Exit (#11). Start trip counter at the booth.

0.0 Turn right on Route 202 into Gray, and at the light, turn right south on Route 100.

5.2 At amber flashing light, turn right onto Blackstrap Road, cross over the turnpike, and turn into the Blue Rock pit (#1 on Fig. 1) at **5.7**, where we will park for our walkaround of the West Cumberland site.

return to Route 100 (red light now) at **6.2** Turn left (north). Start counting the number of underground tanks along the way. You can recognise them by the vent pipes with funny little **V** or **T** caps, at the side of service station or other facility buildings.

18.9 Look for big brick Mason's Lodge. This is where we park for our walking tour of Upper Gloucester.