Final
Feasibility Study Report
KRY Site

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FINAL

FEASIBILITY STUDY REPORT

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ACRONYMS AND ABBREVIATIONS

BER	Board of Environmental Review
bgs	Below ground surface
BNSF	BNSF Railway Company
CECRA	Comprehensive Environmental Cleanup and Responsibility Act
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	Cubic feet per second
COC	Contaminant of concern
COPC	Contaminant of potential concern
CP	chlorophenol
cPAH	Carcinogenic polycyclic aromatic hydrocarbons
DCE	Dichloroethene
DCP	Dichlorophenol
DEQ	Montana Department of Environmental Quality
DEQ-7	Montana Numeric Water Quality Standards, Circular DEQ-7
DNRC	Montana Department of Natural Resources and Conservation
DRO	Diesel range organics
DSR	Data summary report
EPA	U.S. Environmental Protection Agency
ERCL	Environmental Requirements, Criteria, or Limitations
ERM	Environmental Resources Management
FRTR	Federal Remediation Technology Roundtable
FS	Feasibility study
ft/day	Feet per day
ft/y	Feet per year
gpm	Gallons per minute
HHRA	Human health risk assessment
HRC	Hydrogen Release Compound
IASD	Initial Alternatives Screening Document
KPT	Kalispell Pole and Timber
KRY Site	Kalispell Pole and Timber, Reliance Refinery Company, and Yale Oil Corporation facilities
LNAPL	Light nonaqueous phase liquid
MCA	Montana Code Annotated
mg/kg	Milligram per kilogram
mg/L	Milligram per liter
µg/L	Microgram per liter
MNA	Monitored natural attenuation
MSE	MSE, Inc.

ACRONYMS AND ABBREVIATIONS
(Continued)

NAPL	Nonaqueous phase liquid
O&M	Operation and maintenance
ORC	Oxygen Release Compound
PAH	Polynuclear Aromatic Hydrocarbons
PCP	Pentachlorophenol
PLP	Potentially liable person
ppm	Part per million
PRG	Preliminary remediation goal
PRAO	Preliminary remedial action objective
RBC	Rotating biological contactor
RBCA	Montana’s Tier 1 Risk-Based Corrective Action Guidance for Petroleum Releases
RBSL	Risk-based screening level
RCRA	Resource Conservation and Recovery Act
Reliance	Reliance Refining Company
RI	Remedial investigation
ROD	Record of decision
SPLP	Synthetic precipitation leaching procedure
SVOC	semivolatile organic compounds
2,3,7,8 TCDD	2, 3, 7, 8-Tetrachlordibenzo-p-dioxin
TCE	Trichloroethene
TEF	Toxicity equivalency factor
TEQ	Toxicity equivalency quotient
TPH	Total petroleum hydrocarbon
TtEMI	Tetra Tech EM Inc.
UV	Ultraviolet
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
VCP	Voluntary cleanup plan
VOC	Volatile organic compound
WHO	World Health Organization
WRI	Western Research Institute
WQB-7	Water Quality Bureau – Bulletin Circular 7
Yale Oil	Yale Oil Corporation

1.0 INTRODUCTION

The Montana Department of Environmental Quality (DEQ), Remediation Division, conducted a feasibility study (FS) for the Kalispell Pole and Timber (KPT), Reliance Refining Company (Reliance), and Yale Oil Corporation (Yale Oil) facilities (collectively referred to as the KRY Site). The KRY Site is located just outside the northeastern city limits of Kalispell, in the community of Evergreen in Flathead County, Montana. Tetra Tech EM Inc. (TtEMI) conducted major parts of the FS and prepared the Final Draft FS report in accordance with Task Order No. 37, DEQ Contract No. 402014. DEQ completed the Final FS report.

DEQ is the lead agency for implementing the remedial investigation (RI) and FS process under the Comprehensive Environmental Cleanup and Responsibility Act (CECRA) at the KRY Site. DEQ is also responsible for soliciting community involvement and comments at the decision-making point of the CECRA remediation process.

1.1 REPORT ORGANIZATION

This FS report consists of eight text sections, followed by a list of references, figures and tables, and appendices. The contents of Sections 1.0 through 8.0 are briefly described below.

Section 1.0, Introduction, describes the report organization, the report purpose and objectives, describes the site, and provides a summary of the site history.

Section 2.0, Site Characterization Summary, describes the KRY Site climate, geology, hydrogeology, surface water hydrology, population data and land use, and cultural resources. This section also summarizes the nature and extent of contamination as understood from field observations, field measurements, and validated analytical data results from soil, surface water, sediment, and groundwater samples. In addition, this section summarizes the fate and transport of contaminants of concern (COC), and provides a summary of the human health and ecological risk analysis.

Section 3.0, Development of Remedial Action Objectives, summarizes the Environmental Requirements, Criteria, or Limitations (ERCLs) requirements under CECRA and identifies action-, contaminant-, and location-specific requirements that the remedial action must meet. This section also describes the preliminary remedial action objectives (PRAOs) and cleanup levels and presents volume estimates of contaminated media.

Section 4.0, Development and Screening of Remedial Action Alternatives, summarizes the Initial Alternatives Screening Document (IASD). The IASD, finalized in March 2007 (TtEMI 2007b), identifies applicable general response actions; evaluates and screens technology and process options; and identifies the remedial technologies retained for evaluation in this FS. Section 4.0 also briefly describes the remedial technologies retained and summarizes the initial screening of the technologies.

Section 5.0, Detailed Description of Technology Options, describes in detail the representative remedial alternatives selected for further evaluation in the FS.

Section 6.0, Detailed Analysis of Alternatives, outlines the CECRA criteria for analyzing alternatives and presents the detailed analysis of alternatives. It also compares the remedial alternatives under the CECRA criteria and summarizes the conclusions of the report.

Section 7.0 contains references cited, considered, or relied upon in developing this report.

1.2 PURPOSE AND OBJECTIVES

The FS evaluated remedial alternatives to address contamination in soil and groundwater at the KRY Site. Contamination in surface water is not addressed in this FS. Please see section 2.2.3 for more discussion about surface water impacts. A comprehensive range of remedial alternatives was previously developed and screened in the IASD (TtEMI 2007b). The most applicable alternatives were retained for detailed evaluation in the FS based on a review of the IASD. The initial development and screening of remedial alternatives required the following:

(1) Identifying applicable and relevant state or federal ERCLs;
(2) Identifying PRAOs and specifying the contaminants and media of interest, exposure pathways, and remediation goals;
(3) Identifying potential treatment and containment technologies that will satisfy these objectives;
(4) Identifying volumes or areas of media where the general response actions may be applied;
(5) Screening the technologies based on their effectiveness, implementability, and cost; and
(6) Identifying technologies and alternatives to be further evaluated in the FS for treatment of contaminated media at the site.

This FS report includes a summary of the IASD, a summary of the factors (such as are listed above) used for the IASD screening and in the FS, and a detailed analyses of the alternatives retained. Complete treatment trains were not assembled for evaluation in the FS. Instead, individual alternatives are evaluated that were then assembled into treatment trains in the Proposed Plan. Alternatives were compiled into technology-type groups according to their applicability and methodologies for this detailed evaluation. One or more representative alternatives from each group was then selected for a detailed evaluation. Alternatives were selected based on their applicability to the site and by their ability to represent the technology-type group. In addition, certain alternatives were combined, as appropriate, for the discussions and evaluations.

The detailed analysis compares the alternatives with the CECRA cleanup criteria, as well as against each other, presenting sufficient information to allow decision makers to select a remedy for soils and groundwater. No alternatives for surface water are presented in this document (see Section 2.2.3). The detailed analysis of alternatives is required to meet specific statutory requirements for remedial actions that are addressed in a ROD and are supported by the FS report. Each alternative must:

(1) Attain a degree of cleanup that assures protection of public health, safety, and welfare and of the environment;
(2) Be consistent with applicable state or federal environmental requirements, criteria, or limitations and may consider substantive state or federal environmental requirements, criteria, or limitations that are relevant to the site conditions;
(3) Demonstrate acceptable mitigation of exposure to risks to the public health, safety, and welfare and the environment;
(4) Be effective and reliable in the short term and the long term;
(5) Be technically practicable and implementable;
(6) Use treatment or resource recovery technologies if practicable, giving due consideration to engineering controls; and
(7) Be cost-effective.

Treatment alternatives that permanently and significantly reduce the volume, toxicity, or mobility of the contaminants are preferred over those that do not involve treatment, when practicable. Remedial alternatives were evaluated in detail against the seven evaluation criteria above. The seven evaluation criteria and related discussion are provided in Section 6.0 of this FS.

1.3 SITE DESCRIPTION

The KRY Site is located just outside the northeastern city limits of Kalispell, in the community of Evergreen in Flathead County, Montana (Figure 1-1). The site is located at 48°12' North latitude, 114°17' West longitude, and is in (1) the Northeast ¼ of the Northwest ¼ of Section 8, (2) the Northwest ¼ of the Northeast ¼ of Section 8, and (3) the Southeast ¼ of the Southwest ¼ of Section 5; all within Township 28 North, Range 21 West of the Montana Principal Meridian. The boundaries of the KRY Site generally extend from the Stillwater River on the north and west, Highway 2 and the BNSF Railway Company (BNSF) railroad line on the east, Montclair Drive on the south, and Whitefish Stage Road on the west (Figure 1-2). Current ownership of the individual parcels and historical property ownership within this area are presented in Section 2.3 of the data summary report (DSR) (TtEMI 2005). As described in the summary report, there are multiple owners of land at the KRY Site. CECRA defines a “facility” as any area where contamination has come to be located and is not restricted to or defined by property boundaries. Therefore, defining a site boundary based on land ownership is not appropriate. The FS, therefore, based the study area boundary on the extent of groundwater and soil contamination identified through the RI; the boundary can be seen on Figure 1-2.

The RI identified three primary sources of contamination at the KRY Site. These sources include KPT, Reliance, and Yale Oil. However, comparison of detected concentrations to cleanup levels established in the risk analysis shows that KPT and Reliance will require extensive cleanup with some potential limited cleanup occurring at Yale Oil. Please see Section 2.4 for more information about the risk analysis.

KPT, Reliance, and Yale Oil are described in more detail in Section 2 of this FS report. No other source areas are attributable to the KRY Site based on the results of groundwater and soil sampling.

1.4 SITE HISTORY

This section provides a brief chronology of the history for KPT, Reliance, and Yale Oil; further detail on the history and regulatory actions can be found in the RI report (DEQ and TtEMI 2008a). A complete review of the various field investigations at the KRY Site and the results of the investigations are provided in the RI report (DEQ and TtEMI 2008a). This review includes investigations conducted on behalf of the liable persons and DEQ. Soil and groundwater sampling locations for all previous investigations at the KRY Site are shown on Figures 1-3 and 1-4.

Interim remedial actions have also been conducted at the KRY Site. These interim remedial actions are discussed in the RI Report (DEQ and TtEMI 2008a).

1.4.1 Kalispell Pole and Timber

KPT is a former wood treating operation that operated from approximately 1945 to 1990. The KPT Company leased portions of the property from BNSF or its predecessors. The KPT Company also owned some property. The surficial portion of KPT encompasses approximately 35 acres. Soils and groundwater were contaminated from spills or leaks of diesel-based wood treating oil that contained pentachlorophenol (PCP) and dioxins/furans from the treatment vats and aboveground storage tanks as well as drippage from treated wood. Contaminants include PCP, dioxins/furans, polynuclear aromatic hydrocarbons (PAHs), and petroleum hydrocarbons, including free-product (also referred to as non-aqueous phase liquid (NAPL) or light NAPL (LNAPL) throughout this FS). Groundwater is also contaminated with dissolved metals associated with the breakdown of petroleum hydrocarbons and free-product (TtEMI 2005, DEQ and TtEMI 2008).

BNSF and its predecessors owned and currently own a portion of the property where KPT operated and where the wood treatment operation was located. BNSF and its predecessor also operated and current operate at KPT. BNSF shipped freight via railcar to and from KPT. Freight shipped by BNSF to KPT included untreated poles, PCP, and oil. BNSF or its predecessors also transported treated poles from KPT (BNSF v. KPTC 2000). BNSF and its predecessor companies have and currently lease property to lumber-processing companies. When the KPT Company dissolved it sold the property it owned to Swank Enterprises and Montana Mokko; Swank Enterprises subsequently sold some of the property to Klingler Lumber Company. Klingler Lumber Company is operating either on or directly adjacent to the former pole treating area. Montana Mokko/Stillwater Forest Products had operated adjacent to (west of) the former pole treating area, but these operations appeared to have ceased by the time RI field activities were conducted and a stone processing company (Glacier Stone Company) is operating in its place (DEQ and TtEMI 2008).

1.4.2 Reliance Refining Company

The Reliance Refining Company operated an oil refinery from 1924 to the 1960s. The surficial portion of Reliance encompasses approximately 7 acres. Onsite disposal of sludge, leaks of sludge and oil from aboveground storage tanks, and releases of petroleum products from the operations of the refinery and railroad contaminated soil with petroleum hydrocarbons and some metals, notably lead. Groundwater beneath Reliance is contaminated with petroleum hydrocarbons, including free product, PCP, dioxins/furans, and PAHs. Groundwater is also contaminated with dissolved metals associated with the breakdown of petroleum hydrocarbons and free product (TtEMI 2005, DEQ and TtEMI 2008).

The Reliance Refining Company owned and operated the refinery from 1924 to 1930. The refinery property was sold for back taxes to the State of Montana in 1930, and the final deed was issued in 1935. Boris Aronow, doing business as Unity Petroleum Corporation, leased the property and facilities from the state in 1930, with a lease expiration date of 1935. However, the Reliance Refining Company property and associated operations were sold to Unity Petroleum Corporation (Boris Aronow) in February 1932. The Unity Petroleum Corporation continued to operate the refinery on the property until 1969 (EPA FIT 1986, EPA 1992, TtEMI 2005).

The State of Montana leased the property to KPT Company in 1969 for the storage of poles and used the property for this purpose until its dissolution in 1990. BNSF and its predecessors owned and currently own the property underlying the mainline railroad tracks on the east side of Reliance and the property underlying the spur line that intersects Reliance (DEQ v. BNSF et al 2008). BNSF or its predecessors operated these lines, transporting crude oil to the refinery and transporting refined petroleum products out of the refinery (DEQ 2008c). Swank Enterprises also owns property at Reliance which it purchased from the KPT Company (TtEMI 2005).

1.4.3 Yale Oil Corporation

Yale Oil is a former petroleum bulk plant and product refinery that operated from 1938 to 1978. The surficial portion of Yale Oil encompasses approximately 2.3 acres. Leaks and possible spills from aboveground storage tanks contaminated on-site soils. Thermal desorption, using a permitted unit, was conducted on the soils to remove petroleum contamination. However, groundwater beneath Yale Oil is contaminated with low-levels of PCP, dioxins/furans, and petroleum hydrocarbons (TtEMI 2005, DEQ and TtEMI 2008).

Yale Oil Corporation owned and operated the property for use as a refinery and bulk plant from the 1930s to 1944, when the property was sold to Carter Oil Company. The property was used for distribution operations through 1978. Through a series of mergers, Exxon Corporation became the owner of the property. Kalispell Partners, LLC, purchased the property in 1996 and a commercial business currently exists at the location (TtEMI 2005, DEQ and TtEMI 2008).

2.0 SITE CHARACTERIZATION SUMMARY

This section summarizes the physical characteristics and environmental setting, the nature and extent of contamination, contaminant fate and transport characteristics, and environmental risks to human health and ecological receptors at the KRY Site. Further details on the site characteristics can be found in the RI report (DEQ and TtEMI 2008).

2.1 PHYSICAL CHARACTERISTICS AND ENVIRONMENTAL SETTING

Physical characteristics of the KRY Site pertinent to the FS include the climate, geology, hydrogeology, surface water hydrology, land use, and cultural resources. The following sections describe those characteristics.

2.1.1 Climate

Kalispell's climate is considered semiarid, with an average 15.15 inches of precipitation per year and an average temperature of 44.4 °F. The climate records extend from the year 1948 to 2005. In the 57-year period of record, the maximum amount of precipitation in one year was 20.29 inches in 1959; the minimum amount of precipitation in 1 year was 8.79 inches in 1952. The average maximum monthly temperature of 81.9 °F was reported for July, and the average minimum monthly temperature of 14.4 °F was reported in January (WRCC 2005).

2.1.2 Geology

The KRY Site is located adjacent to or in proximity of the Stillwater River, just north of Kalispell, at an elevation of 2,920 feet above mean sea level (ThermoRetec 2001). The area in the vicinity of the KRY Site is a relatively flat, broad floodplain that is composed of Quaternary age materials ranging from clay- to cobble-sized materials (EPA 1992). Lithologic materials at the KRY Site consist of a mixture of fine- to course-grained alluvial materials ranging in size from clay to cobbles. The dominant lithology at the KRY Site is sandy silty gravel and gravelly silty sand. Also present are intervals of clay, silt, silty fine- to medium-grained sand, and fine- to coarse-grained sand. Cobbles are present throughout the KRY Site within various lithologies but are generally found within the sandy gravel and gravelly sand (DEQ and TtEMI 2008).

2.1.3 Hydrogeology

This section describes site hydrogeology, including site stratigraphy and hydrogeology, groundwater gradients and flow direction, and aquifer testing results.

2.1.3.1 Site Stratigraphy and Hydrogeology

Lithologic materials at the KRY Site consist of a mixture of fine- to course-grained alluvial materials ranging in size from clay to cobbles. The dominant lithology at the KRY Site is sandy silty gravel and gravelly silty sand. Table 2-1 summarizes the physical parameters of the subsurface materials. Three distinctive hydrostratigraphic units are present at the KRY Site. From the ground surface downward, these units can be described as (1) an unconfined aquifer composed of unconsolidated alluvium with discontinuous lenses of clays and/or silts, which can range from 80 to 125 feet thick; (2) a low-permeability confining unit composed of clayey gravelly silt and silty clay at the base of the unconfined aquifer, which was encountered from a depth of 80 feet down to 243 feet at various locations throughout the KRY Site; and (3) a confined aquifer system composed of unconsolidated alluvium underlying the low-permeability unit. The maximum depth and thickness of the confining unit was not estimated during the RI (DEQ and TtEMI 2008). Four geologic cross-sections were developed from the borehole drilling data: the geologic cross-section locations are shown in Figure 2-2 and the cross-sections are shown in Figures 2-3, 2-4, 2-5, and 2-6.

2.1.3.2 Groundwater Gradients and Flow Direction

Groundwater level measurements were collected monthly during the period of July 2006 through July 2007. Groundwater level measurements indicate that groundwater flow is generally toward the southeast in both the upper and lower portions of the unconfined aquifer; however, mounding that is evident in several areas may cause localized flow patterns that are different from the primary aquifer flow direction. The overall site-wide horizontal groundwater gradient in August 2006 was 0.0057 feet/foot in the upper portion of the unconfined aquifer. The horizontal groundwater gradient in the lower portion of the unconfined aquifer was 0.0055 feet/foot. Localized areas within the KRY Site show both shallower horizontal gradients (in the western portion of the KRY Site and at the eastern end of the gravel pit) and steeper horizontal gradients (on the eastern and southeastern portions of the KRY Site). Localized changes in horizontal gradients are likely a result of changes in site lithologies and aquifer permeabilities.

Groundwater contour maps for both the shallow and deep monitoring wells are shown in Figures 2-7, 2-8, 2-9 and 2-10; monthly water level measurements for July 2006 through July 2007 are reported in Table 2-

2(A-D). Groundwater samples were collected for the RI in July 2006, and DEQ personnel collected monthly water level measurements from August 2006 through July 2007 to monitor the water level fluctuation as well as the extent of LNAPL at this site. DEQ selected an appropriate set of wells to be monitored for water level and LNAPL thickness measurements.

Although the lower portion of the unconfined aquifer shows a relatively constant gradient generally toward the southeast, two areas of apparent groundwater mounding are identified in the upper portion of the unconfined aquifer (Figures 2-7, 2-8, 2-9, and 2-10). One area of groundwater mounding is centered around monitoring wells KRY137A and KRY135A on the eastern portion of the KRY Site. Another area of groundwater mounding is present near monitoring wells GWY-3, KRY125A, and KRY129A, located near the Office Max, Rocky Mountain Marine, and Town Pump properties, on the southeastern portion of the KRY Site. The two groundwater mounds show steeper gradients and varying directions of groundwater flow in these areas of the upper portion of the unconfined aquifer. Groundwater in the mounded areas moves radially away from the centers of the mounds. Groundwater that flows radially off the mounds eventually returns to the shallow groundwater flow system, which generally flows toward the southeast.

The groundwater mounding appears to be associated with areas where shallow monitoring wells are completed in finer-grained materials dominated by silt, silty clay, or clay. Groundwater measurements indicate a decrease in water levels from July to August in monitoring wells completed in coarser-grained materials such as sand and gravel. Water levels in monitoring wells completed in these materials decreased approximately 1 to 1½ feet between the July and August measurements. In contrast, groundwater levels in monitoring wells completed in silts and silty clays decreased less than ½ foot. The less-permeable materials likely slow the vertical movement of groundwater. The occurrence of groundwater mounding on the eastern portion of the KRY Site and near the Town Pump property was also identified in previous investigations (Spratt and Associates 1992; Pioneer Technical Services 2000).

Water levels in 20 locations with paired shallow and deep monitoring wells were used to calculate vertical hydraulic gradients using water level date collected in July and August 2006. Twelve of the paired monitoring well locations showed downward vertical gradients, while eight paired monitoring well locations showed upward vertical gradients. Based on these water level measurements and vertical gradient calculations, there does not appear to be a predominant vertical gradient direction at the KRY Site.

2.1.3.3 Aquifer Testing Results

Aquifer test results obtained during the RI and during previous investigations are similar. Hydraulic conductivities of 17 to 326 feet per day (ft/day) were calculated from the results of an aquifer pumping test conducted in August 2006 as part of the RI (Table 2-3). The calculated results are consistent with observed site lithologies and published literature values for silty sand to clean sand (Freeze and Cherry 1979). Hydraulic conductivities calculated by RETEC (1995) on wells in the western portion of the KRY Site ranged from 34 to 48 ft/day based on the results from five rising head slug tests (Table 2-4). Data from investigations by Spratt and Associates (1992) showed hydraulic conductivities to range from 0.4 ft/day (well EH-3) to 322 ft/day (well MW-14 on the southeastern portion of the KRY Site) (Table 2-4). The Spratt and Associates aquifer test investigations included four slug tests and three short-term pumping tests.

The estimated groundwater velocity ranges from 0.39 ft/day to 7.4 ft/day using calculated hydraulic conductivity values ranging from 17 ft/day to 326 ft/day, an average horizontal gradient of 0.0057 feet per foot, and a literature estimate for effective porosity for silty sands of 0.25 (unitless) (Fetter 1980).

2.1.4 Surface Water Hydrology

The Stillwater River is adjacent to portions of the KRY Site (Figure 1-1). The river generally flows from west to east, but there are currently no nearby operational stream gauging stations (U.S. Geological Survey [USGS] 1996). It appears that the majority of the KRY Site is situated outside of the 100- and 500-year floodplains, except for a small area on the western edge of the KRY Site and a small area near the railroad tracks on the northeastern edge of the KRY Site (FEMA 2007). The RI confirmed (see below) that surface water and groundwater in the unconfined aquifer are generally interconnected (MSE, Inc. [MSE] 1989), with the Stillwater River likely discharging to the upper aquifer near the KRY Site (EPA 1992; ThermoRetec 2001). The Board of Environmental Review (BER) classifies the Whitefish River from the outlet of Whitefish Lake to the Stillwater River as B-2 and the Flathead River above Flathead Lake as B-1 (Administrative Rules of Montana 17.30.608). These classifications indicate that waters should be suitable for drinking, culinary use, and food processing after conventional treatment; for bathing, swimming, and recreation; for growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl, and furbearers; and for agricultural and industrial water supply.

Surface water and groundwater levels were collected at the KRY Site from July 2006 through July 2007. Surface water levels from KRY201, KRY202, and KRY203 were compared to near by monitoring wells

KRY100A, KRY105A, and KRY109A respectively. The surface water elevations at KRY201 and KRY203 are higher than the groundwater elevations at KRY100A and KRY109A for the period of measurement indicating recharge from the river to the unconsolidated aquifer. The surface water elevations at KRY202 are lower than the groundwater elevations at KRY105A for the period of measurement possibly indicating discharge from the unconsolidated aquifer to the river in this area. However, monitoring well KRY105A is approximately 300 ft south of the location of KRY202 and may not be a good indication of surface water groundwater interaction. Regions of groundwater to surface water recharge are likely present upgradient or downgradient (or both) of the KRY Site. Additional studies would be necessary to locate these regions.

2.1.5 Human Population and Land Use

The KRY Site is located on the northeastern edge but outside the city limits of the City of Kalispell in the community of Evergreen in Flathead County, Montana (Figure 1-1). Kalispell is the county seat of Flathead County and is the largest city and commercial center of northwest Montana. As of the 2000 census, the total population of Kalispell was 14,223, and its 2004 population was estimated at 17,381 (U.S. Census Bureau 2005). The area is zoned a mixture of heavy industrial, business, and residential according to the Flathead County Planning Department. Land use near the KRY Site includes a mix of residential, commercial, industrial, and open space. Examples of commercial and light-industrial businesses in the area include lumber processing, open-cut gravel mining, recycling, retail stores, storage, and a motel. There are approximately 89 residential properties adjacent to or within the KRY Site.

Potable wells in the form of public water supply wells, residential wells (drinking water and/or irrigation), and commercial wells are located adjacent to or within the KRY Site in the shallow groundwater, as shown on Figure 1-4. In addition, other nondomestic use water is known to come from the shallow aquifer via several individual wells. Waste water disposal and treatment in the vicinity is provided by individual septic systems and public sanitary systems. Locations without individual septic systems are assumed to be connected to the public sanitary systems.

2.1.6 Cultural and Biological Resources

There are no recorded historic or archaeological sites within the KRY Site based on the Montana National Register of Historic Places and the Montana Historical Society, State Historic Preservation Office (2003).

The scattered and intermixed areas of forest, grass, cultivated fields, and water of the Upper Flathead Valley Area provide good food and cover for all kinds of wildlife, and lakes and rivers are considered excellent habitat for shore birds, blackbirds, and herons. Canada geese nest along the Flathead and Stillwater Rivers, and streams and marshes provide excellent habitat for beaver and muskrat. Trout is the principal fish species; pheasants and Hungarian partridge are the main upland game birds, and the white-tailed deer is the main big game animal of the valley. Other common mammals include skunks, cottontail and snowshoe rabbits, ground squirrels, and pocket gophers (U.S. Department of Agriculture [USDA] 1960). Although historical USGS maps of the Kalispell region indicate the presence of a "Stillwater Wildlife Preserve," the Montana Department of Fish Wildlife and Parks no longer has a record of such a preserve in its database (TtEMI 2005).

The Montana Natural Heritage Program has identified four animal species of concern in the vicinity of the KRY Site (2005); there were no plant species of concern. Animal species of concern include the bald eagle (*Haliaeetus leucocephalus*), westslope cutthroat trout (*Oncorhynchus clarki lewisi*), bull trout (*Salvelinus confluentus*), and lynx (*Lynx canadensis*). None of these species was observed at the KRY Site during the RI field investigation. The Stillwater River is considered an impaired stream since it only partially supports a cold water fishery and aquatic life, and cannot be used as a drinking water source.

2.2 NATURE AND EXTENT OF CONTAMINATION

This section presents a summary of the nature and extent of contamination at the KRY Site, including contaminant sources and resultant groundwater contamination where COC concentrations exceed the site-specific cleanup levels and warrant remedial action. Figures that show contaminated areas exceeding regulatory screening levels were created for the RI and can be reviewed in the RI report (DEQ and TtEMI 2008). Since the RI was completed, site-specific cleanup levels have been identified; those levels, along with figures that identify areas to be remediated, are included in Section 3.

Data considered in this FS include the data presented in Appendix A, both historical data and data collected during the RI. The FS considers surface soil samples as samples collected from ground surface to 2 feet below ground surface (bgs), and subsurface samples are considered samples collected below 2 feet bgs.

2.2.1 Soil Impacts

After comparison to site-specific cleanup levels, the primary sources of contamination at the KRY Site are the source areas on the western and eastern portions of the KRY Site (Figures 3-2(A-B), 3-3(A-B), 3-4(A-B), 3-5(A-B), and 3-6(A-B). Primary sources of organic COCs appear to be on the western and eastern portion of the KRY Site. The primary source of inorganic contamination appears to be elevated lead concentrations in surface soil in the southeastern portion of the KRY Site. No surface or subsurface samples from locations outside the source areas identified contained COCs at concentrations above screening criteria, with the following exceptions:

- Surface soil samples in some residential areas contained dioxins/furans at levels slightly above the residential preliminary remediation goal (PRG).
- One subsurface soil sample collected from a residential property north of the KRY Site exhibited levels of C9-C18 aliphatic hydrocarbons that were above residential, commercial, and leaching screening criteria.

Surface and subsurface soil with COCs at concentrations above screening criteria are considered potential sources for groundwater contamination. Soils contaminated with dioxins/furans, which do not tend to leach from soil to groundwater, are not considered potential sources for groundwater contamination.

Petroleum sludge is also present on the eastern portion of the KRY Site (Figure 3-8). One isolated surface sludge pit (approximately 40 feet long by 12 feet wide) is located within the fenced area on the eastern portion of the KRY Site near the northeast corner between the mainline and spur line railroad grades. In addition to the main sludge pit, several minor, very shallow surface expressions of sludge occur along the east fence line, which are not extensive in area or volume. Additionally, a few isolated areas of thin subsurface sludge layers were encountered in test pits along the eastern edge of the KRY Site, although they were sporadic and volumes were minimal. The sludge is not classified as a Resource Conservation and Recovery Act (RCRA) hazardous waste based on sample results.

An isolated area of buried sawdust exists in the vicinity of monitoring well KRY-103A on the western portion of the KRY Site. Based on the well log for monitoring well KRY-103A, the sawdust extends to a depth of approximately 14 feet in this area.

2.2.2 Groundwater Impacts

The highest concentrations of groundwater contamination by PCP and dioxins/furans at the KRY Site were found to be associated with the western portion of the KRY Site (Figure 3-1). High concentrations of petroleum hydrocarbons have also been reported at the KRY Site, including the presence of free-product (Figure 3-7). Petroleum contamination, specifically benzene contamination, at the Seaman Shelton site (near Northern Energy Propane) does not appear to be related to or connected with petroleum contamination at the KRY Site. Groundwater contamination south of Office Max may be from a source other than the KRY Site.

2.2.3 Surface Water and Sediment Impacts

One COC (2,3,7,8-tetrachlordibenzo-p-dioxin [2,3,7,8-TCDD] toxicity equivalency quotient [TEQ]) was reported in surface water samples collected during the RI at concentrations greater than the DEQ human health standard (DEQ 2006a) and background concentrations. No COCs were reported in sediment at concentrations above site-specific screening criteria (DEQ and TtEMI 2008).

The presence of dioxins/furans in surface water above screening criteria and background concentrations indicated potential impacts to the nearby Stillwater River. Dioxins/furans generally adhere strongly to soils and would be expected to be found in sediments at levels that correspond to those detected in surface water, but were not. Because the sediment concentrations were inconsistent with the surface water concentrations and because a limited number of surface water/sediment samples (three, plus a duplicate) were analyzed for dioxins/furans, DEQ contractors conducted additional sampling of the Stillwater River surface water in October 2007. This sampling demonstrated that there was no significant difference between dioxin/furan concentrations in the surface water at sample locations throughout the reach of the Stillwater River adjacent to the KRY Site (background/upstream versus downstream locations), regardless of flow conditions. Therefore, DEQ has not identified COCs for surface water or sediments at the KRY Site and no additional investigation or cleanup of the river is necessary as part of the remedial action (PTS 2007). The data associated with this sampling effort has been included in Appendix A.

2.3 SUMMARY OF CONTAMINANT FATE AND TRANSPORT

Fate and transport for COCs at the KRY Site is discussed in detail in the RI report (DEQ and TtEMI 2008). Site physical characteristics, contaminant characteristics, and an analysis of the fate and transport processes were combined in the evaluation of contaminant fate and transport. The RI considered five COCs or groups of COCs as the most significant from a risk and remediation standpoint: PCP, dioxins/furans, PAHs, petroleum hydrocarbons, and lead.

2.3.1 Soil Leaching to Groundwater Modeling

DEQ performed chemical fate and transport modeling to develop site-specific cleanup levels for the soil leaching to groundwater pathway at the KRY Site. These cleanup levels are concentrations of COCs in surface and subsurface soils that are protective of water quality standards and screening levels for COCs that do not have water quality standards. The modeling was performed to predict COC concentrations in groundwater directly beneath the contaminated soil source area. The COCs and corresponding cleanup levels computed for the soil leaching to groundwater pathway are further discussed, along with direct contact cleanup levels, in Section 2.4. A Technical Memorandum for Chemical Fate and Transport Analysis of Soil Contaminants Leaching to Groundwater is provided in Appendix C.

2.3.1.1 Optional Approach of Using Synthetic Precipitation Leaching Procedure

DEQ recognizes the benefits and limitations of vadose zone modeling and has determined it may be appropriate to provide the option of allowing the use of the Synthetic Precipitation Leaching Procedure (SPLP) to determine compliance with remediation goals. SPLP (also known as EPA Method 1312) is used to evaluate the potential for contaminants in soil to leach into groundwater. This method provides a realistic assessment of contaminant mobility under actual field conditions (i.e. what happens when precipitation percolates through the soil). SPLP is an appropriate method of evaluating fate and transport of contaminants at some sites and may have good application to the fate and transport study conducted at KRY Site. Because the leaching tests are conducted with actual soil samples taken from the site and consider media and waste constituent properties (i.e., solubility and mobility), results developed using this test are expected to be representative of site conditions. Further assessment of SPLP will occur if DEQ selects the use of SPLP in the ROD. Any use of SPLP will need to ensure protectiveness of human health and the environment and comply with RCRA requirements (DEQ 2008a).

2.3.2 Natural Attenuation Modeling

Groundwater modeling to aid in the evaluation of remedial alternatives was also conducted for the FS, as presented in Appendix B of the FS. The groundwater modeling evaluates monitored natural attenuation (MNA) and source area reduction for the two chemicals of concern at the KRY Site that are the most widespread and the hardest to remediate: PCP and dioxins/furans. The objective of groundwater modeling was to estimate the time required for compliance with Montana’s water quality standards at the KRY Site. This analysis was performed using computer software designed to generate screening-level predictions of chemical attenuation and compliance time frames for (1) source areas containing free-product, and (2) dissolved plumes extending downgradient of the source areas. In the first case, the modeling considered two PCP free-product source management scenarios, consisting of natural attenuation, and 90 percent free-product source reduction by in-situ technologies. The time required for Montana’s water quality standards to be achieved in the free-product source area was calculated. In the second case, the amount of time for the dissolved PCP and dioxin/furan plumes to achieve compliance with Montana’s water quality standards was modeled. Model results describe the amount of time required for the entire dissolved chemical plumes to achieve compliance with Montana’s water quality standards after water quality at the source meets standards.

PCP plume attenuation modeling results indicated that approximately 40 years is required for plume concentrations to reduce to cleanup levels when the source concentrations are treated to water quality standards by in-situ technologies. The modeling indicated that desorption of PCP from aquifer organic carbon provides a source of groundwater contamination throughout the length of the plume. Given these results, it is appropriate to consider the PCP sorbed to the aquifer within the plume footprint as a potential source of PCP contamination, and factor this condition into the evaluation and design of the remediation technologies.

Dioxin/furan partitioning properties indicate this chemical is highly sorbed to aquifer organic carbon. Plume attenuation modeling results indicate that a time frame on the order of centuries is required for plume concentrations to decrease to cleanup levels when the source concentrations are treated to water quality standards by in-situ technologies. These results indicate that a proposed remediation method for groundwater needs to consider the entire dioxin/furan plume as the source area.

The predicted time for the PCP NAPL to dissolve, assuming no remediation of the source material varies, depending on the modeled hydraulic conductivity of the aquifer; these results reflect a screening-level analysis. However, the modeling results demonstrate that the NAPLs represent a potential long-term source of groundwater contamination, and indicate that highly effective NAPL remediation is required to achieve groundwater quality targets in a reasonable time frame. The modeling indicates that incomplete NAPL remediation may still result in an extended time period necessary for Montana’s water quality standards to be achieved. Therefore, free product removal is critical to reach cleanup levels.

Fate and transport modeling was performed to evaluate the importance of chemical leaching from the vadose zone to the predicted remediation time frames. Modeling results indicated that the PCP contamination present in the aquifer provides the primary source of the dissolved PCP plume. Sources of PCP contamination include NAPLs and PCP sorbed to aquifer organic carbon. However, model results indicated that PCP present in the vadose zone will also impact groundwater quality over an extended time frame if vadose zone PCP concentrations are not reduced.

2.4 SUMMARY OF HUMAN HEALTH AND ECOLOGICAL RISK ANALYSIS

DEQ has prepared technical memorandum that document DEQ’s analysis of risks to human health and the environment at the KRY Site. DEQ developed risk-based cleanup levels generally using the approach employed for the Missoula White Pine & Sash Facility in Missoula, Montana, including a qualitative evaluation of ecological risks. A site-specific fate and transport evaluation has also been conducted using data gathered during the RI. The risk analysis and addendum to the risk analysis technical memorandum and the fate and transport evaluation are provided in Appendix C.

2.4.1 Similarities and Differences between the KRY Site and the Missoula White Pine Sash Facility

As stated above, DEQ has developed risk-based cleanup levels for the KRY Site using the general risk assessment approach employed at the Missoula White Pine Sash Facility in Missoula, Montana. DEQ chose this approach because of the similarities between the KRY Site and the Missoula White Pine Sash Facility.

Contamination: Both the KRY Site and Missoula White Pine Sash Facility have PCP, dioxins/furans, and petroleum contamination in soils and groundwater. However, the KRY Site has additional contaminants that required modification of the general approach used at the Missoula White Pine Sash Facility.

Geology and Hydrogeology: Both the KRY Site and the Missoula White Pine Sash Facility have very transmissive aquifers and perched groundwater layers.

Demographics: Both the KRY Site and the Missoula White Pine Sash Facility are bordered by a mix of industrial and residential properties. There are no schools or daycare centers located within close proximity to the KRY Site. Therefore, for the most part, the potential receptors and exposure pathways are the same for the KRY Site and the Missoula White Pine Sash Facility. However, while current residential property is likely to remain residential, there will be no additional future residential use or, with the potential exception of the Stillwater River, future recreational use of the KRY Site.

Climate: The KRY Site and the Missoula White Pine Sash Facility have very similar climates with nearly identical average and extreme temperatures. Precipitation patterns are also very similar with the wettest months being May and June.

Ecology: Both the KRY Site and the Missoula White Pine Sash Facility are located in an urban industrial/residential area and are unlikely to support or significantly impact any ecological resources either currently or in the future. There is nothing about the KRY Site which would cause wildlife to visit the area preferentially and the level of human activity on or near the KRY Site is likely to discourage significant usage by wildlife, although an occasional deer or other large mammal may cross the site.

2.4.2 Site Conceptual Exposure Model

Populations that could theoretically be exposed to contamination at the KRY Site include current and future residents, current and future commercial/industrial workers, current and future trespassers, future construction workers, current and future Stillwater River recreators, and current and future ecological receptors.

These populations have the potential to come in contact with contaminants through dermal contact with contaminated soil, groundwater, and surface water; ingestion of soil, groundwater, surface water, produce grown in contaminated soil, and breast milk; and inhalation of contaminated dust, volatiles released during use of groundwater, and volatiles released from groundwater into indoor air.

Evaluation of Receptors and Pathways

DEQ has conducted an evaluation of receptors and pathways and determined that some of the previously mentioned pathways are not complete, or do not need to be quantitatively evaluated. DEQ has provided a discussion of these pathways below. More detail regarding the evaluation of receptors and pathways is provided in DEQ's Risk Analysis Technical Memorandum, provided in Appendix C.

- Future residents: DEQ has conducted an evaluation of reasonably anticipated future usage of the KRY Site and determined that to be commercial/industrial use, with the exception of properties currently in residential use. Institutional controls to prohibit other uses and therefore, will not develop soil cleanup levels for future residents.
- Current residents: Dioxins/furans are the only COC from the KRY Site for residential soil and they were found in surface soil. DEQ calculated a cleanup level for dioxins/furans based on residential exposure. Volatile contaminants associated with the KRY Site have not been detected in groundwater beneath residential property; therefore, DEQ did not develop cleanup levels based on residential exposure to contamination via the vapor intrusion pathway.
- Current and future commercial/industrial workers: Inhalation of volatiles during use of groundwater in this commercial/industrial scenario is not expected to result in significant exposure; therefore, the groundwater standards and screening levels are assumed to be protective of this pathway and DEQ did not evaluate it separately. Further supporting this position, the evaluation of volatilization from groundwater to indoor air, which is discussed in the Risk Analysis Technical Memorandum (Appendix C), is expected to result in greater exposure at the KRY Site. Currently, accurate methods for direct evaluation of volatiles released from subsurface soil to indoor air do not exist. Soil gas samples are typically collected where volatile compounds are the primary risk drivers. However, levels of volatiles that are protective of leaching to groundwater pathway are likely also protective of this pathway at the KRY Site.
- Current and future trespassers: Cleanup levels protective of commercial/industrial workers are protective for the types of trespassers that would be present at the site; therefore, DEQ did not develop cleanup levels separately for these receptors.

- Current and future Stillwater River recreators: Data collected during the RI showed potential impacts to the nearby Stillwater River from dioxins/furans in surface water. Dioxins/furans generally adhere strongly to soils and would be expected to be found in sediments at similar concentrations to those detected in surface water, but were not. Therefore, for this reason, and because there were a limited number of surface water/sediment samples analyzed for dioxins/furans, DEQ contractors conducted additional sampling of the Stillwater River surface water in October 2007. This sampling demonstrated that there was no significant difference between dioxin/furan concentrations in the surface water at sample locations throughout the reach of the Stillwater River adjacent to the KRY Site (background/upstream versus downstream locations), regardless of flow conditions. Therefore, DEQ has not identified COCs for surface water or sediments at the KRY Site and no additional investigation or cleanup of the river is necessary as part of the remedial action (PTS 2007). The data associated with this sampling effort has been included in Appendix A.
- Current and future ecological receptors: The KRY Site is located in an urban industrial/residential area and is unlikely to significantly impact any ecological resources currently or in the future. As mentioned previously, data collected during the RI showed potential impacts to the nearby Stillwater River from dioxins/furans in surface water. However, subsequent sampling determined there were no impacts to the Stillwater River attributable to the KRY Site. Therefore, a complete Ecological Risk Assessment will not be necessary. Please see Section 2.4.4 (below) for more discussion of the Ecological Risk Analysis.

2.4.3 Determination of COCs

DEQ determined which COCs should be retained from the list of COPCs presented in the Final Remedial Investigation Report (DEQ and TtEMI 2008). The primary COCs for the KRY Site are PCP, dioxins/furans, petroleum compounds, and lead, although other compounds have been retained as COCs as well. The following sections provide a discussion of COCs for each media and the established cleanup levels. More information about the process used to determine COCs and calculate cleanup levels is provided in DEQ’s Risk Analysis Technical Memorandum and Addendum to the Risk Analysis Technical Memorandum (Appendix C).

DEQ updated the Montana Tier 1 Risk-Based Corrective Action Guidance for Petroleum Releases (RBCA) in 2007 because some of the toxicity information for the compounds reflected in RBCA had recently changed and because other changes to RBCA were also necessary (DEQ 2007). DEQ used this newer information in the screening of the COPC list to ensure that the most recent information was used in the screening process. Additionally, for soils, DEQ used the direct contact and leaching Risk-Based Screening Levels (RBSLs) from the Master Table of All Potential Tier 1 RBSLs for Soil (Appendix C) from the RBCA guidance. This table shows the various RBSLs calculated for different purposes, unlike Tables 1 and 2 from within the RBCA Guidance, which only show the most protective RBSLs. DEQ did not utilize the levels calculated for beneficial use, as they are a reflection of aesthetic properties of soils (e.g., appearance and odor). Free-product removal and excavation of contaminated soils to address direct contact and leaching to groundwater risks will also address beneficial use. Additionally, given that this analysis was conducted to calculate cleanup numbers, and not as an initial screening, the direct contact and leaching numbers are the most appropriate to use.

EPA released Regional Screening Levels in May 2008 (EPA 2008) that replaced the Region 9 Preliminary Remediation Goals (EPA 2004c) that DEQ had previously used for screening purposes. The release of the Regional Screening Levels prompted DEQ to compare the list of COPCs to the new screening levels to ensure that revised screening levels did not change the list of COCs at the KRY Site. The re-screening effort ultimately resulted in the elimination of some compounds as COCs for the KRY Site, which required that DEQ change the proposed cleanup levels. Specifically, aluminum and iron were eliminated as COCs for surface soil. Aluminum was eliminated as a COC for subsurface soil, and 1,2,4-trimethylbenzene was retained as a COC for leaching from subsurface soil. The compound 1,3,5-trimethylbenzene was eliminated as a COC for groundwater and vapor intrusion, and n-butylbenzene was eliminated as a COC for groundwater because there is no longer accepted toxicity information available for these compounds. Lastly, the slope factor for dioxin was revised, which also required that DEQ change the proposed dioxin/furan cleanup levels.

The re-screening process is documented in the addendum to the risk analysis technical memorandum provided in Appendix C and the revised cleanup levels have been included in the lists provided below and in Tables 3-1 and 3-2.

2.4.3.1 Groundwater

For compounds that have them, the DEQ-7 standards are the applicable cleanup level. For dioxins/furans (TEQ – WHO1998) and metals, DEQ took into account background concentrations from newly installed monitoring well KRY-101A and that background concentration, rather than the DEQ-7 standard, is used as the cleanup level. These particular compounds are found naturally-occurring in the environment and DEQ accounted for that using the background concentrations. DEQ also applied RBCA RBSLs for petroleum compounds and EPA tap water screening levels for compounds that do not have DEQ-7 standards or RBSLs.

The COCs for groundwater, along with their corresponding cleanup levels, are provided below. The COCs are divided into COCs with DEQ-7 human health standards that are the cleanup levels, and COCs without DEQ-7 human health standards for which RBSLs or tap water screening levels are the cleanup levels. Additionally, DEQ also evaluated naphthalene and 1,2,4-trimethylbenzene as COCs for vapor intrusion to indoor air. DEQ utilized the EPA vapor intrusion model with some site-specific data added (soil classification, distance to groundwater, exposure assumptions, etc.) to calculate risk-based groundwater concentrations for the compounds based on a basement scenario, which was the most protective (EPA 2004b). The calculated concentrations are greater than the EPA tap water screening levels for these two compounds. Therefore, the EPA tap water screening levels will be used as the cleanup levels for these two compounds and those levels will also be protective of the volatilization to indoor air pathway.

COCs with DEQ-7 Human Health Standards

- Dioxins/furans – 5.61 picograms per liter (pg/L) (Background concentration)
- PCP – 1 ug/L
- Arsenic – 10 ug/L
- Benzene – 5 ug/L
- Ethylbenzene – 700 ug/L
- Iron – 300 ug/L
- Manganese – 778 ug/L (Background concentration)
- Naphthalene – 100 ug/L
- Toluene – 1,000 ug/L

COCs without DEQ-7 Human Health Standards

- 1,2,4-Trimethylbenzene – 15 ug/L
- C11-C22 Aromatics – 1,000 ug/L
- C5-C8 Aliphatics – 800 ug/L
- C9-C10 Aromatics – 1,000 ug/L
- C9-C12 Aliphatics – 500 ug/L

2.4.3.2 Soils

Direct contact cleanup levels were calculated for soils using equations developed by the EPA (EPA 2004c). Compounds were separated based on their effect (i.e., non-carcinogenic or carcinogenic). Cleanup levels for non-carcinogenic compounds in each media (surface and subsurface soil) were calculated to ensure that the total hazard index for compounds with the same target organs or critical effects do not exceed 1 for any organ or effect. Cleanup levels for carcinogenic compounds in each media (surface and subsurface soil) were calculated to ensure that the total cancer risk does not exceed $1x10^{-5}$. The most recent toxicity information was used to calculate cleanup levels, including updates that were recently incorporated into RBCA and those from EPA's May 2008 Regional Screening Levels. DEQ utilized the new information to re-screen the list of COPCs to ensure that compounds were retained or eliminated appropriately, and to recalculate cleanup levels. However, DEQ has determined that its approach for calculating site-specific cleanup levels is protective. Since this approach has previously undergone public review and it continues to be protective, DEQ will retain the general approach for calculating site-specific cleanup levels.

DEQ has developed site-specific target levels for the soil leaching to groundwater pathway at the KRY Site. These site-specific target levels are concentrations of COCs in surface and subsurface soils that are protective of groundwater (DEQ-7 standards). Chemical fate and transport modeling was performed to predict COC concentrations at the source. A more thorough discussion of the methods used to calculate these site-specific target levels can be found in the Soil Leaching to Groundwater Modeling technical memo, which is an attachment to DEQ's Risk Analysis Technical Memorandum, as well as in DEQ's Addendum to the Risk Analysis Technical Memorandum, provided in Appendix C.

The COCs for each media (surface soil and subsurface soil) for dermal contact and leaching to groundwater are provided below, along with their corresponding cleanup levels. To ensure protection of human health and the environment, the most protective of the leaching to groundwater cleanup level or dermal contact cleanup level will be used as the cleanup level. Additionally, for compounds with a leaching number for both surface soil and subsurface soil, the cleanup level for surface soil will be used where there is only surface soil contamination. If subsurface soil contamination exists, the subsurface soil leaching cleanup level will be used. Lastly, for compounds where the leaching to groundwater cleanup level is not the most protective and where the excavation cleanup level is lower than the commercial cleanup levels, surface soil will be cleaned up to excavation cleanup levels. Therefore, only the most protective cleanup level is provided in the lists below for each compound, although the approach of using SPLP analysis will be considered by DEQ.

2.4.3.2.1 Surface Soils

Two different exposure scenarios were used for calculating cleanup levels in surface soil: a commercial scenario and a residential scenario. As stated before, the most protective cleanup level that applies to each compound is reported.

Commercial/Industrial Soil: The following are the COCs for surface soil for direct contact and leaching to groundwater and their corresponding cleanup levels. DEQ used its calculated Action Level for Arsenic in Surface Soil (DEQ 2005a) of 40 mg/kg as both the screening and the cleanup level for arsenic at the KRY Site. In addition, DEQ calculated a cleanup level representing a total carcinogenic polycyclic aromatic hydrocarbon (cPAH) concentration using the approach outlined in EPA Guidance (EPA 1993), which is based on the toxicity of benzo(a)pyrene. The relative toxicity of each cPAH compound relative to benzo(a)pyrene is used to adjust its concentration. Following this adjustment, the resulting concentrations are summed. The summed concentration must not exceed the total cPAH cleanup level. Lastly, DEQ applied the World Health Organization 2005 TEFs relative to 2,3,7,8-TCDD (WHO 2005) to concentrations of dioxins/furans for comparison to the cleanup level to determine where and how much cleanup is necessary.

- Arsenic – 40 mg/kg
- cPAHs – 1.7 mg/kg
  - cPAHs for surface soil includes benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene.
- C11-C22 Aromatics – 33,445 mg/kg
- C9-C18 Aliphatics – 2,634 mg/kg
- Chromium - 150 mg/kg
- Dioxins/furans – 103 ng/kg (parts per trillion)
- Lead – 800 mg/kg
- Methylene Chloride – 0.82 mg/kg
- PCP – 12 mg/kg (unless subsurface soil is contaminated too, then it would be 0.43 mg/kg)

Residential Soil: Dioxins/furans were the only compounds retained as a COPC for residential surface soil in the RI and therefore are the only compounds retained as a COC for risk analysis purposes. DEQ applied the World Health Organization 2005 TEFs relative to 2,3,7,8-TCDD (WHO 2005) to concentrations of dioxins/furans for comparison to the cleanup level to determine where and how much cleanup is necessary.

- Dioxins/furans – 62.5 ng/kg (parts per trillion)

2.4.3.2.2 Subsurface Soils

An excavation exposure scenario was used for calculating direct contact cleanup levels for subsurface soil. Cleanup levels protective of soils leaching to groundwater were also calculated. As stated before, the most protective cleanup level that applies to each compound is reported.

The following are the COCs for subsurface soil for direct contact and leaching to groundwater. As mentioned previously, DEQ used its calculated Action Level for Arsenic in Surface Soil (DEQ 2005a) of 40 mg/kg as both the screening and the cleanup level for arsenic in subsurface soil at the KRY Site. In addition, DEQ calculated a cleanup level representing a total carcinogenic polycyclic aromatic hydrocarbon (cPAH) concentration using the approach outlined in EPA Guidance (EPA 1993), which is based on the toxicity of benzo(a)pyrene. Lastly, DEQ applied the World Health Organization 2005 TEFs relative to 2,3,7,8-TCDD (WHO 2005) to concentrations of dioxins/furans for comparison to the cleanup level to determine where and how much cleanup is necessary.

- Acenaphthene – 27,000 mg/kg
- Arsenic – 40 mg/kg
- cPAHs - 13 mg/kg
  - cPAHs for subsurface soil includes benz(a)anthracene and benzo(a)pyrene.
- C11-C22 Aromatics – 33,445 mg/kg
- C19-C36 Aliphatics – 260,154 mg/kg
- C5-C8 Aliphatics – 730 mg/kg
- C9-C10 Aromatics – 4,800 mg/kg
- C9-C12 Aliphatics – 1,550 mg/kg
- C9-C18 Aliphatics – 2,634 mg/kg
- Carbazole - 99 mg/kg
- Chromium – 20 mg/kg
- Dioxins/furans – 736 ng/kg
- Ethylbenzene – 320 mg/kg
- Fluorene – 130,000 mg/kg
- Iron – 46,686 mg/kg
- Lead – 800 mg/kg
- 2-Methylnaphthalene – 1,982 mg/kg
- Naphthalene – 220 mg/kg
- PCP – 0.43 mg/kg
- Selenium – 1.7 mg/kg
- Toluene – 260 mg/kg
- Xylenes – 486 mg/kg

2.4.3.3 Surface Water and Sediments

Only dioxins/furans were detected in surface water at levels exceeding screening levels and background throughout the reach of the river adjacent to the KRY Site. However, in co-located sediment samples, the background sample had the highest concentrations of all detected compounds.

Dioxins/furans generally adhere strongly to soils and would be expected to be found in sediments at similar concentrations to those detected in surface water, but were not. Therefore, for this reason, and because there were a limited number of surface water/sediment samples collected for dioxins/furans, DEQ contractors conducted additional sampling of the Stillwater River surface water in October 2007. This sampling demonstrated that there was no significant difference between dioxin/furan concentrations in the surface water at sample locations throughout the reach of the Stillwater River adjacent to the KRY Site (background/upstream versus downstream locations), regardless of flow conditions. Therefore, DEQ has not identified COCs for surface water or sediments at the KRY Site and no additional investigation or cleanup of the river is necessary as part of the remedial action (PTS 2007). The report associated with this investigation is included as Appendix G.

2.4.4 Ecological Risk Evaluation

The KRY Site is located in an urban industrial/residential area and is unlikely to significantly impact any ecological resources currently or in the future. The main areas of contamination are partially or wholly fenced or covered with weeds. Small rodents and birds may live onsite. These organisms may visit the contaminated areas and inhale dust or ingest contaminated soil periodically. However, there is nothing particularly attractive about the contaminated areas of the KRY Site over the surrounding area that would cause birds or rodents to visit the contaminated areas preferentially. The level of human activity near and throughout the KRY Site is likely to discourage significant usage by wildlife, although an occasional deer or other large mammal may cross the KRY Site. In addition, no designated wetlands exist on or within a mile of the KRY Site. No populations of designated federal or Montana species of concern exist on the KRY Site or surrounding the area and no threatened or endangered species exist primarily within four miles of the KRY Site.

Data collected during the RI showed potential impacts to the nearby Stillwater River from dioxins/furans in surface water. Minimal data was collected for surface water and sediments during the RI. Therefore, DEQ contractors conducted additional sampling of the Stillwater River surface water in October 2007. This sampling demonstrated that there was no significant difference between dioxin/furan concentrations in the surface water at sample locations throughout the reach of the Stillwater River adjacent to the KRY Site (background/upstream versus downstream locations), regardless of flow conditions (PTS 2007). Therefore, DEQ has determined that a complete Ecological Risk Assessment will not be necessary because cleanup levels protective of human health would also reduce any limited ecological exposure that may occur.

3.0 REMEDIAL ACTION OBJECTIVES AND VOLUME ESTIMATES

The goal of the RI/FS process at the KRY Site is to delineate the nature and extent of contamination at the KRY Site and develop and select remedies in accordance with CECRA. Remedial actions undertaken pursuant to CECRA, §§ 75-10-701, et seq., Montana Code Annotated (MCA), must "attain a degree of cleanup of the hazardous or deleterious substance and control of a threatened release or further release of that substance that assures protection of public health, safety, and welfare and of the environment." Additionally, DEQ "shall require cleanup consistent with applicable state or federal environmental requirements, criteria, or limitations" and "may consider substantive state or federal environmental requirements, criteria or limitations that are relevant to the site conditions."

3.1 ENVIRONMENTAL REQUIREMENTS, CRITERIA, AND LIMITATIONS

Appendix D includes a summary of the preliminary ERCLs for the KRY Site. CECRA defines cleanup requirements as state and federal ERCLs. Remedial designs, implementation, operation, and maintenance must, nevertheless, comply with all other applicable laws, including local, state, and federal. Many such laws, although not strictly environmental, have environmental impacts. The persons implementing the remedy remain responsible to identify and comply with all other laws.

A distinction exists between "applicable" requirements and those that are "relevant." "Applicable" requirements would legally apply at the facility, regardless of the CECRA action. "Relevant" requirements are not applicable, but address situations or problems sufficiently similar to those at the facility and, therefore, are relevant for use at the facility.

ERCLs are grouped into three categories: contaminant-specific, location-specific, and action-specific. Contaminant-specific requirements establish an allowable level or concentration of a hazardous or deleterious substance in the environment or describe a level or method of treatment for a hazardous or deleterious substance. Location-specific requirements serve as restrictions on the concentration of a hazardous or deleterious substance or the conduct of activities solely because they are in specific locations. Action-specific requirements are relevant or applicable to implementation of a specific remedy. Action-specific requirements do not in themselves determine the remedy but rather indicate the manner in which the remedy must be implemented.

The ERCLs are preliminary and are subject to change when the selected remedy for the KRY Site is selected.

3.2 PRELIMINARY REMEDIAL ACTION OBJECTIVES

PRAOs are established to allow the identification and screening of remedial alternatives that will achieve protection of human health and the environment. Cleanup levels are acceptable contaminant concentrations for each medium. PRAOs and cleanup levels for the KRY Site were developed based on the results of human health and ecological risk analyses, as well as the preliminary ERCLs discussion in Section 3 and Appendix D. Final ERCLs will be evaluated when the remedial action is selected in the ROD.

3.2.1 PRAOs for Groundwater

The following PRAOs are proposed for groundwater at the KRY Site:

- Meet groundwater cleanup levels for COCs in groundwater throughout the KRY Site.
- Comply with ERCLs for free-product and COCs in groundwater.
- Reduce potential future migration of free-product and contaminated groundwater plume.
- Prevent exposure of humans to free-product and to COCs in groundwater at concentrations above cleanup levels.

Cleanup levels for groundwater COCs, including free-product, are presented in Table 3-1. The development of groundwater cleanup levels is based on the results of the risk analysis (Appendix C) and the ERCLs (Appendix D).

3.2.2 PRAOs for Surface Water and Sediment

PRAOs have not been developed for surface water or sediment. Surface water and sediment samples were collected from the Stillwater River adjacent to the KRY Site during the RI (DEQ and TtEMI 2008). Detected analytes included metals, semivolatile organic compounds, and petroleum compounds. One chemical, 2,3,7,8-TCDD TEQ, was detected at a concentration above screening criteria and background levels and is considered a COC in surface water. Additional sampling and evaluation were necessary to delineate the exact nature and extent of the TCDD TEQ. Therefore, DEQ contractors conducted additional sampling of the Stillwater River surface water in October 2007. This sampling demonstrated that there was no significant difference between dioxin/furan concentrations in the surface water at sample locations throughout the reach of the Stillwater River adjacent to the KRY Site (background/upstream versus downstream locations), regardless of flow conditions. Therefore, DEQ has not identified COCs for surface water or sediments at the KRY Site and no additional investigation or cleanup of the river is necessary (PTS 2007). The data associated with this sampling effort has been included in Appendix A.

No chemicals were detected in sediment samples at concentrations above the freshwater sediment criteria.

3.2.3 PRAO for Soil

The following PRAOs are proposed for soil at the KRY Site:

- Prevent migration of COCs that would potentially leach from soil to groundwater.
- Prevent exposure of humans to free-product/sludge and to COCs in soil at concentrations above cleanup levels.
- Meet soil cleanup levels for COCs.
- Comply with ERCLs for free-product/sludge in soil.

Cleanup levels for surface and subsurface soils, as well as sludge, are presented in Table 3-2. The development of soil cleanup levels is based on the results of risk analysis and vadose soil modeling presented in Appendix C.

3.3 REMEDIATION VOLUME ESTIMATES

Areas and volumes of media contaminated at concentrations above the cleanup levels were calculated as part of the FS. In completing these calculations, all assessments of the lateral and vertical extent of soil and groundwater contamination were based on a comparison of soil and groundwater sampling results to cleanup levels. The release of EPA’s May 2008 EPA Regional Screening Levels resulted in changes to the cleanup levels. These changes to the cleanup levels will likely decrease the volume estimates, since cleanup levels increased resulting in less soil that requires cleanup. However, DEQ did not revise the volume estimates as a result of the revised cleanup levels.

Figure 3-1 illustrates the aerial extent of groundwater contaminated above cleanup levels at the KRY Site. The area with shallow groundwater contamination covers approximately 2,176,142 square feet (50 acres). The average thickness of the contaminated aquifer is estimated at 40 feet, approximately half the thickness of the unconfined aquifer. Assuming an aquifer effective porosity of 27 percent, the volume of contaminated groundwater in the upper portion of the unconfined aquifer at the KRY Site is estimated at 87 million cubic feet (176 million gallons). The area with groundwater contamination in the deep portion of the unconfined aquifer covers 220,030 square feet (5.05 acres). The average thickness of the contaminated aquifer is estimated at 40 feet, approximately half the thickness of the unconfined aquifer. Assuming an aquifer effective porosity of 27 percent, the volume of contaminated groundwater in the deep portion of the unconfined aquifer at the KRY Site is estimated at 8.8 million cubic feet (17.8 million gallons). Volume estimate calculations, on a contaminant specific basis, are provided in Table 3-4. Contaminant plumes for individual compounds may overlap; therefore, the aerial extent and volumes calculated for individual compounds do not necessarily add up to the aerial extent and volume calculated for the shallow or deep portions of the aquifer.

Figure 3-2(A-B) illustrates the aerial extent of surface soil contaminated at concentrations above cleanup levels at the KRY Site. The area of surface soil contamination totals 273,000 square feet (6.3 acres). The depth of soil contamination was defined as 2 feet for surface soils (surface soils are identified as from 0 to 2 feet bgs) to estimate the volumes of contaminated soil. The total volume of contaminated surface soil was estimated at 20,224 cubic yards. DEQ then determined that it was appropriate to apply a multiplication factor of 1.8 to the volume to account for DEQ Petroleum Compensation Board experience with cost increases due to increased soil volume (DEQ 2008b). Application of the multiplier results in an estimate of 36,403 cubic yards of contaminated surface soil. Volume estimate calculations, on a contaminant specific basis, are provided in Table 3-5. Areas of contamination for individual compounds may overlap; therefore, the aerial extent and volumes calculated for individual compounds do not necessarily add up to the aerial extent and volume calculated for the surface soil as a whole.

Figures 3-3(A-B), 3-4(A-B), 3-5(A-B), and 3-6(A-B) illustrate the aerial extent of subsurface soil on a contaminant-specific basis, contaminated at concentrations above cleanup levels. The area of subsurface contamination for the most prevalent COCs is provided below. The figures identifying the aerial extent of subsurface soil contamination and volume estimates for contaminated subsurface soils were created/calculated using EVS/MVS Mining Visualization System software (C Tech 2008), which modeled contamination based on concentrations from samples that were determined to be useable in the DSR and RI (TtEMI 2005; DEQ and TtEMI 2008). Measured contaminant concentrations were used to determine the aerial extent and depth of the contaminated soils. Only samples collected deeper than 2 feet below ground surface were used in depicting aerial extent and in calculating volumes. The total volume of contaminated subsurface soil was estimated at 42,317 cubic yards. DEQ then determined that it was appropriate to apply a multiplication factor of 1.8 to the volume to account for DEQ Petroleum Compensation Board experience with cost increases due to increased soil volume (DEQ 2008b). Application of the multiplier results in an estimate of 77,317 cubic yards of contaminated subsurface soil, which is broken out for the most prevalent COCs as indicated below. The area of contamination for each compound is also provided below.

- PCP: 192,793 square feet (4.4 acres) and 44,987 cubic yards;
- Dioxins/Furans: 287,119 square feet (6.6 acres) and 7,630 cubic yards;
- Lead: 7,404 square feet (0.2 acres) and 1,429 cubic yards;
- Petroleum Hydrocarbons: 267,706 square feet (6.1 acres) and 23,270 cubic yards.

Data gaps identified for groundwater and soil and recommendations for filling those gaps were outlined in the RI report (DEQ and TtEMI 2008). Any additional data needed to better define soil and groundwater remediation areas will be gathered during remedial design and before remedial action.

LNAPL volumes were estimated using a worst-case scenario where the LNAPL thickness was assumed to be equal to the average maximum thickness observed during 12 months of recent monthly well monitoring, from July 2006 to July 2007 (Table 3-3(A-B)). LNAPL presence was inferred in the areas between wells with documented LNAPL occurrences. The aerial extent of LNAPL based on these observations and inferences totals 462,471 square feet (10.62 acres) (Figure 3-7). The calculated volume of LNAPL based on this evaluation is 164,097 gallons, as shown in Table 3-6.

4.0 DEVELOPMENT AND SCREENING OF REMEDIAL OPTIONS

This section documents the initial steps involved in developing and screening remediation options for contaminated soil and groundwater at the KRY Site. This section also identifies general response actions and screens viable technology types that will remediate contaminated media and attain the PRAOs. Finally, this section summarizes the remedial technologies that will be carried forward into the detailed description of selected technology options (Section 5.0).

Screening and evaluating remedial options is based on the type, distribution, and volume of contaminants found in soil and groundwater at the KRY Site and on the PRAOs discussed in Section 3.

This section also identifies and screens potential technology types for remediation of contaminated soil and groundwater at the KRY Site. Technology types are identified for each general response action identified in the IASD. These technologies have been reviewed against site-specific conditions and analyzed based on three preliminary criteria: effectiveness, implementability, and relative cost. The basis for applying each of these three criteria in the evaluation of individual technologies is described below.

Effectiveness Evaluation. This evaluation focused on the potential effectiveness of each process option in remediating the contaminated soil and groundwater and in meeting the PRAOs. Specific information considered included types and levels of contamination, the volume and aerial extent of contaminated soil and groundwater, and the time to achieve remediation goals. Each process option was classified as being effective, limited, or not effective.

Implementability Evaluation. This evaluation rated the relative degree of technical implementability and feasibility of implementing the technology or option. Aspects considered included any substantive requirements of potential permits for actions, availability of treatment, storage and disposal services, and the availability of necessary equipment and skilled workers to implement the technology. The implementability of each technology was classified as easy, moderately difficult, difficult, or not implementable.

Cost Evaluation. The cost evaluation was based on engineering judgment, and each process was evaluated in relation to other process options of the same technology type. Both capital and operating costs were considered. The costs of each technology were classified as low, moderate, high, or very high.

4.1 INITIAL ALTERNATIVES SCREENING DOCUMENT

DEQ and its contractor prepared an IASD (TtEMI 2005). The IASD was intended to identify and evaluate all potential remedial alternatives for remediation of contaminated soil and groundwater at the KRY Site. TtEMI therefore identified and described (in table form) all viable remedial alternatives for LNAPL, contaminated soil, and contaminated groundwater; selected and described evaluation criteria to be used for the initial screening of alternatives; provided a reference list for the alternatives and evaluation criteria; and further evaluated alternatives for cost, effectiveness, and implementability. Finally, TtEMI proposed potential remedial alternatives to be retained for subsequent evaluation in this FS report.

The final IASD, which consists of two tables is included in Appendix E. Table 1 is an initial screen of all potential alternatives against criteria selected from the Federal Remediation Technology Roundtable (FRTR) database (FRTR 2002). Table 2 is a more detailed screening of alternatives retained from Table 1 using the cost, effectiveness, and implementability criteria and identifies the alternatives retained for detailed evaluation in this FS. In addition, a technical memorandum (TtEMI 2007c) was prepared that presents a detailed description of the FS scoping meeting, the discussions that ensued, the decisions reached during and after the scoping meeting, and the rationale for the decisions. This technical memorandum is also presented in Appendix E. The alternatives that were retained for further consideration in this FS include:

- No Further Action
- Institutional Controls
    - Land use controls and groundwater use restrictions
- Engineering Controls
    - Site security measures
- Groundwater Monitoring
- Monitored Natural Attenuation
- NAPL Collection and Treatment
    - Multi-phase extraction, trenches and drains, hydraulic pumps, and passive and active skimmers
- Groundwater Containment
    - Pumping wells, french drains, and extraction trenches
- Groundwater Collection
    - Trenches and extraction wells
- Ex Situ Groundwater Treatment
    - Land treatment, engineered bioreactors, carbon adsorption, other adsorption, chemical, ozone, or ultraviolet (UV) oxidation, ion exchange, precipitation, coagulation, and flocculation, and membrane technologies

- Groundwater Discharge
    - Land application, injection wells or trenches, discharge to surface water, and disposal offsite
- In Situ Groundwater Treatment
    - Enhanced bioremediation (aerobic and anaerobic), in situ chemical oxidation, and air sparging
- Soil Containment
    - Horizontal barrier
- Soil Removal and Transport
    - Excavation
- Ex Situ Soil Treatment
    - Land farming, biopiles, soil washing, separation, thermal desorption, and incineration
- Disposal
    - Solid waste landfill, hazardous waste landfill, reclamation and recycling, and backfill excavations
- In Situ Soil Treatment
    - Enhanced bioremediation [aerobic and anaerobic], bioventing, in situ chemical oxidation, solidification/stabilization, and in situ thermal desorption

The effectiveness, implementability, and cost of the retained alternatives are evaluated in the IASD Table 2, included in Appendix E. The retained alternatives are discussed further below.

4.2 GENERAL RESPONSE ACTIONS AND SCREENING OF TECHNOLOGY AND PROCESS OPTIONS

General response actions are broad classes of actions that potentially satisfy the PRAOs for the site. General response action categories for the KRY Site were identified based on the nature and extent of contamination, as described in Section 2.0, and are shown in the IASD (Appendix E). The following sections discuss each general response action and its applicability to the contaminated media at the KRY Site.

4.2.1 No Further Action

No Further Action indicates that no remedial action will be conducted on the KRY Site. The site is allowed to continue in its current state, and no future actions are conducted to remove or remediate the contamination. No access restrictions are put into place, and no deed restrictions are imposed on the site. DEQ procedures require that “no action” be included among the general response actions evaluated in every FS.

The No Further Action option provides a baseline for comparison with other options and alternatives. This option entails no future activities to contain or remediate contaminants at a site, provides no treatment for contaminants, and entails no legal or administrative protection of human health or the environment. This option assumes that physical conditions at the KRY Site remain unchanged.

The No Further Action option will not achieve PRAOs; however, it is retained as a stand-alone alternative to be used as a baseline for comparison with other alternatives.

4.2.2 Institutional Controls

Institutional controls are nonengineering measures, such as administrative or legal controls, that help minimize the potential for human exposure to contamination and protect the integrity of a remedy by limiting land or resource use. Although institutional controls do nothing to remediate the contamination at the site, they can be effective for managing human exposure to contaminants. The effectiveness of institutional controls depends on the mechanisms used and the durability of the institutional control. Institutional controls may be layered to improve effectiveness. Institutional controls are considered easy to implement and have low implementation and maintenance costs. There are three general categories of institutional controls: governmental controls; proprietary controls; and enforcement and permit tools with institutional control components. Examples of institutional controls that may be applicable to contamination at the KRY Site include land use controls and groundwater use restrictions.

4.2.2.1 Land Use Controls

Zoning. Flathead County has implemented zoning regulations for the properties within and surrounding the KRY Site. Additional zoning requirements may be proposed to control present and future land uses on or around a source area consistent with the potential hazards present, the nature of remedial measures implemented, and future land-use patterns. (Flathead 2006a and 2006b) The objective of additional zoning would be to prevent public or private misuse of a contaminated area that could jeopardize the effectiveness of remedial measures taken or pose an unacceptable potential for human exposure to the contaminants present.

Restrictive Covenants. Restrictive covenants are limits on uses of property to assist in mitigating risk to human health. They provide notice of the limitations on the use of the property to prospective purchasers and remain on the property if it is transferred. The limitations preserve and protect the effectiveness of remedial measures that may have been taken. They are contemplated and authorized by § 75-10-727, MCA.

Environmental Control Easements. Montana has established environmental control easements (Section 76-7-101 et seq. MCA), an enforceable easement mechanism for imposing restrictions on the use of a site and for requiring operation and maintenance that may help protect public health, safety, and welfare, and the environment. The environmental control easement is intended to be used at sites throughout the state that contain or may contain hazardous wastes or substances that may require remediation, reclamation, or restoration pursuant to federal, state, or local law or regulation. Protection of public health, safety, or welfare or the environment may be enhanced by application and enforcement of certain restrictions on the future use of the site or requirements for certain activities.

4.2.2.2 Groundwater Use Restrictions

Controlled Groundwater Areas. Under Section 85-2-506(2)(e-g), MCA, a controlled groundwater area may be designated by the Montana Department of Natural Resources and Conservation (DNRC) through a petition of a state or local public health agency for identified public health risks if (but not limited to): (1) excessive groundwater withdrawals would cause contaminant migration, (2) groundwater withdrawals that adversely affect groundwater quality within the groundwater area are occurring or are likely to occur, or (3) groundwater quality within the groundwater area is not suited for a specific beneficial use. The DNRC may grant either a permanent or a temporary controlled groundwater area. Restrictions within the controlled groundwater area may include provisions such as prohibition of new wells or special permitting and monitoring requirements for new and existing wells within the designated area.

4.2.3 Engineering Controls

Engineering controls are measures that are capable of managing environmental and health risks by reducing contamination levels or limiting exposure pathways. Engineering controls encompass a variety of engineered remedies (e.g., soil capping, fencing) to contain and/or reduce exposure to contamination and/or physical barriers intended to limit access to property. Although engineering controls do nothing to remediate the contamination at the KRY Site, they can be effective for managing exposure to contaminants. The effectiveness of engineering controls depends on the mechanisms used and the durability of the engineering control. The initial cost of some engineering controls can be high, and generally engineering controls require some long-term maintenance, etc. Examples of engineering controls that may be applicable to contamination at the KRY Site include fencing or other site security measures.

4.2.3.1 Site Security Measures

Fencing or security measures may be required during implementation of the selected remedy to prevent unintentional use of or exposure to contaminated media. Additionally, fencing or other security measures may be required to protect against injury to workers or others that may enter work areas where heavy equipment is operating or where open excavations are present. Site security measures may also be used to protect the integrity of certain remedial actions, such as repositories.

4.2.4 Long-term Monitoring

A long-term monitoring program is critical to evaluate the effectiveness of any remediation. The long-term monitoring program for the KRY Site may include sampling of any of the existing monitoring well network that now includes 114 wells. Monitoring may also include some or all of the existing nearby domestic and commercial/industrial wells to ensure that these wells do not become contaminated above cleanup levels. Each alternative, except No Further Action, will include the provision for continued monitoring to ensure the continued protection of public health and to evaluate the effectiveness of the remediation.

4.2.5 Monitored Natural Attenuation

According to EPA guidance, MNA refers to the use of natural attenuation processes to achieve site-specific remedial objectives once contaminants sources are removed and/or controlled (EPA 1999). Under favorable conditions, the natural attenuation processes, in association with source control or removal, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in situ processes include biodegradation; dispersion; dilution; sorption; volatilization; and the chemical or biological stabilization, transformation, or destruction of contaminants. Naturally occurring biological stabilization or destruction of contaminants (also known as intrinsic bioremediation) can be a dominant process in the fate and transport of contaminants. Natural attenuation takes place when naturally occurring microorganisms consume or otherwise degrade contaminants either aerobically or anaerobically. Depending on the contaminant, natural attenuation may ultimately transform the contaminants into harmless byproducts. Monitoring is essential to evaluate the effectiveness of natural attenuation.

Natural attenuation has occurred to some degree at the KRY Site, as indicated by the Western Research Institute report presented in Appendix A of the RI report (DEQ and TtEMI 2008). However, natural attenuation of PCP is limited. A preliminary evaluation of natural attenuation using groundwater modeling techniques (Appendix B) indicates that MNA alone will not achieve PRAOs within a reasonable timeframe at the KRY Site, partially because MNA is not effective at remediating free-product. The modeling results also demonstrate that the free-product represents a potential long-term source of groundwater contamination, and indicate that highly effective free-product remediation is required to achieve groundwater quality targets in a reasonable timeframe. The modeling indicates that incomplete free-product remediation may result in an extended time period necessary for Montana’s water quality standards to be achieved. Therefore, MNA may be used as a follow-up to other, more aggressive, remediation efforts and may be considered in conjunction with other options to form alternatives.

4.2.6 NAPL Collection and Treatment

ERCLs require that NAPL sources must be removed to the maximum extent practicable. Source removal is also an initial step for many technologies to meet the PRAOs for groundwater and soil.

4.2.6.1 Physical Collection and Treatment

Physical methods are used to remove NAPL from the subsurface. Once above ground, the extracted liquid-phase organic compounds and groundwater are separated and treated by ex situ treatment methods or are disposed of appropriately.

Multi-Phase Extraction. Multi-phase extraction is a combination of bioventing and vacuum-enhanced free-product recovery. Multi-phase extraction typically occurs in an extraction well. A high vacuum system is applied to simultaneously remove various combinations of contaminated ground water, separate-phase petroleum product, and hydrocarbon vapor from the subsurface. Multi-phase extraction is also known as dual-phase extraction. Extracted liquids and vapor are treated and collected for disposal. Multi-phase extraction as a stand-alone option is not expected to achieve PRAOs within the source areas or associated contaminated portions of the aquifer. The technology will be considered in conjunction with other options that require treatment of soil and groundwater.

Trenches/Drains. The collection trench or drain would typically be constructed as a gravel-filled trench or drain placed below the water table that contains perforated pipe, near the NAPL groundwater interface, and is connected to a collection sump and pump. Trenches and drains are the most hydraulically efficient means for removing fluids from the aquifer and may be used to recover mobile LNAPL at shallow depths (15 to 20 bgs). Trenches are excavated perpendicular to the direction of groundwater flow, and LNAPL is allowed to pool in the trench for recovery. The trench is sometimes lined on the downgradient side to contain the LNAPL. Open trenches can be converted to drains by backfilling with permeable materials.

Sumps or wells may be installed along the trench or drain to collect LNAPL. Pump-and-treat scenarios using trenches as a stand-alone option are not expected to achieve PRAOs within the source areas or associated contaminated portions of the aquifer. The technology will be considered in conjunction with other options that require treatment of soil and groundwater.

Hydraulic Pumps. Hydraulic pumps (for example, bladder pumps such as Enviroequip's Genie) involve pumping LNAPL from wells or trenches under ambient pressure. Groundwater can simultaneously be recovered to increase the hydraulic gradient to help induce the flow of LNAPL to the well or trench. Hydraulic pumps using wells or trenches as a stand-alone option are not expected to achieve PRAOs within the source areas or associated contaminated portions of the aquifer. The technology will be considered in conjunction with other options that require treatment of soil and groundwater.

Passive and Active Skimmers. Passive and active skimmers (for example, belt skimmers, QED passive or active skimmer by Enviroequip, or Blackhawk's LNAPL recovery attachment) recover LNAPL by skimming under ambient pressure. They are often applied where LNAPL can be concentrated, such as in a trench with a LNAPL barrier. They can also be used in an extraction well. Skimmers are more effective when used where hydraulic controls have been placed on groundwater. Skimmers as a stand-alone option are not expected to achieve PRAOs within the source areas or associated contaminated portions of the aquifer, although the technology has proven effective at recovering LNAPL at the KRY Site. This collection technology will be considered in conjunction with other treatment and disposal options.

4.2.7 Groundwater Containment

Containment actions control or reduce migration of the contaminated materials into the surrounding environment. They could also be used to isolate contaminated soil and groundwater to reduce the possibility of exposure by direct contact. These actions may involve the use of physical barriers to block a contaminant migration pathway. Containment measures for contaminated groundwater typically include caps, hydraulic gradient controls, and barriers. Slow contaminant removal (as a consequence of the gradient control system) or natural attenuation may gradually achieve cleanup levels within the contained area.

4.2.7.1 Hydraulic Barriers

Pumping Wells, French Drains, or Extraction Trenches. Two types of barrier technologies are considered applicable to the KRY Site source areas: extraction wells and collection trenches to limit migration of the contaminated plume. Small-diameter (2- to 6-inch) wells are the most common method of extracting contaminated groundwater and could be used in all areas of the KRY Site. Extraction wells are typically placed vertically into the aquifer with a well screen and pump installed below the water table. Design of the extraction wells, including spacing, would be based on aquifer characteristics such as hydraulic gradient and hydraulic conductivity. Computer modeling may be used to predict the required well spacing and pumping rate, but pilot testing is recommended to further define system design parameters. Extraction wells could be designed to remove water from specific depths within the aquifer or from across the entire saturated thickness. Hydraulic containment alone would not achieve PRAOs within the source areas; however, hydraulic containment could be an integral part of a remedial approach to clean up groundwater downgradient of source areas. Hydraulic containment alone is not retained as an alternative; however, this alternative will be evaluated further as part of a groundwater extraction and cleanup alternative.

4.2.8 Groundwater Collection

Collection is used to reduce groundwater contaminant levels more rapidly than plume containment or MNA in addition to preventing further migration of the plume. An extraction system is used to remove contaminated groundwater from the affected aquifer. This step is followed by treatment, if required, and discharge or reinjection of treated water back into the aquifer. Extraction can be achieved by using pumping wells, french drains, or extraction trenches. Pumping may be continuous or pulsed to remove contaminants after time has been allowed for them to desorb from the aquifer material and equilibrate with groundwater. Aboveground treatment may involve physical and chemical processes such as air stripping, carbon adsorption, and biological treatment, depending on the physical and chemical properties of the contaminants.

4.2.8.1 Groundwater Extraction Systems

Pump-and-treat scenarios using trenches alone are not expected to achieve PRAOs within the source areas or the associated contaminated portions of the aquifer. However, trenches will be retained in conjunction with ex situ groundwater treatment options. Two types of collection technologies are considered applicable to the KRY Site source areas: extraction wells and collection trenches.

Trenches. The collection trench would typically be constructed as a gravel-filled trench placed below the water table that contains perforated pipe connected to a collection sump and pump. However, horizontal extraction could be difficult to construct at the KRY Site because of the depth of the groundwater and the thickness of the unconfined aquifer. Collection trenches may also serve as a hydraulic barrier and can be more effective than vertical extraction wells at preventing offsite migration of contamination. Aquifer testing results indicate that collection of groundwater via collection trenches and groundwater pumps would be effective for intercepting and extracting groundwater in the shallow formation. If the source of groundwater contamination is addressed and the calculated volume of groundwater to be treated is 56.6 million gallons, it is estimated it would take between 4 and 18 years to effectively treat the groundwater with this technology. In addition, the technology would provide only minimal source mass reduction (limited by source dissolution rates into groundwater) and would not be expected to achieve PRAOs in the source areas within a reasonable timeframe. Limited drawdown was observed during the aquifer testing, which would affect this technology's ability to control the contaminant plume in the lower portion of the aquifer. Furthermore, results of aquifer testing suggest that pump technology from a trench would not effectively maintain hydraulic control to prevent migration of the leading edge of a contaminant plume or prevent the future release of subsurface contamination beyond a hydraulic barrier. This technology could be used in conjunction with other technologies to prevent migration of the leading edge of the contaminant plume.

Extraction Wells. Small-diameter (2- to 6-inch) wells are the most common method of extracting contaminated groundwater and could be used in all areas of the KRY Site. Extraction wells are typically placed vertically into the aquifer with a well screen and pump installed below the water table. Design of the extraction wells, including spacing, would be based on aquifer characteristics such as hydraulic gradient and hydraulic conductivity. Computer modeling may be used to predict required well spacing and pumping rate, but pilot testing is recommended to further define system design parameters. Extraction wells could be designed to remove water from specific depths within the aquifer or from across the entire saturated thickness.

4.2.9 Ex Situ Groundwater Treatment

Ex situ treatment consists of actions that treat contaminants after removal from the subsurface. Ex situ treatment of contaminated groundwater includes methods to separate, remove, or degrade contaminants. Methods to separate or remove contaminants include carbon adsorption, other adsorption, ion exchange, precipitation, coagulation, flocculation, and membrane technologies. Methods of ex situ degradation generally include chemical and biological. Ex situ chemical oxidation involves pumping a chemical such as hydrogen peroxide, potassium permanganate, ozone, or persulfate into the previously extracted groundwater to break down the contaminants into less harmful substances such as water and carbon dioxide. Ex situ bioremediation involves adding nutrients or an oxygen source (such as air) into the previously extracted groundwater to enhance biodegradation of contaminants.

4.2.9.1 Biological Treatment

Land Treatment. Ex situ land treatment processes contaminated groundwater by spraying the groundwater over an area of soil that is landfarmed. Land treatment has been proven most successful in treating petroleum hydrocarbons and PCP. As a rule, the higher the molecular weight (for example, the more carbon rings with a PAH), the slower the degradation rate. In addition, the more chlorinated the compound, the more difficult it is to degrade. Land treatment is less effective on groundwater contaminated with metals or dioxins/furans.

Engineered Bioreactors. Biodegradation of contaminants in extracted groundwater is achieved by putting contaminants into contact with microorganisms through either attached or suspended growth biological systems. In suspended growth biological systems, such as an activated sludge system, contaminated groundwater is circulated in an aeration basin where microbial populations aerobically degrade organic matter. The degradation products may then be concentrated and further treated as sludge. In attached growth systems, such as rotating biological contractors and trickling filters, microorganisms are cultured on an inert support matrix; as groundwater is passed through the support matrix, contaminants are aerobically degraded when they contact the attached microorganisms. Full-scale bioreactors are most effective in treating semivolatile organic compounds (SVOCs), fuel hydrocarbons, and other biodegradable organic material; little information is available on the effectiveness of full-scale bioreactors for treatment of dioxins/furans. Therefore, it is considered to have limited effectiveness for dioxins/furans but is effective for the other COCs. Engineered bioreactor technology will be retained as a water treatment option, primarily for water that does not exhibit dioxin/furan contamination.

4.2.9.2 Physical/Chemical Treatment

Carbon Adsorption. Carbon adsorption is a simple and well-known technology used to remove volatile organic compounds (VOCs) and SVOCs from water. Liquid-phase carbon sorption involves pumping groundwater through a series of vessels containing granular activated carbon. Granular activated carbon adsorbs aqueous contaminants to active sites on the surface of each carbon element. As granular activated carbon active sites become saturated with contaminant, “breakthrough” begins to occur, effluent water quality decreases, and contaminant concentrations increase. When the concentrations of contaminants in the effluent from the granular activated carbon exceed a target level, the carbon may be either removed and regenerated (heat treated to remove contaminants) or disposed of and replaced with new granular activated carbon. Carbon adsorption is one of the most commonly used technologies for remediation of groundwater contaminated with PCP, petroleum, and dioxins/furans such as those found at the KRY Site. Carbon adsorption could be, and has been, effectively used to remediate groundwater to discharge limits at the KRY Site by TtEMI. However, given the current contamination levels at the KRY Site, using carbon adsorption as a stand alone technology is not recommended because of the massive quantities of carbon that would be required. It is possible that carbon could be used to meet discharge limits as a final treatment to "polish" remnant contaminants.

Other Adsorption. Other forms of adsorption are available and include activated alumina, forage sponge, lignin adsorption, sorption clays, and synthetic resins. Other forms of adsorption involve pumping groundwater through a series of vessels that contain the material that adsorbs the contaminants. The material may be either removed and regenerated or disposed of and replaced with new material, depending on the specific material, when the concentrations of contaminants in the effluent from the adsorbed material exceed a target level. Given the current contamination levels at the KRY Site, using adsorption as a stand-alone technology is not recommended because of the massive quantities of material that would be required. However, it is anticipated that carbon adsorption would likely be more effective than most other adsorption methods used to polish the groundwater to discharge limits, and therefore other adsorption media will not be retained as a water treatment option.

Chemical Oxidation, Ozonation, UV Oxidation. Addition of oxidants generates free radicals that chemically convert hazardous organic contaminants to nonhazardous or less toxic compounds. UV irradiation also generates free radicals that destroy organic contaminants and can be used to enhance chemical oxidation. A wide variety of organic contaminants are susceptible to destruction by chemical and UV oxidation, including petroleum hydrocarbons and chlorinated SVOCs such as PCP. Chemical and UV oxidation will not be retained as an ex-situ water treatment option because other technologies provide equal or greater effectiveness at lower cost. Ozonation will be retained for use as an ex situ groundwater treatment method, as it has been shown to be successful at this site by both TtEMI and BNSF.

Ion Exchange. Ion exchange removes ions from the aqueous phase by the exchange of cations or anions between the contaminants and the exchange medium. Ion exchange materials may consist of resins made from materials that contain ionic functional groups that attach to exchangeable ions. Resins can be regenerated for re-use after the capacity of the resin has been exhausted. By itself, ion exchange is not expected to be an effective stand-alone treatment technology at the site because LNAPL in the groundwater may clog the exchange resin. In addition, oxidants in groundwater may damage the ion exchange resin. However, ion exchange can be used as an effective polishing technology for additional removal of metals in the groundwater.

Precipitation, Coagulation, and Flocculation. Precipitation has been a primary method for treating metals in industrial wastewater and has also been proven successful in treating groundwater that contains metals. In groundwater treatment applications, the metal precipitation process is often used as a pretreatment for other treatment technologies (such as chemical oxidation or air stripping) where the presence of metals would interfere with the other treatment processes. In the precipitation process, coagulation and flocculation are used to increase particle size through aggregation and, therefore, the efficiency of the process. After the coagulants have increased particle size, flocculation is used to promote contact between the particles. Precipitation, coagulation, and flocculation will be retained as a potential pretreatment option for removal of metals in groundwater.

Membrane Technologies. Membrane technologies can include reverse osmosis, electrodialysis, or pervaporation. Reverse osmosis is the process of pushing a solution through a filter that traps solute on one side and allows the solvent to pass through to the other side. This process is best known for its use in desalination. Electrodialysis is a physical method for removing ionic contaminants. Contaminated water is exposed to an electric current as it passes through a semi-permeable membrane. This action separates the contaminant ions from groundwater and surface water. Pervaporation is a new membrane process to remove and concentrate VOCs from contaminated water. Two different membrane configurations have been tested using hollow fibers. Pervaporation was described by a resistance-in-series model: a liquid film resistance, and a membrane resistance. Membrane technologies will be retained as a potential pretreatment option for removal of metals in groundwater.

4.2.10 Groundwater Discharge

When any ex situ treatment option is complete, the treated water may be disposed of through land application, direct discharge to surface water, reinjection to the aquifer, or offsite disposal. No sanitary or storm sewer system is present at the site.

4.2.10.1 Discharge of Treated or Untreated Groundwater

Land Application. Land application could be used on untreated groundwater in combination with landfarming any groundwater that is free from metals or dioxins/furans. Groundwater treated to levels that comply with groundwater quality standards that are included as ERCLs could be applied directly to the ground at the KRY Site. This application can increase the hydraulic gradient in the aquifer and therefore the effectiveness of downgradient extraction wells or collection trenches. The application can also increase biodegradation of contaminants by increasing dissolved oxygen levels in the aquifer. These enhancements are less beneficial than would be provided by the injection wells or trenches approach.

Land application will be retained in conjunction with extraction and treatment options. The location for the application will be based on the design of the remediation system, the concentration of contamination, and the exact contaminants.

Injection Wells or Trenches. Reinjection of treated water into the aquifer will also require that the water be treated to levels that comply with groundwater quality standards that are included as ERCLs. Reinjection can increase the hydraulic gradient in the aquifer and therefore the effectiveness of downgradient extraction wells or collection trenches. Reinjection can also increase biodegradation of contaminants by increasing dissolved oxygen levels in the aquifer. Reinjection to the aquifer will be retained in conjunction with extraction and treatment options.

Discharge to Surface Water. Discharge to surface waters will require the water to meet surface water quality standards that are included as ERCLs. Discharge to surface water will be retained in conjunction with extraction and treatment options.

Disposal Offsite. Discharge of treated groundwater to offsite disposal facilities is considered an effective means of disposal. The discharge option selected will depend on the specific design and hydraulic balance of the remediation system, the water quality standards, and whether the system is being used in conjunction with other remedial technologies. Disposal offsite will be retained in conjunction with extraction and treatment options. Selection of the proper disposal location or facility will be based on the design and success of the remediation system.

4.2.11 In Situ Groundwater Treatment

In situ treatment consists of actions that treat contaminants in place. In situ treatment of contaminated soil or groundwater generally includes methods to separate and breakdown contaminants or to degrade contaminants in place. In situ treatment methods to separate and breakdown contaminants include both aerobic and anaerobic enhanced bioremediation and in situ chemical oxidation. In situ degradation generally involves adding agents to the subsurface (via wells or treatment walls) that facilitate chemical or biological destruction. The types of in situ degradation most frequently used at hazardous waste sites include various types of in situ biological treatment and permeable treatment walls or gates. In situ groundwater bioremediation involves pumping nutrients or an oxygen source (such as air) into the aquifer to enhance biodegradation of contaminants in the groundwater. Contaminants can also be degraded in place using in situ oxidation. This technology involves pumping a chemical such as hydrogen peroxide, potassium permanganate, or ozone into the subsurface to break down the organic contaminants into compounds such as water and carbon dioxide.

4.2.11.1 Biological Treatment

Enhanced Bioremediation (Aerobic). Biodegradation of SVOCs and petroleum hydrocarbons in groundwater, such as PCP and petroleum products, may be accomplished in a highly aerobic environment. Aerobic biodegradation can be promoted by the addition of oxygen into a contaminated area to provide an electron acceptor to the existing in situ population of dechlorinating microorganisms (called chlororespirators). In addition, organic carbon may be introduced into the contaminated area to provide a growth substrate to culture and enhance the population of chlororespirators. The microbes then use in situ oxygen or injected oxygen enhancements to aerobically degrade the contaminants.

The rate of aerobic biodegradation of petroleum hydrocarbons is reduced when the concentration of oxygen in the subsurface is limited. Oxygen-enhanced aerobic bioremediation entails the addition of oxygen to the groundwater to facilitate more rapid biological degradation of contaminants. Oxygen enhancement can be accomplished by several methods, including air sparging or the addition of an electron acceptor such as hydrogen peroxide or Regenesis Oxygen Release Compound (ORC). In general, ORC is expected to reduce the PCP and petroleum contaminants to meet PRAOs; however, the time needed to achieve PRAOs varies based on contaminant concentrations and hydrogeologic conditions. ORC’s effectiveness on dioxins/furans is presumably less and is uncertain. The use of hydrogen peroxide for oxygen enhancement is limited for in situ groundwater treatment. Lower concentrations must be maintained because concentrations of hydrogen peroxide greater than 200 ppm in groundwater inhibit the growth of microorganisms. The achievable degradation rate and the effectiveness of the treatment are limited at these lower concentrations. Pilot testing at the KRY Site would help define reaction rates and influence areas of ORC or hydrogen peroxide in situ.

Groundwater monitoring at the KRY Site has shown that petroleum hydrocarbons and, to a lesser extent, PCP, are being broken down by existing microorganisms. Thus, oxygen enhancement at the KRY Site may be appropriate for use in combination with other source removal options and will be retained for further consideration.

Enhanced Bioremediation (Anaerobic). Under anaerobic conditions, certain bacteria are able to gain energy for growth by reducing chlorinated VOCs and SVOCs. During this process, the chlorinated organic compounds are used as an electron acceptor, and a chlorine atom is removed and replaced with a hydrogen atom. Further reduction is more effectively accomplished under aerobic conditions. An appropriate electron donor must be present because chlorinated compounds are used as electron acceptors during reductive dechlorination. The electron donor used by most reductive dechlorinating microbes is molecular hydrogen, which may be produced by fermentation of a variety of organic substrates. Potential sources of molecular hydrogen include natural organic matter, fuel hydrocarbons, or organic substrates. Organic carbon sources that have been added to stimulate dechlorination include lactate, butyrate, acetate, molasses, refined sugars (fructose), Regenesis Hydrogen Release Compound (HRC), edible oils, and plant mulch. The addition of carbon into the contaminated area also provides a substrate to promote and enhance the existing culture of chlororespirator microorganisms. Neither lactate nor HRC generates vapor emissions that would need to be collected and treated. The effectiveness of both lactate and HRC can be limited by the presence of clay lenses in the aquifer, as a layer of clay will slow movement of the injected material through the contaminant mass in the saturated area. In general, injection of lactate or HRC is expected to reduce the contaminants; however, the time needed to achieve PRAOs varies based on contaminant concentrations and hydrogeologic conditions. Pilot testing at the KRY Site will help define reaction rates and influence areas of lactate and HRC addition in situ. Anaerobic enhancement using lactate or HRC may be used as part of a phased approach for in situ remediation of the chlorinated SVOCs.

4.2.11.2 Physical/Chemical Treatment

In Situ Chemical Oxidation. In situ chemical oxidation involves injection of a chemical oxidant such as ozone, hydrogen peroxide, potassium permanganate, or sodium permanganate into the groundwater to treat both contaminated groundwater and soil. BNSF is currently using ozonation to treat groundwater at the KRY Site. This application appears to have been successful in reducing PCP concentrations in groundwater in the immediate vicinity of the ozone injection wells (ERM 2007). However, the long-term success of this application in treating PCP in groundwater without a separate technology to treat PCP in soil and residual free-product was not demonstrated. This technology may be considered for the organic contaminant plumes at the KRY Site in conjunction with source removal options.

4.2.12 Soil Containment

Containment actions control or reduce migration of the contaminated materials into the surrounding environment. They could also be used to isolate contaminated soil to reduce the possibility of exposure by direct contact. These actions may involve physical barriers to block a contaminant migration pathway. Containment measures for contaminated soil typically include vertical and horizontal barriers. Slow contaminant removal or natural attenuation may gradually achieve cleanup levels within the contained area.

4.2.12.1 Physical Barriers

Horizontal Barrier. Capping could be used for the KRY Site to reduce precipitation infiltration through contaminated soil and potentially to prevent recharge to groundwater in source areas. An impermeable cap over contaminated soil areas could be constructed of clay, asphalt, concrete, or by using synthetic liners such as polyvinyl chloride or polyethylene. The areas above contaminated soil at the KRY Site may include some building foundations. However, the integrity of these foundations is unknown. Containment with physical barriers alone would not achieve PRAOs within the source areas. However, horizontal barriers or caps are retained because they may be used in conjunction with other technologies.

4.2.13 Soil Removal and Transport

This action involves complete or partial removal of source material followed by transportation, treatment, and disposal. Source materials would be excavated using conventional earth-moving equipment such as front-end loaders and hydraulic excavators. Shoring, sheet piling, or other specialized techniques may be necessary to excavate near buildings or other structures. Excavation below groundwater or to depths below the reach of conventional excavators (approximately 15 feet) may require specialized equipment. Containment and treatment of water encountered during excavation may be necessary. Dust suppression during excavation may also be necessary. Removed source material would be transported to onsite or offsite treatment facilities or disposal sites in trucks or railcars. Factors that can affect the costs and feasibility of truck hauling include but are not limited to haul distances, required road construction, and type and volume of materials.

4.2.13.1 Excavation

Excavation. Source materials could be excavated in the vadose zone or the upper portions of the saturated zone using conventional earth-moving equipment such as hydraulic excavators, backhoes, and front-end loaders. Containment and treatment of water encountered during excavation at or beneath the water table may be necessary. Removed source material would be transported to a treatment area or disposal site in trucks or rail cars. Factors that can affect the costs and feasibility of truck hauling and rail cars include haul distances, the volume of materials, and container requirements. Excavation and transportation of contaminated soil is a common and effective alternative and will be retained in conjunction with soil treatment and disposal options.

4.2.14 Ex Situ Soil Treatment

Ex situ treatment consists of actions that treat contaminants after they have been removed from the subsurface. Ex situ treatment of contaminated soil includes methods to stabilize, separate and remove, or degrade contaminants. Ex situ treatment methods to stabilize contaminants include solidification or stabilization. Solidification refers to a process that binds the polluted soil or sludge and cements it into a solid block. Stabilization refers to changing the contaminants so they become less harmful or less mobile. Methods to separate and remove contaminants include soil washing, thermal treatment, and mechanical aeration. Soil washing involves introduction of water, chemical surfactants, or cosolvents into the soil to strip or dissolve contaminants and then remove them. Thermal treatment mobilizes contaminants in the soil through heating, and then removes the contaminants by vapor extraction. Mechanical aeration involves injecting air or oxygen into the soil while mixing to strip volatile contaminants. Stripped or volatilized contaminants are either discharged directly to the atmosphere or are further treated.

Methods of ex situ degradation generally include thermal, physical/chemical, and biological. Thermal destruction (incineration) is similar to thermal treatment, but at temperatures high enough to break down chemicals into elemental constituents. Ex situ chemical degradation, or chemical oxidation, involves pumping a chemical such as hydrogen peroxide, potassium permanganate, or ozone into the soil to break down the contaminants into less harmful substances such as water and carbon dioxide. Ex situ bioremediation involves adding nutrients or an oxygen source (such as air) into the soil to enhance biodegradation of contaminants. Ex situ bioremediation includes biopiles.

4.2.14.1 Biological Treatment

Landfarming. Landfarming is a bioremediation technology that mixes contaminated soil with soil amendments such as soil bulking agents and nutrients, and that is then periodically tilled for aeration. Contaminants are degraded, transformed, and immobilized by microbiological processes and by oxidation. Contaminated soil may be applied over and tilled into uncontaminated soil or held within a lined land treatment unit with the ability to collect and store leachate. An irrigation system is used to control moisture and to add nutrients. Collected leachate can be reapplied to the land farm or treated separately and disposed of. Soil conditions that typically control the rate of contaminant degradation include moisture content, aeration, pH, nutrients, and soil amendments. In addition, tilling and exposure to atmospheric air allow VOCs and to some extent SVOCs to volatilize. Land farms usually require greater treatment areas than composting since the treatment thickness is limited by tilling depth. Treated soil could be backfilled into excavation areas or used as common fill. Ex situ landfarming of contaminated soil is retained as a treatment technology because it has been shown to be effective in treating PCP- and petroleum-contaminated soil at similar sites in Montana. However, landfarming is less effective at treating dioxins/furans or metals.

Biopiles. Biopiles is a process that degrades organic wastes by microorganisms at elevated temperatures under either aerobic or anaerobic conditions. Soil is excavated and mixed with bulking agents and organic amendments, such as wood chips and plant wastes that enhance porosity. Maintaining proper oxygen and moisture content and closely monitoring the temperature help achieve maximum degradation efficiency. Typical compost temperatures range from 54° to 65° Celsius. The increased temperatures result from heat produced by microorganisms during degradation of the organic material in the waste. Biopiles produce a byproduct that is stable and in some circumstances results in complete degradation of the contaminant. Biopiles may generate leachate waste streams, which may require additional treatment. Treated soil could be backfilled into excavation areas or used as common fill.

Biopiles are designed as an aerobic static pile. Compost is formed into piles that may be enclosed, such as with a geomembrane liner. The biopile is aerated with blowers or vacuum pumps, and an installed irrigation system provides a means for controlling nutrients and moisture. Soil piles can be up to 20 feet high. Biopiles will be retained because of their use in treating PCP and petroleum-contaminated soil at similar sites in Montana. However, it should be noted that landfarming has proven to be more effective than biopiles in treating PCP contamination at some of these sites.

4.2.14.2 Physical/Chemical Treatment

Solidification/Stabilization. Solidification generally refers to processes that encapsulate the waste in a solid of high structural integrity and helps physically bind the waste into an unyielding structure. Stabilization generally refers to processes that reduce risk posed by the waste by converting the contaminants into a less soluble, immobile, less-toxic form. Most of the processes used in the application of solidification and stabilization are directed at encapsulating or immobilizing the hazardous constituents and include mixing. Solidification is generally used for inorganic contaminants; however, applications such as in situ vitrification can destroy or remove most organic contaminants (including dioxins/furans). Ex situ solidification/stabilization will be retained for use at the KRY Site. Although in situ vitrification would be applicable to more of the COCs, this technology is generally considered costly, and actual field scale operations have been limited.

Soil Washing. Soil washing consists of separating contaminated material that has sorbed onto soil particles, using an aqueous process that flushes the soil with water to remove contaminants. The wash water can be supplemented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals. Most organic and inorganic contaminants tend to bind and sorb to clay, silt, and organic soil particles that are stuck to larger particles such as sand and gravel. Washing separates the small particles from the large particles by breaking the adhesive bonds. The separated material is smaller in volume and is more easily disposed of or treated further. Treated soil could be backfilled into excavation areas or used as common fill. Ex situ soil washing will not be retained based on the difficulty of implementation, uncertainty in meeting PRAOs, and potential excessive cost. Other treatment options provide greater demonstrated effectiveness.

Separation. Separation physically removes contaminated concentrates from soils to leave relatively uncontaminated “treated” fractions. This process is usually conducted in conjunction with another technology. Separation is generally used as a pre-treatment method for other technologies and is generally not effective as a stand-alone technology. Physical separation of contaminants would likely be only moderately effective because of the large number of COCs at the KRY Site. In addition, separation is not expected to be effective as a pre-treatment technology because of the diverse number of COCs at this site. Therefore, separation is not considered a viable option for the KRY Site.

4.2.14.3 Thermal Treatment

Thermal Desorption. Ex situ thermal desorption is a physical separation process that heats contaminants to volatilize water and organic contaminants, either on or offsite. Vapors are then removed from the system using a carrier gas or through pressure venting, treated if necessary, and off-gassed to the atmosphere. Petroleum hydrocarbons and most SVOCs (including PCP) at the KRY Site would be expected to be effectively treated using thermal desorption. However, metal and dioxin/furan contamination at the KRY Site would not be effectively treated using thermal desorption, so application of thermal desorption should be limited to soils where dioxins/furans and metals concentrations are below the PRAOs. Excavated soil would be processed through the thermal desorption unit and treated until the PRAOs for PCP and other petroleum hydrocarbons were achieved. Treated soil could be backfilled into excavation areas or used as common fill. Thermal desorption will be retained in conjunction with excavation, transportation, and disposal options.

Incineration/Thermal Destruction. Ex situ incineration is similar to thermal desorption but involves use of a combustion chamber or kiln operating at temperatures of 1,600 to 2,200 ^{o}F to destroy organic constituents in contaminated materials. Excavated soil would be processed through the incinerator and treated to meet PRAOs. Off gases and combustion residuals may require additional treatment. If treated onsite, soil could be backfilled into excavation areas or used as common fill. Incineration is a highly effective process in removing or destroying SVOCs, petroleum hydrocarbons, and dioxins/furans in soil. Incineration will not be considered as a stand-alone treatment method for all the contaminated soil at the site because of the costs; however, offsite incineration will be retained for use on dioxin/furan- and potentially PCP-contaminated soil.

4.2.15 Soil Disposal

Offsite disposal involves placing excavated contaminated material in an engineered, licensed containment facility located outside the boundary of the KRY Site. Nonhazardous wastes could possibly be disposed of in an offsite permitted solid waste landfill. Materials that are deemed hazardous waste would require disposal in a Resource Conservation and Recovery Act (RCRA)-permitted treatment, storage, and disposal facility. These facilities are also known as RCRA Subtitle C facilities.

Onsite disposal options could be applied to treated or untreated contaminated materials. The design configuration of an onsite repository would depend on the toxicity and type of material that requires disposal. The design could range in complexity from an earthen cap, to an earthen cap with a geomembrane liner, a modified RCRA Subtitle C repository, or a RCRA Subtitle C repository.

4.2.15.1 Offsite Disposal

Solid Waste Landfill. Offsite disposal options for contaminated soil from the KRY Site include a solid waste landfill (for nonhazardous wastes) and a hazardous waste landfill. Offsite disposal involves holding excavated contaminated material in an engineered, licensed containment facility located outside the boundary of the KRY Site. Nonhazardous wastes could possibly be disposed of in an offsite permitted solid waste landfill in compliance with applicable laws. It is expected that some materials incidental to remedial actions will be disposed of in this manner. Disposal at a solid waste landfill will be retained for nonhazardous materials.

Hazardous Waste Landfill. Materials that are deemed hazardous waste would require disposal in a RCRA-permitted treatment, storage, and disposal RCRA Subtitle C facility. Excavation and disposal at an offsite RCRA hazardous waste landfill is considered very costly because of the high costs for transportation and disposal. The closest RCRA hazardous waste landfill locations are in Idaho, Oregon, and Utah. The closest facility that accepts PCP contaminated hazardous waste is located in Utah.

Because of the RCRA land disposal restrictions, offsite disposal of PCP- and dioxin/furan-contaminated soil at a hazardous waste landfill will be retained as an alternative; however, treatment alternatives that involve excavation, treatment, or disposal of the soil may be more economically applied only to certain portions of the site, such as highly contaminated areas.

Reclamation/Recycling. Petroleum-contaminated soil could be recycled by incorporating the soil in asphalt. Assurances would need to be made that the contaminated soil meets acceptance criteria for the asphalt facility. One facility has been identified that would accept the wastes; however, this facility currently requires the burden of cost for any potential problems with the waste to be carried by the generator. Reclamation and recycling will not be retained as a stand-alone alternative, but may be used in conjunction with other options to form alternatives.

4.2.15.2 Onsite Disposal

Backfill Excavations. Soil that has been treated to meet the PRAOs may be backfilled into an excavation area or used as common fill. Soil treated to PRAOs will no longer pose unacceptable risks to human health or the environment. Additionally, onsite backfill of soils treated to remove PCP below PRAOs, but still containing dioxins/furans at concentrations above the PRAO, may be necessary due to the limited number of treatment options available for dioxin/furan-contaminated soil.

Some treatment options may alter the geotechnical properties of the soil, making it unacceptable for some structural applications. Geotechnical testing may be necessary before treated soil is backfilled for certain uses. Backfill of excavations will be retained as an alternative technology for treated soil. Onsite disposal of untreated soil will not be retained as a stand-alone alternative, however, since other, more effective and permanent, soil treatment options can meet PRAOs at similar costs.

4.2.16 In Situ Soil Treatment

In situ treatment consists of actions that treat contaminants in place. In situ treatment of contaminated soil generally includes methods to separate and remove contaminants or to degrade contaminants in place. In situ treatment methods to separate and remove contaminants include soil flushing, in situ thermal treatment, and bioventing. In situ thermal treatment methods are ways to mobilize contaminants in the subsurface through heating, and then removing the contaminants by vapor extraction.

Methods of in situ degradation generally involve adding agents to the subsurface (via wells or treatment walls) that facilitate chemical or biological destruction. In situ bioremediation involves pumping nutrients or an oxygen source (such as air) into the aquifer to enhance biodegradation of contaminants in the groundwater and soil. Contaminants can also be degraded in place using in situ chemical oxidation. This technology involves pumping a chemical such as hydrogen peroxide, potassium permanganate, ozone, or persulfate into the subsurface to break down the organic contaminants into compounds such as water and carbon dioxide.

4.2.16.1 Biological Treatment

Enhanced Bioremediation (Aerobic). Biodegradation of SVOCs and petroleum hydrocarbons in soil, such as PCP and petroleum products, may be accomplished in a highly aerobic environment. Aerobic biodegradation can be promoted by the addition of oxygen into a contaminated area to provide an electron acceptor to the existing in situ population of dechlorinating microorganisms (called chlororespirators). This process is similar to aerobic bioremediation in groundwater, as discussed in Section 4.2.11.1. Oxygen enhancement alone is not considered appropriate for the KRY Site because of the presence of NAPL. However, oxygen enhancement may be appropriate to enhance degradation of the SVOCs and PCP if the NAPL source is removed.

Enhanced Bioremediation (Anaerobic). Under anaerobic conditions, certain bacteria are able to gain energy for growth by reducing chlorinated VOCs and SVOCs. During this process, the chlorinated organic compounds are used as an electron acceptor, and a chlorine atom is removed and replaced with a hydrogen atom. Anaerobic bioremediation alone is not considered appropriate for the contamination at the KRY Site because existing anaerobic areas do not show a significant reduction in contaminant concentrations. Anaerobic bioremediation may be appropriate for use in combination with other in situ options for the contamination present at the KRY Site and will be retained for further consideration.

4.2.16.2 Physical/Chemical Treatment

Bioventing. Bioventing is a promising new technology that stimulates the natural in situ biodegradation of any aerobically degradable compounds in soil by providing oxygen to existing soil microorganisms. In contrast to soil vapor vacuum extraction, bioventing uses low air flow rates to provide only enough oxygen to sustain microbial activity. Oxygen is most commonly supplied through direct injection of air into residual contamination in soil. In addition to degradation of adsorbed fuel residuals, volatile compounds are biodegraded as vapors move slowly through biologically active soil. Bioventing will not be retained as a treatment option because enhanced aerobic bioremediation provides greater effectiveness at lower cost.

In Situ Chemical Oxidation. In situ chemical oxidation involves the injection of a chemical oxidant such as ozone, hydrogen peroxide, potassium permanganate, or sodium permanganate into the subsurface to treat both contaminated groundwater and soil. BNSF is currently using ozonation to treat groundwater at the KRY Site. This application appears to have been successful in reducing PCP concentrations in groundwater in the immediate vicinity of the ozone injection wells (ERM 2007). However, the long-term success of this application in treating PCP in groundwater without a separate technology to treat PCP in soil and residual free-product was not demonstrated. As a result, this technology may be considered in conjunction with source removal options.

Solidification/Stabilization. Solidification generally refers to processes that encapsulate the waste in a solid of high structural integrity, and helps physically bind the waste into an unyielding structure. Stabilization generally refers to processes that reduce risk posed by the waste by converting the contaminants into a less soluble, immobile, less-toxic form. Most of the processes used in the application of solidification and stabilization are directed at encapsulating or immobilizing the hazardous constituents and include mixing. Solidification is generally used for inorganic contaminants; however, applications such as in situ vitrification can destroy or remove most organic contaminants (including dioxins/furans). Implementation of in situ solidification/stabilization could be complicated due to the following factors: 1) potential mixing difficulties associated with the variable lithologies; 2) difficulties associated with determining extent of contamination in subsurface soils; 3) presence of multiple COCs in potential areas of application; and 4) difficulties associated with sampling and testing of solidified/stabilized material. Therefore, in situ solidification/stabilization will not be further retained.

In Situ Thermal Desorption. In situ thermal treatment methods include steam injection, electrical resistance heating, and radiofrequency heating of the subsurface. Thermal treatment is typically used in saturated zone areas where high concentrations of NAPL-contaminated soil or mobile NAPL are present. High concentrations of NAPL-contaminated soil are present on both the western and eastern portions of the KRY Site. The increased temperatures help to volatilize VOCs and SVOCs and enhance in situ oxidation. Vaporized contaminants rise to the unsaturated zone and are collected in soil vapor extraction system, then treated for release to the atmosphere. Thermal treatments are effective in removing oily waste accumulations and in retarding downward and lateral migration of organic contaminants. It is most effectively applied to sites with soil containing light to dense NAPLs, including SVOCs and petroleum hydrocarbons. Mobile and recoverable NAPL has been found at the KRY Site. However, excavation and ex situ treatment or other NAPL extraction technologies can be applied with similar or greater effectiveness and lower cost; therefore, in situ thermal treatments were eliminated from further consideration.

5.0 DETAILED DESCRIPTION OF RETAINED TECHNOLOGY OPTIONS

Retained technologies and process options are further developed in this section. In addition, representative technologies for each process option are identified in this section after a site-specific analysis of the alternatives. The identification of these representative technologies in no way limits the final selection of treatment options for the KRY Site (to be completed in the ROD). Any and all technologies retained from Section 4.0 are considered viable for the KRY Site and can be combined and included in the final cleanup.

5.1 RETAINED REMEDIAL TECHNOLOGY OPTIONS

Based on the results from the technology and process option screening in the IASD and Section 4, this section provides rationale for selecting specific technologies and alternatives that best represent the process options and are considered the most likely technologies for achieving PRAOs at the KRY Site. Technology options that are expected to be included in all alternatives (except No Further Action) were grouped as common elements. Final configuration of the remedial alternatives will be established during the proposed plan and ROD, as well as in the remedial design.

5.1.1 Site-Wide Elements

All remedial alternatives, except No Further Action, have site-wide elements. These site-wide elements are described here and are not repeated in the detailed descriptions of alternatives (Section 6.0). These elements include institutional controls, engineering controls, and long-term monitoring. The following assumptions are provided for the common elements. Costs associated with these common elements are provided in Appendix F and assumptions are provided in Table 5-1. The total present worth value for the site-wide elements is $4,981,017.

1. **Institutional controls**. Section 4.2.2 details the examples given below of possible institutional controls that may be established for the KRY Site. Specific institutional controls necessary at the KRY Site will be identified when the final remedy has been selected.
    a. **Land Use Controls**. Land use controls could include zoning or rezoning the property or requiring the placement of restrictive covenants on deed records.
    b. **Groundwater Use Restrictions**. It is assumed that a controlled groundwater area will be established for the KRY Site. In addition, restrictive covenants may be used to restrict groundwater use, if necessary.

2. **Engineering Controls**. Actual engineering controls necessary for the KRY Site will be identified during selection and implementation of the final remedy for the KRY Site. Therefore, the site-wide elements cost estimate in the FS does not include costs for engineering controls.

3. **Long-term monitoring**. The long-term monitoring program for the KRY Site will include sampling of any of the existing monitoring well network that now includes 114 wells, or any additional wells that may be installed during remedial design. Monitoring may also include some or all of the existing nearby residential, commercial/industrial, or public water supply wells to ensure that nearby wells do not become contaminated above drinking water standards. In addition, up to five surface water stations may be sampled. At a minimum, monitoring is assumed to be conducted on a semi-annual basis during high and low groundwater elevations for the first five years and at a reduced frequency thereafter, until cleanup levels are achieved. For cost estimation purposes in the FS, DEQ assumed 50 years for the extent of the long-term sampling.

5.1.2 No Further Action

No Further Action indicates that no remedial action will be conducted on the KRY Site. The No Further Action option provides a baseline for comparing other options and alternatives. This option entails no future activities to contain or remediate contaminants at a site, provides no treatment for contaminants, and provides no legal or administrative protection of human health. This option assumes that physical conditions at the KRY Site remain unchanged. The No Further Action option is not effective in remediating the contaminated soil and groundwater and in meeting the PRAOs for protection of human health and the environment. However, DEQ procedures require that “no action” be included among the general response actions evaluated in the FS.

5.1.3 LNAPL Technologies

Section 5.3 describes the selected LNAPL remediation alternatives, the reasons they are considered at the KRY Site, and their applications at the KRY Site. Two options have been considered as representative of the various LNAPL remediation technologies that could address LNAPL at and downgradient of the identified source areas. The selection of these representative options in no way limits the final selection of technologies. Any and all process options retained in Section 4.0 will be considered in any final determination for cleanup and in preparation of the ROD. These two are simply viewed as representative for the LNAPL technologies considered for the detailed analysis. The LNAPL treatment technologies that are to be discussed in detail are:

- Multi-phase Extraction and Disposal; and
- LNAPL Extraction and Disposal.

5.1.4 Groundwater Technologies

Section 5.4 describes selected groundwater remediation alternatives, the reasons they are considered for the KRY Site, and their application at the KRY Site. Three options have been considered as representative of the various technologies that could address remediation of groundwater at and downgradient of the identified source areas. The selection of these options in no way limits the final selection of technologies. Any and all process options retained in Section 4.0 will be considered when making any final determination for cleanup and in preparation of the ROD. These three are simply viewed as representative for the groundwater technologies considered for use in the detailed analysis. The groundwater treatment technologies that are to be discussed in detail are:

- Extraction, Ex Situ Treatment, and Discharge;
- In Situ Bioremediation; and
- In Situ Chemical Treatment.

5.1.5 Soil Options

Section 5.5 describes the selected soil remediation technologies, the reasons they are selected for the KRY Site, and their application at the KRY Site. Four options have been considered as representative of the various technologies that could address remediation of soil at and downgradient of the identified source areas. The selection of these options in no way limits the final selection of technologies. Any and all process options retained in Section 4.0 will be considered when making any final determination for cleanup and in preparation of the ROD. These four are simply viewed as representative for the soil technologies considered for use in the detailed analysis. The soil treatment technologies that are to be discussed in detail are:

- Excavation and Offsite Disposal;
- Excavation, Onsite or Ex Situ Treatment, and Backfill;
- In Situ Bioremediation; and
- In Situ Chemical Treatment.

5.1.6 Monitored Natural Attenuation

MNA refers to the use of natural processes to breakdown contamination and thereby achieve site-specific remedial objectives once contaminant sources are removed and/or controlled. Under favorable conditions, the natural attenuation processes, in association with source control or removal, act without human intervention to reduce mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in situ processes include biodegradation, which takes place when naturally occurring microorganisms consume or otherwise degrade contaminants either in the presence or absence of oxygen. Natural attenuation also includes dispersion; dilution; sorption; volatilization; and the chemical or biological stabilization, transformation, or destruction of contaminants. Depending on the contaminant, natural attenuation may ultimately transform the contaminants into harmless byproducts.

Natural attenuation modeling was performed during the FS to aid in evaluation of remedial alternatives. This modeling indicates that MNA alone will not achieve cleanup objectives within a reasonable timeframe at the KRY Site, partially because MNA is not effective at remediating free-product. The modeling results also demonstrate that the free-product represents a potential long-term source of groundwater contamination, and indicate that highly effective free-product remediation is required to achieve groundwater quality targets in a reasonable timeframe. The modeling indicates that incomplete free-product remediation may still result in an extended time period necessary for Montana’s water quality standards to be achieved. Therefore, MNA may be used as a follow-up to other, more aggressive, remediation efforts and may be considered in conjunction with other options to form alternatives.

5.2 NO FURTHER ACTION

No Further Action is retained per DEQ procedures to provide a baseline for comparing other options and alternatives.

5.3 LNAPL OPTIONS

This section presents the LNAPL remedial options for the KRY Site source areas.

5.3.1 Multi-phase Extraction and Disposal

Although this general class of technologies is broadly referred to as multi-phase extraction or dual-phase extraction, significant variations in the technology exist. For example, even though the adjective “high-vacuum” is sometimes used to describe dual-phase extraction technologies, not all dual-phase extraction systems use a high vacuum. Dual-phase extraction technologies can be divided into two general categories:

1. LNAPL, groundwater, and soil vapor are extracted together as a high-velocity, dual-phase stream using a single pump or serious of pumps, or

2. LNAPL, groundwater, and soil vapor are extracted separately using two or more pumps.

This discussion will focus on multi-phase extraction using vacuum enhancement because the extraction of LNAPL using a separate pump is described in Section 5.3.2, and the extraction of groundwater is discussed in Section 5.4.1. Therefore, multi-phase extraction is generally a combination of bioventing and vacuum-enhanced free-product recovery. A high-vacuum system is applied to simultaneously remove various combinations of contaminated groundwater, separate-phase petroleum product, and hydrocarbon vapor from the subsurface. When they are extracted, groundwater, LNAPL, and vapor would be separated and treated above ground. Separated LNAPL would be disposed of offsite in the appropriate disposal facility based upon classification and contaminants present. Separated groundwater and vapor would either be treated and then disposed of, or disposed of as contaminated material. As shown on Figure 3-7, there is a large area of LNAPL identified where multi-phase extraction could be applied. A typical multi-phase extraction system would include a series of vacuum extraction wells screened in the zone of contaminated soils and groundwater. The well is designed to remove contaminants from above and below the water table. The system lowers the water table around the well, exposing more of the formation. Contaminants in the newly exposed vadose zone are then accessible to vapor extraction. Once above ground, the extracted vapors or liquid-phase organic contaminants and groundwater are separated and treated (EPA 2004a).

As shown on Figure 3-7 and Figure 2-4, the LNAPL is located in an area of sandy gravel and gravelly sand. The LNAPL in this area is generally located at approximately 20 feet bgs, with a maximum thickness of 3.12 feet observed in January 2007 (Table 3-3). Well KPT-3 had an observed maximum fluctuation in LNAPL depth from 16.88 to 18.59 (1.7 feet) during the July through September 2006 water level measuring events (Table 2-2A). The actual configuration of an extraction well would need to be selected when the final treatment configuration is decided; data such as are described above would be used to design the extraction wells. However, the detailed evaluation made certain assumptions for a multi-phase extraction system, which are described in Table 5-1. A cost estimate is provided in Appendix F.

The majority of the LNAPL plume is located in the area of sandy gravel and gravelly sand; however, a portion of the LNAPL plume is located in a clay lens that extends from wells KRY136A to KRY137A. This clay lens may account for the higher elevation of LNAPL that has been consistently observed in well KRY135A at a maximum LNAPL thickness of 3.12 feet (Table 3-3(A-B)). Additional pumping of the groundwater may be required in the area with sandy gravel and gravelly sands. Aquifer testing at the KRY Site indicates that it may be difficult to achieve an optimal drawdown in the sandy gravel and gravelly sand lens. Although aquifer testing was not completed on any of the wells located within the main plume area, wells KRY108A and KRY113B were tested, where the water table interface is located in the same sandy gravel and gravelly sand lens. A pilot study would be required to identify specific parameters for a multi-phase extraction system or a combination multi-phase extraction system and groundwater pumping system. Multi-phase extraction is not recommended for the portion of the LNAPL plume located in the clay lens because there is the potential to leave isolated lenses of undissolved product in the formation in lower permeability formations. The other locations of LNAPL identified are also located either in or just above tighter formations of soil. Pilot studies would be required in these areas to evaluate the feasibility of multi-phase extraction.

Multi-phase extraction is generally combined with bioremediation, air sparging, or bioventing to shorten the cleanup time at a site. As discussed earlier, it also can be used with pump-and-treat technologies to recover groundwater in higher-yielding aquifers. Under optimal conditions, it would generally take 6 months to 2 years for complete LNAPL removal using multi-phase extraction. However, it is unlikely that multi-phase extraction would result in 100 percent source removal because of the heterogeneous nature of the subsurface in the LNAPL plume areas. As discussed in Appendix B, without complete source removal, remediation through natural attenuation of contaminated groundwater will not occur within a reasonable time frame. Therefore, although multi-phase extraction could be applied to certain portions of the KRY Site, other alternatives would need to be considered to remove the remainder of the source (EPA 2004a).

For purposes of calculating a cost estimate, a conceptual LNAPL extraction system was designed for the KRY Site. The LNAPL extraction system would include an array of 26 wells on the western portion and 20 wells on the eastern portion of the KRY Site. These 6-inch diameter wells would feed 2 tanks, one on the western portion and one on the eastern portion of the KRY Site. These wells, based on drawdown requirements, are located on 50 foot centers. The liquid extraction rate based on 5 gallons per minute would results in 130 gallons per minute on the western portion and 100 gallons per minute on the eastern portion of the KRY Site. This option would also require carbon adsorption treatment of water generated during the process. The water would be discharged via a discharge pipeline upon receipt of data from confirmation samples to verify all cleanup levels have been met. The potential for optimal recovery of LNAPL on the eastern portion of the KRY Site is less favorable than potential recovery of LNAPL on the western portion of the KRY Site and pilot testing will be required to determine the most favorable design of the recovery system. The cost estimate for the system is provided in Appendix F, and the criteria evaluation is provided in Section 6.0.

5.3.2 LNAPL Extraction and Disposal

This technology involves removing LNAPL from wells or trenches under ambient pressure. LNAPL can be extracted and disposed of through the use of hydraulic pumps (such as bladder pumps), or with passive or active skimmers. LNAPL extraction using this technology is most effective in permeable hydrogeologic settings. It is often combined with groundwater pumping to increase the hydraulic gradient to help induce the flow of LNAPL to the well or trench for more effective LNAPL recovery. However, a groundwater pump can also emulsify water and LNAPL (U.S. Army Corps of Engineers 2003).

A typical LNAPL recovery system would consist of a pump or skimmer located within an open trench, a backfilled trench with recovery wells, or an extraction well. Water table depth and gradient are considered in selecting a recovery method. Installation of a trench may not be cost effective given the depth of LNAPL at the KRY Site (approximately 20 feet bgs). Therefore, a potential configuration for LNAPL extraction at the KRY Site would be a pump or skimmer in an extraction well or series of extraction wells. When an extraction well is used, slurry walls can be used to guide the groundwater and LNAPL to the well, where it can then be removed with either a pump or a skimmer. However, the use of a slurry wall is not preferred due to the depth of the LNAPL, as previously discussed. Extraction wells can either be single pump, double pump, or double shaft. A single-pump system would be similar to a multi-phase extraction system where one well is used to recover both LNAPL and groundwater. The liquid would then need to be separated at the surface and disposed of or treated separately. The extracted groundwater could also be reinjected upgradient of the source if the primary purpose of groundwater pumping is drawdown to enhance LNAPL recovery. A double-pump system combines a product recovery pump or skimmer with a groundwater drawdown pump into a single well. A double-shaft system consists of two concentric casings in one well. Groundwater drawdown is achieved by a pump located in the inner casing, while free-product is recovered from the outer casing.

LNAPL recovery using passive skimmers has been used with some effectiveness at the KRY Site in the past; therefore, this technology is used for the detailed evaluation and cost analyses with the assumptions provided in Table 5-1. Skimmers recover LNAPL by skimming under ambient pressure. As shown on Figure 3-7, a large area of LNAPL has been identified where LNAPL extraction could be applied. LNAPL recovery using pumps or skimmers may not be as effective as multi-phase extraction with vacuum enhancement and is may not completely remove the source. In addition, portions of the LNAPL plume are located in lower-permeability soils, where LNAPL recovery would be less effective. Excavation combined with LNAPL recovery may be required to adequately remove the source at the KRY Site in those portions of the plume (EPA 2004a).

For purposes of calculating a cost estimate, a conceptual LNAPL extraction system was designed for the KRY Site. The LNAPL extraction system would include an array of 26 wells on the western portion and 20 wells on the eastern portion of the KRY Site. These 6-inch diameter wells would feed 2 tanks, one on the western portion and one on the eastern portion of the KRY Site. These wells, based on drawdown requirements, are located on 50 foot centers. The liquid extraction rate based on 5 gallons per minute would results in 130 gallons per minute on the western portion and 100 gallons per minute on the eastern portion of the KRY Site. This option would also require carbon adsorption treatment of water generated during the process. The water would be discharged via a discharge pipeline upon receipt of data from confirmation samples to verify all cleanup levels have been met. The cost estimate is provided in Appendix F, and the criteria evaluation is provided in Section 6.0.

5.4 GROUNDWATER OPTIONS

This section presents the groundwater remedial options for the KRY Site source areas.

5.4.1 Extraction, Ex Situ Treatment, and Discharge

A combination of collection, treatment, and discharge, also described as pump-and-treat, is used to provide hydraulic containment and to reduce groundwater contaminant levels in a portion of the plume. An extraction system is used to remove contaminated groundwater from the affected aquifer, which is followed by groundwater treatment, if required, and discharge or reinjection of the groundwater into the aquifer or discharge to surface water. Groundwater would be extracted from within identified areas at the KRY Site. The estimated extent of groundwater with contaminant levels above cleanup levels is shown on Figure 3-1. Groundwater could be extracted for treatment for any or all of the areas shown on Figure 3-1. The final selection on a treatment alternative for groundwater at the KRY Site will be included in the ROD.

Two types of collection technologies are considered applicable to the KRY Site: extraction wells and collection trenches. Small-diameter (2- to 6-inch) wells are the most common method of extracting contaminated groundwater and could be used in all areas of the KRY Site. Extraction wells are typically placed vertically into the aquifer with a well screen and pump below the water table. Design of the extraction wells, including spacing, would be based on aquifer characteristics such as hydraulic gradient and hydraulic conductivity. Data collected from aquifer tests completed as part of the RI were used to estimate the hydrogeologic properties of the aquifer in the vicinity of the pumping tests (DEQ and TtEMI 2008). However, the aquifer test data are limited since they were acquired from short-duration and low-volume pumping tests. Testing results indicated low discharge rates as a result of limitations on the size of the pump used in the 2-inch and 4-inch diameter wells that were tested. The maximum discharge rate that could be achieved for the 2-inch wells was approximately 6 gpm, and the maximum discharge rate for the 4-inch wells was approximately 30 gpm (from the lower aquifer). The short-duration and low-volume pumping tests conducted during the RI minimally stressed the unconfined aquifer; therefore, the amount of drawdown was limited at pumping wells and was not measurable at observation wells. The calculated hydraulic conductivities at the site ranged from 17 to 326 ft/day (DEQ and TtEMI 2008a). Results from previous aquifer tests showed hydraulic conductivities ranging from 0.4 to 322 ft/day (DEQ and TtEMI 2008a). The estimated groundwater seepage velocity ranged from 0.39 ft/day to 7.4 ft/day using calculated hydraulic conductivity values ranging from 17 ft/day to 326 ft/day, an average horizontal gradient of 0.0057 ft/ft, and a literature estimate for effective porosity for silty sands of 0.25 (unitless) (Fetter 1980).

Aquifer test results obtained during this RI indicate that hydraulic conductivities of the aquifer vary throughout the KRY Site and represent silty fine sand, clean sand, and gravelly sand lithologies. Therefore, specific well design and pumping rates would depend on the exact placement of an extraction well, which will be determined during the remedial design.

In general, higher hydraulic conductivities are observed west of Highway 2, and lower hydraulic conductivities are present in the vicinity of and east of Highway 2. Computer modeling may also be used to predict required well spacing and pumping rate, but pilot testing is recommended to further define system design parameters.

Extraction wells could be designed to remove water from specific depths within the aquifer or from across the entire saturated thickness. The saturated thickness of the aquifer is approximately 40 feet in the upper portion of the aquifer. Contaminants were detected in the lower portion of the aquifer during the RI. The highest concentration of PCP within the lower portion of the unconfined aquifer is located at monitoring well KRY129B, 2,000 feet southeast of the former wood treatment area on the western portion of the KRY Site. A concentration of 40 µg/L was detected at this location in a sample collected at a depth of 127 to 137 feet bgs. However, PCP was not detected in samples from the upper portion of the unconfined aquifer at this location (well KRY129A). Additional sampling of the lower aquifer was recommended during the RI and would be required before a specific design could be developed for this portion of the aquifer.

Collection trenches or horizontal wells are not recommended for the KRY Site, where depths to the base of the aquifer are generally at 60 feet. Horizontal extraction trenches are difficult to construct at depths greater than 40 to 45 feet.

Once extracted, ex situ treatment of groundwater can be accomplished in a number of ways, as discussed in Section 4. Ex situ treatment alternatives that have been retained for the KRY Site include engineered bioreactors, carbon adsorption, chemical oxidation/ozonation/UV oxidation, ion exchange, precipitation/coagulation/flocculation, and membrane technologies. Carbon adsorption is generally used as a polishing technique and is not cost effective as a primary treatment method because of the cost of exchanging the carbon canisters. However, this technology can be effectively used as a final treatment method to meet discharge limits. Ozonation has been used at the KRY Site as both an in situ and ex situ technology. An evaluation of the existing in situ ozonation system suggests that the ozonation system may be reducing PCP concentrations near the locations of the ozone injection wells, but that PCP concentrations in groundwater rebound downgradient of the ozonation system because of the PCP source material (LNAPL) located in that area. Therefore, the effectiveness of any ex situ treatment system depends on removal of the source area (LNAPL and soil smear zone). The evaluation also indicated that the ozonation system is not creating potentially toxic byproducts from degradation of PCP (DEQ and TtEMI 2008). Ion exchange, precipitation/coagulation/flocculation, and membrane technologies are primarily considered treatment technologies for metals, as previously discussed. Although groundwater at the KRY Site is contaminated by metals, metals are a small fraction of the COCs identified for groundwater.

Bioreactors degrade contaminants in water with microorganisms through attached or suspended biological systems. Bioreactors can consist of suspended growth or attached growth systems. Suspended growth systems include activated sludge, fluidized beds, or sequencing batch reactors. Attached growth systems can include fixed film bioreactors, rotating biological contactors (RBCs), and trickling filters. Bioreactors are used primarily to treat SVOCs, fuel hydrocarbons, and any biodegradable organic material. A bioreactor is considered representative of the ex situ treatment technologies because it is capable of treating the majority of COCs identified in the groundwater. An ex situ bioreactor could be installed south of the railroad tracks on the eastern portion of the KRY Site. The location of the ex situ bioreactor is not limited to this area, however existing fencing could be used to secure the bioreactor in this area. Cost of implementing an ex situ bioreactor are included in Appendix F using the assumptions identified on Table 5-1. Multiple treatment technologies may be required for groundwater because of the complex array of COCs identified at the KRY Site. An ex situ bioreactor is one example of the treatment technologies that could be applied.

Treated water may be disposed of through land application, injection wells or trenches, discharge to surface water, or offsite disposal. Costs were evaluated assuming that treated groundwater would be discharged to the Stillwater River 1,000 feet from the proposed treatment area. Treated groundwater discharged to the Stillwater River would be required to meet the surface water quality standards that are included as ERCLs.

For purposes of calculating a cost estimate, a conceptual system was designed for the KRY Site. This conceptual design assumed, based on drawdown, that 1 deep and 11 shallow 6-inch wells would be installed on the KRY Site on approximately 100 foot centers. Two deep 6-inch wells would also be required to treat the contamination present in lower portion of the unconfined aquifer in the vicinity of Highway 2. The majority of the wells would feed into a single bioreactor designed to treat 300 gallons per minute, while the wells in the southeastern portion of the KRY Site, near Highway 2, would feed into a separate bioreactor designed to treat 80 gallons per minute. The groundwater would then require carbon adsorption treatment prior to discharge to the Stillwater River. A pilot test is proposed prior to full scale implementation. The cost estimate is provided in Appendix F, and the criteria evaluation is provided in Section 6.0.

5.4.2 In Situ Bioremediation

In situ bioremediation has been successfully implemented at other, similar sites and is one of the most commonly selected in situ groundwater treatment technologies (FRTR 2002). However, the effectiveness of in situ bioremediation is highly dependent on removal of NAPL. When NAPL has been removed, this technology could be applied at the KRY Site source areas. In situ bioremediation can consist of enhanced anaerobic bioremediation or enhanced aerobic bioremediation. Often, the two are used in conjunction with enhanced anaerobic bioremediation followed by enhanced aerobic bioremediation. As shown in Appendix B, MNA (a passive form of bioremediation) with source removal can be effective at the KRY Site for treating petroleum hydrocarbons and to some extent PCP, but is less effective on dioxins/furans. However, enhanced in situ bioremediation will shorten the anticipated treatment times.

A typical enhanced anaerobic bioremediation system would involve the addition of nutrients (such as lactate, butyrate, acetate, molasses, fructose, HRC, edible oils, and plant mulch) to promote biodegradation of chlorinated SVOCs. These nutrients are discussed further in Section 4. Aerobic biodegradation can be promoted by the addition of oxygen (in the form of air, hydrogen peroxide, or ORC) into a contaminated area to provide an electron donor to the existing in situ population of dechlorinating microorganisms (called chlororespirators). ORC is considered a viable method of oxygen enhancement for the KRY Site because it is effective at depths up to 60 feet and does not generate vapor emissions as do the other delivery methods. Enhanced bioremediation is effective on most VOCs, SVOCs, and petroleum hydrocarbons. Limited studies have been completed on the effectiveness of bioremediation for dioxins/furans; however, some studies suggest bioremediation can effectively reduce dioxin/furan levels (FRTR 2002).

WRI assessed microbiology and related parameters at the KRY Site, and the results were reported in the RI (DEQ and TtEMI 2008a). The results demonstrate that a diversity of anaerobic bacteria were present in the groundwater onsite. These microbial populations include denitrifying, iron-reducing, sulfate-reducing, fermenting, methanogenic and dechlorinating bacteria. Denitrifying bacteria appear to be the dominant species that is present in high populations in groundwater. *Dehalococcoides* sp. was detected in high numbers in groundwater collected from wells with PCP contamination, indicating active dechlorination of PCP. The enhancements to date applied to microcosms resulted in the increased growth of bacteria populations. Data suggest that denitrifying bacteria may be the most active population and is responsible for a substantial amount of diesel-range petroleum biodegradation. This study suggests that in situ enhancement of denitrifying bacteria may increase the rate of diesel-range petroleum (and possibly other hydrocarbons) biodegradation on the eastern portion of the KRY Site. However, further studies are warranted to optimize the enhancement of and maximize denitrifying bacteria activity and the rates of hydrocarbon biodegradation.

Further studies and pilot testing at the KRY Site would help to define the exact parameters of such a system; however, example costs associated with this type of system are provided in Appendix F, and the assumptions used are provided in Table 5-1. A vendor provided much of the information regarding approximate locations, amounts, and frequency of the injections. A total of 1,300 injections points would be required with yearly injections. The injections would be made to an average depth of 30 feet. A total of 55,158 pounds of ORC would be injected yearly. This estimate includes all drilling costs and associated labor. A complete criteria evaluation is provided in Section 6.0.

5.4.3 In Situ Chemical Treatment

In situ chemical oxidation involves injection of a chemical oxidant such as ozone, hydrogen peroxide, potassium permanganate, sodium permanganate, or persulfate into the groundwater to treat both contaminated groundwater and soil. An active in situ ozonation system has been operating at the KRY Site. The ozonation system is installed along the BNSF property line (in the vicinity of the cluster of OMW, OSW, and SBM monitoring wells depicted on Figure 1-4), which is located within the LNAPL plume identified from water level and LNAPL measurements. According to a recent report on the ozonation system (ERM 2007), 28 months of operation, during which approximately 26,000 pounds of ozone was injected into the subsurface, reduced LNAPL thickness and PCP concentrations in wells onsite.

Review of the ozonation system confirms that PCP concentrations appear to be reduced in the immediate vicinity of the ozone injection barrier and that these reduced levels may reflect the destruction of PCP in the dissolved phase by the ozone treatment. In addition, there were no detectable concentrations of acetone, bromate, or formaldehyde (principal byproducts that may result from chemical oxidation reactions) in any of the monitoring wells in the immediate vicinity of the ozone injection barrier. Therefore, byproduct generation does not appear to be a significant issue at this time. However, LNAPL is still present downgradient of the barrier, as evidenced by free-product measurements in downgradient monitoring wells. In addition, PCP concentrations in downgradient wells, including those installed in the deeper portion of the aquifer, were elevated in comparison to the immediate vicinity of the ozone injection barrier. Therefore, it appears that the current ozonation system is not effectively remediating the entire LNAPL and dissolved phase plumes and that there is a substantial rebound in PCP concentrations downgradient of the ozone injection barrier. This rebound may result from the solubilization of PCP from the LNAPL residual into the dissolved phase downgradient of the barrier. Another contributing factor may be the presence of PCP-contamination in the soils in the vicinity of the former treatment area, which continue to leach to groundwater.

Although it appears that the current ozonation system on the KRY Site is effective at treating dissolved PCP, the current configuration is not effectively treating the source area and therefore is allowing for rebound of PCP downgradient of the system. As a result, an evaluation and reconfiguration of the ozonation system may be warranted to include the entire source area and include injection points to address the deeper portion of the aquifer, which would affect more of the PCP plume. Placement of additional ozone (or other form of chemical treatment) will depend on the specific lithologies, as clay lenses and subsurface chemical reactions can make it difficult to deliver the oxidant to the contaminant. Applied oxidants can be also consumed by natural organic matter in the aquifer, other organic contaminants (petroleum), and dissolved iron.

Further studies and pilot testing at the KRY Site would help to define the exact parameters of such a system; however, example costs associated with this type of system are provided in Appendix F, and the assumptions used are provided in Table 5-1. A vendor provided much of the information regarding approximate locations, amounts, and frequency of the ozone injections. To provide adequate coverage of the contaminated groundwater plume(s), approximately 348 injection points would be required at the KRY Site, including 3 deep injection points to address contamination in the deeper portion of the aquifer. Injection points would be attached to 25 separate ozone generation systems. This system would remain in place for approximately 10 years. A complete criteria evaluation is provided in Section 6.0.

5.5 SOIL OPTIONS

This section presents the remedial options for the contaminated soils at the KRY Site.

5.5.1 Barrier Technologies

Soil barriers, such as a horizontal cap, can be used to minimize exposure, prevent vertical infiltration of water and leachate, contain waste while treatment is being applied, control vapor and odor emission, or to create a land surface that is suitable to the intended reuse of the property. Capping is the most common form of barrier remediation because it is generally less expensive than other technologies and may effectively manage the human health risk.

The design of caps is site specific and can range from a one-layer system of vegetated soil to a complex multi-layer system of soils and geosynthetic liners. Less complex systems are generally required in dryer climates such as in Montana. A horizontal cap could be applied at any or all of the contaminated areas shown on Figures 3-2 (A-B), 3-3 (A-B), 3-4 (A-B), 3-5 (A-B), and 3-6 (A-B). However, installation of a cap could be inhibited by current operations, buildings, or equipment.

The most critical components of a cap are the low-permeability barrier layer and the drainage layer. The most effective single-layer caps are composed of soil, concrete, or bituminous asphalt with a geomembrane, which are used to form a surface barrier between contaminated soil and the environment. An asphalt or concrete cap would reduce leaching through the cap into an adjacent aquifer; however, it would not address continued leaching from contaminated vadose zone soils that periodically come in contact groundwater, nor would it prevent leaching from the smear zone. Due to these factors, a cap would likely not be considered as a stand alone technology. Estimated costs for a single-layer cap are included in Appendix F using the assumptions shown in Table 5-1. A complete criteria evaluation is provided in Section 6.0.

Horizontal caps may be temporary or final. Temporary caps can be installed before final closure to minimize generation of leachate until a better remedy is selected. Installation of a permanent cap does not reduce the toxicity or volume of hazardous waste, but may partially reduce the mobility of a hazardous waste. Horizontal caps can protect against the vertical migration of water through the soil, therefore reducing the vertical mobility of the contaminated soil. However, a cap alone will not prevent horizontal flow of groundwater through the contaminated soil. Installation of a horizontal cap is considered most effective for contaminated surface soil (Figures 3-2 (A-B)), which is not affected by groundwater. A cap as a long-term technology would require land use controls, site restrictions, and long-term operations and maintenance.

In many cases, caps are used in conjunction with vertical walls to minimize horizontal flow and migration. The effective life of a cap can be extended by long-term inspection and maintenance. Vegetation with a tendency for deep root penetration must be eliminated from the cap area. In addition, precautions must be taken to assume that the integrity of the cap is not compromised by land use.

5.5.2 Excavation and Offsite Disposal

Under this alternative, soil would be excavated within the remediation areas identified at the KRY Site and disposed of offsite. The estimated extent of soil with contaminants at levels above cleanup levels is shown on Figures 3-2 (A-B), 3-3 (A-B), 3-4 (A-B), 3-5 (A-B), and 3-6 (A-B). Soil would be excavated from the ground surface to approximately the bottom of the contaminated zone shown on these figures. The total volume of contaminated soil that exceeds cleanup criteria is 136,293 cubic yards. It is assumed overburden soil that is not contaminated will be stockpiled onsite. Sloping is assumed to be used for slope stabilization during excavation. Excavation areas are assumed to be backfilled with the clean stockpiled overburden soil and clean fill. The disposal location or facility would be selected based on the type and level of contamination in the soil and the facility’s acceptance criteria.

Alternatives that involve excavation and transport of the soil are generally higher in cost because of the large volume of soil at the KRY Site. An estimate of costs for this alternative is provided in Appendix F, and the associated assumptions are shown in Table 5-1. Treatment alternatives that involve excavation, treatment, or disposal of the soil may be more economically applied to only certain portions of the site, such as the zone containing the LNAPL and the highly contaminated smear zone soils. Excavation and transport could also be an effective means of removing the source for more effective in situ bioremediation, chemical treatment, or monitored natural attenuation. A complete criteria evaluation is provided in Section 6.0.

5.5.3 Excavation, Onsite or Ex Situ Treatment, and Backfill

Under this alternative, soil would be excavated within identified remediation areas at the KRY Site. The estimated extent of soil with contaminants at levels above cleanup levels is shown on Figures 3-2 (A-B), 3-3 (A-B), 3-4 (A-B), 3-5 (A-B), and 3-6 (A-B). Soil would be excavated from the ground surface to approximately the bottom of the contaminated zone shown on these figures. The total volume of contaminated soil with contaminants at concentrations that exceed cleanup criteria is approximately 136,293 cubic yards. It is assumed that overburden soil that is not contaminated will be stockpiled onsite. Sloping is assumed to be used for slope stabilization during excavation. Soil desorption equipment would be temporarily located in the immediate vicinity of the soil removal areas. Excavation areas are assumed to be backfilled with the clean stockpiled overburden soil and the treated soil.

Excavated soil can either be treated onsite or offsite. Soil could be treated onsite using any combination of the ex situ treatment alternatives discussed in Section 4.0. Applicable ex situ treatment alternatives for the KRY Site include landfarming in a land treatment unit, solidification/stabilization, and thermal treatment (thermal desorption, or incineration/thermal destruction).

Landfarming is a form of bioremediation, as discussed in Section 4.2.14.1. Excavated soils are mixed with soil amendments and spread on a treatment area that includes leachate collection systems and some form of aeration. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation. A large amount of space would be required for a land treatment unit, and the treatment area would need to be contained with an impermeable liner to minimize leaching. Leachate collected can be reapplied to the landfarm or treated and disposed. Treatment thickness is limited by tilling depth. VOC and potentially SVOC emissions and escaping odors may also need to be controlled. Treatment timeframes for landfarming are dependent upon site-specific characteristics, although timeframes for similar sites in Montana have been a few months to several years. Treatability studies are needed to determine treatment timeframes and optimize system design.

Solidification/stabilization is a form of chemical treatment, as discussed in Section 4.2.14.2. Excavated soils are mixed with agents that encapsulate or immobilize the contamination. Solidification/stabilization is generally used for inorganic contaminants.

Thermal desorption heats soil directly or indirectly, and contaminants are desorbed into a gas stream. The resulting contaminated gas stream can be treated in a variety of ways. Thermal desorption is classified as either high temperature or low temperature. High-temperature systems typically operate from 600 to 1,000 °F, and low-temperature systems operate from 200 to 600 °F. An onsite thermal desorption system was used during an interim action to treat soil contaminated with petroleum hydrocarbons from the southeastern portion of the KRY Site. This technology is proven for petroleum, VOCs, and SVOCs. Offsite thermal desorption may be a more viable option. Thermal desorption separates contaminants from soil and concentrates them into a much smaller waste stream that will require disposal. Advantages of thermal desportion include a shorter treatment time, estimated to be less than a year, depending on how quickly material is fed through the treatment unit.

Incineration is the most effective form of treatment for dioxins/furans. However, a RCRA permit would be required because of the PCP in the soil. Without a RCRA permit, contaminated soil would require excavation and transport to an offsite licensed RCRA facility. High temperatures are used to combust contaminants in soil. Ash residue that contains metals would be disposed of at an appropriate chemical waste landfill.

Alternatives that involve excavation and treatment of the soil are generally higher in cost because of the large volume of soil at this site that would require treatment. In addition, options such as thermal desorption and incineration are costly. An estimate of costs using landfarming as the treatment mechanism in this alternative is provided in Appendix F, and the associated assumptions are provided in Table 5-1. Treatment alternatives that involve excavation, treatment, or disposal of the soil may be more economically applied to only certain portions of the site, such as the zone that contains the LNAPL and the highly contaminated smear zone soils. These alternatives could also be an effective means of removing the source for more effective in situ bioremediation, chemical treatment, or monitored natural attenuation. A complete criteria evaluation is provided in Section 6.0.

5.5.4 In Situ Bioremediation

In situ bioremediation has been successfully implemented at other, similar sites and is one of the most commonly selected in situ groundwater treatment technologies (FRTR 2002). In addition, in situ bioremediation is a viable treatment alternative for saturated and vadose zone soils. The technology is often implemented for both soil and groundwater remediation, rather than for one or the other media types. Therefore, the discussion in Section 5.3.3 also applies for application of in situ bioremediation for soil. In addition, cost assumptions and estimates that were provided for the technology comparison and discussion apply for in situ bioremediation as both a soil and a groundwater technology.

Further studies and pilot testing at the KRY Site would help to define the exact parameters of such a system; however, example costs associated with this type of system are provided in Appendix F, and the assumptions used are provided in Table 5-1. A complete criteria evaluation is provided in Section 6.0.

5.5.5 In Situ Chemical Treatment

In situ chemical oxidation involves injection of a chemical oxidant such as ozone, hydrogen peroxide, potassium permanganate, sodium permanganate, or persulfate into the groundwater to treat both contaminated groundwater and soil. The active ozonation system that has been operating at the KRY Site is further discussed in Section 5.4.3. Although other forms of chemical treatment are available, ozone appears to be effective for the KRY Site, as long as it is applied correctly. Therefore, example costs for a full-scale chemical oxidation system using ozone is provided in Appendix F, and the assumptions used are provided in Table 5-1. A complete criteria evaluation is provided in Section 6.0. Further examination of the existing ozone treatment system at the KRY Site and additional treatability studies would help to define the exact parameters of a full-scale ozonation system and aid in the optimization of such a system.

5.6 SUMMARY

Remedial technologies and process options considered applicable to contamination at the KRY Site were developed, evaluated, and screened using preliminary criteria in Section 4.0. Options that were retained as key remedial options are further discussed in Section 5.0. In addition, options were grouped together in more definable treatment alternatives. Finally, representative technologies from each group were selected for detailed evaluation and cost estimation. However, the selection of these representative alternatives in no way restricts selection of the final cleanup options for the KRY Site. Any or all of the options retained from Section 4.0 are available for selection for the final remedy for the KRY Site. The final remedial alternatives for cleanup of contaminated soil and groundwater at the KRY Site were identified in the Proposed Plan and will be selected in the ROD.

6.0 ANALYSIS OF ALTERNATIVES

This section evaluates the retained alternatives based on the seven criteria in § 75-10-721, MCA. The criteria are listed and described below. DEQ also considers present and reasonable anticipated future uses of the site and institutional controls when evaluating and selecting a remedy. A summary of the comparison is provided in Table 6-1.

6.1 CLEANUP CRITERIA

1. Protectiveness. Overall protection of human health and the environment addresses whether an alternative provides adequate protection in both the short-term and the long-term from unacceptable risks posed by hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing, or controlling exposure to protective levels. This criterion is a threshold that must be met by the selected alternative or combinations of alternatives.

2. Compliance with ERCLs. This criterion evaluates whether each alternative will meet applicable or relevant state and federal ERCLs. This criterion is a threshold that must be met by the selected alternative or combination of alternatives unless an ERCL is waived.

3. Mitigation of Risk. This criterion evaluates mitigation of exposure to risks to public health, safety, and welfare and the environment to acceptable levels.

4. Effectiveness and Reliability. Each alternative is evaluated, in the short-term and the long-term, based on whether acceptable risk levels are maintained and further releases are prevented.

5. Practicability and Implementability. Under this criterion, alternatives are evaluated with respect to whether this technology and approach could be applied at the site.

6. Treatment or Resource Recovery Technologies. This criterion addresses use of treatment technologies or resource recovery technologies, if practicable, giving due consideration to engineering controls. These technologies are generally preferred to simple disposal options.

7. Cost Effectiveness. Cost effectiveness is evaluated through an analysis of incremental costs and incremental risk reduction and other benefits of alternatives considered. This analysis includes taking into account the total anticipated short-term and long-term costs, including operation and maintenance (O&M) activities. The cost estimate for each alternative is based on present worth estimates of capital and O&M costs for a specific time period. The costs are developed using environmental costing software and vendor information. The types of costs that are assessed include the following:

- Capital costs, including both direct and indirect costs
- Annual O&M costs, including long-term effectiveness monitoring cost
- Periodic cost
- Enforcement of ICs
- Net present worth of capital, O&M costs, periodic costs, and enforcement of ICs

Appendix F contains spreadsheets that show each component of the present worth costs.

6.2 LIST OF ALTERNATIVES

Following are the alternatives used for a detailed comparison against the cleanup criteria identified above:

- Alternative 1 – No Further Action
- Alternative 2 – Multi-Phase Extraction and Disposal
- Alternative 3 – LNAPL Extraction and Disposal
- Alternative 4 – Extraction, Ex Situ Treatment and Discharge
- Alternative 5 – In Situ Bioremediation for Groundwater and Soil
- Alternative 6 – In situ Groundwater Chemical Treatment for Groundwater and Soil
- Alternative 7 – Soil Barriers
- Alternative 8 – Excavation and Offsite Disposal
- Alternative 9 – Excavation, Ex Situ Treatment and Backfill
- Alternative 10 – Monitored Natural Attenuation

6.3 ALTERNATIVES EVALUATION

6.3.1 Alternative 1 – No Action

DEQ compares other options against the baseline No Action Alternative. No further cleanup is considered under this alternative. Contamination would remain onsite and would continue to affect soil and groundwater. No Further Action is not protective of human health and the environment in the short-term or long-term because people would continue to be exposed to unacceptable levels of contamination in the soil and groundwater and contaminants would continue to leach to groundwater. Alternative 1 is not expected to reach groundwater cleanup levels for over 100 years, free-product would remain on the groundwater, and contamination would remain in the soil and would continue to leach, causing exceedances of Montana water quality standards. Therefore, the No Action Alternative does not meet ERCLs. Unacceptable risks would remain and risk would not be mitigated. This alternative would not be effective and reliable in the short-term and long-term because unacceptable levels of contamination would remain and contaminants would continue to be released to the environment. This alternative is easily implemented but does not use treatment or resource recovery technologies. The total present worth cost for implementing No Further Action at the KRY Site is $0.

6.3.2 Alternative 2 – Multi-Phase Extraction and Disposal

Multi-phase extraction and disposal of LNAPL would significantly reduce the amount of LNAPL source. Removal of LNAPL source is an important step in addressing groundwater contamination. Contaminated soil and groundwater would remain onsite at unacceptable levels; therefore, alternative 2 is not protective of human health and the environment. However, this alternative could be used in conjunction with other alternatives and meet the protectiveness criteria. Sludge would remain in the soil and contaminated soil would continue to leach to groundwater causing exceedances of Montana water quality standards. Therefore, this alternative does not meet ERCLs on its own, but could be combined with other alternatives to meet ERCLs. Unacceptable risks would remain and risk would not be mitigated because of residual soil and groundwater contamination. This alternative is effective and reliable for removing LNAPL, which would accelerate the cleanup of contaminated groundwater, but other alternatives would be needed to address residual soil and groundwater contamination. This technology is technically and administratively implementable at the KRY Site. The installation of wells and pumps is considered a standard construction practice. This alternative is a proven recovery technology. The total present worth cost for implementing multi-phase extraction and disposal at the KRY Site is $9,910,800.

6.3.3 Alternative 3 – LNAPL Extraction and Disposal

LNAPL extraction and disposal would significantly reduce the amount of LNAPL source. Removal of LNAPL source is an important step in addressing groundwater contamination. Contaminated soil and groundwater would remain onsite at unacceptable levels; therefore, alternative 3 is not protective of human health and the environment. However, this alternative could be used in conjunction with other alternatives and meet the protectiveness criteria. Sludge would remain in the soil and contaminated soil would continue to leach to groundwater causing exceedances of Montana water quality standards. Therefore, this alternative does not meet ERCLs on its own, but could be combined with other alternatives to meet ERCLs. Unacceptable risks would remain and risk would not be mitigated because of residual soil and groundwater contamination. This alternative is effective and reliable for removing LNAPL, which would accelerate the cleanup of contaminated groundwater, but other alternatives would be needed to address residual soil and groundwater contamination. This technology is technically and administratively implementable at the KRY Site. The installation of wells and skimmer pumps is considered a standard practice in the environmental field. This alternative is a proven recovery technology. The total present worth cost for implementing LNAPL extraction and disposal at the KRY Site is $12,392,100.

6.3.4 Alternative 4 – Extraction, Ex-Situ Treatment and Discharge

Ex-situ treatment of groundwater via a bioreactor would significantly reduce the amount of contaminated groundwater at the KRY Site. This alternative would need to be preceded by LNAPL and contaminated soil removal or treatment. This alternative by itself would not be protective of human health and the environment. The LNAPL source would remain and sludge in soil and contaminated soil would continue to leach to groundwater causing exceedances of Montana water quality standards. Therefore, this alternative does not meet ERCLs on its own, but could be combined with other alternatives to meet ERCLs. An ex-situ bioreactor uses biological processes to degrade contaminants in groundwater to less harmful ones. Therefore, there would be some mitigation of risk although LNAPL, sludge, and residual soil contamination would remain. This alternative is not expected to be effective on dioxins/furans or metals. An activated carbon filter would likely be required to remove additional contaminants prior to discharge. A pilot study would be necessary to evaluate the effectiveness of this alternative at the KRY Site. This technology is technically and administratively implementable at the KRY Site. The equipment and services to install and operate the extraction, treatment, and discharge equipment are commercially available. The use of bioreactors is a proven treatment technology. The total present worth cost for implementing extraction, ex-situ treatment and discharge at the KRY Site is $36,223,000.

6.3.5 Alternative 5 – In-Situ Bioremediation of Groundwater and Soil

In-Situ bioremediation would significantly reduce contaminant concentrations of petroleum hydrocarbons and PCP in soil and groundwater site-wide. However, this alternative may not address dioxin/furan and metals contamination and will not address LNAPL on the groundwater and sludge in the soils at the KRY Site. Therefore, contaminants would remain at unacceptable concentrations. This alternative by itself would not be protective of human health and the environment, but could be combined with other alternatives to meet the protectiveness criteria. By itself, this alternative does not meet ERCLs and may not meet ERCLs in combination with other alternatives given the possible resistance of dioxins/furans to bioremediation treatment. In-situ bioremediation uses biological processes to degrade contaminants in groundwater and soil to less harmful ones. Therefore, there would be some mitigation of risk although LNAPL, sludge, and residual dioxin/furan contamination would remain in soil and groundwater and metals contamination would remain in soils.   Bioremediation has been demonstrated effective on PCP and petroleum hydrocarbons but is not expected to be effective on dioxins/furans or metals. Pilot testing at the KRY Site would be needed to define reaction rates and the types of enhancements needed to improve efficiency. This technology is technically and administratively implementable at the KRY Site. The equipment and services to install and operate the treatment injection system is commercially available. The use of bioremediation via oxygen enhancement is a proven treatment technology. The total present worth cost for implementing in-situ groundwater and soil bioremediation at the KRY Site is $52,272,900.

6.3.6 Alternative 6 – In-Situ Chemical Treatment of Groundwater and Soil

In-situ chemical treatment of soil and groundwater would significantly reduce contaminant concentrations of PCP and petroleum hydrocarbons in groundwater and soil site-wide. Based on site-specific data from the operation of an ozonation system, dioxin/furan concentrations are likely to decrease in groundwater; however, this alternative’s ability to treat dioxins/furans in soil is uncertain and it is unlikely that metals contamination in soil would be addressed. Therefore, this alternative by itself is not protective of human health and the environment in the short-term and long-term because people would continue to be exposed to unacceptable levels of contamination in the soil. However, this alternative may be combined with other alternatives to meet the protectiveness criteria. The free-product would remain in groundwater and sludge would remain in soil. Therefore, this alternative does not meet ERCLs on its own, but could be combined with other alternatives to meet ERCLs. Chemical treatment destroys contaminants in groundwater and soil. Therefore, there would be some mitigation of risk although LNAPL, sludge, and residual dioxins/furans and metals contamination may remain in soil and groundwater. Ozonation has been shown to be effective on dissolved petroleum and PCP at the KRY Site. The amount of ozone required is directly related to contaminant concentrations. Excessive amounts of ozone could hinder biological activity at the KRY Site. However, it is unlikely to be effective on metals contamination present at the KRY Site. Chemical oxidation is technically and administratively implementable at the KRY Site. In-situ chemical oxidation by ozone injection is a well-established technology used to treat contaminants in groundwater and soils. The technology is currently in use on a portion of the KRY Site. Chemical oxidation is a proven treatment technology. The total present worth cost for implementing in-situ chemical treatment via ozone injection for groundwater and soil at the KRY Site is $15,668,701.

6.3.7 Alternative 7 – Soil Barriers

Soil barriers would limit the mobility of contamination in the vadose zone. However, contamination would remain in the soil and in site wide groundwater. People could still be exposed to contaminated soil and groundwater. Institutional controls and long-term maintenance would be needed to ensure the integrity of the barrier and prevent direct contact with contamination. Therefore, this alternative by itself is not protective of human health and the environment in the short-term and long-term because free-product would remain and fluctuating groundwater would continue to mobilize contaminants, but could be combined with other alternatives to meet the protectiveness criteria. Alternative 7 alone would not reach groundwater cleanup levels for over 100 years, free-product would remain on the groundwater, and sludge would remain in the soil. Therefore, this alternative does not meet ERCLs on its own, but could be combined with other alternatives to meet ERCLs. This alternative mitigates some direct exposure to contaminated soils, but contamination would remain in soil and continue to impact groundwater. Because fluctuating groundwater would continue to mobilize contaminants from the soil and free-product, this alternative is only somewhat effective. In addition, barriers are susceptible to long-term weathering and may crack and reduce the effectiveness of the barrier. Maintenance of the barrier in perpetuity would be required. Soil barriers are technically and administratively implementable at the KRY Site. Soil barriers are considered a standard construction practice. Soil barriers provide no form of treatment or resource recovery. The total present worth cost for implementing soil barriers at the KRY Site is $5,599,800.

6.3.8 Alternative 8 – Excavation and Offsite Disposal

Excavation and offsite disposal would significantly reduce the amount of contamination in soil. However, free-product and contaminated groundwater would remain. Therefore, this alternative by itself is not protective of human health and the environment in the short-term and long-term, but could be combined with other alternatives to meet the protectiveness criteria. Free-product would remain on the groundwater. In addition, some soil contains a RCRA hazardous waste that is precluded from being land disposed. This alternative does not meet ERCLs on its own, but could be combined with other alternatives to meet ERCLs. Excavation would remove all contaminants in the soil that exceed acceptable levels, including sludge, lead, and dioxins/furans. Therefore, there would be some mitigation of risk although LNAPL and contaminated groundwater would remain. This alternative is considered highly effective at removing contaminated soil in the vadose zone up to 30 feet below ground surface. Because waste would be disposed of at a licensed engineered offsite facility, regulatory requirements for the offsite disposal facility would effectively control the contamination. Excavation and offsite disposal is technically and administratively implementable at the KRY Site. The equipment and services to remove and transport the contaminated soil are commercially available. This alternative is not a treatment or resource recovery technology. The total present worth for implementing excavation and offsite disposal at the KRY Site is $120,950,900.

6.3.9 Alternative 9 – Excavation, Ex-Situ Treatment, and Backfill

Excavation, ex-situ treatment, and backfill would significantly reduce the amount of contamination in soil. However, free-product and contaminated groundwater would remain. Therefore, this alternative by itself is not protective of human health and the environment in the short-term and long-term, but could be combined with other alternatives to meet the protectiveness criteria. Free-product would remain on the groundwater. In addition, some soil contains a RCRA hazardous waste that would require special handling for onsite treatment. If contaminated soil is treated to cleanup levels it would be available for use as backfill material at the KRY Site. This alternative does not meet ERCLs on its own, but could be combined with other alternatives to meet ERCLs. Excavation would remove all contaminants in the soil that exceed acceptable levels, including sludge, lead, and dioxins/furans. Subsequent ex-situ treatment would reduce the toxicity and volume of some contaminants in the soil. It is uncertain if ex-situ treatment will reduce dioxin/furan concentrations to acceptable levels. Therefore, there would be some mitigation of risk although LNAPL and contaminated groundwater would remain. This alternative is considered highly effective at removing contaminated soil in the vadose zone up to 30 feet below ground surface. However, the effectiveness of ex-situ treatment on dioxin/furan contamination is uncertain. This alternative may need to be combined with other alternatives. Excavation and ex-situ treatment is technically and administratively implementable at the KRY Site. The equipment and services to remove and treat the contaminated soil are commercially available. The use of ex-situ soil treatment is a proven treatment technology. The total present worth for implementing excavation, ex situ treatment, and backfill at the KRY Site is $8,526,496.

6.3.10 Alternative 10 – Monitored Natural Attenuation

MNA relies on slow natural processes to breakdown groundwater contamination. One hundred years or more would be required for groundwater to reach cleanup levels under this alternative. Therefore, this alternative by itself is not protective of human health and the environment in the short-term and long-term, but could be combined with other alternatives to meet the protectiveness criteria. ERCLs would not be met for over 100 years under this alternative. If used alone, free product, sludge in soil, and contaminated soils would remain and risk from groundwater would not be mitigated for decades. Unacceptable levels of contamination would remain for more than 100 years and contamination would continue to be released to the environment. Therefore, this alternative is not effective and reliable in the short-term and long-term. This alternative is easily implementable and uses treatment technologies in the form of natural processes to treat some contaminated groundwater. The total present worth for implementing MNA at the KRY Site is $4,952,892.

6.4 COMPARATIVE ANALYSIS

The alternatives were evaluated and compared against the seven cleanup criteria identified in § 75-10-721, MCA. Protectiveness and compliance with ERCLs are threshold criteria that must be met for any remedy. In the comparative analysis, the remaining criteria are weighed and evaluated to identify the best overall alternatives for each media. Each criterion is listed individually below.

6.4.1 Protection of public health, safety, and welfare and of the environment (Protectiveness):

Alternative 1, 2, and 3 would not provide adequate protection of public health, safety, and welfare and the environment in the short-term or long-term because people would continue to be exposed to unacceptable levels of contamination in the soil and contaminants would continue to leach to groundwater. However, alternatives 2 and 3, if combined with soil and groundwater alternatives, may provide adequate protection in the long-term. Alternatives 4 through 9 cannot provide adequate protection in the short-term and long-term unless they are combined with other alternatives to address the risks posed by all of the contaminated media at the KRY Site. For instance, alternatives 2 or 3 could be combined with alternatives 5 or 6 to be protective. It may also be possible to combine alternatives 2 or 3 with some combination of alternatives 4, 7, 8, and 9 to ensure protectiveness. Institutional controls would be necessary for short-term and long-term protectiveness no matter what alternatives are selected. Alternatives 1, 7, and 10 as stand alone options would not provide adequate protection for over 100 years. Alternatives 2, 3, 8, and 9 as stand alone options would likely not provide adequate protection for 40 to 100 years. Alternatives 4, 5, and 6 would likely not provide adequate protection for 10 years. However, the timeframe could be drastically reduced for some of these alternatives, specifically 2, 3, 8, and 9, if used in conjunction with other alternatives.

6.4.2 Compliance with ERCLs

Alternative 1 is not expected to reach groundwater cleanup levels for more than 100 years. However, when compared to other alternatives this is not a reasonable timeframe. Free product would also remain. Therefore, alternative does not meet ERCLs. Alternatives 2 through 9 will comply with ERCLs when combined with other alternatives. Any combination of alternatives that would remove free-product to the maximum extent practicable, reduce groundwater concentrations to levels that meet Montana water quality standards, and treats PCP-contaminated soils that are banned from land disposal to site-specific cleanup levels, including leaching to groundwater numbers would comply with ERCLs. Alternatives 1, 7, and 10 as stand alone options would not meet ERCLs for over 100 years. Alternatives 2, 3, 8, and 9 as stand alone options would likely not meet ERCLs for 40 to 100 years. Alternatives 4, 5, and 6 would likely not meet ERCLs for 10 years. However, the timeframe could be drastically reduced for some of these alternatives, specifically 2, 3, 8, and 9, if used in conjunction with other alternatives.

6.4.3 Mitigation of Risk

Under Alternative 1, free-product, sludge in soil and contaminated soils and groundwater would remain at the KRY Site. Unacceptable risk would exist and would not be mitigated by this alternative. Alternatives 2 and 3 do not mitigate risk because residual sludge, soil, and groundwater contamination would remain. Some mitigation of risk would occur as a result of removing free-product that continues to release contaminants to groundwater. Alternative 4 mitigates some risks posed by groundwater contamination because it treats contaminated groundwater. However, it does not mitigate risk associated with sludge, free-product in the groundwater, or soil contamination. Alternative 5 mitigates some risks because it treats PCP and petroleum contamination in soil and groundwater. However, it is unlikely that this alternative would be effective at treating free-product, sludge, dioxins/furans or metals and therefore would not mitigate risk associated with those compounds. Alternative 6 mitigates some risks because it treats PCP, petroleum and may treat dioxins/furans. It would not effectively treat free-product, sludge or metals. Alternative 7 mitigates some direct exposure to contaminated soils but contamination would remain in soil and fluctuating groundwater would continue to mobilize contaminants from soil and free-product. Institutional controls and long-term maintenance would be needed to ensure the integrity of the barrier and prevent direct contact with contamination. Alternative 8 would mitigate risk posed by contaminated soils because they would be excavated and removed from the KRY Site. However, free-product and contaminated groundwater would remain and people may be exposed to contaminants. Alternative 9 would mitigate some risk because all contaminants in the soil would be removed and treated. However, it is uncertain if this alternative will reduce dioxin/furan concentrations to acceptable levels. Free-product and contaminated groundwater would also remain and people may be exposed to contaminants. Unacceptable risk would exist and would not be mitigated under Alternative 10, as free-product, sludge, and contaminated soils and groundwater are not addressed. Alternatives 2 through 10 have the potential to mitigate risks when combined with other alternatives in the right combinations.

6.4.4 Effectiveness and Reliability in the Short-Term and Long-Term

Alternative 1 is not effective and reliable in the short-term and long-term because unacceptable levels of contamination would remain and contaminants would continue to be released to the environment. Alternative 2 and 3 are effective and reliable for removing free-product but other alternatives would be needed to address residual soil and groundwater contamination. Alternative 4 would be effective on some contaminants at the KRY Site, but is not expected to be effective on dioxins/furans or metals. Additional treatment would likely be required. A pilot study would be necessary to better evaluate the effectiveness of this alternative. Alternative 5 would be effective for PCP and petroleum, but is not expected to be effective for treating dioxins/furans or metals. Pilot testing would be needed to define reaction rates and identify enhancements that would be needed to improve efficiency. Site-specific tests demonstrate that ozonation, which could be a component of Alternative 6, is effective at treating dissolved petroleum, PCP and dioxins/furans. However, it is unlikely to be effective on metals contamination or free-product. It is also uncertain if this alternative would achieve dioxin/furan cleanup levels in soils. Pilot testing would be needed to determine the effectiveness of this alternative on soils at the KRY Site. Alternative 7 is somewhat effective at preventing people from directly contacting contaminated soils. Barriers are susceptible to weathering and may crack, reducing the effectiveness of the barrier in the long-term. Maintenance of the barrier in perpetuity would be required. Because contaminated soil would remain and fluctuating groundwater would continue to mobilize contaminants, this alternative is not effective on its own for free-product and site wide groundwater contamination. Alternative 8 is effective in the short-term and long-term at removing contaminated soil up to 30 feet below ground surface. Because contaminated soil would be disposed of at a licensed engineered offsite facility, regulatory requirements for the offsite facility would effectively control contaminants in the long-term. This alternative by itself is not effective for treating free-product or groundwater contamination. Alternative 9 is effective in the short-term and long-term at removing contaminated soil up to 30 feet below ground surface. Subsequent ex-situ treatment would reduce the toxicity and volume of some contaminants in the soil. The effectiveness of ex-situ treatment at reducing dioxin/furan concentrations to acceptable levels is uncertain. This alternative by itself is not effective for treating free-product or groundwater contamination. Alternative 10 is not effective and reliable in the short-term and long-term because unacceptable levels of contamination would remain and continue to be released to the environment.

6.4.5 Technically Practicable and Implementable

All the alternatives are technically practicable and implementable at the KRY Site.

6.4.6 Treatment Technologies or Resource Recovery Technologies (Giving due consideration to engineering controls)

Alternatives 1, 7, and 8 do not use treatment or resource recovery technologies. The remaining alternatives include some form of treatment or resource recovery technology. Any alternative that requires onsite treatment will likely require fencing of portions of the KRY Site to ensure protection of human health in the short-term.

6.4.7 Cost Effectiveness

Alternatives 1 through 4 are less costly than the other alternatives (see Table 6-2 and Appendix F). However, alternatives 1 through 4 by themselves do not sufficiently reduce risks associated with contaminated soils.

Alternative 5 or Alternative 6 combined with either free-product recovery alternative (2 and 3) provides substantial risk reduction and requires less long-term care than Alternative 7. Alternatives 5 and 6 are less expensive than Alternative 8 but require more care and provide less risk reduction.

Alternative 7 provides for risk reduction by preventing direct contact with contaminated soils. However, it does not reduce risk associated with free-product or contaminated groundwater. Long-term costs associated with Alternative 7 are included in the estimated cost. Aside from Alternatives 1 and 10, Alternative 7 is the least expensive alternative. However, with the exception of Alternatives 1 and 10, Alternative 7 also provides the least amount of risk reduction.

Alternative 8 combined with Alternative 4, or the groundwater component of Alternatives 5 or 6, and either free-product recovery alternative (2 and 3) provides greater risk reduction than other alternatives, but any of these alternatives combined with Alternative 8 are the most costly.

Alternative 9 combined with Alternative 4, or the groundwater component of Alternatives 5 or 6, and either free-product recovery alternative (2 and 3) provides substantial risk reduction and requires less long-term care than Alternative 7.

Alternative 10 is less costly than other alternatives, but does not reduce risks associated with contaminated soils, sludge, free-product on groundwater, or groundwater (as long as contaminant concentrations exceed cleanup levels). Alternative 10 combined with any combination of alternatives that removed source materials in soil and groundwater provides some risk reduction at a negligible increase in cost over the cost associated with the other alternatives.

6.5 SUMMARY

The process options and alternatives retained for consideration in the FS were evaluated for their effectiveness on any or all portions of the KRY Site. Based on this evaluation, an effective combination of technologies for contaminated soil and groundwater across the entire KRY Site will be developed and documented in the ROD for the KRY Site.

7.0 REFERENCES

Autodesk Map 3D 2006. 2008. Version Z.77.0.

Bugni, Bob. 2007. Expert Report Regarding Discount Rate for Determining Present Value for Funds Held by the State of Montana to Conduct Superfund Cleanup Actions. June 14.

Burlington Northern & Santa Fe Railway v. Kalispell Pole & Timber Co. (BNSF v. KPTC). 2000. No. SV97-177-M-DWM (D. Mont.) (Joint Statement of Uncontroverted Facts and Second Set of Joint Fact Stipulations). Filed March 3.

California Department of Health Services (CDHS). 1986. Report on chlorinated dioxins and dibenzofurans. Part B. Health effects of chlorinated dioxins and dibenzofurans. California Department of Health Services, and California Air Resources Board. Sacramento, CA.

C Tech Development Corporation (C Tech). 2008. Mining Visualization System EVS/MVS Version 9.13. Released May 5.

Environmental Resources Management (ERM) 2007. Memorandum to Mr. Dave Smith, BNSF, from Mr. Jay Dablow, P.G., C.E.G, and Mr. Mike Quillin, P.G.. In Situ Ozonation System 2006 Status Report, Former Kalispell Pole and Timber Site. March 8 2007.

Federal Emergency Management Agency (FEMA). 2007. Flathead County floodplain map (ID# 30029C1810G). Available on line at http://msc.fema.gov/webapp/wcs/stores/servlet/FemaWelcomeView?storeId=10001&catalogId=10001&langId=-1. Updated September 28.

Federal Remediation Technologies Roundtable (FRTR). 2002. Screening Matrix and Reference Guide, Version 4.0. Available on-line at http://www.frtr.gov/matrix2/section3/3_7.html.

Fetter, C.W. 1980. Applied Hydrogeology. Merrill Publishing Company, Ohio. 488pp.

Flathead County. 2005. FEMA floodplain maps prepared by Flathead County GIS. Available on-line at http://maps.co.flathead.mt.us/DownloadLinks.htm

Flathead County Planning and Zoning Office (Flathead). 2006a. Flathead County Zoning Maps. Available online at http://maps.co.flathead.mt.us/. Provided via email on November 28, 2006.

Flathead. 2006b. Flathead County Zoning Regulations. Available online at http://www.co.flathead.mt.us/fcpz/zoneregs/fcounty.pdf. Accessed on December 4, 2006.

Freeze, R.A., and J.A. Cherry. 1979. Groundwater. Prentice-Hall, New Jersey. 604 pp.

Montana Natural Register of Historic Places and the Montana Natural Historical Preservation Office. 2003.

Montana Department of Environmental Quality (DEQ). 2002. Final Voluntary Cleanup and Redevelopment Act Application Guide. August. Available on-line at http://deq.mt.gov/StateSuperfund/VCRA_Guide/FinalVCRAguide.pdf

DEQ. 2005a. Action Level for Arsenic in Surface Soil. Montana Department of Environmental Quality Remediation Division, Site Response Section. April.

DEQ. 2005b. Site Files for the Kalispell Pole and Timber, Reliance, and Yale Oil Facilities. Copies of Documents Provided to TtEMI by DEQ for Review. July.

DEQ. 2006a. Circular DEQ-7 criteria: Montana Numeric Water Quality Standards. Planning, Prevention, and Assistance Division, Water Quality Standards Section. Helena, Montana. January. Available on-line at http://www.deq.state.mt.us/wqinfo/Circulars/WQB-7 criteria.PDF

DEQ. 2007. Montana Tier 1 Risk Based Corrective Action Guidance for Petroleum Releases June 2007 Revised Tables. Montana Department of Environmental Quality. July.

DEQ. 2008a. Memorandum to the Facility File, from Cynthia Brooks, DEQ Attorney. Subject: Use of the Synthetic Precipitation Leaching Procedure at the KRY Site. May.

DEQ. 2008b. Personal contact regarding Montana Petroleum Tank Release Compensation Board multiplier for excavated soils. Between Moriah Bucy (DEQ) and Paul Hicks (PTRCB). April.

DEQ. 2008c. Historical Studies/Site Identification File for Reliance Refinery. File No. 40-01-06.

DEQ and Tetra Tech Environmental, Inc. (DEQ and TtEMI). 2008. Final Remedial Investigation Report for the Kalispell Pole & Timber, Reliance Refining Company, and Yale Oil Corporation Facilities. Kalispell, Montana. March.

State of Montana, ex rel Department of Environmental Quality v. Burlington Northern Santa Fe Railway Company, Exxon Mobil Corporation, Kalispell Pole & Timber Company, Klingler Lumber Company, Inc., Montana Department of Natural Resources and Conservation, Montana Mokko, Inc., Swank Enterprises, and Does 1 through 100 (DEQ v. BNSF et al). 2008. No. DV-2004-596 (First Judicial District Court Lewis and Clark County. Pretrial Order. Filed March 12.

Montana Natural Heritage Program. 2005. Species of Concern Report for Township 28 North, Range 21 West. August. Available on-line at http://mtnhp.org.

MSE, Inc. (MSE). 1989. Final Report for Kalispell Post and Pole/Reliance Refinery, Kalispell, Montana. June 30.

Pioneer Technical Services, Inc. (PTS). 2000. Final Phase I Remedial Investigation Report for the Reliance Refinery Site, Kalispell, Montana. December.

PTS. 2007. Sampling and Analysis Results Letter Report for the Kalispell Pole & Timber, Reliance Refinery and Yale Oil Facilities (KRY Site). December 5.

Remediation Technologies, Inc. (RETEC). 1995. Site Investigation Report for Kalispell Pole and Timber, Kalispell, Montana. Unpublished report prepared for Burlington Northern Railroad. July.

Spratt and Associates, Consulting Hydrogeology. 1992. Phase III Environmental Site Assessment Seamen Mobile Homes, Kalispell, Montana. August 24.

Tetra Tech EM Inc. (TtEMI). 2005. Final Data Summary Report for the KRY Site. Prepared for the Montana Department of Environmental Quality. December.

TtEMI. 2007a. Remedial Investigation Report, Final Draft, Kalispell Pole and Timber, Reliance Refinery, and Yale Oil Facilities. January.

TtEMI. 2007b. Initial Alternatives Screening Document, Kalispell Pole and Timber, Reliance Refinery, and Yale Oil Facilities, Kalispell, Montana. March.

TtEMI. 2007c. Technical Memorandum, Feasibility Study Scoping Meeting, Kalispell Pole and Timber, Reliance Refinery, and Yale Oil Facilities (KRY Site), Kalispell, Montana. February 20.

ThermoRetec Consulting Corporation (ThermoRetec). 2001. Kalispell Pole & Timber Data Summary Report, Kalispell, Montana: Volume 1 of 2: Report and Appendix A. July 17.

U.S. Army Corps of Engineers. 2003. Safety and Health Aspects of HTRW Remediation Technologies. August.

U.S. Census Bureau. 2005. 2000 Census. Available on-line at http://www.census.gov/census2000/states/mt.html

U.S. Department of Agriculture (USDA). 1960. Soil Survey. Upper Flathead Valley Area, Montana. Prepared by USDA Soil Conservation Service, in cooperation with Montana Agricultural Experiment Station. September.

EPA. 1992. Preliminary Extent of Soil Contamination and Hydrogeological Investigation, Kalispell Pole and Timber Site, Kalispell, Montana. Prepared by Roy F. Weston. Final report. February.

EPA. 1993. Provisional Guidance for Quantitative Risk Assessment of Polycyclic Aromatic Hydrocarbons. U.S. Environmental Protection Agency. March.

EPA. 1999. Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action and Underground Storage Tank Sites. OSWER Directive 9200.4-17-P. April 21.

EPA. 2002. Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites. OSWER 9355.4-24. December.

EPA. 2004a. How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites: A Guide for Corrective Action Plan Reviewers. EPA 510-R-04-002. May.

EPA. 2004b. User's Guide for Evaluating Subsurface Vapor Intrusion Into Buildings. Prepared by Environmental Quality Management, Inc. February 22.

EPA. 2004c. Region 9 Preliminary Remediation Goals 2004 Table. Available online at http://www.epa.gov/region09/waste/sfund/prg/files/04prgtable.pdf. October.

EPA. 2008. Regional Screening Levels for Chemical Contaminants at Superfund Sites. May 20. Available online at http://www.epa.gov/region09/waste/sfund/prg/index.html.

EPA Field Investigation Team (FIT). 1986. Sampling Activities Report for Reliance Refinery, Kalispell, Montana and Draft Analytical Results Report for Reliance Refinery, Kalispell, Montana. April 15 and July 22.

U.S. Geological Survey (USGS). 1996. Geographic, Geologic, and Hydrologic Summaries of Intermontane Basins of the Northern Rocky Mountains, Montana. U.S. Geological Survey. Water-Resources Investigations Report 96-4025. August.

Western Regional Climate Center (WRCC). 2005. Historical Climate Information for Kalispell, Montana. Available on-line at http://www.wrcc.dri.edu/CLIMATEDATA.html. August.

WHO. (World Health Organization). 1998. Toxicity equivalency factors (TEFs) for PCBs, PCDDs, PCDFs for humans and wildlife. [van den Berg, et al. Summary of World Health Organization Findings in Environmental Health Perspectives 106(12):775-792].

WHO. 2005. Project for the Re-evaluation of Human and Mammalian Toxicity Equivalency Factors (TEFs) of Dioxin and Dioxin-like Compounds. Available online at www.who.int/entity/ipcs/assessment/tef_update/en/.

TABLES

TABLE 2-1
SUMMARY OF SOIL PHYSICAL PARAMETERS
KRY SITE

Sample Number	**Sample Date**	**Well**	**Sample Depth (ft bgs)**	**Moisture Content (%)**	**Specific Gravity^A**	**Porosity (%)**	**pH**	**Unified Soil Classification^B**	**TOC (%)**
KRY113ASB001	5/23/2006	KRY113A	5 – 18	1.4	2.721	19*	7.96	GP-GM	---
KRY115ASB001	5/4/2006	KRY115A	10 – 15	11.4	2.701	24	9.12	CL^1	---
KRY115ASB002	5/4/2006	KRY115A	23 – 27	3.6	NA	NA	8.10	SP-SM	---
KRY121ASB001	5/4/2006	KRY121A	10 – 15	17.7	2.494	23	7.97	CL^2	---
KRY121ASB002	5/4/2006	KRY121A	24 – 28.5	7.5	2.683	18	7.48	SW-SM	---
KRY139BSB001	6/10/2006	KRY139B	30 - 42	21.4	2.662	36	7.71	CL^3	---
KRY121BSB001	4/20/2006	KRY121B	12.5 – 15	---	---	---	---	---	2.24
KRY121BSB002	4/20/2006	KRY121B	25 – 27	---	---	---	---	---	1.77

Notes:

*	8% saturated moisture content used for porosity calculation
A	Analyzed by American Association of State Highway and Transportation Officials (AASHTO) test method T100
B	Analyzed by ASTM Method D2487

bgs	Below ground surface
CL^1	Sandy lean clay with gravel
CL^2	Sandy lean clay
CL^3	Lean clay
GP-GM	Poorly graded gravel with silt
SP-SM	Poorly graded sand with silt
SW-SM	Well graded sand with silt and gravel
TOC	Total organic carbon
NA	Not applicable
---	No Data

TABLE 2-2a
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information						July 2006				August 2006				September 2006				October 2006						
Well Number	**Top of Screen (ft bgs)**	**Bottom of Screen (ft bgs)**	**Well Depth (ft bgs)**	**Measuring Point**	**Measuring Point Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Change Jul to Aug**	**Change Aug to Sept**	**Change Sept to Oct**
CLCW-1	---	---	---	Top of PVC	2935.61			22.70	2912.91			24.37	2911.24			24.38	2911.23			23.64	2911.97	-1.67	-0.01	0.74
GW-1	11.9	21.9	24.0	Top of PVC	2933.94			13.20	2920.74			14.36	2919.58			14.87	2919.07			17.71	2916.23	-1.16	-0.51	-2.84
GW-5	14.0	24.0	24.5	Top of PVC	2934.64			18.90	2915.74			20.25	2914.39			20.59	2914.05			20.16	2914.48	-1.35	-0.34	0.43
GWRM-1	15.0	25.0	25.0	Top of PVC	Unknown			19.07	---			---	---			---	---			---	---			
GWRM-2	15.0	25.0	25.0	Top of PVC	Unknown			17.83	---			---	---			---	---			---	---			
GWRR-1	11.9	21.9	24.0	Top of PVC	2929.32			13.00	2916.32			14.3	2915.02			14.64	2914.68			14.23	2915.09	-1.30	-0.34	0.41
GWRR-2	12.85	22.85	25.0	Top of PVC	2932.54			16.94	2915.60			18.33	2914.21			18.64	2913.90			18.21	2914.33	-1.39	-0.31	0.43
GWRR-3	8.65	18.65	20.0	Top of PVC	2928.75			11.63	2917.12			11.65	2917.10			11.70	2917.05	11.68	0.01	11.69	2917.07	-0.02	-0.05	0.02
GWRR-4	4.75	14.75	20.0	Top of PVC	2931.76			12.10	2919.66			12.46	2919.30			13.10	2918.66			13.44	2918.32	-0.36	-0.64	-0.34
GWRR-5	13.0	23.0	23.3	Top of PVC	2932.36	16.81	0.03	16.84	2915.54			18.15	2914.21			18.45	2913.91			18.02	2914.34	-1.33	-0.30	0.43
GWRR-6	4.75	14.75	25.0	Top of PVC	2930.34			10.19	2920.15			10.37	2919.97			10.69	2919.65			10.89	2919.45	-0.18	-0.32	-0.20
GWRR-7	6.25	16.25	16.5	Top of PVC	2931.12	11.56	0.45	12.01	2919.48	11.74	0.02	11.76	2919.38	12.06	0.24	12.30	2919.02	12.15	0.38	12.53	2918.90	-0.11	-0.36	-0.11
GWRR-8	20.5	30.5	32.0	Top of PVC	2938.15			22.48	2915.67			23.85	2914.30			24.20	2913.95			23.76	2914.39	-1.37	-0.35	0.44
GWRR-9	16.0	26.0	28.0	Top of PVC	2934.27			locked	---	20.08	0.03	20.11	2914.18			20.42	2913.85			19.98	2914.29		-0.33	0.44
GWY-3	10.0	30.0	30.0	Top of PVC	2934.92			13.72	2921.20			14.64	2920.28			15.53	2919.39			15.57	2919.35	-0.92	-0.89	-0.04
GWY-4	10.0	30.0	30.0	Top of PVC	2934.06			18.56	2915.50			19.99	2914.07	20.24	0.01	20.25	2913.82			19.88	2914.18	-1.43	-0.25	0.36
GWY-10	10.0	30.0	30.0	Top of PVC	2933.75			18.27	2915.48			19.68	2914.07			19.99	2913.76			19.6	2914.15	-1.41	-0.31	0.39
GWY-12	10.0	30.0	30.0	Top of PVC	2933.13			17.55	2915.58			18.98	2914.15			19.27	2913.86			18.89	2914.24	-1.43	-0.29	0.38
GWY-13	10.0	30.0	30.0	Top of PVC	2932.56			17.03	2915.53			18.46	2914.10	18.74	0.01	18.75	2913.82			18.36	2914.20	-1.43	-0.28	0.38
GWY-14	10.0	30.0	30.0	Top of PVC	2934.62			22.41	2912.21			24	2910.62			24.03	2910.59			23.21	2911.41	-1.59	-0.03	0.82
KPT-1	13.0	28.0	29.0	Top of PVC	2939.84			18.99	2920.85			20.15	2919.69			20.65	2919.19			20.51	2919.33	-1.16	-0.50	0.14
KPT-2	13.0	28.0	29.0	Top of Steel	2938.55			17.78	2920.77			18.99	2919.56	19.48	0.01	19.49	2919.07			19.34	2919.21	-1.21	-0.49	0.14
KPT-3	13.0	28.0	29.0	Top of PVC	2937.17	16.88	0.05	16.93	2920.28			18.09	2919.08	18.59	0.01	18.60	2918.58	18.39	0.06	18.45	2918.77	-1.20	-0.50	0.19
KPT-4	13.0	28.0	29.0	Top of PVC	2935.44			17.95	2917.49			19.31	2916.13			19.75	2915.69			19.44	2916.00	-1.36	-0.44	0.31
KPT-5	13.0	28.0	29.0	Top of PVC	2934.66			17.66	2917.00			19.09	2915.57			19.48	2915.18			19.09	2915.57	-1.43	-0.39	0.39
KPT-6	13.0	28.0	29.0	Top of PVC	2936.18			15.95	2920.23			17.15	2919.03			17.64	2918.54			17.46	2918.72	-1.20	-0.49	0.18
KPT-7	12.5	27.5	28.5	Top of PVC	2935.31			17.27	2918.04			18.48	2916.83			18.87	2916.44			18.56	2916.75	-1.21	-0.39	0.31
KPT-8	110.0	120.0	122.0	Top of PVC	2935.16			17.18	2917.98			18.41	2916.75			18.79	2916.37			18.51	2916.65	-1.23	-0.38	0.28
KPT-9	6.0	16.0	23.0	Top of Steel	2925.77			6.39	2919.38			7.41	2918.36			7.82	2917.95			7.68	2918.09	-1.02	-0.41	0.14
KPT-10	8.0	23.0	27.0	Top of PVC	2925.35			8.90	2916.45			10.28	2915.07			10.60	2914.75			10.19	2915.16	-1.38	-0.32	0.41
KPT-11	52.0	72.0	74.0	Top of PVC	2925.84			9.48	2916.36			10.84	2915.00			11.11	2914.73			10.7	2915.14	-1.36	-0.27	0.41
KPT-12	14.0	24.0	24.5	Top of PVC	2939.51			18.70	2920.81			19.93	2919.58			20.44	2919.07			20.25	2919.26	-1.23	-0.51	0.19
KPT-13	109.0	119.0	120.0	Top of PVC	2927.55			8.59	2918.96			9.68	2917.87			10.11	2917.44			9.84	2917.71	-1.09	-0.43	0.27
KPT-14	96.0	106.0	109.0	Top of PVC	2925.95			9.64	2916.31			10.96	2914.99			11.29	2914.66			10.88	2915.07	-1.32	-0.33	0.41
KPT-15	101.0	111.0	117.0	Top of PVC	2934.80			19.12	2915.68			20.48	2914.32			20.82	2913.98			20.37	2914.43	-1.36	-0.34	0.45
KPT-16	14.0	29.0	29.5	Top of PVC	2935.66			19.91	2915.75			21.27	2914.39			21.63	2914.03			21.21	2914.45	-1.36	-0.36	0.42
KPT-17	7.5	12.5	13.0	Top of PVC	2929.58			10.59	2918.99			10.7	2918.88			10.99	2918.59			11.11	2918.47	-0.11	-0.29	-0.12
KPT-18	24.0	34.0	34.5	Top of PVC	2929.71			12.55	2917.16			12.83	2916.88			13.04	2916.67			13.11	2916.60	-0.28	-0.21	-0.07
KPT-19	13.00	23.00	23.50	Top of PVC	2932.89			16.63	2916.26			17.98	2914.91			18.29	2914.60			17.88	2915.01	-1.35	-0.31	0.41
KPT-20	10.00	20.00	20.00	Top of PVC	2932.90			16.18	2916.72			17.48	2915.42			17.81	2915.09			17.46	2915.44	-1.30	-0.33	0.35
KPT-21	8.00	23.00	23.00	Top of PVC	2933.50			17.30	2916.20			18.64	2914.86			18.97	2914.53			18.56	2914.94	-1.34	-0.33	0.41
KPT-22	6.00	16.00	16.00	Top of PVC	2926.78			10.33	2916.45			11.67	2915.11			11.98	2914.80			11.58	2915.20	-1.34	-0.31	0.40
KRY100A	6	26	28	Top of PVC	2936.60			10.06	2926.54			10.88	2925.72			11.26	2925.34			11.2	2925.40	-0.82	-0.38	0.06
KRY101A	9	29	31	Top of PVC	2941.08			16.22	2924.86			17.31	2923.77			17.77	2923.31			17.69	2923.39	-1.09	-0.46	0.08
KRY101B	85	95	100	Top of PVC	2940.80			16.29	2924.51			17.4	2923.40			17.88	2922.92			17.75	2923.05	-1.11	-0.48	0.13
KRY102A	13	33	33.5	Top of PVC	2945.27			23.91	2921.36			25.15	2920.12			25.67	2919.60			25.52	2919.75	-1.24	-0.52	0.15
KRY102B	95	105	110	Top of PVC	2945.26			23.89	2921.37			25.11	2920.15			25.62	2919.64			25.49	2919.77	-1.22	-0.51	0.13
KRY103A	5	25	27	Top of PVC	2940.30			12.69	2927.61			13.45	2926.85			13.82	2926.48			13.77	2926.53	-0.76	-0.37	0.05
KRY103B	55	65	70	Top of PVC	2939.94			12.23	2927.71			12.98	2926.96			13.34	2926.60			13.13	2926.81	-0.75	-0.36	0.21
KRY104A	20	40	40.5	Top of PVC	2946.68			25.84	2920.84			27.18	2919.50			27.72	2918.96			27.57	2919.11	-1.34	-0.54	0.15
KRY105A	5	25	27	Top of PVC	2932.27			7.37	2924.90			8.3	2923.97			8.69	2923.58	8.55	0.01	8.56	2923.72	-0.93	-0.39	0.14
KRY106A	6	26	28	Top of PVC	2932.25			10.28	2921.97			11.45	2920.80			11.90	2920.35			11.77	2920.48	-1.17	-0.45	0.13

TABLE 2-2a
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information						July 2006				August 2006				September 2006				October 2006						
Well Number	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Well Depth (ft bgs)	Measuring Point	Measuring Point Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Change Jul to Aug	Change Aug to Sept	Change Sept to Oct
KRY106B	73	83	88	Top of PVC	2932.42			10.22	2922.20			11.4	2921.02			11.83	2920.59			11.67	2920.75	-1.18	-0.43	0.16
KRY107A	9	29	29.5	Top of PVC	2938.92			18.10	2920.82			19.32	2919.60			19.85	2919.07			19.64	2919.28	-1.22	-0.53	0.21
KRY107B	121	131	136	Top of PVC	2938.73			20.55	2918.18			21.85	2916.88			22.35	2916.38			22.07	2916.66	-1.30	-0.50	0.28
KRY108A	10	30	32	Top of PVC	2941.11			20.18	2920.93			21.35	2919.76			21.85	2919.26			21.73	2919.38	-1.17	-0.50	0.12
KRY109A	5	25	27	Top of PVC	2928.85			10.10	2918.75			10.7	2918.15			10.99	2917.86			10.99	2917.86	-0.60	-0.29	0.00
KRY110A	35	55	55	Top of PVC	2926.90			8.17	2918.73			9.13	2917.77			9.55	2917.35			9.42	2917.48	-0.96	-0.42	0.13
KRY110B	76	86	91	Top of PVC	2926.96			9.01	2917.95			10.04	2916.92			10.43	2916.53			10.2	2916.76	-1.03	-0.39	0.23
KRY111A	5	25	25.5	Top of PVC	2936.61			19.80	2916.81			21.21	2915.40			21.62	2914.99			21.23	2915.38	-1.41	-0.41	0.39
KRY111B	123	133	138	Top of PVC	2936.96			18.82	2918.14			21	2915.96			20.55	2916.41			20.21	2916.75	-2.18	0.45	0.34
KRY112A	9	29	29.5	Top of PVC	2935.59			18.50	2917.09			20.08	2915.51			20.58	2915.01			20.22	2915.37	-1.58	-0.50	0.36
KRY112B	110	120	125	Top of PVC	2935.78			18.75	2917.03			20.04	2915.74			20.54	2915.24			20.23	2915.55	-1.29	-0.50	0.31
KRY113A	15	35	37	Top of PVC	2940.77			19.72	2921.05			20.98	2919.79			21.46	2919.31			21.32	2919.45	-1.26	-0.48	0.14
KRY113B	102	112	117	Top of PVC	2940.96			20.23	2920.73			21.53	2919.43			21.96	2919.00			21.81	2919.15	-1.30	-0.43	0.15
KRY114A	7	27	29	Top of PVC	2934.65	18.55	0.85	19.40	2915.95	19.55	0.94	20.49	2914.94	19.89	0.01	19.90	2914.76	19.54	0.04	19.58	2915.10	-1.02	-0.18	0.34
KRY114B	108	118	122	Top of PVC	2935.09			18.65	2916.44			19.85	2915.24			20.19	2914.90			19.75	2915.34	-1.20	-0.34	0.44
KRY115A	12	32	32.5	Top of PVC	2936.78			21.05	2915.73			22.42	2914.36			22.73	2914.05			22.31	2914.47	-1.37	-0.31	0.42
KRY115B	107	117	122	Top of PVC	2936.68			20.63	2916.05			21.97	2914.71			22.41	2914.27			22.04	2914.64	-1.34	-0.44	0.37
KRY116A	7	27	29.5	Top of PVC	2931.53			15.10	2916.43			16.42	2915.11			16.98	2914.55			16.68	2914.85	-1.32	-0.56	0.30
KRY116B	95.5	105.5	110.5	Top of PVC	2931.97			15.70	2916.27			17.03	2914.94			17.53	2914.44			17.21	2914.76	-1.33	-0.50	0.32
KRY117A	5	29	27	Top of PVC	2929.25			13.75	2915.50			15.07	2914.18			15.39	2913.86			14.98	2914.27	-1.32	-0.32	0.41
KRY118A	6	26	28	Top of PVC	2924.44			11.25	2913.19			12.44	2912.00			12.57	2911.87			11.45	2912.99	-1.19	-0.13	1.12
KRY118B	95	105	110	Top of PVC	2924.21			11.45	2912.76			12.54	2911.67			12.25	2911.96	11.23	0.01	11.24	2912.98	-1.09	0.29	1.02
KRY119A	5	25	25	Top of PVC	2929.69			13.75	2915.94			14.08	2915.61			14.21	2915.48	14.23	0.01	14.24	2915.46	-0.33	-0.13	-0.02
KRY121A	12	32	32.5	Top of PVC	2937.39			21.80	2915.59			23.18	2914.21			23.49	2913.90			23.04	2914.35	-1.38	-0.31	0.45
KRY121B	119	129	134	Top of PVC	2937.35			21.90	2915.45			23.26	2914.09			23.56	2913.79			23.1	2914.25	-1.36	-0.30	0.46
KRY122A	7	27	29	Top of PVC	2930.07			14.23	2915.84			15.65	2914.42			16.16	2913.91			15.96	2914.11	-1.42	-0.51	0.20
KRY122B	83	93	98	Top of PVC	2929.80			14.12	2915.68			15.47	2914.33			15.91	2913.89			15.68	2914.12	-1.35	-0.44	0.23
KRY123A	5	25	25	Top of PVC	2928.93			16.40	2912.53			17.85	2911.08			17.65	2911.28			16.41	2912.52	-1.45	0.20	1.24
KRY125A	5	25	25	Top of PVC	2934.75			15.50	2919.25			15.81	2918.94			16.14	2918.61			16.29	2918.46	-0.31	-0.33	-0.15
KRY125B	116	126	126	Top of PVC	2934.40			22.84	2911.56			24.21	2910.19			24.53	2909.87			24.27	2910.13	-1.37	-0.32	0.26
KRY126A	5	25	27	Top of PVC	2927.54			15.05	2912.49			16.55	2910.99			16.31	2911.23			15.06	2912.48	-1.50	0.24	1.25
KRY127A	5	25	27	Top of PVC	2923.05			11.08	2911.97			13.6	2909.45			12.07	2910.98			10.53	2912.52	-2.52	1.53	1.54
KRY128A	5	25	27.5	Top of PVC	2928.07			14.69	2913.38			16.24	2911.83			16.05	2912.02			14.92	2913.15	-1.55	0.19	1.13
KRY128B	145	155	160	Top of PVC	2928.05			16.56	2911.49			17.98	2910.07			17.82	2910.23			17	2911.05	-1.42	0.16	0.82
KRY129A	9	29	31	Top of PVC	2931.84			14.28	2917.56			12.69	2919.15			11.88	2919.96			11.55	2920.29	1.59	0.81	0.33
KRY129B	127	137	142	Top of PVC	2931.10			20.74	2910.36			22.1	2909.00			22.33	2908.77			21.91	2909.19	-1.36	-0.23	0.42
KRY130A	25	45	45	Top of PVC	2926.68			15.80	2910.88			16.17	2910.51			17.03	2909.65			16.14	2910.54	-0.37	-0.86	0.89
KRY130B	153	163	168	Top of PVC	2926.85			16.14	2910.71			17.51	2909.34			17.35	2909.50			16.55	2910.30	-1.37	0.16	0.80
KRY132A	6	26	28.5	Top of PVC	2930.75			9.50	2921.25			10.51	2920.24			10.92	2919.83			10.82	2919.93	-1.01	-0.41	0.10
KRY133A	8	28	30	Top of PVC	2939.44			18.61	2920.83			19.82	2919.62			20.31	2919.13			20.15	2919.29	-1.21	-0.49	0.16
KRY134A	8	28	30	Top of PVC	2935.11			18.72	2916.39			20.05	2915.06			20.39	2914.72			19.98	2915.13	-1.33	-0.34	0.41
KRY135A	5	25	25	Top of PVC	2931.22	13.10	2.15	15.25	2917.75	13.83	0.17	14	2917.36	13.76	0.01	13.77	2917.46	13.84	2.62	16.46	2916.93	-0.39	0.10	-0.53
KRY136A	5	25	25	Top of PVC	2935.39	19.67	0.47	20.14	2915.64	20.98	0.39	21.37	2914.34	21.28	0.02	21.30	2914.11	20.85	0.28	21.13	2914.49	-1.30	-0.24	0.39
KRY137A	5	25	25	Top of PVC	2929.90			11.25	2918.65			11.5	2918.40			11.91	2917.99			12.07	2917.83	-0.25	-0.41	-0.16
KRY138A	5	25	25	Top of PVC	2934.14	19.61	0.04	19.65	2914.52	20.87	0.01	20.88	2913.27			21.25	2912.89			20.8	2913.34	-1.25	-0.38	0.45
KRY139A	7	27	29	Top of PVC	2919.51			10.95	2908.56			12.15	2907.36			12.54	2906.97			12.41	2907.10	-1.20	-0.39	0.13
KRY139B	166	176	181	Top of PVC	2919.24			10.23	2909.01			11.52	2907.72			11.81	2907.43			11.45	2907.79	-1.29	-0.29	0.36
NTL-MW-3	5.2	15.2	15.2	Top of PVC	2915.31			--	---			7.08	2908.23			7.29	2908.02			6.94	2908.37		-0.21	0.35
NTL-MW-4	5.70	15.70	16.00	Top of PVC	2917.76			--	---			11.19	2906.57			11.55	2906.21			11.39	2906.37		-0.36	0.16
NW-1	10.0	30.0	30.5	Top of PVC	2923.79			16.54	2907.25			---	---			---	---			---	---			
NW-2	11.5	26.5	26.9	Top of PVC	2919.14			13.47	2905.67			---	---			---	---			---	---			
NW-4	12.2	32.2	33.0	Top of PVC	2925.77			18.58	2907.19			---	---			---	---			---	---			

TABLE 2-2a
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information						July 2006				August 2006				September 2006				October 2006						
Well Number	**Top of Screen (ft bgs)**	**Bottom of Screen (ft bgs)**	**Well Depth (ft bgs)**	**Measuring Point**	**Measuring Point Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Change Jul to Aug**	**Change Aug to Sept**	**Change Sept to Oct**
PW-1	14.5	24.6	25.0	Top of PVC	2926.67			18.92	2907.75			20.39	2906.28			20.44	2906.23			19.78	2906.89	-1.47	-0.05	0.66
PW-2C	15.0	25.0	25.0	Top of PVC	2924.58			18.46	2906.12			---	---			---	---			---	---			
PW-2D	12.0	22.0	22.0	Top of PVC	2924.47			18.51	2905.96			---	---			---	---			---	---			
PW-3	12.0	22.0	22.0	Top of PVC	2922.55			16.04	2906.51			17.61	2904.94			17.59	2904.96			16.79	2905.76	-1.57	0.02	0.80
SW-9	10.0	20.0	20.0	Top of PVC	2922.82			14.11	2908.71			15.49	2907.33			15.75	2907.07			15.49	2907.33	-1.38	-0.26	0.26
OMW1	12.0	27.0	27.5	Top of PVC	2929.20			--	---			10.56	2918.64			11.01	2918.19			10.87	2918.33	---	-0.45	0.14
OMW2	12.0	27.0	27.5	Top of PVC	2934.84			--	---			19.38	2915.46			19.76	2915.08			19.22	2915.62	---	-0.38	0.54
OMW3	12.0	27.0	27.5	Top of PVC	2927.52			--	---			11.99	2915.53			12.29	2915.23			11.97	2915.55	---	-0.30	0.32
OMW4	12.0	27.0	27.5	Top of PVC	2935.10			--	---	20.03	1.37	21.4	2913.70	20.34	0.17	20.51	2914.59	19.97	0.09	20.06	2915.04	---	0.89	0.45
OMW5	Unknown	Unknown	Unknown	Top of PVC	2934.71			--	---	19.71	0.21	19.92	2914.79	20.08	0.04	20.12	2914.59	19.67	0.04	19.71	2915.00	---	-0.20	0.41
OMW6	Unknown	Unknown	Unknown	Top of PVC	2935.59			--	---			19.29	2916.30			19.73	2915.86			19.41	2916.18	---	-0.44	0.32
OSW1	11.0	26.0	26.0	Top of PVC	2936.24			--	---			16.61	2919.63			17.04	2919.20			16.86	2919.38	---	-0.43	0.18
OSW2	11.0	26.0	26.0	Top of PVC	2934.32			--	---			17.21	2917.11	17.63	0.02	17.65	2916.67			17.3	2917.02	---	-0.44	0.35
SBM1	17.0	28.0	30.6	Top of PVC	2936.64			--	---			19.72	2916.92			20.18	2916.46	19.85	0.05	19.9	2916.74	---	-0.46	0.28
SBM2	17.0	28.0	30.2	Top of PVC	2937.11			--	---			20.66	2916.45			21.09	2916.02			20.78	2916.33	---	-0.43	0.31

Notes:

1. Water level corrected for LNAPL in wells with LNAPL
2. Correction factor for wells with LNAPL $h_c = h_m + (H_o (d_o/d_w))$

h_c - Hydraulic head corrected
h_m - Measured elevation of hydrocarbon-water interface
H_o - Thickness of hydrocarbon layer
d_o - Hydrocarbon density (for diesel = 0.827)
d_w - Water density (assumed = 1.0)
ft - Feet

bgs - Below ground surface
amsl - Above mean sea level
GW - Groundwater
PVC - Polyvinyl chloride (well casing)
LNAPL - Light nonaqueous phase liquid (petroluem hydrocarbon, PCP)
SWL - Static water level

July water levels collected on July 11-12, 2006
August water levels collected on August 1-3, 2006
September water levels collected on September 5-7, 2006
October water levels collected on October 3-5, 2006
Blank cell indicates no measureable LNAPL present
--- Not measured

Note: Field notes that included "no evidence of product" and the presence of "brown flecks or algae" were eliminated from this data summary as product detected in the respective well.

TABLE 2-2b
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information						November 2006				December 2006				January 2007				February 2007						
Well Number	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Well Depth (ft bgs)	Measuring Point	Measuring Point Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Change Nov to Dec	Change Dec to Jan	Change Jan to Feb
CLCW-1				Top of PVC	2935.61			23.60	2912.01			23.48	2912.13			23.56	2912.05			23.65	2911.96	0.12	-0.08	-0.09
GW-1	11.9	21.9	24.0	Top of PVC	2933.94			14.81	2919.13			14.66	2919.28			14.72	2919.22			14.84	2919.10	0.15	-0.06	-0.12
GW-5	14.0	24.0	24.5	Top of PVC	2934.64			20.20	2914.44			20.06	2914.58			20.10	2914.54			20.21	2914.43	0.14	-0.04	-0.11
GWRM-1	15.0	25.0	25.0	Top of PVC	Unknown			Gate locked	---			20.25	---			20.27	---			20.40	---	---	---	---
GWRM-2	15.0	25.0	25.0	Top of PVC	Unknown			Gate locked	---			19.01	---			19.03	---			19.15	---	---	---	---
GWRR-1	11.9	21.9	24.0	Top of PVC	2929.32			14.29	2915.03			14.17	2915.15			14.21	2915.11			14.33	2914.99	0.12	-0.04	-0.12
GWRR-2	12.85	22.85	25.0	Top of PVC	2932.54			18.23	2914.31			18.1	2914.44			18.12	2914.42	18.3	0.01	18.31	2914.23	0.13	-0.02	-0.19
GWRR-3	8.65	18.65	20.0	Top of PVC	2928.75			11.71	2917.04			11.75	2917.00			11.77	2916.98			11.8	2916.95	-0.04	-0.02	-0.03
GWRR-4	4.75	14.75	20.0	Top of PVC	2931.76			13.75	2918.01			14	2917.76			13.82	2917.94			14.17	2917.59	-0.25	0.18	-0.35
GWRR-5	13.0	23.0	23.3	Top of PVC	2932.36	18.05	0.01	18.06	2914.30	17.91	0.01	17.92	2914.44	17.93	0.03	17.96	2914.40	18.06	0.02	18.08	2914.28	0.14	-0.04	-0.12
GWRR-6	4.75	14.75	25.0	Top of PVC	2930.34			11.11	2919.23			11.44	2918.90			11.60	2918.74			11.7	2918.64	-0.33	-0.16	-0.10
GWRR-7	6.25	16.25	16.5	Top of PVC	2931.12	12.39	0.37	12.76	2918.36	12.57	0.60	13.17	2917.95	12.47	0.65	13.12	2918.00	12.6	0.30	12.9	2918.22	-0.41	0.05	0.22
GWRR-8	20.5	30.5	32.0	Top of PVC	2938.15			23.80	2914.35			23.62	2914.53			23.65	2914.50			23.76	2914.39	0.18	-0.03	-0.11
GWRR-9	16.0	26.0	28.0	Top of PVC	2934.27			20.00	2914.27			19.85	2914.42			19.91	2914.36	20	0.01	20.01	2914.26	0.15	-0.06	-0.10
GWY-3	10.0	30.0	30.0	Top of PVC	2934.92			16.01	2918.91			15.99	2918.93			15.34	2919.58			16.01	2918.91	0.02	0.65	-0.67
GWY-4	10.0	30.0	30.0	Top of PVC	2934.06			19.90	2914.16			19.75	2914.31			19.80	2914.26			19.92	2914.14	0.15	-0.05	-0.12
GWY-10	10.0	30.0	30.0	Top of PVC	2933.75			19.62	2914.13			19.48	2914.27			19.53	2914.22			19.65	2914.10	0.14	-0.05	-0.12
GWY-12	10.0	30.0	30.0	Top of PVC	2933.13			18.87	2914.26			18.75	2914.38			18.79	2914.34			18.91	2914.22	0.12	-0.04	-0.12
GWY-13	10.0	30.0	30.0	Top of PVC	2932.56			18.38	2914.18			18.34	2914.22			18.29	2914.27			18.4	2914.16	0.04	0.05	-0.11
GWY-14	10.0	30.0	30.0	Top of PVC	2934.62			23.19	2911.43			23.7	2910.92			23.11	2911.51			23.2	2911.42	-0.51	0.59	-0.09
KPT-1	13.0	28.0	29.0	Top of PVC	2939.84			20.62	2919.22			20.44	2919.40			20.48	2919.36			20.6	2919.24	0.18	-0.04	-0.12
KPT-2	13.0	28.0	29.0	Top of Steel	2938.55			19.40	2919.15	19.26	0.02	19.28	2919.27	19.31	0.05	19.36	2919.19	19.44	0.06	19.5	2919.05	0.12	-0.08	-0.14
KPT-3	13.0	28.0	29.0	Top of PVC	2937.17			18.50	2918.67	18.34	0.03	18.37	2918.80			18.40	2918.77	18.52	0.05	18.57	2918.60	0.13	-0.03	-0.17
KPT-4	13.0	28.0	29.0	Top of PVC	2935.44			19.49	2915.95			19.38	2916.06			19.39	2916.05			19.51	2915.93	0.11	-0.01	-0.12
KPT-5	13.0	28.0	29.0	Top of PVC	2934.66			19.17	2915.49			18.99	2915.67			19.07	2915.59			19.16	2915.50	0.18	-0.08	-0.09
KPT-6	13.0	28.0	29.0	Top of PVC	2936.18			17.55	2918.63			17.42	2918.76			17.48	2918.70	17.57	0.01	17.58	2918.60	0.13	-0.06	-0.10
KPT-7	12.5	27.5	28.5	Top of PVC	2935.31			18.65	2916.66			18.53	2916.78			18.59	2916.72			18.7	2916.61	0.12	-0.06	-0.11
KPT-8	110.0	120.0	122.0	Top of PVC	2935.16	18.55	0.01	18.56	2916.60			18.43	2916.73			18.50	2916.66	18.6	0.01	18.61	2916.55	0.13	-0.07	-0.11
KPT-9	6.0	16.0	23.0	Top of Steel	2925.77			7.81	2917.96			7.75	2918.02			7.80	2917.97			7.92	2917.85	0.06	-0.05	-0.12
KPT-10	8.0	23.0	27.0	Top of PVC	2925.35			10.25	2915.10			10.15	2915.20			10.20	2915.15			10.34	2915.01	0.10	-0.05	-0.14
KPT-11	52.0	72.0	74.0	Top of PVC	2925.84			10.77	2915.07			10.65	2915.19			10.70	2915.14	10.81	0.01	10.82	2915.02	0.12	-0.05	-0.12
KPT-12	14.0	24.0	24.5	Top of PVC	2939.51			20.35	2919.16			20.18	2919.33			20.25	2919.26	20.36	0.01	20.37	2919.14	0.17	-0.07	-0.12
KPT-13	109.0	119.0	120.0	Top of PVC	2927.55			9.94	2917.61			9.82	2917.73			9.86	2917.69			9.98	2917.57	0.12	-0.04	-0.12
KPT-14	96.0	106.0	109.0	Top of PVC	2925.95			10.92	2915.03			10.81	2915.14			10.85	2915.10			10.97	2914.98	0.11	-0.04	-0.12
KPT-15	101.0	111.0	117.0	Top of PVC	2934.80			20.41	2914.39			20.27	2914.53			20.31	2914.49			20.43	2914.37	0.14	-0.04	-0.12
KPT-16	14.0	29.0	29.5	Top of PVC	2935.66			21.21	2914.45			21.06	2914.60			21.11	2914.55			21.21	2914.45	0.15	-0.05	-0.10
KPT-17	7.5	12.5	13.0	Top of PVC	2929.58			11.25	2918.33			11.37	2918.21			11.26	2918.32	11.31	0.01	11.32	2918.26	-0.12	0.11	-0.06
KPT-18	24.0	34.0	34.5	Top of PVC	2929.71			13.17	2916.54			13.21	2916.50			13.08	2916.63	13.2	0.01	13.21	2916.50	-0.04	0.13	-0.13
KPT-19	13.00	23.00	23.50	Top of PVC	2932.89			17.93	2914.96			17.8	2915.09	17.87	0.01	17.88	2915.01	17.96	0.02	17.98	2914.91	0.13	-0.08	-0.10
KPT-20	10.00	20.00	20.00	Top of PVC	2932.90			17.51	2915.39			17.38	2915.52			17.43	2915.47			17.56	2915.34	0.13	-0.05	-0.13
KPT-21	8.00	23.00	23.00	Top of PVC	2933.50			18.62	2914.88			18.49	2915.01			18.54	2914.96			18.64	2914.86	0.13	-0.05	-0.10
KPT-22	6.00	16.00	16.00	Top of PVC	2926.78			11.63	2915.15			11.54	2915.24			11.58	2915.20			11.7	2915.08	0.09	-0.04	-0.12
KRY100A	6	26	28	Top of PVC	2936.60			11.29	2925.31			11.12	2925.48			11.01	2925.59			11.1	2925.50	0.17	0.11	-0.09
KRY101A	9	29	31	Top of PVC	2941.08			17.78	2923.30			covered	---			17.70	2923.38			17.84	2923.24	---	---	-0.14
KRY101B	85	95	100	Top of PVC	2940.80			17.80	2923.00			covered	---			17.71	2923.09	17.85	0.01	17.86	2922.94	---	---	-0.15
KRY102A	13	33	33.5	Top of PVC	2945.27			25.98	2919.29			25.41	2919.86			25.45	2919.82			25.57	2919.70	0.57	-0.04	-0.12
KRY102B	95	105	110	Top of PVC	2945.26			25.55	2919.71			25.39	2919.87			25.46	2919.80			25.61	2919.65	0.16	-0.07	-0.15
KRY103A	5	25	27	Top of PVC	2940.30			13.84	2926.46			13.66	2926.64			13.73	2926.57			13.88	2926.42	0.18	-0.07	-0.15
KRY103B	55	65	70	Top of PVC	2939.94			13.36	2926.58			13.2	2926.74			13.28	2926.66			13.4	2926.54	0.16	-0.08	-0.12
KRY104A	20	40	40.5	Top of PVC	2946.68			27.64	2919.04			27.47	2919.21			27.49	2919.19			27.63	2919.05	0.17	-0.02	-0.14
KRY105A	5	25	27	Top of PVC	2932.27			8.61	2923.66			8.45	2923.82			8.63	2923.64			8.85	2923.42	0.16	-0.18	-0.22
KRY106A	6	26	28	Top of PVC	2932.25			11.88	2920.37			11.78	2920.47			11.81	2920.44			11.96	2920.29	0.10	-0.03	-0.15
KRY106B	73	83	88	Top of PVC	2932.42			11.78	2920.64			11.65	2920.77			11.69	2920.73			11.82	2920.60	0.13	-0.04	-0.13
KRY107A	9	29	29.5	Top of PVC	2938.92			19.74	2919.18			19.57	2919.35			19.61	2919.31			19.73	2919.19	0.17	-0.04	-0.12
KRY107B	121	131	136	Top of PVC	2938.73			22.12	2916.61			21.99	2916.74			21.98	2916.75			22.11	2916.62	0.13	0.01	-0.13

TABLE 2-2b
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information						November 2006				December 2006				January 2007				February 2007						
Well Number	**Top of Screen (ft bgs)**	**Bottom of Screen (ft bgs)**	**Well Depth (ft bgs)**	**Measuring Point**	**Measuring Point Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Change Nov to Dec**	**Change Dec to Jan**	**Change Jan to Feb**
KRY108A	10	30	32	Top of PVC	2941.11			21.82	2919.29			21.63	2919.48			21.68	2919.43			21.81	2919.30	0.19	-0.05	-0.13
KRY109A	5	25	27	Top of PVC	2928.85			11.20	2917.65			11.01	2917.84			11.00	2917.85			11.16	2917.69	0.19	0.01	-0.16
KRY110A	35	55	55	Top of PVC	2926.90			9.58	2917.32			9.5	2917.40			9.56	2917.34			9.68	2917.22	0.08	-0.06	-0.12
KRY110B	76	86	91	Top of PVC	2926.96			10.31	2916.65			10.24	2916.72			10.25	2916.71			10.37	2916.59	0.07	-0.01	-0.12
KRY111A	5	25	25.5	Top of PVC	2936.61			21.26	2915.35	21.13	0.03	21.16	2915.45	21.11	0.02	21.13	2915.48	21.36	0.06	21.42	2915.19	0.10	0.03	-0.29
KRY111B	123	133	138	Top of PVC	2936.96			20.24	2916.72			20.12	2916.84			20.16	2916.80			20.31	2916.65	0.12	-0.04	-0.15
KRY112A	9	29	29.5	Top of PVC	2935.59			20.25	2915.34			20.12	2915.47			20.16	2915.43			20.27	2915.32	0.13	-0.04	-0.11
KRY112B	110	120	125	Top of PVC	2935.78			20.26	2915.52			20.12	2915.66			20.17	2915.61	20.28	0.01	20.29	2915.49	0.14	-0.05	-0.12
KRY113A	15	35	37	Top of PVC	2940.77			21.42	2919.35			21.26	2919.51			21.30	2919.47			21.41	2919.36	0.16	-0.04	-0.11
KRY113B	102	112	117	Top of PVC	2940.96			21.88	2919.08			21.74	2919.22			21.76	2919.20			21.9	2919.06	0.14	-0.02	-0.14
KRY114A	7	27	29	Top of PVC	2934.65	19.56	0.06	19.62	2915.03	19.45	0.05	19.5	2915.15	19.47	0.11	19.58	2915.07	19.61	0.14	19.75	2914.90	0.12	-0.08	-0.17
KRY114B	108	118	122	Top of PVC	2935.09			19.75	2915.34			19.64	2915.45			19.69	2915.40			19.83	2915.26	0.11	-0.05	-0.14
KRY115A	12	32	32.5	Top of PVC	2936.78			22.31	2914.47			22.17	2914.61			22.21	2914.57	22.3	0.01	22.31	2914.47	0.14	-0.04	-0.10
KRY115B	107	117	122	Top of PVC	2936.68			22.03	2914.65			21.91	2914.77			21.95	2914.73			22.09	2914.59	0.12	-0.04	-0.14
KRY116A	7	27	29.5	Top of PVC	2931.53			16.69	2914.84			16.57	2914.96			16.60	2914.93			16.76	2914.77	0.12	-0.03	-0.16
KRY116B	95.5	105.5	110.5	Top of PVC	2931.97			17.23	2914.74			17.11	2914.86			17.14	2914.83			17.28	2914.69	0.12	-0.03	-0.14
KRY117A	5	29	27	Top of PVC	2929.25			15.02	2914.23			14.93	2914.32			14.96	2914.29			15.09	2914.16	0.09	-0.03	-0.13
KRY118A	6	26	28	Top of PVC	2924.44			11.41	2913.03			11.35	2913.09			11.36	2913.08			11.45	2912.99	0.06	-0.01	-0.09
KRY118B	95	105	110	Top of PVC	2924.21			11.14	2913.07			11.11	2913.10			11.06	2913.15			11.15	2913.06	0.03	0.05	-0.09
KRY119A	5	25	25	Top of PVC	2929.69	14.29	0.01	14.30	2915.39			14.31	2915.38			14.23	2915.46			14.34	2915.35	-0.01	0.08	-0.11
KRY121A	12	32	32.5	Top of PVC	2937.39			23.06	2914.33			22.91	2914.48	22.92	0.01	22.93	2914.46			23.05	2914.34	0.15	-0.02	-0.12
KRY121B	119	129	134	Top of PVC	2937.35			23.13	2914.22			22.97	2914.38			23.02	2914.33			23.15	2914.20	0.16	-0.05	-0.13
KRY122A	7	27	29	Top of PVC	2930.07			15.95	2914.12			15.83	2914.24			15.85	2914.22			16.09	2913.98	0.12	-0.02	-0.24
KRY122B	83	93	98	Top of PVC	2929.80			15.69	2914.11			15.55	2914.25			15.61	2914.19			15.78	2914.02	0.14	-0.06	-0.17
KRY123A	5	25	25	Top of PVC	2928.93			16.30	2912.63			16.19	2912.74			16.24	2912.69			16.35	2912.58	0.11	-0.05	-0.11
KRY125A	5	25	25	Top of PVC	2934.75			Gate locked	---			16.7	2918.05			16.75	2918.00			16.97	2917.78	---	-0.05	-0.22
KRY125B	116	126	126	Top of PVC	2934.40			Gate locked	---			24.15	2910.25			24.19	2910.21			24.33	2910.07	---	-0.04	-0.14
KRY126A	5	25	27	Top of PVC	2927.54	14.50	0.01	14.51	2913.03			14.83	2912.71			14.89	2912.65			14.99	2912.55	-0.32	-0.06	-0.10
KRY127A	5	25	27	Top of PVC	2923.05			10.38	2912.67			10.25	2912.80			10.30	2912.75			10.41	2912.64	0.13	-0.05	-0.11
KRY128A	5	25	27.5	Top of PVC	2928.07			14.80	2913.27			14.8	2913.27			14.86	2913.21			14.84	2913.23	0.00	-0.06	0.02
KRY128B	145	155	160	Top of PVC	2928.05			16.88	2911.17			16.82	2911.23			16.89	2911.16			17.01	2911.04	0.06	-0.07	-0.12
KRY129A	9	29	31	Top of PVC	2931.84			12.56	2919.28			14.04	2917.80			14.42	2917.42			14.9	2916.94	-1.48	-0.38	-0.48
KRY129B	127	137	142	Top of PVC	2931.10			21.85	2909.25			21.71	2909.39			21.76	2909.34			21.93	2909.17	0.14	-0.05	-0.17
KRY130A	25	45	45	Top of PVC	2926.68			16.08	2910.60			16	2910.68			16.01	2910.67	16.08	0.01	16.09	2910.59	0.08	-0.01	-0.08
KRY130B	153	163	168	Top of PVC	2926.85			16.49	2910.36			16.37	2910.48			16.40	2910.45			16.47	2910.38	0.12	-0.03	-0.07
KRY132A	6	26	28.5	Top of PVC	2930.75			11.00	2919.75	10.91	0.01	10.92	2919.83			10.94	2919.81			11.08	2919.67	0.08	-0.02	-0.14
KRY133A	8	28	30	Top of PVC	2939.44			20.26	2919.18			20.06	2919.38			20.12	2919.32			20.5	2918.94	0.20	-0.06	-0.38
KRY134A	8	28	30	Top of PVC	2935.11			20.00	2915.11			19.91	2915.20			19.96	2915.15			20.11	2915.00	0.09	-0.05	-0.15
KRY135A	5	25	25	Top of PVC	2931.22	13.99	2.73	16.72	2914.50	14.07	2.51	16.58	2914.64	13.85	3.12	16.97	2914.25	14.1	2.60	16.7	2914.52	0.14	-0.39	0.27
KRY136A	5	25	25	Top of PVC	2935.39	20.90	0.30	21.20	2914.19	20.75	0.25	21	2914.39	20.78	0.22	21.00	2914.39	20.9	0.35	21.25	2914.14	0.20	0.00	-0.25
KRY137A	5	25	25	Top of PVC	2929.90			12.26	2917.64			12.5	2917.40			12.27	2917.63			12.43	2917.47	-0.24	0.23	-0.16
KRY138A	5	25	25	Top of PVC	2934.14			20.82	2913.32			20.69	2913.45			20.72	2913.42	20.84	0.01	20.85	2913.29	0.13	-0.03	-0.13
KRY139A	7	27	29	Top of PVC	2919.51			12.41	2907.10			12.22	2907.29			12.27	2907.24			12.43	2907.08	0.19	-0.05	-0.16
KRY139B	166	176	181	Top of PVC	2919.24			11.42	2907.82			11.23	2908.01			11.32	2907.92			14.52	2904.72	0.19	-0.09	-3.20
NTL-MW-3	5.2	15.2	15.2	Top of PVC	2915.31			6.91	2908.40			6.82	2908.49			6.92	2908.39	7.10	0.01	7.11	2908.20	0.09	-0.10	-0.19
NTL-MW-4	5.70	15.70	16.00	Top of PVC	2917.76			11.38	2906.38			11.18	2906.58			11.23	2906.53	11.36	0.01	11.37	2906.39	0.20	-0.05	-0.14
NW-1	10.0	30.0	30.5	Top of PVC	2923.79			---	---			---	---			---	---			---	---	---	---	---
NW-2	11.5	26.5	26.9	Top of PVC	2919.14			---	---			---	---			---	---			---	---	---	---	---
NW-4	12.2	32.2	33.0	Top of PVC	2925.77			---	---			---	---			---	---			---	---	---	---	---
PW-1	14.5	24.6	25.0	Top of PVC	2926.67			19.74	2906.93			19.59	2907.08			19.61	2907.06			19.77	2906.90	0.15	-0.02	-0.16
PW-2C	15.0	25.0	25.0	Top of PVC	2924.58			---	---			---	---			---	---			---	---	---	---	---
PW-2D	12.0	22.0	22.0	Top of PVC	2924.47			---	---			---	---			---	---			---	---	---	---	---
PW-3	12.0	22.0	22.0	Top of PVC	2922.55			16.73	2905.82			16.64	2905.91			16.61	2905.94			16.71	2905.84	0.09	0.03	-0.10
SW-9	10.0	20.0	20.0	Top of PVC	2922.82	15.48	0.01	15.49	2907.33			15.3	2907.52			15.39	2907.43			15.48	2907.34	0.19	-0.09	-0.09

TABLE 2-2b
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information						November 2006				December 2006				January 2007				February 2007						
Well Number	**Top of Screen (ft bgs)**	**Bottom of Screen (ft bgs)**	**Well Depth (ft bgs)**	**Measuring Point**	**Measuring Point Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Change Nov to Dec**	**Change Dec to Jan**	**Change Jan to Feb**
OMW1	12.0	27.0	27.5	Top of PVC	2929.20			11.02	2918.18			10.96	2918.24			11.00	2918.20	11.11	0.01	11.12	2918.08	0.06	-0.04	-0.12
OMW2	12.0	27.0	27.5	Top of PVC	2934.84			19.59	2915.25			19.34	2915.50			19.38	2915.46	19.48	0.01	19.49	2915.35	0.25	-0.04	-0.11
OMW3	12.0	27.0	27.5	Top of PVC	2927.52			12.03	2915.49			11.91	2915.61			11.96	2915.56	12.08	0.01	12.09	2915.43	0.12	-0.05	-0.13
OMW4	12.0	27.0	27.5	Top of PVC	2935.10	20.02	0.08	20.10	2915.00	19.91	0.05	19.96	2915.14	19.96	1.07	21.03	2914.07	20.06	0.09	20.15	2914.95	0.14	-1.07	0.88
OMW5	Unknown	Unknown	Unknown	Top of PVC	2934.71	19.68	0.10	19.78	2914.93	19.58	0.03	19.61	2915.10	19.61	0.18	19.79	2914.92	19.73	0.24	19.97	2914.74	0.17	-0.18	-0.18
OMW6	Unknown	Unknown	Unknown	Top of PVC	2935.59			19.44	2916.15			19.35	2916.24			19.36	2916.23			19.49	2916.10	0.09	-0.01	-0.13
OSW1	11.0	26.0	26.0	Top of PVC	2936.24			16.95	2919.29			16.82	2919.42	16.85	0.05	16.90	2919.34	16.99	0.05	17.04	2919.20	0.13	-0.08	-0.14
OSW2	11.0	26.0	26.0	Top of PVC	2934.32			17.44	2916.88			17.29	2917.03	17.35	0.02	17.37	2916.95	17.47	0.28	17.75	2916.57	0.15	-0.08	-0.38
SBM1	17.0	28.0	30.6	Top of PVC	2936.64			19.91	2916.73			19.8	2916.84			19.82	2916.82			19.96	2916.68	0.11	-0.02	-0.14
SBM2	17.0	28.0	30.2	Top of PVC	2937.11			21.83	2915.28			20.72	2916.39			20.75	2916.36			20.88	2916.23	1.11	-0.03	-0.13

Notes:

1. Water level corrected for LNAPL in wells with LNAPL
2. Correction factor for wells with LNAPL $h_c = h_m + (H_o (d_o/d_w))$

h_c - Hydraulic head corrected

h_m - Measured elevation of hydrocarbon-water interface

H_o - Thickness of hydrocarbon layer

d_o - Hydrocarbon density (for diesel = 0.827)

d_w - Water density (assumed = 1.0)

ft - Feet

bgs - Below ground surface

amsl - Above mean sea level

GW - Groundwater

PVC - Polyvinyl chloride (well casing)

LNAPL - Light nonaqueous phase liquid (petroluem hydrocarbon, PCP)

SWL - Static water level

Blank cell indicates no measureable LNAPL present

--- Not measured

Note: Field notes that included "no evidence of product" and the presence of "brown flecks or algae" were eliminated from this data summary as product detected in the respective well.

TABLE 2-2c
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information						March 2007				April 2007				May 2007				June 2007						
Well Number	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Well Depth (ft bgs)	Measuring Point	Measuring Point Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Change Mar to Apr	Change Apr to May	Change May to June
CLCW-1				Top of PVC	2935.61			23.36	2912.25			21.94	2913.67			21.51	2914.10			22.78	2912.83	1.42	0.43	-1.27
GW-1	11.9	21.9	24.0	Top of PVC	2933.94			14.47	2919.47			13.33	2920.61			12.88	2921.06			13.18	2920.76	1.14	0.45	-0.30
GW-5	14.0	24.0	24.5	Top of PVC	2934.64			19.80	2914.84			18.83	2915.81			18.34	2916.30			18.88	2915.76	0.97	0.49	-0.54
GWRM-1	15.0	25.0	25.0	Top of PVC	Unknown			20.06	---			19.05	---			18.44	---			18.95	---	---	---	---
GWRM-2	15.0	25.0	25.0	Top of PVC	Unknown			18.80	---			17.82	---			17.33	---			17.80	---	---	---	---
GWRR-1	11.9	21.9	24.0	Top of PVC	2929.32			13.90	2915.42	12.83	0.01	12.84	2916.48			12.38	2916.94			12.94	2916.38	1.06	0.46	-0.56
GWRR-2	12.85	22.85	25.0	Top of PVC	2932.54			12.89	2919.65			16.9	2915.64			16.44	2916.10			16.96	2915.58	-4.01	0.46	-0.52
GWRR-3	8.65	18.65	20.0	Top of PVC	2928.75			11.51	2917.24			11.62	2917.13			11.69	2917.06			11.74	2917.01	-0.11	-0.07	-0.05
GWRR-4	4.75	14.75	20.0	Top of PVC	2931.76			11.91	2919.85			12.09	2919.67			12.66	2919.10			12.66	2919.10	-0.18	-0.57	0.00
GWRR-5	13.0	23.0	23.3	Top of PVC	2932.36			12.67	2919.69			16.68	2915.68			16.22	2916.14			16.75	2915.61	-4.01	0.46	-0.53
GWRR-6	4.75	14.75	25.0	Top of PVC	2930.34			10.25	2920.09			10.33	2920.01			10.47	2919.87			10.55	2919.79	-0.08	-0.14	-0.08
GWRR-7	6.25	16.25	16.5	Top of PVC	2931.12	11.27	0.23	11.50	2919.62	11.55	0.26	11.81	2919.31	11.92	0.46	12.38	2918.74	12.05	0.2	12.25	2918.87	-0.31	-0.57	0.13
GWRR-8	20.5	30.5	32.0	Top of PVC	2938.15			23.38	2914.77			22.42	2915.73			21.98	2916.17			22.47	2915.68	0.96	0.44	-0.49
GWRR-9	16.0	26.0	28.0	Top of PVC	2934.27			19.65	2914.62			19.65	2914.62			18.14	2916.13			18.7	2915.57	0.00	1.51	-0.56
GWY-3	10.0	30.0	30.0	Top of PVC	2934.92			16.01	2918.91			16.12	2918.80			15.63	2919.29			15.13	2919.79	-0.11	0.49	0.50
GWY-4	10.0	30.0	30.0	Top of PVC	2934.06			19.57	2914.49			18.56	2915.50			18.06	2916.00			18.58	2915.48	1.01	0.50	-0.52
GWY-10	10.0	30.0	30.0	Top of PVC	2933.75			19.30	2914.45			18.3	2915.45			17.79	2915.96			18.31	2915.44	1.00	0.51	-0.52
GWY-12	10.0	30.0	30.0	Top of PVC	2933.13			18.56	2914.57			17.55	2915.58			17.07	2916.06			17.6	2915.53	1.01	0.48	-0.53
GWY-13	10.0	30.0	30.0	Top of PVC	2932.56			18.06	2914.50			17.04	2915.52			16.57	2915.99			17.08	2915.48	1.02	0.47	-0.51
GWY-14	10.0	30.0	30.0	Top of PVC	2934.62			22.93	2911.69			21.52	2913.10			21.10	2913.52			22.42	2912.20	1.41	0.42	-1.32
KPT-1	13.0	28.0	29.0	Top of PVC	2939.84			20.24	2919.60			19.08	2920.76			18.65	2921.19			18.96	2920.88	1.16	0.43	-0.31
KPT-2	13.0	28.0	29.0	Top of Steel	2938.55	19.08	0.02	19.10	2919.45	18	0.01	18.01	2920.54	17.55	0.03	17.58	2920.97	17.83	0.07	17.9	2920.65	1.09	0.43	-0.32
KPT-3	13.0	28.0	29.0	Top of PVC	2937.17			18.14	2919.03			17.06	2920.11			17.59	2919.58			16.91	2920.26	1.08	-0.53	0.68
KPT-4	13.0	28.0	29.0	Top of PVC	2935.44			19.12	2916.32			19.15	2916.29			17.61	2917.83			17.97	2917.47	-0.03	1.54	-0.36
KPT-5	13.0	28.0	29.0	Top of PVC	2934.66			18.75	2915.91			17.73	2916.93			17.20	2917.46			17.65	2917.01	1.02	0.53	-0.45
KPT-6	13.0	28.0	29.0	Top of PVC	2936.18			17.20	2918.98			16.07	2920.11			15.63	2920.55			15.95	2920.23	1.13	0.44	-0.32
KPT-7	12.5	27.5	28.5	Top of PVC	2935.31			18.28	2917.03			17.2	2918.11			16.75	2918.56			17.21	2918.10	1.08	0.45	-0.46
KPT-8	110.0	120.0	122.0	Top of PVC	2935.16			18.19	2916.97			17.09	2918.07			17.64	2917.52			17.13	2918.03	1.10	-0.55	0.51
KPT-9	6.0	16.0	23.0	Top of Steel	2925.77			7.51	2918.26			6.07	2919.70			6.48	2919.29			6.18	2919.59	1.44	-0.41	0.30
KPT-10	8.0	23.0	27.0	Top of PVC	2925.35			9.81	2915.54			8.78	2916.57			8.32	2917.03			8.88	2916.47	1.03	0.46	-0.56
KPT-11	52.0	72.0	74.0	Top of PVC	2925.84			10.38	2915.46			9.32	2916.52			8.85	2916.99			9.46	2916.38	1.06	0.47	-0.61
KPT-12	14.0	24.0	24.5	Top of PVC	2939.51			20.00	2919.51			18.93	2920.58			18.49	2921.02			---	---	1.07	0.44	---
KPT-13	109.0	119.0	120.0	Top of PVC	2927.55			9.58	2917.97			8.35	2919.20			7.97	2919.58			8.41	2919.14	1.23	0.38	-0.44
KPT-14	96.0	106.0	109.0	Top of PVC	2925.95			10.54	2915.41			9.5	2916.45			9.06	2916.89			9.6	2916.35	1.04	0.44	-0.54
KPT-15	101.0	111.0	117.0	Top of PVC	2934.80			20.02	2914.78			19.06	2915.74			18.56	2916.24			19.08	2915.72	0.96	0.50	-0.52
KPT-16	14.0	29.0	29.5	Top of PVC	2935.66			20.82	2914.84			19.85	2915.81			19.36	2916.30			19.89	2915.77	0.97	0.49	-0.53
KPT-17	7.5	12.5	13.0	Top of PVC	2929.58			10.28	2919.30			10.32	2919.26			10.66	2918.92			10.85	2918.73	-0.04	-0.34	-0.19
KPT-18	24.0	34.0	34.5	Top of PVC	2929.71			12.17	2917.54	12.45	0.01	12.46	2917.25			12.58	2917.13			12.75	2916.96	-0.29	-0.12	-0.17
KPT-19	13.00	23.00	23.50	Top of PVC	2932.89			17.56	2915.33			16.51	2916.38			16.10	2916.79			16.59	2916.30	1.05	0.41	-0.49
KPT-20	10.00	20.00	20.00	Top of PVC	2932.90			16.96	2915.94			16.09	2916.81			15.68	2917.22			16.13	2916.77	0.87	0.41	-0.45
KPT-21	8.00	23.00	23.00	Top of PVC	2933.50			18.19	2915.31			17.2	2916.30			16.77	2916.73			17.27	2916.23	0.99	0.43	-0.50
KPT-22	6.00	16.00	16.00	Top of PVC	2926.78			11.25	2915.53			10.14	2916.64			9.69	2917.09			10.25	2916.53	1.11	0.45	-0.56
KRY100A	6	26	28	Top of PVC	2936.60			frozen	---			9.64	2926.96			9.32	2927.28			9.64	2926.96	---	0.32	-0.32
KRY101A	9	29	31	Top of PVC	2941.08			17.55	2923.53			16.46	2924.62			16.06	2925.02			16.29	2924.79	1.09	0.40	-0.23
KRY101B	85	95	100	Top of PVC	2940.80			17.55	2923.25			16.41	2924.39			16.00	2924.80			16.27	2924.53	1.14	0.41	-0.27
KRY102A	13	33	33.5	Top of PVC	2945.27			25.17	2920.10			24.24	2921.03			23.85	2921.42			24.03	2921.24	0.93	0.39	-0.18
KRY102B	95	105	110	Top of PVC	2945.26			25.20	2920.06			24.27	2920.99			23.86	2921.40			24.03	2921.23	0.93	0.41	-0.17
KRY103A	5	25	27	Top of PVC	2940.30			13.73	2926.57			12.29	2928.01			12.02	2928.28			12.27	2928.03	1.44	0.27	-0.25
KRY103B	55	65	70	Top of PVC	2939.94			13.26	2926.68			11.91	2928.03			11.55	2928.39			11.82	2928.12	1.35	0.36	-0.27
KRY104A	20	40	40.5	Top of PVC	2946.68			27.25	2919.43			26.28	2920.40			25.80	2920.88			26.03	2920.65	0.97	0.48	-0.23
KRY105A	5	25	27	Top of PVC	2932.27			8.58	2923.69			7.2	2925.07			6.91	2925.36			7.23	2925.04	1.38	0.29	-0.32
KRY106A	6	26	28	Top of PVC	2932.25			11.52	2920.73	10.24	0.01	10.25	2922.00			9.88	2922.37			10.23	2922.02	1.27	0.37	-0.35
KRY106B	73	83	88	Top of PVC	2932.42			11.44	2920.98			10.21	2922.21			9.83	2922.59			10.17	2922.25	1.23	0.38	-0.34
KRY107A	9	29	29.5	Top of PVC	2938.92			19.35	2919.57			18.3	2920.62			17.86	2921.06			18.11	2920.81	1.05	0.44	-0.25
KRY107B	121	131	136	Top of PVC	2938.73			21.78	2916.95			20.81	2917.92			20.33	2918.40			20.61	2918.12	0.97	0.48	-0.28
KRY108A	10	30	32	Top of PVC	2941.11			21.44	2919.67	20.29	0.01	20.3	2920.81			19.85	2921.26			20.18	2920.93	1.14	0.45	-0.33
KRY109A	5	25	27	Top of PVC	2928.85			10.84	2918.01			9.89	2918.96			9.66	2919.19			9.9	2918.95	0.95	0.23	-0.24
KRY110A	35	55	55	Top of PVC	2926.90			9.25	2917.65			7.85	2919.05			7.53	2919.37			7.96	2918.94	1.40	0.32	-0.43
KRY110B	76	86	91	Top of PVC	2926.96			9.95	2917.01			8.65	2918.31			8.32	2918.64			8.74	2918.22	1.30	0.33	-0.42
KRY111A	5	25	25.5	Top of PVC	2936.61	20.98	0.02	21.00	2915.61	19.92	0.43	20.35	2916.26	19.42	0.79	20.21	2916.40	18.81	2.19	21	2915.61	0.65	0.14	-0.79

TABLE 2-2c
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information						March 2007				April 2007				May 2007				June 2007						
Well Number	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Well Depth (ft bgs)	Measuring Point	Measuring Point Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Change Mar to Apr	Change Apr to May	Change May to June
KRY111B	123	133	138	Top of PVC	2936.96			19.93	2917.03			18.91	2918.05			18.47	2918.49			18.83	2918.13	1.02	0.44	-0.36
KRY112A	9	29	29.5	Top of PVC	2935.59			19.94	2915.65			18.95	2916.64			18.35	2917.24			18.61	2916.98	0.99	0.60	-0.26
KRY112B	110	120	125	Top of PVC	2935.78			19.97	2915.81			19.04	2916.74			18.53	2917.25			18.8	2916.98	0.93	0.51	-0.27
KRY113A	15	35	37	Top of PVC	2940.77			21.05	2919.72			19.92	2920.85			19.47	2921.30			19.78	2920.99	1.13	0.45	-0.31
KRY113B	102	112	117	Top of PVC	2940.96			21.54	2919.42			20.49	2920.47			19.97	2920.99			20.29	2920.67	1.05	0.52	-0.32
KRY114A	7	27	29	Top of PVC	2934.65			19.18	2915.47			18.17	2916.48			17.68	2916.97	18.21	0.36	18.57	2916.08	1.01	0.49	-0.89
KRY114B	108	118	122	Top of PVC	2935.09			19.43	2915.66			18.4	2916.69			18.91	2916.18			18.52	2916.57	1.03	-0.51	0.39
KRY115A	12	32	32.5	Top of PVC	2936.78			21.93	2914.85			19.99	2916.79			20.54	2916.24			21.03	2915.75	1.94	-0.55	-0.49
KRY115B	107	117	122	Top of PVC	2936.68			21.75	2914.93			20.8	2915.88			20.30	2916.38			20.67	2916.01	0.95	0.50	-0.37
KRY116A	7	27	29.5	Top of PVC	2931.53			16.30	2915.23			15.54	2915.99			15.00	2916.53			15.25	2916.28	0.76	0.54	-0.25
KRY116B	95.5	105.5	110.5	Top of PVC	2931.97			16.97	2915.00			16.05	2915.92			15.51	2916.46			15.8	2916.17	0.92	0.54	-0.29
KRY117A	5	29	27	Top of PVC	2929.25			14.64	2914.61			13.58	2915.67			13.13	2916.12			13.69	2915.56	1.06	0.45	-0.56
KRY118A	6	26	28	Top of PVC	2924.44			11.02	2913.42			9.52	2914.92			9.32	2915.12			11.29	2913.15	1.50	0.20	-1.97
KRY118B	95	105	110	Top of PVC	2924.21			10.84	2913.37			9.5	2914.71			9.40	2914.81			11.11	2913.10	1.34	0.10	-1.71
KRY119A	5	25	25	Top of PVC	2929.69			12.84	2916.85			13.25	2916.44			13.64	2916.05			13.92	2915.77	-0.41	-0.39	-0.28
KRY121A	12	32	32.5	Top of PVC	2937.39			22.66	2914.73			21.71	2915.68			21.26	2916.13			21.76	2915.63	0.95	0.45	-0.50
KRY121B	119	129	134	Top of PVC	2937.35			22.79	2904.75			21.79	2915.56			21.34	2916.01			21.88	2915.47	10.81	0.45	-0.54
KRY122A	7	27	29	Top of PVC	2930.07			15.81	2914.26			14.87	2915.20			13.95	2916.12			14.42	2915.65	0.94	0.92	-0.47
KRY122B	83	93	98	Top of PVC	2929.80			15.56	2914.24			14.52	2915.28			14.28	2915.52			14.18	2915.62	1.04	0.24	0.10
KRY123A	5	25	25	Top of PVC	2928.93			16.03	2912.90			14.73	2914.20			14.64	2914.29			16.02	2912.91	1.30	0.09	-1.38
KRY125A	5	25	25	Top of PVC	2934.75			16.71	2918.04			16.42	2918.33			16.34	2918.41			16.24	2918.51	0.29	0.08	0.10
KRY125B	116	126	126	Top of PVC	2934.40			24.18	2910.22			23	2911.40			22.44	2911.96			22.77	2911.63	1.18	0.56	-0.33
KRY126A	5	25	27	Top of PVC	2927.54			14.63	2912.91			13.36	2914.18			13.28	2914.26			14.65	2912.89	1.27	0.08	-1.37
KRY127A	5	25	27	Top of PVC	2923.05			10.08	2912.97			8.76	2914.29			8.88	2914.17			10.33	2912.72	1.32	-0.12	-1.45
KRY128A	5	25	27.5	Top of PVC	2928.07			14.53	2913.54			13.22	2914.85			12.94	2915.13			14.86	2913.21	1.31	0.28	-1.92
KRY128B	145	155	160	Top of PVC	2928.05			16.65	2911.40			15.28	2912.77			14.99	2913.06			16.51	2911.54	1.37	0.29	-1.52
KRY129A	9	29	31	Top of PVC	2931.84			15.09	2916.75			14.65	2917.19			17.39	2914.45			14.47	2917.37	0.44	-2.74	2.92
KRY129B	127	137	142	Top of PVC	2931.10			21.72	2909.38			20.36	2910.74			19.90	2911.20			20.5	2910.60	1.36	0.46	-0.60
KRY130A	25	45	45	Top of PVC	2926.68			15.87	2910.81			14.42	2912.26			14.09	2912.59			15.5	2911.18	1.45	0.33	-1.41
KRY130B	153	163	168	Top of PVC	2926.85			16.25	2910.60			14.85	2912.00			14.51	2912.34			15.8	2911.05	1.40	0.34	-1.29
KRY132A	6	26	28.5	Top of PVC	2930.75			10.46	2920.29			9.21	2921.54			8.80	2921.95			9.27	2921.48	1.25	0.41	-0.47
KRY133A	8	28	30	Top of PVC	2939.44			19.88	2919.56			18.84	2920.60			18.37	2921.07	18.76	-0.11	18.65	2920.79	1.04	0.47	-0.28
KRY134A	8	28	30	Top of PVC	2935.11			19.67	2915.44			18.64	2916.47			18.15	2916.96			18.71	2916.40	1.03	0.49	-0.56
KRY135A	5	25	25	Top of PVC	2931.22	11.90	0.90	12.80	2918.42	12.18	0.86	13.04	2918.18	13.21	1.84	15.05	2916.17	13.41	0.46	13.87	2917.35	-0.24	-2.01	1.18
KRY136A	5	25	25	Top of PVC	2935.39	20.52	0.24	20.76	2914.63	19.51	0.37	19.88	2915.51	19.03	0.86	19.89	2915.50	19.57	0.45	20.02	2915.37	0.88	-0.01	-0.13
KRY137A	5	25	25	Top of PVC	2929.90			11.18	2918.72			11.49	2918.41			11.70	2918.20			11.77	2918.13	-0.31	-0.21	-0.07
KRY138A	5	25	25	Top of PVC	2934.14			20.48	2913.66			19.47	2914.67			18.98	2915.16	19.5	0.05	19.55	2914.59	1.01	0.49	-0.57
KRY139A	7	27	29	Top of PVC	2919.51			12.25	2907.26			10.6	2908.91			10.12	2909.39			10.41	2909.10	1.65	0.48	-0.29
KRY139B	166	176	181	Top of PVC	2919.24			12.50	2906.74			10.28	2908.96			9.40	2909.84			9.79	2909.45	2.22	0.88	-0.39
NTL-MW-3	5.2	15.2	15.2	Top of PVC	2915.31			6.79	2908.52			5.65	2909.66			5.07	2910.24			5.55	2909.76	1.14	0.58	-0.48
NTL-MW-4	5.70	15.70	16.00	Top of PVC	2917.76			11.21	2906.55			9.62	2908.14			9.09	2908.67			9.37	2908.39	1.59	0.53	-0.28
NW-1	10.0	30.0	30.5	Top of PVC	2923.79			---	---			---	---			---	---			---	---	---	---	---
NW-2	11.5	26.5	26.9	Top of PVC	2919.14			---	---			---	---			---	---			---	---	---	---	---
NW-4	12.2	32.2	33.0	Top of PVC	2925.77			---	---			---	---			---	---			---	---	---	---	---
PW-1	14.5	24.6	25.0	Top of PVC	2926.67			19.54	2917.57			18	2908.67			17.52	2909.15			18.57	2908.10	-8.90	0.48	-1.05
PW-2C	15.0	25.0	25.0	Top of PVC	2924.58			---	---			---	---			---	---			---	---	---	---	---
PW-2D	12.0	22.0	22.0	Top of PVC	2924.47			---	---			---	---			---	---			---	---	---	---	---
PW-3	12.0	22.0	22.0	Top of PVC	2922.55			15.51	2907.04			15.02	2907.53			14.64	2907.91			15.86 (obstruction)	---	0.49	0.38	---
SW-9	10.0	20.0	20.0	Top of PVC	2922.82			frozen	---			13.75	2909.07			13.26	2909.56			13.74	2909.08	---	0.49	-0.48
OMW1	12.0	27.0	27.5	Top of PVC	2929.20			10.69	2918.51			9.27	2919.93			8.93	2920.27			9.39	2919.81	1.42	0.34	-0.46
OMW2	12.0	27.0	27.5	Top of PVC	2934.84			19.06	2915.78			18.07	2916.77			17.56	2917.28			18.05	2916.79	0.99	0.51	-0.49
OMW3	12.0	27.0	27.5	Top of PVC	2927.52			11.61	2915.91			10.58	2916.94			10.08	2917.44	10.62	0.02	10.64	2916.88	1.03	0.50	-0.56
OMW4	12.0	27.0	27.5	Top of PVC	2935.10	19.64	0.07	19.71	2915.39			18.63	2916.47	18.14	0.03	18.17	2916.93	18.7	0.02	18.72	2916.38	1.08	0.46	-0.55
OMW5	Unknown	Unknown	Unknown	Top of PVC	2934.71			19.31	2915.40			18.3	2916.41			17.79	2916.92			18.34	2916.37	1.01	0.51	-0.55
OMW6	Unknown	Unknown	Unknown	Top of PVC	2935.59			19.12	2916.47			18.09	2917.50			17.62	2917.97			17.99	2917.60	1.03	0.47	-0.37
OSW1	11.0	26.0	26.0	Top of PVC	2936.24	16.58	0.05	16.63	2919.61			15.42	2920.82			15.29	2920.95			15.41	2920.83	1.21	0.13	-0.12
OSW2	11.0	26.0	26.0	Top of PVC	2934.32	17.05	0.05	17.10	2917.22			15.95	2918.37			15.53	2918.79			15.95	2918.37	1.15	0.42	-0.42
SBM1	17.0	28.0	30.6	Top of PVC	2936.64			19.59	2917.05			18.52	2918.12			18.02	2918.62			18.38	2918.26	1.07	0.50	-0.36
SBM2	17.0	28.0	30.2	Top of PVC	2937.11			20.49	2916.62			19.47	2917.64			18.99	2918.12			19.33	2917.78	1.02	0.48	-0.34

TABLE 2-2c
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information						March 2007				April 2007				May 2007				June 2007						
Well Number	**Top of Screen (ft bgs)**	**Bottom of Screen (ft bgs)**	**Well Depth (ft bgs)**	**Measuring Point**	**Measuring Point Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Change Mar to Apr**	**Change Apr to May**	**Change May to June**

Notes:

1. Water level corrected for LNAPL in wells with LNAPL
2. Correction factor for wells with LNAPL $h_c = h_m + (H_o (d_o/d_w))$

h_c - Hydraulic head corrected

h_m - Measured elevation of hydrocarbon-water interface

H_o - Thickness of hydrocarbon layer

d_o - Hydrocarbon density (for diesel = 0.827)

d_w - Water density (assumed = 1.0)

ft - Feet

bgs - Below ground surface

amsl - Above mean sea level

GW - Groundwater

PVC - Polyvinyl chloride (well casing)

LNAPL - Light nonaqueous phase liquid (petroluem hydrocarbon, PCP)

SWL - Static water level

Blank cell indicates no measureable LNAPL present

--- Not measured

Note: Field notes that included "no evidence of product" and the presence of "brown flecks or algae" were eliminated from this data summary as product detected in the respective well.

TABLE 2-2d
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information								July 2007				
Well Number	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Well Depth (ft bgs)	EASTING	NORTHING	Measuring Point	Measuring Point Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Change June to July
CLCW-1				1,479,033.03000	800,782.60000	Top of PVC	2935.61			24.57	2911.04	#REF!
GW-1	11.9	21.9	24.0	1,479,882.54000	799,018.63000	Top of PVC	2933.94			14.81	2919.13	#REF!
GW-5	14.0	24.0	24.5	1,479,477.72470	799,878.71000	Top of PVC	2934.64			20.74	2913.90	#REF!
GWRM-1	15.0	25.0	25.0	1,478,730.05120	800,453.99960	Top of PVC	Unknown			20.79	---	---
GWRM-2	15.0	25.0	25.0	1,478,784.00950	800,325.90000	Top of PVC	Unknown			19.66	---	---
GWRR-1	11.9	21.9	24.0	1,479,876.67000	800,066.61000	Top of PVC	2929.32			14.80	2914.52	#REF!
GWRR-2	12.85	22.85	25.0	1,479,376.82580	800,187.48140	Top of PVC	2932.54			18.78	2913.76	#REF!
GWRR-3	8.65	18.65	20.0	1,479,667.08000	800,353.71000	Top of PVC	2928.75			11.77	2916.98	#REF!
GWRR-4	4.75	14.75	20.0	1,479,759.07000	799,965.48000	Top of PVC	2931.76			13.39	2918.37	#REF!
GWRR-5	13.0	23.0	23.3	1,479,442.46000	800,130.91000	Top of PVC	2932.36	18.58	0.05	18.63	2913.73	#REF!
GWRR-6	4.75	14.75	25.0	1,479,478.88000	800,352.84000	Top of PVC	2930.34			10.72	2919.62	#REF!
GWRR-7	6.25	16.25	16.5	1,479,597.11000	800,303.76000	Top of PVC	2931.12	12.28	0.44	12.72	2918.40	#REF!
GWRR-8	20.5	30.5	32.0	1,479,327.36790	799,889.53110	Top of PVC	2938.15			24.32	2913.83	#REF!
GWRR-9	16.0	26.0	28.0	1,479,357.80510	800,119.37470	Top of PVC	2934.27	20.55	0.02	20.57	2913.70	#REF!
GWY-3	10.0	30.0	30.0	1,478,975.95000	800,516.44000	Top of PVC	2934.92			15.46	2919.46	#REF!
GWY-4	10.0	30.0	30.0	1,478,978.12000	800,321.15000	Top of PVC	2934.06			20.45	2913.61	#REF!
GWY-10	10.0	30.0	30.0	1,478,852.78000	800,236.95000	Top of PVC	2933.75			20.17	2913.58	#REF!
GWY-12	10.0	30.0	30.0	1,479,235.35000	800,364.42000	Top of PVC	2933.13			19.44	2913.69	#REF!
GWY-13	10.0	30.0	30.0	1,479,113.08000	800,525.87000	Top of PVC	2932.56			18.93	2913.63	#REF!
GWY-14	10.0	30.0	30.0	1,479,090.71000	800,811.44000	Top of PVC	2934.62			24.21	2910.41	#REF!
KPT-1	13.0	28.0	29.0	1,479,859.18000	798,815.11000	Top of PVC	2939.84			20.58	2919.26	#REF!
KPT-2	13.0	28.0	29.0	1,479,675.45000	799,138.05000	Top of Steel	2938.55	19.44	0.07	19.51	2919.04	#REF!
KPT-3	13.0	28.0	29.0	1,479,446.76000	799,173.14000	Top of PVC	2937.17	18.53	0.02	18.55	2918.62	#REF!
KPT-4	13.0	28.0	29.0	1,479,413.01000	799,509.11000	Top of PVC	2935.44			20.85	2914.59	#REF!
KPT-5	13.0	28.0	29.0	1,479,548.69000	799,529.47000	Top of PVC	2934.66			19.61	2915.05	#REF!
KPT-6	13.0	28.0	29.0	1,479,764.63000	799,340.51000	Top of PVC	2936.18			17.60	2918.58	#REF!
KPT-7	12.5	27.5	28.5	1,479,738.85000	799,537.49000	Top of PVC	2935.31			18.94	2916.37	#REF!
KPT-8	110.0	120.0	122.0	1,479,741.06000	799,541.82000	Top of PVC	2935.16			18.88	2916.28	#REF!
KPT-9	6.0	16.0	23.0	1,479,924.02000	799,538.55000	Top of Steel	2925.77	7.76	0.01	7.77	2918.00	#REF!
KPT-10	8.0	23.0	27.0	1,479,986.84000	799,920.45000	Top of PVC	2925.35			10.78	2914.57	#REF!
KPT-11	52.0	72.0	74.0	1,479,981.09000	800,043.18000	Top of PVC	2925.84			11.30	2914.54	#REF!
KPT-12	14.0	24.0	24.5	1,479,451.75000	798,828.02000	Top of PVC	2939.51			20.38	2919.13	---
KPT-13	109.0	119.0	120.0	1,479,931.25000	799,543.86000	Top of PVC	2927.55			10.06	2917.49	#REF!
KPT-14	96.0	106.0	109.0	1,479,985.52000	799,919.05000	Top of PVC	2925.95			11.47	2914.48	#REF!
KPT-15	101.0	111.0	117.0	1,479,472.72470	799,878.71000	Top of PVC	2934.80			20.93	2913.87	#REF!
KPT-16	14.0	29.0	29.5	1,479,373.81000	799,733.21000	Top of PVC	2935.66			21.76	2913.90	#REF!
KPT-17	7.5	12.5	13.0	1,479,844.05750	800,181.96240	Top of PVC	2929.58			11.14	2918.44	#REF!
KPT-18	24.0	34.0	34.5	1,479,836.33030	800,188.81460	Top of PVC	2929.71			13.14	2916.57	#REF!
KPT-19	13.00	23.00	23.50	1,479,735.25130	799,811.43630	Top of PVC	2932.89	18.45	0.02	18.47	2914.42	#REF!
KPT-20	10.00	20.00	20.00	1,479,748.20120	799,719.43520	Top of PVC	2932.90			17.98	2914.92	#REF!
KPT-21	8.00	23.00	23.00	1,479,693.48150	799,896.78600	Top of PVC	2933.50			19.14	2914.36	#REF!
KPT-22	6.00	16.00	16.00	1,479,874.48650	799,691.77900	Top of PVC	2926.78			12.16	2914.62	#REF!
KRY100A	6	26	28	1,480,152.85258	798,473.17523	Top of PVC	2936.60			10.95	2925.65	#REF!
KRY101A	9	29	31	1,479,871.40392	798,341.01454	Top of PVC	2941.08			17.71	2923.37	#REF!
KRY101B	85	95	100	1,479,873.53474	798,332.52536	Top of PVC	2940.80			17.81	2922.99	#REF!
KRY102A	13	33	33.5	1,479,227.94765	798,422.84576	Top of PVC	2945.27			25.55	2919.72	#REF!

TABLE 2-2d
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information								July 2007				
Well Number	Top of Screen (ft bgs)	Bottom of Screen (ft bgs)	Well Depth (ft bgs)	EASTING	NORTHING	Measuring Point	Measuring Point Elevation (ft amsl)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	SWL (ft bgs)	GW Elevation (ft amsl)	Change June to July
KRY102B	95	105	110	1,479,227.62778	798,431.30756	Top of PVC	2945.26			27.61	2917.65	#REF!
KRY103A	5	25	27	1,480,565.31196	798,509.04568	Top of PVC	2940.30			13.65	2926.65	#REF!
KRY103B	55	65	70	1,480,558.92503	798,511.82993	Top of PVC	2939.94			13.19	2926.75	#REF!
KRY104A	20	40	40.5	1,479,157.00195	798,796.29854	Top of PVC	2946.68			19.73	2926.95	#REF!
KRY105A	5	25	27	1,480,264.41571	798,980.61413	Top of PVC	2932.27			8.69	2923.58	#REF!
KRY106A	6	26	28	1,480,076.81035	799,175.47778	Top of PVC	2932.25			11.85	2920.40	#REF!
KRY106B	73	83	88	1,480,074.84283	799,182.19322	Top of PVC	2932.42			11.79	2920.63	#REF!
KRY107A	9	29	29.5	1,479,223.16462	799,175.24597	Top of PVC	2938.92			22.31	2916.61	#REF!
KRY107B	121	131	136	1,479,223.75807	799,180.54799	Top of PVC	2938.73			22.07	2916.66	#REF!
KRY108A	10	30	32	1,479,715.80638	798,832.77967	Top of PVC	2941.11			21.79	2919.32	#REF!
KRY109A	5	25	27	1,480,178.20356	799,720.15764	Top of PVC	2928.85			11.33	2917.52	#REF!
KRY110A	35	55	55	1,480,017.04371	799,592.22972	Top of PVC	2926.90			9.49	2917.41	#REF!
KRY110B	76	86	91	1,480,008.26329	799,592.51558	Top of PVC	2926.96			10.35	2916.61	#REF!
KRY111A	5	25	25.5	1,479,305.33211	799,534.66845	Top of PVC	2936.61	21.13	-0.55	20.58	2916.03	#REF!
KRY111B	123	133	138	1,479,299.41267	799,535.42224	Top of PVC	2936.96			20.61	2916.35	#REF!
KRY112A	9	29	29.5	1,478,962.21190	799,461.85776	Top of PVC	2935.59			20.53	2915.06	#REF!
KRY112B	110	120	125	1,478,965.33652	799,449.69302	Top of PVC	2935.78			22.86	2912.92	#REF!
KRY113A	15	35	37	1,479,766.25381	798,823.71560	Top of PVC	2940.77			21.40	2919.37	#REF!
KRY113B	102	112	117	1,479,761.68975	798,832.73058	Top of PVC	2940.96			21.91	2919.05	#REF!
KRY114A	7	27	29	1,479,596.32355	799,812.63628	Top of PVC	2934.65	20.10	0.21	20.31	2914.34	#REF!
KRY114B	108	118	122	1,479,597.99814	799,807.44598	Top of PVC	2935.09			20.33	2914.76	#REF!
KRY115A	12	32	32.5	1,479,032.95793	799,831.58222	Top of PVC	2936.78			22.45	2914.33	#REF!
KRY115B	107	117	122	1,479,034.86424	799,826.51529	Top of PVC	2936.68			16.99	2919.69	#REF!
KRY116A	7	27	29.5	1,478,757.26712	799,718.07228	Top of PVC	2931.53			17.55	2913.98	#REF!
KRY116B	95.5	105.5	110.5	1,478,750.69776	799,716.15153	Top of PVC	2931.97			23.61	2908.36	#REF!
KRY117A	5	29	27	1,479,947.02292	800,042.35685	Top of PVC	2929.25			15.55	2913.70	#REF!
KRY118A	6	26	28	1,480,222.70548	800,277.91309	Top of PVC	2924.44			12.91	2911.53	#REF!
KRY118B	95	105	110	1,480,220.75639	800,289.70103	Top of PVC	2924.21			12.62	2911.59	#REF!
KRY119A	5	25	25	1,479,945.70763	800,233.64818	Top of PVC	2929.69			14.25	2915.44	#REF!
KRY121A	12	32	32.5	1,479,211.63975	800,125.25313	Top of PVC	2937.39			23.71	2913.68	#REF!
KRY121B	119	129	134	1,479,208.80364	800,130.19500	Top of PVC	2937.35			20.51	2916.84	#REF!
KRY122A	7	27	29	1,478,410.92749	799,959.69598	Top of PVC	2930.07			16.00	2914.07	#REF!
KRY122B	83	93	98	1,478,417.68998	799,963.86628	Top of PVC	2929.80			15.96	2913.84	#REF!
KRY123A	5	25	25	1,479,920.15674	800,476.00120	Top of PVC	2928.93			17.94	2910.99	#REF!
KRY125A	5	25	25	1,478,742.31196	800,531.19173	Top of PVC	2934.75			16.56	2918.19	#REF!
KRY125B	116	126	126	1,478,733.96432	800,529.17095	Top of PVC	2934.40			24.69	2909.71	#REF!
KRY126A	5	25	27	1,479,831.10306	800,569.50266	Top of PVC	2927.54			16.59	2910.95	#REF!
KRY127A	5	25	27	1,480,095.75003	800,673.96396	Top of PVC	2923.05			12.29	2910.76	#REF!
KRY128A	5	25	27.5	1,479,471.19439	800,742.88193	Top of PVC	2928.07			16.34	2911.73	#REF!
KRY128B	145	155	160	1,479,463.32699	800,741.81489	Top of PVC	2928.05			18.18	2909.87	#REF!
KRY129A	9	29	31	1,478,777.32362	800,810.83953	Top of PVC	2931.84			13.83	2918.01	#REF!
KRY129B	127	137	142	1,478,783.10878	800,818.67823	Top of PVC	2931.10			22.42	2908.68	#REF!
KRY130A	25	45	45	1,479,242.15759	801,057.77712	Top of PVC	2926.68			17.24	2909.44	#REF!
KRY130B	153	163	168	1,479,238.46205	801,046.49742	Top of PVC	2926.85			17.55	2909.30	#REF!
KRY132A	6	26	28.5	1,479,905.71237	799,319.12769	Top of PVC	2930.75			10.89	2919.86	#REF!
KRY133A	8	28	30	1,479,398.69809	799,019.85014	Top of PVC	2939.44			20.25	2919.19	#REF!

TABLE 2-2d
SUMMARY OF GROUNDWATER ELEVATIONS
KRY SITE

Well Information								July 2007				
Well Number	**Top of Screen (ft bgs)**	**Bottom of Screen (ft bgs)**	**Well Depth (ft bgs)**	**EASTING**	**NORTHING**	**Measuring Point**	**Measuring Point Elevation (ft amsl)**	**Depth to LNAPL (ft bgs)**	**LNAPL Thickness (ft)**	**SWL (ft bgs)**	**GW Elevation (ft amsl)**	**Change June to July**
KRY134A	8	28	30	1,479,496.66564	799,724.63685	Top of PVC	2935.11			20.58	2914.53	#REF!
KRY135A	5	25	25	1,479,686.33789	800,208.39507	Top of PVC	2931.22	13.80	0.12	13.92	2917.30	#REF!
KRY136A	5	25	25	1,479,482.37855	800,009.34048	Top of PVC	2935.39	21.42	0.31	21.73	2913.66	#REF!
KRY137A	5	25	25	1,479,561.40995	800,396.60200	Top of PVC	2929.90			12.22	2917.68	#REF!
KRY138A	5	25	25	1,479,338.79932	800,304.98839	Top of PVC	2934.14	21.35	0.09	21.44	2912.70	#REF!
KRY139A	7	27	29	1,478,871.67512	801,567.28851	Top of PVC	2919.51			12.40	2907.11	#REF!
KRY139B	166	176	181	1,478,872.69434	801,555.32374	Top of PVC	2919.24			11.77	2907.47	#REF!
NTL-MW-3	5.2	15.2	15.2	1,478,618.96743	801,062.18519	Top of PVC	2915.31			7.41	2907.90	#REF!
NTL-MW-4	5.70	15.70	16.00	1,478,594.67754	801,332.58889	Top of PVC	2917.76			11.43	2906.33	#REF!
NW-1	10.0	30.0	30.5	801,181.96240	1,479,076.83630	Top of PVC	2923.79			---	---	---
NW-2	11.5	26.5	26.9	801,274.73910	1,478,892.83300	Top of PVC	2919.14			---	---	---
NW-4	12.2	32.2	33.0	801,142.45380	1,479,003.09300	Top of PVC	2925.77			---	---	---
PW-1	14.5	24.6	25.0	1,478,958.43590	801,164.00570	Top of PVC	2926.67			20.51	2906.16	#REF!
PW-2C	15.0	25.0	25.0	801,136.30610	1,479,068.51840	Top of PVC	2924.58			---	---	---
PW-2D	12.0	22.0	22.0	801,181.83230	1,478,986.36540	Top of PVC	2924.47			---	---	---
PW-3	12.0	22.0	22.0	1,479,045.77660	801,195.00190	Top of PVC	2922.55			17.62	2904.93	---
SW-9	10.0	20.0	20.0	1,478,976.08350	801,303.87100	Top of PVC	2922.82			15.72	2907.10	#REF!
OMW1	12.0	27.0	27.5	1479806.43	799538.84	Top of PVC	2929.20			10.92	2918.28	#REF!
OMW2	12.0	27.0	27.5	1479806.43	799538.84	Top of PVC	2934.84			19.90	2914.94	#REF!
OMW3	12.0	27.0	27.5	1479806.43	799538.84	Top of PVC	2927.52	12.43	0.02	12.45	2915.07	#REF!
OMW4	12.0	27.0	27.5	1479806.43	799538.84	Top of PVC	2935.10	20.55	0.16	20.71	2914.39	#REF!
OMW5	Unknown	Unknown	Unknown	1479540.93	799608.47	Top of PVC	2934.71	20.24	0.07	20.31	2914.40	#REF!
OMW6	Unknown	Unknown	Unknown	1479430.50	799582.22	Top of PVC	2935.59			19.80	2915.79	#REF!
OSW1	11.0	26.0	26.0	1479806.43	799538.84	Top of PVC	2936.24			17.06	2919.18	#REF!
OSW2	11.0	26.0	26.0	1479806.43	799538.84	Top of PVC	2934.32	17.65	0.41	18.06	2916.26	#REF!
SBM1	17.0	28.0	30.6	1479806.43	799538.84	Top of PVC	2936.64			20.20	2916.44	#REF!
SBM2	17.0	28.0	30.2	1479806.43	799538.84	Top of PVC	2937.11			21.15	2915.96	#REF!

Notes:

1. Water level corrected for LNAPL in wells with LNAPL
2. Correction factor for wells with LNAPL $h_c = h_m + (H_o (d_o/d_w))$

h_c - Hydraulic head corrected
h_m - Measured elevation of hydrocarbon-water interface
H_o - Thickness of hydrocarbon layer
d_o - Hydrocarbon density (for diesel = 0.827)
d_w - Water density (assumed = 1.0)
ft - Feet

bgs - Below ground surface
amsl - Above mean sea level
GW - Groundwater
PVC - Polyvinyl chloride (well casing)
LNAPL - Light nonaqueous phase liquid (petroluem hydrocarbon, PCP)
SWL - Static water level

Note: Field notes that included "no evidence of product" and the presence of "brown flecks or algae" were eliminated from this data summary as product detected in the respective well.

TABLE 2-3
SUMMARY OF AQUIFER TEST RESULTS
KRY SITE

Well Number	Well Diameter (inches)	Aquifer Zone(1)	Aquifer Thickness (feet)	Test Date	Test Type Conducted	Test Duration (minutes)	Pumping Rate (gpm)	Maximum Drawdown (feet)	Solution Method	Transmissivity (ft^2/day)	Hydraulic Conductivity (ft/day)
KRY108A	2	Upper Unconfined	91	8/21/06	Pumping Well Drawdown	94	6.1	0.03	NC (2)	NC (2)	NC (2)
KRY113B	2	Lower Unconfined	91	8/21/06	Pumping Well Drawdown	112	6.1	1.1	Theis Unconfined	5,500	60
KRY121A	2	Upper Unconfined	106	8/18/06	Pumping Well Drawdown	56	6.1	0.1	NC (2)	NC (2)	NC (2)
KRY121B	4	Lower Unconfined	106	8/16/06	Pumping Well Drawdown	42	30	1.1	Theis Unconfined	34,600	326
KRY139A	4	Upper Unconfined	164	8/22/06	Pumping Well Drawdown	105	5.8	2.97	Theis Unconfined	2,800	17
KRY139A	4	Upper Unconfined	14.6(3)	8/22/06	Pumping Well Recovery	15	5.8	2.97	Theis Confined	138	9
KRY139B	2	Lower Unconfined	164	8/22/06	Pumping Well Drawdown	84	6.1	1.3	Theis Unconfined	8,941	55

Notes:
(1) Upper Unconfined refers to wells completed in upper portion of unconfined aquifer. Lower Unconfined refers to wells completed in lower portion of unconfined aquifer.
(2) NC = not calculated Aquifer tests at wells KRY108A and KRY121A yielded insufficient drawdown to complete the analysis.
(3) Calculation of transmissivity and hydraulic conductivity used the length of the saturated portion of the well screen.

Solution Methods: Theis (1935)

Gpm	Gallons per minute
ft^2/d	Feet squared per day

TABLE 2-4

SUMMARY OF PREVIOUS AQUIFER TESTING RESULTS
KRY SITE

Well Number	Well Diameter (inches)	Screen Interval (feet bgs)	Aquifer Zone (1)	Test Type Conducted	Solution Method	Hydraulic Conductivity (ft/day)
Data from RETEC 1995 Site Investigation Report for KPT						
KPT-1	4	13-28	Upper unconfined	Slug Test	Bower/Rice	34
KPT-5	4	13-28	Upper unconfined	Slug Test	Bower/Rice	37
KPT-7	4	12.5-27.5	Upper unconfined	Slug Test	Bower/Rice	34
KPT-8	4	110-120	Lower unconfined	Slug Test	Bower/Rice	43
GW-1	4	12-22	Upper unconfined	Slug Test	Bower/Rice	48
Data from Spratt & Associates 1992 Phase III Environmental Site Assessment for Seaman Mobile Homes						
EH-1	2	3-11	Upper unconfined	Pumping test	NA	12
EH-2	2	8-18	Upper unconfined	Pumping test	NA	4
EH-3	2	6-16	Upper unconfined	Pumping test	NA	0.4
MW-14	4	10-30	Upper unconfined	Slug Test	NA	322
SW-5	4	20-40	Upper unconfined	Slug Test	NA	0.5
SW-6	4	17-37	Upper unconfined	Slug Test	NA	1.7
SW-7	4	12-32	Upper unconfined	Slug Test	NA	15

Notes:

1. Unconfined refers to wells completed in upper portion of unconfined aquifer
2. Lower unconfined refers to wells completed in lower portion of unconfined aquifer

NA = Not available

Table 3-1
Groundwater Cleanup Levels
KRY Site

Contaminant of Concern	Cleanup Level (ug/L)	Rationale for Cleanup Level Selection			
		Background	DEQ-7 Standard	RBCA RBSL	Tap Water PRG
1,2,4-Trimethylbenzene	15				X
Arsenic	10		X		
Benzene	5		X	X	
C11-C22 Aromatics	1000			X	
C5-C8 Aliphatics	800			X	
C9-C10 Aromatics	1000			X	
C9-C12 Aliphatics	500			X	
Dioxins/furans (TEQ - WHO 1998)	5.61 pg/L	X			
Ethylbenzene	700		X	X	
Iron	300		X		
Manganese	778	X			
Naphthalene	100		X	X	
Pentachlorophenol	1		X		
Toluene	1000		X	X	
Free-product	1/8 inch*				

ug/L - microgram per liter (parts per billion)
pg/L - picograms per liter (parts per quadrillion)
* - 40 CFR 280.64 and ARM 17.56.607 require removal of free-product to the maximum extent practicable; determined by DEQ to be 1/8 inch or less.

Table 3-2
Soil Cleanup Levels
KRY Site

Contaminant of Concern	Surface Soil Commercial/Industrial Cleanup Level (mg/kg)	Surface Soil Residential Cleanup Level (ng/kg)[f]	Subsurface Soil Construction/Excavation Cleanup Level (mg/kg)
1,2,4-Trimethylbenzene	NA	NA	**25**
Acenaphthene	NA	NA	**27,000**
Arsenic	40[a]	NA	40[a]
Benz(a)anthracene	[b]	NA	[g]
Benzo(a)pyrene	[b]	NA	[g]
Benzo(b)fluoranthene	[b]	NA	NA
C11-C22 Aromatics	33,445[*]	NA	33,445
C19-C36 Aliphatics	NA	NA	260,154
C5-C8 Aliphatics	NA	NA	730
C9-C10 Aromatics	NA	NA	**4,800**
C9-C12 Aliphatics	NA	NA	1,550
C9-C18 Aliphatics	2,634[*]	NA	2,634
Carbazole	NA	NA	**99**
Chromium	**150**	NA	**20**
Dibenzo(a,h)anthracene	[b]	NA	NA
Dioxins/furans (TEQ - 2005)	103 ng/kg	54	850 ng/kg
Ethylbenzene	NA	NA	**320**
Fluorene	NA	NA	**130,000**
Indeno(1,2,3-cd)pyrene	[b]	NA	NA
Iron	NA	NA	46,686
Lead	800[c]	NA	800[c]
Methylene Chloride	**0.82**	NA	NA
2-Methylnaphthalene	NA	NA	1,982
Naphthalene	NA	NA	**220**
Pentachlorophenol	**12**[d]	NA	**0.43**
Selenium	NA	NA	**1.7**
Sludge	Visible[e]	NA	Visible[e]
Toluene	NA	NA	**260**
Xylenes	NA	NA	486

mg/kg - milligrams per kilogram (parts per million)
ng/kg - nanograms per kilogram (parts per trillion)
Cleanup levels in **bold** are based on leaching to groundwater (assumes contamination only in the surface soil with clean subsurface soils).

[*] - Cleanup levels are based on excavation because that pathway is more protective

[a] - DEQ Action Level from DEQ's April 2005 Arsenic Position Paper

[b] - Total cPAH cleanup level is 1.7 mg/kg (determined using the approach outlined in EPA,1993). cPAHs include benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene, and indeno(1,2,3-cd)pyrene for surface soils. See Risk Analysis for more information.

[c] - EPA Region 9 Industrial Preliminary Remediation Goa

[d] - Cleanup level unless subsurface soil is contaminated in same area, then it is 0.43 mg/kg (the excavation leaching to groundwater level - see * above).

[e] - 40 CFR 280.64 and ARM 17.56.607 require removal of free product to the maximum extent practicable. For soil, this is based on visual observation.

[f] - Dioxins/furans were the only COC for residential soil

[g] - Total cPAH cleanup level is 13 mg/kg (determined using the approach outlined in EPA, 1993). cPAHs include benzo(a)anthracene and benzo(a)pyrene for subsurface soils. See Risk Analysis for more information.

NA - Not applicable

TABLE 3-3a
SUMMARY OF LNAPL THICKNESSES
KRY SITE

Well Number	Jul-06		Aug-06		Sep-06		Oct-06		Nov-06		Dec-06		Max Thickness
	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	
CLCW-1	--	--	--	--	--	--	--	--	--	--	--	--	
GW-1	--	--	--	--	--	--	--	--	--	--	--	--	
GW-5	--	--	--	--	--	--	--	--	--	--	--	--	
GWRM-1	--	--	--	--	--	--	--	--	--	--	--	--	
GWRM-2	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-1	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-2	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-3	--	--	--	--	--	--	11.68	0.01	--	--	--	--	0.01
GWRR-4	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-5	16.81	0.03	--	--	--	--	--	--	18.05	0.01	17.91	0.01	0.01
GWRR-6	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-7	11.56	0.45	11.74	0.02	12.06	0.24	12.15	0.39	12.39	0.37	12.57	0.6	0.45
GWRR-8	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-9	--	--	20.08	0.03	--	--	--	--	--	--	--	--	0.03
GWY-3	--	--	--	--	--	--	--	--	--	--	--	--	
GWY-4	--	--	--	--	20.24	0.01	--	--	--	--	--	--	0.01
GWY-10	--	--	--	--	--	--	--	--	--	--	--	--	
GWY-12	--	--	--	--	--	--	--	--	--	--	--	--	
GWY-13	--	--	--	--	18.74	0.01	--	--	--	--	--	--	0.01
GWY-14	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-1	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-2	--	--	--	--	19.48	0.01	--	--	--	--	19.26	0.02	0.02
KPT-3	16.88	0.05	--	--	18.59	0.01	18.39	0.06	--	--	18.34	0.03	0.06
KPT-4	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-5	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-6	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-7	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-8	--	--	--	--	--	--	--	--	18.55	0.01	--	--	0.01
KPT-9	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-10	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-11	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-12	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-13	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-14	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-15	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-16	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-17	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-18	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-19	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-20	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-21	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-22	--	--	--	--	--	--	--	--	--	--	--	--	
KRY100	--	--	--	--	--	--	--	--	--	--	--	--	
KRY101A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY101B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY102A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY102B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY103A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY103B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY104	--	--	--	--	--	--	--	--	--	--	--	--	
KRY105	--	--	--	--	--	--	8.55	0.01	--	--	--	--	0.01
KRY106A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY106B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY107A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY107B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY108A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY109	--	--	--	--	--	--	--	--	--	--	--	--	
KRY110A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY110B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY111A	--	--	--	--	--	--	--	--	--	--	21.13	0.03	0.03
KRY111B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY112A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY112B	--	--	--	--	--	--	--	--	--	--	--	--	

TABLE 3-3a
SUMMARY OF LNAPL THICKNESSES
KRY SITE

Well Number	Jul-06		Aug-06		Sep-06		Oct-06		Nov-06		Dec-06		Max Thickness
	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	
KRY113A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY113B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY114A	18.55	0.85	19.55	0.94	19.89	0.01	19.54	0.04	19.56	0.06	19.45	0.05	0.94
KRY114B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY115A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY115B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY116A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY116B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY117	--	--	--	--	--	--	--	--	--	--	--	--	
KRY118A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY118B	--	--	--	--	--	--	11.23	0.01	--	--	--	--	0.01
KRY119	--	--	--	--	--	--	14.23	0.01	14.29	0.01	--	--	0.01
KRY121A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY121B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY122A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY122B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY123	--	--	--	--	--	--	--	--	--	--	--	--	
KRY125A	--	--	--	--	--	--	--	--	locked	--	--	--	
KRY125B	--	--	--	--	--	--	--	--	locked	--	--	--	
KRY126	--	--	--	--	--	--	--	--	14.5	0.01	--	--	0.01
KRY127	--	--	--	--	--	--	--	--	--	--	--	--	
KRY128A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY128B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY129A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY129B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY130A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY130B	--	--	--	--	--	--	--	--	--	--	--	--	
KRY132	--	--	--	--	--	--	--	--	--	--	10.91	0.01	0.01
KRY133	--	--	--	--	--	--	--	--	--	--	--	--	
KRY134	--	--	--	--	--	--	--	--	--	--	--	--	
KRY135	13.1	2.15	13.83	0.17	13.76	0.01	13.84	2.62	13.99	2.73	14.07	2.51	2.73
KRY136	19.67	0.47	20.98	0.39	21.28	0.02	20.85	0.28	20.9	0.3	20.75	0.25	0.47
KRY137	--	--	--	--	--	--	--	--	--	--	--	--	
KRY138	19.61	0.04	20.87	0.01	--	--	--	--	--	--	--	--	0.04
KRY139A	--	--	--	--	--	--	--	--	--	--	--	--	
KRY139B	--	--	--	--	--	--	--	--	--	--	--	--	
NTL-MW-3	--	--	--	--	--	--	--	--	--	--	--	--	
NTL-MW-4	--	--	--	--	--	--	--	--	--	--	--	--	
OMW-1	--	--	--	--	--	--	--	--	--	--	--	--	
OMW-2	--	--	--	--	--	--	--	--	--	--	--	--	
OMW-3	--	--	--	--	--	--	--	--	--	--	--	--	
OMW-4	--	--	20.03	1.37	20.34	0.17	19.97	0.09	20.02	0.08	19.91	0.05	1.37
OMW-5	--	--	19.71	0.21	20.08	0.04	19.67	0.04	19.68	0.1	19.58	0.03	0.21
OMW-6	--	--	--	--	--	--	--	--	--	--	--	--	
OSW-1	--	--	--	--	--	--	--	--	--	--	--	--	
OSW-2	--	--	--	--	17.63	0.02	--	--	--	--	--	--	0.02
RW-1	--	--	--	--	--	--	--	--	13.24	1.04	13.37	0.03	1.04
RW-2	--	--	--	--	--	--	--	--	15.14	0.53	15.3	0.53	0.53
PW-1	--	--	--	--	--	--	--	--	--	--	--	--	
PW-3	--	--	--	--	--	--	--	--	--	--	--	--	
SBM-1	--	--	--	--	--	--	--	--	--	--	--	--	
SBM-2	--	--	--	--	--	--	19.85	0.05	--	--	--	--	0.05
SW-9	--	--	--	--	--	--	--	--	15.48	0.01	--	--	0.01

TABLE 3-3b
SUMMARY OF LNAPL THICKNESSES
KRY SITE

Well Number	Jan-07		Feb-07		Mar-07		Apr-07		May-07		Jun-07		Jul-07		Max Thickness
	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	
CLCW-1	--	--	sheen	--	--	--	--	--	--	--	--	--	--	--	
GW-1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GW-5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWRM-1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWRM-2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-1	--	--	--	--	--	--	12.83	0.01	--	--	--	--	--	--	0.01
GWRR-2	--	--	18.3	0.01	--	--	--	--	--	--	--	--	--	--	0.01
GWRR-3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-5	17.93	0.03	18.06	0.02	--	--	--	--	--	--	--	--	18.58	0.05	0.05
GWRR-6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-7	12.47	0.65	12.6	0.3	11.27	0.23	11.55	0.26	11.92	0.46	12.05	0.2	12.28	0.44	0.65
GWRR-8	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWRR-9	--	--	20	0.01	--	--	--	--	--	--	--	--	20.55	0.02	0.03
GWY-3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWY-4	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWY-10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWY-12	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWY-13	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
GWY-14	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-2	19.31	0.05	19.44	0.06	19.08	0.02	18	0.01	17.55	0.03	17.83	0.07	19.44	0.07	0.07
KPT-3	--	--	18.52	0.05	--	--	--	--			--	--	18.53	0.02	0.06
KPT-4	--	--	19.5	0.01	--	--	--	--	--	--	--	--	--	--	0.01
KPT-5	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-6	--	--	17.57	0.01	--	--	--	--	--	--	--	--	--	--	0.01
KPT-7	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-8*	--	--	18.6	0.01	--	--	--	--	--	--	--	--	--	--	0.01
KPT-9	--	--	--	--	--	--	--	--	--	--	--	--	7.76	0.01	0.01
KPT-10	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-11*	--	--	10.81	0.01	--	--	--	--	--	--	--	--	--	--	0.01
KPT-12	--	--	20.36	0.01	--	--	--	--	--	--	--	--	--	--	0.01
KPT-13*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-14*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-15*	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-16	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-17	--	--	11.31	0.01	--	--	--	--	--	--	--	--	--	--	0.01
KPT-18	--	--	13.2	0.01	--	--	12.45	0.01	--	--	--	--	--	--	0.01
KPT-19	17.87	0.01	17.96	0.02	--	--	--	--	--	--	--	--	18.45	0.02	0.03
KPT-20	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-21	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KPT-22	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-100	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-101A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-101B	--	--	17.85	0.01	--	--	--	--	--	--	--	--	--	--	0.01
KRY-102A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-102B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-103A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.01
KRY-103B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-104	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-105			--	--	--	--	--	--	--	--	--	--	--	--	0.01
KRY-106A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-106B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-107A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-107B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-108A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-109	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-110A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-110B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-111A	21.11	0.02	21.36	0.06	20.98	0.02	19.92	0.43	19.42	0.79	18.81	2.19	21.13	0.55	2.19
KRY-111B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-112A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-112B	--	--	20.28	0.01	--	--	--	--	--	--	--	--	--	--	0.01
KRY-113A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-113B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-114A	19.47	0.11	19.61	0.14	--	--	--	--	--	--	18.21	0.36	20.1	0.21	0.94
KRY-114B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-115A	--	--	22.3	0.01	--	--	--	--	--	--	--	--	--	--	0.01
KRY-115B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-116A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-116B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-117	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-118A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-118B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.01
KRY-119	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.01
KRY-121A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY121B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-122A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	

TABLE 3-3b
SUMMARY OF LNAPL THICKNESSES
KRY SITE

Well Number	Jan-07		Feb-07		Mar-07		Apr-07		May-07		Jun-07		Jul-07		Max Thickness
	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	Depth to LNAPL (ft bgs)	LNAPL Thickness (ft)	
KRY-122B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-123	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-125A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-125B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-126	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.01
KRY-127	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-128A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-128B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-129A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-129B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-130A	--	--	16.08	0.01	--	--	--	--	--	--	--	--	--	--	0.01
KRY-130B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-132	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.01
KRY-133	--	--	--	--	--	--	--	--	--	--	18.65	0.11	--	--	0.11
KRY-134	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-135	13.85	3.12	14.1	2.6	11.9	0.9	12.18	0.86	13.21	1.84	13.41	0.46	13.8	0.12	3.12
KRY-136	20.78	0.22	20.9	0.35	20.52	0.24	19.51	0.37	19.03	0.86	19.57	0.45	21.42	0.31	0.86
KRY-137	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-138	--	--	20.84	0.01	--	--	--	--	--	--	19.5	0.05	21.35	0.09	0.09
KRY-139A	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
KRY-139B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
NTL-MW3	--	--	7.1	0.01	--	--	--	--	--	--	--	--	--	--	0.01
NTL-MW4	--	--	11.36	0.01	--	--	--	--	--	--	--	--	--	--	0.01
OMW-1	--	--	11.11	0.01	--	--	--	--	--	--	--	--	--	--	0.01
OMW-2	--	--	19.48	0.01	--	--	--	--	--	--	--	--	--	--	0.01
OMW-3	--	--	12.08	0.01	--	--	--	--	--	--	10.62	0.02	12.43	0.02	0.02
OMW-4	19.96	1.07	20.06	0.09	19.64	0.07	--	--	18.14	0.03	18.7	0.02	20.55	0.16	1.37
OMW-5	19.61	0.18	19.73	0.24	--	--	--	--	--	--	--	--	20.24	0.07	0.24
OMW-6	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
OSW-1	16.85	0.05	16.99	0.05	16.58	0.05	--	--	--	--	--	--	--	--	0.05
OSW-2	17.35	0.02	17.47	0.28	17.05	0.05	--	--	--	--	--	--	17.65	0.41	0.41
RW-1	13.31	0.62	13.42	0.48	12.2	0.2	12.5	0.23	12.83	0.92	12.91	0.3	13.15	0.32	1.04
RW-2	15.22	0.68	15.35	0.03	14.02	0.4	14.3	0.08	14.68	1.09	14.78	0.02	15.01	0.6	1.09
PW-1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
PW-3	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
SBM-1	--	--	--	--	--	--	--	--	--	--	--	--	--	--	
SBM-2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.05
SW-9	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.01

TABLE 3-4
Estimated Volume of Contaminated Groundwater
KRY SITE

COCs	Surface Area (square feet)	Volume (gallons)*	Cleanup Level (ug/L)
Dioxins/Furans	1,086,308	87,768,038	5.61 pg/L
PCP	513,442	41,483,443	1.0
Petroleum Hydrocarbons	139,879	11,301,496	[a]
Metals	2,103,990	169,991,451	[b]

* - Voume calculation based on estimated aquifer thickness of 40 feet (for shallow or deep portion) and an aquifer effective porosity of 27%.

[a] - Cleanup Levels are different for different compounds. Volume calculation includes C11-C22 Aromatics, C5-C8 Aliphatics, C9-C10 Aromatics, and C9-C12 Aliphatics, as these are the COCs for the KRY Site. See Table 3-1 for cleanup levels for individual compounds.

[b] - Cleanup Levels are different for different compounds. Volume calculation includes arsenic, iron, and manganese, as these are the COCs for the KRY Site. See Table 3-1 for cleanup levels for individual compounds.

Table 3-5
Estimated Volume of Contaminated Soil
KRY Site

COCs	Surface Soil Volume (cy)	Surface Soil Volume with Multiplier* (cy)	Cleanup Level (mg/kg)	Subsurface Soil Volume (cy)	Subsurface Soil Volume with Multiplier* (cy)	Cleanup Level (mg/kg)
Dioxins/Furans	19,898	35,816	89 ng/kg	4,239	7,630	736 ng/kg
PCP	8,865	15,957	0.43	24,993	44,987	0.43
Petroleum Hydrocarbons	2,867	5,161	[a]	12,928	23,270	[b]
Lead	1,135	2,043	800	794	1,429	800

* - Multiplier of 1.8 applied to soil volumes to account for DEQ Petroleum Release Compensation Board experience with estimated volume increases for excavation-related remedial actions.

[a] - Cleanup levels are different for different compounds (see Table 10). Volume calculation for surface soil includes C5-C8 Aliphatics and C9-C18 Aliphatics, as they were the only petroleum compounds with exceedances of cleanup levels.

[b] - Cleanup levels are different for different compounds (see Table 11). Volume calculation for subsurface soil includes C5-C8 Aliphatics, C9-C10 Aromatics, C9-C12 Aliphatics, C9-C18 Aliphatics, as they were the compounds with exceedances of cleanup levels.

TABLE 3-6
WORSE CASE ESTIMATED VOLUME OF LNAPL
KRYSITE

Area Description	Surface Area (square feet)	LNAPL Volume (gallons)	Average Maximum Thickness (feet)
Less Viscous	186,901	81,921	0.279
More Viscous	139,487	82,176	0.375
Total	326,388	164,097	NA

LNAPL volume = Surface Area x Average Maximum LNAPL Thickness x 7.481 (gallons per cubic foot) x 0.21 (value of effective porosity)

Average Maximum LNAPL Thickness derived from monthly LNAPL thickness measurements collected from KRY Site monitoring wells from July 2006 through July 2007.

Note: LNAPL presence is inferred in the areas between wells with documented LNAPL occurrences.

NA - Not Applicable

Table 3-7
Estimated Volume of Sludge
KRY Site

Feature	Description	Estimated Sludge Volume (cy)
Sludge Pit	Liquid layer (0 ft to 0.5 ft)	9
Sludge Pit	Sludge mixed with debris (0.5 ft to 4 ft)	31
Area Distribution of Sludge	Potential sludge area based on boring logs	2,871
Area Distribution of Sludge	Surface sludge at low depressions and surrounding GWRR-3	10
Area Distribution of Sludge	Surface sludge in the triangular area	122
Fenced-off Sludge Area (East of Railroad)	Sludge at the ground surface (0.5 ft estimated maximum thickness)	83
	Grand Total -- Sludge Volume Estimate	**3,126**

TABLE 5-1
DESIGN ASSUMPTIONS
KRY SITE

Option	Primary Source Treated	Description	Unit	Quantity
Multi-phase Extraction	LNAPL	6-in Extraction Wells	ea	46
		Well Depth	ft	30
		Bioslurping System Liquid Extraction Rate	gpm	35
		Vapor Recovery Rate	scfm	1,000
LNAPL Extraction	LNAPL	6-in Extraction Wells	ea	46
		Skimmers	ea	46
		Well Depth	ft	30
		Total LNAPL Volume	gal	165,000
Extraction and Ex Situ Treatment	Groundwater	6-in Extraction Wells (each)	Shallow	11
			Deep	3
		Well Depth (feet)	Shallow	30
			Deep	100+
		Groundwater Extraction and Treatment Rate	gpm	75
In Situ Enhanced Bioremediation	Groundwater and Soil	ORC Injection Point	ea	1,300
		Maximum Injection Depth	ft	30
		ORC Injection Rate	lb each yr	55,158
In Situ Chemical Oxidation[1]	Groundwater and Soil	Injection Wells (each)	Shallow	345
			Deep	3
		Well Depth (feet)	Shallow	22
			Deep	100+
		Ozone Generation Systems	ea	25
Soil Barrier	Soil	Cap Area	sf	750,000
		Geomembrane Thickness	mm	40
		Asphalt Thickness	in	4
		Base Gravel Thickness	in	12
Excavation and Offsite Disposal	Soil	Excavation Volume	cy	272,000
		Overburden	percent	50
		Non-hazardous Waste	cy	73,000
		Hazardous Waste	cy	69,000
Excavation, Ex Situ Treatment and Backfill[1]	Soil	Excavation Volume	cy	262,822
		Overburden	percent	50
Site-wide Elements	Groundwater	Wells to be Sampled	shallow	42
			deep	15
		Cost of Analysis[2]	per well	$1,773
Monitored Natural Attenuation	Groundwater	Wells to be Sampled	shallow	42
			deep	15
		Cost of Analysis[2]	per well	$1,773

[1] - These cost estimates, and therefore design assumptions, were revised based on public comments and the revised costs/design assumptions were included in the Final FS Report.

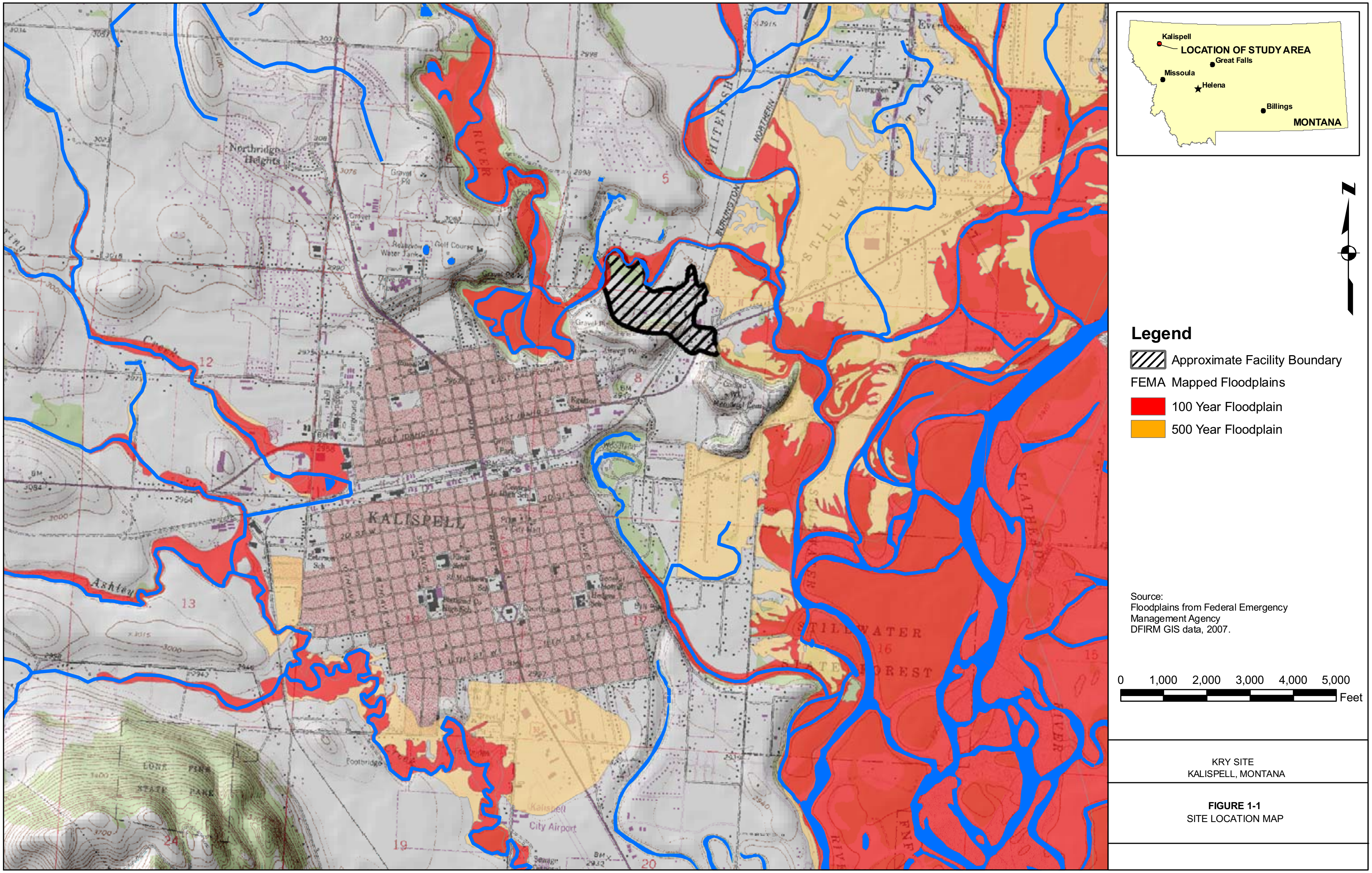
cy - cubic yards
ea - each
ft - feet
gal - gallons
gpm - gallons per minute
in - inches
lb - pounds
mm - millimeter
scfm - standard cubic feet per minute
sf - square feet
yr - year

[2] - Analytical suite includes MNA parameters (dissolved oxygen, temperature, pH, oxidation/reduction potential, nitrate, sulfate ferrous iron, and dissolved manganese), PCP (low-level, in combination with SVOCs), dioxins/furans, petroleum hydrocarbons (EPH/VPH), and metals. Costs reported as a lump sum per well, which includes costs for all of these analyses.

Table 6-1
Comparison of Alternatives
KRY Site

Alternatives	Protectiveness	Compliance with ERCLs	Mitigation of Risk	Effectiveness and Reliability	Implementability and Practicability	Treatment or Resource Recovery Technologies	Present Cost at 3% Over 100 Years
1 - No Action	No	No	No	No	Yes	No	$0
2 - Multi-Phase Extraction and Disposal	Yes (when combined)	Yes (when combined)	Yes (when combined)	Yes (for LNAPL)	Yes	Yes	$ 9,910,800
3 - LNAPL Extraction and Disposal	Yes (when combined)	Yes (when combined)	Yes (when combined)	Yes (for LNAPL)	Yes	Yes	$ 12,392,100
4 - Extraction, Ex-Situ Treatment, and Discharge of Groundwater	Yes (when combined)	Yes (when combined)	Yes (Groundwater contamination) No (LNAPL, sludge, soil contamination)	Yes (for petroleum and PCP) No (for dioxins/furans and metals)	Yes	Yes	$ 36,223,000
5 - In-Situ Bioremediation of Groundwater and Soil	Yes (when combined)	Yes (when combined)	Yes (PCP and petroleum) No (LNAPL, sludge, dioxin/furan and metals)	Yes (PCP and petroleum) No (dioxin/furans and metals)	Yes	Yes	$ 52,272,900
6 - In-Situ Chemical Treatment of Groundwater and Soil	Yes (when combined)	Yes (when combined)	Yes (PCP and petroleum) No (LNAPL, sludge, metals) Maybe (dioxins/furans)	Yes (PCP and petroleum) No (metals) Maybe (dioxins/furans)	Yes	Yes	$ 15,688,701
7 - Soil Barriers	Yes (when combined)	Yes (when combined)	Yes (when combined)	Yes (when combined)	Yes	No	$ 5,599,800
8 - Excavation, Off-Site Disposal	Yes (when combined)	Yes (when combined)	Yes (for soils) No (for LNAPL and groundwater)	Yes (for soils)	Yes	No	$ 120,950,900
9 - Excavation, Ex-Situ Treatment, and Backfill	Yes (when combined)	Yes (when combined)	Yes (for soils) No (for LNAPL and groundwater) Maybe (dioxin)	Yes (when combined)	Yes	Yes	$8,526,496.00
10 - Monitored Natural Attentuation	Yes (when combined)	Yes (when combined)	Yes (for groundwater) No (for soils, sludge, and LNAPL)	Yes (for groundwater, when combined)	Yes	Yes	$4,952,892.00

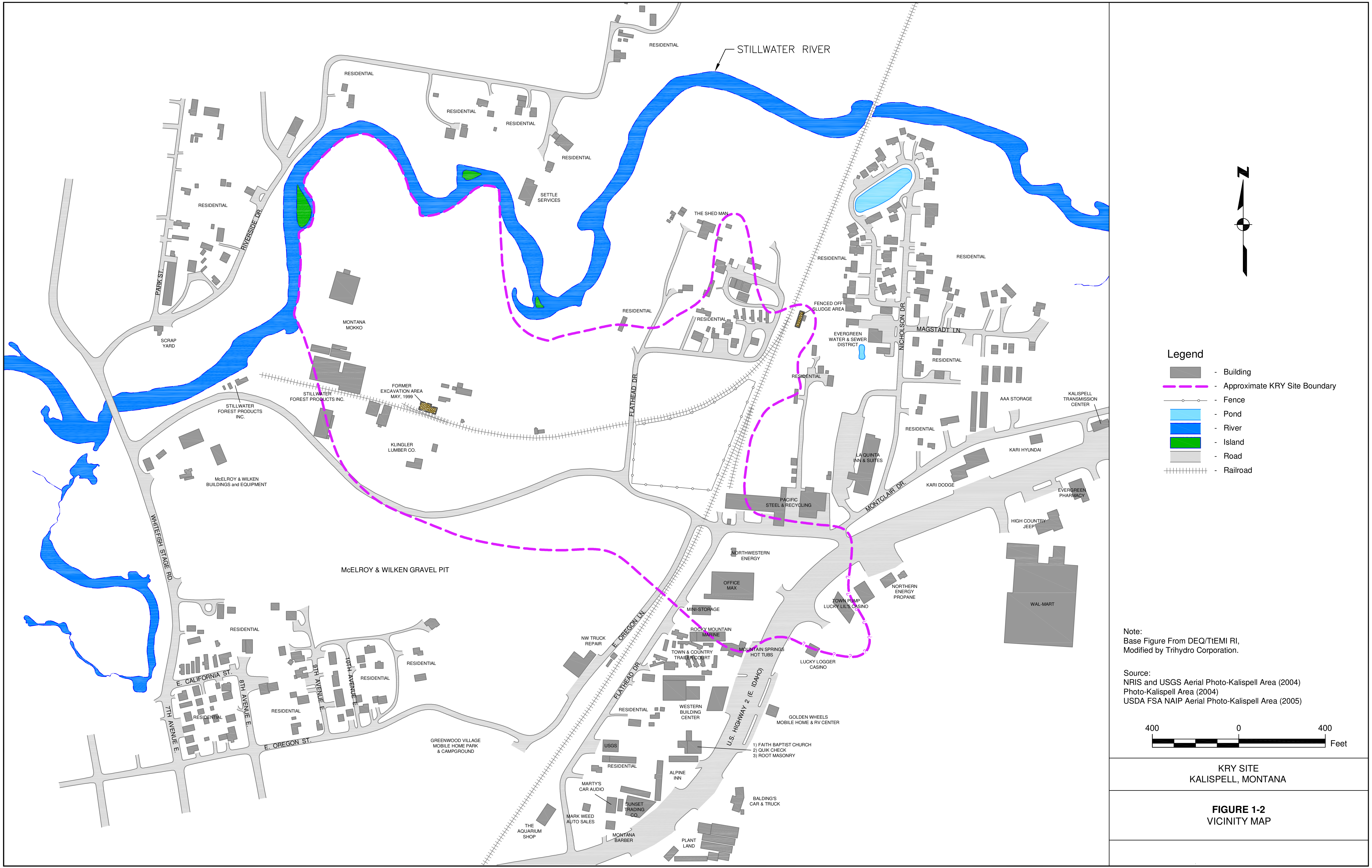
FIGURES



Source:
Floodplains from Federal Emergency
Management Agency
DFIRM GIS data, 2007.

KRY SITE
KALISPELL, MONTANA

FIGURE 1-1
SITE LOCATION MAP



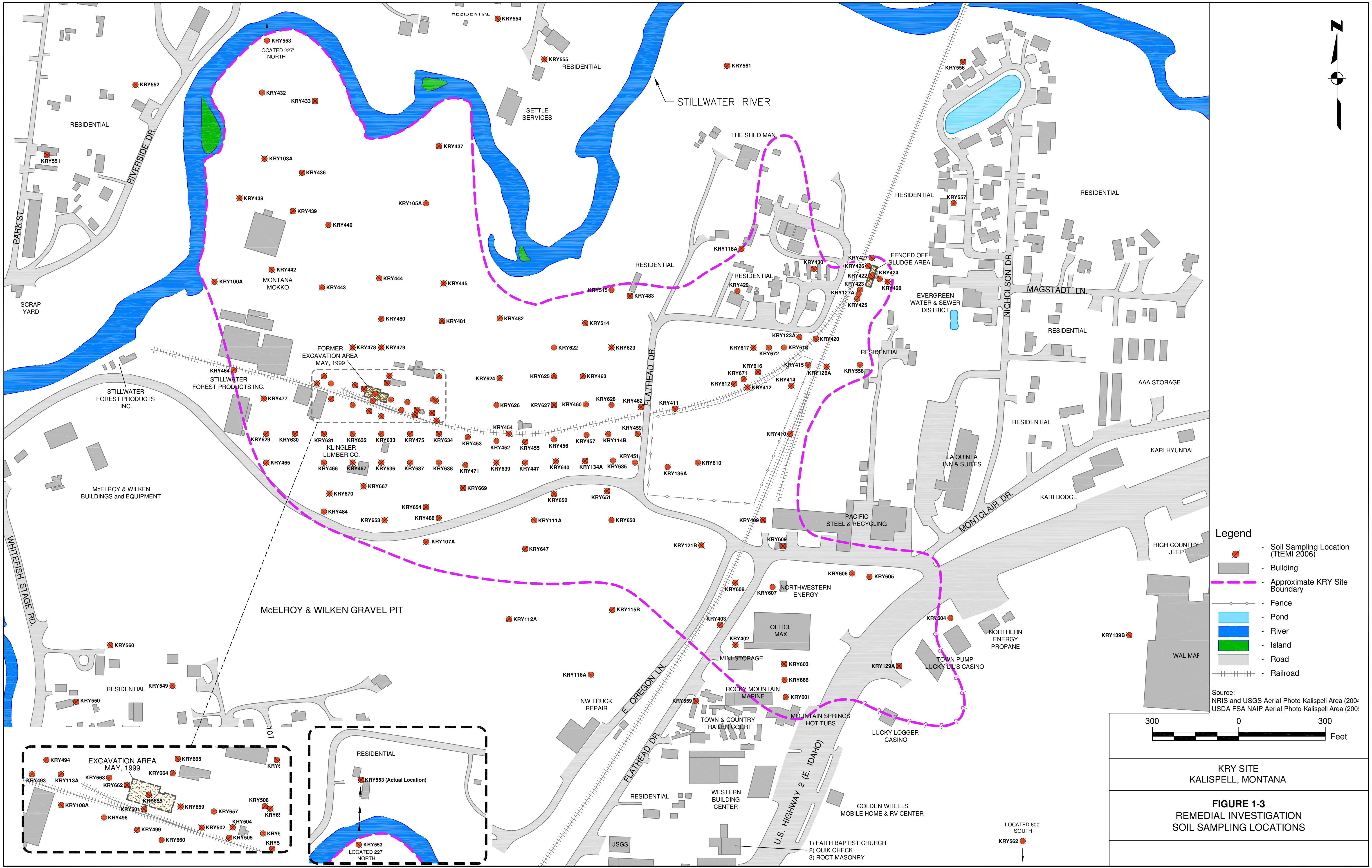
Note:
Base Figure From DEQ/TtEMI RI,
Modified by Trihydro Corporation.

Source:
NRIS and USGS Aerial Photo-Kalispell Area (2004)
Photo-Kalispell Area (2004)
USDA FSA NAIP Aerial Photo-Kalispell Area (2005)

KRY SITE
KALISPELL, MONTANA

FIGURE 1-2
VICINITY MAP

FIG 1-2_VICINITY MAP.dwg - DWH - 07/24/2007 - S1176-37-KPT010



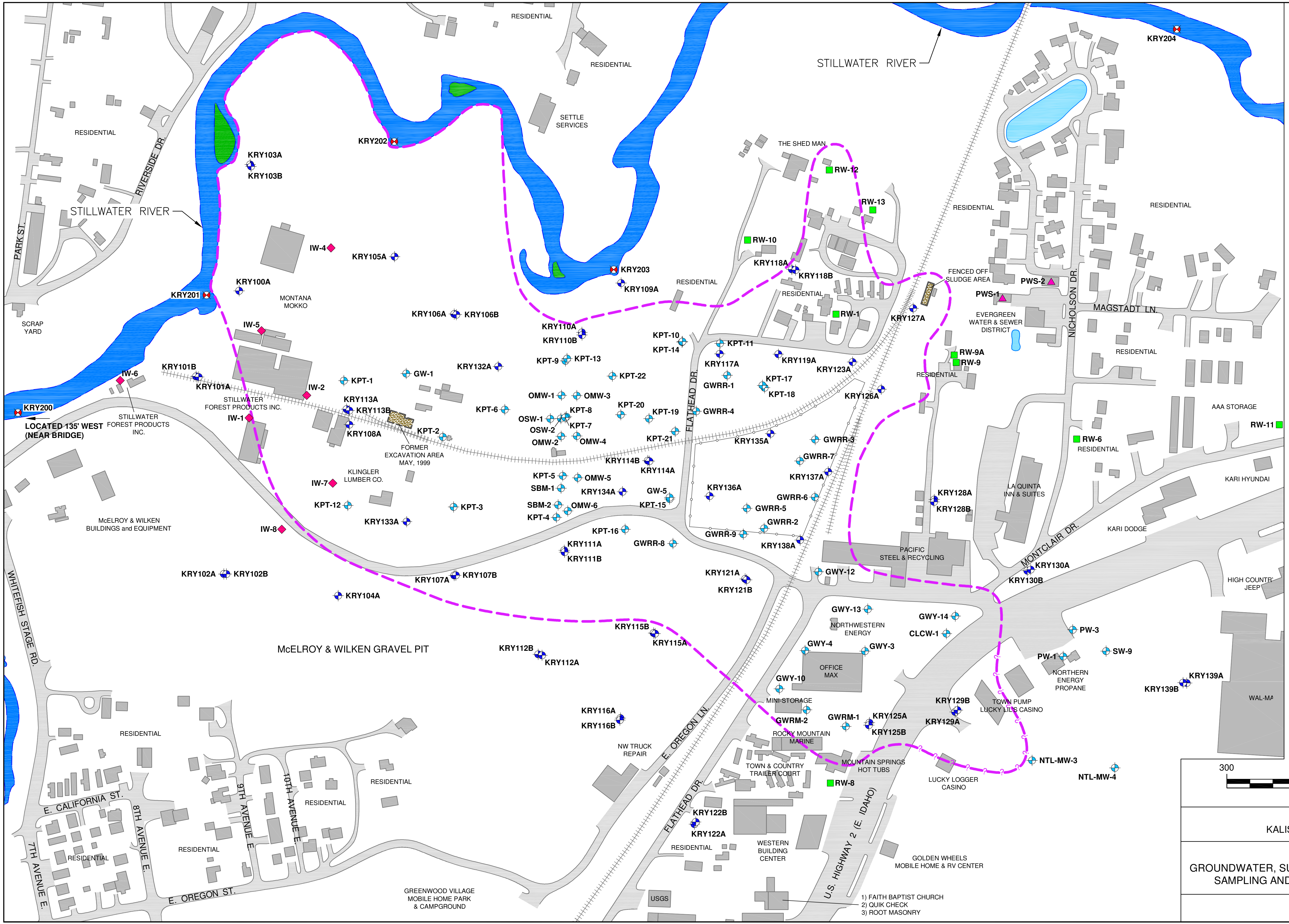
Legend
- Soil Sampling Location (TtEMI 2006)
- Building
- Approximate KRY Site Boundary
- Fence
- Pond
- River
- Island
- Road
- Railroad

Source:
NRIS and USGS Aerial Photo-Kalispell Area (200
USDA FSA NAIP Aerial Photo-Kalispell Area (200

KRY SITE
KALISPELL, MONTANA

FIGURE 1-3
REMEDIAL INVESTIGATION
SOIL SAMPLING LOCATIONS

FIG 1-3_SOIL SAMPLING LOCATIONS.dwg - DWH - 07/24/2007 - S1176-37-KPT010



Legend

- Monitoring Well (Installed by TtEMI in 200
- Monitoring Well (Installed Previously)
- Surface Water / Sediment Sample (TtEMI 2006)
- Industrial Well
- Public Water Supply Well
- Residential Well
- Building
- Approximate KRY Site Boundary
- Fence
- Pond
- River
- Island
- Road
- Railroad

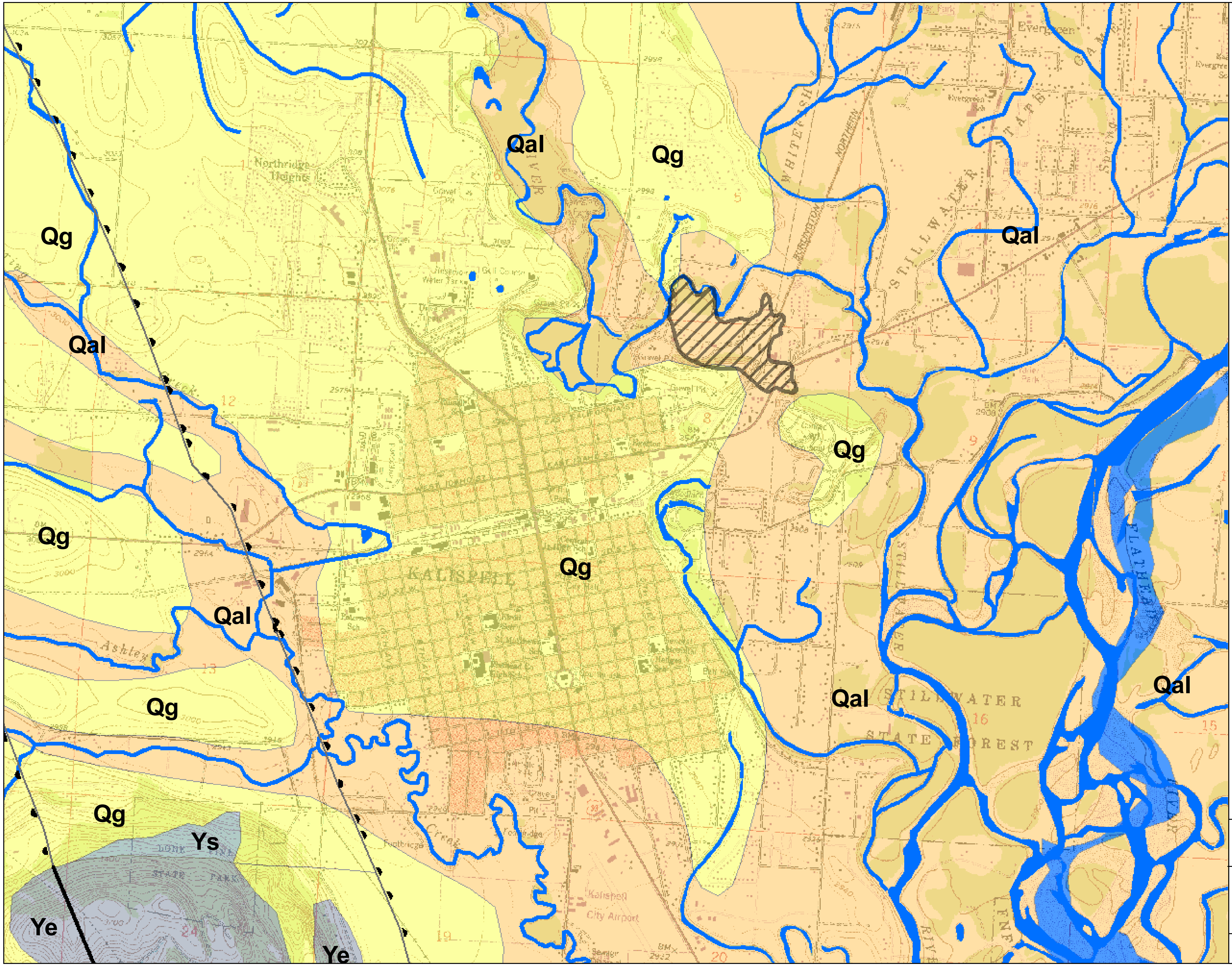
Note:
Base Figure From DEQ/TtEMI RI,
Modified by Trihydro Corporation.

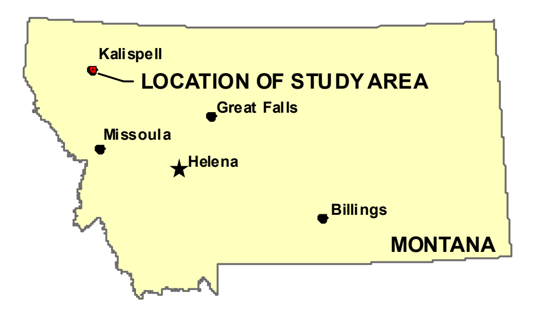
Source:
NRIS and Aerial Photo-Kalispell Area (2004)
USDA FSA NAIP Aerial
Photo-Kalispell Area (2005)
ThermoRetec 2001

KRY SITE
KALISPELL, MONTANA

FIGURE 1-4
GROUNDWATER, SURFACE WATER AND SEDIMENT SAMPLING AND MONITORING LOCATIONS

FIG 1-4_WATER SAMPLING LOCATIONS.dwg - DWH - 07/24/2007 - S1176-37-KPT010





Legend

▨ Approximate KRY Site Boundary

Geologic Units

■ Qal - Alluvial deposits

■ Qg - Glacial and fluvioglacial deposits

■ Ye - Empire Formation

■ Ys - Spokane Formation

Faults

— Fault, unknown offset; dotted where concealed.

-•-•- High-angle fault, known offset; dotted where concealed. Ball on downthrown side.

Note:
Base Figure From DEQ/TtEMI FS, MODIFIED By Trihydro Corporation

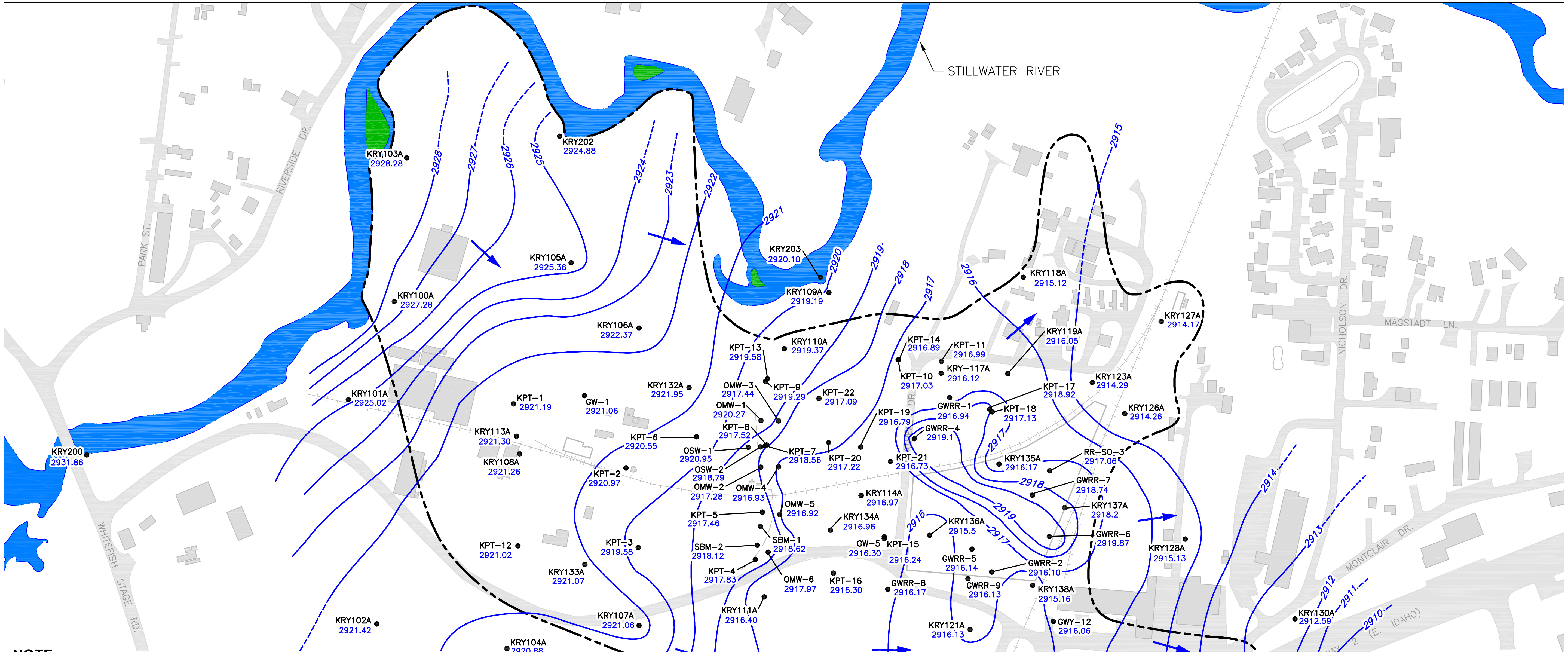
Source:
Harrison, J.E., Cressman, E.R., Whipple, J.W., 1992, Geologic and structure maps of Kalispell 1- by 2- degree quadrangle, Montana and Alberta, British Columbia, United States Geological Survey: Miscellaneous Geologic Investigation 2267, 1 sheet(s), 1:250,000

2,100 0 2,100
Feet

KEY SITE
KALISPELL, MONTANA

FIGURE 2-1
GENERAL GEOLOGY

Fig2-1_KPT_general_geology2_060608.mxd



NOTE:

1. THIS GROUNDWATER ELEVATION CONTOUR MAP REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM DEQ WATER LEVEL MONITORING EVENTS; OTHER INTERPRETATIONS ARE POSSIBLE.
2. THE PRIMARY FLOW DIRECTION IN THE AQUIFER IS TOWARD THE SOUTHEAST; HOWEVER, MOUNDING THAT IS EVIDENT IN SEVERAL AREAS MAY CAUSE LOCALIZED FLOW PATTERNS THAT ARE DIFFERENT FROM THE PRIMARY AQUIFER FLOW DIRECTION.

SOURCES:

1. MODIFIED FROM SITE VICINITY MAP CREATED BY TtEMI, JANUARY 2007, PROVIDED BY MDEQ
2. NRIS AND USGS AERIAL PHOTO-KALISPELL AREA (2004)
3. USDA FSA NAIP AERIAL PHOTO-KALISPELL AREA (2005)
4. THERMORETEC 2001

EXPLANATION

● KRY102A 2921.42	MONITORING WELL LOCATION AND DESIGNATION SHOWING GROUNDWATER ELEVATION IN FT AMSL
2917	LINE OF EQUAL ELEVATION OF POTENTIOMETRIC-SURFACE (FT AMSL, DASHED WHERE INFERRED)
←	GENERAL DIRECTION OF GROUNDWATER FLOW
— · — · —	APPROXIMATE KRY SITE BOUNDARY
—x—x—	FENCE
🟦	RIVER
┼┼┼┼	RAILROAD
▭	ROAD
▭	BUILDING OR STRUCTURE
FT AMSL	FEET ABOVE MEAN SEA LEVEL

N

0 300'

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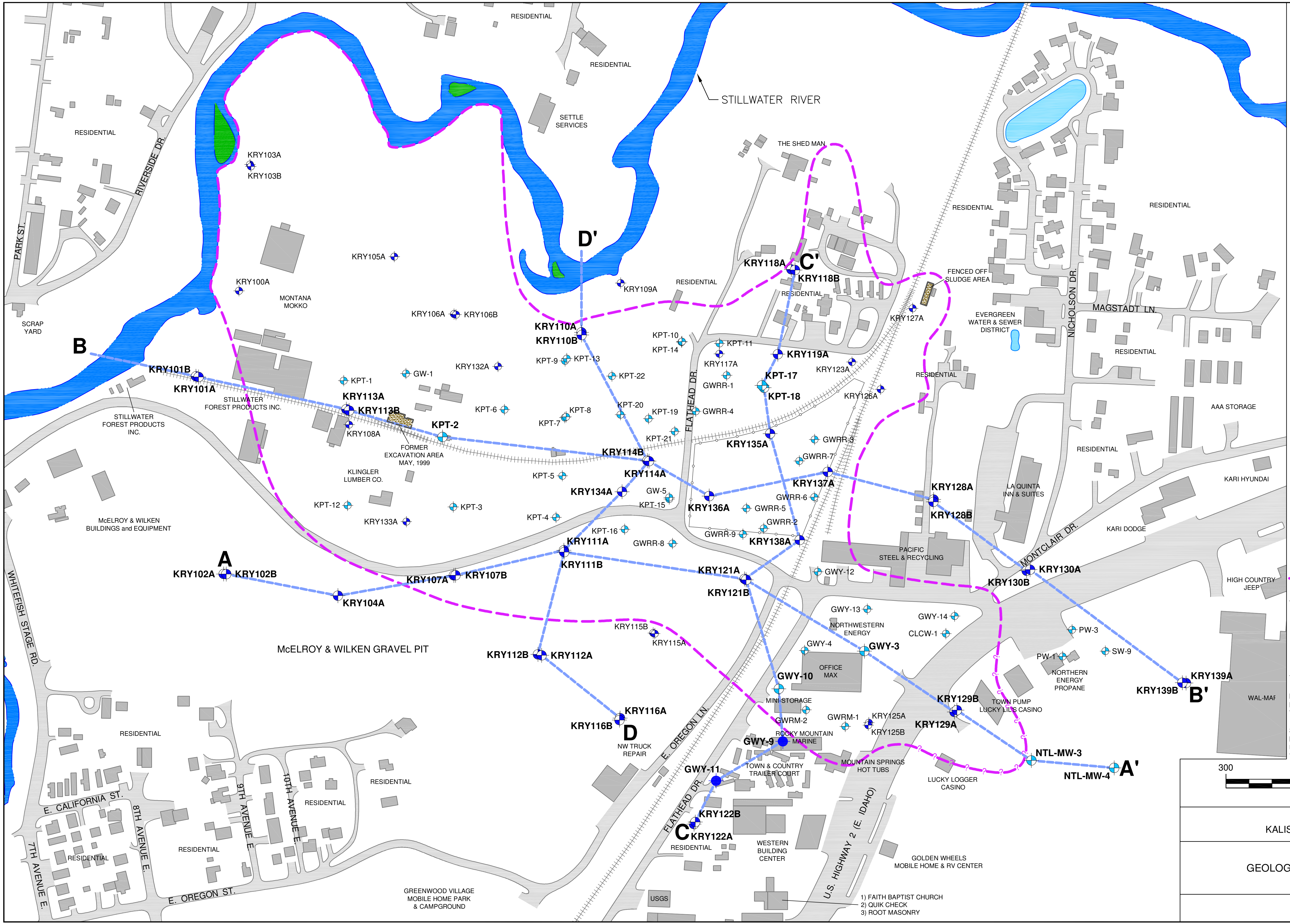
FIGURE 2-10
GROUNDWATER ELEVATION CONTOUR MAP UPPER PORTION OF UNCONFINED AQUIFER (MAY 2007)

KRY SITE
KALISPELL, MONTANA

Drawn By: REP | Checked By: CC | Scale: 1" = 300' | Date: 5/21/08 | File: 776004PS200705-EDITS-FS



Legend

	-	Monitoring Well (Installed by TtEMI in 200
	-	Monitoring Well (Installed Previously)
●	-	Abandoned Monitoring W
▨	-	Building
	-	Approximate KRY Site Boundary
	-	Fence
	-	Pond
	-	River
🟩	-	Island
	-	Road
	-	Railroad

NOTE:
Base Figure From DEQ/TtEMI FS, Modified By Trihydro Corporation

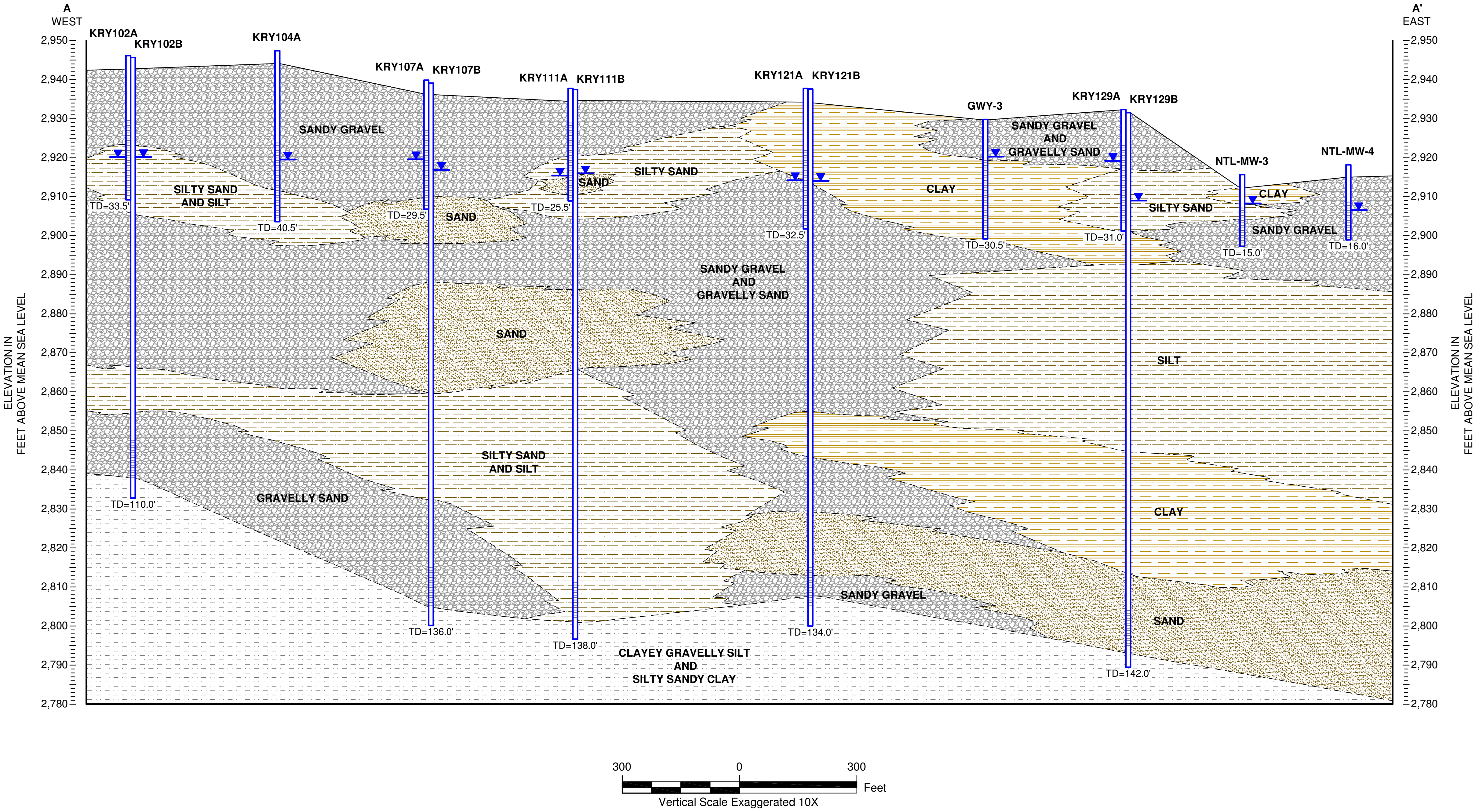
Source:
NRIS and USGS Aerial Photo-Kalispell Area (200
USDA FSA NAIP Aerial Photo-Kalispell Area (200
ThermoRetec 2001

300 0 300 Feet

KRY SITE
KALISPELL, MONTANA

FIGURE 2-2
GEOLOGIC CROSS-SECTION
PLAN MAP

FIG 2-2_XSECT PLAN MAP.dwg - DWH - 07/24/2007 - S1176-37-KPT010



Legend

▨ - Sandy Gravel and/or Gravelly Sand

▤ - Silty Sand and/or Silt

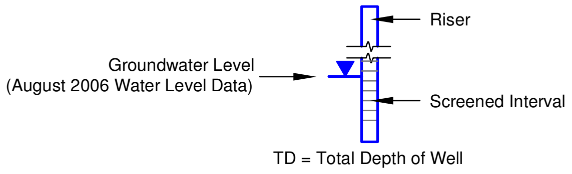
▨ - Sand

▤ - Clay

▭ - Clayey Gravelly Silt and Silty Sandy Clay

– – – – - Lithologic Contact, Located Approximately or Inferred

Monitoring Well Detail



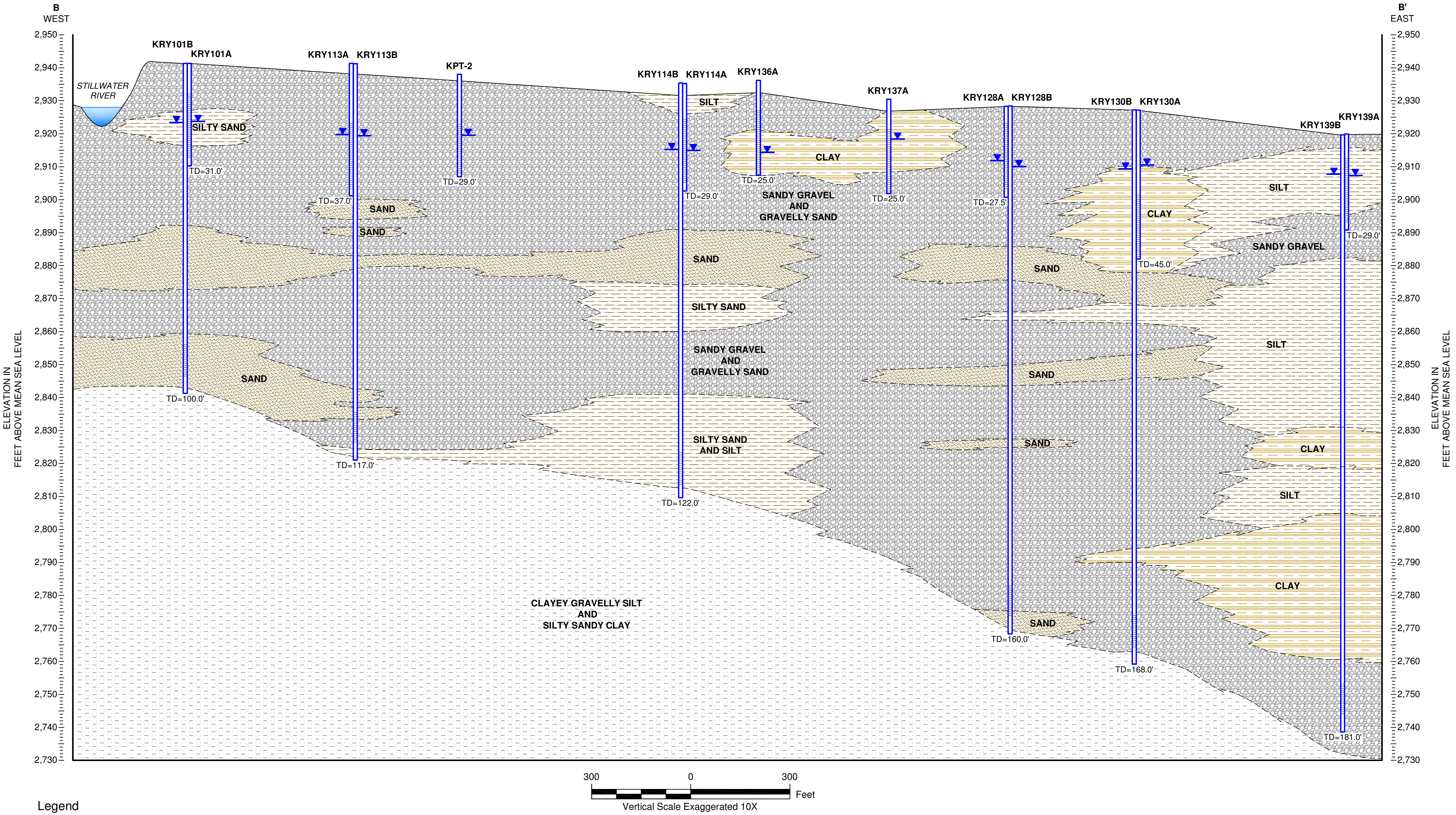
NOTES:
1. Base Figure From DEQ/TtEMI, FS, Modified By Tridydro Corporation
2. This Cross-Section Represents One Interpretation Based on Available Data from the DEQ/TtEMI RI; Other Interpretations Are Possible

Source:
Interpreted From Borehole Logs - Appendix D
RETEC 1995
ThermoRetec 2001

KRY SITE
KALISPELL, MONTANA

FIGURE 2-3
GEOLOGIC CROSS-SECTION A-A'

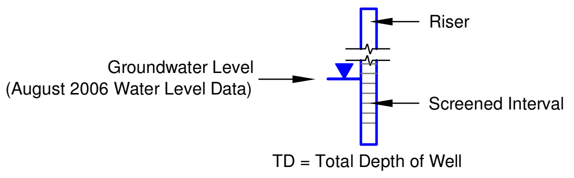
FIG 2-3_XSECT A-A'.dwg - DWH - 05/01/2007 - S1176-37-KPT010



Legend

- ▩ - Sandy Gravel and/or Gravelly Sand
- ▤ - Silty Sand and/or Silt
- ▨ - Sand
- ▤ - Clay
- ▭ - Clayey Gravelly Silt and Silty Sandy Clay
- – – – - Lithologic Contact, Located Approximately or Inferred

Monitoring Well Detail



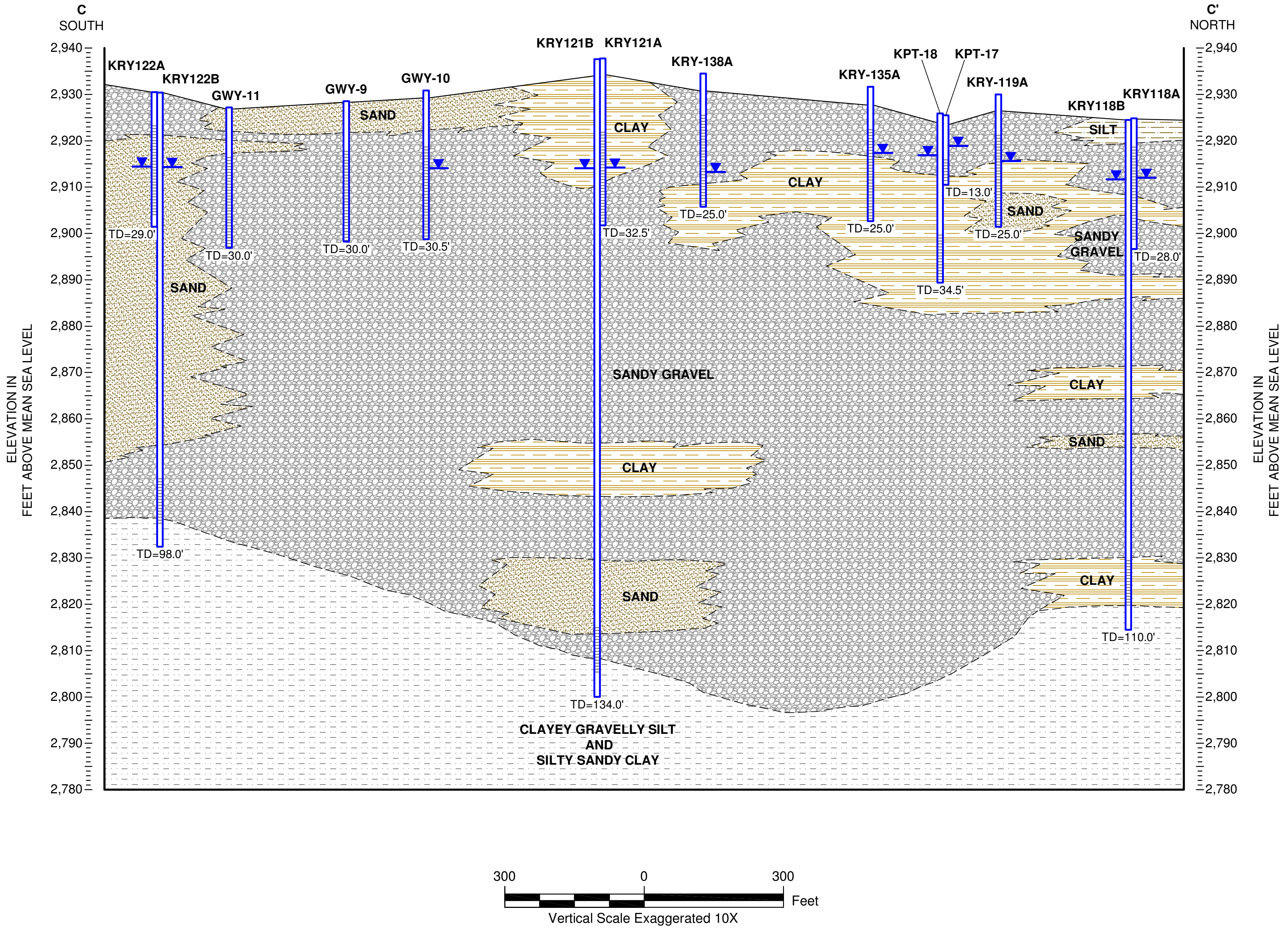
NOTES:
1. Base Figure From DEQ/TtEMI FS, Modified By Trihydro Corporation.
2. Cross-Section Hatches Were Modified By Trihydro Corporation.
3. This Cross-Section Represents One Interpretation Based on Available Data from the DEQ/TtEMI RI; Other Interpretations Are Possible.

Source:
Interpreted From Borehole Logs - RI - Appendix D
RETEC 1995
ThermoRetec 2001

KRY SITE
KALISPELL, MONTANA

FIGURE 2-4
GEOLOGIC CROSS-SECTION B-B'

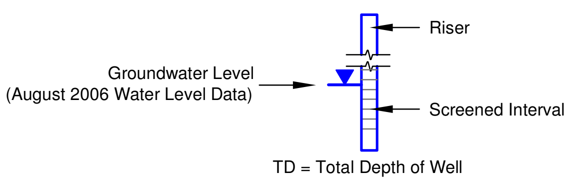
FIG 2-4_XSECT B-B'.dwg - DWH - 05/01/2007 - S1176-37-KPT010



Legend

▨ - Sandy Gravel and/or Gravelly Sand
▤ - Silty Sand and/or Silt
▨ - Sand
▤ - Clay
▢ - Clayey Gravelly Silt and Silty Sandy Clay
– – – - Lithologic Contact, Located Approximately or Inferred

Monitoring Well Detail

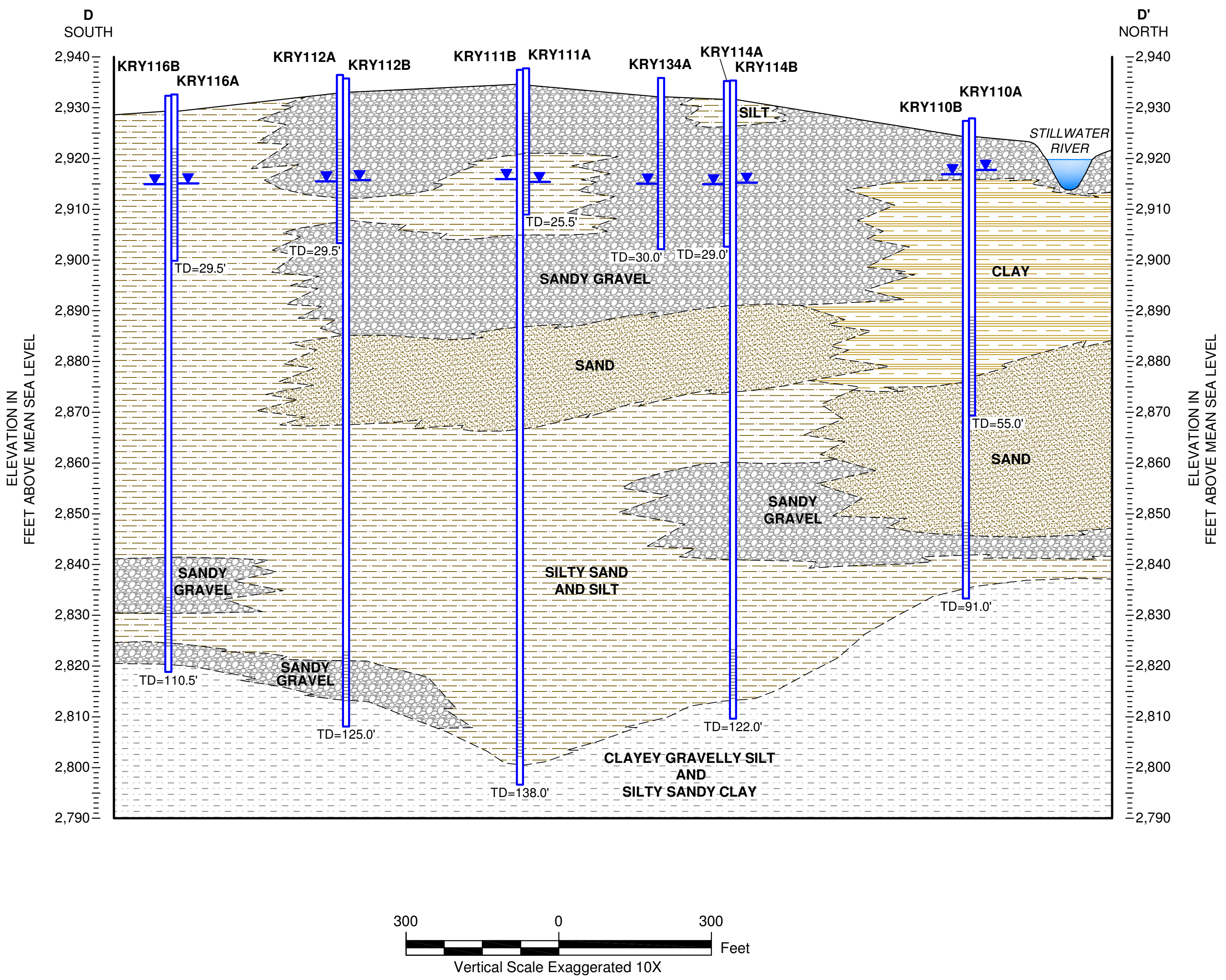


NOTES:
1. Base Figure From DEQ/TtEMI FS, Modified By Trihydro Corporation
2. Cross-Section Hatches Were Modified By Trihydro Corporation
3. This Cross-Section Represents One Interpretation Based on Available Data from the DEQ/TtEMI RI; Other Interpretations Are Possible

Source:
Interpreted From Borehole Logs - RI - Appendix D
RETEC 1995
ThermoRetec 2001

KRY SITE
KALISPELL, MONTANA

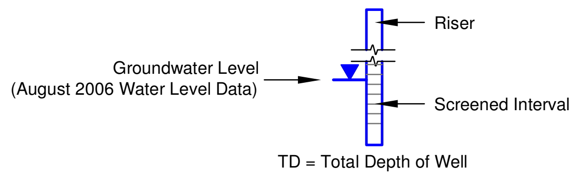
FIGURE 2-5
GEOLOGIC CROSS-SECTION C-C'



Legend

▨ - Sandy Gravel and/or Gravelly Sand
▨ - Silty Sand and/or Silt
▨ - Sand
▨ - Clay
▨ - Clayey Gravelly Silt and Silty Sandy Clay
– – – – - Lithologic Contact, Located Approximately or Inferred

Monitoring Well Detail

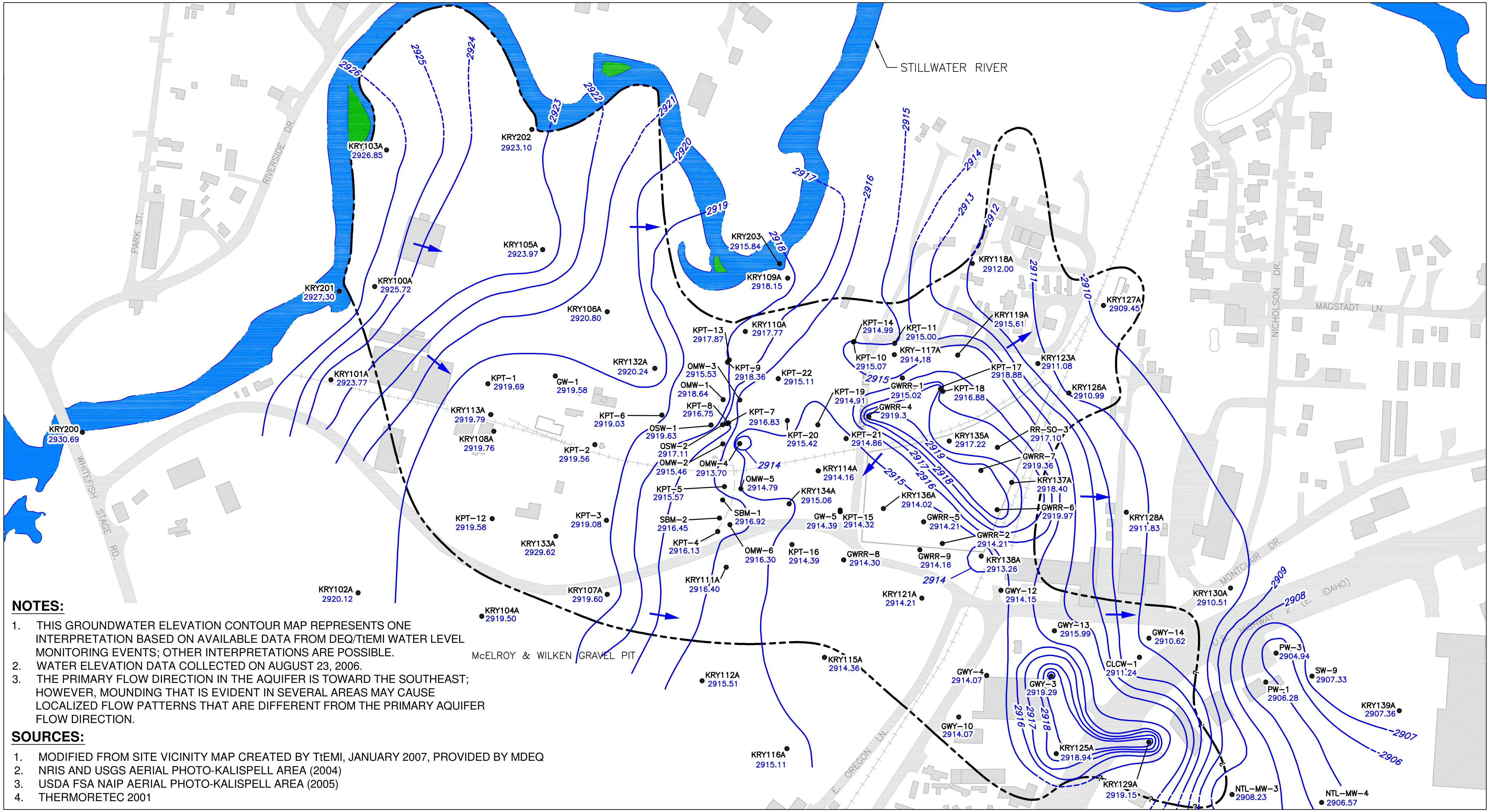


NOTES:
1. Base Figure From DEQ/TtEMI FS, Modified By Trihydro Corporation
2. This Cross-Section Represents One Interpretation Based on Available Data from the DEQ/TtEMI RI; Other Interpretations Are Possible

Source:
Interpreted From Borehole Logs - Appendix D
RETEC 1995
ThermoRetec 2001

KRY SITE
KALISPELL, MONTANA

FIGURE 2-6
GEOLOGIC CROSS-SECTION D-D'



NOTES:

1. THIS GROUNDWATER ELEVATION CONTOUR MAP REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM DEQ/TtEMI WATER LEVEL MONITORING EVENTS; OTHER INTERPRETATIONS ARE POSSIBLE.
2. WATER ELEVATION DATA COLLECTED ON AUGUST 23, 2006.
3. THE PRIMARY FLOW DIRECTION IN THE AQUIFER IS TOWARD THE SOUTHEAST; HOWEVER, MOUNDING THAT IS EVIDENT IN SEVERAL AREAS MAY CAUSE LOCALIZED FLOW PATTERNS THAT ARE DIFFERENT FROM THE PRIMARY AQUIFER FLOW DIRECTION.

SOURCES:

1. MODIFIED FROM SITE VICINITY MAP CREATED BY TtEMI, JANUARY 2007, PROVIDED BY MDEQ
2. NRIS AND USGS AERIAL PHOTO-KALISPELL AREA (2004)
3. USDA FSA NAIP AERIAL PHOTO-KALISPELL AREA (2005)
4. THERMORETEC 2001

EXPLANATION

● KRY102A 2920.12	MONITORING WELL LOCATION AND DESIGNATION SHOWING GROUNDWATER ELEVATION IN FT AMSL
2917	LINE OF EQUAL ELEVATION OF POTENTIOMETRIC-SURFACE (FT AMSL, DASHED WHERE INFERRED)
←	GENERAL DIRECTION OF GROUNDWATER FLOW
— - — -	APPROXIMATE KRY SITE BOUNDARY
—x—x—	FENCE
🟦	RIVER
—+—+—	RAILROAD
▭	ROAD
▭	BUILDING OR STRUCTURE
FT AMSL	FEET ABOVE MEAN SEA LEVEL

N

0 300'

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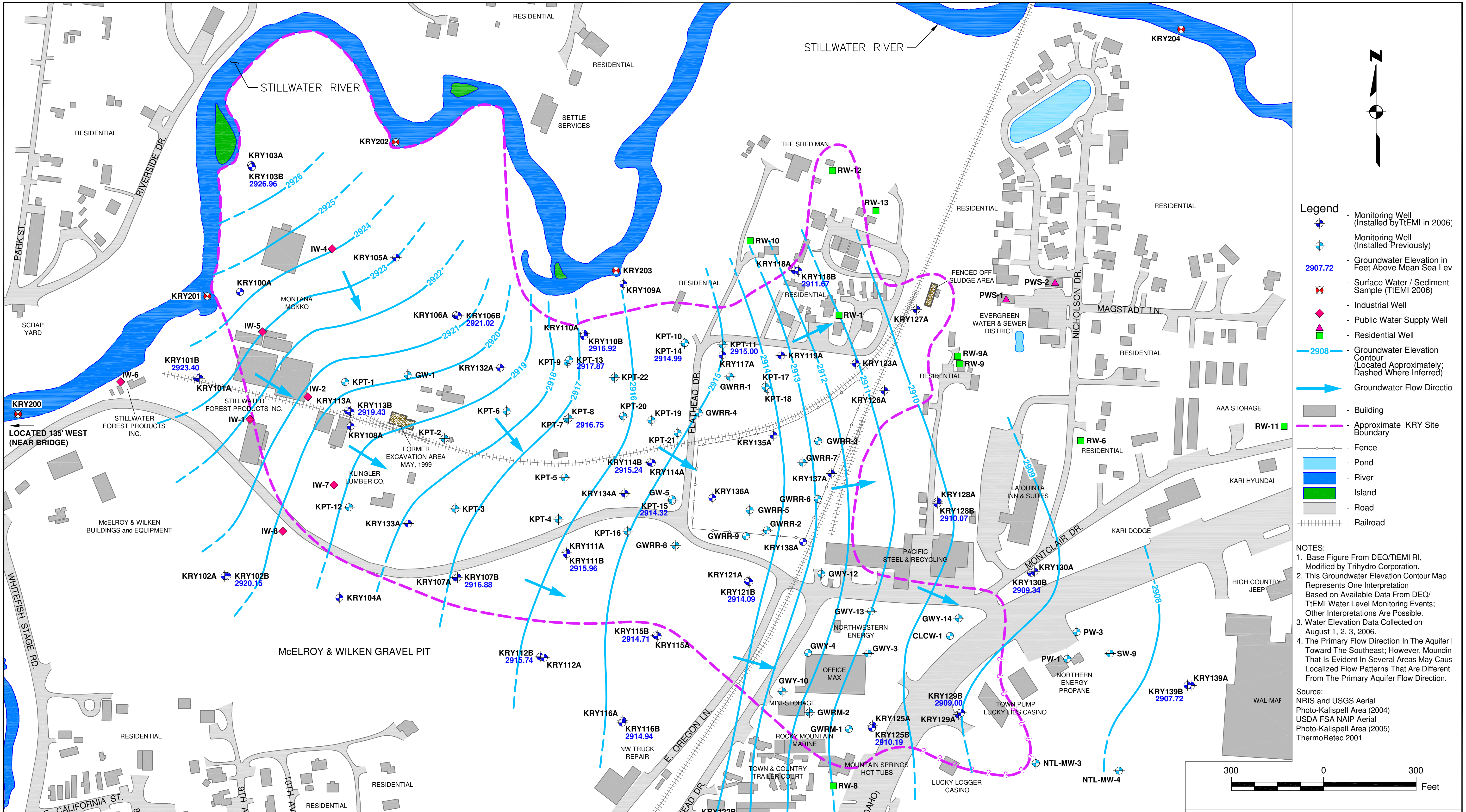
FIGURE 2-7
GROUNDWATER ELEVATION CONTOUR MAP UPPER PORTION OF UNCONFINED AQUIFER (AUGUST 2006)

KRY SITE KALISPELL, MONTANA

Drawn By: REP | Checked By: CC | Scale: 1" = 300' | Date: 5/21/08 | File: 776004PS200608-EDITS-FS



NOTES:

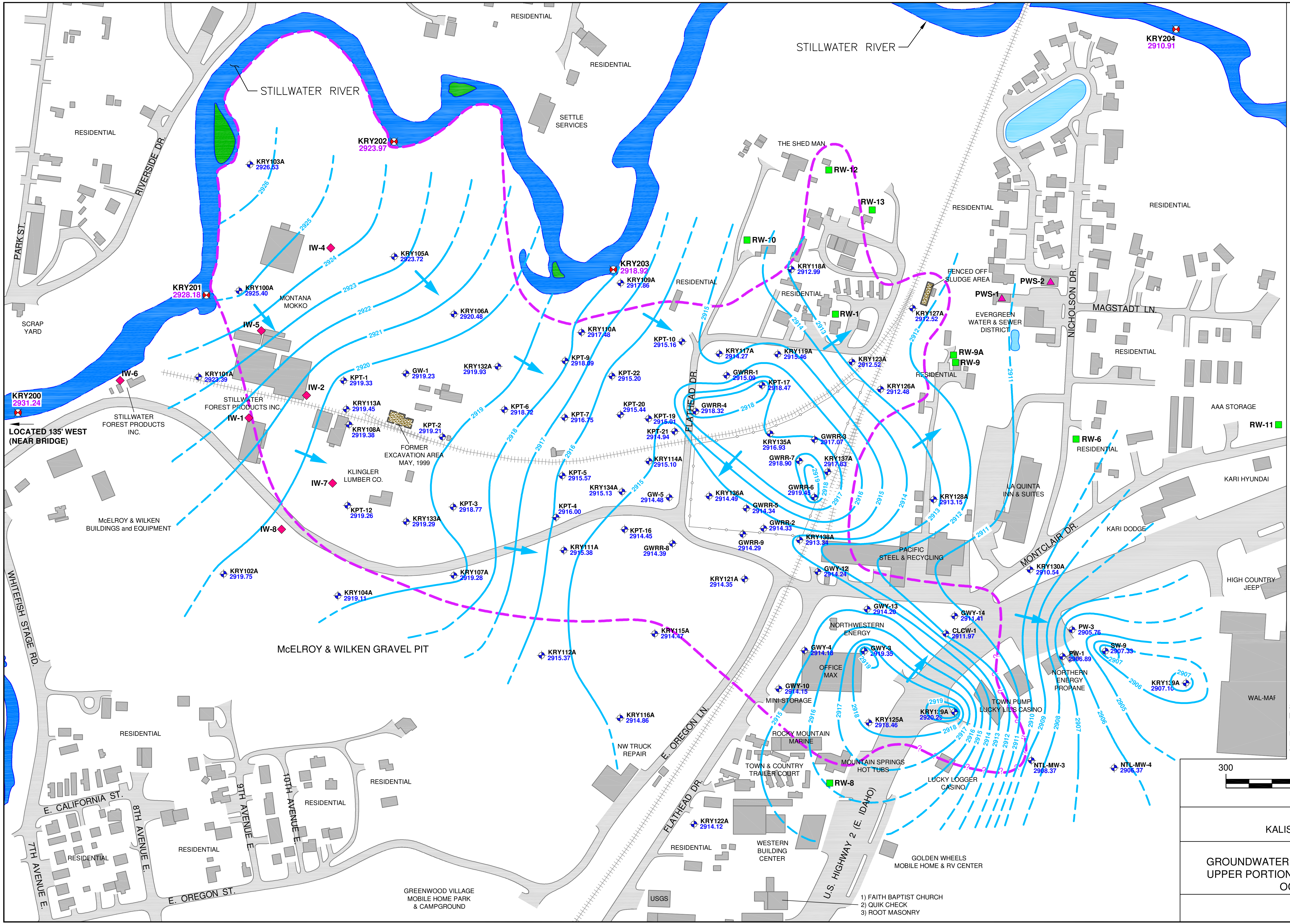
1. Base Figure From DEQ/TtEMI RI, Modified by Trihydro Corporation.
2. This Groundwater Elevation Contour Map Represents One Interpretation Based on Available Data From DEQ/ TtEMI Water Level Monitoring Events; Other Interpretations Are Possible.
3. Water Elevation Data Collected on August 1, 2, 3, 2006.
4. The Primary Flow Direction In The Aquifer Toward The Southeast; However, Moundin That Is Evident In Several Areas May Caus Localized Flow Patterns That Are Different From The Primary Aquifer Flow Direction.

Source:
NRIS and USGS Aerial
Photo-Kalispell Area (2004)
USDA FSA NAIP Aerial
Photo-Kalispell Area (2005)
ThermoRetec 2001

KRY SITE
KALISPELL, MONTANA

FIGURE 2-8
GROUNDWATER ELEVATION CONTOUR MAP LOWER PORTION OF UNCONFINED AQUIFER AUGUST 2006

FIG 2-8_GW ELEV CONT-AUG 06_LOWER.dwg - DWH - 07/24/2007 - S1176-37-KPT010



Legend

⊕	- Monitoring Well
2907.10	- Groundwater Elevation in Feet Above Mean Sea Lev
⊗	- Surface Water / Sediment Sample (TtEMI 2006)
2910.91	- Surface Water Elevation in Feet Above Mean Sea Lev
◆	- Industrial Well
▲	- Public Water Supply Well
🟩	- Residential Well
—2906—	- Groundwater Elevation Contour (Located Approximately; Dashed Where Inferred)
→	- Groundwater Flow Directio
▨	- Building
— — —	- Approximate KRY Site Boundary
—○—○—	- Fence
▨	- Pond
▨	- River
▨	- Island
▨	- Road
┼┼┼┼┼┼	- Railroad

NOTES:
1. Base Figure From DEQ/TtEMI RI, Modified by Trihydro Corporation.
2. This Groundwater Elevation Contour Map Represents One Interpretation Based on Available Data From DEQ/ TtEMI Water Level Monitoring Events; Other Interpretations Are Possible.
3. The Primary Flow Direction In The Aquifer I Toward The Southeast; However, Moundin That Is Evident In Several Areas May Caus Localized Flow Patterns That Are Different From The Primary Aquifer Flow Direction.

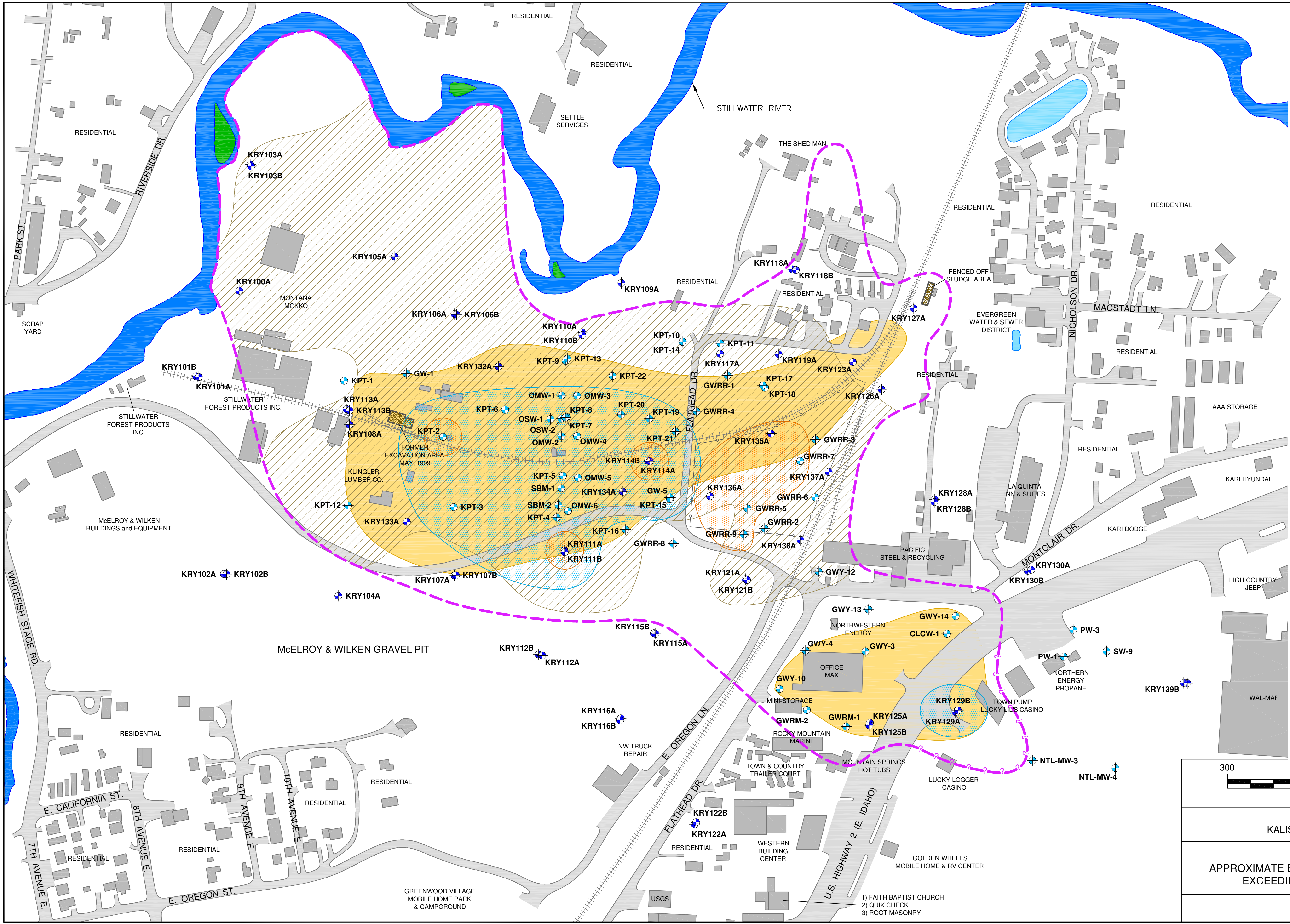
Source:
NRIS and USGS Aerial Photo-Kalispell Area (2004)
USDA FSA NAIP Aerial Photo-Kalispell Area (2005)
ThermoRetec 2001

300 0 300 Feet

KRY SITE
KALISPELL, MONTANA

FIGURE 2-9
GROUNDWATER ELEVATION CONTOUR MAP
UPPER PORTION OF UNCONFINED AQUIFER
OCTOBER 2006

FIG 3-7B_GW ELEV CONT-OCT 06_UPPER.dwg - DWH - 01/22/2007 - S1176-37-KPT005



NOTES:

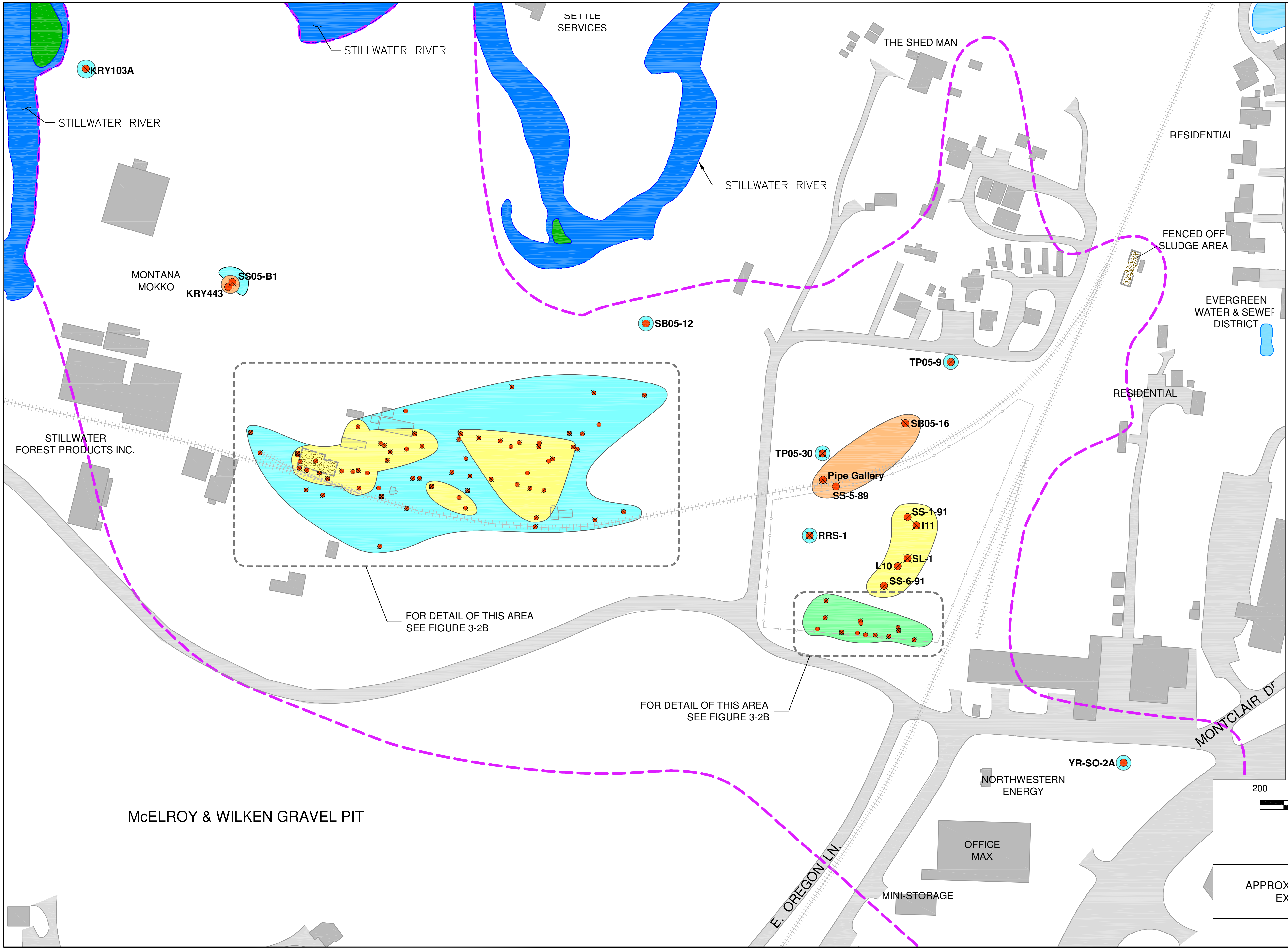
1. Base Figure From DEQ/TtEMI RI, Modified by Trihydro Corporation.
2. Metals-Above Cleanup Levels Were Modified by Trihydro Corporation.
3. Dioxins-Above Cleanup Levels Were Modified b Trihydro Corporation.
4. This Figure Represents One Interpretation Based on Available Data from the DEQ/TtEMI F and Retec Semiannual Monitoring Reports; other interpretations are possible
5. Data used to Represent the Approximate Extent of Dioxins included Data from January 2004 through October 2007 because not Every Well was Sampled for Dioxins at each Sampling Eve

Source:
NRIS and USGS Aerial Photo-Kalispell Area (2004
USDA FSA NAIP Aerial Photo-Kalispell Area (200
ThermoRetec 2001

KRY SITE
KALISPELL, MONTANA

FIGURE 3-1
APPROXIMATE EXTENT OF GROUNDWATER EXCEEDING CLEANUP LEVELS

Groundwater Results-EXCEEDANCES.dwg - DWH - 07/26/2007 - S1176-37-KPT010



COLOR	CONSTITUENT AND ESTIMATED TOTAL AREA
🟦	DIOXIN - 152,918 sq ft
🟩	LEAD - 19,420 sq ft
🟨	PCP - 80,366 sq ft
🟧	PETROLEUM - 20,250 sq ft

Legend

⊗	- Surface Sampling Location
▭	- Building
‒ ‒	- Approximate KRY Site Boundary
‒	- Fence
▭	- Pond
▭	- River
▭	- Island
▭	- Road
┼┼┼	- Railroad

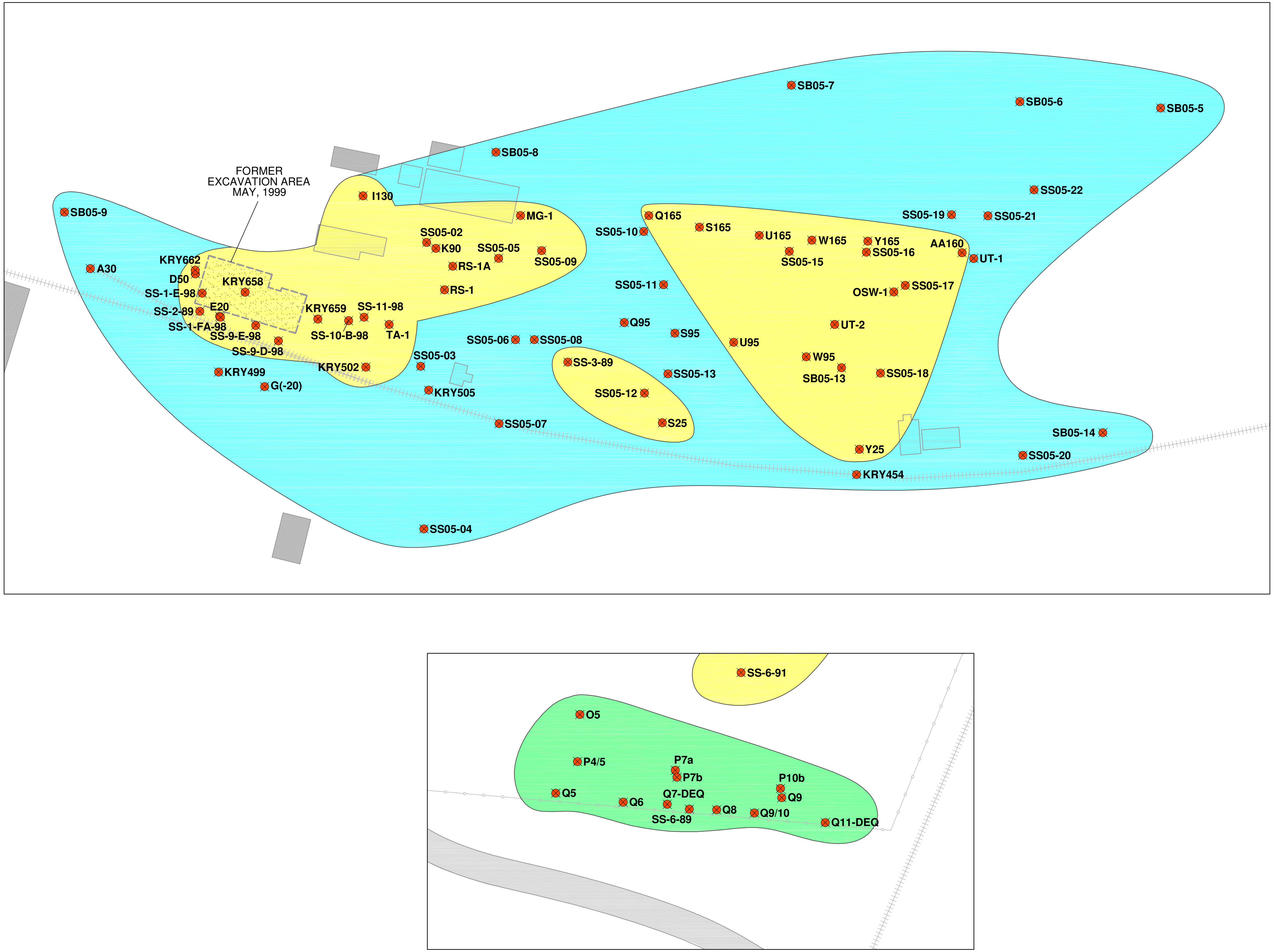
NOTES:
1. Base Figure From DEQ/TtEMI RI, Modified by Trihydro Corporation.
2. This Figure Represents One Interpretation Based on Available Data identified as usable in the DEQ/TtEMI RI and TtEMI DSR; Other Interpretations Are Possible

Source:
NRIS and USGS Aerial Photo-Kalispell Area (2004)
USDA FSA NAIP Aerial Photo-Kalispell Area (2005)
ThermoRetec 2001

KRY SITE
KALISPELL, MONTANA

FIGURE 3-2A
APPROXIMATE EXTENT OF SURFACE SOIL EXCEEDING CLEANUP LEVELS SITEWIDE

FIG 3-2A_Surface Soil Exceedances-Sitewide.dwg - DWH - 07/30/2007 - S1176-37-KPT010



COLOR	CONSTITUENT AND ESTIMATED TOTAL AREA
🟦	DIOXIN - 152,918 sq ft
🟩	LEAD - 19,420 sq ft
🟨	PCP - 80,366 sq ft
🟧	PETROLEUM - 20,250 sq ft

Legend

⊗ - Surface Sampling Location
▬ - Building
- Fence
- Road
- Railroad

NOTES:
1. Base Figure From DEQ/TtEMI RI, Modified by Trihydro Corporation.
2. This Figure Represents One Interpretation Based on Available Data identified as usable in the DEQ/TtEMI RI and TtEMI DSR; Other Interpretations Are Possible
3. Area of Lead Impacts modified by Trihydro Corp.
4. Sample SS-9-A-98 removed from original figure by Trihydro Corp.

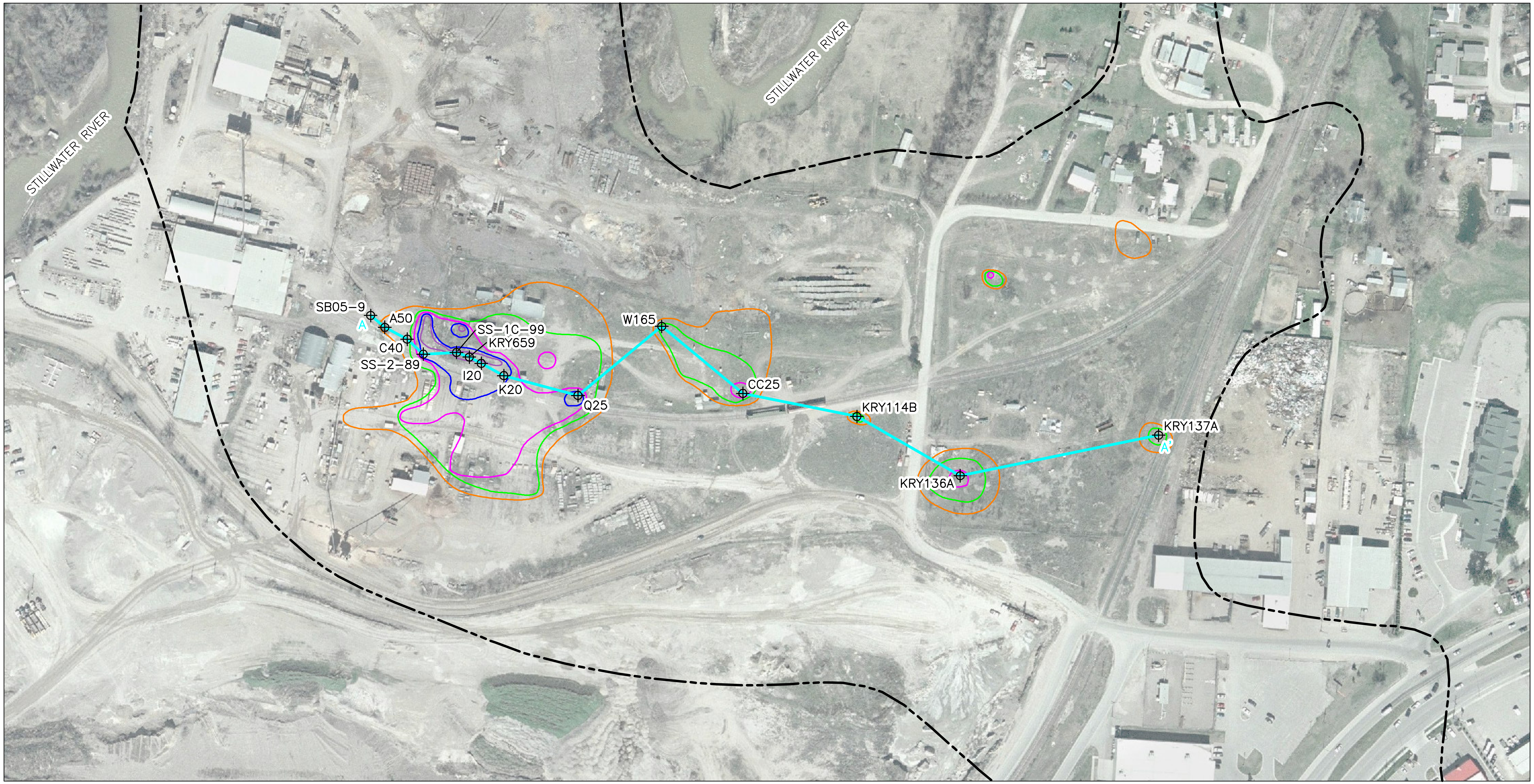
Source:
NRIS and USGS Aerial Photo-Kalispell Area (2004)
USDA FSA NAIP Aerial Photo-Kalispell Area (2005)
ThermoRetec 2001

80 0 80
Feet

KRY SITE
KALISPELL, MONTANA

FIGURE 3-2B
APPROXIMATE EXTENT OF SURFACE SOIL EXCEEDING CLEANUP LEVELS DETAIL

FIG 3-2B_Surface Soil Exceedances-Detail.dwg - DWH - 07/30/2007 - S1176-37-KPT010



Basemap: Flathead County GIS, High Resolution Ortho-Rectified Aerial Image, Flathead County, Montana, Publication: July 19, 2005.

EXPLANATION

KRY659 BORING LOCATION AND DESIGNATION

APPROXIMATE KRY SITE BOUNDARY

MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 0.43 mg/kg)

MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 1 mg/kg)

MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 10 mg/kg)

MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 100 mg/kg)

MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 500 mg/kg)

CROSS-SECTION A-A'

mg/kg	MILLIGRAMS PER KILOGRAM (ppm)
ppm	PARTS PER MILLION

N

0 200'

NOTES:

1. LOWEST PCP CLEANUP LEVEL = 0.43 mg/kg
2. THIS FIGURE REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM THE DEQ/TtEMI RI AND TtEMI DSR; OTHER INTERPRETATIONS ARE POSSIBLE

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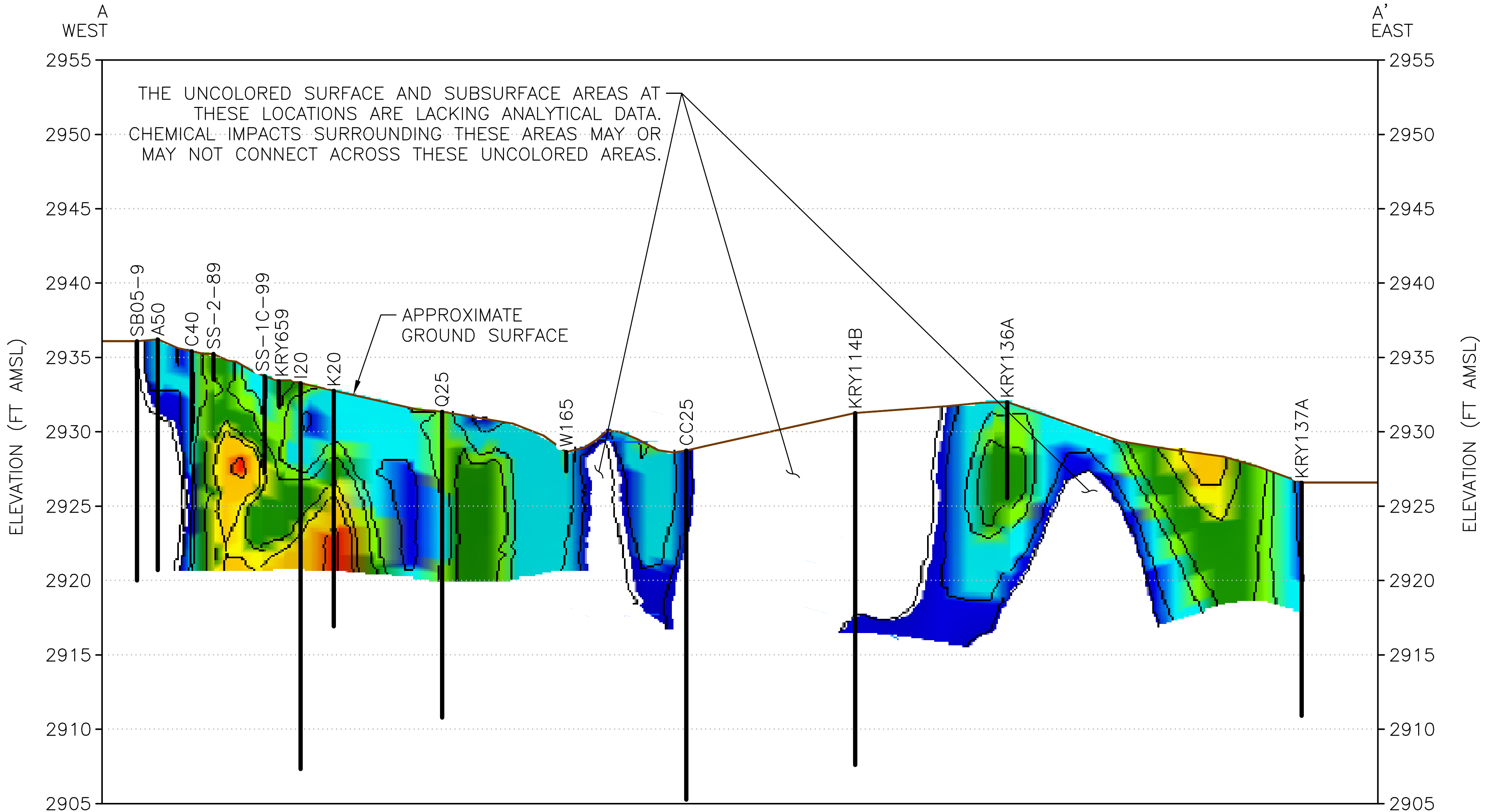
FIGURE 3-3A

PCP CONCENTRATIONS IN SUBSURFACE SOIL EXCEEDING CLEANUP LEVEL
MAP VIEW

KRY SITE
KALISPELL, MONTANA

Drawn By: REP | Checked By: CC | Scale: 1" = 200' | Date: 5/22/08 | File: 776004PCP-200805-EDITS



THE UNCOLORED SURFACE AND SUBSURFACE AREAS AT THESE LOCATIONS ARE LACKING ANALYTICAL DATA. CHEMICAL IMPACTS SURROUNDING THESE AREAS MAY OR MAY NOT CONNECT ACROSS THESE UNCOLORED AREAS.

APPROXIMATE GROUND SURFACE

Source: Trihydro Modeling Software Output, February 2008.

EXPLANATION

🟦	0.43 mg/kg TO 1 mg/kg
🟦	1 mg/kg TO 5 mg/kg
🟩	5 mg/kg TO 10 mg/kg
🟩	10 mg/kg TO 50 mg/kg
🟨	50 mg/kg TO 100 mg/kg
🟧	100 mg/kg TO 500 mg/kg
🟥	500 mg/kg TO 1000 mg/kg
🟪	1000 mg/kg TO 7000 mg/kg
FT AMSL	FEET ABOVE MEAN SEA LEVEL
mg/kg	MILLIGRAMS PER KILOGRAM (ppm)
ppm	PARTS PER MILLION

0 ~10'
VERTICAL

NOTES:

1. PCP CONCENTRATIONS ARE IN mg/kg
2. CHEMICAL CONCENTRATIONS ARE PRESENTED FOR SOILS BETWEEN THE GROUND SURFACE AND THE WATER TABLE
3. LOWEST PCP CLEANUP LEVEL = 0.43 mg/kg
4. THIS FIGURE REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM THE DEQ/TtEMI RI AND TtEMI DSR; OTHER INTERPRETATIONS ARE POSSIBLE

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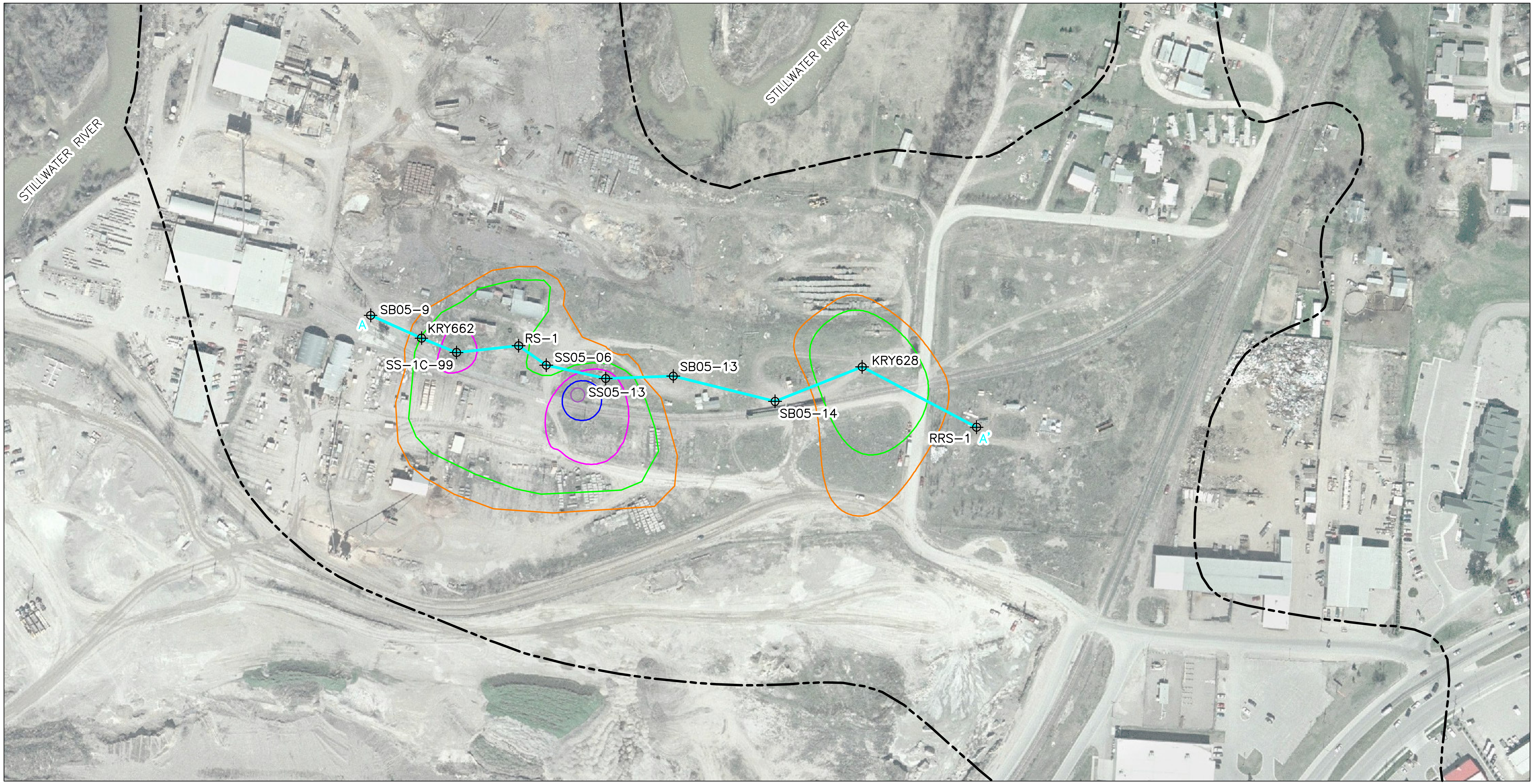
FIGURE 3-3B

PCP CONCENTRATIONS IN SUBSURFACE SOIL EXCEEDING CLEANUP LEVEL CROSS-SECTION A-A'

**KRY SITE
KALISPELL, MONTANA**

Drawn By: REP | Checked By: CC | Scale: AS SHOWN | Date: 5/22/08 | File: 776004PCP-200805-EDITS



Basemap: Flathead County GIS, High Resolution Ortho-Rectified Aerial Image, Flathead County, Montana, Publication: July 19, 2005.

EXPLANATION

⌖ KRY662	BORING LOCATION AND DESIGNATION
— · —	APPROXIMATE KRY SITE BOUNDARY
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 736 ng/kg)
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 1000 ng/kg)
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 5000 ng/kg)
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 10000 ng/kg)
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 20000 ng/kg)
—	CROSS-SECTION A-A'
ng/kg	NANOGRAMS PER KILOGRAM (ppt)
ppt	PARTS PER TRILLION

N

0 200'

NOTES:

1. SUBSURFACE DIOXIN/FURAN CLEANUP LEVEL =850 ng/kg
2. THIS FIGURE REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM THE DEQ/TtEMI RI AND TtEMI DSR; OTHER INTERPRETATIONS ARE POSSIBLE

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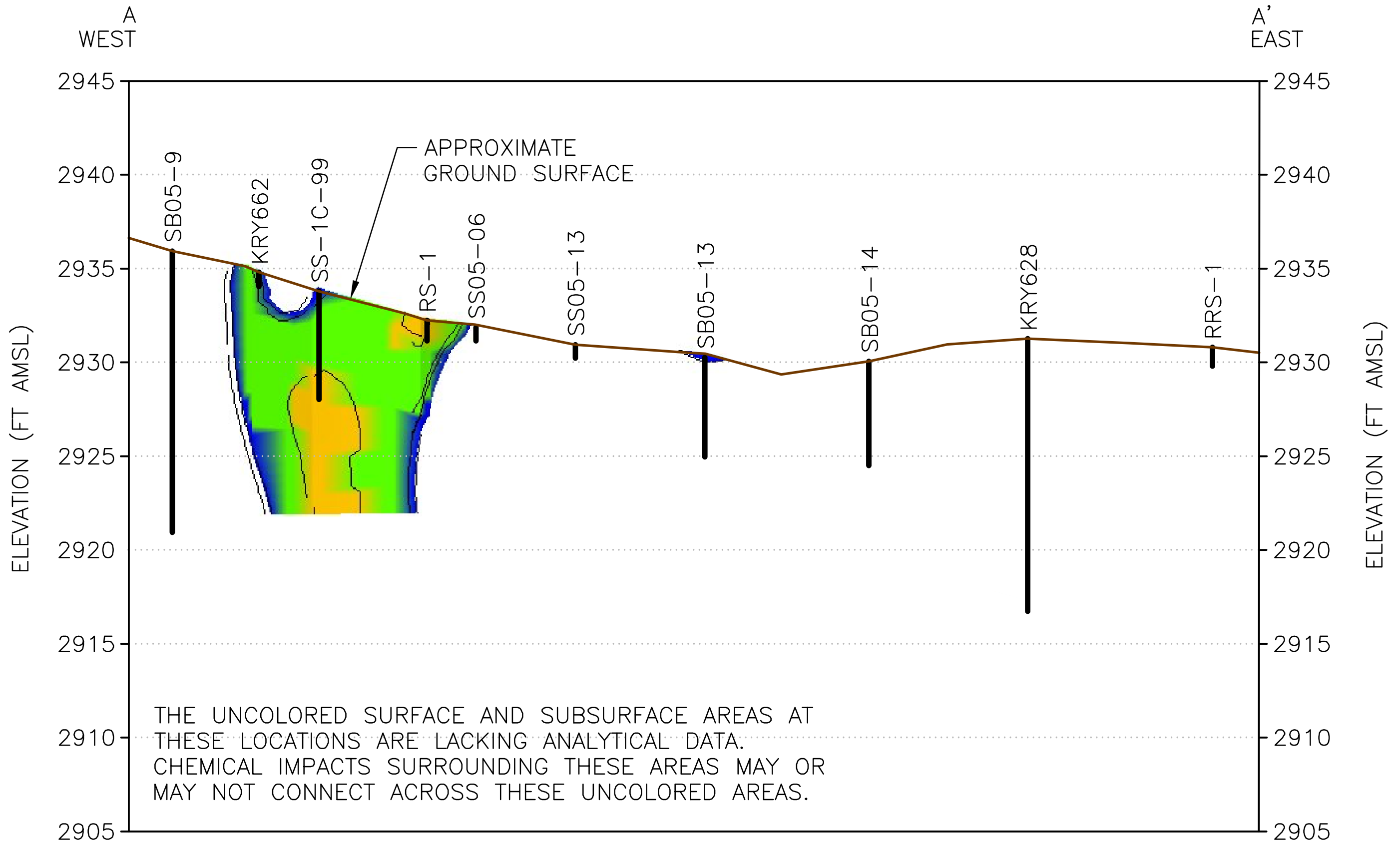
FIGURE 3-4A

DIOXIN/FURAN CONCENTRATIONS IN SUBSURFACE SOIL EXCEEDING CLEANUP LEVEL MAP VIEW

KRY SITE
KALISPELL, MONTANA

Drawn By: REP	Checked By: CC	Scale: 1" = 200'	Date: 5/28/08	File: 776004DIOXIN-MAP200805



THE UNCOLORED SURFACE AND SUBSURFACE AREAS AT THESE LOCATIONS ARE LACKING ANALYTICAL DATA. CHEMICAL IMPACTS SURROUNDING THESE AREAS MAY OR MAY NOT CONNECT ACROSS THESE UNCOLORED AREAS.

Source: Trihydro Modeling Software Output, February 2008.

EXPLANATION

🟦	736 ng/kg TO 1000 ng/kg
🟩	1000 ng/kg TO 3000 ng/kg
🟧	3000 ng/kg TO 10000 ng/kg
FT AMSL	FEET ABOVE MEAN SEA LEVEL
ng/kg	NANOGRAMS PER KILOGRAM (ppt)
ppt	PARTS PER TRILLION

0 ~10'

VERTICAL

NOTES:

1. DIOXIN/FURAN CONCENTRATIONS ARE IN ng/kg
2. CHEMICAL CONCENTRATIONS ARE PRESENTED FOR SOILS BETWEEN THE GROUND SURFACE AND THE WATER TABLE
3. LOWEST DIOXIN/FURAN CLEANUP LEVEL = 850 ng/kg
4. THIS FIGURE REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM THE DEQ/TtEMI RI AND TtEMI DSR; OTHER INTERPRETATIONS ARE POSSIBLE

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FIGURE 3-4B

DIOXIN/FURAN CONCENTRATIONS IN SUBSURFACE SOIL EXCEEDING CLEANUP LEVEL CROSS-SECTION A-A'

KRY SITE
KALISPELL, MONTANA

Drawn By: REP | Checked By: CC | Scale: AS SHOWN | Date: 5/22/08 | File: 776004DIOXIN-XSEC200805

Basemap: Flathead County GIS, High Resolution Ortho-Rectified Aerial Image, Flathead County, Montana, Publication: July 19, 2005.

EXPLANATION

⌖ P4	BORING LOCATION AND DESIGNATION
—·—	APPROXIMATE KRY SITE BOUNDARY
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 800 mg/kg)
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 2500 mg/kg)
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 5000 mg/kg)
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 10000 mg/kg)
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 15000 mg/kg)
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 20000 mg/kg)
—	MAXIMUM EXTENT OF SUSPECTED SUBSURFACE CONTAMINATION (CONCENTRATION > OR = 25000 mg/kg)
—	CROSS-SECTION A-A'
mg/kg	MILLIGRAMS PER KILOGRAM (ppm)
ppm	PARTS PER MILLION

N

0 100'

NOTES:

1. LEAD CLEANUP LEVEL = 800 MG/KG
2. THIS FIGURE REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM THE DEQ/TtEMI RI, TtEMI DSR, AND LAND & WATER CONSULTING (JULY 2002); OTHER INTERPRETATIONS ARE POSSIBLE

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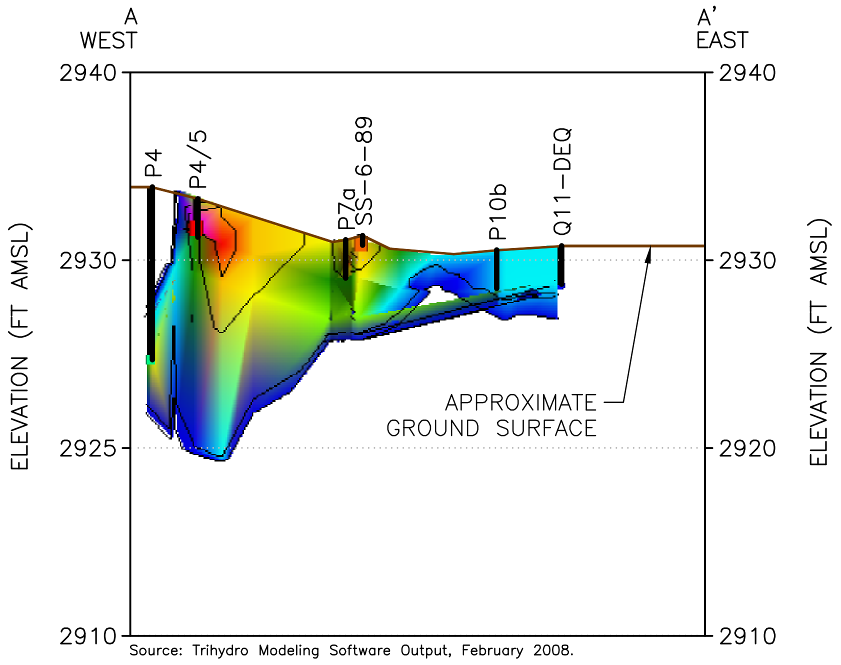
FIGURE 3-5A

LEAD CONCENTRATIONS IN SUBSURFACE SOIL EXCEEDING CLEANUP LEVEL MAP VIEW

KRY SITE
KALISPELL, MONTANA

Drawn By: REP	Checked By: CC	Scale: 1" = 100'	Date: 5/22/08	File: 776004LEAD-200805-EDITS



Source: Trihydro Modeling Software Output, February 2008.

EXPLANATION

🟦	800 mg/kg TO 1000 mg/kg
🟦	1000 mg/kg TO 2500 mg/kg
🟩	2500 mg/kg TO 5000 mg/kg
🟩	5000 mg/kg TO 10000 mg/kg
🟨	10000 mg/kg TO 15000 mg/kg
🟧	15000 mg/kg TO 20000 mg/kg
🟥	20000 mg/kg TO 25000 mg/kg
FT AMSL	FEET ABOVE MEAN SEA LEVEL
mg/kg	MILLIGRAMS PER KILOGRAM (ppm)
ppm	PARTS PER MILLION

0 ~5'
VERTICAL

NOTES:

1. LEAD CONCENTRATIONS ARE IN mg/kg
2. CHEMICAL CONCENTRATIONS ARE PRESENTED FOR SOILS BETWEEN THE GROUND SURFACE AND THE WATER TABLE
3. THIS FIGURE REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM THE DEQ/TtEMI RI, TtEMI DSR, AND LAND & WATER CONSULTING (JULY 2002); OTHER INTERPRETATIONS ARE POSSIBLE

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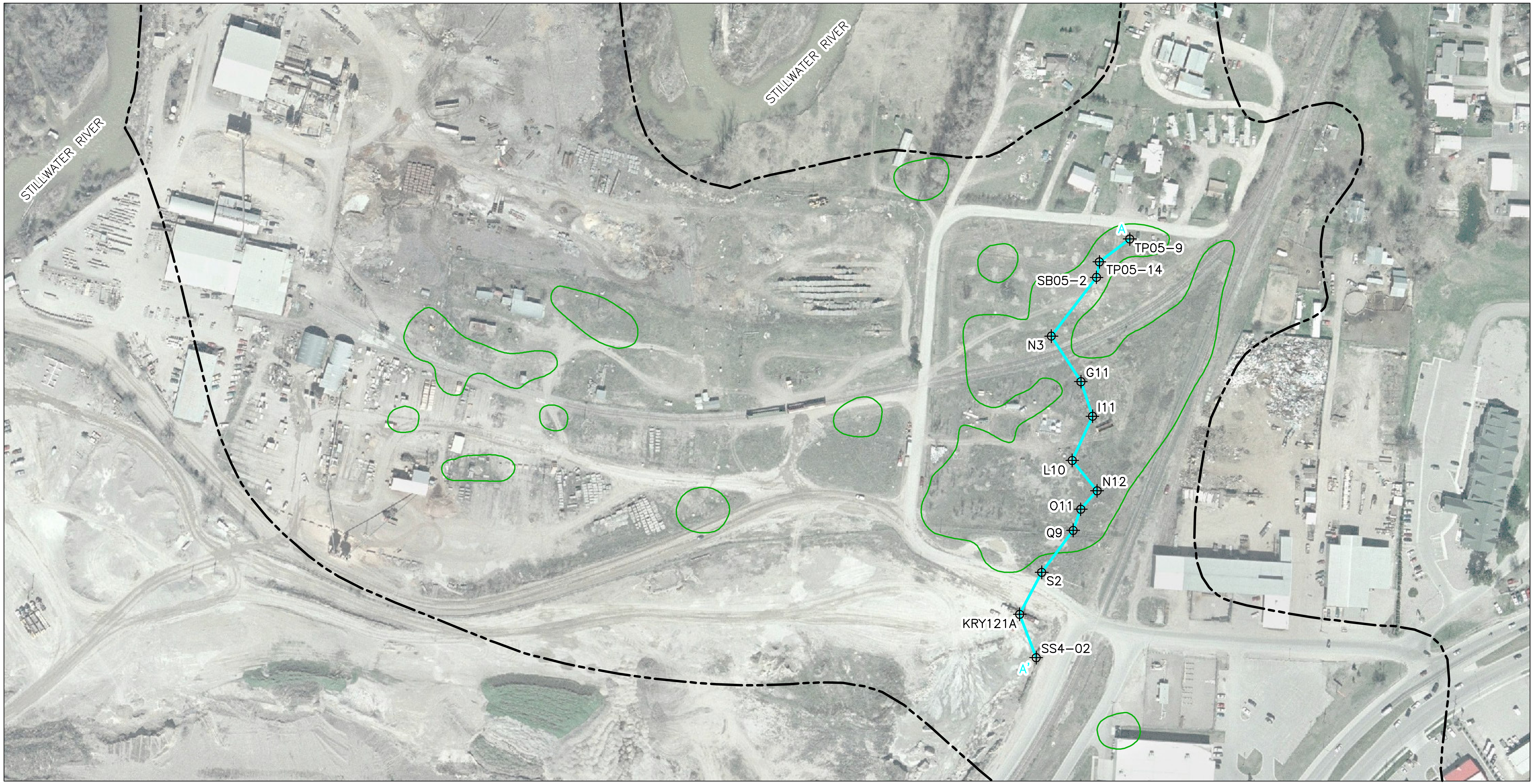
FIGURE 3-5B

LEAD CONCENTRATIONS IN SUBSURFACE SOIL
EXCEEDING CLEANUP LEVEL
CROSS-SECTION A-A'

KRY SITE
KALISPELL, MONTANA

Drawn By: REP | Checked By: CC | Scale: AS SHOWN | Date: 5/22/08 | File: 776004LEAD-200805-EDITS



Basemap: Flathead County GIS, High Resolution Ortho–Rectified Aerial Image, Flathead County, Montana, Publication: July 19, 2005.

EXPLANATION

⌖ SS4–02	BORING LOCATION AND DESIGNATION
— · — · —	APPROXIMATE KRY SITE BOUNDARY
🟩	APPROXIMATE EXTENT OF PETROLEUM HYDROCARBON CONTAMINATION
▬	CROSS-SECTION A-A'
mg/kg	MILLIGRAMS PER KILOGRAM

NOTES:

1. HYDROCARBON CLEANUP LEVELS: C5-C8 ALIPHATICS (730 mg/kg)
   C9-C12 ALIPHATICS (1,550 mg/kg)
   C9-C18 ALIPHATICS (2,634 mg/kg)
   C19-C36 ALIPHATICS (260,154 mg/kg)
   C9-C10 AROMATICS (4,800 mg/kg)
   C11-C22 AROMATICS (33,445 mg/kg)
2. THIS FIGURE REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM THE DEQ/TtEMI RI AND TtEMI DSR; OTHER INTERPRETATIONS ARE POSSIBLE

N

0 200'

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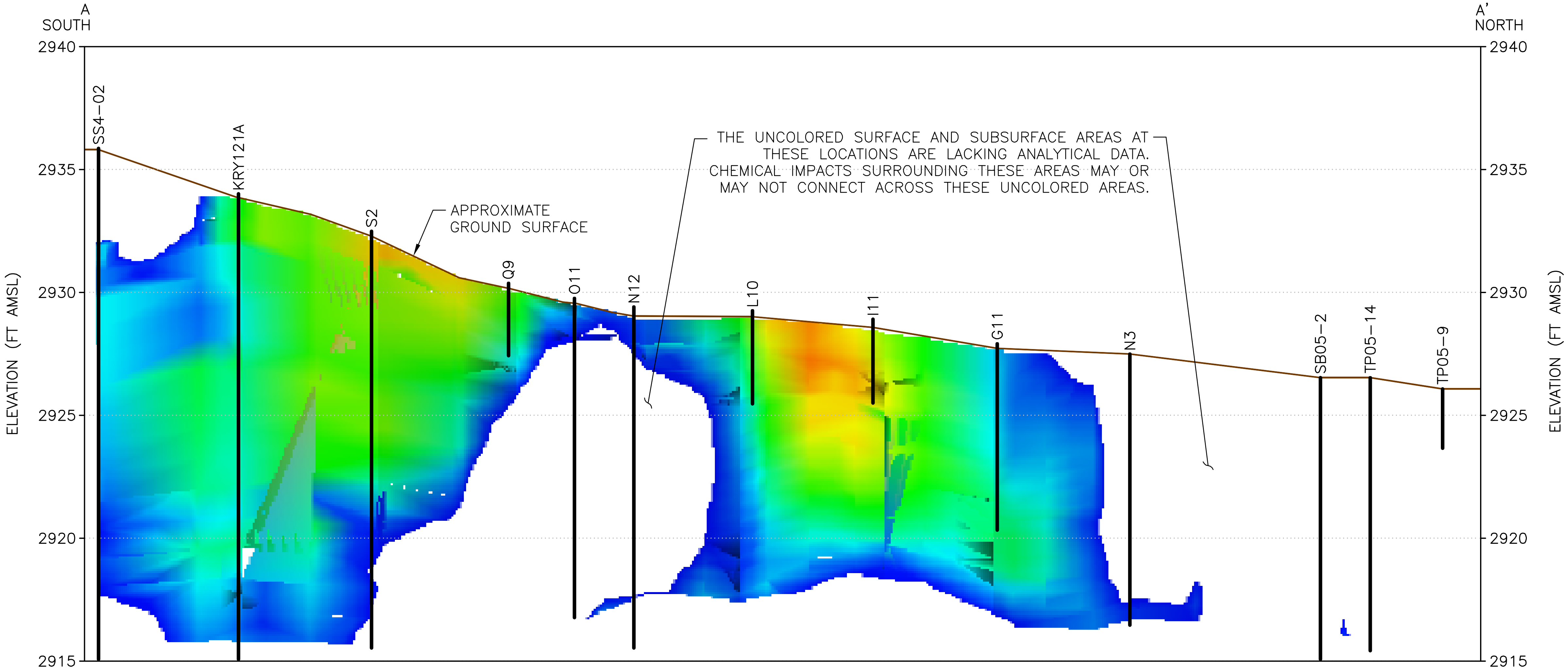
FIGURE 3-6A

PETROLEUM HYDROCARBON FRACTIONS IN SUBSURFACE SOIL EXCEEDING CLEANUP LEVEL MAP VIEW

KRY SITE
KALISPELL, MONTANA

Drawn By: REP	Checked By: CC	Scale: 1" = 200'	Date: 5/22/08	File: 776004HYDFRC-200805-EDITS



Source: Trihydro Modeling Software Output, February 2008.

EXPLANATION

FT AMSL	FEET ABOVE MEAN SEA LEVEL
▨	THE COLORS REPRESENTED HERE MAY NOT ACCURATELY DEPICT THE CONCENTRATIONS OF ANY PARTICULAR HYDROCARBON FRACTION

NOTES:

1. HYDROCARBON CLEANUP LEVELS: C5-C8 ALIPHATICS (730 mg/kg)
   C9-C12 ALIPHATICS (1,550 mg/kg)
   C9-C18 ALIPHATICS (2,634 mg/kg)
   C19-C36 ALIPHATICS (260,154 mg/kg)
   C9-C10 AROMATICS (4,800 mg/kg)
   C11-C22 AROMATICS (33,445 mg/kg)
2. PETROLEUM HYDROCARBON FRACTION CONCENTRATIONS USED IN THIS SIMULATION ARE: C5-C8, C19-C36, C9-12, C9-C18 ALIPHATICS, AND C11-C22, C9-C10 AROMATICS
3. THIS FIGURE REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM THE DEQ/TtEMI RI AND TtEMI DSR; OTHER INTERPRETATIONS ARE POSSIBLE

0 ~5'
VERTICAL

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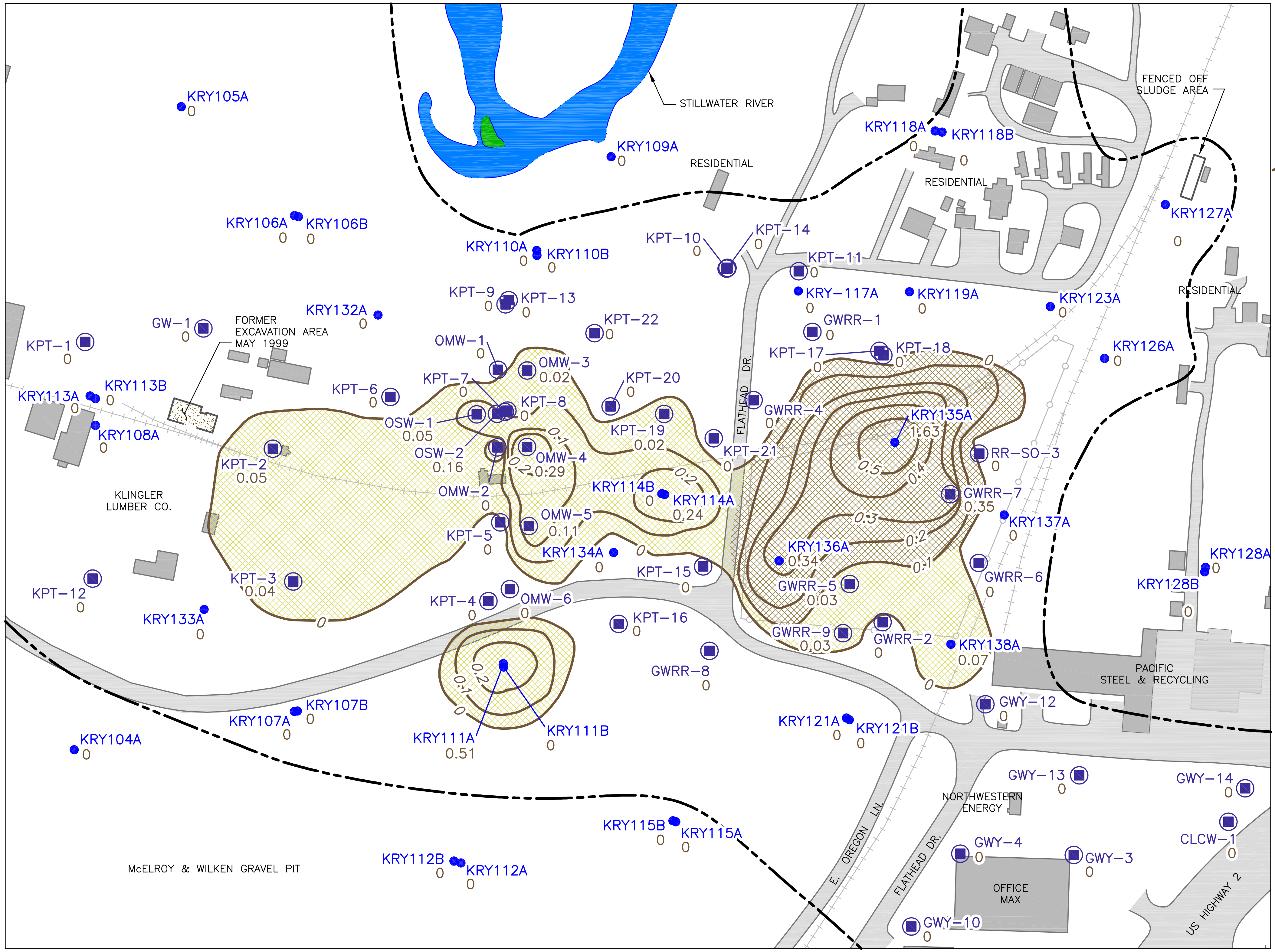
FIGURE 3-6B

PETROLEUM HYDROCARBON FRACTIONS IN SUBSURFACE SOIL EXCEEDING CLEANUP LEVEL CROSS-SECTION A-A'

KRY SITE
KALISPELL, MONTANA

Drawn By: REP | Checked By: CC | Scale: AS SHOWN | Date: 5/22/08 | File: 776004HYDFRC-200805-EDITS



Source: Modified from Site Vicinity Map created by TtEMI, and provided by MDEQ, January 2007.

EXPLANATION

KPT–18 0	MONITORING WELL LOCATION AND DESIGNATION (SHOWING LNAPL THICKNESS IN FEET)
● KRY127A 0	MONITORING WELL LOCATION AND DESIGNATION (INSTALLED BY TtEMI IN 2006, SHOWING LNAPL THICKNESS IN FEET)
0	LNAPL CONTOURS THICKNESS IN FEET
	APPROXIMATE KRY SITE BOUNDARY
	FENCE
	RAILROAD
	ROAD
	BUILDING OR STRUCTURE
	POND
	RIVER
🟩	ISLAND
▨	PRODUCT IN SAMPLE DESCRIPTION SHEETS NOTED AS "LIGHT BROWN FLUID"
▨	PRODUCT IN SAMPLE DESCRIPTION SHEETS NOTED AS "THICK BLACK/ BROWN FLUID OR SIMILAR"

NOTES:

1. LNAPL PRESENCE IS INFERRED IN THE AREAS BETWEEN WELLS WITH DOCUMENTED LNAPL OCCURRENCES.
2. THIS FIGURE REPRESENTS ONE INTERPRETATION BASED ON AVAILABLE DATA FROM DEQ/TtEMI RI AND MONTHLY PRODUCT THICKNESS MEASUREMENTS; OTHER INTERPRETATIONS ARE POSSIBLE

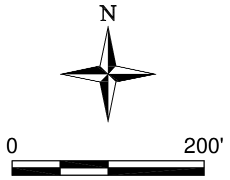


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FIGURE 3-7

AVERAGE LNAPL THICKNESS AND PRODUCT TYPE (AUGUST 2006 THRU JULY 2007)

KRY SITE
KALISPELL, MONTANA

Drawn By: REP	Checked By: CC	Scale: 1" = 200'	Date: 5/21/08	File: 776004LNAPL200805

Source: Modified from Site Vicinity Map provided by TtEMI, January 2007.

EXPLANATION

▲ Q11(4.5)	SOIL BORING LOCATION AND DESIGNATION (WITH INDICATION OF DEPTH OF SLUDGE IN FEET)
△ YR-SO-1	SOIL SAMPLE OR BORING LOCATION AND DESIGNATION (WITH NO MATERIAL DESCRIPTION PROVIDED OR NO SLUDGE INDICATED)
▣ GWY-12	MONITORING WELL LOCATION AND DESIGNATION
● KRY121B	MONITORING WELL LOCATION AND DESIGNATION (INSTALLED BY TtEMI IN 2006)
- · - · -	APPROXIMATE KRY SITE BOUNDARY
─○─	FENCE
┼┼┼	RAILROAD
🟩	APPROXIMATE EXTENT OF SLUDGE
▭	ROAD
■	BUILDING OR STRUCTURE

NOTE:
SLUDGE AREAS INTERPRETED FROM DATA PRESENTED IN THE PTS PHASE I RI AND THE DEQ/TtEMI RI.

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FIGURE 3-8

SLUDGE EXTENT MAP

KRY SITE
KALISPELL, MONTANA

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