SITE CHARACTERIZATION AND CORRECTIVE ACTION PLAN WILLIAMS ALASKA PETROLEUM, INC. NORTH POLE REFINERY

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SITE CHARACTERIZATION AND CORRECTIVE ACTION PLAN
WILLIAMS ALASKA PETROLEUM, INC., NORTH POLE REFINERY

1.0 INTRODUCTION

Williams Alaska Petroleum, Inc., operates a petroleum refinery near North Pole, Alaska (formerly operated by MAPCO Alaska Petroleum, Inc.), that receives crude oil from the Trans-Alaska Pipeline system and produces a variety of petroleum distillate products. The refinery occupies about 80 acres of an approximately 240-acre site in Section 16, Township 2 South, Range 2 East, Fairbanks Meridian. The site is leased from the State of Alaska.

This report presents information regarding our understanding of subsurface hydrology and geology at the refinery, historical contaminant concentrations, and preventive measures in place to minimize soil and groundwater contamination. We also provide the most recent available information about the types of soil and groundwater contamination present, the estimated extent of the groundwater benzene plume, trends in benzene concentration at various refinery locations, the current extent of the subsurface NAPL, and amounts of product recovered from the subsurface. This report includes a conceptual site model illustrating the contaminant extent, as well as a contaminant pathway analysis to assess the potential risk of exposure to contaminants attributable to refinery operations.

Finally, we present a Corrective Action Plan and long-term monitoring schedule in Section 7.0, which details the types and frequency of measurements to be made at various locations around the refinery. We include a current list of all monitoring, observation, and recovery wells at the facility, as well as a description of their functions at the refinery. A listing of previous site characterization and remediation activities at the refinery through 1999 is provided in the appendix to this report.

1.1 Background

Williams has reported, and the Alaska Department of Environmental Conservation (ADEC) has documented, a variety of oil spills attributable to operations at the refinery. These spills have resulted in light non-aqueous phase liquid (NAPL) floating on the water table, hydrocarbons sorbed to the soil under the facility, and an associated dissolved hydrocarbon plume. Since 1986, the refinery has been operating under an ADEC-issued Compliance Order by Consent (COBC) that required (among other things): reactivation of existing, and installation of additional, collection wells as needed to recover free NAPL; installation of twenty monitoring wells around the perimeter of the facility to monitor migration of NAPL and the dissolved hydrocarbon plume; monthly sampling of all on-site drinking water wells; and expansion/modification of the on-site wastewater holding pond (Lagoon B). Monthly sampling of on-site drinking water wells is no longer performed, as the refinery is now supplied with North Pole municipal drinking water. Since 1995, ADEC oversight at the refinery has focused on recovery of NAPL, treatment of water produced by recovery operations prior to re-injection, and monitoring of NAPL and groundwater plumes.

In 1989, the United States Environmental Protection Agency (EPA) issued the refinery Administrative Orders on Consent, requiring completion of a RCRA Facility Assessment (RFA), performance of an Interim Measures program (to remove hazardous waste from Lagoon B, Tank 192, and Sumps 901, 905, 909-B, and 05-7), completion of a RCRA Facility Investigation (RFI), and completion of a Corrective Measures Study (CMS).

The EPA has determined the Williams Refinery has obtained clean closure on the units subject to the consent orders, and now needs to develop a facility-wide corrective measures plan. The overall plan is to consist of a site characterization review, development of intermediate- and long-term corrective action plans, and institutionalization of the corrective action plan by a new COBC. Site characterization review entails defining the nature and extent of existing soil and groundwater contamination by NAPL and dissolved hydrocarbons, as well as defining the nature and extent of any changes in hydrogeology at the site.

In our December 2000 report (*Draft Site Characterization and Corrective Action Plan, Williams Alaska Petroleum, Inc., North Pole, Alaska*), we reviewed contaminant data available from previous investigations at the facility to characterize current conditions and assess changes in contamination and hydrogeology at the site. Various reports written in response to the EPA Consent Orders (e.g., RFA Report, September 1988; Description of Current Conditions, April 1989; RFI Report, October 1, 1990) described subsurface geology and hydrology as well as the nature and extent of contamination at the site up to 1990. In the course of reviewing the historical site data, Shannon & Wilson identified a number of analytes in groundwater and soils that had been present at concentrations greater than the established cleanup levels as of the latest sampling events. We designated those analytes present at the refinery above applicable groundwater or soil cleanup levels as "contaminants of interest" (COIs). However, many of the analytes had been detected in samples collected more than 10 years ago, and we did not consider those data sufficient to characterize the current nature and extent of contamination at the site.

In addition to reviewing the refinery's historical contaminant data for the December 2000 report, we also completed an inventory of the wells present at the refinery. With an accurate list of the refinery's wells in hand, we assessed their value for tracking groundwater contamination, NAPL presence, variations in seasonal groundwater table and gradient, and groundwater geochemistry for hydrocarbon natural attenuation potential. Based on the historical contaminant data review and the evaluation of the refinery's wells, we recommended a long-term sampling program for dissolved hydrocarbons and NAPL, and interim measures to fill data gaps in our knowledge about the type and distribution of environmental contaminants at the refinery. These recommendations were presented in a brief letter report to Williams (*Monitoring Program, Williams Alaska Petroleum, Inc., North Pole Refinery*), dated April 20, 2001. Other recommendations in that report included:

- surveying the refinery's major features and well locations to update the base map of the facility,
- obtaining elevation data for several wells for determining future variations in groundwater direction and gradient,
- measurement of groundwater geochemistry to assess the contribution of naturally occurring microbial populations to hydrocarbon attenuation at and downgradient from the refinery,
- abandonment of old wells no longer useful or able to perform their original function,
- repair of a few frost-jacked monitoring wells, and
- cleaning and periodic assessment of recovery well productivity.

The report was reviewed and the monitoring program and interim measures approved by ADEC in early May 2001.

During the summer of 2001, Shannon & Wilson obtained additional soil and groundwater samples to fill data gaps regarding COIs currently at the refinery. The effort was designed to discover as wide a variety of groundwater and soil contaminants present at the refinery as possible. We therefore chose to generally sample areas at the refinery most likely to be contaminated. Soil borings and new groundwater monitoring wells were placed to both delineate the extent of subsurface hydrocarbon contamination and provide adequate contaminant detection coverage along the northwest edge of the known groundwater benzene plume. We also collected samples from areas anticipated to be free of contamination to assess potential background concentrations of naturally occurring metals, as well as establish the absence of contamination at these locations. Based on the results of the summer 2001 study, the list of COIs was refined; several potential COIs identified in the 2000 *Draft Site Characterization and Corrective Action Plan* were eliminated from the list of contaminants currently present. The locations of the new wells and soil borings, and results of the sampling exercise are presented in an October 2001 Shannon & Wilson report (*Contaminant Characterization Study, Williams North Pole Refinery, North Pole, Alaska*). Some of the results tabulated in that report are also presented in this report, as they represent the most up-to-date information available.

A number of monitoring and observation wells were identified in the April 2001 report as being superfluous and were recommended for removal. This also was done during the summer of 2001. The monitoring, observation, and recovery wells that remained at the end of the summer 2001 season were designated for periodic measurements of dissolved hydrocarbons, depths to groundwater, NAPL presence and/or product thickness in the well, and natural attenuation geochemistry.

The depths to groundwater have been measured twice since the April 2001 report, and these data were used to determine recent variations in groundwater direction and gradient reported here. NAPL presence/absence data have been collected twice, as well, and were used to determine the current extent of subsurface NAPL at the facility. Groundwater geochemical parameters relevant to hydrocarbon natural attenuation have been measured three times.

2.0 PREVENTIVE MEASURES

The Williams North Pole Refinery has taken several measures to minimize the potential for contaminant release to soils and groundwater at the facility, as well as prevent subsurface off-site contaminant migration.

An environmental technician is responsible for checking equipment five days a week and seeing that water and product pumps are fully functional at all active recovery wells; this technician also records the amount of product recovered in the previous 24 hours. Depth to groundwater is checked in several observation wells semiannually (April and October) to determine the groundwater gradient and direction at the facility. Several observation wells are checked quarterly to delineate the extent of subsurface NAPL, and groundwater product recovery has been ongoing 365 days a year since 1989. The groundwater collected is treated by air strippers prior to release for recharging the local aquifer; the strippers are checked daily for proper operation, and the volume of water treated in the previous 24 hours is recorded. Stripper effluent is discharged to gravel pits on the site, and monitoring wells downgradient from these discharge locations are sampled monthly for water quality. A monthly status report describing these activities is provided to ADEC.

Groundwater monitoring wells are distributed in an array around the facility, downgradient of the known areas of dissolved hydrocarbon contamination. They are sampled at a frequency sufficient to detect potential migration of dissolved hydrocarbons. Monitoring wells are sampled at least annually, though many wells are sampled monthly, quarterly, or semiannually; the schedule is designed to be flexible, so the sampling frequency may be adjusted in response to new releases and deteriorating or improving groundwater quality. Details about the groundwater monitoring sampling frequency are provided in Section 7 (Corrective Action Plan).

2.1 Oil Discharge Prevention and Contingency Plan

Williams has an oil spill prevention and contingency plan designed to decrease the probability of product release and minimize the impact to the environment should one occur. The prevention program includes spill prevention training and periodic refresher courses for all refinery personnel involved in operations that could lead to a spill or are in positions to prevent spills. Substance abuse and medical examination programs are in place to ensure the safety of all refinery employees and prevent spill situations caused by mentally or physically impaired refinery workers. Regular tours of the refinery grounds are made every two hours by a number of personnel; because of this surveillance, anything unusual is attended to quickly and effectively. The facility is well-lighted with permanent lighting throughout the refinery, and temporary lighting is available if needed for spill response activities.

Product transfer procedures have been examined to minimize the possibility of spillage during these activities. Wherever possible, hard-piped product transfers are made to avoid manual pipe connections of potentially greater risk. Where manual connections are performed (i.e., truck, asphalt, and railcar loading facilities), emergency shut-off buttons are readily accessed by personnel at that location, and systems are in place to prevent product transfers until all proper loading conditions are met.

Details regarding tank and pipe protection and detection of leaks are contained in the Williams Refinery Oil Discharge Prevention and Contingency Plan. Oil storage tanks are constructed on compacted gravel foundations within lined dike containment areas and are inspected and tested periodically. The dikes are checked daily for the presence of oil and debris, and more detailed and thorough inspections are performed annually. The railcar loading rack has secondary containment within the railbeds, consisting of fiberglass catchment basins that fit between the rails, and drain to a sump and then to the wastewater system. The truck and asphalt loading areas are fully paved, and designed to allow any spills to drain into a sump and the wastewater system. Briefly, pipe protection includes siting most piping abovegrade with appropriate hardware to mitigate the effects of thermal expansion and contraction, fire proofing, and periodic inspection and maintenance. Underground piping is limited to road crossings where access would be restricted by overhead racks, and a 1,400-foot line connecting the refinery and the military pipeline. All underground road crossings have been provided with cathodic protection.

2.2 Additional Measures

In addition to the preventive measures discussed above, Williams has recently initiated two new programs designed to further reduce the likelihood of petroleum releases. The first is the internal reporting of all "near misses" at the facility. Employees are encouraged to report to refinery management officially nonreportable events (i.e., potential safety problems, close calls potentially leading to property damage, small spills below reporting thresholds, etc.) with the understanding that they will not be reprimanded. This allows the refinery's management to identify early those potential problem areas that may ultimately lead to real problems, and learn the lessons necessary to keep large problems from developing. The other program recently introduced at the facility is "root cause analysis," which is a systematic analysis of the causes of spills at the refinery. These causes may include personnel factors, infrastructure issues, process parameters, and other causes of spills not otherwise evident in proximity to the spill event. Through evaluation of near misses and the root causes of spills, the refinery is continually striving to reduce the number and volume of hydrocarbon releases at the facility.

3.0 SUBSURFACE CONDITIONS

3.1 Geology and Soils

As noted in the 1989 *Description of Current Conditions* report, the refinery is located on the floodplain of the Tanana River. Subsurface investigations were performed prior to construction of the refinery in 1975 and 1976, to prepare for additions to the refinery in 1981 and 1982, and at several times since 1987 during installation of monitoring wells and collection of soil samples from soil borings. The data indicate the site originally contained 1 to 6 feet of surficial silty soils, generally underlain by sands and gravels to a considerable depth. The thickness of alluvial sediments overlying bedrock in the area of the site is not known but is estimated to be as great as 400 to 500 feet. The granular deposits can exhibit substantial lateral variability, likely the result of old river channels filled with materials of different grain size. In areas not cleared for refinery construction, the alluvial soils are overlain by up to 2 feet of peaty, organic topsoil. Where major structures at the refinery were placed, the silty surface soils were removed and replaced with a compacted backfill of sandy gravel or gravelly sand. Aerial photographs taken prior to refinery construction show a prominent slough with a meander loop underlying the truck loading area at the north end of the refinery. Deep silt deposits were encountered during excavation for construction of the truck loading rack.

Permafrost was encountered at two locations during the original subsurface investigations for the refinery; one of these areas was to the southeast of the truck loading rack (frozen to a depth of 19 feet), and the other was to the west of Lagoon B. Subsequently, permafrost also was encountered to a depth of 15 feet during construction of the truck loading rack. The northwest, generally undeveloped, portion of the refinery is covered by an insulative layer of organic soils and black spruce forest. Borings drilled in April 1987, during installation of monitoring wells MW-102 (northwest of the truck loading area) and MW-104 (directly north of the facility), demonstrated the existence of permafrost north of the refinery. The boring at MW-102 found frozen soils from the ground surface to 52.5 feet deep, and MW-104 exhibited frozen soils from 9 to 57.5 feet below grade. A boring for MW-120, made three years later (1990) about 100 feet north of MW-104, encountered frozen soils from 21 to 42 feet deep. This suggests either a rapid thinning of the permafrost within a short distance from MW-104 or natural ablation of the permafrost due to soil warming or other factors.

On May 19, 2000, two borings were drilled approximately 5 and 30 feet south of monitoring well MW-104 to assess permafrost presence in the area. The year 2000 borings were drilled to a depth of 20 feet without encountering permanently frozen soils, though some seasonally-frozen soils were found. The area adjacent to the road on which the monitoring wells are located has been cleared and filled. It is possible that some permafrost thinning or loss has occurred in the area as a result of fill placement. Without extensive permafrost explorations at the refinery and in the region around the refinery, it is difficult to attribute a direct cause to the apparent decrease in permafrost thickness or extent.

3.2 Hydrology

Hydrologic studies were performed at the refinery in 1982 by Duane Miller, and in 1987, 1998, and 1999 by Shannon & Wilson, Inc. In addition, several wells at the refinery were re-surveyed during the summer of 2001, and a semiannual schedule (April and October) of determining the water table elevation at a number of locations was initiated. Two scheduled sets of measurements at these wells have been made, and groundwater gradients determined from them. The recent measurements indicate the refinery's groundwater gradient (i) is about 5.5 feet per mile (i.e., i = 0.001 feet per foot), with a generally northwesterly flow, though small-scale variations due to subsurface heterogeneity at the facility likely exist. The wells used to assess groundwater flow are shown in Figure 1, along with the flow directions determined in October 2001 and April 2002.

The 1987 study estimated the hydraulic conductivity of the sand and gravel strata at the site ranges from 14 feet per day (based on laboratory tests) to between 100 and 1,000 feet per day (based on field tests). Laboratory hydraulic conductivity data for silt samples exhibited a range of 0.0027 to 0.037 foot per day. Thus, silt strata may represent relatively impermeable barriers when present.

Data from the hydrology studies at the refinery were used to estimate the groundwater velocity in the subsurface at the site. Disregarding subsurface anomalies such as permafrost, areas of high-density silt, and small-scale variations in gradient, the linear seepage velocity ($v_x = Ki/n_e$) at the refinery was calculated using an average hydraulic conductivity (K) of 400 feet per day, the measured gradient (i) of 0.001 foot per foot, and an estimated effective porosity (n_e) of 0.3. These values yield an estimated groundwater velocity (v_x) of about 1.3 feet per day.

Based on this estimated average seepage velocity and the continual presence of subsurface petroleum contamination under the refinery for the last several years, one would predict that petroleum hydrocarbons should be evident in groundwater samples collected north of the refinery (e.g., MW-102 and MW-131, about 400 to 500 feet downgradient of the truck loading area). In fact, no contamination has been detected in MW-102 (screen depth 61.5 to 71.5 feet bgs) since 1990, or in MW-131 (screen depth 20 to 24.5 feet bgs) since its installation in July 1998.

4.0 CURRENT SITE CONTAMINANT DATA

4.1 Evaluation of Contaminants of Interest

Pursuant to consent agreements between the refinery and the EPA, a variety of analyses were performed to detect and characterize contaminants at the refinery through 1990. Soil and water samples from borings and monitoring wells installed for the RFI, were subjected to analyses for total petroleum hydrocarbons, metals, and volatile organic compounds (VOCs), including chlorinated solvents. Several analytes were detected in some of the sampling events prior to 1990, though most were either not detectable or below the 1990 closure criteria when the main sampling effort was completed in August 1990.

Groundwater samples have been collected frequently since 1990, and monitoring wells at the facility are routinely sampled on at least an annual basis for analysis of benzene, toluene, ethylbenzene, and xylenes (BTEX). A list of all currently existing groundwater monitoring wells at the facility, the highest groundwater concentrations of benzene observed at these locations, and the latest BTEX concentrations observed (either Autumn 2001 or Spring 2002) is presented in Table 1. Samples also have been collected for analysis of polynuclear aromatic hydrocarbons (PAH) since mid-2000 from the influent to the groundwater treatment air strippers at the refinery. The PAHs naphthalene, phenanthrene and fluorene have been observed in these samples at concentrations well below their respective groundwater cleanup levels; the April 2002 samples contained a maximum naphthalene concentration of 8.7 μg/l, and phenanthrene and fluorene were not detected.

As noted in the Introduction, to provide a more up-to-date evaluation of conditions at the refinery Shannon & Wilson undertook a Contaminant Characterization Study during 2001. Groundwater samples were obtained from twelve of the previously existing monitoring wells and from four wells installed for the Study. Water samples were analyzed for gasoline range organic compounds (GRO; Alaska Method AK 101) or GRO plus BTEX (combination Alaska Method AK101/EPA Method 8021), as well as diesel range organics (DRO; Alaska Method AK 102) and residual range organics (RRO; Alaska Method AK 103). Samples from a number of the wells also were analyzed for the metals antimony, arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver (EPA Method 6000/7000 series). Groundwater samples from wells anticipated to be contaminated with hydrocarbons were analyzed for VOCs (EPA Method 8260) and semivolatile organics (SVOCs; EPA Method 8270) in addition to the whole fuels analyses. The concentrations of metals and hydrocarbons detected in groundwater samples collected for the Study are presented in Table 2.

Eight soil borings were drilled as part of the 2001 Contaminant Characterization Study, which yielded samples for analysis of GRO or GRO plus BTEX. Soil samples also were analyzed for DRO, RRO, and the same metals analyzed in the groundwater samples (see above). In addition to these analyses, VOCs and SVOCs were determined in soil samples considered to be hydrocarbon-contaminated based on photoionization detector (PID) field-screening results. The concentrations of metals and hydrocarbons detected in these soil samples, and the locations where they were collected, are presented in Table 3. Details relating to sampling and analysis, and the laboratory analytical reports for the Study, are presented in the Shannon & Wilson report *Contaminant Characterization Study, Williams North Pole Refinery, North Pole, Alaska*, dated October 2001.

To evaluate the presence of contaminants of potential interest at the site in the context of the State of Alaska's regulations (Tables B1 and B2 in 18 AAC 75.341 migration to groundwater cleanup levels for soils, and Table C in 18 AAC 75.345 cleanup levels for groundwater), the most recent groundwater data and the results from the Contaminant Characterization Study were examined. Analytes detected during these sampling efforts at concentrations greater than the established soil or groundwater cleanup levels (maximum contaminant level, or MCL) are designated "contaminants of interest" (COIs). Based on this determination, COIs can then be evaluated for their potential to migrate from the site, or pose a threat to human health or the environment. This is addressed in Section 7.

4.2 Groundwater Contaminants of Interest

Based on an examination of current groundwater sampling data (Table 1) and the results from the recent 2001 Contaminant Characterization Study (Table 2), four analytes qualify as groundwater COIs (tabulated below).

Groundwater Contaminants of Interest

Analyte (MCL in µg/l)	Sample Location	Sample Date	Concentration (µg/l)	MCL
Benzene	Several	April 2002	Maximum 11,000 @MW-116	5 µg/l
Toluene	Several	April 2002	Maximum 3,200 @MW-135	1000 µg/l
1,2,4-trimethylbenzene	MW-115, MW-116	May 2001	Maximum 621 @MW-116	70 µg/l
Arsenic	MW-110, MW-116	May 2001	Maximum 68.5 @MW-116	50 µg/l

Arsenic was the only metal found to exceed its groundwater MCL (50 µg/l); this was in samples from MW-110 (55.1 µg/l) and MW-116 (68.5 µg/l). As noted in our October 2001 report (*Contaminant Characterization Study, Williams North Pole Refinery, North Pole, Alaska*), a study performed by the Alaska District U.S. Army Corps of Engineers (*Background Data Analysis for Arsenic, Barium, Cadmium, Chromium, & Lead on Fort Wainwright, Alaska*, March 1994) assessed the distribution of naturally occurring metals in Fairbanks area soils and groundwater. They computed mean metals concentrations and their 95 percent upper confidence limits (UCLs) for area groundwater, and recommended that area groundwater action levels be set for background values of a metal's 95 percent UCL plus one standard deviation. For arsenic this value was 72.24 µg/l, which is above the maximum measured concentration of arsenic.

As seen in the preceding table, of the organic analytes assayed in water samples, benzene, toluene, and 1,2,4-trimethylbenzene are the only ones characterized as exceeding MCLs. A number of other organic compounds also were found, but at concentrations less than their respective MCLs (Table 2).

4.3 Soil Contaminants of Interest

Following a review of data available from the soil analyses performed for Shannon & Wilson's 2001 Contaminant Characterization Study, similar to that performed above for the groundwater data, organic and inorganic analytes were classified as COIs if their concentrations exceeded the Alaska soil cleanup regulations listed in 18 AAC 75.341, Tables B1 and B2. The data were compared to the soil cleanup levels for the migration to groundwater contaminant pathway for the less than 40 inches of annual precipitation zone. The following table identifies the analytes exceeding the cleanup thresholds in soils at the refinery as of the most recent sampling for which data are available (spring and summer 2001).

Soil Contaminants of Interest

Analyte	Migration to Groundwater Cleanup Standard	Sample Location	Concentration (mg/Kg)
Benzene	0.02 mg/Kg	MW135 MW139 Boring B1[(1)] Boring B2[(1)] Boring B4[(1)]	82.0 0.0587 1.61 0.0719 3.08
Toluene	5.4 mg/Kg	MW135	398
Ethylbenzene	5.5 mg/Kg	MW135 Boring B1[(1)] Boring B4[(1)]	96.0 49.1 5.58
Xylenes (total)	78 mg/Kg (total xylenes)	MW135 Boring B1[(1)]	482 289.7
1,3,5-trimethylbenzene	25 mg/Kg	MW135 Boring B1[(1)]	43.5 38.3
1,2,4-trimethylbenzene	95 mg/Kg	MW135 Boring B1[(1)]	115 115
Naphthalene	43 mg/Kg	Boring B1[(1)]	53.7
2-Methyl-naphthalene	95 mg/Kg	Boring B1[(1)]	80.8
Arsenic	2.0 mg/Kg	MW135 MW139 MW140 Boring B1[(1)] Boring B2[(1)] Boring B3[(1)] Boring B4[(1)]	4.10 4.86 2.66 2.41 2.63 5.42 3.88

[(1)] See Shannon & Wilson's *Contaminant Characterization Study, Williams North Pole Refinery, North Pole, Alaska*, dated October 2001 for a site map showing boring locations for the study. Boring locations are described in Table 3 in this report.

As with the groundwater data, the only inorganic analyte found to exceed the soil cleanup level was arsenic. As reported in our 2001 *Contaminant Characterization Study*, the value recommended by the Alaska District U.S. Army Corps of Engineers (*Background Data Analysis for Arsenic, Barium, Cadmium, Chromium, & Lead on Fort Wainwright, Alaska*, March 1994) as a background concentration for arsenic in area soils is 14.46 mg/kg, more than twice the maximum value observed at the site.

Several organic analytes were detected in the 2001 soil samples (Table 3), and eight of these were found to exceed soil cleanup levels. The analytes considered COIs include the BTEX compounds, as well as 1,3,5-trimethylbenzene, 1,2,4-trimethylbenzene, naphthalene, and 2-methyl-naphthalene.

5.0 CURRENT GROUNDWATER QUALITY

5.1 Spatial Distribution of Groundwater Contamination

A review of recent groundwater quality data (through April 2002) indicates water quality downgradient of the refinery and well inside the property boundary does not currently exceed groundwater cleanup levels for BTEX. Concentrations of dissolved BTEX determined in monitoring wells at various locations around the facility (Table 1) suggest that aqueous subsurface contamination is concentrated in the southern, upgradient portion of the facility (i.e., area of Lagoon B, and Crude Units #1 and #2), as well as the northern area in the vicinity of the truck loading rack. In all cases, the latest benzene concentrations measured in monitoring wells are substantially below the peak values seen historically at each location (Table 1). Using these data, the areal distribution of benzene in groundwater was examined, and the 5 μg/l benzene concentration isopleth was estimated for the downgradient extent of the contaminant plume shown in Figure 2. This figure also shows the locations of the refinery monitoring wells (MWs) and the most recent groundwater benzene concentration data available for each location.

5.2 Water Quality Trends by Location

Benzene data also were plotted to evaluate groundwater quality trends for these locations (Figures 3 to 12). Note that the vertical scales vary to accommodate differing levels of contaminant, and the time scales for all plots begin in April 1987 irrespective of the well installation date. The plots indicate benzene concentrations have varied substantially over time at these locations. These variations may be attributable to a number of factors, including fluctuating groundwater elevations, variations in sampling and laboratory error over time, and discrete product spill events.

Trends in groundwater contamination vary according to location at the refinery. Data from monitoring wells located at the extreme south end of the facility (MW-105 and MW-105A; Figure 3) are upgradient from potential hydrocarbon source areas at the Williams refinery, and have been generally free of benzene contamination for the last five years. Benzene concentration data obtained from wells immediately downgradient from the Crude Unit #1 and Crude Unit #2 oil refining units (MW-115 and MW-116; Figure 4) and west of this area (MW-110; Figure 5) indicate benzene concentrations exceed drinking water standards, generally with no clear trend; an exception is the apparent increase and decrease in benzene in the last four years at MW-110, north of Lagoon B. This appears to correspond with a short-term increase in benzene seen at

MW-109 (Figure 5), west of Lagoon B (Figure 2); benzene was not detected in the MW-109 groundwater sample collected in April 2002.

Wells west of the rail loading area (MW-106, MW-111, MW-113; Figure 6) show benzene concentrations well below historic peaks; they are currently below the benzene MCL and are exhibiting stable trends with time. Wells farther to the west (MW-101 and MW-101A; Figure 7) do not contain detectable concentrations of BTEX, and samples from these wells have contained no detectable contamination since 1994. The newly installed MW-141 monitors wastewater discharged to surface waters from the stripper effluent and has been sampled twice; no BTEX compounds were detected.

Some of the monitoring wells in the northwestern area represent "sentry" wells, useful for assessing groundwater contaminant migration downgradient of the refinery. Given the apparent groundwater flow direction generally to the north-northwest (Figure 1), the wells likely most important for the sentry function are MW-127, MW-139, and MW-142 (Figure 8) immediately northwest of the truck loading area (Figure 2), and wells MW-140, MW-131, and MW-102 (Figure 9) north of this area (Figure 2). Benzene concentrations had been seen to be increasing at MW-127 since 1997 (Figure 8), which led Williams to evaluate the effectiveness of their active recovery wells upgradient from this location. Shannon & Wilson subsequently treated a recovery well southeast of MW-127 (well R-40) in early September 2000; benzene reached a peak at this location in May 2001 and has been decreasing steadily since September 2001 (Figure 8). A new monitoring well (MW-139; Figure 2) installed in July 2001 in conjunction with the Contaminant Characterization Study also has been decreasing in benzene concentration since October 2001 (Figure 8). MW-142 (Figure 8), MW-140, MW-131, and MW102 (Figure 9) have not recently yielded groundwater samples containing measurable benzene.

Three wells monitor groundwater quality north of the truck loading area. These wells are MW-104, MW-118, and MW-126 (Figure 2). The benzene concentration trends at these locations have been stable for years, with benzene not detectable above laboratory practical quantitation limits (Figure 10).

There are several wells monitoring groundwater quality in the truck loading rack area (Figure 2). These include wells that have been present for at least five (MW-129, installed October 1996) or ten years (MW-124 and MW-125, installed June 1990), as well as three wells installed during the 2001 Contaminant Characterization Study (MW-135, MW-136, and MW-137, installed March 2001). Benzene concentration trends at each of these wells are presented in the plots shown in

Figure 11. As can be seen in these plots, groundwater benzene concentrations in the area have fluctuated substantially over time (e.g., see MW-125). In addition, there appears to have been an event leading to recent increases in dissolved benzene at MW-124, MW-129, MW-135, MW-136, and MW-137, with most of these wells exhibiting peak benzene concentrations in October 2001 (Figure 11). This may indicate a recent release of product in the area of Tanks 616 – 619 (Figure 2), or may reflect fluctuations in groundwater elevation resulting in increases in dissolved hydrocarbons as groundwater contacts nearby residual NAPL present in a "smear zone" (see Section 5.3).

The wells along the eastern portion of the refinery (MW-132, MW-133, MW-134; Figure 2) yielded groundwater samples free of detectable BTEX during the most recent sampling events (October 2001 or April 2002; Table 1). With one exception (March 2000 at MW-132), when benzene has been detected at these wells, it has been below the groundwater MCL (Figure 12).

The presence of NAPL, either as free-phase product or residue sorbed to the aquifer matrix (see Section 5.3), represents a potential ongoing source of dissolved phase hydrocarbons. However, based on the observed trends in groundwater contamination in the area near and north of the truck loading rack, it appears that active recovery of free NAPL, coupled with active pumping of groundwater and treatment by air strippers, is proving successful in curtailing off-site dissolved contaminant migration.

5.3 Product Thickness Data and Extent of NAPL

NAPL thickness data collected since 1993 at the refinery facility from observation and some recovery wells were compiled and evaluated for potential spatial and temporal trends. This evaluation indicated random variations in NAPL thickness occurred over time at the refinery, and no trend was discernable (data not shown). Thus NAPL thickness, as observed in recovery and observation wells, has proved to be a poor predictor of variations in subsurface NAPL areal extent at the refinery over time. While attempts are often made to relate product thickness measured in wells with that in the surrounding formation, there generally has been no demonstrated correlation between NAPL observed in wells and the actual amount in the subsurface matrix. Thus the utility of NAPL thickness data appears to be limited to assessments of free product presence/absence and whether the product is sufficiently mobile to be recoverable (e.g., based on results of bail-down tests). As noted in the Introduction, Shannon & Wilson suggested in April 2001 (*Monitoring Program, Williams Alaska Petroleum, Inc., North Pole*

Refinery) that Williams pursue a long-term sampling program for NAPL presence at several observation and recovery wells.

We have used the latest observation data to assess the current extent of NAPL at the facility. Based on any NAPL presence in 2001 and 2002, we have attempted to delineate the current subsurface extent of NAPL at the refinery (Figure 13). Comparing the apparent current area of subsurface NAPL to the estimate generated for the 1989 *Description of Current Conditions* report (Figure 14), the extent of NAPL does not appear to have increased since the last assessment was performed. The northern extent of NAPL appears to be roughly equivalent to that observed in 1989, while the southernmost (i.e., near Crude Unit #1) and eastern extents have apparently diminished. As seasonal groundwater table fluctuations occur at this facility, the current areal extent of NAPL likely also approximates an area that could be characterized as a "smear zone." In other words, free product floating on groundwater will have sorbed to the subsurface matrix, leading to soil contamination above the water table as water levels fall. The inferred distribution of both dissolved hydrocarbons and NAPL is graphically described in a conceptual site model (Section 6.0).

5.4 Product Recovery Data

Data were compiled to assess trends in NAPL recovery from the subsurface. Volumes of product recovered from each recovery well (and, in some cases, observation wells) were sorted according to the area at the facility where the recovery occurred, and plotted for the period from January 1990 through March 2002 (Figures 15 to 20). Despite substantial variations in amounts recovered over time, it is apparent from the plots that there is a generally decreasing trend in the volume of product recovered at most areas in the facility; the variations observed (e.g., occasional spikes in volume recovered) may be due to new recovery wells coming on line and are not necessarily associated with product releases. This provides evidence that operations at the facility (e.g., preventive measures, rapid response to releases, and improved recovery efficiency) have generally been successful in curtailing the frequency and/or volume of material released over time. It also suggests that much of the NAPL at the facility may be present as a residual phase sorbed to subsurface sands and gravels in a "smear zone" in the range of water table fluctuation. This NAPL is more difficult to capture in groundwater recovery wells designed to increase NAPL recovery by creating a groundwater cone of depression.

5.5 Groundwater Geochemistry and Natural Attenuation Potential

Shannon & Wilson suggested in our April 2001 report, *Monitoring Program, Williams Alaska Petroleum, Inc., North Pole Refinery*, that Williams pursue a long-term sampling program that includes measuring groundwater geochemistry. These measurements allow one to assess the contribution of naturally occurring microbial populations to hydrocarbon attenuation at and downgradient from the refinery. The approach involves determining the groundwater concentrations of oxidants (electron acceptors) that can be used by microbes oxidizing petroleum compounds in the subsurface. Knowing the abundance of oxidants (oxygen, nitrate, ferric iron, and sulfate) available in groundwater not contaminated by hydrocarbons allows one to estimate the "assimilative capacity" of the aquifer for petroleum biodegradation. This represents the amount of reduced carbon substrate (i.e., hydrocarbon) that microbes can oxidize before exhausting available oxidant. In addition, comparing oxidant concentrations (or their reduced by-products) in hydrocarbon-contaminated and contaminant-free areas provides evidence that microbial hydrocarbon degradation is occurring *in situ*. These measurements were recommended to be performed quarterly for one year to assess potential seasonal variations in geochemistry, after which the frequency would be reduced to a semiannual basis.

Three sampling episodes for the geochemistry measurements have occurred (July and December 2001, and March 2002) thus far. Three types of sampling location were chosen for these samples: upgradient and uncontaminated wells (MW-105, MW-105A, MW-133, MW-134; Figure 2); wells known to be contaminated (MW-125 and MW-127; Figure 2); and wells not contaminated, but downgradient from contamination (MW-131 and MW-102). In theory, the upgradient wells should provide information on the assimilative capacity of the groundwater for biodegradation, the contaminated wells should show there is a "demand" for oxidants *in situ* (i.e., a reduction in oxidant concentration compared to background), and the downgradient wells should also exhibit a deficit in oxidants compared to background. The geochemical data collected from these wells are presented in Table 4.

The data indicate that the groundwater in the area is generally anoxic, as all the dissolved oxygen data are in the range of 1 mg/l or lower (i.e., within the error range of the assay). The rest of the data are difficult to interpret, as there is substantial variation in most analytes among sampling locations and sampling dates (Table 4). In addition, one "background" location (MW-134; Table 4) appears to have anomalous geochemistry compared both to areawide aquifer values and other refinery wells; this well had no measurable sulfate, high iron, and the highest alkalinity of all the wells. The anomalous data at this location may be attributable to the presence of buried organic matter or an old slough in the subsurface.

The contaminated wells also exhibit geochemical data difficult to understand. They generally yielded groundwater with relatively high nitrate, despite the presence of measurable sulfide (Table 4). Sulfide is produced by reduction of sulfate coupled to bio-oxidation of organic matter, and should be absent when nitrate is abundant (nitrate reduction is microbially energetically more favorable and should preclude sulfate reduction). However, the presence of sulfide does indicate that sulfate reduction (and probably hydrocarbon biodegradation) is actively occurring in the vicinity of these wells; contaminated well MW-125 had among the highest sulfide concentrations measured. Other evidence that hydrocarbon biodegradation is occurring in the subsurface at the refinery is the generally higher alkalinity in contaminated wells compared to background (disregarding well MW-134). Elevated alkalinities in the context of organic matter degradation are commonly attributed to consumption of protons during denitrification, iron reduction, and sulfate reduction processes.

Using nitrate, sulfate, and ferric iron concentration data from three of the four "background" wells (omitting data from MW-134), one can use the stoichiometry of carbon oxidation by nitrate, sulfate and iron reduction to estimate the hydrocarbon biodegradation assimilative capacity of the refinery's groundwater. Each milligram per liter of nitrate can support oxidation of 193 μg/l of carbon, 1 mg/l of ferric iron can support oxidation of 43 μg/l of carbon, and 1 mg/l of sulfate can support oxidation of 200 μg/l of carbon. Assuming background concentrations of 1.8 mg/l nitrate, 1.3 mg/l ferric iron, and 35 mg/l sulfate, the assimilative capacity of the groundwater should be approximately 7.4 mg carbon per liter, equivalent to about 8 mg benzene per liter. The latest measured concentrations of BTEX carbon (carbon content is approximately 91% of the total BTEX mass) exceed this assimilative capacity at wells MW-116 (15.3 mg BTEX carbon per L), MW-135 (10.1 mg BTEX carbon per L), and MW-136 (9.1 mg BTEX carbon per L), though other wells appear to be below the 7.4 mg carbon per liter value. MW-116 is located in the upgradient portion of the refinery, but MW-135 and MW-136 are located near the northern end of the facility (Figure 2).

The wells exceeding the aquifer's assimilative capacity contain more organic matter than microbes could oxidize using the oxidants present. MW-116 is located far enough upgradient on the refinery property that other, nondestructive attenuation mechanisms (e.g., dilution or sorption) could act on the contamination before it migrates off site. It is likely these nondestructive mechanisms will also act to attenuate the dissolved hydrocarbon contamination seen at MW-135 and MW-136 as well, but there is less opportunity for these mechanisms to act before off-site migration might occur. Therefore, continuous operation of the groundwater recovery wells in the northern area of the refinery will be necessary to prevent dissolved hydrocarbons from migrating north to or beyond the sentry wells. Also, since control of contaminant source areas (i.e., free or residual NAPL) is an important component of contaminant control by natural attenuation, continued efforts to recover free NAPL will remain important. As recovery of residual NAPL sorbed to the subsurface matrix beneath the facility is impractical, operation of the recovery wells to create a hydraulic boundary in the northern portion of the refinery will also remain an important function of these wells.

Dissolved hydrocarbons are apparently supporting microbial growth beneath the refinery (based on observed sulfide and alkalinity data; Table 4). Except for those locations exceeding the assimilative capacity, the major limitations to hydrocarbon biodegradation maintaining groundwater quality at the site are likely to be low temperatures and continuing dissolution of petroleum compounds into the aquifer from NAPL. The continued presence of hydrocarbons in the aquifer at the site for many years has provided strong selective pressure for hydrocarbon-degrading microbes in the groundwater. Little is known about subarctic aquifer microbiology, but the evidence from the geochemistry at this site indicates hydrocarbon biodegradation is occurring *in situ*, though at an unknown rate. Thus, coupled with efforts to minimize releases, recover NAPL, and create a hydraulic boundary at the northern end of the refinery, microbially mediated natural attenuation represents another mechanism for preventing off-site migration of dissolved groundwater contaminants.

6.0 CONCEPTUAL SITE MODEL

A schematic conceptual site model was constructed (Figure 21) based on the groundwater quality data presented above to concisely describe the inferred extent of subsurface contamination. This figure represents a cross-section through the refinery along a transect (A – A') roughly parallel to the groundwater flow direction; the transect is shown in Figure 13. In addition to the schematic conceptual site model, an analysis of the potential receptors of hydrocarbon contamination from the refinery was performed, evaluating the likelihood of their exposure to contaminants via groundwater migration, ingestion, and inhalation. The pathway analysis is presented graphically as a flow diagram in Figure 22.

6.1 Refinery Cross-section

The information presented in the Figure 21 refinery cross-section was derived from observations of NAPL extent in observation and recovery wells, and the presence of dissolved petroleum compounds in samples from monitoring wells at the refinery. Note that the vertical scale is expanded compared to the horizontal scale in this figure to allow a clearer depiction of subsurface conditions and well depths. Some of the wells shown on the cross-section in Figure 21 did not fall directly on the transect A – A' in Figure 13 but were included in the figure to include more data in the model; these wells (S-19, S-18A, MW-115, S-38, MW-127, and S-9) were projected onto the transect.

As shown in Figure 21, the mean depth to water at the refinery is approximately 7 to 8 feet below the ground surface (bgs). Depth to groundwater is greatest in the winter months; the mean depth to groundwater was approximately 9 feet bgs in March 2001, and approximately 8.5 feet bgs in December 2001. The mean groundwater level at the refinery in July 2001 was about 6.7 feet bgs. Measured winter maximum and summer minimum depth to groundwater data from 2001 were used to estimate the zone of water table fluctuation at the refinery, which appears to vary from about 3 feet to 12 feet bgs.

The screening depths and intervals for the wells depicted in Figure 21 are defined by hatch marks across the vertical lines representing each well, and the wells shown are identified by their well number. As shown in the figure, most of the wells depicted are screened to depths intersecting the mean water table elevation, though some wells shown in this figure (e.g., S-19, S-18A, S-20, R-32, R-1) do not penetrate to the water table when it is at its deepest in winter. However, based on the winter mean depth to groundwater of approximately 9 feet bgs, many of the recovery wells at the refinery are screened sufficiently deep for product recovery during this season; possible exceptions to this would be some of the shallower culvert wells.

The screening depth of monitoring wells in the downgradient portion of the transect appears to be adequate for detecting groundwater contamination, as measurable concentrations of dissolved petroleum compounds have been observed in MW-127 (screened from 20 to 24.5 feet bgs). Three new wells (MW-139, MW-140, and MW-142) were installed in 2001 north and west of MW-127 to improve the ability to monitor dissolved contaminants potentially migrating downgradient from this location; they are each screened from about 5 to 25 feet bgs. Of the five other MWs north of the truck loading area (MWs 126, 118, 104, 131, and 102), two of them (MW-126 and MW-131) are screened at the same depth as MW-127, one is screened about 10 feet deeper (MW-118 at 38.5 to 43 feet bgs), and two (MW-104 and MW-102) are screened at greater than 60 feet bgs. In our opinion, if contamination is present migrating in groundwater beyond the truck loading area, it should be apparent in samples collected from these wells.

Subsurface free product extent was estimated from historical and recent observations of NAPL at the refinery, with the recent data derived from observation and recovery well observations as described above. The "smear zone" of soil contamination in the subsurface was estimated by the historical extent of NAPL contamination and the estimated range of groundwater fluctuation. We have assumed the earlier maximum rather than the more recent NAPL extent in estimating the smear zone.

Three release areas are presented in Figure 21, representing some of the larger product releases at the refinery. The locations depicted in the figure represent releases from Crude Unit #1, from the former bolted tanks area (near well S-35) and the area near Tanks 510 – 514 (near MW-130). It is assumed these release areas are primarily responsible for the NAPL lens floating on the water table at the refinery, though it is likely there have been other contributions to this lens from occasional smaller releases over time.

The extent of dissolved hydrocarbon contamination in the groundwater at the refinery shown in the cross-section was estimated based on analytical data from samples collected at the monitoring wells depicted in Figure 21. The upgradient extent of the dissolved contaminant plume shown was assumed to begin at the upgradient edge of the estimated smear zone, as residual product sorbed to the aquifer matrix is expected to contribute to the dissolved contamination. Hydrocarbon concentrations appear to decrease with distance downgradient along the transect A – A', with benzene concentrations falling off steeply from MW-115 to MW-

127 (Table 3). No dissolved hydrocarbons were detected in MW-131 or MW-102, indicating that groundwater recovery and treatment efforts upgradient continue to curtail contaminant migration off the site via groundwater.

The estimated permafrost extent was not included in the Figure 21 illustration, as the May 2000 effort did not locate any permafrost north of the refinery.

6.2 Contaminant Exposure Pathway Analysis

The flow diagram presented in Figure 22 presents the results of an analysis of potential routes through which downgradient receptors or site workers might be exposed to dissolved hydrocarbon contaminants originating at the refinery. As noted in the figure legend, dashed lines in the figure indicate pathways either incomplete or insignificant. For this analysis, surface water, sediment, and biota were not considered to be potentially affected media. Surface water in the area is restricted to gravel pits on the site, and no petroleum contamination has been detected in monitoring wells near these pits for more than 5 years. Groundwater monitoring also indicates that the dissolved hydrocarbons plume does not extend to any surface water at or near the refinery.

As the surface water bodies at the refinery are the only potential source of sediment, this medium is also considered an unlikely potential route of exposure. Ingestion of plants, as well, is considered an incomplete or insignificant exposure pathway, as petroleum compounds are not found to be taken up by plants, there are no plants at the locations of surface spills or contamination, and the absence of substantial surface contamination at the refinery minimizes the migration of contamination by wind-borne dust. Wild game are generally excluded from the refinery by fences (excepting some small animals), and ingestion of plants is not expected to lead to bioaccumulation in animal biomass.

Two exposure pathways were considered potentially complete but insignificant: exposure to affected soil and to contaminated groundwater. Direct releases of petroleum into the soil have occurred at the facility; thus soil is an affected medium potentially leading to contaminant exposure. However, as there is a minimal area of contaminated soil exposed at the ground surface, the potential exposure routes for downgradient receptors are considered incomplete. Site workers, on the other hand, may become exposed to contaminated soils at the refinery if excavation activities expose contaminated subsurface soils. However, it is expected that exposure to soil contaminants by site workers would be unlikely, as personal protective equipment (PPE) and other mitigative measures would be employed in the event of excavation activities at the site.

Petroleum contamination is known to exist in groundwater under the refinery, and efforts are underway continuously to extract the groundwater and treat it to prevent contaminant migration off the site. That this approach has been successful is indicated by the general absence of observable petroleum contamination in monitoring wells downgradient from the truck loading area at the refinery. Thus, only site workers would potentially be exposed to contaminated groundwater. No drinking water at the facility is obtained from the groundwater at the site. In addition, as the three enclosed buildings in the NAPL-affected area (laboratory, fire house, and distribution office; Figure 13) are constructed with a slab-on-grade cement foundation, infiltration of volatiles into buildings is likely to be negligible. Therefore, the potential exposure pathways would likely only be completed if groundwater were exposed during excavation activities at the refinery, or during water sampling or measurement of NAPL in the refinery wells. As with the potential soil exposure pathway, it is expected that this potential exposure would be mitigated by PPE or other on-site controls.

7.0 CORRECTIVE ACTION PLAN

7.1 Refinery Wells

Given recent data indicating soil and groundwater contamination remains within the boundaries of the refinery site, it appears practices at the refinery and timely response to spill events have generally resulted in stable contaminant conditions. Contaminant source control through preventive measures, rapid response to spill events, NAPL recovery efforts, hydraulic control using recovery wells, and treatment of contaminated groundwater with air strippers, together with natural contaminant attenuation at the site, have resulted in no hydrocarbon contamination leaving the refinery site. Increases in benzene previously seen at MW-127 and MW-125 appeared to be related to ineffective hydraulic control in the vicinity of recovery wells R-40 and R-35. Following the cleaning and rehabilitation of these wells, benzene concentrations in MW-127 (Figure 8) and MW-125 (Figure 11) have decreased.

In May 2000, an inventory of all existing monitoring, observation, and recovery wells was performed. Wells were evaluated for their present and likely future utility in assessing groundwater gradient, determining contaminant levels, delineating NAPL extent, and effecting product recovery. Based on this evaluation, recommendations were made regarding sampling frequency and future disposition of the inventoried wells, and some wells were removed. Of those wells remaining, selected wells are now being used for determination of groundwater table elevations and gradients, the magnitude of their seasonal variation, and ongoing contaminant and geochemical analysis for natural attenuation monitoring. The remaining wells were surveyed for location, and those used for water level determinations were also surveyed for elevation. Wells used for groundwater elevation assessment will be re-surveyed as needed if frost-jacking occurs. The site plan of the refinery has been updated to reflect changes in facilities at the site, since the previous survey work was done more than a decade ago, and now includes the locations of all currently active monitoring, observation, and recovery wells.

The details regarding the wells, their functions, and sampling or observation frequencies are contained in Table 5 (monitoring wells), Table 6 (observation wells), and Table 7 (recovery wells). A site map showing the groundwater monitoring well locations and current BTEX sampling frequency is presented in Figure 23. Observation wells are to be used for detecting the presence of NAPL, measuring NAPL thickness for product recovery (selected wells, Table 6) and measuring groundwater elevation (selected wells, Table 6); their locations are shown on the site map presented in Figure 24. Recovery well locations are shown in Figure 25; some actively pump groundwater for NAPL recovery and/or creating a hydraulic boundary at the northern end of the refinery facility (Table 7). Other recovery wells serve as collection points for free-phase NAPL floating on the water table, but do not have groundwater pumps to create zones of groundwater depression to enhance NAPL recovery ("static" recovery wells, Table 7).

7.2 Contaminants of Interest

Arsenic was the only metal detected at the refinery above soil and groundwater cleanup levels. As noted in Sections 4.2 and 4.3, the presence of arsenic above cleanup levels in soil and groundwater samples at the refinery appears to be attributable to the natural abundance of this element in the area. Arsenic is not a metal known to be associated with crude oil, refined petroleum products, or the process of refining and is therefore not likely to be a soil or groundwater contaminant resulting from refinery practices. It is our opinion that arsenic's presence at the concentrations observed in refinery soil and water samples should not be cause for corrective action.

A variety of petroleum hydrocarbons exceeding cleanup levels have been detected in soil and/or groundwater samples from the refinery. Consideration of the physical properties of the hydrocarbon contaminants detected suggests that benzene remains the best analyte to measure for tracking petroleum contamination potentially migrating from the refinery property. The migration of a hydrocarbon compound in an aquifer is primarily controlled by two of the compound's physical properties: the aqueous solubility and the compound's tendency to sorb to the subsurface soil matrix. The latter factor can be estimated using the compound's octanol-water partition coefficient (K_{OW}), which measures the equilibrium distribution of the compound between an organic (nonpolar) and aqueous phase. As K_{OW} values commonly occur over a large range for various compounds, the log K_{OW} is typically reported. High log K_{OW} values indicate a compound has a greater tendency to sorb to the aquifer matrix, thereby increasing the probability its subsurface migration would be retarded.

The hydrocarbon analytes found to exceed either the soil or groundwater cleanup levels have the following approximate aqueous solubilities (solubility varies as a function of temperature and other solute concentrations) and log K_{OW} values:

Soil and Groundwater Hydrocarbon Contaminants of Interest

Compound	Aqueous Solubility (mg/l)	Log K_{OW}
Benzene	1780	2.13
Toluene	515	2.69
Ethylbenzene	152	3.13
o-Xylene m-Xylene p-Xylene	220 160 215	3.15 3.20 3.18
1,3,5-trimethylbenzene	48.2	3.42
1,2,4-trimethylbenzene	57	3.63
Naphthalene	31	3.37
2-Methyl-naphthalene	24.6	3.86

As is apparent from the above data, benzene is the most soluble COI, and its migration in the subsurface is the least likely to be retarded. Benzene also has the most stringent groundwater cleanup level. It is therefore our opinion that benzene is the most appropriate analyte to track migration of hydrocarbons in the subsurface at the refinery. Therefore, continued monitoring of the BTEX compounds appears appropriate and should be sufficient to detect subsurface movement of dissolved petroleum compounds in groundwater at the refinery.

7.3 Monitoring Program

As noted in the Introduction, Shannon & Wilson generated a number of suggestions for long-term monitoring in our report to Williams (*Monitoring Program, Williams Alaska Petroleum, Inc., North Pole Refinery*), dated April 20, 2001. This report recommended that groundwater quality monitoring for BTEX be performed at different frequencies (monthly at maximum, annually at minimum) depending on the location and the water quality in that area. The sampling frequency was designed to be varied in response to improvement or deterioration in groundwater quality. In some cases frequent sampling (monthly or quarterly) was recommended, which would then be reduced based on the trend in hydrocarbon concentrations observed at that location over time. The basis for decreasing the sampling frequency would be a statistically significant decreasing trend (determined using the Mann-Kendall test for trends) in benzene concentration. The current complement of groundwater monitoring wells at the refinery and their recommended sampling frequency for BTEX is provided in Table 5.

In addition to BTEX monitoring, we recommend continued monitoring of groundwater geochemistry to assess the contribution of naturally occurring microbial populations to attenuation of hydrocarbon contamination at and downgradient from the site. Monitoring for natural attenuation is currently being performed quarterly to determine how these parameters may vary seasonally. As noted in Section 5.5, the data collected thus far are difficult to interpret, and little is currently known about subarctic aquifer microbiology, but it is apparent that some microbial biodegradation of petroleum is occurring in the subsurface at the refinery. One more quarterly sampling episode is planned, after which the geochemistry sampling will decrease to a semiannual basis. In our opinion, with further geochemical sampling the accumulation of additional data should help us better understand the processes at play beneath the refinery leading to destruction of dissolved hydrocarbons. It may be desirable to collect this information from other locations at the refinery in the future, as this may allow us to interpret anomalous data (e.g., the geochemistry of MW-134).

A number of wells have been designated for groundwater elevation measurements (see Tables 5 and 6, and Figure 1). Groundwater elevation at these locations is currently measured semiannually. These measurements should be continued for the next few years to build a data set showing the degree of variation in groundwater flow direction. We expect there to be some variation (we have detected an approximately 8° variation between the autumn 2001 and spring 2002 measurements), but generally anticipate the refinery's groundwater flow direction to match that measured regionally in the area (i.e., to the north-northwest) as influenced by the nearby Tanana River.

Observation and recovery wells are being used together to monitor the size and potential movement of NAPL beneath the facility. The presence of NAPL is assessed at least quarterly at the observation wells (Table 6, Figure 24) and more frequently as needed in recovery wells (Table 7).

Recovery wells (Table 7, Figure 25) are used for floating product recovery. "Static" recovery has been employed in many wells, using skimmers or other techniques to collect NAPL floating on standing water in the wells. Other wells have used water pumping to depress the water table for enhanced NAPL recovery; water pumped from these wells has been treated in stripping towers before being discharged to on-site gravel pits. An important function of some of these enhanced recovery wells (i.e., R-21, R-40, R-39, and R-35) has been to effect hydraulic control in the vicinity near the truck loading area. Recovery well R-35 had not been actively pumping water for several years due to encrustation of the well screen, and wells R-40 and R-41 had not been sufficiently productive to effect hydraulic control at this location. Subsequently, wells R-21, R-35, R-39, R-40 and the other recovery wells equipped with groundwater pumps were cleaned by brushing, adding acid, and surging. Flow from R-35, R-39, and R-40 apparently increased, and R-40 was then also connected to the refinery water recovery system. Based on the response of MW-127 (benzene concentrations decreasing; Figure 8), it appears these wells are exerting a strong influence on groundwater flow and are once again effective at creating a hydraulic boundary in the northern area of the refinery.

In our opinion, the measures suggested above will provide the information needed to effectively monitor NAPL and groundwater quality. Corrective measures (i.e., groundwater pumping, product recovery, air stripping, spill control/response, natural attenuation) will be employed to maintain contaminant plume stability and reduce its extent, and prevent off-site contaminant migration for the life of the facility. Williams Alaska Petroleum, Inc., expects this facility to be in operation for approximately the next 50 years. Annual review of NAPL and benzene extent data will allow for modifications to corrective measures as necessary to maintain protection of downgradient receptors. Further measures may be applied as necessary if monitoring does not demonstrate stable conditions. Annual reports on the effectiveness of corrective measures will be generated in addition to the status reports written as directed by the Williams Alaska wastewater discharge permits. Any remedies needed to achieve site closure when operations at the refinery cease will be addressed according to regulations extant at that time.

8.0 LIMITATIONS

This report presents conclusions based on analysis of samples collected in selected areas of the refinery. The locations sampled may not represent the highest levels of contamination present at the site and were not generally chosen to delineate the extent of contamination. It was not our intent to detect the presence of soil or groundwater affected by contaminants other than those for which laboratory analyses were performed. No conclusions can be drawn regarding the presence or absence of other contaminants.

The data presented in this report should be considered representative of the time we made our observations and collected samples. Changes due to natural forces or human activity can occur on the site. Because of such changes beyond our control, our observations and interpretations may need to be revised. In addition, there can be no assurance that a regulatory agency or its staff will reach the same conclusions as Shannon & Wilson.

Table 1
2001/2002 BTEX and Historical
Maximum Benzene Concentrations Observed
at Williams Alaska Petroleum, Inc., North Pole Refinery

Well	Screen Depth	Highest Benzene Observed	Date Highest Benzene Observed	Most Recent Sample Date	Most Recent Sample Data				Location
					Benzene (µg/L)	Toluene (µg/L)	Ethyl benzene (µg/L)	Xylenes (µg/L)	
MW-101	56-61'	**10**	5/22/90	4/3/02	ND	ND	ND	ND	West of Truck Loading Area
MW-101A	18-23'	**6**	11/28/88	4/3/02	ND	ND	ND	ND	West of Truck Loading Area
MW-102	61.5-71.5'	**17**	9/28/88	4/9/02	ND	ND	ND	ND	NW of Truck Loading Area
MW-104	63-67'	**20**	4/20/90	4/9/02	ND	ND	ND	ND	North of Truck Loading Area
MW-105	58-63'	**41**	2/21/90	4/10/02	ND	ND	ND	ND	SE corner of Refinery
MW-105A	18-23'	**270**	9/19/95	4/10/02	ND	ND	ND	ND	SE corner of Refinery
MW-106	18.5-23'	**6**	12/18/90	4/5/02	ND	ND	ND	ND	West of Fire Training Area
MW-109	9.5-14'	**140**	9/28/88	4/3/02	ND	ND	ND	ND	West Edge of Lagoon B
MW-110	13.5-18'	**5500**	9/14/99	10/9/01	**2000**	**1100**	83	650	NE Corner of Lagoon B
MW-111	14.5-19.5'	**530**	11/30/88	4/3/02	3.4	ND	ND	ND	SW of Rail Car Loading Area
MW-113	11.5-16'	**350**	9/8/93	4/3/02	ND	ND	ND	ND	West of Rail Car Loading Area
MW-115	12.5-17'	**22000**	5/24/90	4/9/02	**1500**	ND	24	1200	Between Crude Units #1 and #2
MW-116	12-17'	**24000**	9/17/91	4/9/02	**11000**	ND	190	5600	Crude Unit #1
MW-118	38.5-43'	**1500**	4/19/90	4/4/02	ND	ND	ND	ND	North of Truck Loading Area
MW-124	20-24.5	**4000**	6/6/90	4/8/02	3.9	ND	ND	ND	SE of Truck Loading Area
MW-125	19.5-24'	**24000**	6/26/90	4/4/02	**9.0**	ND	ND	ND	South of Truck Loading Area
MW-126	20-24.5'	**1200**	8/30/91	4/4/02	ND	ND	ND	ND	North of Truck Loading Area
MW-127	20-24.5	**210**	7/21/99	4/4/02	**130**	ND	ND	ND	NW Corner of Truck Loading Area
MW-129	37-41.5'	**39**	12/17/96	4/4/02	ND	ND	ND	ND	E Corner of Truck Loading Area
MW-130	19-23'	**1600**	9/26/97	4/3/02	**90**	26	19	40	SE Corner of Tanks 820 - 823
MW-131	20-24.5'	ND	7/29/98	4/8/02	ND	ND	ND	ND	NW of Truck Loading Area

Table 1
2001/2002 BTEX and Historical Maximum Benzene Concentrations Observed at Williams Alaska Petroleum, Inc., North Pole Refinery

Well	Screen Depth	Highest Benzene Observed	Date Highest Benzene Observed	Most Recent Sample Date	Most Recent Sample Data				Location
					Benzene (μg/L)	Toluene (μg/L)	Ethyl benzene (μg/L)	Xylenes (μg/L)	
MW-132	17.5-22'	4	9/15/99	4/8/02	ND	ND	ND	ND	East of Tank 515
MW-133	17.5-22'	ND	9/15/99	10/10/01	ND	ND	ND	ND	East of Tank 515
MW-134	17-21.5'	ND	9/15/99	10/10/01	ND	ND	ND	ND	NE of Crude Unit #2
MW-135	10.57'-19.49	**14000**	10/9/01	3/6/02	**6000**	**3200**	390	1430	NE of Tank 513
MW-136	10.11'-19.07	**11000**	10/9/01	2/4/02	**6500**	**1700**	360	1380	NE of Tank 513
MW-137	10.42'-19.32	**1400**	11/14/01	4/8/02	**470**	ND	1.7	1.0	NE of Tank 513
MW-138	3.86'-18.06'	No data	No data	No data	No data	No data	No data	No data	North of Crude Unit #2
MW-139	5.70'-25.02'	**220**	10/9/01	4/8/02	**110**	ND	35	740	West of Truck Loading Area
MW-140	4.20'-23.50'	ND	7/11/01	4/9/02	ND	ND	ND	ND	North of Truck Loading Area
MW-141	7.94'-22.40'	ND	4/5/02	4/5/02	ND	ND	ND	ND	Far west of Rail Loading Area
MW-142	5.35'-19.35'	ND	8/13/01	8/13/01	ND	1.2	ND	ND	NW of Truck Loading Area

Bold face values exceed groundwater cleanup levels (18 AAC75.345)
ND = Analyte not detected above laboratory practical quantitation limit (0.5 μg/L for benzene, 1.0 μg/L for toluene and ethylbenzene, and 2.0 μg/L for xylenes).

Table 2
Metals and Hydrocarbons Determined in Groundwater Samples From Williams Alaska Petroleum, Inc. North Pole Refinery

Location	Date Collected	Screen Interval (feet bgs)	Antimony (µg/L)	Arsenic (µg/L)	Barium (µg/L)	Cadmium (µg/L)	Chromium (µg/L)	Lead (µg/L)	Mercury (µg/L)	Selenium (µg/L)	Silver (µg/L)
Groundwater Cleanup Level		⟶	6	50	2000	5	100	15	0.2	50	180
MW101	5/10/01	56-61	<1.11	10.9	71.2	3.74	<4.44	<2.22	<0.200	<5.56	4.92
MW101A	5/10/01	18-23	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW105	5/10/01	58-63	<1.11	<5.56	80.0	3.90	<4.44	<2.22	<0.200	<5.56	4.92
MW105A	5/10/01	18-23	<1.11	5.69	134	3.71	<4.44	<2.22	<0.200	<5.56	4.99
MW106	5/10/01	18.5-23	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW110	6/13/01	13.5-18	1.32	**55.1**	523	<2.00	29.7	8.80	<0.200	<5.00	<2.00
MW115	5/10/01	12.5-17	<1.11	32.4	601	3.86	8.67	3.24	<0.200	5.66	5.02
MW116	5/10/01	12-17	<1.11	**68.5**	243	3.82	6.19	<2.22	<0.200	<5.56	5.00
MW125	5/10/01	19.5-24	<1.11	19.4	155	3.75	<4.44	<2.22	<0.200	<5.56	4.88
MW127	5/10/01	20-24.5	<1.11	15.6	215	3.77	<4.44	<2.22	<0.200	<5.56	4.90
MW130	5/10/01	19-23	<1.11	23.8	229	4.09	4.99	<2.22	<0.200	<5.56	4.93
MW133	5/10/01	17.5-22	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW135	7/19/01	10.57-19.49	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW139	7/19/01	5.7-25.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW140	7/19/01	4.2-23.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW142	8/13/01	5.35-19.35	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

Only the maximum values for analytes from duplicate samples are shown (duplicates collected from MW105, MW105A, MW125, and MW142).

Only the analytes detected in water samples are presented.

NA = Not analyzed (analyte not determined in sample)

-- = No groundwater cleanup level exists for this analyte

Table 2
Metals and Hydrocarbons Determined in Groundwater Samples From Williams Alaska Petroleum, Inc. North Pole Refinery

Location	Date Collected	Screen Interval (feet bgs)	GRO (mg/L)	DRO (mg/L)	RRO (mg/L)	Benzene (µg/L)	Toluene (µg/L)	Ethyl-benzene (µg/L)	p&m-Xylenes (µg/L)	o-Xylene (µg/L)	1,2,4-Trimethyl-benzene (µg/L)	1,3,5-Trimethyl-benzene (µg/L)	n-Propyl-benzene (µg/L)	Isopropyl-benzene (cumene) (µg/L)	4-Isopropyl-toluene (µg/L)
Groundwater Cleanup Level		⟶	1.3	1.5	1.1	5	1000.0	700	10,000 (total xylenes)		70	1850	--	3650	--
MW101	5/10/01	56-61	<0.0900	0.818 [1]	<0.990	<0.500	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA
MW101A	5/10/01	18-23	<0.0900	1.20 [1]	<0.990	<0.500	<2.00	<2.00	3.89	<2.00	NA	NA	NA	NA	NA
MW105	5/10/01	58-63	0.153	<0.495	<0.990	1.64	9.46	6.46	33.9	10.4	NA	NA	NA	NA	NA
MW105A	5/10/01	18-23	<0.0900	<0.495	<0.990	<0.500	2.37	2.21	6.92	2.12	NA	NA	NA	NA	NA
MW106	5/10/01	18.5-23	<0.0900	<0.495	<0.990	0.698	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA
MW110	6/13/01	13.5-18	**8.69**	**2.87** [2]	<1.00	**3,080**	372	51.0	283	97.0	30.9	8.62	5.71	6.15	1.38
MW115	5/10/01	12.5-17	**5.62** [3]	**2.44** [3,4]	<0.990	**966**	<1.00	44.0	914	2.70	**281**	87.3	48.8	37.4	6.99
MW116	5/10/01	12-17	**36.8** [3]	**4.57**	<1.02	**3,960**	3.14	**753**	1,140	1,770	**621**	203	162	106	18.3
MW125	5/10/01	19.5-24	0.214	<0.495	<0.990	**90.0**	<1.00	1.68	1.77	<1.00	<1.00	<1.00	<1.00	1.62	<1.00
MW127	5/10/01	20-24.5	1.01	<0.495	<0.990	**170**	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	<1.00	1.38	<1.00
MW130	5/10/01	19-23	0.678 [3]	**1.66** [3,4]	<1.00	**55.5**	15.3	5.78	16.5	8.67	7.58	1.74	2.31	1.78	<1.00
MW133	5/10/01	17.5-22	<0.0900	<0.495	<0.990	<0.500	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA
MW135	7/19/01	10.57-19.49	**32.9**	**3.38** [5]	<1.05	**5470**	**3,980**	332	964	442	NA	NA	NA	NA	NA
MW139	7/19/01	5.7-25.2	**2.98**	**1.59** [5]	<1.00	**110**	<2.00	97.7	638	196	NA	NA	NA	NA	NA
MW140	7/19/01	4.2-23.5	<0.0900	<0.505	<1.01	<0.500	<2.00	<2.00	<2.00	<2.00	NA	NA	NA	NA	NA
MW142	8/13/01	5.35-19.35	0.085 [6]	0.568 [7]	NA	<1.0	1.2	<1.0	<2.0	<1.0	NA	NA	NA	NA	NA

Notes:
Only the maximum values for analytes from duplicate samples shown (duplicates collected from MW105, MW105A, MW12
Only the analytes detected in water samples are presented.
NA = Not analyzed (analyte not determined in sample)
-- = No groundwater cleanup level exists for this analyte

[1] DRO/RRO - Unknown hydrocarbon peak between C_{12}-C_{13} alkane range.
[2] DRO - Pattern consistent with weathered middle distillate or highly weathered gasoline.
[3] DRO - Pattern consistent with weathered gasoline.
[4] DRO/RRO - Pattern consistent with weathered middle distillate.
[5] DRO - Unknown hydrocarbon with several peaks.
[6] GRO - Gasoline pattern observed.
[7] DRO - Unknown hydrocarbon pattern present.

Table 2
Metals and Hydrocarbons Determined in Groundwater Samples From Williams Alaska Petroleum, Inc. North Pole Refinery

Location	Date Collected	Screen Interval (feet bgs)	n-Butylbenzene (µg/L)	sec-Butylbenzene (µg/L)	Naphthalene (µg/L)	1,1-Dichloroethene (µg/L)	cis-1,2-Dichloroethene (µg/L)	Naphthalene (µg/L)	2-Methylnaphthalene (µg/L)	2,4-Dimethylphenol (µg/L)	di-n-Octylphthalate (µg/L)
Groundwater Cleanup Level		→	--	--	1,460	7	70	1,460	1500	--	--
MW101	5/10/01	56-61	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW101A	5/10/01	18-23	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW105	5/10/01	58-63	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW105A	5/10/01	18-23	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW106	5/10/01	18.5-23	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW110	6/13/01	13.5-18	1.58	1.21	20.4	<1.00	<1.00	11	13	<9.9	<9.9
MW115	5/10/01	12.5-17	4.03	6.56	76.1	1.57	<1.00	33	15	15	<9.9
MW116	5/10/01	12-17	14.3	18.6	316	<2.00	2.84	120	70	22	<10
MW125	5/10/01	19.5-24	<1.00	<1.00	2.83	4.77	<1.00	<9.9	<9.9	<9.9	12
MW127	5/10/01	20-24.5	<1.00	<1.00	<1.00	<1.00	<1.00	<9.9	<9.9	<9.9	<9.9
MW130	5/10/01	19-23	<1.00	<1.00	16.2	1.70	<1.00	<9.9	<9.9	<9.9	<9.9
MW133	5/10/01	17.5-22	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW135	7/19/01	10.57-19.49	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW139	7/19/01	5.7-25.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW140	7/19/01	4.2-23.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW142	8/13/01	5.35-19.35	NA	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

Only the maximum values for analytes from duplicate samples shown (duplicates collected from MW105, MW105A, MW12

Only the analytes detected in water samples are presented.

NA = Not analyzed (analyte not determined in sample)

-- = No groundwater cleanup level exists for this analyte

Table 3
Metals and Hydrocarbons Determined in Soil Samples from Williams Alaska Petroleum, Inc. North Pole Refinery

Location	Description	Date Collected	Depth (feet bgs)	Antimony (mg/kg)	Arsenic (mg/kg)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Lead (mg/kg)	Mercury (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)
Soil Cleanup Level →				3.6	2	1,100	5	26	1,000 †	1.4	3.5	21
MW-135	Northeast area of refinery, south of truck loading rack	3/8/01	10.0 - 11.5	<0.893	**4.10**	91.7	<0.0478	21.1	<5.98	<0.0418	<0.478	<0.191
MW-139	West of rail loading area and MW-127	5/29/01	10.0 - 11.5	0.342	**4.86**	61.8	0.257	13.8	4.58	<0.0386	<1.14	<0.114
MW-140	North of truck loading rack.	5/29/01	7.5 - 9.0	<0.314	**2.66**	60.6	<0.209	8.17	3.43	<0.0357	<1.05	<0.105
MW-142	West of rail loading area and MW-139	8/10/01	7.5-9.0	NA	NA	NA	NA	NA	NA	NA	NA	NA
B1	Central portion of refinery, in old bolted tanks area	5/30/01	7.5 - 9.0	0.324	**2.41**	61.3	<0.206	21.1	3.79	<0.0357	<1.03	<0.103
B2	Near asphalt tanks, north of MW-130	5/30/01	10.0 - 11.5	<0.299	**2.63**	52.0	0.279	13.3	3.70	<0.0349	<0.998	<0.0998
B3	North of crude unit #1	5/30/01	10.0 - 11.5	0.366	**5.42**	103	0.469	21.9	7.48	<0.0415	<1.01	0.107
B4	West of rail loading area, near MW-113	5/30/01	7.5 - 9.0	<0.328	**3.88**	59.7	0.219	15.3	4.03	<0.0378	<1.09	<0.109

Notes:
Only the maximum values for analytes from duplicate samples are shown (duplicates collected from MW135 and B1)
Only the analytes detected in soil samples are presented.
NA = Not analyzed (analyte not determined in sample)
† Lead soil cleanup value is for industrial land use

Table 3
Metals and Hydrocarbons Determined in Soil Samples from Williams Alaska Petroleum, Inc. North Pole Refinery

Location	Description	Date Collected	Depth (feet bgs)	GRO (mg/kg)	DRO (mg/kg)	RRO (mg/kg)	Benzene (mg/kg)	Toluene (mg/kg)	Ethylbenzene (mg/kg)	p&m-Xylenes (mg/kg)	o-Xylene (mg/kg)
Soil Cleanup Level ⟶				300	250	11,000	0.02	5.4	5.5	78 (Total xylenes)	
MW-135	Northeast area of refinery, south of truck loading rack	3/8/01	10.0 - 11.5	**7,730**	**1630** [1]	127 [1]	**82.0**	**398**	**96.0**	**348**	**134**
MW-139	West of rail loading area and MW-127	5/29/01	10.0 - 11.5	2.23	<11.8	<23.6	**0.0587**	<0.0375	<0.0375	0.378	0.137
MW-140	North of truck loading rack.	5/29/01	7.5 - 9.0	<1.77	<10.6	<21.3	<0.00885	<0.0354	<0.0354	<0.0354	<0.0354
MW-142	West of rail loading area and MW-139	8/10/01	7.5-9.0	<3.96	17.3 [2]	NA	<0.0198	<0.0793	<0.0793	<0.0793	<0.0793
B1	Central portion of refinery, in old bolted tanks area	5/30/01	7.5 - 9.0	**1,980**	**3460** [3]	<217	**1.61**	<0.835	**49.1**	**202**	**87.7**
B2	Near asphalt tanks, north of MW-130	5/30/01	10.0 - 11.5	4.69	<10.7	<21.5	**0.0719**	0.372	0.106	0.327	0.117
B3	North of crude unit #1	5/30/01	10.0 - 11.5	<23.8	79.1 [4]	82.4 [4]	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124
B4	West of rail loading area, near MW-113	5/30/01	7.5 - 9.0	**381**	**331** [5]	<22.7 [5]	**3.08**	3.73	**5.58**	16.7	5.87

Notes:
Only the maximum values for analytes from duplicate samples are shown (duplicates collected from MW135 and B1)
Only the analytes detected in soil samples are presented.
NA = Not analyzed (analyte not determined in sample)
[1] DRO: Pattern consistent with weathered middle distillate. DRO/RRO: Possible crude oil pattern.
[2] DRO: Pattern consistent with highly weathered middle distillate.
[3] DRO: Pattern consistent with middle distillate.
[4] DRO: Heavier hydrocarbons contributing to diesel range quantitation. DRO/RRO: Possible lube oil pattern.
[5] DRO/RRO: Pattern consistent with weathered middle distillate.

Table 3

Metals and Hydrocarbons Determined in Soil Samples from Williams Alaska Petroleum, Inc. North Pole Refinery

Location	Description	Date Collected	Depth (feet bgs)	Isopropylbenzene (Cumene) (mg/kg)	n-Propylbenzene (mg/kg)	1,3,5-Trimethylbenzene (mg/kg)	tert-Butylbenzene (mg/kg)	1,2,4-Trimethylbenzene (mg/kg)	sec-Butylbenzene (mg/kg)	4-Isopropyltoluene (p-cymene) (mg/kg)	n-Butylbenzene (mg/kg)	Trichlorofluoromethane (mg/kg)	Naphthalene (mg/kg)	2-Methylnaphthalene (mg/kg)	Dibenzofuran (mg/kg)	Fluorene (mg/kg)	Phenanthrene (mg/kg)
Soil Cleanup Level ——→				227	--	25	--	95	--	--	--	--	43	43	--	--	4300
MW-135	Northeast area of refinery, south of truck loading rack	3/8/01	10.0 - 11.5	19.8	40.7	**43.5**	<12.8	**115**	<12.8	<12.8	<12.8	22.7	5.94	9.04	0.524	0.483	1.37
MW-139	West of rail loading area and MW-127	5/29/01	10.0 - 11.5	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-140	North of truck loading rack.	5/29/01	7.5 - 9.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-142	West of rail loading area and MW-139	8/10/01	7.5-9.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
B1	Central portion of refinery, in old bolted tanks area	5/30/01	7.5 - 9.0	19.1	38.8	**38.3**	<0.835	**115**	12.0	9.12	13.0	<0.835	**53.7**	**80.8**	<35.9	<35.9	<35.9
B2	Near asphalt tanks, north of MW-130	5/30/01	10.0 - 11.5	<0.0113	0.0145	0.0180	<0.0113	0.0567	<0.0113	<0.0113	<0.0113	<0.0113	0.0570	<0.358	<0.358	<0.358	<0.358
B3	North of crude unit #1	5/30/01	10.0 - 11.5	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.0124	<0.741	<0.741	<0.741	<0.741
B4	West of rail loading area, near MW-113	5/30/01	7.5 - 9.0	3.55	3.80	5.60	0.0812	14.8	1.55	1.39	<2.25	<0.0225	6.64	1.30	<0.368	<0.368	<0.368

Notes:

Only the maximum values for analytes from duplicate samples are shown (duplicates collected from MW135 and B1)

Values for napthalene are the maximum detected in either the VOC or SVOC analysis.

Only the analytes detected in soil samples are presented.

NA = Not analyzed (analyte not determined in sample)

-- = No soil cleanup level is established for this analyte

Table 4
Groundwater Geochemistry for Natural Attenuation Assessment at Williams Alaska Petroleum, Inc. North Pole Refinery

Well #	Date	O_2 (mg/L)	NO_3^- (mg/L)	Fe^{2+} (mg/L)	Fe3+ (mg/L)	Fe_{tot} (mg/L)	SO_4^{2-} (mg/L)	Filtered S^{2-} (mg/L)	Alkalinity (mg/L as CaCO3)
MW105	7/10/01	0.4	2.1	0.03	1.03	1.06	47	No data	132
	12/10/01	0.4	2.1	0.79	0.26	1.05	32	0.000	118
	3/6/02	0.7	2.1	1.02	0.01	1.03	32	0.006	104
MW105A	7/10/01	1	22.3	0.16	2.6	2.76	32	No data	152
	12/10/01	0.4	2.7	1.42	1.42	2.84	29	0.007	133
	3/6/02	0.2	2.4	2.57	0.2	2.77	28	0.009	128
MW133	7/10/01	0.5	1.8	0.11	0.05	0.16	47	0.003	118
	12/11/01	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen
	3/6/02	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen	Frozen
MW134	7/10/01	0.6	0.2	4.04	1.86	5.9	0	0.040	329
	12/10/01	0	2	7.5	2	9.5	0	0.016	251
	3/6/02	0.1	0.9	7.7	3.37	11.07	0	0.000	290
MW125	7/10/01	0.5	4.2	0.11	4.5	4.6	34	0.033	167
	12/10/01	0.4	1.7	3.26	1.04	4.3	30	0.018	168
	3/6/02	0.1	3.4	2.2	2.12	4.32	34	0.170	131
MW127	7/10/01	0.4	5.3	1.8	2.2	4.0	35	0.008	223
	12/11/01	0.4	1.6	4.7	0.5	5.2	28	0.003	174
	3/6/02	0.5	4.4	4.0	0.3	4.3	30	0.004	143
MW131	7/10/01	0.6	1.8	0.2	0.03	0.23	32	0.003	201
	12/11/01	0.2	1.1	0.18	0.01	0.19	25	0.004	154
	3/6/02	0.2	1	0.18	0	0.18	28	0.006	160
MW102	7/10/01	0.4	2	0.17	0.09	0.26	44	0.000	105
	12/11/01	No sample	No sample	No sample	No sample	No sample	No sample	No sample	No sample
	3/6/02	0.4	1.9	0.25	0.03	0.28	29	0.002	105

Table 5
Existing Monitoring Wells, Screened Intervals, Functions, and Sampling Frequencies

Groundwater Monitoring Wells	Screen Interval (feet bgs)	Function	Sampling Frequency (A = annual, S = semiannual, Q = quarterly, M = monthly)
MW-101	56-61'	1) "Far north" sentry well for BTEX 2) Groundwater elevation check	1) A 2) S
MW-101A	18-23'	1) "Far north" sentry well for BTEX 2) Groundwater elevation check	1) A 2) S
MW-102	61.5-71.5'	1) "Far north" sentry well for BTEX 2) Geochemistry for natural attenuation	1) A 2) Q
MW-104	63-67'	"Far north" sentry well	A
MW-105	58-63'	1) Upgradient well for BTEX 2) Geochemistry for natural attenuation 3) Groundwater elevation check	1) S 2) Q 3) S
MW-105A	18-23'	1) Upgradient well for BTEX 2) Geochemistry for natural attenuation 3) Groundwater elevation check	1) S 2) Q 3) S
MW-106	18.5-23'	1) Monitor wastewater discharge for BTEX 2) Groundwater elevation check	1) S 2) S
MW-109	9.5-14'	Leak detection (BTEX) for Lagoon B	S
MW-110	13.5-18'	Groundwater BTEX monitoring	Q
MW 111	14.5-19.5'	Groundwater BTEX monitoring	S
MW-113	11.5-16'	1) Groundwater BTEX monitoring 2) Groundwater elevation check	1) S 2) S
MW-115	12.5-17'	Groundwater BTEX monitoring	A
MW-116	12-17'	Groundwater BTEX monitoring	A
MW-118	38.5-43'	Sentry well for BTEX	A
MW-124	20-24.5'	Groundwater BTEX monitoring	M
MW-125	19.5-24'	1) Groundwater BTEX monitoring 2) Geochemistry for natural attenuation	1) S 2) Q

Table 5
Existing Monitoring Wells, Screened Intervals, Functions, and Sampling Frequencies

Groundwater Monitoring Wells	Screen Interval (feet bgs)	Function	Sampling Frequency (A = annual, S = semiannual, Q = quarterly, M = monthly)
MW-126	20-24.5'	Groundwater BTEX monitoring	Q
MW-127	20-24.5'	1) Groundwater BTEX monitoring 2) Geochemistry for natural attenuation	1) M 2) Q
MW-129	37-41.5'	1) Groundwater BTEX monitoring 2) Groundwater elevation check	1) M 2) S
MW-130	19-23'	Groundwater BTEX monitoring	Q
MW-131	20-24.5'	1) Groundwater BTEX monitoring 2) Geochemistry for natural attenuation	1) Q 2) Q
MW-132	17.5-22'	Groundwater BTEX monitoring	Q
MW-133	17.5-22'	1) Groundwater BTEX monitoring 2) Geochemistry for natural attenuation	1) S 2) Q
MW-134	17-21.5'	1) Groundwater BTEX monitoring 2) Geochemistry for natural attenuation 3) Groundwater elevation check	1) S 2) Q 3) S
MW-135	10.57'-19.49'	Groundwater BTEX monitoring	M
MW-136	10.11'-19.07'	Groundwater BTEX monitoring	M
MW-137	10.42'-19.32'	Groundwater BTEX monitoring	M
MW-138	3.86'-18.06'	No regular sampling; well installed for propylene glycol monitoring.	As needed
MW-139	5.70'-25.02'	Groundwater BTEX monitoring	Q
MW-140	4.20'-23.50'	Groundwater BTEX monitoring	Q
MW-141	7.94'-22.40'	1) Groundwater BTEX monitoring 2) Groundwater elevation check	1) S 2) S
MW-142	5.35'-19.35'	Groundwater BTEX monitoring	Q

Table 6
Observation Wells, Depths, Functions, and Observation Frequencies

Well ID	Install Date	Screened Section Depth (feet bgs)	Total Depth (feet bgs)	Function	Frequency
S-9	Aug-01	2" PVC, 0.01" slotted 4.88' - 18.88'	19.8'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-10	Aug-01	2" PVC, 0.01" slotted 4.85' - 18.95'	19.9'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-19	Nov-86	4" PVC, bottom 10' slotted 0.02"	11.7'	GW Elevation	Semi-annual (April/October)
S-20	May-87	2" PVC, 0.02" slotted 2.7' - 12.45'	12.1'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-21	May-87	2" PVC, 0.02" slotted 2.92' - 12.67'	13.4'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-22	May-87	2" PVC, 0.02" slotted 4.5' - 14.2'	14.7'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-23	Sep-86	2" PVC, 0.02" slotted 3.51-12.85'	13.6'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-26	Sep-86	2" PVC, 0.02" slotted 4.20-13.6'	14.3'	GW Elevation	Semi-annual (April/October)
S-27	Nov-87	5' of 4" ABS, 10' of 4" slotted PVC 0.20"	12.3'	NAPL Product thickness and presence/absence; recover NAPL as needed.	Quarterly (January/April/ July/October)
S-28	Nov-87	5' of 4" ABS, 10' of 4" slotted PVC 0.20"	11.7'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-29	Nov-87	5' of 4" ABS, 10' of 4" slotted PVC 0.20"	11.4'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-32	Nov-87	5' of 4" ABS, 10' of 4" slotted PVC 0.20"	11.3'	NAPL Product thickness and presence/absence; recover NAPL as needed.	Quarterly (January/April/ July/October)

Table 6
Observation Wells, Depths, Functions, and Observation Frequencies

Well ID	Install Date	Screened Section Depth (feet bgs)	Total Depth (feet bgs)	Function	Frequency
S-33	Nov-87	5' of 4" ABS, 10' of 4" slotted PVC 0.20"	12'	NAPL Product thickness and presence/absence; recover NAPL as needed.	Quarterly (January/April/ July/October)
S-34	Dec-89	7.94-12.94'	13'	NAPL Product thickness and presence/absence; recover NAPL as needed.	Quarterly (January/April/ July/October)
S-35	Dec-89	8.0-13.0'	13'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-36	Dec-89	7.70-12.70'	13'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-37	Dec-89	6.75-11.75'	12'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-38	Dec-89	7.90-12.90'	13'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-39	Dec-89	7.53-12.53'	13'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-40	Dec-89	7.75-12.75	13'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-41	3/22/90	12.07-16.52'	17'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-42	6/5/91	3.16'-12.66'	13'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-43	6/5/91	3.37'-12.7'	13'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-44	6/5/91	3.16'-12.64'	13'	NAPL Presence/Absence	Quarterly (January/April/ July/October)

Table 6
Observation Wells, Depths, Functions, and Observation Frequencies

Well ID	Install Date	Screened Section Depth (feet bgs)	Total Depth (feet bgs)	Function	Frequency
S-47	Before 1998	10.4'-20.4'	20.7'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-48	Before 1998	7.0'-17.0'	17.3'	NAPL Presence/Absence	Quarterly (January/April/ July/October)
S-49	Before 1998	5.4'-15.4'	15.7'	NAPL Product thickness and presence/absence; recover NAPL as needed.	Quarterly (January/April/ July/October)
S-50	7/15/97	4" PVC, slots 0.020", 3.88'-13.56'	15'	NAPL Product thickness and presence/absence; recover NAPL as needed.	Quarterly (January/April/ July/October)
S-51	6/12/97	2" PVC, slots 0.020", 4.75'-14.43'	15'	NAPL Product thickness and presence/absence; recover NAPL as needed.	Quarterly (January/April/ July/October)
S-52	7/15/97	4" PVC, slots 0.020", 4.46'-14.14'	15'	NAPL Product thickness and presence/absence; recover NAPL as needed.	Quarterly (January/April/ July/October)
S-54	7/1/98	2" PVC, 0.02" slotted 10' - 15'	15'	GW Elevation	Semi-annual (April/October)
S-55	7/1/98	2" PVC, 0.02" slotted 10' - 15'	15'	GW Elevation	Semi-annual (April/October)

Table 7
Recovery Wells, Descriptions, Functions, and Recovery Frequencies

Recovery Wells	Installed	Location	Well Type and Screen Interval	Function	Frequency
R-1	Jun-86	SE corner T820-823	4.16' diam. culvert; total depth 9.3'	Use for static product recovery.	As needed.
R-3	Nov-82	So. of CU#1	3.15' diam. culvert; total depth 6.92'	Use for static product recovery.	As needed.
R-4	Nov-82	So. of CU#1	4.15' diam. culvert; total depth 8.56'	Use for static product recovery.	As needed.
R-5	Jun-86	No. of CU#1	3.15' diam. culvert; total depth 7.23'	Use for static product recovery.	As needed.
R-6	Nov-82	So. of CU#1	3.15' diam. culvert; total depth 5.95'	Use for static product recovery.	As needed.
R-9	Jun-86	E. of Tank 402	4.17' diam. culvert; total depth 7.98'	Use for static product recovery.	As needed.
R-10	Jun-86	E. of Tank 515	1.65' diam. culvert; total depth 9.14'	Use for static product recovery.	As needed.
R-10A	Jun-86	E. of Tank 515	3.15' diam. culvert; total depth 5.96'	Use for static product recovery.	As needed.
R-11	Jun-86	NE. of Tank 515	1.66' diam. culvert; total depth 8.13'	Use for static product recovery.	As needed.
R-12	Jun-86	SE of Tank 514	4" ABS; 4.0 -7.6'	Use for static product recovery.	As needed.
R-13	Jun-86	So of T510 514	1.63' diam. culvert; total depth 9.65'	Use for static product recovery.	As needed.
R-14	Jun-86	NW of T820-823	1.65' diam. culvert; total depth 6.06'	Use for static product recovery.	As needed.
R-14A	1987	NW of T820-823	4" ABS; 4.0 -10.73'	Use for static product recovery.	As needed.

Table 7
Recovery Wells, Descriptions, Functions, and Recovery Frequencies

Recovery Wells	Installed	Location	Well Type and Screen Interval	Function	Frequency
R-18	Jun-87	No. of Tank 193	10" diam. steel; 7.65-32.77'	Use for static product recovery.	As needed.
R-19	Jun-87	In dike around T403-404	10" diam. steel; 8.64-21.17'	Use for static product recovery.	As needed.
R-20	Jun-87	In dike around T403-404	10" diam. steel; 8.83-33.92'	Use for static product recovery.	As needed.
R-21	Oct-87	W of T820-823	12" diam. Steel; 4.17-24.17' (29.17B.O.H.)	Use for active product recovery and hydraulic control south of truck loading area.	Continuous.
R-22	Oct-87	NW of T820-823	12" diam. steel; 4.65-24.65' (29.65' B.O.H.)	Use for static product recovery.	As needed.
R-25	Oct-87	No. of air strippers	3' diam. culvert; 5.5-9.45'	Use for static product recovery.	As needed.
R-26	Nov-87	So. of T403/515 dike	2' diam. culvert; total depth 8.66'	Use for static product recovery.	As needed.
R-27	Nov-87	So. of T403/515 dike	2' diam. culvert; total depth 9.31'	Use for static product recovery.	As needed.
R-28	Nov-87	E. of T403/515 dike	2' diam. culvert; total depth 6.73'	Use for static product recovery.	As needed.
R-29	Nov-87	E. of T403/515 dike	2' diam. culvert; total depth 7.32'	Use for static product recovery.	As needed.
R-30	Nov-87	NW of T403/515	2' diam. culvert; total depth 6.95'	Use for static product recovery.	As needed.
R-31	Nov-87	W of T403/515	2' diam. culvert; total depth 10.95'	Use for static product recovery.	As needed.

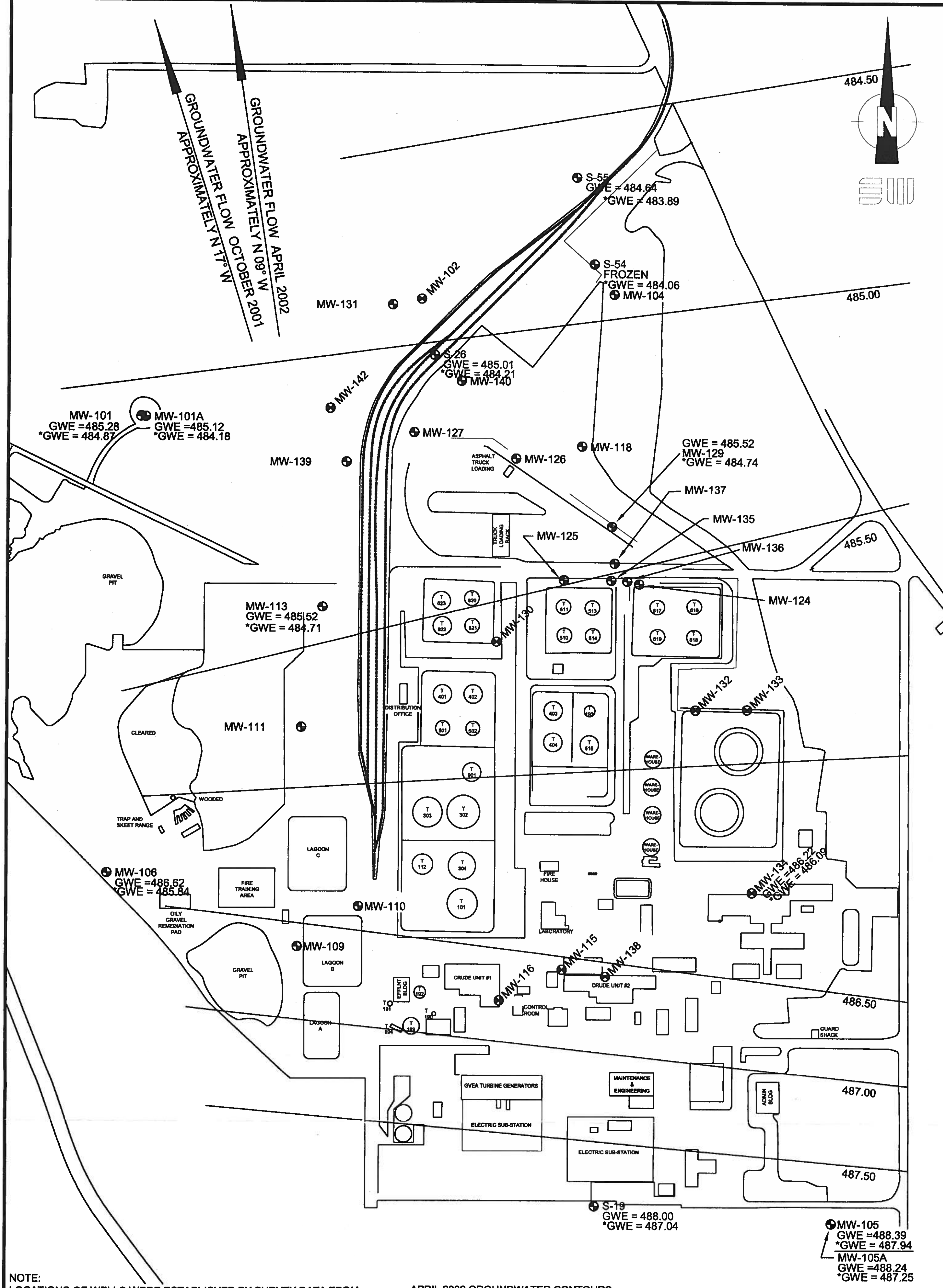
Table 7
Recovery Wells, Descriptions, Functions, and Recovery Frequencies

Recovery Wells	Installed	Location	Well Type and Screen Interval	Function	Frequency
R-32	Nov-87	W of T403/515	2' diam. culvert; total depth 10.97'	Use for static product recovery.	As needed.
R-33	Aug-88	No. of CU#1	12" diam. steel; 7.4-24.6'	Use for static product recovery.	As needed.
R-34	Aug-88; new screen added Sep-01	W of T403/515	12" diam. steel casing, 10" diam. stainless steel screen installed in 2001; 0.5 - 20.83 '	Use for active product recovery .	Continuous.
R-35	Aug-88	W of T510-514	12" diam. steel; 7.1-24.2'	Use for active product recovery.	Continuous.
R-36	Aug-88	So. of T403/515	12" diam. steel; 7.1-25.3'	Use for static product recovery.	As needed.
R-37	Aug-88	E of T403/515	12" diam. steel; 6.7-24.5'	Use for active product recovery .	As needed.
R-38	Aug-88	So. of CU#1 & CU#2	2' diam. culvert; total depth 9.8'	Use for static product recovery.	As needed.
R-39	1989	No. of T510-514	10" diam. steel; 6.25 to 25.5'	Use for active product recovery and hydraulic control south of truck loading area.	Continuous.
R-40	Jul-91	E of T820-823	10" diam. steel; 6.0 - 25.17'	Use for active product recovery and hydraulic control south of truck loading area.	Continuous.

Table 7
Recovery Wells, Descriptions, Functions, and Recovery Frequencies

Recovery Wells	Installed	Location	Well Type and Screen Interval	Function	Frequency
R-41	Oct-99	E of T820-823	5" diam. stainless steel; 19.5'-24.5'	Recovery well not in use. Well R-40 is nearby and was successfully rehabilitated in 2000.	Not used.

File: C:\My Documents\My Pictures\Refinery basemap 05.07.02.dwg Date: 06-04-2002 Author: srs



NOTE:
LOCATIONS OF WELLS WERE ESTABLISHED BY SURVEY DATA FROM SHANNON & WILSON INC. AND HISTORICAL DATA FROM DESIGN ALASKA INC. LOCATIONS OF OTHER FEATURES WERE DIGITIZED FROM AERIAL PHOTOGRAPHS SUPPLIED BY WILLIAMS ALASKA INC.
NO BOUNDARY SURVEY WAS PERFORMED.

DEPTH TO GROUNDWATER DATA COLLECTED BY WILLIAMS ALASKA INC. DURING OCTOBER 2001 AND APRIL 2002. OCTOBER 2001 DATA INDICATED BY ASTERISK (*). WELL S-54 WAS FROZEN DURING APRIL 2002; NO DATA COLLECTED.

DATA FROM MW-101 AND MW-105 DISREGARDED FOR PURPOSES OF THIS GROUNDWATER MODEL.

APRIL 2002 GROUNDWATER CONTOURS CALCULATED BY LINEAR INTERPROLATION AND TRIANGULATION FROM DATA SET SHOWN. GROUNDWATER ELEVATION GRADIENT APPROXIMATLEY 1 FOOT (V) / 1000 FEET (H).

0 300 600
Scale in Feet

WILLIAMS ALASKA INC.
NORTH POLE REFINERY
NORTH POLE, ALASKA

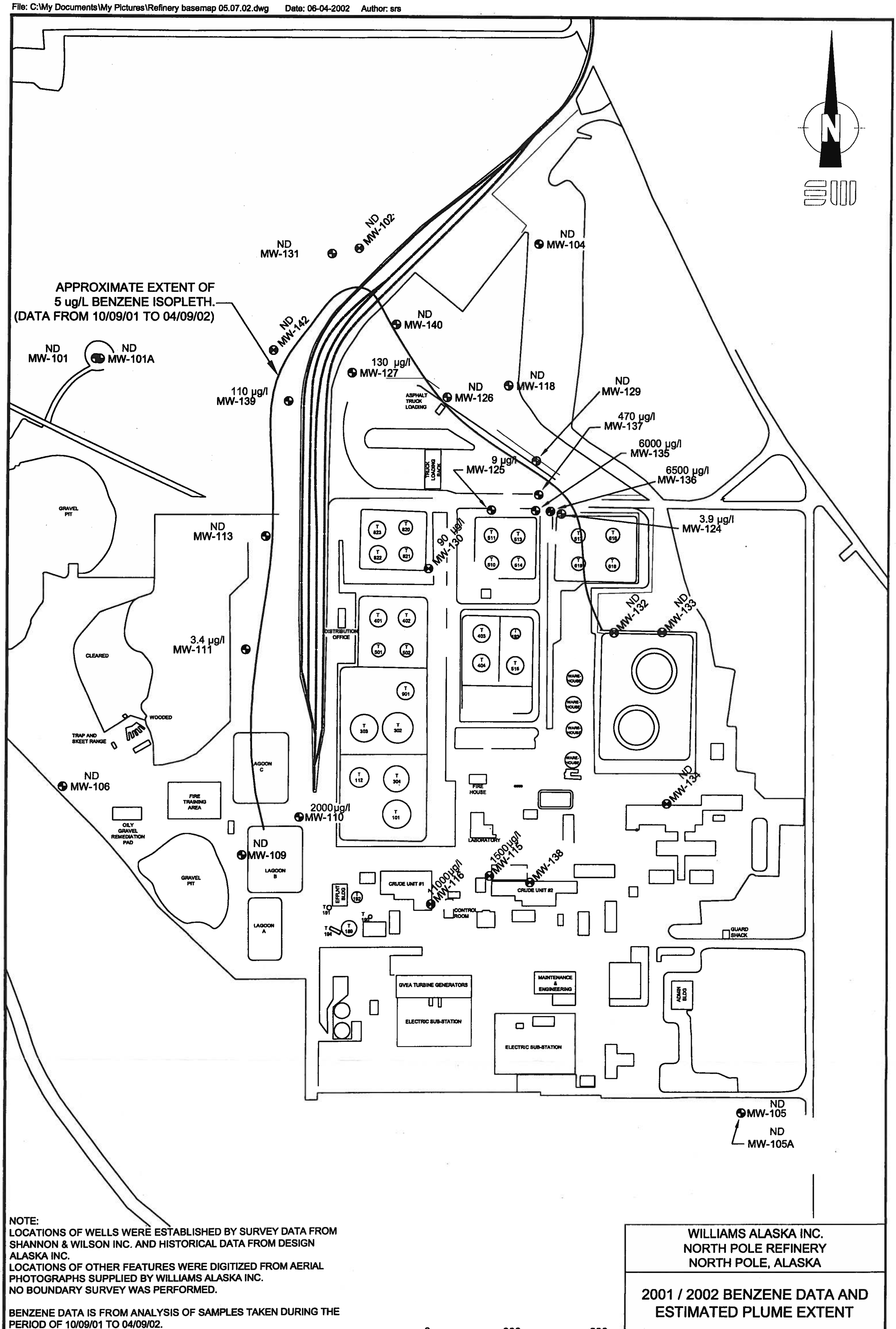
GROUNDWATER GRADIENT

June 2002 31-1-11066-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Figure 1

File: C:\My Documents\My Pictures\Refinery basemap 05.07.02.dwg Date: 06-04-2002 Author: srs



NOTE:
LOCATIONS OF WELLS WERE ESTABLISHED BY SURVEY DATA FROM SHANNON & WILSON INC. AND HISTORICAL DATA FROM DESIGN ALASKA INC.
LOCATIONS OF OTHER FEATURES WERE DIGITIZED FROM AERIAL PHOTOGRAPHS SUPPLIED BY WILLIAMS ALASKA INC.
NO BOUNDARY SURVEY WAS PERFORMED.

BENZENE DATA IS FROM ANALYSIS OF SAMPLES TAKEN DURING THE PERIOD OF 10/09/01 TO 04/09/02.

ND INDICATES THAT BENZENE WAS NOT PRESENT IN QUANTITIES GREATER THAN THE DETECTION LIMIT FOR THE TEST METHOD USED.

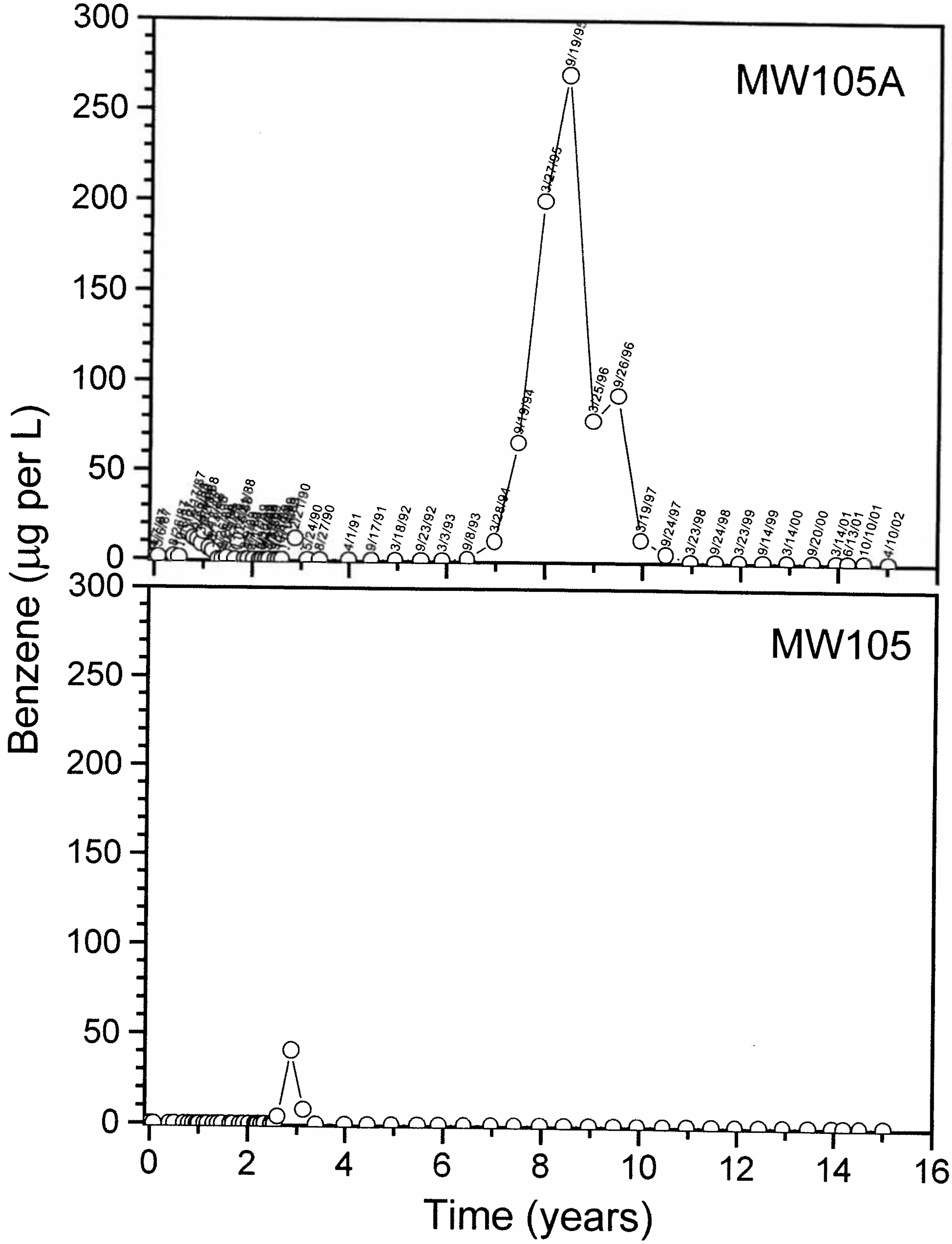
WILLIAMS ALASKA INC.
NORTH POLE REFINERY
NORTH POLE, ALASKA

2001 / 2002 BENZENE DATA AND ESTIMATED PLUME EXTENT

June 2002 | 31-1-11066-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Figure 2



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

BENZENE CONCENTRATIONS
MW-105 AND MW-105A

June 2002 | 31-1-11066-002

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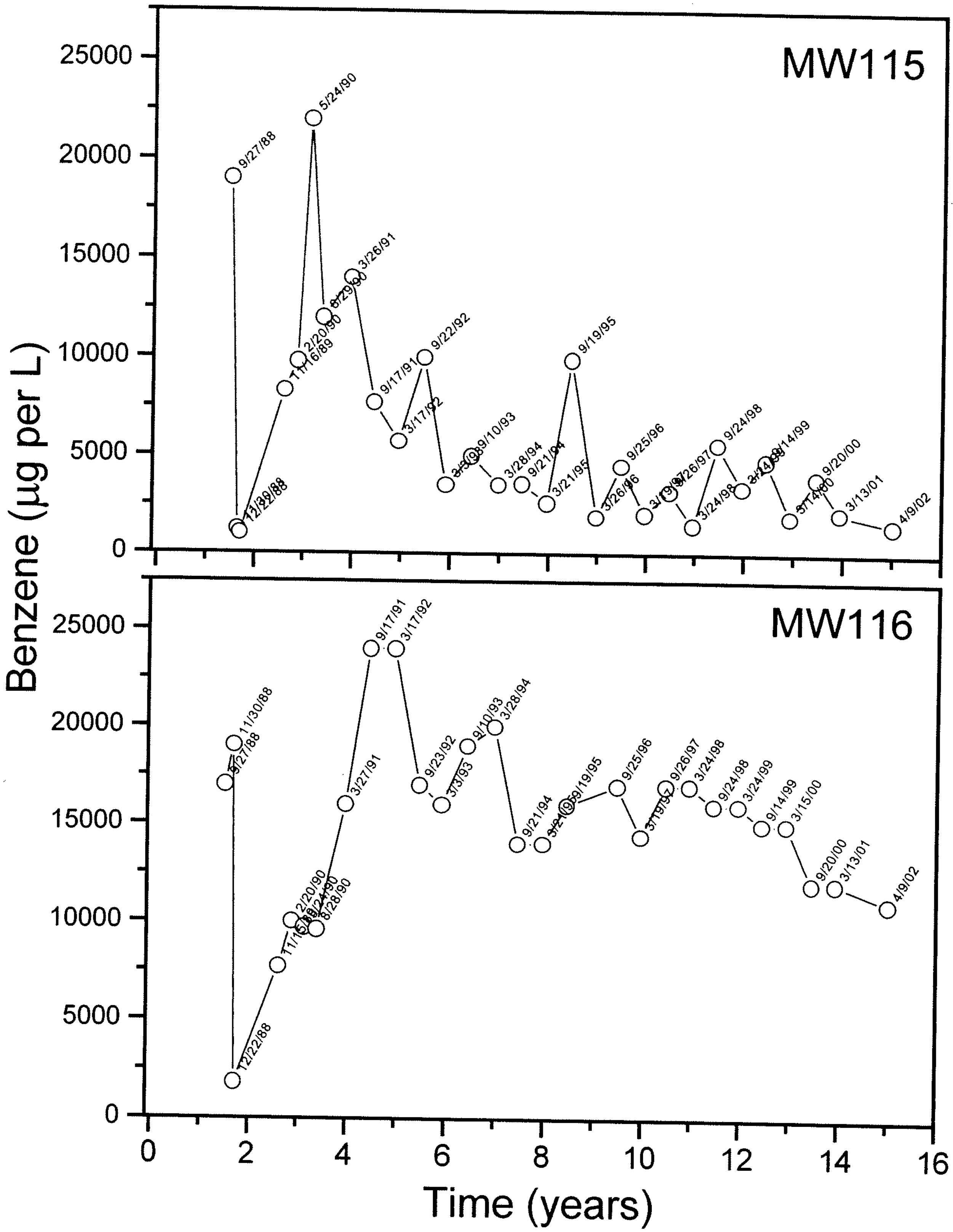
Figure 3



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

BENZENE CONCENTRATIONS
MW-115 AND MW-116

June 2002 | 31-1-11066-002

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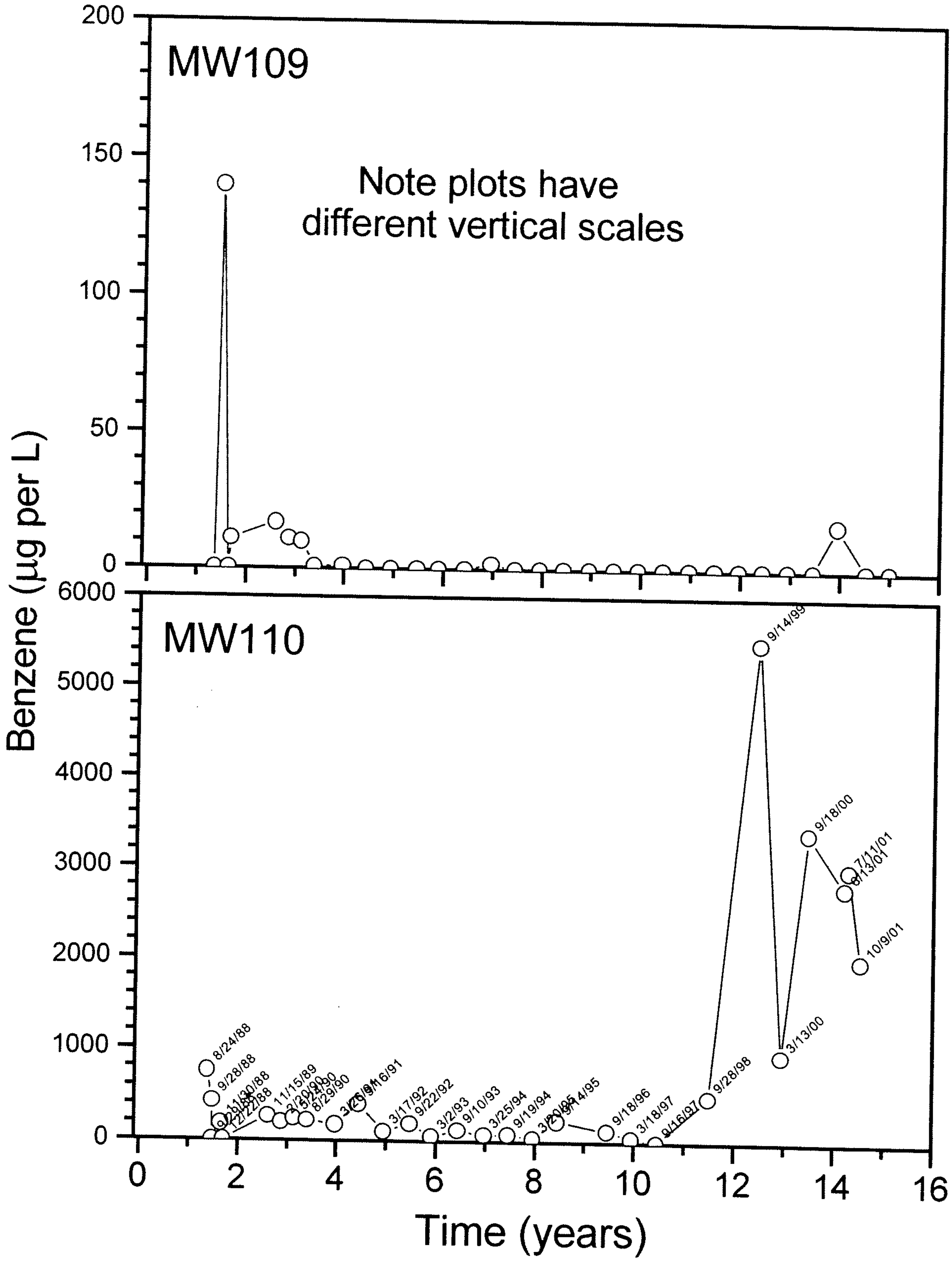
Figure 4



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

BENZENE CONCENTRATIONS
MW-109 AND MW-110

June 2002 31-1-11066-002

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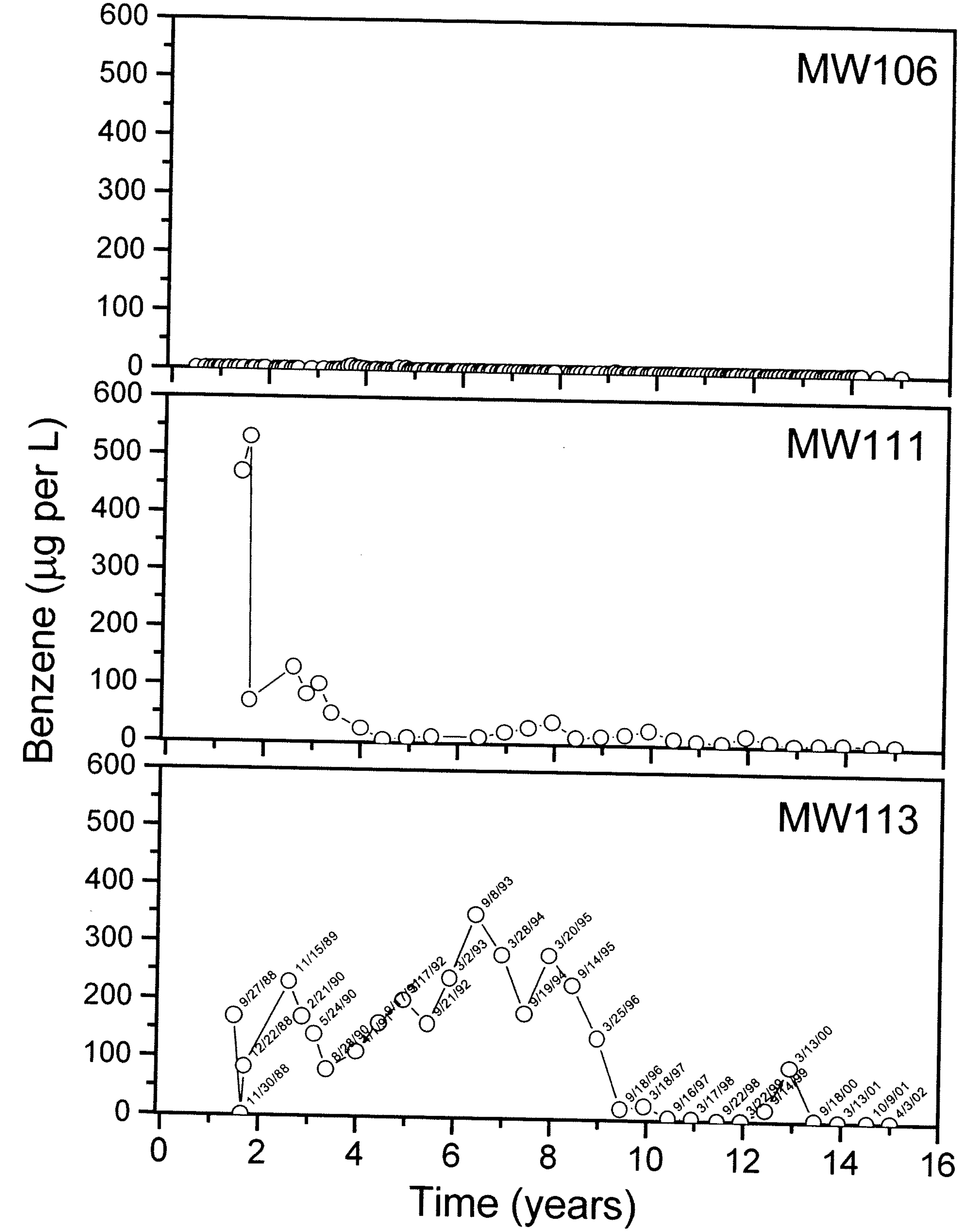
Figure 5



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

BENZENE CONCENTRATIONS
MW-106, MW-111, AND MW-113

June 2002 | 31-1-11066-002

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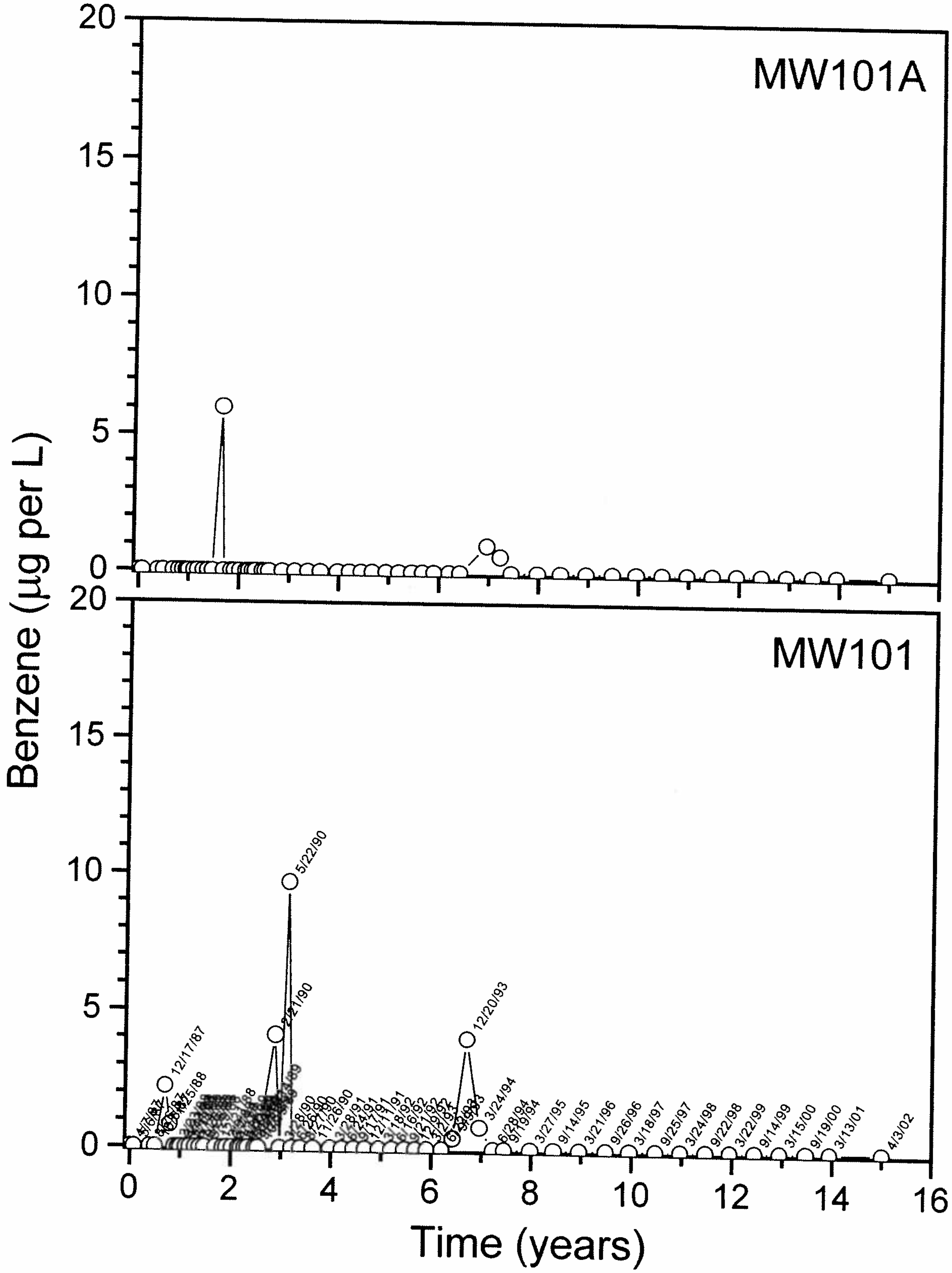
Figure 6



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

BENZENE CONCENTRATIONS
MW-101 AND MW-101A

June 2002

31-1-11066-002

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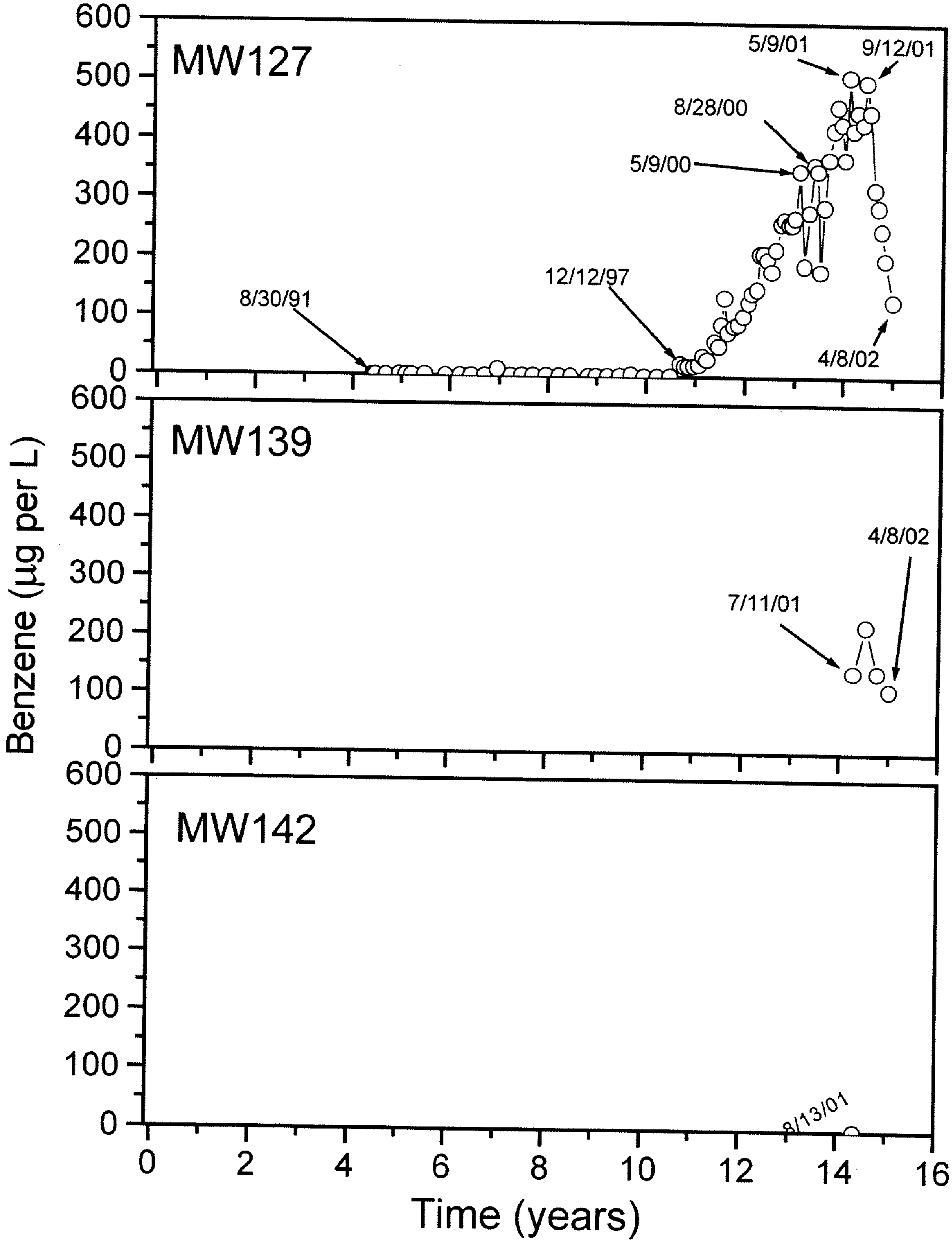
Figure 7



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

BENZENE CONCENTRATIONS
MW-127, MW-139, AND MW-142

June 2002 31-1-11066-002

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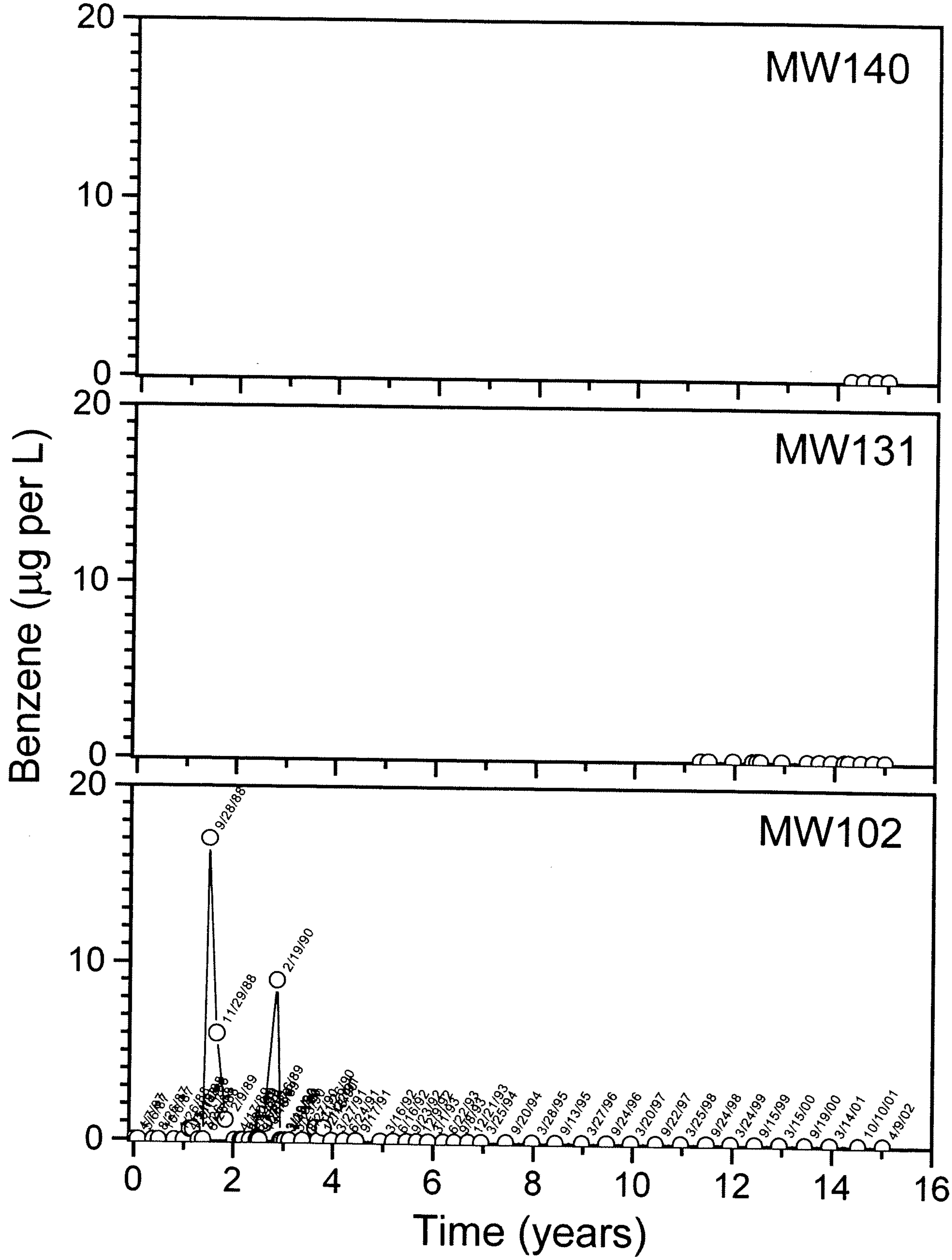
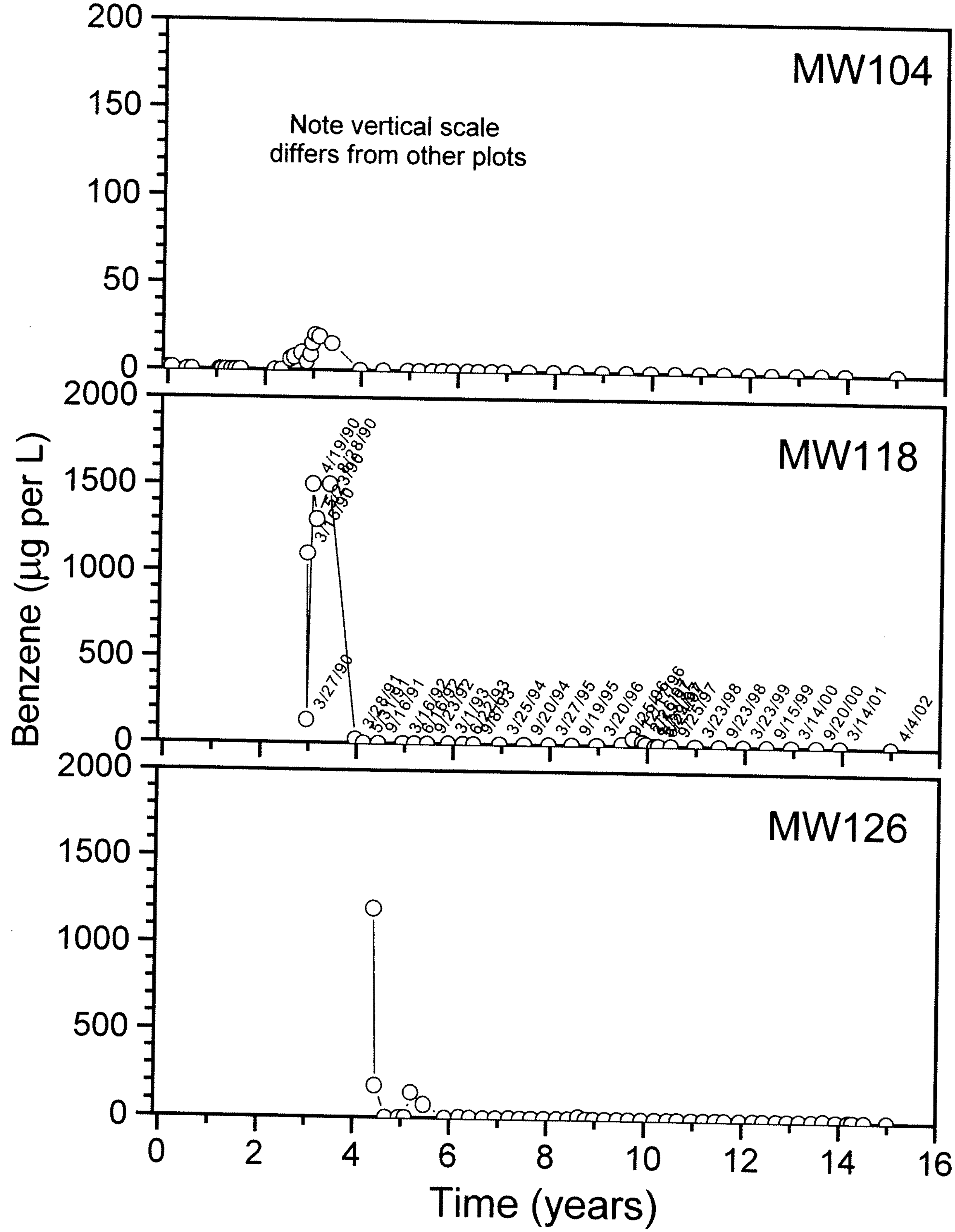
Figure 8



Williams Alaska Petroleum, Inc. Refinery, North Pole, Alaska	
BENZENE CONCENTRATIONS MW-140, MW-131, AND MW-102 June 2002 31-1-11066-002	
SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS	Figure 9



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

BENZENE CONCENTRATIONS
MW-104, MW-118, AND MW-126

June 2002

31-1-11066-002

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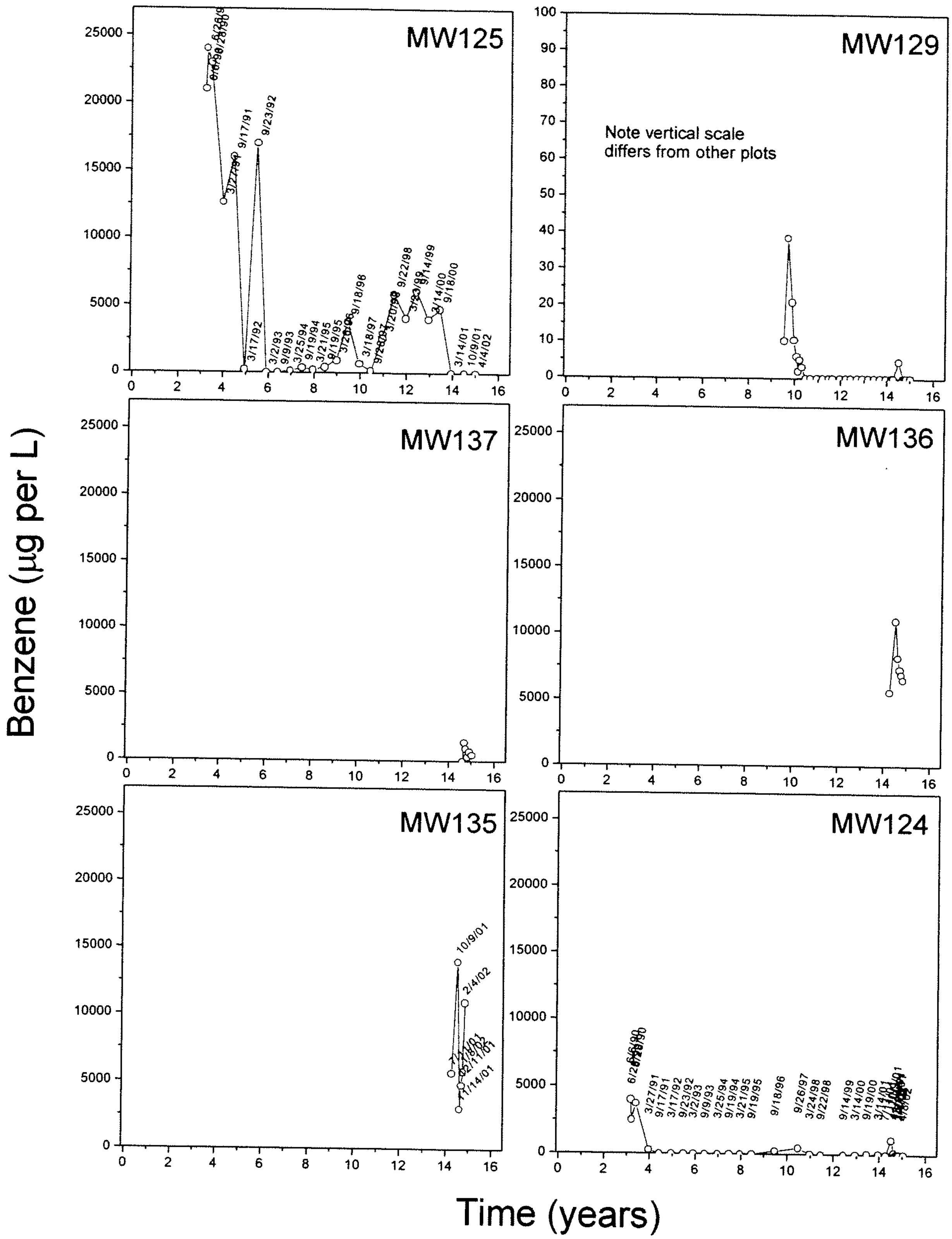
Figure 10



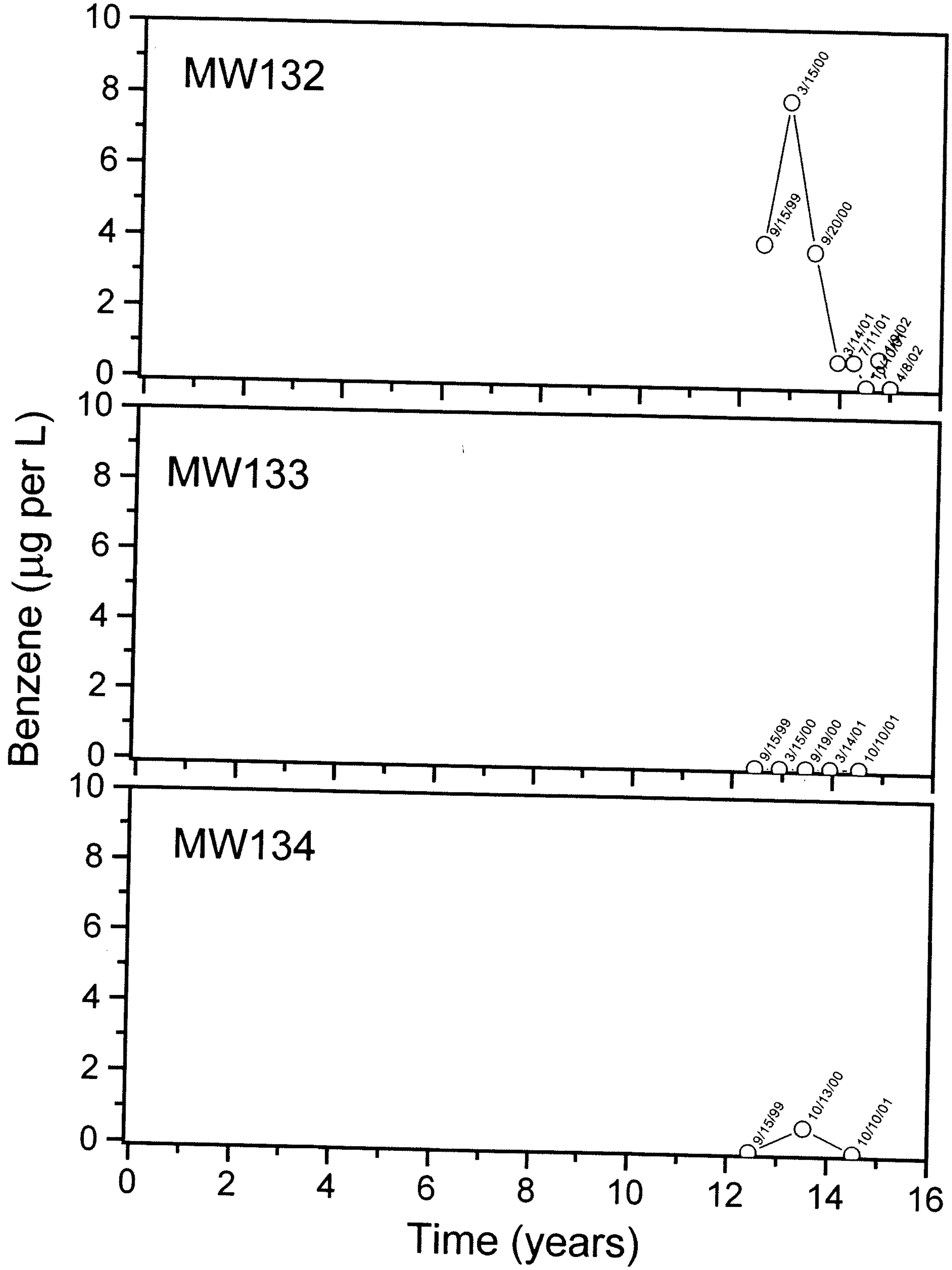
Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

BENZENE CONCENTRATIONS
MW-125, MW-129, MW-137,
MW-136, MW-135, AND MW-124

June 2002 31-1-11066-002

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Figure 11



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

BENZENE CONCENTRATIONS
MW-132, MW-133, AND MW-134

June 2002

31-1-11066-002

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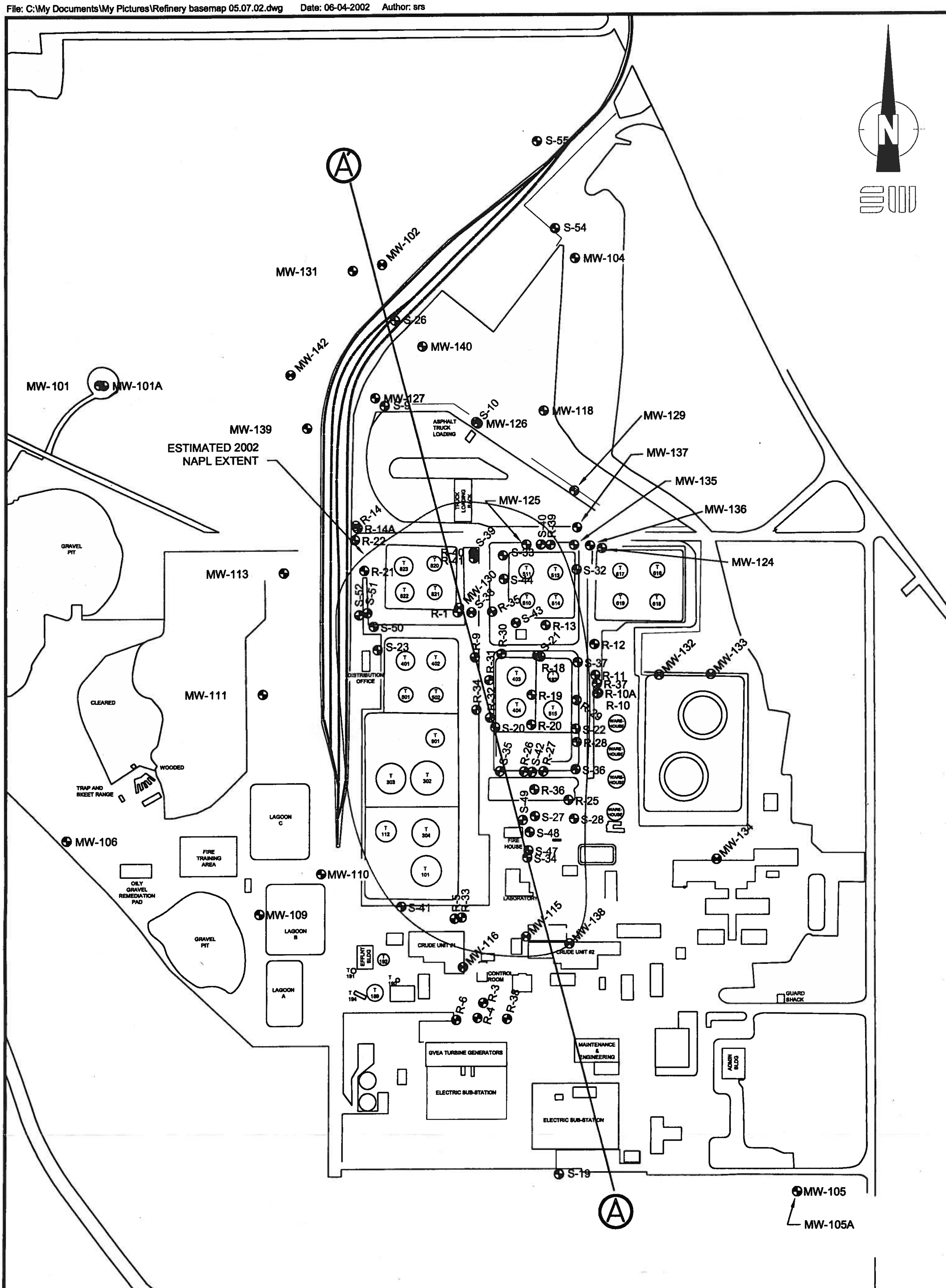
Figure 12

File: C:\My Documents\My Pictures\Refinery basemap 05.07.02.dwg   Date: 06-04-2002   Author: srs



NOTE:
LOCATIONS OF WELLS WERE ESTABLISHED BY SURVEY DATA FROM SHANNON & WILSON INC. AND HISTORICAL DATA FROM DESIGN ALASKA INC.
LOCATIONS OF OTHER FEATURES WERE DIGITIZED FROM AERIAL PHOTOGRAPHS SUPPLIED BY WILLIAMS ALASKA INC.
NO BOUNDARY SURVEY WAS PERFORMED.

PLUME EXTENT BASED ON NAPL THICKNESS AND RECOVERY DATA COLLECTED IN 2001 AND 2002.

NAPL DEPTH AND THICKNESS ALONG TRANSECT A-A' IS SHOWN IN FIGURE X

0 300 600
Scale in Feet

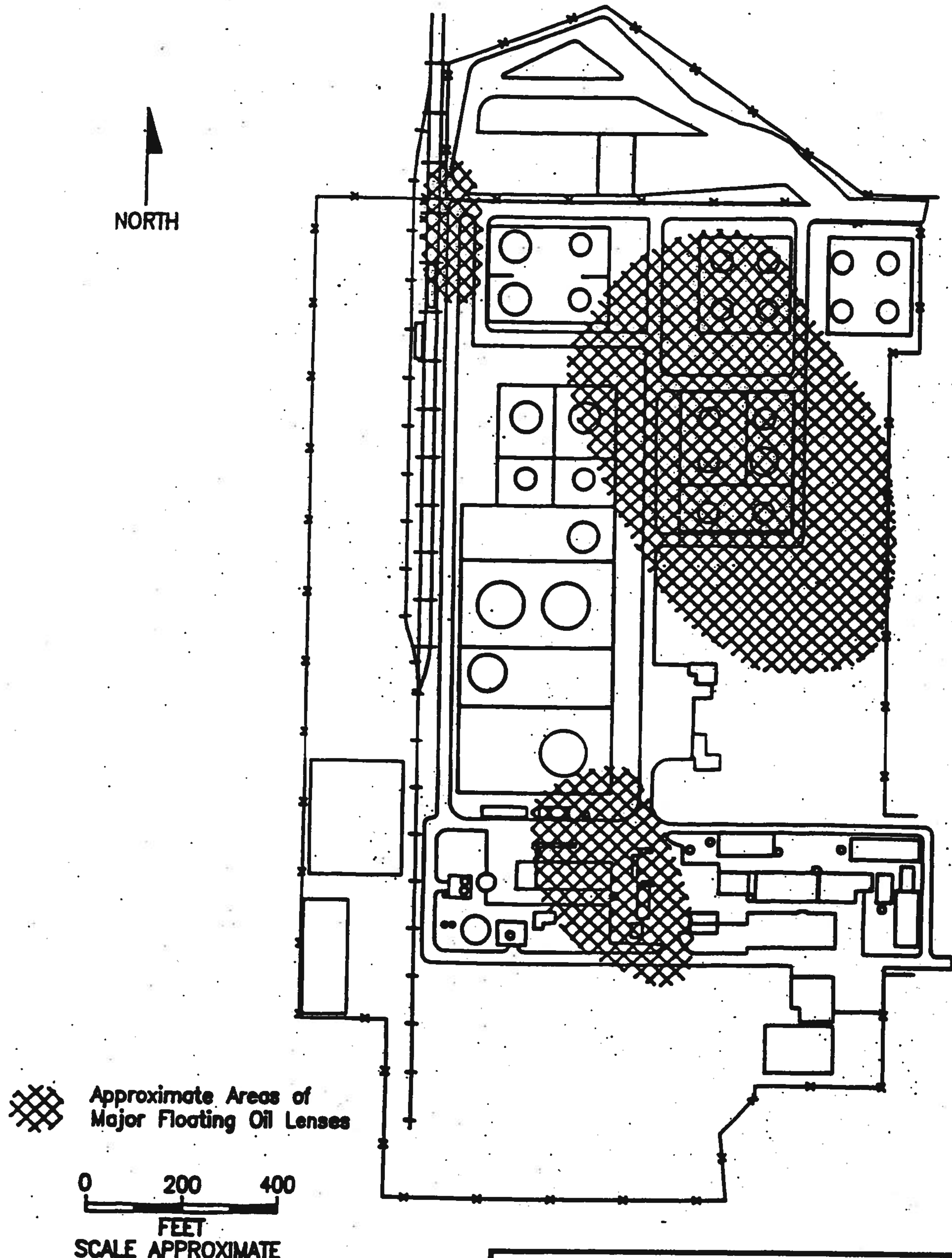
WILLIAMS ALASKA INC.
NORTH POLE REFINERY
NORTH POLE, ALASKA

ESTIMATED 2002
NAPL EXTENT AND TRANSECT

June 2002 31-1-11066-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Figure 13



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

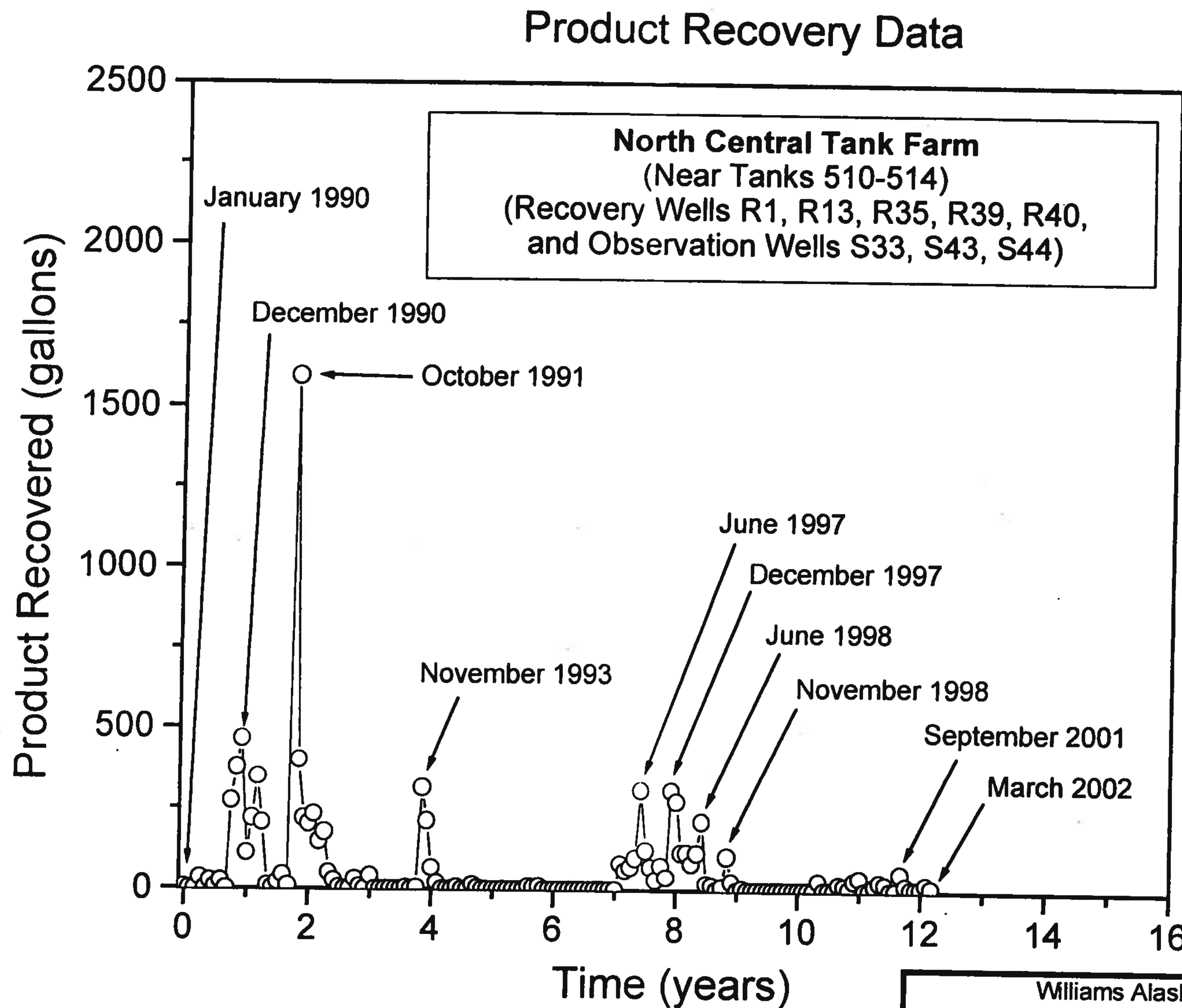
ESTIMATED LOCATION OF MAJOR FLOATING OIL LENSES, APRIL 1989 "DESCRIPTION OF CURRENT CONDITIONS"

June 2002

31-1-11066-002

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Figure 14



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

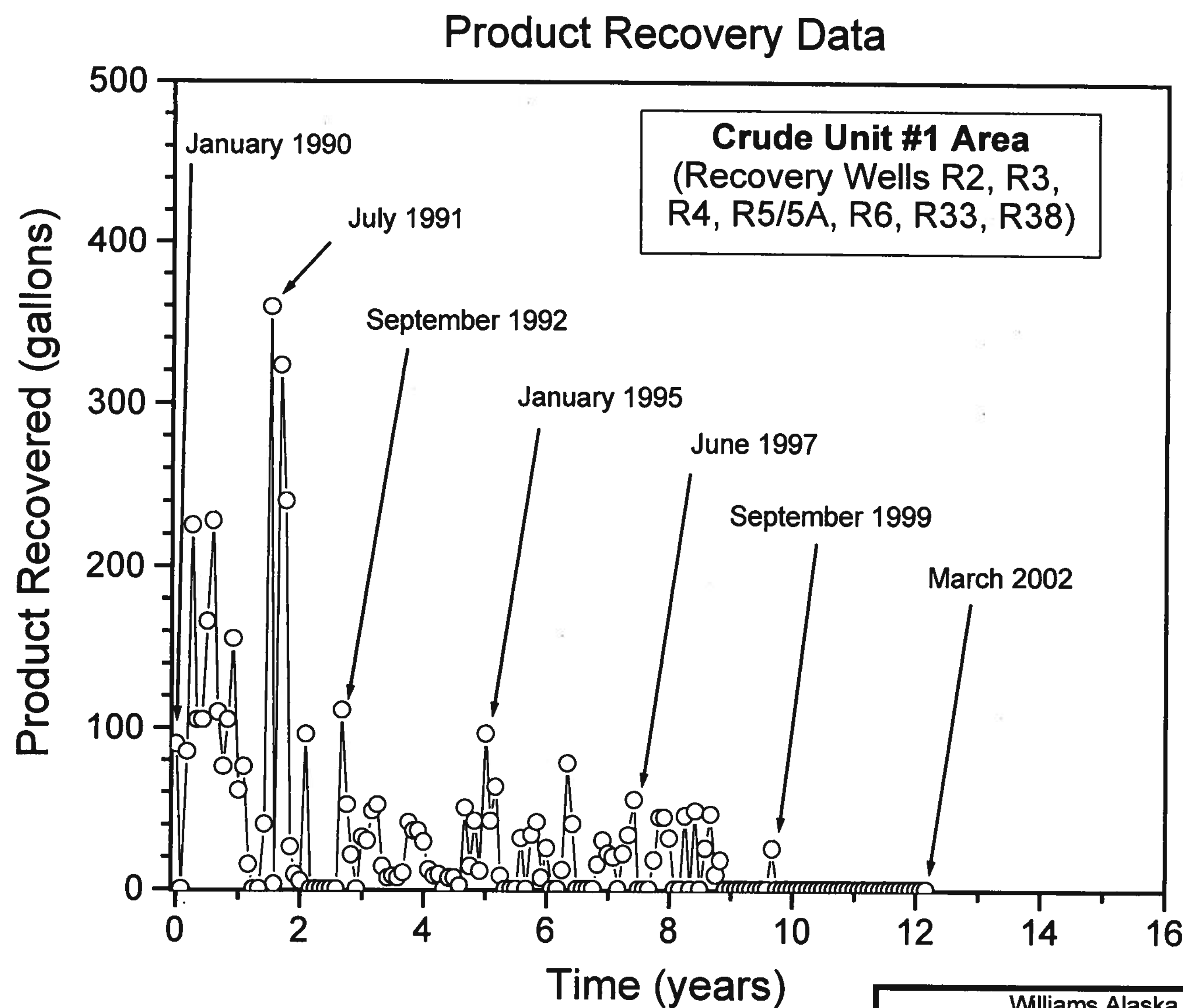
PRODUCT RECOVERY
NORTH CENTRAL TANK FARM

June 2002 | 31-1-11066-002

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Figure 15

Figure 15



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

PRODUCT RECOVERY
CRUDE UNIT #1 AREA

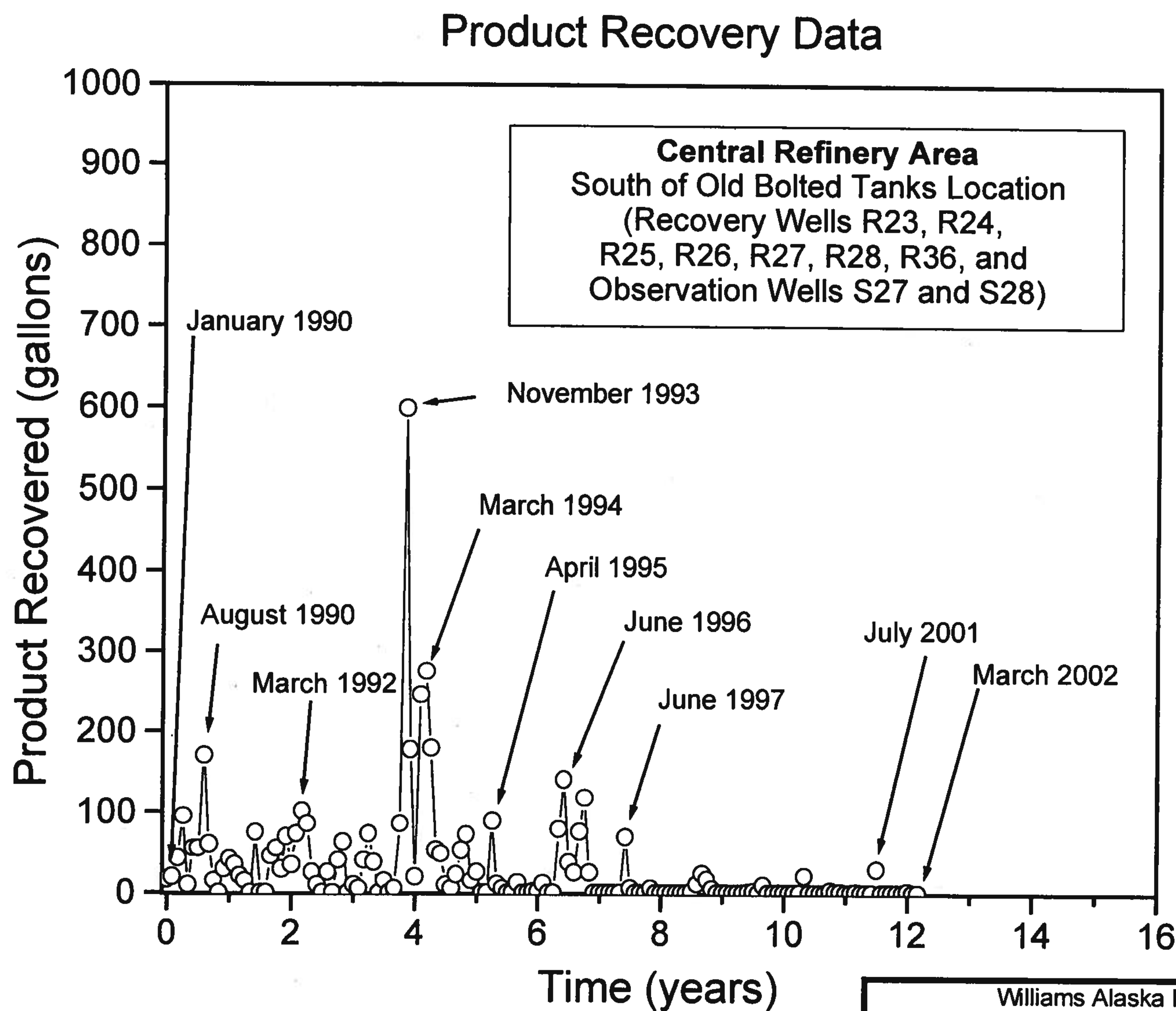
June 2002

31-1-11066-002

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Figure 16

Figure 16



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

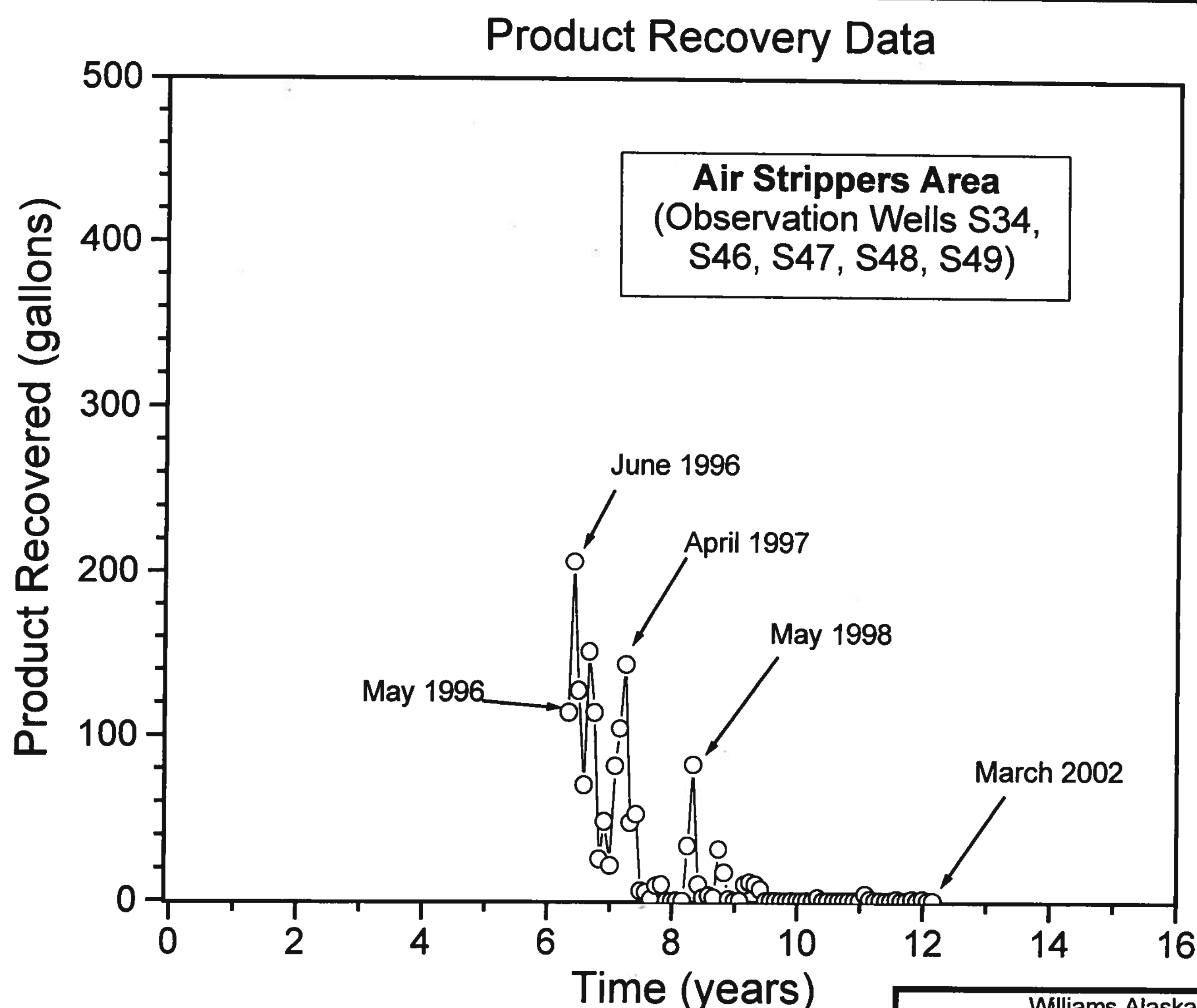
PRODUCT RECOVERY
CENTRAL REFINERY AREA

June 2002 31-1-11066-002

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Figure 17

Figure 17



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

PRODUCT RECOVERY
AIR STRIPPERS AREA

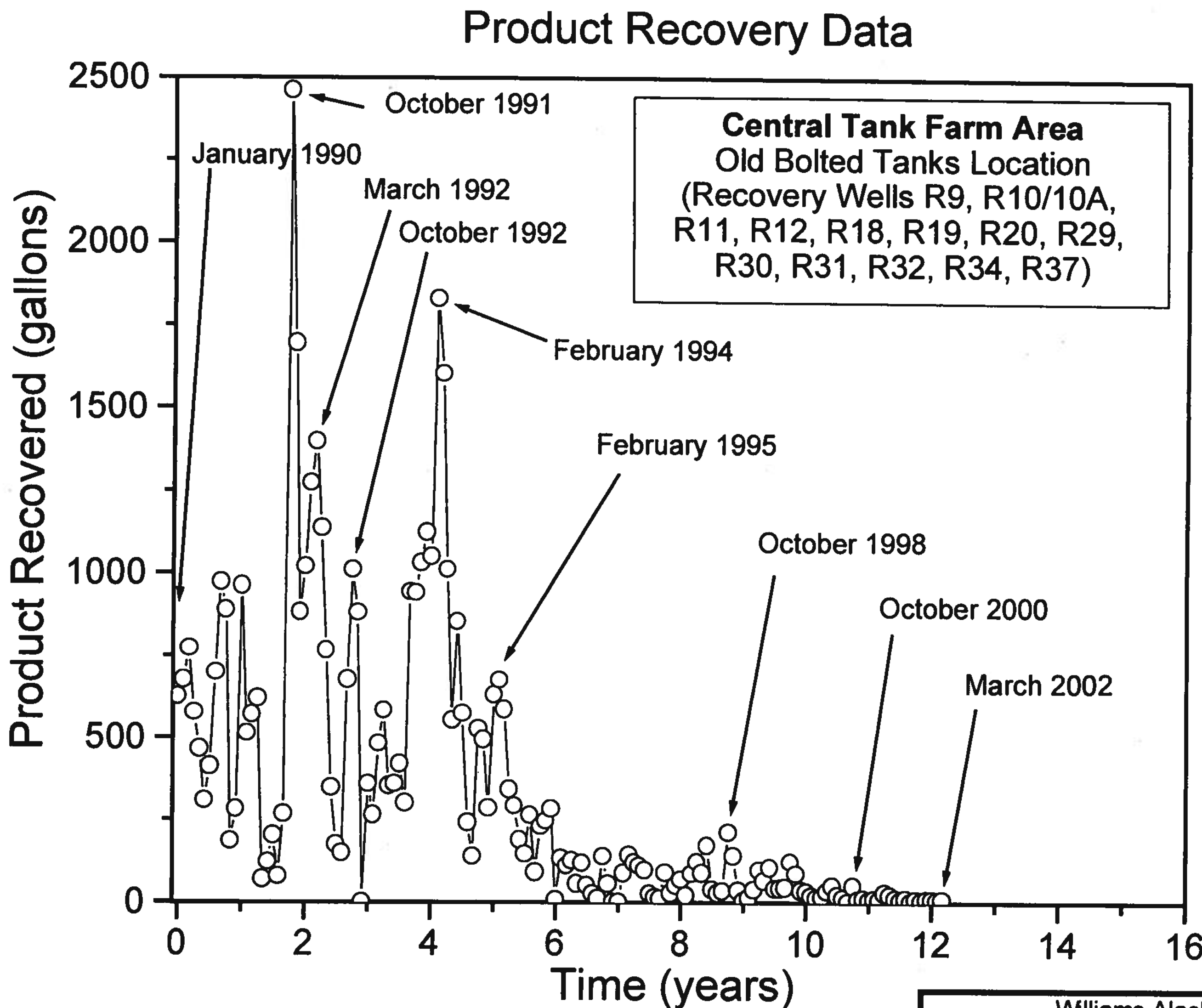
June 2002

31-1-11066-002

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

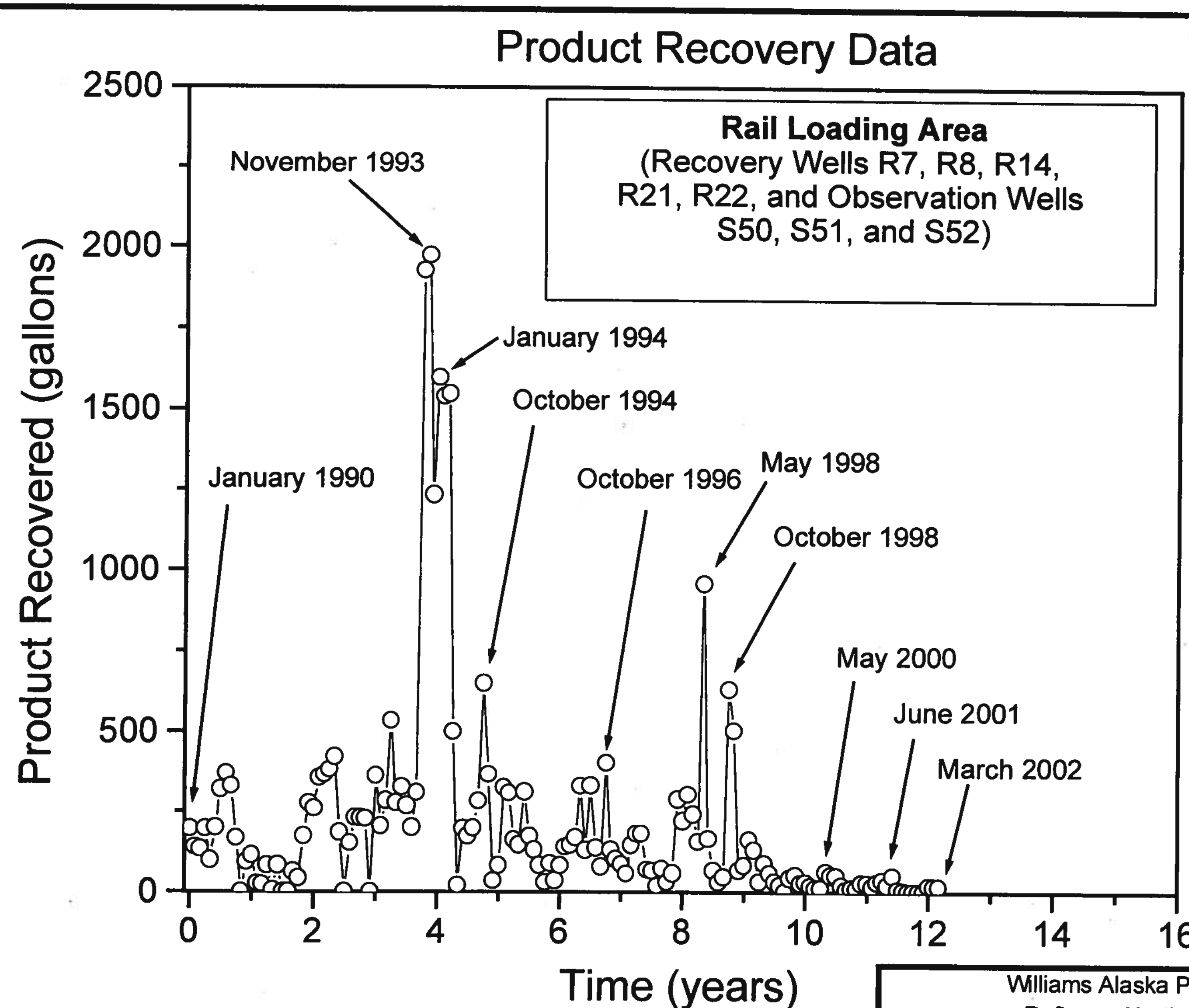
Figure 18

Figure 18



Williams Alaska Petroleum, Inc. Refinery, North Pole, Alaska	
PRODUCT RECOVERY CENTRAL TANK FARM AREA June 2002 31-1-11066-002	
SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS	Figure 19

Figure 19



Williams Alaska Petroleum, Inc.
Refinery, North Pole, Alaska

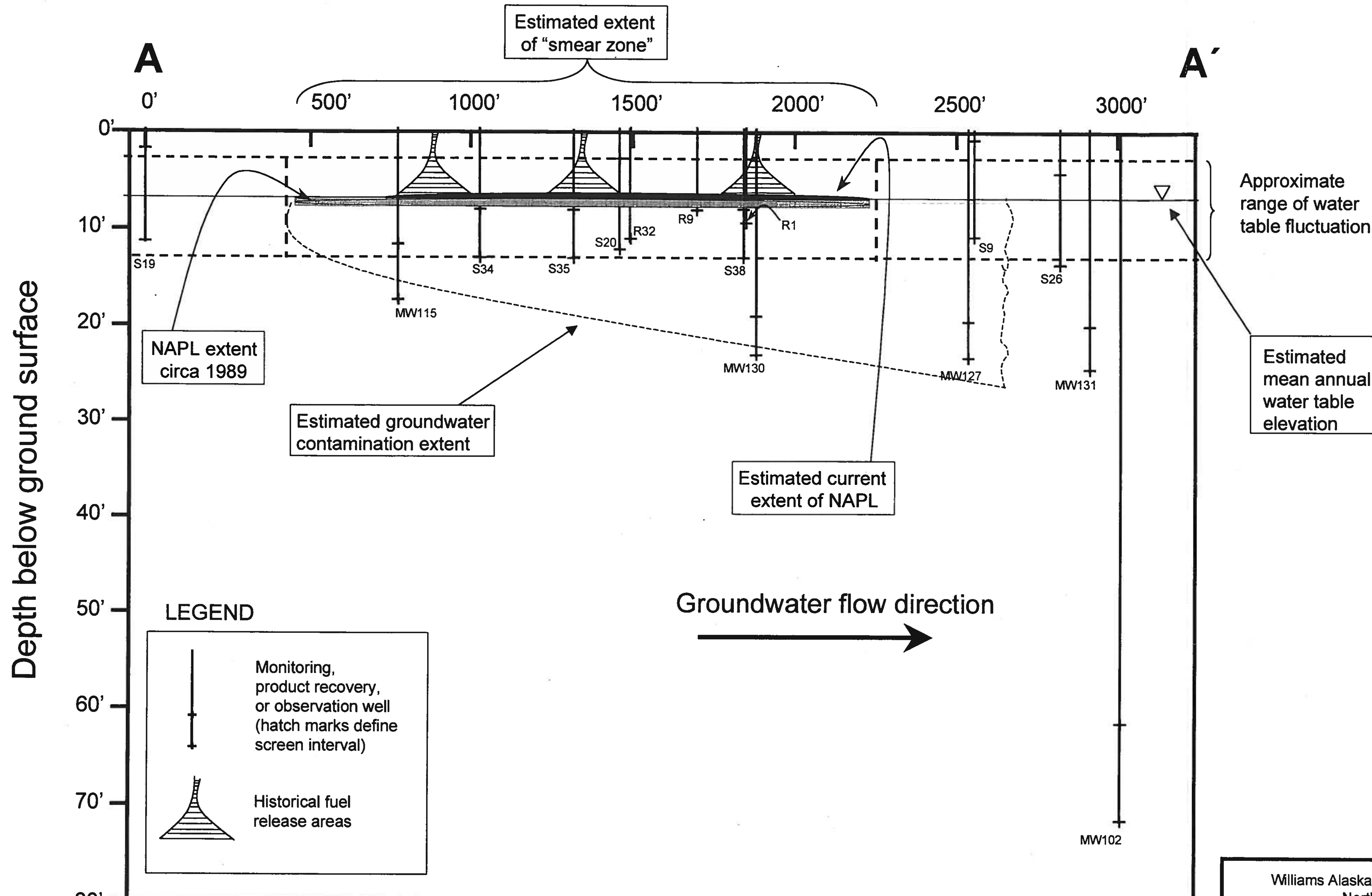
PRODUCT RECOVERY
RAIL LOADING AREA

June 2002 | 31-1-11066-002

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Figure 20

Figure 20



Williams Alaska Petroleum, Inc. Refinery
North Pole, Alaska

CONCEPTUAL SITE MODEL CROSS-SECTION ALONG TRANSECT A-A' AT REFINERY

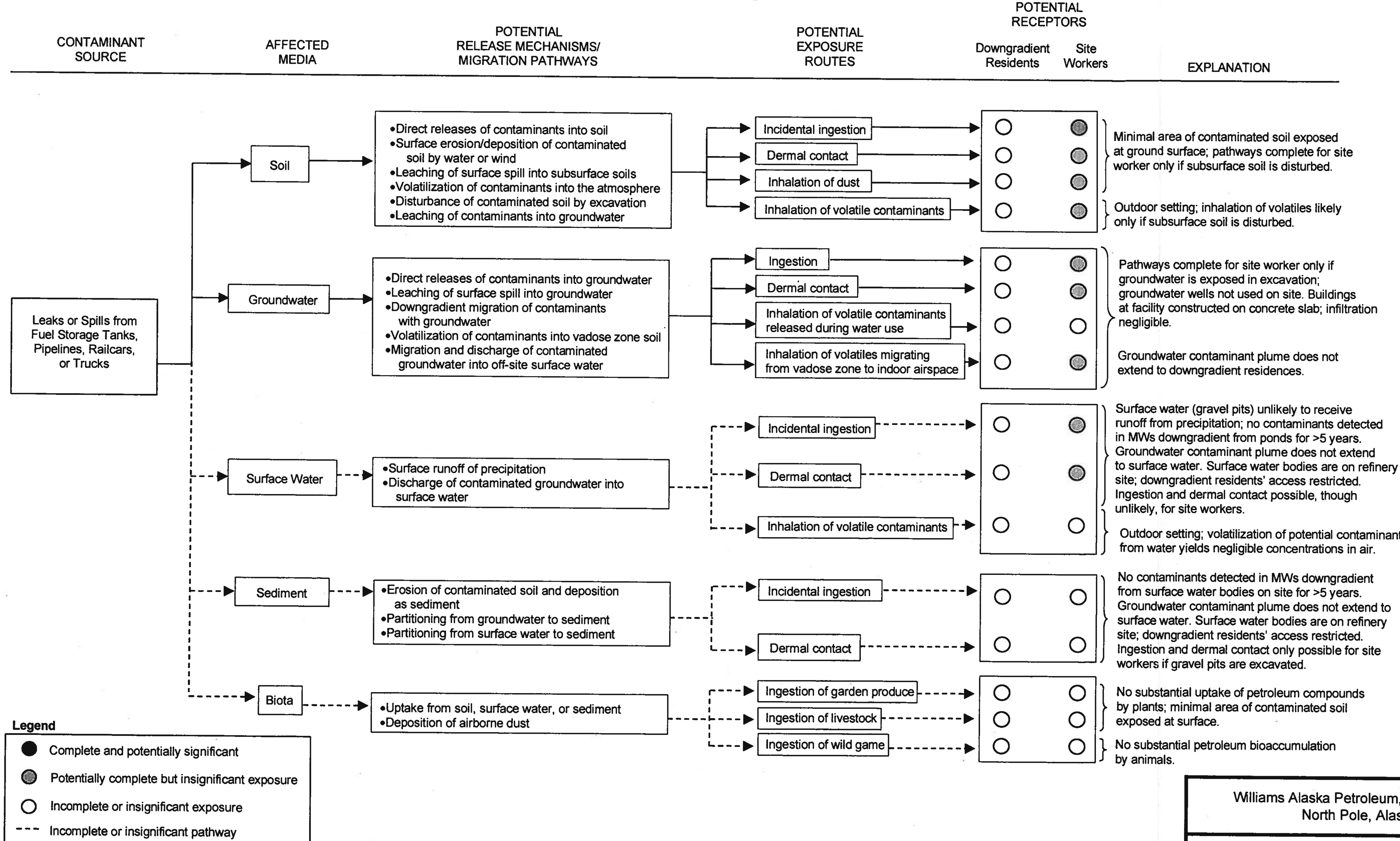
June 2002

31-1-11066-002

SHANNON & WILSON, INC. GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Figure 21

Williams Alaska Petroleum, Inc.
North Pole Refinery Conceptual Site Model



Williams Alaska Petroleum, Inc. Refinery
North Pole, Alaska

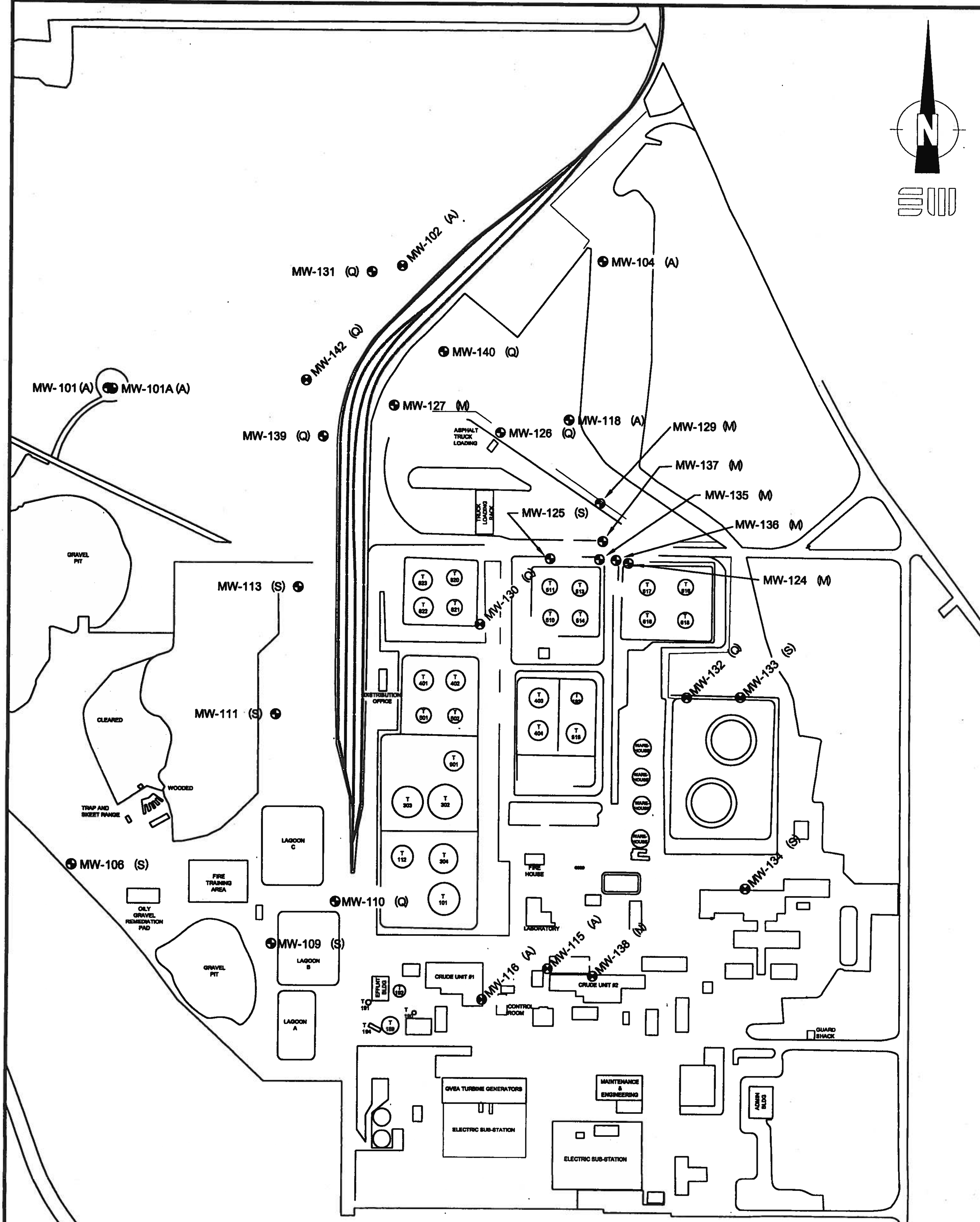
CONCEPTUAL SITE MODEL
POTENTIAL CONTAMINANT EXPOSURE
PATHWAY ANALYSIS

June 2002 | 31-1-11066-002

SHANNON & WILSON, INC.
GEOTECHNICAL AND ENVIRONMENTAL CONSULTANTS

Figure 22

File: C:\My Documents\My Pictures\Refinery basemap 05.07.02.dwg Date: 05-16-2002 Author: srs



WELL BTEX SAMPLING FREQUENCY LEGEND

(A) ANNUALLY
(S) SEMI-ANNUALLY
(Q) QUARTERLY
(M) MONTHLY
(N) NOT SAMPLED FOR BTEX

NOTE:
LOCATIONS OF WELLS WERE ESTABLISHED BY SURVEY DATA FROM SHANNON & WILSON INC. AND HISTORICAL DATA FROM DESIGN ALASKA INC.
LOCATIONS OF OTHER FEATURES WERE DIGITIZED FROM AERIAL PHOTOGRAPHS SUPPLIED BY WILLIAMS ALASKA INC.
NO BOUNDARY SURVEY WAS PERFORMED.

0 300 600
Scale in Feet

WILLIAMS ALASKA INC.
NORTH POLE REFINERY
NORTH POLE, ALASKA

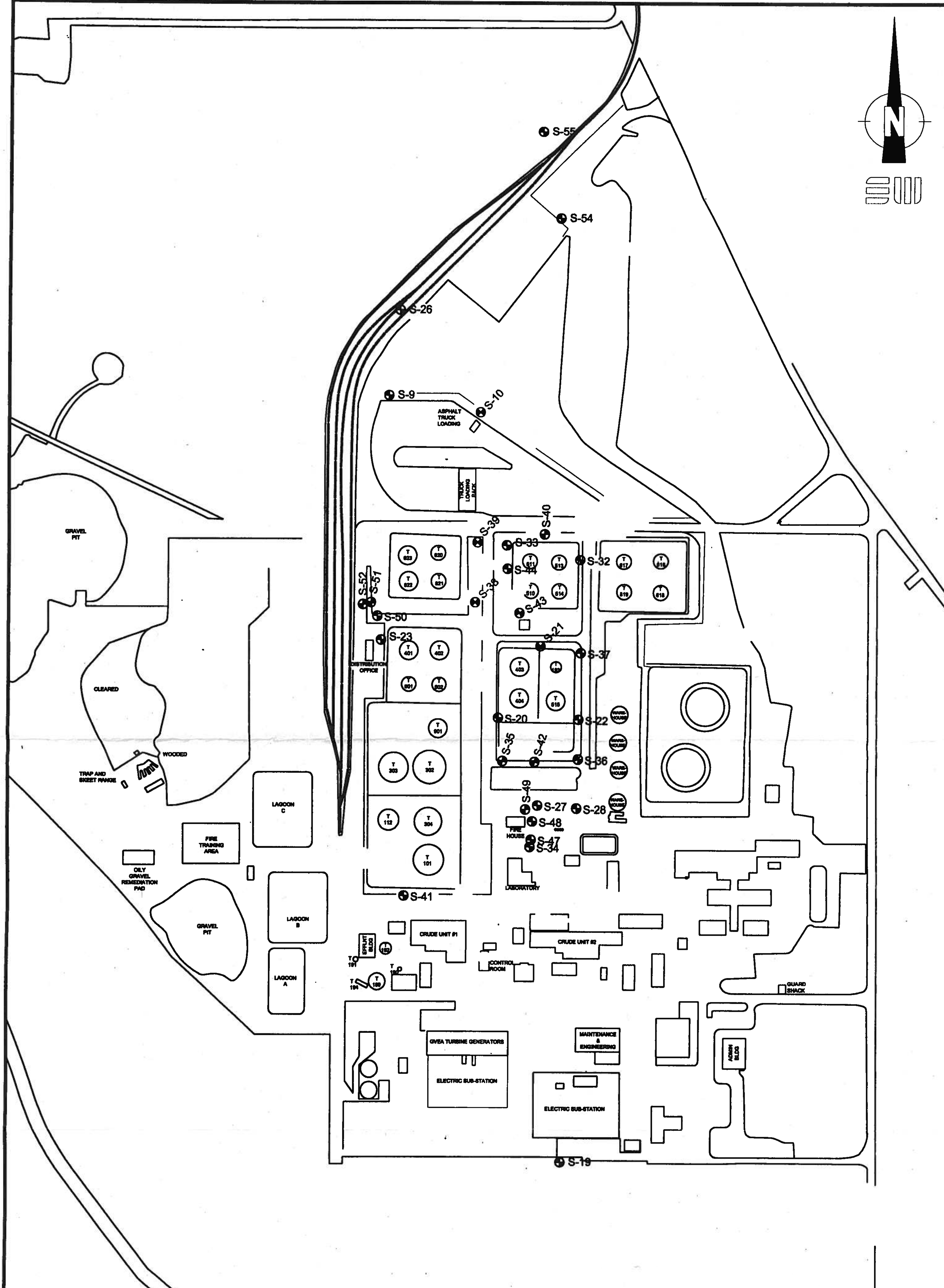
MONITORING WELLS
W/ BTEX SAMPLING FREQUENCIES

June 2002 31-1-11066-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Figure 23

File: C:\My Documents\My Pictures\Refinery basemap 05.07.02.dwg Date: 05-16-2002 Author: srs



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LOCATIONS OF OTHER FEATURES WERE DIGITIZED FROM AERIAL PHOTOGRAPHS SUPPLIED BY WILLIAMS ALASKA INC.
NO BOUNDARY SURVEY WAS PERFORMED.

0 300 600
Scale in Feet

WILLIAMS ALASKA INC.
NORTH POLE REFINERY
NORTH POLE, ALASKA

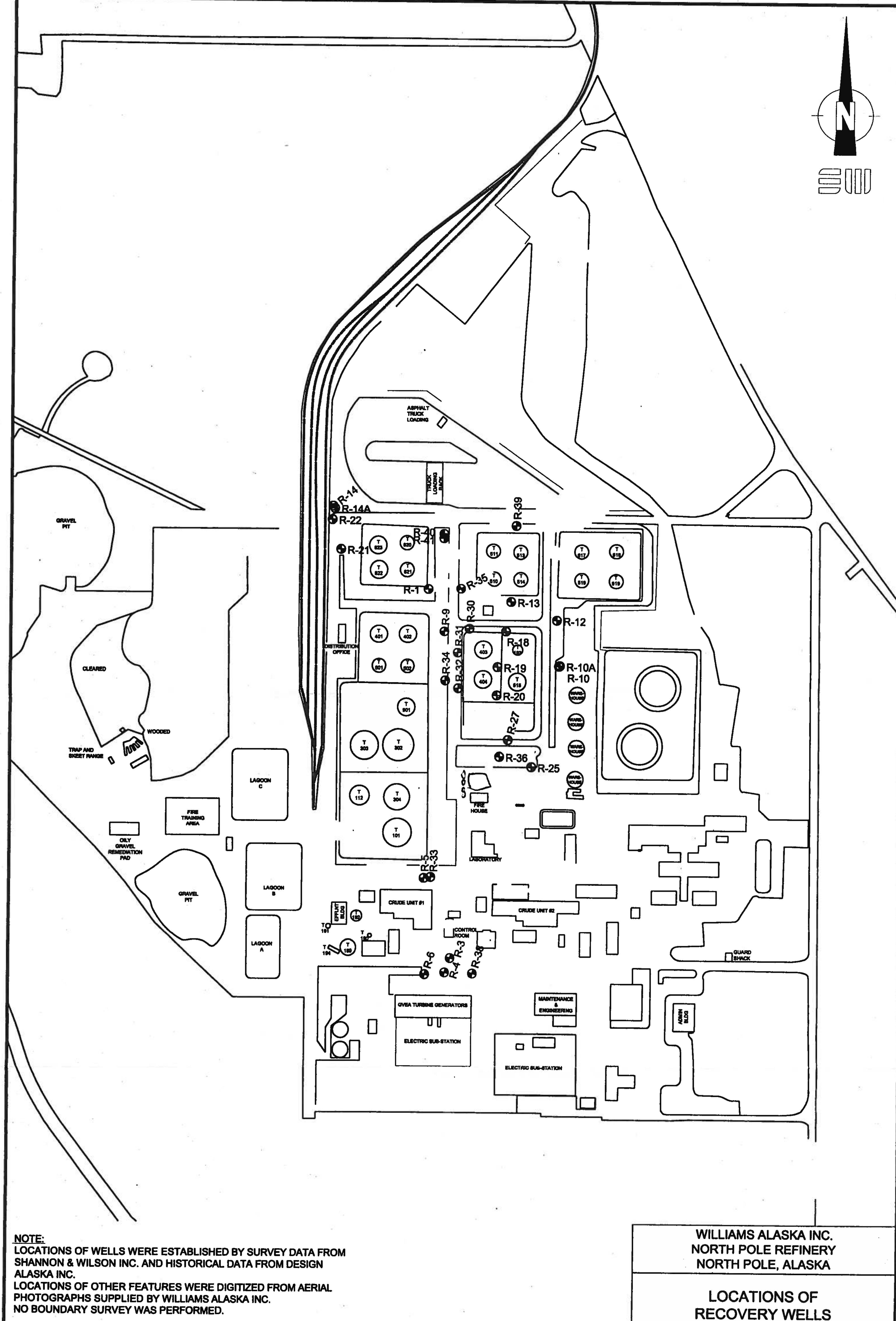
LOCATIONS OF OBSERVATION WELLS

June 2002 31-1-11066-001

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Figure 24

File: C:\My Documents\My Pictures\Refinery basemap 05.07.02.dwg Date: 05-16-2002 Author: srs



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NO BOUNDARY SURVEY WAS PERFORMED.

WILLIAMS ALASKA INC.
NORTH POLE REFINERY
NORTH POLE, ALASKA

LOCATIONS OF RECOVERY WELLS

June 2002 31-1-11066-002

SHANNON & WILSON, INC.
Geotechnical and Environmental Consultants

Figure 25

APPENDIX
Site Characterization and Remediation Activities at Williams Alaska Petroleum, Inc., North Pole Refinery

MAPCO/WILLIAMS NORTH POLE REFINERY FILE SUMMARY
(in chronological order)

Date	Shannon & Wilson Project Number	Title/Description
12/86		***ADEC Consent Order (Compliance order by consent #86-3-1-1-224-1)*** Required to: reactivate existing collection wells and install additional collection wells as needed to recover free NAPL; install 20 monitoring wells around the perimeter of the facility to monitor migration of NAPL and dissolved hydrocarbon plume; perform monthly sampling of all on-site drinking water wells; expand/modify Lagoon B.
9/88		***RCRA Facility Assessment (AT Kearney, Inc.)*** During the course of the RFA, 16 solid waste management units (SWMUs) and two areas of concern were identified, characterized, and ranked according to potential for ongoing releases of petroleum and other contaminants to the environment. SWMUs and areas of concern identified were: Oily water sewer system; Tank 192; Tank 112; Wastewater Lagoon A; Wastewater Lagoon B; Tanks 508 and 509; Distillation furnace stack, crude unit #1; Tetraethyl lead (TEL) sump; Temporary Hazardous Waste Storage area; Equipment Cleaning area; Rail Car loading area catchment basins and sump; Truck loading rack sump; Contaminated soil/gravel pile; Former Boneyard area; Infiltration Gallery; Product Spill Areas; Contaminated Soil, east side of effluent building. Based on the results of the RFA, corrective action was recommended for: Tank 192 – improve secondary containment; Lagoon A – test integrity of liner; if integrity of liner breached, perform borings and soil testing for hydrocarbons; Lagoon B – soil borings around the lagoon to determine whether hydrocarbons present; Rail car loading area containment basins and sump – soil sampling to determine whether hydrocarbons present; further remedial action related to soil contamination should then be assessed; Former boneyard area – soil borings to determine presence of hydrocarbons or metals; if contaminants detected, should install groundwater monitoring wells; Product spill areas – ongoing remediation should be reviewed to determine adequacy of monitoring, recovery and treatment activities; Contaminated Soil, east side of effluent building – stained soil should be sampled for hydrocarbons; if present, soil contamination should be excavated and treated.

1/89		***EPA Consent orders (RCRA Docket #1087-12-01-3008(a) and EPA Docket # 1088-11-14-3008(h))*** Required to: complete a RCRA Facility Assessment (RFA); undertake an Interim Measures (IM) program to remove hazardous waste from Lagoon B, Tank 192, and Sumps 901, 905, 909-b and 05-7; complete a RCRA Facility Investigation (RFI); perform a Corrective Measures Study (CMS) to provide an informational basis upon which corrective action may be taken at the facility.
4/1/89		***Mapco Alaska Petroleum, Inc., North Pole Refinery, 90-Day Response to Administrative Order on Consent, EPA Docket No. 1008-11-14-3008(h), Task I: Description of Current Conditions*** by Radian Corporation Contains history of site ownership, and waste generation, treatment, storage, and disposal activities; nature and extent of contamination; interim measures taken; and interim measures proposed.
2/13/90	X-0262	*No letter report.* Apparently, Mapco asked Shannon & Wilson to interpret BTEX data and plan how to "delineate the dissolved contaminant plume." Included in the file is proposal file for KP-1749, which became X-0264. Included Mapco's BTEX data for MW-101 through MW-116; WW-1, WW-3, WW-4; utility well, gravel pit, and recovery wells 18, 20, 21, 33, and 34.
4/3/90		***Monitoring Well Installation at Mapco Alaska Petroleum Refinery, North Pole, Alaska*** Installed MW-122 and MW-123 and Observation Well S-41 near RR and northeast and southeast corners of Lagoon B.
4/4/90	X-0264	***Monitoring Well Installation and Groundwater Sampling, Mapco Alaska Petroleum, North Pole Refinery, North Pole, Alaska*** Shannon & Wilson installed five groundwater monitoring wells (MW-117 through MW-121) north of the refinery in March 1990. Groundwater samples were collected and submitted for laboratory analysis for purgeable aromatics. Laboratory results were transmitted directly to Mapco by the laboratory. The letter report includes boring logs and chain-of-custody forms.
5/3/90	X-0285	Consulting services related to preparation of legal documents related to Mapco vs. Gibraltar Casualty Insurance, et.al. (no data in file)
6/18/90	X-0166-42	***Soil Sampling at the Boneyard, Mapco Alaska Petroleum Refinery, North Pole, Alaska*** Shannon & Wilson drilled six shallow borings and collected seven soil samples from the "boneyard" at the refinery. Samples were collected from native materials below the base of the fill. Samples were submitted for laboratory analysis, with results transmitted directly to Mapco.

6/21/90	X-0300	***Monitoring Well Installation at Mapco Alaska Petroleum, North Pole Refinery, North Pole, Alaska*** Two monitoring wells (MW-124 and MW-125) were installed just north of the JP-4 tank area on June 6. MW-124 was intended to evaluate potential groundwater contamination from the gasoline storage tanks and piping; MW-125 was intended to provide information on dissolved hydrocarbons in the vicinity of the floating product layer in the JP-4 tank area to the south. Groundwater samples were collected, with results to be transmitted directly to Mapco. The letter report contains boring logs.
10/90	X-0166	***Mapco Alaska Petroleum, Inc., North Pole Refinery, Task IV RFI Report*** by Radian Corporation RFI report including investigation of Lagoon B; Tank 192; Sumps 901, 905, 909-b, and 05-7; the former boneyard, Lagoon A, the rail car loading area containment basins and sumps, and contaminated soil on the east side of the Effluent Building. Four sumps were closed and no contamination was found in the surrounding soils or groundwater. The closure of Lagoon B was scheduled for completion in 1991, and Mapco was to continue monitoring groundwater in the vicinity until closure was complete. The rail car loading area was monitored under the ADEC remediation program. A geophysical study was being performed at the refinery to evaluate the lateral and vertical extent of permafrost.
11/90		***Report of Electrical Resistivity Study at Mapco North Pole Refinery, North Pole, Alaska*** by Geo-Recon International Limited Electrical resistivity study conducted north of the refinery.
6/12/91	X-0410	***Environmental Drilling Services, Mapco North Pole Refinery, North Pole, Alaska*** Two groundwater monitoring wells (MW-126 and MW-127) and four observation wells (S-42 through S-45) were installed. Boring logs are included with the letter report; no sampling was conducted.
9/30/91	X-0457	***Monitoring Well Installation, Mapco Refinery, North Pole, Alaska*** One boring (B-128) was drilled and a monitoring well installed and developed. A boring log is included with the letter report; no samples were collected.
10/91		***RCRA Unit Closures (MAPI, Final Report).*** *Lagoon B* – Closure activities July 1990 and July 1991. Sludge removal, solids and liner dried and disposed, liquids treated in Lagoon A and discharged to North Pole POTW. Soils under liner checked for contamination due to tears observed in liner. Only benzene detected above acceptable levels in water, but is in known contaminated groundwater area undergoing remediation directed by ADEC. *Sumps 901, 905, 909-B, and 05-7* – Closure activities March/April 1990. Sumps cleaned, cracks repaired, steel liners installed. Groundwater sampling. No chlorinate solvents, but benzene detected; area overlies known contaminated gw

		undergoing remediation directed by ADEC. *Boneyard Area* – General cleanup of "boneyard" area began in summer 1986; all wastes removed by end of 1987. Closure activities included soil sampling and groundwater monitoring. Benzene detected, but area overlies known contaminated groundwater undergoing remediation directed by ADEC. *Tank 192* – Dried sludge removed from tank, and recovered for fuel or solids disposed. Tank dismantled in July 1989.
5/92		***Installation and Maintenance of Groundwater Monitoring Wells Located in Permafrost Soils***, publication by K.M. McCullom and J.E. Cronin. Discusses issues relating to installation of monitoring wells in permafrost soils for sampling of dissolved hydrocarbons, and use of boring log information to calibrate permafrost soil resistivity survey data. Installation of the monitoring wells through permafrost allowed verification of the absence of off-site contaminant migration, and the effectiveness of groundwater remediation activities.
6/10/94	X-0661	***Results of Field Screening, Truck Loading Rack Excavation, Mapco North Pole Refinery, North Pole, Alaska, ADEC Spill No. 93310931501*** 11,500 gal of kerosene spilled at the truck loading rack on 11/11/93. The majority of the release was contained, but some kerosene spilled over the containment curb onto the unpaved area south of Lane #1. Shannon & Wilson field screened soil near the boundaries of an excavation at the south edge of the truck loading rack. The results of the field screening ranged from 11 to 1,600 ppm, with the depth of the screening locations ranging between 8 inches and 1.5 feet.
7/7/94	X-0665	***Summary of Services Performed on June 28, 1994, Mapco Refinery, North Pole, Alaska*** Shannon & Wilson assisted with collecting groundwater levels from seven monitoring wells and the air strippers. Groundwater levels were also measured. No data is transmitted in the letter.
10/17/94	X-0681	***Spill Cleanup Observation and Sampling, Mapco North Pole Refinery, North Pole, Alaska*** 8/30/94 leaded gasoline (≈1,200 gal) spill at the asphalt loading rack at the RR on the west side of refinery. S&W observed the excavation of contaminated soils, collected soil samples for testing from the excavation and soil stockpiles, and submitted a letter report. The analytical results showed contamination remaining at the base and east side of the excavation at concentrations above the least stringent ADEC soil criteria. Additional excavation was subsequently conducted and a passive soil ventilation system was installed to enhance removal of volatile compounds from the soil.
6/27/95		***Wastewater Disposal Permit (Permit # 9531-DB009)*** Waste disposal permit for treated non-domestic wastewater from the air stripping facility at the Mapco North Pole Refinery. Authorizes discharge of treated water from air strippers to holding ponds on site. Stipulates that benzene

		not exceed 5 µg per L, and BTEX not exceed 100 µg per L, in the discharged wastewater. Also requires the pH of the effluent to remain near neutral (pH 6.0 to 8.5), and prohibits discharge of floating solids, garbage, grease, foam, or oily waste which produce a sheen on the surface of receiving waters. Requires monthly monitoring of the wastewater stream, and groundwater downgradient from receiving waters, measurement of flow rates fives times per week, and monthly reporting of results to ADEC.
7/13/95	X-0717-1	***Evaluation of Scaling and Biofouling of Groundwater Treatment System, North Pole Refinery, North Pole, Alaska*** The letter report summarized the results of Shannon & Wilson's evaluation, alternatives for the initial system cleanout of the water conveyance piping, and recommendations of treatment considered most applicable for use. Recommendations included chemical cleaning of the air stripper packing material and pretreatment of the process water. ***Addenda to the above title*** This letter, dated May 8, 1996, included the evaluation of applicable filtration methods to precede the air stripping towers, qualitative and quantitative evaluation of the scale-forming media, and a discussion of the air stripping tower liquid distributors applicable for the variable flow rates.
12/29/95	X-0717-2	***Delineation of Western Extent of JP-4/Kerosene Plume, Tank 401-502 Area, Mapco Refinery, North Pole, Alaska*** Eight steel well points were installed along dikes containing tanks 401, 402, 501, 502, and 901. Product samples were collected from three well points; two well points contained a mixture of kerosene and JP-4 and the other contained JP-4. Variations in product thickness did not allow precise definition of the western plume boundary. Recommended periodic product measurement and potential installation of additional well points.
12/29/95	X-0717-3	*Recovery Well Optimization Study, Mapco Refinery, North Pole, Alaska* ***Shannon & Wilson reviewed available data on the operating history of the dual-pump wells (pumping rate, oil recovery, time of year) and performed a limited scope pumping test to develop a set of distance/drawdown curves for the site. The objective was to determine water table depression pumping rates that would result in optimal product recovery in existing recovery wells, and the optimal spacing for recovery wells. One additional well point (OB1) was installed for the pumping test. Recovery well R-34 exhibited inefficiencies during the pumping test that may be attributable to partial blockage of the well screen by corrosion, encrustation, sanding, or biofouling***

		Target recovery well pumping rates of 300 gpm were recommended; it was estimated that 40 recovery wells at the target pumping rate would be required to remove the floating product in the area. However, concern was also expressed regarding contamination of soil to a greater depth within the cone of depression during pumping.
5/8/96	X-0717-5	***Additional Evaluation of Western Extent of Product Plume, Tank 401-502 Area, NP Refinery, NP, Alaska*** Product measurements were made to monitor product on the groundwater in the Tank 401-502 area and to develop preliminary recommendations for the feasibility of a product recovery system in that area. Product measurement data collected in March 1996 were compared to product thickness measurements from August and September 1995. It was concluded that although recoverable free product is present in the Tank 401-502 area and product recovery rates appeared amenable to recovery using a dual pump recovery system. A complete product recovery system design could not be completed based on existing information. Recommendations to Mapco included: (1) a complete evaluation of the maximum capacity of the existing product recovery and water treatment system for selection of the optimum number, spacing, and pumping rates of additional product recovery wells; (2) installation of additional well points along the western dike of the Tank 401-502 area to more accurately define the plume boundary; and (3) collection of additional information regarding the physical parameters of the soil and product in the Tank 401-502 area (grain size distribution, permeability, and viscosity).
5/28/96	X-0787	***Product Monitoring and Well Installation, North Pole Refinery, North Pole, Alaska*** An underground "oily waste" return pipeline was found to have leaked the week of 5/6/96, near the lab and fire house. Nearby monitoring wells S27 and S34 were pumped, and product recovery thickness measured. Four new monitoring wells were installed; three of the wells contained free product. The product thickness and rate of accumulation observed suggested a significant amount of product had been released. At the time of Shannon & Wilson's letter report, Mapco was proceeding with recovery operations by periodic removal of the product within the wells using a vacuum truck and, installation of a dedicated pumping system (product only) in wells S-27, S-48, and S-49.
10/22/96	X-0824-1	***Remove and Replace Monitoring Well MW-117, Mapco Refinery, North Pole, Alaska*** A new monitoring well (MW-129) was installed 9 feet east of frost-jacked MW-117. MW-117 was pulled and decommissioned. A groundwater sample was collected for BTEX analysis, with the results transmitted directly to Mapco. The letter report contains a well log and chain-of-custody form.
2/97	X-0833-01	***Remedial Planning Position Paper, MAPI North Pole Refinery, North Pole, Alaska*** Plan describes Shannon & Wilson's role in assisting MAPI achieve goals of environmental compliance and site restoration. The plan presents a number of short-term and long-term objectives. Short-term goals included

		regaining hydraulic control at the fence line wells, reviewing existing data and identifying data needs, characterizing the contaminant distribution inside the fence line (tank farm and process areas), and planning for summer 1997 construction. Long-term objectives included evaluating the current distribution of floating product vs. product recovery, the efficiency and cost-effectiveness of hydraulic control, the efficiency and cost-effectiveness of product recovery, the possible reduction or improvement of efficiency in data collection, and other possible options for hydraulic control.
2/18/97	X-0833-05	***Water Depth and Reservoir Perimeter Survey, Fire Water Supply Reservoir, Mapco Alaska Refinery, North Pole, Alaska*** Shannon & Wilson drilled holes through ice covering the reservoir with an electric drill, and measured the depth to the bottom of the reservoir with respect to the ice surface. Forty-six measurements were made across the reservoir. The locations and elevations of measurements were surveyed by Design Alaska and a map of the reservoir provided.
2/19/97	X-0833-02	***Observation of Downhole Video Camera Inspection of Recovery Wells, North Pole Refinery*** Downhole inspection was conducted for three recovery wells (R-35, R-37, and R-39). For wells R-35 and R-37 • the portion of the screen above the water table was heavily incrusted • a floating product layer was present • the water in the wells was extremely turbid, preventing clear observation of the well screen. Brief glimpses of the screen showed it to be heavily blocked by solid incrustation or biological slime. Slime appeared to be present in the water. • sediment accumulation did not appear to have occurred at the bottom of the wells. For R-39 • the incrustation of the well screen above the water table was not as severe • some thickness of floating product was present • the well screen below the water table was relatively free of incrustation • the pump was observed sitting on the bottom of the well in an accumulation of sediment. Shannon & Wilson recommended brushing and pumping the wells and reinspection with a video camera.

		Discussion of potential methods of well rehabilitation included redevelopment by surging and pumping and chemical cleaning.
3/97	K-1439	***Geotechnical Studies Proposed Crude Unit #3 and Storage Tanks, Mapco Alaska Petroleum Refinery, North Pole, Alaska*** The purpose of Shannon & Wilson's study was to explore and evaluate the subsurface conditions at the site and develop foundation recommendations for support of the proposed facility structures. The scope of work included drilling and sampling eight borings: six borings in the proposed crude unit area and two in the storage tank area. The report contains recommendations for site preparation, various foundations, backfill, drainage and grading.
5/6/97	X-0833-07	***Remove and Replace Monitoring Well MW-117, Mapco Refinery, North Pole, Alaska*** (This title is incorrect, since the letter report concerns only Monitoring Well MW-130) A new monitoring well (MW-130) was installed to a depth of 23 feet outside the dike area southeast of Tank 821 on April 22, 1997. The purpose the well was to monitor groundwater quality in vicinity of a propylene glycol release from a subsurface pipe. A boring log for the well was included in the letter report.
7/1/97	X-0833-08	***Product Thicknesses July 1, 1997 (Figure), Mapco Refinery, North Pole, Alaska*** Product thickness measured 7/1/97 in well points in vicinity of tanks 302, 303, 901, 401, 402, 501, and 502.
7/3/97	X-0833-06	***Monitoring Well Maintenance and Repair*** Monitoring wells MW-111 and MW-112 were replaced due to significant frost-jacking; the old wells were removed and new wells installed at the same locations. Monitoring wells MW-101, MW-105, MW-105A, and MW-126 were rehabilitated by cutting off the well casings and replacing the monuments. Monitoring wells MW-106, MW-126, and MW-128 were pumped with a 2-inch diaphragm pump to remove sand from the wells. Boring logs for the reinstalled wells are included in the letter report.
7/22/97	X-0833-01	***Summary Report of Product Recovery, North Pole Refinery*** Shannon & Wilson prepared a summary report of product recovery operations at the MAPCO refinery. The purpose of this report was to compile and summarize the available product (free-phase petroleum hydrocarbons) thickness and product recovery data to identify locations of product accumulation, and locations and effectiveness of product recovery operations. Based on historical and 1996 data, product thickness appeared to be greatest in the Tanks 404 and 515 area. Shannon & Wilson recommended resumption of dual-pump recovery from recovery well R-20 in this area. It was noted that static recovery contributed significantly to the total volume of product recovered. Where possible,

		Shannon & Wilson recommended static skimming pumps be installed in wells that continuously accumulate product, and manual recovery efforts be continued in the other wells. Shannon & Wilson also recommended the collection of weekly data on groundwater pumping rates, drawdown, static groundwater level, and product recovery at specific dual-pump recovery wells, with static groundwater levels collected from a surveyed well location outside the cone of depression.
8/1/97	X-0833-01	***Recommendations for Recovery Well Cleaning and Rehabilitation, North Pole Refinery*** Shannon & Wilson evaluated groundwater data, downhole video surveys, and other well observations and data, and recommended a well cleaning and rehabilitation program for recovery wells at the refinery. The program included a pre-cleaning assessment of well performance, cleaning and possible rehabilitation of the wells, and a post-cleaning assessment of well performance.
8/4/97	X-0833-01	***Recovery Well Cleaning Plan, North Pole Refinery, Alaska*** Request for approval from the ADEC for a well cleaning plan. The well cleaning plan consisted of the addition of chemicals (detergent, chlorine bleach, and acid) to the well bore in three separate phases, separated by physical agitation (surging) to disperse the chemicals into the surrounding formation and mobilize dislodged particulates into the wellbore for removal.
8/13/97	K-1439-02	***Soil Resistivity Testing, Crude Unit #3 and Storage Tanks, Mapco Alaska Petroleum Refinery, North Pole, Alaska*** Resistivity tests were conducted at five locations at the Crude Unit #3 site and 2 locations at the storage tank site. Letter report includes resistivity results for Crude Unit #3, Crude Unit #3 drawing dated 2/7/97, and Electrical Resistivity Test Location Plans provided by Flour Daniel.
8/1/97	X-0858	***Observation Well Installation, North Pole Refinery, Alaska*** Shannon & Wilson installed three observation wells at the refinery to investigate a release from a ruptured oily-water return line. Wells were installed on June 12 and July 15 1997, in the vicinity of a pipe rack at the southwest corner of the diked containment area for tanks 820, 821, 822, and 823. Three 2-inch PVC observations wells (designated A, B, and C) were installed at locations chosen by Mapco Personnel on June 12. No soil sampling was performed and no geologist or engineer from Shannon & Wilson was present. Following monitoring of product accumulation by Mapco personnel for several weeks, Shannon & Wilson removed observation wells A and C on July 15, 1997, and replaced them with 4-inch-diameter observation wells. The observation wells were redesignated S-50 through S-52.
1/98	K-1481-01	***Geotechnical Study, Mapco Alaska Petroleum Refinery, Process Expansion, North Pole, Alaska***

		The purpose was to determine the general subsurface conditions at the site and develop foundation recommendations for support of the proposed expansion. The report consists of a summary of soil conditions, recommendations for pile foundations and installation, excavation and site preparation, backfill, and drainage and grading. Also included are boring logs and a Mapco drawing (Plot Plan Bore Hole Location for 1997 Expansion).
5/98	K-1482-02	***Pile Installation Report, New Pipe Rack Facilities, Mapco Refinery, North Pole, Alaska*** The report summarizes geotechnical observations made during pile installation at the MAPCO refinery between April 22 and May 1, 1998. The purpose of the work was to observe and document that pile driving activities met project specifications recommended in Shannon & Wilson's January 1998 geotechnical report. The report included figures, pile driving records, technical memorandums with V. Mosalski of MAPCO, and various Mapco drawings (Offsite Pipe Rack and Foundation Plan – 2/5/98, Tank Farm Pipe Rack Foundation Plan – 3/20/98).
5/5/98	X-0833-11	***Measurement of permafrost and thawing*** A map of the estimated permafrost thickness at the property, based on a geophysical survey using electro-magnetics or ground penetrating radar. A geophysical survey was performed at the northern portion of the property, in association with identifying well locations. The legend indicates that the squares are grid points where no permafrost was determined and the crosses indicate grid points where the top and bottom of permafrost was determined. The contours map the upper and lower surfaces of the permafrost.
6/1/98	X-0833-12	***Product Fingerprinting, Crude Piperack, Crude Oil Tank Dike, Crude Unit #3, North Pole Refinery, North Pole, Alaska*** Shannon & Wilson drilled and sampled two borings in the area of the newly constructed crude piperack within the crude oil tank dike at Crude Unit #3. The objective was to determine the type of product encountered during the installation of pilings for the new crude pipe rack in April 1998. One soil sample from each boring was submitted for laboratory analysis; the analytical testing indicated the product most closely resembles JP-8.
7/10/98	X-0833-13	***Groundwater Monitoring Well MW-131 Installation and Piezometer Installation, Railroad Corridor, North Pole Refinery, North Pole, Alaska*** One monitoring well was installed to a depth of 25 feet in the area north of railroad corridor, about 90 feet west of MW-102. Monitoring well MW-131 was intended to serve as an additional groundwater sampling point in the area generally downgradient of recovery well R-40, monitoring well MW-127, and the floating product plume at the Railcar Loading Area. No soil or groundwater samples were collected. Mapco personnel were to sample the well. Three piezometers (S-53 through S-55) were installed in the northeastern portion of the railroad corridor, south and

		west of monitoring well MW-121. The intent of the piezometers was to determine the groundwater flow direction in the railroad corridor. Based on surveyed piezometer elevations and water table measurements, the inferred groundwater flow direction is N 25° E, or generally parallel to the orientation of the railroad tracks. This direction differs from the prevailing direction at the developed portions of the refinery of N 10° W. The hydraulic gradient calculated from the groundwater contours along the railroad corridor ranged from 2.5 feet to 5.1 feet per mile, which is comparable to hydraulic gradient measurements made elsewhere at the refinery. Shannon & Wilson recommended the installation of monitoring wells to sample groundwater along the railroad corridor groundwater flow path, as well as measurement of groundwater flow direction at other times of the year.
2/24/99	X-0833-13	***Groundwater Level Measurements, Railroad Corridor, North Pole Refinery, North Pole, Alaska*** Shannon & Wilson measured groundwater levels in monitoring well MW-131 and piezometers S-26, S-54, and S-55. Piezometer S-53 was not located and was assumed to have been destroyed. The objective was to evaluate the groundwater flow direction during winter low groundwater table conditions for comparison with the July 1998 results. The February 1999 data shows a northerly flow direction at the northeast end of the railroad corridor, with a trend toward the northwest in the vicinity of MW-131. When piezometer S-53 was omitted from the July 1998 data so that both potentiometric surfaces were developed using the same measurement locations, the July data appears to show a slight northeasterly flow direction, rather than the more pronounced northeasterly gradient presented in our July 1998 report. It is possible that the flow direction observed in February could be influenced by the lack of piezometer S-53, and a more northeasterly flow would have been observed if S-53 were available. When all available data are considered, both the July 1998 and February 1999 groundwater elevations show a north to northwesterly flow direction between piezometer S-26 and monitoring well MW-131.
9/27/99	X-0833-17	***Pile Driving Observations, Fire Water Supply System, Williams Alaska Petroleum Refinery, North Pole, Alaska*** Shannon & Wilson observed the redriving of steel pipe piles along the pipeline that delivers water for fire suppression from a storage lake to the refinery. The existing piles were being driven deeper to provide more resistance to pile jacking. The additional length driven and the blow counts are tabulated in the letter report.

MISCELLANEOUS DATA

1/9/97	Mapco Letter to ADEC summarizing remediation and planned 1997 efforts 1,195 gallon of free product recovered from wells around 5/2/96 utilidor spill 2,662 gallons of free product recovered from enhanced recovery double-pump systems In all of 1996, 4,576 gallons of free product recovered Weekly groundwater levels measured for 4 wells in 1996 Installed monitoring wells MW-106, 128, 121, 126, 129, 127 in Dec. (MW-117 replaced by MW-129 in 10/96) Recovery wells R-39 & 40 slowing down in 1996 Sample results (12/11/96) influent/effluent of groundwater remediation air strippers
5/6/96	Mapco Letter to ADEC summarizing April or March 1996 efforts/results
7/22/94	Plot Plan of Observation, Recovery, and Monitoring Wells showing wells suitable for dual pump
2/97	Monitoring Well Water Sampling by Columbia ASI
3/93 – 9/96	Monitoring Wells Concentrations, graphs and maps
4/87 – 12/96	BTEX Results by Monitoring Wells
1988 - 1996	"A, B, C, D" for Recovery Wells, graphed by year (2 different sets)
Spring 1998	Articles *Water Oil Recovery Equipment, Inc.'s Tray Aeration Water Treatment System Using High-Vacuum Technology in Soil Remediation*

WELL SURVEY DATA (for AutoCAD)

8/97	Mapco Coordinate Locations for Monitoring Wells, Recovery wells, Samples, and Well points

MISCELLANEOUS PRODUCT THICKNESS AND RECOVERY DATA

1992-1996	Oil Recovery #s by (R & S) well
1988-1996	Table of GPM and Gallon Product Recovered from Enhanced Recovery Wells
1988-1991	Another set of tables on oil recovery
6/86 – 2/89	*Summary of Monthly Oil Recovery by Recovery Well*
1/23/97	Table of Sampling Observation Well Data
9/2/77 – 12/23/90	Big table of North Pole Refinery Oil Spill Report Summary (one format)
1/29/91 – 11/13/94	Same as above just slightly different format, table is fronted by a "Facility Drainage" diagram – undated
11/27/87	Diagrams showing Product Thickness Contours
1992 – 1996	2 sets of graphs by year showing Product Recovery, one set also includes 1998
1/93 – 3/97	3 sets of Product Thickness Tables, recovery wells 12 and 14A and sampling wells. Also a matching set of graphs by year.
1992-1996	Graph of Groundwater Elevations at S-14, mini-version with table of data
1992-1995	Graphs showing Observation Wells Water Surface Elevations, by year - S-8, 14, 2A, & 18A
1996	Table of fluctuations S-8, 14, 2A, & 18A