ROGER LOWE ASSOCIATES INC.
EARTH SCIENCES

August 12, 1980

Union Oil Company of California
2901 Western Avenue
Seattle, Washington 98121

Attention: Mr. A. L. Barone

Geotechnical Recommendations & Considerations
Monitoring & Recovery Operations for
Gasoline Spills
RLAI Project No. 197-06

Gentlemen:

This letter transmits three copies of our "Geotechnical Recommendations and Considerations, Monitoring and Recovery Operations for Oil Spills." Union Oil originally requested this information during a meeting on June 24, 1980. This report was included as a portion of our professional services as described in our "Confirmation of Agreement and Recommendations for Monitoring" dated June 26, 1980.

The recommendations provided herein are based on our review of available literature and on our experience gained following the gasoline spill at Westlake Avenue and Mercer Street in Seattle, Washington. Our recommendations are intended to be applicable to any gasoline spill in porous soil where the gasoline migrates downward to the water table. However, each site where a spill occurs will have its own unique problems, and modifications of some of our suggestions will undoubtedly be necessary on a case by case basis.

It is our understanding that the discussions provided herein will be used by Union Oil to prepare a general procedures manual regarding gasoline spill prevention and mitigation. We have not included discussion of problems or procedures related to safety or vapor detection, which we understand will be addressed by Union Oil.

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It has been a pleasure to serve you on this project. Please call us if you have any questions regarding our report or if we may be of additional service.

Yours very truly,
ROGER LOWE ASSOCIATES INC.

James A. Miller

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Senior Geologist

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GEOTECHNICAL RECOMMENDATIONS AND CONSIDERATIONS
MONITORING AND RECOVERY OPERATIONS FOR GASOLINE SPILLS

INTRODUCTION

Gasoline spills can occur in a great variety of geological environments, and the size and rate of spills can vary widely. Consequently, precise instructions for monitoring and recovering gasoline following a spill is not possible. The information contained herein is intended to apply to most gasoline spills where gasoline has entered porous subsurface soils and reached the water table.

We developed the information presented in this report from our experience gained following the gasoline spill at Westlake Avenue and Mercer Street in Seattle, Washington, and on a review of several technical publications. Two of the more pertinent publications are cited at the end of this report.

A general discussion regarding the fate of hydrocarbons in the subsurface, including recovery operations where the hydrocarbon is absorbed by the soil before it reaches the water table, is presented in API Publication No. 4149 (American Petroleum Institute, 1972). This report is intended to augment Publication No. 4149.

GENERAL BACKGROUND

When gasoline is spilled on the surface of the ground or underground, two primary forces act on the fluid. Gravity acts to draw the fluid downward from higher elevation to lower elevation along the path of least resistance. Simultaneously, capillary (pellicular) forces tend to hold a portion of the gasoline on the surfaces and along contact points between the solid particles which comprise the subsurface soil or rock material. When liquid gasoline migrates through porous materials, a portion of the gasoline is retained in the soil mass by capillarity.

Downward gravity flow of gasoline within porous materials will continue until the fluid encounters layers or lenses of relatively impervious material, until the gasoline reaches the water table, or until all of the available fluid is held by capillarity within intergranular spaces in the subsurface material. When a relatively impervious surface is encountered by downward migrating gasoline, most of the gasoline will be directed laterally in the downslope direction along the impermeable interface (depending on the permeability ratio of the two materials, a portion of the gasoline will enter the relatively impervious material and flow through it). When the gasoline encounters the water table, the gasoline will float on top of water interface and flow downslope parallel to the direction of groundwater flow and the slope of the water table. A relatively small amount of the gasoline will dissolve in the water, but most will remain separated due to the immiscibility and density differences of the two fluids.

The migrating gasoline will follow the path of least resistance along natural or artificial avenues of higher permeability. The rate of gasoline migration as well as the path is related to soil permeability.

In general, fine-grained soils such as silt or clay would be expected to retain a relatively large percentage of gasoline by capillarity, and gasoline would migrate slowly within these soils. Coarse-grained sand or gravel soils, however, are capable of rapid intergranular fluid movement and will hold a relatively small fraction of gasoline permanently.

In urban areas, the most convenient path of travel for the gasoline is frequently a trench which is backfilled with imported sand and gravel or loosely compacted native soil. It is quite possible, for instance, that gasoline may travel only a few feet into silt or clay native soils, while at the same time, the gasoline may migrate several hundred feet within the sand and gravel backfill in a utility trench.

INITIAL DATA COLLECTION AND ANALYSIS

When a spill occurs, a leak is detected, or gasoline is found in groundwater, the immediate problem is to determine the boundary of the spill in the subsurface. It is also important that the source of the spill be located, and, if possible, an estimate of the volume of spill should be developed from available records.

Once a spill occurs or is detected, speed is important in determining the extent of the spill in the subsurface, particularly if sand or gravel soils occur in the vicinity of the spill or if a groundwater aquifer is threatened with contamination. A geotechnical consultant should be retained for expert advice for all large spills or spills in environmentally sensitive areas.

The boundary of the gasoline in the subsurface can be determined by drilling monitor wells in the vicinity of the spill. The monitor wells should extend at least 5 feet to 10 feet below the water table. A small diameter (2") slotted plastic pipe should be set to the bottom of each well, and the lower portion of the drill hole should be backfilled with coarse sand or pea gravel so that subsurface fluids have easy access to the well casing.

After completion of each monitor well, the elevation of the top of each well casing should be determined to an accuracy of 0.01 feet using an established, stable datum or local benchmark. The plan locations of each well also should be surveyed to an accuracy of 0.5 feet and a site map should be prepared showing pertinent physical features, the location of each well, and the site of the spill. Accuracy is very important in correctly establishing the water table conditions and evaluating the direction of fluid movement.

When the well casing has had one or more hours to equilibrate after installation, the casing should be "stuck" for the presence of liquid gasoline using water finding paste (or other appropriate water level recording devices), and the upper portion of the well casing should be tested for hydrocarbon vapors with an explosimeter. If liquid gasoline is detected in a monitor well, an additional monitor well should be drilled a greater distance from the spill site.

Sufficient wells should be drilled to plot the limits of the spill in the subsurface with reasonable accuracy. In general, a minimum of 10 monitor wells will be necessary to establish the subsurface boundary of a spill. The number and location of the wells should be related to the local geology or construction history in the area. Expert advice from a geotechnical consultant should be obtained in planning the locations of monitor wells.

When several wells have been drilled and the water levels have equilibrated in each, the "effective" water table elevations should be determined and plotted on the site map. The "stick" data from the monitor wells will include the depth to the water level from the top of the casing and the thickness of gasoline which is floating on top of the water. The "effective" water table elevation can be calculated using the following equation:

$$W_e = E - D + (T)(G),$$ where

W_e = Effective water table elevation

E = Elevation of top of well casing

D = Depth from top of well casing to water level, as indicated by water-finding paste

T = Thickness of gasoline above the water/gas interface

G = Specific gravity of gasoline (usually about 0.6)

The calculations are facilitated if all measurements are in feet and decimal fractions of a foot.

Once the effective elevation of the water table is plotted for all monitor wells, the data can be contoured to determine the slope of the water table. Gasoline floating on the water table will generally travel downslope perpendicular to the orientation of the water table contour lines. The contour map therefore can be used to predict the direction of gasoline migration.

If the water table is fairly shallow, or if there are relatively impermeable soils in the spill area, utility trenches in the spill area should be tested for the presence of gasoline. The trenches can be tested by excavating test pits at selected locations, or monitor wells can be drilled within the utility trench backfill adjacent to the conduit. (The latter method would require very accurate information on conduit location, which often is not available).

Relatively undisturbed core samples of the subsurface soil or rock should be obtained for most, or all, of the monitor wells. The core samples will allow visual examination and classification of subsurface materials, and some of the samples can be tested to determine their moisture content, density, void ratio, particle size distribution, organic content, or permeability (as appropriate).

GASOLINE RECOVERY

Once the base line data on the extent of the spill and water table slope have been developed, one or more gasoline recovery wells should be constructed. If possible, the recovery wells should consist of large diameter (24" to 36") casing which is slotted or perforated. The base of the recovery wells should extend at least 6 feet below the water table, and the backfill outside the well casing should consist of washed gravel or pea gravel.

For areas of shallow water table, the recovery wells can be constructed by excavating a trench, installing the well casing, and backfilling the trench with gravel. The larger the trench, the more effective the well will be in recovering gasoline. Recovery wells in areas with a deeper water table may have to be constructed using a bucket auger or traditional well drilling equipment. As for the monitor wells, the rim elevation and location of the recovery wells should be surveyed and plotted on the site plan.

Where shallow water table conditions apply and a large diameter well casing is used, it is possible to pump water and gasoline separately and simultaneously from the well. Water can be withdrawn from the well using a submersible pump with the drawdown controlled manually or by automatic detectors. The gasoline can be removed by separate skimming units which float on the fluid surface inside the well casing. If the skimming units are operated by a vacuum lift, it may not be possible to use the units where the depth to the water table is great. In this case, a single pump may have to be used to pump gasoline and water, and the liquids would have to be separated later.

When fluid is withdrawn from a well, the liquid level in the well drops in rough proportion to the rate of pumping. As a result of pumping, a "cone of depression" is formed on the surrounding water table, and the slope of the water table outside the well becomes directed toward the well. It is desirable to generate a cone of depression for two reasons:

1. Since floating gasoline travels in the direction of the slope of the water table, the cone of depression will cause the gasoline to flow toward the recovery well and thereby increase the rate of hydrocarbon recovery.

2. Once the cone of depression spreads beyond the boundary of the spill, the migration of gasoline should be contained and further movement by gravity away from the spill site should not occur.

It may be necessary to construct two or more recovery wells to develop cones of depression which extend beyond the limits of the spill.

Once pumping operations have begun, it is important that accurate records be maintained to evaluate the effectiveness and completeness of the recovery operation. At a minimum, the following should be recorded:

1. "Stick" readings of water and gasoline levels in the monitor wells and pumping wells should be recorded once every four hours at the start of the pumping cycle. This data is used to monitor the spread of the cone of depression. After about two days the time interval between readings can be increased to once every 12 hours. Reading intervals can be gradually increased during the recovery program, and eventually readings once a week may be sufficient.

2. It is very important that a daily and running total of gasoline recovery be maintained on a time chart. Normally the daily rate of gasoline recovery will decline as a logarithmic function of time. Therefore, it is possible to plot the recovery/time data on a semi-log plot and project the length of time which will be required for the recovery program as well as the total volume of gasoline recoverable by pumping.

3. A daily site log should be maintained which documents site activities, times of pumping, equipment malfunctions or calibrations, and other occurrences which may affect the recovery operation.

Using laboratory testing techniques on soil samples collected from the spill area, it is possible to estimate the total quantity of gasoline which will be recoverable by pumping. However, the necessary calculations often are seriously in error. The best method of predicting the volume of gasoline recoverable and the time of the required recovery period is to use the gasoline recovery/time chart discussed above (with total gasoline recovery plotted on an arithmetic scale and time in days since start of pumping plotted on a logarithmic scale). Generally, a full log cycle of data (10 days) should be obtained before attempting extrapolation of the data. Pumping during the initial period of data collection should be relatively constant. Obviously, accurate and timely data is extremely important to successful use and extrapolation of the recovery/time curve.

As discussed previously, only a fraction of the volume of gasoline spilled will be recovered by pumping. In most cases 20 to 80 percent of the spill volume will be retained in the soil by capillary forces, depending on soil type and the depth to the water table. Eventually, the gasoline left in the soil will dissipate by evaporation and consumption by aerobic bacteria. Two years or more probably will be required for complete dissipation (McKee, et al, 1972).

In some cases additional liquid gasoline can be recovered by allowing the water table to rise and flush gasoline out of soil pore spaces. However, laboratory studies (McKee, et al, 1972) indicated that once gasoline is held in capillarity by soil, water flushing has little effect in freeing the gasoline. If flushing is attempted the water table can rise naturally due to seasonal variations in precipitation, by periodically shutting off the water level drawdown pumps, or by injecting water into the ground. If water injection is done, the point(s) of injection should be outside the boundary of the spill so that the change in water table slope caused by injection does not force some of the gasoline to migrate farther away from the recovery well.

Yours very truly,
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REFERENCES CITED

American Petroleum Institute, 1972, The Migration of Petroleum Products in Soil and Ground Water: API Publication No. 4149, 36 p.

McKee, J.E., Laverty, F.B., and Hertel, R.M., 1972, Gasoline in Groundwater: Journal Water Pollution Control Federation, Vol. 44, No. 2, p. 293-302.