WORK PLAN FOR LNAPL MITIGATION METHODS EVALUATION, NORTHEASTERN LNAPL AREA

Defense Fuel Support Point Norwalk
15306 Norwalk Boulevard
Norwalk, CA 90650

04-NDLA-007

Prepared For:

Defense Logistics Agency
8725 John J. Kingman Avenue
Fort Belvoir, Virginia 22060-6222

Prepared By:

THE SOURCE GROUP, INC.

1962 Freeman Avenue
Signal Hill, California 90755

June 30, 2015

Prepared By:

Paul Parmentier
Principal Hydrogeologist

Reviewed By:

Neil F. Irish, P.G. 5484
Principal Geologist

TABLE OF CONTENTS

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

On behalf of our client, Defense Logistics Agency - Energy (DLA), The Source Group, Inc. (SGI) is submitting this Workplan for Light Non Aqueous Phase Liquids (LNAPL) Mitigation Methods Evaluation, Northeastern LNAPL Area (LNAPL Workplan) for the former Defense Fuel Support Point (DFSP) Norwalk facility located at 15306 Norwalk Boulevard, Norwalk, California (Site; Figure 1). Remediation at the Site has included soil vapor extraction (SVE), biosparging, groundwater extraction and treatment (Figure 2), and all primary sources of contamination (tanks and pipelines associated with the tanks) have been removed. This Workplan was prepared to supplement two additional on-going activities of site investigation and remediation: a soil remediation task, and a LNAPL investigation in the northeastern part of the Site. Petroleum hydrocarbon (PHC) impacts to soil, groundwater, and soil gas have been documented in the northeast area, and multiple PHC fuel releases resulting in the subsurface occurrence of LNAPL may have occurred.

A November 30, 2014 Soil Remedial Action Plan (Soil RAP; SGI, 2014a) was submitted to address soil remediation at the Site, and the Soil RAP included a summary of proposed remedial actions for the Site including soil removal for shallow soil (0-10 ft below grade) and potentially accessible deep soil in areas of significant hydrocarbon contamination extending from shallow zone to near groundwater. The Soil RAP measures are being implemented. The Regional Water Quality Control Board (RWQCB) requested on January 7, 2015 as conditional approval of the Soil RAP, that DLA submit a workplan for enhanced recovery of LNAPL. This Workplan addresses that requirement.

In addition, the documentation in 2010 of free product LNAPL in a specific area within the northeast area that is centered on off-site groundwater monitoring well GMW-62 (and referred to as the GMW-62 Plume area, Figure 3) was followed by a series of investigations that included soil and soil gas sampling, and the installation of three additional groundwater-monitoring wells. In 2014, the RWQCB requested a workplan for further evaluation of what is referred to as the GMW-62 LNAPL plume, and on December 15, 2014, SGI submitted a Revised *Work Plan for Further Evaluation of GMW-62 LNAPL Plume* (GMW-62 Workplan; SGI 2014b). The GWM-62 Workplan included installation of three additional groundwater monitoring wells, the collection of soil, groundwater, and LNAPL samples and testing for detailed evaluation of potential source of the LNAPL, and volume and potential mobility of the LNAPL.

This LNAPL Workplan proposes sampling, testing and evaluation of soil, groundwater, and LNAPL in the northeastern part / GMW-62 Area of the Site to supplement the tasks proposed in the GMW-62 Workplan and also as an evaluation of potential LNAPL mitigation measures potentially applicable for the northeastern part of the Site as well as Site-wide.

The northeastern part of the Site is scheduled to become a city park and that part of the site will likely be the first to be redeveloped.

1.1 Site Location and Vicinity

The DFSP Norwalk facility is a 50-acre facility that formerly included 12 aboveground storage tanks used for storage of jet propellant (JP)-4, JP-5, and JP-8. Aviation gasoline was reportedly distributed at the truck rack, but not stored in the above ground tanks. Santa Fe Pacific Pipeline, L.P. (SFPP), an operating partner of Kinder Morgan Energy Partners, L.P. (KMEP), leases a 2-acre easement along the southern and eastern boundaries of DFSP for operation of its pipelines, which convey gasoline, diesel, and jet fuel. Within the southern easement lie three active pipelines, one of which is a 16-inch diameter pipeline, designated LS-1. LS-1 bends at the southeastern corner of the facility and continues northward within the eastern easement. An abandoned pipeline also runs along the eastern boundary of the Site. The DLA has decommissioned the site, but SFPP pipelines continue to operate.

1.2 Objectives of the LNAPL Mitigation Evaluation Workplan

This LNAPL Workplan presents the rationale and investigation methods to further evaluate the subsurface occurrence, mobility and potential mitigation of LNAPL present in the vicinity of GMW-62. The findings of the proposed investigation will also be used to evaluate the remedial methods to be applied for LNAPL mitigation that may be required site-wide.

Specifically, the objectives of this LNAPL Workplan, in conjunction with the tasks outlined in the GMW62 Workplan are:

- Further define the lateral and vertical extent of LNAPL in the vicinity of GMW-62;
- Develop additional information on LNAPL characteristics and the nature of LNAPL occurrence in sediments of varying lithology, at specific locations and depth intervals;
- Evaluate the mobility and potential baseline recoverability of LNAPL at specific well locations, under conditions of relatively low groundwater potentiometric surface;
- Evaluate LNAPL recoverability using enhanced extraction techniques at one pilot test location near GWM-62;
- Update the LNAPL conceptual site model for the GMW-62 area and establish a technically sound foundation for developing a range of strategies and tactics for managing LNAPL in the GMW-62 area, as well as site-wide.

1.3 LNAPL Mitigation Evaluation Tasks

The tasks outlined in this LNAPL Workplan consists of investigation tasks, pilot testing and data evaluation including

- Conduct drilling and soundings to define the lateral and vertical occurrence of LNAPL
- Pilot testing of LNAPL removal from the saturated zone by several methods: groundwater extraction, water flushing, surfactant flushing, and polymer flushing

- Pilot testing of the vadose zone / dewatered smear zone by vacuum extraction and bioventing; and
- Data evaluation to estimate the LNAPL distribution, recoverability and long-term mobility

2.0 LNAPL CONCEPTUAL SITE MODEL, GMW-62 AREA

The *Conceptual Site Model and Remedial Action Evaluation for Soil, Groundwater and LNAPL* (Parsons, 2013), provides a detailed description of the site-wide geology and hydrogeology. A brief summary of the site geology and hydrogeology, using the 2013 reported information as a basis, is provided in this section as well as an updated LNAPL Conceptual Site Model (CSM) for the GMW-62 area (Section 2.3).

2.1 Site Geology and Hydrogeology

DFSP Norwalk is located between the Montebello Forebay and the Downey Plain in the Central Basin pressure area. Approximately 50 to 60 feet of alluvium (primarily sand, gravel, silt, and clay) cover the underlying Lakewood Formation in this area. Alluvial sediments exposed in the area of the site include mixtures and layers of sand, gravel, silt, and clay. The underlying Lakewood Formation consists of marine and continental gravel, sand, silt, and clay deposits, under which the San Pedro Formation, approximately 300 feet below grade, consists of marine and continental gravel, sandy silt, silt, and clay deposits.

Lithologic logs of borings drilled during previous investigations indicate that sediments beneath the site consist of clayey silt, sandy silt, silty sand, fine to coarse-grained sand, and deeper coarse-grained sand with granitic cobbles. The top of a clay layer, preliminarily identified as the uppermost sediment layer of the Bellflower Aquitard, was encountered at a depth of approximately 55 to 65 feet during previous investigations.

A shallow semi-perched aquifer, consisting of silt and fine to coarse sand, exists in the alluvial sediments underlying the site, with a depth to groundwater ranging between approximately 25 to 35 feet below grade. This shallow aquifer is approximately 25 to 35 feet thick, based on the depth to groundwater and the reported presence of a clay layer, thought to be the Bellflower Aquitard, at approximately 55 to 65 feet below grade.

The depth to the potentiometric surface associated with this semi-perched aquifer has been monitored at DFSP Norwalk since the mid-1980s. Historical records from monitoring efforts indicate that the potentiometric surface elevation was at a low point in 1991 and 1992, with a groundwater elevation of approximately 41 to 43 ft above mean sea level; AMSL). The potentiometric surface rose by approximately 12 feet to peak in 2005 (at approximately 54 ft AMSL), and has been declining since 2005 and is approaching 1991 and 1992 levels, as discussed further in section 2.3. Recent groundwater level declines in the shallow aquifer have resulted in localized increases in apparent LNAPL thickness as reported for certain monitoring wells at the site.

The potentiometric surface data indicate that lateral groundwater flow within the semi-perched aquifer is generally directed toward the northwest. Under native conditions, a vertical component to groundwater flow exists and it is directed downward. A groundwater pumping system has operated at the site since April 1996 to control groundwater flow. Extraction of groundwater by the system alters the natural flow direction and rate in the vicinity of extractions wells. In general, during pumping system operational periods the groundwater continues to flow to the northwest and is captured, and the extraction also results in a decreased gradient for downward flow from the shallow aquifer.

The Exposition Aquifer underlies the Bellflower Aquitard. The groundwater potentiometric surface associated with the Exposition Aquifer ranges between 49 and 56 feet below grade with a groundwater gradient from northwest to the southeast, opposite the direction of groundwater flow in the shallow aquifer.

2.2 LNAPL and Groundwater Contamination in the GWM-62 Area

Site characterization data obtained for the GWM-62 area indicate that multiple fuel releases resulting in LNAPL occurrence in the subsurface have likely occurred and at least one of these releases took place prior to 1992 or 1993. Figure 4 shows the locations investigated by drilling in the GMW-62 area where documentation indicates the presence of LNAPL. The documentation includes:

- detection of LNAPL accumulation in monitoring wells;
- UVOST detection of LNAPL;
- relatively high groundwater hydrocarbon concentrations (specifically Benzene, Toluene, Ethyl Benzene, and Xylenes or BTEX); and
- the visual observation of smear zone staining (indicating the historical, if not contemporary, presence of LNAPL and/or pore water containing high concentration of hydrocarbon constituents).

LNAPL accumulation in monitoring wells has been observed at GMW-60, 61, 62 and GW-15. LNAPL accumulation has also been observed in wells some 100 ft or more west of the GMW-62 area (e.g., GMW-58). In 2010, LNAPL was observed for the first time in GWM-62 and has been consistently present to some degree in that well since 2010. The initiation and rate of movement of LNAPL from the formation and filter pack through the GMW-62 well screen appears to be correlated with the vertical position and movement (up or down) of the groundwater potentiometric surface. Additionally, groundwater sampling and LNAPL recovery activity (i.e., bailing, sorbent sock use, groundwater pumping) has influenced LNAPL accumulation. LNAPL entry into GMW-62 has been occurring since the groundwater level, declining since 2005, encountered the 29 ft-bg depth level in 2010. Groundwater levels continue to decline as the regional drought continues into 2015. In October 2014, an apparent LNAPL thickness of 5.63 feet was measured in GMW-62 while at the same time 0.05 ft was measured in GW-15 (this groundwater extraction well had been in operation).

Previous investigations included soil and soil gas sampling and UVOST-CPT sounding profiles in the northeast area including the vicinity of GWM-62 and did not identify a potential shallow source of the observed LNAPL in the vicinity of GWM-62, despite numerous shallow soil and soil gas samples, which contained very low to no detectable hydrocarbon concentrations. The source of

LNAPL is certainly from a surface or near surface release but the release location(s) may not be within the GMW-62 vicinity. The data from previous investigations also indicated that in the area including B-120, GMW-62, and UV-12, the LNAPL is relatively deep seated, i.e., in a depth horizon that has been occasionally submerged. This indicates that the smear zone, and LNAPL that may still be present in the smear zone, exists due to lateral migration from some distant release point. This outcome suggests the importance of discrete zones or preferential pathways (sub-vertical and sub-horizontal) of historical LNAPL migration with respect to the current LNAPL plume architecture.

The accumulation of LNAPL in several wells demonstrates that LNAPL in a mobile form is present within the depth horizon intercepted by the well screens and associated filter packs, generally in the 25 to 40 ft-bg depth range. In addition to this information on the LNAPL accumulation, the careful inspection of core acquired during drilling at boring B-120 (twenty feet southeast of GMW-62) and the results from a UVOST-CPT profile at UV-12 (approximately 140 ft west-southwest of GM-62) shed significant light on the vertical distribution of LNAPL. At B-120 LNAPL droplets were observed oozing out of the retrieved core from discontinuities (referred to as “fractures”) at the contact between a thin silty sandy layer and a silty clay layer. It appears that the LNAPL was primarily present within the silty clay in the general horizon 28.5 to 31 ft-bg. Staining suggestive of a smear zone was also documented from the 28.5 ft-bg depth to approximately 36 ft-bg. Alternating layers of silty clay and fine silty sand were documented within this depth horizon with neither lithology class dominating. Thus, an approximately 8 ft thick smear zone coinciding with a depth horizon exhibiting abrupt permeability contrasts of two or more orders of magnitude was encountered at B-120.

At UV-12 on the other hand, fluorescent detection of LNAPL with JP-5-like characteristics was observed at approximately 28.5 to 30 ft-bg. While UVOST only detected high PHC mass at this depth interval, the signal was strong, providing a reliable indicator of LNAPL at that depth interval. Thus, strong evidence of LNAPL occurrence at approximately 29 ft-bg is available for the two locations B-120 and UV-12 east and west of GMW-62 respectively. Initiation of LNAPL accumulation in GMW-62 when the groundwater level declined to 29 ft-bg is supportive (and is discussed in more detail in the next section) of that interpretation. This information suggests that:

1. there was a fuel release at some point in the past when the surface of the saturated zone (or groundwater surface) was positioned near 29 ft-bg and LNAPL spread laterally across the area (including UV-12 and B-120 locations), and
2. assuming the UVOST sounding detected all LNAPL that was present, the area at and near UV-12, with a smear zone of only one or two feet in height, experienced a different LNAPL migration history compared to the B-120 area where a nominal eight feet thick smear zone exists.

Although it is assumed that LNAPL occurrence leads to a smear zone that can eventually be detected by visual inspection due to coloration changes (staining or darkening), it is not known if LNAPL is still present in the smear zone. It is noted that at B-120, relatively high dissolved phase BTEX concentrations suggestive of the presence of LNAPL were detected in a discrete groundwater sample collected a few feet below the bottom of the smear zone, at a depth interval of 44 to 48 ft-bg. This information may provide evidence that LNAPL mass is still present in the lower portion of the smear zone.

As part of previous investigations, LNAPL samples were obtained from GMW-62 for limited characterization on February 2011 and June 2012. The characterization tests involved GC/FID chromatogram development, analysis for additives, analysis for PIANO constituents (paraffins, isoparffins, aromatics, naphthenes, olephins), analysis for degree of weathering, and quantification of relative density, absolute viscosity, and interfacial tension (air, water, oil-phase). The GC/FID analysis indicated a blend of gasoline and middle distillate in the LNAPL. However, benzene, MTBE, and TBA were not detected in the LNAPL within the limits of detection. The relative density and viscosity data reported for the GMW-62 LNAPL samples suggesting that the LNAPL has a relative density similar to gasoline (i.e., approximately 0.78 at 80 F, which is at or slightly above the expected maximum value for fresh gasoline) and a viscosity at 80 F (the values 0.61 and 0.88 cp were derived) that is also similar to fresh gasoline (0.6 cp). Fresh kerosene or JP-5 relative density and viscosity would be approximately 0.85 and 2.5 cp, respectively. An interfacial tension value (water to LNAPL) of 24 dynes/cm (60 F) was estimated for one sample and is in the range that might be expected for a gasoline-kerosene (or JP-5) mixture, perhaps influenced (reduced) to some degree by naturally entrained non-petroleum based constituents.

These LNAPL characterization data indicate that two types of fuel were likely released at some location and time period in the vicinity of GMW-62: gasoline and JP-5. Further evidence of at least one gasoline release pre-2005 is represented by groundwater and sampling data associated with many sampling locations immediately around GMW-62: widespread occurrence of benzene and MTBE and/or TBA reported in soil and groundwater is highly suggestive that gasoline fuel entered the subsurface in the vicinity of GMW-62. The release(s) likely occurred during MTBE additive use, or soon after being officially discontinued in 2005. Thus, a release of gasoline containing MTBE may have occurred as recently as approximately ten years ago. The yellow kerosene based jet fuel JP-5 was developed in 1952 and is still in use today. In summary, LNAPL samples obtained from GMW-62 appear to be a mixture of fuels, perhaps gasoline and some JP-5. Sufficient data are not available to compare the GMW-62 LNAPL characteristics to characteristics of LNAPL obtained from other wells in the GMW-62 area.

2.3 Conceptual Understanding of LNAPL Release, Migration, and Current Status in the GWM-62 Area

Site characterization data including data obtained from the locations highlighted in Figure 3 were used to develop an interpretation of the lateral and vertical extent of LNAPL in the GMW-62 area. The interpreted lateral distribution of LNAPL is presented in Figure 4. Figure 4 shows a plan view alignment for a north to south oriented vertical hydrogeologic profile referred to as A – A'. The profile A-A', presented as Figure 5, depicts the vertical relationship of LNAPL observed at B-120/GMW-62 and UV-12 locations relative to (a) the alternating permeable and less permeable lithology and (b) fluctuating groundwater levels. A continuous thin zone of relatively high LNAPL pore saturation along the profile from near B-34 to near B-59 is depicted as is the vertical range of the smear zone observed at B-120.

While it is likely that more than one fuel release occurred at some time in the past near GMW-62, and separate LNAPL bodies may exist, the working assumption for the remedial evaluation is that there is a single LNAPL body in the area of interest. The irregular area of the LNAPL body has maximum dimensions of 300 ft in the southwest to northeast oriented axis and 180 ft for the perpendicular axis (Figure 4). However, using more representative dimensions the surface area of the LNAPL body is estimated to be approximately 35,500 square ft (approximately 0.8 acres). This estimate of LNAPL occurrence associated with the GMW-62 area is considered relatively uncertain because LNAPL has historically been observed to the west of the GMW-62 area (i.e., GMW-57 and 58), and the eastern limits of LNAPL between GMW-62 and GMW-63, 64, and 65 have not been confirmed. Additionally, there is limited information on the thickness of the smear zone across the area and on the presence of LNAPL at various horizons within the smear zone.

While the GMW-62 area smear zone is known to contain mobile LNAPL at least locally, the LNAPL pore saturation conditions have not been fully determined across the plume. Conceptually, it is understood that the LNAPL saturates pores over a range from zero at the edges of the smear zone to possibly 50 percent or more at various locations within the smear zone. LNAPL pore saturation levels below 20 percent, perhaps even 30 percent, are at or below local residual saturation, resulting in LNAPL in those zones that is not mobile under naturally present groundwater flow/hydraulic gradient conditions. Zones containing LNAPL at saturation levels above residual saturation (where mobile LNAPL could exist) may support migration of LNAPL beyond the current lateral and vertical limits of the smear zone. Zones with LNAPL at or below residual saturation may not be mobile but may represent an on-going source of dissolved hydrocarbon constituents to the groundwater.

The elevation of the thin zone of high LNAPL saturation forming the top of the smear zone is at approximately 48.5 ft AMSL and the bottom of the smear zone is at approximately 40.5 ft AMSL at location B-120. The elevations of the top and bottom of the smear zone were compared to twenty-eight years of groundwater elevation data, from 1986 through 2014 illustrated by two groundwater monitoring well data HL-2 and GMW-1 (Figure 6). The upper LNAPL horizon coincides with the groundwater surface elevation during the period 1997 to 2004, a period in which gasoline (containing MTBE) and JP-5 was likely transported through the adjacent pipeline(s) and when jet fuel such as JP-5 was likely stored in tanks to the west. The lower LNAPL horizon coincides with the groundwater surface elevation during the general period 1991 through 1992. This is also a period when both types of fuel would likely have been transported via pipeline and various types of jet fuel stored in the tank farm.

Clearly, groundwater level fluctuations influence the vertical occurrence of LNAPL in the GMW-62 area. The apparent correlation between historical water levels and the upper bound of the smear zone and the lower bound of the smear zone is probably more than coincidental. A curious aspect that reinforces the uncertainty that currently exists in the interpretations is that the groundwater levels rose significantly after 2004 (approximately six feet) yet no evidence exists that LNAPL has ever been present above 48.5 ft elevation. A range of release-and-LNAPL migration scenarios could be developed to explain the situation. One possibility is that one fuel release occurred prior to or during a period of low groundwater level (the general period 1991 through 1993 being the most recent), establishing the lower portion of the smear zone observed at B-120, and the LNAPL smeared up as the water level rose. The period of approximately seven years (1998 to 2005) established the upper bound of the smear zone observed at B-120 and elsewhere (i.e., 28 to 30 ft-bg depth horizon). For this scenario, the presence of approximately three feet of clay retarded (but did not prevent) the vertical movement of LNAPL during the seven year period and conditions supportive of continued upward migration of LNAPL deteriorated as the water level continued to rise through at least four feet of silt and sandy silt. Other possibilities would likely involve more than one fuel release with an early release (possibly JP-5) and then another release (possibly gasoline) during the seven year period (1998 to 2005). For this alternative scenario the JP-5 LNAPL volume could be depleted through spreading and weathering and the more recently released gasoline could involve more mobile volume and less weathering. LNAPL accumulation in monitoring wells such as GMW-62 would be defined by local conditions but in general would be influenced to a greater degree by gasoline compared to JP-5.

A conceptualized representation of LNAPL Source Release and Migration for the GMW-62 area is presented in Figure 7. This conceptualization is based on one fuel release event from one near-surface point – either a catastrophic release or a slow release. For pipeline releases, a substantial volume of fuel can be released under pressure before the pipeline is shut down. The following scoping calculation provides a context for comparing LNAPL volume in the subsurface over the nominal 0.8 acre to a pipeline release scenario such as conceptualized here.

Assuming that a one foot thick sandy horizon (total porosity of 28 percent), positioned at 29 ft-bg, contains LNAPL at an average pore saturation of 50 percent and the horizon underlies an area of 0.8 acres (35,500 square ft), the following LNAPL volume is calculated:

35,500 ft2 x 1 ft = 35,500 ft3

35,500 ft3 x 0.28 porosity x 0.5 LNAPL saturation x 7.48 gallons per ft3 = 37,200 gallons LNAPL

While only a scoping value, an in-place LNAPL volume of 37,200 gallons or 675 barrels is a reasonable volume of potential fuel released from a pipeline.

A more detailed analysis of LNAPL occurrence and accumulation behavior at B-120 and GMW-62 provides additional insights for assessing the conceptualization presented in Figure 8. The B-120 borehole log, providing the best information on the smear zone for the area, is matched up with the 28-year groundwater hydrograph information and data on LNAPL accumulation in GMW-62 (Figure 8). Possible mechanism(s) of LNAPL movement can be interpreted by correlating water level position (possibly under semi-confinement from time to time), local lithology, and LNAPL accumulation data. Two accelerated LNAPL accumulation events are evident in the record and correlate to the physical presence of the smear zone and the decline of the water surface. For the first event, around November 2010, LNAPL enters the well casing of GMW-62 at approximately the same time that the water level declines into the horizon of the thin horizon of suspected high LNAPL saturation (at approximately 29 ft-bg).

The increased fuel head due to gravity drainage of LNAPL beneath the conceptualized release location to the west may have contributed to the observed LNAPL distribution. The increased fuel head is propagated laterally through lithology containing LNAPL defined by high relative pore saturation and pore continuity to LNAPL present adjacent to the well filter pack and screen. With a sufficiently elevated pressure in the LNAPL phase, LNAPL already resident in the filter pack and screen is pushed into the well. The elevated fuel head beneath the release area may have influenced lateral LNAPL movement at the uppermost horizon (29 ft-bg) and/or at one or more horizons at deeper depth within the screen interval.

The second accelerated LNAPL accumulation event was observed around March 2013. The corresponding water level at GMW-62 was at the general depth horizon of 31 ft-bg. Approximately 2.75 feet of LNAPL accumulated over the ensuing year as the water level continued to decline. Although there is some data uncertainty, it appears that the air-LNAPL interface in the wellbore did not rise above the top of the smear zone (approximately 28.5 ft-bg). This would suggest that the well is acting like a sump in collecting LNAPL flowing in from 28.5 ft-bg. Alternatively, LNAPL could also have been flowing in to the filter pack and screen from a deeper interval. If sufficient LNAPL were accumulating in the well under pressure in excess of hydrostatic then LNAPL may actually have also flowed out of the well and into the formation at the silty sand layer at 28.5 ft-bg. It is possible that the formation represented “an outlet” sufficient to prevent the upper surface of the accumulated LNAPL from rising above 28.5 ft-bg.

As the water level has continued to drop into 2015, and with LNAPL recovery continuing at GMW-62 with the use of absorbent pads and vacuum extraction, the LNAPL present in that well has been reduced.

3.0 PROPOSED MITIGATION METHODS EVALUATION

Prevention of LNAPL migration and reduction in the potential for continued dissolved-phase hydrocarbon plume development (and possible soil gas impacts) are remedial goals applicable to the GMW-62 area as well as the facility as a whole. This section of the work plan presents a series of remedial characterization and design activities aimed at 1) further delimiting the lateral and vertical architecture of the LNAPL plume (and the smear zone, to the extent that useful information is obtained) and 2) evaluating LNAPL occurrence and mobility, migration potential, and recoverability at a practical field scale. Data and insights obtained from these activities will inform decision making concerning LNAPL management in the GMW-62 area as well as other areas of the Norwalk facility.

The 2013 Conceptual Site Model and Remedial Action Evaluation for Soil, Groundwater and NAPL prepared by Parsons for DLA (Parsons, 2013) included evaluation of remedial methods, and in-situ chemical oxidation (ISCO) of the smear zone and LNAPL zone was selected as a remedial methods for the site. Although ISCO may be applicable in later phases of the site remediation, the presence of LNAPL precludes the effective implementation of ISCO. Therefore this workplan focuses on evaluating the effectiveness of LNAPL removal.

The remedial design investigation process represents activities that are in addition to the scope of work included in the December 2014 GWM-62 area work plan (approved with conditions) and includes pilot testing activities focused on the smear zone with certain test activities focused on the saturated horizon of the smear zone and others focused on the (currently) dewatered horizon of the smear zone.

The location of the proposed pilot test area is shown on Figure 9; the locations of additional proposed UVOST soundings are presented on Figure 10; and Figure 11 presents the location of all pilot testing points. The evaluation of methods to mitigate LNAPL concerns in the GMW-62 area will focus on establishing an effective basis for making and interpreting field observations and conducting an integrated testing program that evaluates four separate remedial technologies of enhanced LNAPL recovery or in-situ mass destruction. By focusing on the saturated portion of the smear zone and then focusing on the currently dewatered portion of the smear zone this work plan explicitly recognizes the high probability that groundwater levels will continue to fluctuate up and down and that groundwater levels could rise as precipitation and infiltration patterns trend towards the historical average.

The tasks within this pilot testing work plan build on the proposed investigation outlined in the GMW-62 Workplan (December 2014, approved with conditions) are summarized in the following table.

Proposed LNAPL Mitigation Evaluation Tasks
DEFINITION OF CURRENT LNAPL MASS
Delimiting the GMW-62 area in terms of the lateral extent of the LNAPL body and the vertical distribution of LNAPL, as well as lithology;
Characterizing the lithology and lateral and vertical magnitude and extent of LNAPL in the proposed pilot test plot, located on facility property immediately west of well GMW-62;
Conducting specialized testing of core samples obtained from the smear zone in the pilot test plot, for the purpose of evaluating physical and chemical properties of the sediment, estimating water and LNAPL fluid saturation levels, and developing correlations that may be valuable in predicting LNAPL saturation levels across the GMW-62 area and the facility as a whole;
Collecting LNAPL and groundwater from two direct push boreholes and selected existing wells for use in specialized testing associated with design of surfactant and polymer flushing;
Conducting specialized bench-scale treatability testing to screen pre-selected surfactants and polymer against Site LNAPL and groundwater and to select the multi-component surfactant formulation suitable for field use; permitting of surfactant injection;
PILOT TESTING OF GROUNDWATER ZONE LNAPL REMOVAL
Installing five (5) pilot test points with screen intervals focused on the saturated portion of the smear zone;
Establishing baseline conditions in and around pilot test plot including potentiometric surface position, groundwater water flow direction and rate, and groundwater geochemistry and concentration of hydrocarbons constituents;
Conducting short term **low flow groundwater extraction** using the four pilot extraction points to establish baseline groundwater recovery and, if present, LNAPL recovery;
Flushing the saturated smear zone via a sequence of tests using water, **surfactant solution**, **polymer solution**, then water solution; Collecting post-flushing soil cores;
PILOT TESTING OF DEWATERED SMEAR ZONE
Installing four (4) pilot test points with screens focused on the dewatered portion of the smear zone;
Flushing the dewatered smear zone by vacuum extraction to pull fluids through the dewatered smear zone with maximum test vacuum intended to physically recover LNAPL as well as enhance the volatilization of LNAPL;
Injecting oxygen rich atmospheric air into the dewatered smear zone to enhance aerobic biodegradation of hydrocarbon mass present as LNAPL, sorbed, and dissolved-phase;
DATA EVALUATION OF EFFECTIVENESS OF LNAPL REMOVAL AND POTENTIAL MOBILITY
Analyzing pilot test data to evaluate and report on LNAPL conditions and efficacy and performance of the selected LNAPL mitigation technologies for recovery and in-situ destruction, and present an evaluation of the risks of LNAPL migration or mobilization under natural conditions in comparison with the expected effectiveness of the tested LNAPL removal remedies.

The GMW-62 Workplan scope includes the installation of three monitoring wells east of GMW-62, and also includes special testing of soil core collected from the associated borehole locations in the depth interval where LNAPL (or smear zone) has been defined to the west. These proposed locations (GMW-67, 68 and 69) are expected to provide information on the presence, vertical distribution, and saturation of LNAPL east of GMW-62. However the probability of encountering LNAPL is lower in these targeted areas as they are farther east from the presumed source area (the pipelines corridor) and, therefore, the eastern area is a less favorable site for LNAPL mobility and removal testing. Additionally, the area of these proposed wells is within a public park, limiting access for field tasks, and increasing potential risks associated with equipment and activities within an area open to the public.

Consequently, the LNAPL mitigation methods pilot testing activities included in this work plan are proposed for a location west of GMW-62, within the Norwalk DFSP facility boundary, where LNAPL at high relative saturation and volume is anticipated – a location more appropriate for testing mitigation techniques. To improve the ability to predict LNAPL body architecture within the general GMW-62 area (laterally and vertically) and ensure that the pilot test plot is adequately located the work plan includes application of combined UVOST and cone penetrometer (CPT) technology wherein UVOST-CPT soundings will be conducted to generate profiles at eleven (11) primary locations for lithology and LNAPL detection and type identification. Although considerable investigation has already been conducted at the site, recent trends in site remediation technology indicate that detailed upfront investigations yield more effective remediation. Additionally, the detailed LNAPL investigations proposed for this GMW-62 area will also be applied to site-wide LNAPL remedial options evaluations. The suitability of the pilot test plot proposed herein will be confirmed or an alternative location within the facility boundaries will be identified. Also, the information on the vertical distribution of LNAPL from UVOST/CPT soundings will allow for adjustment of subsequent coring and test point construction details, as appropriate.

3.1 Evaluation of Hydraulic Control in the GWM-62 Area

The scope of work specified herein involves injection of water and chemicals listed on the approved list for General WDR Permitting within the LA RWCB region.The injected water and chemicals are planned to be extracted from new test extraction points positioned within feet of the injection location. The new extraction points represent four of the ten new test points specified in this plan and will surround the central test point used to inject the water and chemicals. The combined extraction volume from the four extraction points will be the same as or slightly higher than the injection volume, as determined over the life of the pilot testing program. Additionally, some level of fluids extraction will be conducted on the same day as fluids injection is taking place. The goal is to prevent the applied water and chemicals from inadvertently displacing the existing LNAPL and dissolved phase contamination.

An additional level of protection with regards to uncontrolled release of injected water and chemicals is provided by the existing GWETS. The proposed pilot test plot is sited in a general upgradient position (hydraulically) from the existing groundwater extraction wells GW-15 and GW-

16. The GWETS has been in operation on and off for approximately half a decade and the effect of extracting groundwater from this area is fairly well understood through empirical and theoretical hydrogeologic and engineering analyses. The well has been operated over a range of groundwater pumping rates and over a range of continuous operating days, as well over a range of meterological conditions and groundwater elevations. The proposed pilot test plot has been located to be within the capture zone of GW-15 at the current pumping rate of 3 gpm.

To confirm that hydraulic capture will occur during and after the pilot testing period, under current groundwater conditions, the extraction well GW-15 and the nearby extraction well GW-16 will be shut down and recovery observed and documented. After at least 90 percent recovery has been achieved relative to the general potentiometric surface elevation for the eastern part of the facility the extraction well GW-15 pump will be started and operated at 6.6 gpm for at least five days. Extraction well GW-16 will not be turned on. The drawdown (or lack thereof) will be observed and documented by periodically gauging all available groundwater monitoring wells in the eastern area. Manual gauging will be the primary means of obtaining field data but instrument-based monitoring will also be conducted with a pressure transducer/data storage unit installed at the extraction well (or nearby observation well) and a unit installed at the central deep test point and at GMW-62. A capture zone map will be prepared. The results will be compared to results obtained from previous aquifer pumping tests conducted at higher pumping rates and during a period of shallower groundwater. The current test will provide confirmation that capture if the pilot test area can be achieved at 6.6 gpm. During the pilot test, GW-15 will be held idle and groundwater extraction will take place at the four close-in test points. At the conclusion of saturated smear zone testing the four test extraction points will be idled and pumping at GW-15 will be conducted, at a rate of approximately 6.6 gpm for at least one month following the end of any pilot injection activity. After the one month of elevated pumping, the current GWETS operation is expected to resume with continuous groundwater extraction at GW-15 of at approximately 3 gpm. Should field observations and data analysis during pilot testing indicate that a higher groundwater extraction rate than 6.6 gpm is warranted to ensure capture then the GW-15 extraction rate will be increased to up to 10 gpm for the period immediately after the conclusion of pilot injection activities.

3.2 Definition of LNAPL Nature and Extent in the GMW-62 Area

3.2.1 Preparatory Tasks

The site- and task-specific health and safety plan (HASP) will be updated prior to field work. SGI and subcontractor personnel will be required to familiarize themselves with the HASP, sign the HASP prior to working on site, and adhere to the provisions of the HASP during all aspects of field work. The HASP identifies the specific chemical compounds known to exist in the subsurface at the site. In addition, the HASP presents the chemical properties of the identified and typical compounds and identifies task-specific health and safety risks.

Prior to the initiation of field activities, monitoring well installation permits will be obtained from the Los Angeles County Department of Health Services. Additionally, the proposed drilling locations will be pre-marked at the Site. Underground Service Alert (USA) will be notified to identify any potential subsurface utilities. As an added precaution, and due to the presence of pipelines in the vicinity and to ensure that no underground utility is disturbed, each CPT- and drilling location will be cleared by an Air Knife to a minimum of 8 feet below ground surface (bgs).

The RWQCB will be notified a minimum of 48 hours prior to the initiation of field activities.

3.2.2 Focused UVOST-CPT Investigation

The UVOST-CPT is an investigation technology that has been proven at the Site to provide reliable information on LNAPL occurrence and distribution, as reported by Parsons in a January 14, 2011 report (Parsons, 2011). The nearest historical UVOST location is located approximately 140 feet west-southwest of GMW-62, approximately 100 feet west-southwest of the area proposed for LNAPL removal pilot testing (Figure 3).

A follow-up round of UVOST-CPT soundings will be performed at eleven (11) pre-selected and cleared locations to investigate the presence of LNAPL, general type of fuel from which the LNAPL may have derived, and lithology. Figure 10 presents the proposed locations of the 11 UVOST-CPT soundings. The depth of data acquisition will be 10 to 50 ft-bg. Three contingency locations will be pre-selected and cleared to be ready for sounding based on field progress as the 11 primary soundings are completed. The data obtained from the soundings will be used to delimit the nature and extent of the GMW-62 LNAPL body. Detailed information on the presence and structure of the smear zone is of particular interest. One of the UVOST-CPT locations will be near B-120 and GMW-62 and data from this location will assist in correlating previous boring logs information from these two locations. Another location will be in the center of the proposed pilot test plot, and the remaining UVOST locations are proposed as delineation points near the periphery of the potential LNAPL plume.

UVOST-CPT sounding holes will be grouted soon after tool retrieval.

3.2.3 Direct Push Sampling in the Proposed Pilot Test Plot

In addition to the one UVOST-CPT sounding that will be advanced in the center of the proposed pilot test plot (Figure 11), one direct push boring (DP70) will be advanced within approximately two feet of the UVOST-CPT sounding location. A second direct push boring (DP71) will be advanced approximately 10 feet from the central boring. The purpose of each direct push boring is to obtain sediment core for hydrogeologic characterization and special off-site testing purposes and to deploy a temporary ¾ to one inch diameter well screen through the direct push rod string to allow sampling of groundwater and LNAPL, if present and flowable. If sufficient volume of groundwater and/or LNAPL is recovered, the fluids will be used for special off-site testing purposes to be decribed in a subsequent section.

Acetate liner sections will be advanced with the direct push rods to obtain continuous core from 25 to 50 ft-bg. The core will be carefully inspected and screened to identify lithology and evidence of LNAPL and discoloration indicative of the presence of a smear zone. The order of core inspection/screening will proceed as follows. (The detailed tasks are further described in later sections).

1. Visual inspection to document gross recovery (footage) and condition of core, splitting of acetate sleeve will be necessary;
2. Rapid PID screening over length of core;
3. Digital image-documentation;
4. Splitting core down the axis into two halves and rapid PID screening over length of core;
5. Use of FLUTe NAPL ribbon sampler to screen for presence of LNAPL;
6. Digital image-documentation of exposed core surfaces and FLUTe NAPL ribbon sampler;
7. Identification, isolation, and packaging of core sections for specialized testing (API RP40);
8. Sub-sampling of core sections using Encore sampler (or equivalent) for TPH and BTEX analysis;
9. Geologic description for borehole log based on visual observations, document all sub-sampling intervals;
10. Dilute hydrochloric acid (HCl) assays to identify carbonate minerals. Results added to borehole log.

Visual description of soil samples will include the following information:

- percentage of sample recovery,
- grain size classification (USCS; percentages of gravel, sand, silt, and clay),
- color (Munsell color chart),
- density,
- odor,
- degree of moisture, and
- depth to first encountered groundwater.

The core and selected sediment samples will be screened in the field for VOCs using an organic vapor monitor equipped with a photo-ionization detector (PID). The primary use of the OVM-PID will be to rapidly screen the core as it is layed out for inspection and sampling. At the field team's discretion, approximately 20 grams of saturated or unsaturated soil will be acquired from the core and placed in a self-sealing plastic bag to allow the pore space to volatilize. The headspace in the plastic bag will then be monitored for VOCs with the PID.

Visual inspection of the core for the presence of LNAPL with be aided by use of the FLUTe NAPL ribbon sampler. The ribbon sampler is a strip of thin fabric-like material that is coated on one side with hydrophobic dye and is permeable to non-aqueous phase liquids. The dye is mobilized by the NAPL and provides a color indicator of NAPL permeation through the ribbon sampler material. The permeation of NAPL will create a dark "wet" spot or area opposite the dye side of the sampler but the dye if entrained in the NAPL improves visual detection. The ribbon sampler is typically used in conjunction with the FLUTe borehole membrane but for this application the ribbon sampler will be used separately on core retrieved from the subsurface. The ribbon sampler is cut to match the length of the core. The core is split down the center and the ribbon sampler is folded and inserted into the core split. The dye side is placed in contact with both newly exposed core surfaces. The core is pressed back together causing intimate contact between the ribbon sampler and newly exposed core surfaces. The core is pressed together for at least two minutes and then allowed to separate. The ribbon sampler is removed and laid out flat, dye side down. The ribbon sampler is then inspected from one end to the other for indication of NAPL permeation. If a dark wet spot or dye colored spot or area is observed, the location on the ribbon sampler indicates the location of LNAPL in the core.

Sampling intervals will be identified where core sections will be separated and containerized for off-site core testing using API Method RP40 (American Petroleum Institute Recommended Practice for Core Analysis). One sampling interval will coincide with the general 28 – 30 ft-bg horizon where LNAPL is known to exist at several nearby locations. The general lithology type – sand, silt, or clay will be recorded. Two additional sampling intervals will be selected from greater depth based on the potential for LNAPL occurrence and lithology type. Of the three samples to be collected, one is to represent sand, one silt, and one clay.

EPA Method 5035 sampling equipment will be used to obtain small isolated core plugs from the same general interval and lithologic material as the RP40 core sample.

Each sediment sample selected for laboratory analysis will be sealed, labeled, and placed on ice pending transport to the analytical laboratory. Sediment samples will be analyzed for TPH in accordance with Environmental Protection Agency (EPA) Method 8015M and for VOCs (including GRO, oxygenates, and BTEX compounds) using EPA Method 8260B.

All sampling equipment will be cleaned in an aqueous solution of a non-phosphate cleanser, rinsed with tap water, and rinsed a second time with de-ionized water to prevent cross contamination between sample intervals.

Concurrent with core inspection and sub-sampling, a temporary well-point will be lowered into the direct push rod column for the purpose of collecting groundwater and LNAPL (if present and flowable into the well-point). The groundwater and LNAPL will be used in off-site bench testing for surfactant formulation development. The LNAPL present in the proposed pilot testing plot requires physical and chemical characterization but it is not known *a priori* if sufficient LNAPL volume will accumulate in newly installed well-points (discussed later). If sufficient LNAPL volume is collected during direct push borehole sampling at DP70 and DP71 to support surfactant testing then any extra LNAPL will be retained and held in archive for possible use in characterization testing.

Following temporary well-point sampling, groundwater and LNAPL will be sampled from existing wells GW-15 and GMW-62 to ensure that sufficient LNAPL and groundwater is available to support surfactant screening.

Immediately after sampling of core, groundwater, and LNAPL and abandonment of all UVOST-CPT and direct push holes, the field team and drilling rig will demobilize and field and laboratory data generated, collated, reviewed and analyzed. Sounding and probing locations will be surveyed as soon as possible during or afterward. The following sub-section describes the laboratory-based testing and subsequent data analysis and specifications review process.

3.2.4 Analytical Testing, Data Analysis, and Finalization of Pilot Test Details

The UVOST-CPT soundings and direct push coring and sampling at DP70 and DP71 will generate data for assessing LNAPL body and smear zone spatial limits and internal architecture with respect to lithology, LNAPL physical and chemical characteristics, and to support more accurate estimation of LNAPL saturation and total volume, and evaluate mobility and migration potential.

The eleven to fourteen UVOST-CPT soundings and two direct push cores will provide data on LNAPL occurrence and, if LNAPL is encountered, on possible original fuel source. If sufficient LNAPL is retrieved from the two direct push boreholes then a sample of the LNAPL will be tested to characterize density, viscosity, interfacial tension, and chemical composition by GC-FID. Analysis for the presence of fuel additives will be performed. If sufficient LNAPL volume is not obtained from the proposed pilot test plot then a sample of LNAPL will be obtained from GMW-62.

The six core samples retained for API RP-40 analysis (three samples from each of DP70 and DP71 cores with sand, silt, and clay lithology equally represented) will be analyzed for grain density, bulk density, total porosity, air-filled porosity, and initial percent water and LNAPL saturation. The Dean-Stark distillation extraction method, Karl Fischer solvent flushing and titration method, or other suitable method discussed in the latest edition of API RP-40 will be used for water and LNAPL saturation estimation.

The information from these activities will be considered together and compared to historical information to develop a correlation of LNAPL occurrence and characteristics as well as representative pore saturation in relation to three dimensional position and lithology. The information will be used to update the CSM for the GMW-62 area and to finalize pilot testing specifications such as testing point location, well screen interval, as introduced later in this work plan.

3.2.5 Surfactant Screening, Formulation Development, and Permitting

Surfactant(s) and polymer will be used within a multi-step testing process to investigate the potential for chemical enhanced oil-phase mobilization and solubilization of LNAPL within the pilot test plot. Following the initial two steps to remove LNAPL (low rate groundwater extraction and water flushing, discussed later), a surfactant solution will be injected and then a polymer solution will be injected followed by a final water flushing. Experience suggests that, if LNAPL is present within the saturated smear zone within the pilot test plot, LNAPL (and/or solubilized LNAPL components) will be produced at appropriately screened and operated extraction well(s). This is a likely outcome even if low rate groundwater extraction and water flushing do not produce LNAPL or groundwater containing elevated PHC constituents. Observing LNAPL behavior during each step of the evaluation process can result in valuable data and insights into presence of absence of LNAPL in various sectors of the test plot, the range of LNAPL pore saturations, and compositional aspects.

In general, any chemical that has some surfactancy property or co-solvent property will enhance LNAPL solubilization and perhaps mobilization potential. However, it is possible to seek optimization of LNAPL mobilization and/or solubilization. A proper polymer flush following a surfactant flush can lead to better subsurface sweep efficiency and up to a doubling of LNAPL recovery. Only surfactant and polymer chemistry that is listed on the approved RWQCB General Waste Discharge Requirement (WDR) permit (R4-2014-0187) will be used in the field.

AOT (essential component Dioctyl Sodium Sulfocuccinate) and Dowfax/Calfax (essential base component Benzenesulfonic acid) are popular high quality and mallible anionic sulfonated surfactants and used together within an electrolyte solution are considered some of the most useful surfactants available for subsurface restoration purposes. These two surfactants are on the LA RWQCB General WDR Appendix A list. Xanthan Gum, as a basis for a shear thinning polymer fluid, is also on the WDR Appendix A list.

A limited scope bench study involving site groundwater, site LNAPL, and the two surfactants (as primary and co-surfactant), will be completed to evaluate efficacy of mobilization enhancement through micro-emulsion development. Approximately one liter of groundwater and one liter of LNAPL will be required and the work plan goal is to obtain these materials from the proposed pilot test plot or as close as possible to the plot. Several surfactant formulations/dosage levels will be developed and tested. Effluent characteristic for the surfactant solution of apparent superior formulation/dosage will be considered.

At the completion of the surfactant screening test, a WDR permit application will be filed.

3.3 Installation of Ten Test Points in Pilot Test Plot

This section presents specifications for drilling, construction, and development ten test points. Five points will be constructed for use in testing the saturated smear zone. Two of the five test points will be installed next to DP70 and DP71. The other five points will be constructed for use in testing the dewatered smear zone. One of these five points will be installed next to DP70 as well. No coring or sampling will be conducted during drilling.

Figure 11 presents the proposed pilot test plot, DP70 and 71, and test point locations. These test points are identified as (for saturated zone) IP-70, EW-71, EW-72, EW-73, EW-74 and (for dewatered zone) VEP-75, SGP-76, SGP-77, SGP-78, and SG-79. SGI will supervise the drilling, installation and development of the test points. The installation work will be performed using a CME-75 or CME-95 hollow-stem auger (HSA) drill rig (or equivalent) equipped with 6-inch and 10-inch-outside diameter augers and operated by a California-licensed drilling contractor.

The test point specifications will be reviewed following the initial phase of data collection and prior to mobilizing to install the test points.

3.3.1 Drilling and Construction of Saturated Smear Zone Test Points

Five points will be installed for use in testing the saturated smear zone. The pattern consists of a central test point located next to DP70 to be used for fluids injection (IP-70) and four test points located around IP-70 at a radius of 10 feet (refer to Figure 11). These four test points will be used for fluids extraction (EP-71, 72, 73, and 74). EP-71 will be located next to DP71 and will have a dual use as it will also serve as a primary soil gas monitoring point during dewatered smear zone testing (discussed in later section).

While the test points will be constructed in general accordance with the July 1995 CalEPA guidance manual “Monitoring Well Design and Construction for Hydrogeologic Characterization.”, these test points are not intended to function as long-term groundwater monitoring wells and important site and test specific modifications are included.

- Use a 10-inch Hollow Stem Auger (HSA) for the central test point (IP-70) and a 6-inch HSA for outer points (EP-71 through EP-74).
- Total depth of drilling will be determined by the results of the first phase of testing including UVOST-CPT and direct push borings DP70 and DP71advanced to 50 ft-bg. The central test injection point (IP-70) is expected to have a total depth of approximately 37 ft-bg. The total depth of the four extraction points is expected to be approximately 40 ft-bg. Due to the lithology contrasts over short vertical distances, the performance of individual test points and the pilot testing as a whole is sensitive to screen interval placement.
- IP-70 casing and screen will be 6 inch diameter and EP-71 through EP-74 casing and screen will be 2 inch diameter.
- Casing will be PVC Schedule 40 flush thread.
- The six-inch diameter EP-70 will have 6-inch diameter 304 Stainless Steel Johnson “Irrigator” round wire wrap screen with 20 slot and compatible sand pack.
- The screen length of this fluids injection point will be five (5) feet and positioned such that the screen is centered on the saturated interval of the smear zone. The sand pack will be placed to six inches below the bottom-most opening of the screen and 12 inches above the upper-most opening of the screen.
- The four 2 inch diameter points (EP-71 through 74) will have 304 Stainless Johnson standard “V” wire wrap screen with 20 slot for the screen size and compatible sand pack.
- The annulus seal will include hydrated bentonite placed immediately above the sand pack to approximately 2 feet bgs and then cement grout to ground surface. Prior to placing the bentonite chips and cement grout, the test point will be surged to settle the sand pack. The test point will be completed at the surface with a 12-inch-diameter Emcon-Wheaton, or

equivalent, traffic-rated well box. Inside of the protective box, the PVC casings will be cut to within four inches of the top of the protective box.

3.3.2 Drilling and Construction of Dewatered Smear Zone Test Points

Five points will be installed for use in testing the dewatered smear zone. Vacuum extraction and bioventing testing will be conducted using these points as well as other points and wells that currently exist. The pattern consists of a central test point located next to DP70 to be used for vacuum extraction and bioventing air injection (VEP-75) and four test points located around VEP-75 at a range of orientations and radii from 5 to 20 feet (refer to Figure 11). These four test points (SGP-76, SGP-77, SGP-78, and SG-79) will be used to monitor pneumatic pressure and volatile organic chemical (VOC) composition of the soil gas phase during vacuum extraction and bioventing tests. Saturated zone groundwater extraction point EP-71 will have a dual use as it will also serve as a primary soil gas monitoring point during dewatered smear zone testing.

Specifications for drilling and construction details for the special pilot test installations follow.

- Use a 10-inch Hollow Stem Auger (HSA) for the central test point (VEP-75) and a 6-inch HSA for outer points (SGP-76 through SGP-79).
- Total depth of drilling will be determined by results of first phase of testing including UVOST-CPT and direct push borings advanced to 50 ft-bg. The central test vacuum extraction and bioventing injection point (VEP-75) is expected to have a total depth of approximately 35 ft-bg. The total depth of the four soil gas monitoring points is also expected to be approximately 35 ft-bg.
- VEP-75 casing and screen is 6 inch diameter and SGP-76 through SG-79 casing and screen are 2 inch diameter.
- Casing will be PVC Schedule 40 flush thread.
- The one six-inch diameter VEP-75 will have 6-inch diameter 304 Stainless Steel Johnson “Irrigator” round wire wrap screen. The slot size and sand pack will be dependent on the sieve and hydrometer analysis. Otherwise, use the minimum commercially available size of 20 slot for the screen size and compatible sand pack.
- The four two inch diameter points (SGP-76 through SGP-79) should have Johnson PVC wire wrap screen. The slot size and sand pack will be dependent on the sieve and hydrometer analysis. Otherwise, use the minimum commercially available size of 10 slot for the screen size and compatible sand pack.
- Because these test points are to be completed in the vadose zone there will be no surging of the sand pack prior to placement of annulus seal.
- Annulus seal and surface completion as described for the saturated smear zone points.

3.3.3 Development of Test Points

Following a 72-hour curing period, each test point completed in groundwater will be developed to increase sand pack area for fluids flow (injection or extraction), remove fine particles/debris, and increase the potential for collection of representative fluids samples (e.g., groundwater and soil gas).

The saturated zone test points will be developed as follows:

- Water jet the screen, surge block and then pump or air lift at a rate that is twice the projected injection/extraction rate.
- The above process is repeated until the SGI representative approves development.

The dewatered smear zone test points will be developed as follows:

- Jet the test point screen along its entire length with compressed air.
- Vacuum extract loose material that has accumulated at the bottom of the screen.

Due to the special purpose of the test points the level of effort in development will be determined by SGI with consideration given to the effects of development on the formation immediately surrounding the test point adjacent to the screen interval. General guidance for the saturated smear zone test points will include 1) removal of a minimum of ten casing volumes, and 2) stabilization of water quality indicator parameters. Water quality parameters including pH, temperature, conductivity, and turbidity will be monitored to calculate stabilization within 10% of each parameter. Stabilization provides an indication that representative groundwater is entering the screen and is being sampled.

During development of the saturated smear zone test points, measurements and observations of general fluid character including the potential presence of PHC including LNAPL will be recorded. Following development, the saturated smear zone test point will be allowed to recover to within 2 feet of the initial water level prior to sampling (or monitoring) or 24 hours, whichever comes first. Following development, each test point will be surveyed.

3.3.4 Test Point Drilling and Development Waste Management

Investigation-derived waste (soil cuttings, development fluids, and decontamination water) will be placed in lined soil bins and/or Department of Transportation (DOT)-approved 55-gallon steel drums that will be sealed, labeled, and stored at the Site pending characterization and disposal. Waste will be handled, transported, and disposed of according to applicable State and Federal regulations.

Waste will be profiled in accordance with California Code of Regulations, Title 22, Division 4.5, Chapters 10 through 32, and Federal RCRA regulations. After analytical results have been received and evaluated, the waste will be transported off site under manifest to a permitted recycling/disposal facility.

3.3.5 Survey – UVOST-CPT, Direct Push Boreholes, and Test Points

SGI will coordinate the surveying of all borehole locations or test point top of casing installed as a result of the pilot testing scope of work.

3.4 Pilot Testing – Saturated Smear Zone

The pilot test will be conducted in two phases. The first phase, addressed in this section, will focus on the saturated smear zone and the second phase will address the dewatered smear zone.

3.4.1 Pre-Flush Conditions Preparation and Testing (Baseline)

After the ten test points are installed and developed, a series of baseline field documentation and test preparation activities will be conducted:

- Confirm operational status of groundwater extraction wells GW-15 and GW-16. As of April 2015 these two wells were each operating consistently at a pumping rate of 3 gpm. The operation of the groundwater treatment components of the GWETS will also be reviewed.
- Manually gauge new test points and all existing monitoring and extraction wells within 200 feet of central pilot test points IP-70 and VEP-75 for depth to water and LNAPL, if present.
- Calculate groundwater elevation, corrected for LNAPL accumulations, and estimate groundwater flow direction and velocity for baseline condition of hydraulic capture pumping at GW-15 and GW-16. Confirm that groundwater in and immediately around proposed pilot test plot is captured by GW-15 or the combination of GW-15 and GW-16.
- Sample test points IP-70 and EP-71 for groundwater and LNAPL, if present. The ground water sample(s) will be shipped to an off-site laboratory for analysis of hydrocarbon constituents and additives and LNAPL sample(s) for fuel type fingerprinting and density, viscosity, and interfacial tension.
- Conduct GW-15 hydraulic capture zone evaluation by temporarily shutting down GW-15 and GW-16, allowing recovery, then conducting a 6.6 gpm multi-well aquifer response test. The capture zone evaluation will conclude with the termination of pumping at GW-15 and GW-16 and the monitoring of recovery. These extraction wells will remain idle during the saturated smear zone testing phase. The hydraulic capture zone evaluation was discussed previously, in Section 3.1.
- Construct temporary groundwater extraction sub-system for EP-71, 72, 73, and 74. The sub-system will include:
    - pneumatic or electric motor driven extraction pump with controller (four units);
    - compressed air source, diesel or gasoline generator or electrical power depending on pump type selected (one);
    - discharge piping connecting pump to wellhead (four);
    - pressure transducer with data logger (four);

  - hand-held digital reader for transducer (one);
  - discharge chemical hose connecting discharge piping at wellhead to dedicated oil-water separator tank (four);
  - manifold with bank of flow meters and pressure gauges (one);
  - oil-water separator tank (four, alternatively one tank with four separate compartments for accumulating LNAPL from each extraction well);
  - centrifugal pump rated to 30 inches water vacuum, integral vacuum gauge, and small diameter PVC vacuum recovery tube with flex hose [pump will be dual use - for in-well LNAPL recovery and as vacuum source for dewatered smear zone testing)] (one);
  - LNAPL containment drum (one);
  - Flexible hose connecting oil-water separator to Baker tank (one to four);
  - Baker tank, nominal 20,000 gallon capacity (one);
  - conduit from Baker tank to GWETS access point (one);
  - secondary containment for piping and storage units (as required);
  - decontamination pad and tools, potable water supply;
  - personnel safety and work space (as required).
- Conduct short term low flow groundwater extraction using the four pilot extraction points to confirm operation of groundwater extraction sub-system and establish baseline groundwater recovery and, if present, LNAPL recovery.

The groundwater extraction sub-system operation will be tested to ensure all components are working satisfactorily on an individual and systems-wide basis, fluids are contained, and working conditions are safe. The four pilot extraction points will be operated at a relatively low flow rate of approximately one to two gpm/point to produce groundwater and create shallow cones of depression for drawing in LNAPL, if present, around each extraction well. Groundwater will be pumped to the surface and directed through the conduits to the oil-water separator and then to the Baker tank. LNAPL that accumulates in the extraction point screen will be detected using manual oil-water interface probe and the centrifigal pump and vacuum recovery tube used to extract the LNAPL to a sheen. The LNAPL will be directed to a dedicated LNAPL storage drum or tank. It is possible that LNAPL may enter into one or more of the extraction points at a rapid rate and depresses the water surface such that the groundwater pump also extracts some of the LNAPL. LNAPL entrained in the pump effluent may form an emulsion and the emulsion may pass through the oil-water separator. Once in the Baker tank, the emulsion may break naturally or require a chemical breaker.

The individual point and combined groundwater extraction rate will be monitored to establish a balance between groundwater extraction and drawdown outside the well screen. Pump-induced dewatering of the smear zone cannot be avoided but can be minimized. The target maximum allowable drawdown as measured or estimated for a point immediately outside the extraction point screen is equivalent to one-half the thickness of the saturated smear zone at the time the activity is conducted. Based on historical hydrogeologic characterization and aquifer pump testing it is anticipated that the maximum target drawdown for an indiviual extraction point will be 1.5 - 2 feet. The corresponding groundwater extraction rate may be one or two gpm. The smear zone dewatering constraint will not be as important during the later water-surfactant-polymer flushing steps as fluids will be introduced to replace fluids that are extracted.

Fluids that are discharged into the Baker tank will be temporarily stored in the tank to allow for settling and oil-phase separation. The fluids will be gauged and sampled to determine contents and water quality. The water quality will be compared to the GWETS-NPDES permit requirements to determine how to manage the effluent. Floating LNAPL that has separated from the groundwater will be extracted from the tank and placed in dedicated LNAPL storage to await off-site disposal or recycling.

To accomplish the dual objectives of this step (sub-system shake-down and assess formation and LNAPL response to groundwater flushing by extraction only) approximately one pore volume of the pilot test plot will be removed. One pore volume is estimated to be 2350 gallons, based on a cylinder with 10 feet radius and 5 feet thickness and porosity of 20 percent. For a continuous period of groundwater extraction at a total of 6 gpm the duration of extraction to reach 2350 gallons is approximately 6.5 hours. If the subsurface is uniform and isotropic, it would be reasonable to expect that, in general, one half of the volume of groundwater extracted (and LNAPL, if present) would be derived during this short period from the internal volume of the plot and the balance from the formation surrounding the plot.

3.4.2 LNAPL Flushing Pilot Test

The LNAPL removal pilot test will include construction of an injectate mixing, storage, and injection sub-system followed by water flushing using IP-70 as the injection point to test injection aspects and collect data on formation and LNAPL response to water flushing. Groundwater extraction from the four extraction points will be operated simultaneously during most or all of the injection period for this and following steps. While this step is being completed the surfactant solution will be prepared via metering of surfactant(s) and electroyle into potable water and mixing to achieve specification. As with subsequent transitions, every reasonable attempt will be made to seamlessly transition from water injection to surfactant solution injection. Polymer solution will be prepared while the surfactant solution is injected. The polymer solution requires significant mixing energy before and during injection due to its shear thinning nature. After the polymer solution has been added the final step of water flushing will be immediately initiated. To achieve near seamless transitions it will be necessary to plan for continuous operations once water flushing is started. Hiatus between injection steps may be scheduled or may be unexpected. Short hiatus of a few minutes to a few hours will not compromise the test but will interject a measure of complexity due to the groundwater mound and drawdown recovery that will happen to some degree and the need to re-establish a balanced force gradient field once operations resume. It will be advantageous to maintain continuous operations during the surfactant and polymer flushing steps and the early period of final water flushing to push the polymer away from the injection point and enter the more permeable flow channels.

The following table provides an estimate of the saturated smear zone testing characteristics in terms of volume of fluids moved and duration of operation.

Generalized Fluid Volume and Time Scale of Saturated Smear Zone Testing for Continuous Operation

Step of Test Sequence	Volume of Ground Water Extracted (PV: Pore Volume)	Volume of Fluid Injected (PV: Pore Volume)	Minimum Duration at Extraction Rate of 2 gpm/point and Injection Rate of 8 gpm
Groundwater extraction from 4 extraction points	1/2 PV	0 PV	2.5 hours
Water injection while groundwater extraction continues	1 PV	1 PV	4.9 hours
Surfactant solution injection while groundwater extraction continues	1 PV	1 PV	4.9 hours
Polymer solution injection while groundwater extraction continues	½ PV	½ PV	2.5 hours
Water injection while groundwater extraction continues	2 PV	2 PV	9.8 hours
Totals	5 PV = 11,750 gal	4 ½ PV = 10,600 gal	24.6 hours (approx 1 day)

Note: PV refers to the pore volume of the pilot test plot, estimated to be 2350 gallons. Post-injection groundwater extraction is not included in the table.

At the point when water injection is terminated the opeeration of the groundwater extraction points will continue for a period, the duration determined by field observations. The GW-15 groundwater extraction well will be taken off idle status and pumped at 6.6 gpm for a one-month period to ensure capture of injected fluids.

The injectate mixing, storage, and injection sub-system will include:

- Potable water source, tankage (one);
- Diesel or gasoline generator (one – need may be satisfied by power supply used by groundwater extraction sub-system);
- Potable water transfer pump (various types possible, one);
- Trash pump, integrated electric or gasoline engine may be included (one);

- Chemical transfer pump for low flow rate transfer of viscous surfactant stock transfer to mixing tank (one);
- Containers of surfactant, salt, polymer (one of each likely, quantity varies);
- Visible dye (e.g., fluorescein) is an option;
- Set of measurement and mixing tools (one);
- 3000 gallon mixing tank (one):
- 3000 gallon storage tank (one):
- chemical resistance hose for transferring fluids between transfer pump(s), tankage, and injection point IP-70 (footage varies);
- manifold with bank of flow meters and pressure gauges (one);
- work area with laboratory measurement and glassware and surfactant probe for quality control testing to check surfactant and polymer solution against specifications.

It is anticipated that a formulation and dosage specification will have been developed from the surfactant screening bench testing for 1) an injectate consisting of Dioctyl Sodium Sulfocuccinate and Benzenesulfonic acid based surfactants, electrolyte (calcium or sodium chloride) and water, and 2) an injectate consisting of xanthum gum polymer and water. The surfactant weight percent is expected to be less than 3 percent and the salt weight percent is also expected to be less than 3 percent. Polymer weight percent is expected to be less than one percent.

As described previously, the groundwater extraction sub-system will be operated during most or all of the injection period. Pressure transducers in the four extraction points will be monitored along with the injection rate at IP-70 and fluid level in adjacent VEP-75 (bottom of screen in the saturated zone) to achieve a balanced forced gradient flow field. Manual gauging will be performed periodically in surrounding wells to provide data for confirming the general nature of the potentiometric surface and capture zone created by the four extraction points producing fluid at a flow rate slightly in excess of injected fluids.

The primary purpose of this test sequence is to assess for the presence of LNAPL in the lower part of the smear zone and, assuming LNAPL is present, to observe conditions required to mobilize LNAPL within the pilot plot. The required conditions may range from natural gradient (did LNAPL enter test points without drawdown assistance?) to pumping-induced gradient to water flushing (injection and extraction) to chemical-enhanced flushing (injection and extraction under reduced interfacial tension and increased aqueous solubility). The interpretation of subsurface testing will also be based on the information on lithology and subsurface hydraulics collected in the pre-testing drilling and sampling tasks.

The four extraction points should yield effluent of a similar quantity and quality to each other at any point during the testing sequence if the hydrogeologic conditions are uniform and isotropic and LNAPL is evenly distributed within and around the test plot, however each extraction point may yield unique responses to pumping and the various injection steps. The quantity and quality of effluent at each extraction point will be monitored frequently. For this test sequence it will not be practical to schedule monitoring on a log basis similar to that used for aquifer pumping tests. Significant changes could happen immediately after pumping starts and at any time during each of the injection stages. The surfactant solution and polymer solution can cause “slugs” of LNAPL to release and enter one or more of the extraction points with little or no indication offered by prior observations and collected data. Monitoring will be conducted at the flow- and pressure-gauge manifold where sections of clear PVC will allow for visual detection of changes in color. Another important monitoring station will be the compartmentalized oil/water separator where the individual effluent streams will be exposed to the atmosphere for the first time since entering the pump. This is also the first location for fluids sampling with the second location at the Baker tank. The dedicated LNAPL storage tank will receive LNAPL removed from the extraction points using the vacuum tube. The volume of LNAPL will be recorded before and after each episode of vacuum recovery. Ultimately, the total volume of groundwater and LNAPL removed from each extraction point, as well as the timing of extraction relative to the start of the test sequence and the start of the individual test step, will be documented. If total fluids pumping results in generation of an emulsion, measures will be taken to estimate the volume of emulsion and partitioning of the volume into groundwater and NAPL phase. A sample or samples of emulsion will be collected and natural and chemical enhanced breakage of the emulsion will be observed in the field lab space to provide a semi-quantitative basis for partitioning the volume.

3.4.3 Post-Flush Conditions Testing

The water level and LNAPL thickness at the four extraction points, GW-15 (under pumping conditions), GMW-62, GMW-60, and GMW-61 as well as GMW-58 will be gauged daily for one week, and then weekly for three more weeks, following the termination of injection activities.

Fluids in the four extraction points and GW-15 (under pumping conditions) will be sampled on a weekly basis for one month to obtain groundwater for checking for the presence of surfactant, salt, and PHC constituents BTEX (at each well where LNAPL has not accumulated or otherwise been detected). The presence of surfactant will be indicated in the field at the time of sampling by a shake test and surfactant probe. The specific conductance (electrical conductivity or TDS), pH, and dissolved oxygen level will also be tested in the field using hand-held meters or indicator strips. A sample will be shipped to analytical laboratory for BTEX analysis.

Approximately 12,000 gallons of effluent are projected to be produced during the saturated smear zone testing sequence. After injection has ceased additional groundwater will be produced by the four extraction points and GW-15. Only the effluent from the four extraction points will be directed to the Baker tank. An estimated additional 4,700 gal will be directed into the Baker tank before extraction of fluids from the pilot test plot ceases. The nominal 17,000 gallons of effluent will be managed with the goal of releasing the maximum volume possible to the on-site GWETS. It may be necessary to arrange for delivery of the entire volume to an off-site disposal or treatment facility if the GWETS-NPDES permit requirements cannot be met in a cost-effective or timely manner.

Careful segregation of the more highly impacted effluent, containing surfactant and oil-phase, may result in a greatly reduced effluent volume requiring special management/treatment.

Finally, a sediment coring event will be scheduled at least three months after the termination of injection activities. Continuous coring from 25 to 50 ft-bg will be performed at four locations within the pilot test area with coring locations sited approximately midway between the injection point IP-70 and each of the extraction points. The same process of coring and core characterization, sampling, and laboratory analysis will be pursued to generate data that is comparable to the data produced prior to the start of the pilot test. If LNAPL was present at the start of testing, the water and oil-phase pore saturation levels are expected to be the primary variables that will change as a result of the completed pilot testing activities.

3.4.4 Groundwater Level Measurement

Water-level measurements will be taken using an interface-probe monitoring instrument. Groundwater (and floating product) levels will be measured to an accuracy of 0.01-foot from the top of each test point or well casing and the readings recorded by the environmental technician on a field gauging sheets. Surveyed measuring points (usually on the north side of the casing) will be marked on each test point casing for measurement consistency. The probe will be cleaned with a non-phosphatic detergent solution and double-rinsed with deionized water prior to each test point or well measurement.

3.4.5 Groundwater Sampling and Analysis

Using low-flow sampling guidelines, each saturated zone test point will be sampled and analyzed for VOCs and petroleum hydrocarbons.

Groundwater samples will be submitted for analysis of TPH; carbon chain characterization, gasoline-range organics (GRO), fuel oxygenates, and VOCs including BTEX. Groundwater samples will be analyzed in accordance with the following test methods:

- TPH will be analyzed in accordance with Environmental Protection Agency (EPA) Method 8015M, and
- VOCs (including GRO, oxygenates, and BTEX compounds) will be analyzed using EPA Method 8260B.

A laboratory-supplied trip blank will accompany the test point samples during fieldwork and will be analyzed for VOCs (including GRO, oxygenates, and BTEX compounds) in accordance with EPA Method 8260B. At the end of each day of fieldwork, one equipment blank sample will be collected to evaluate the effectiveness of decontamination procedures.

3.5 Pilot Testing - Dewatered Smear Zone

Concurrent with the completion of the final testing activities for the saturated smear zone test phase, preparations will be made for conducting the second phase of pilot testing focused on the dewatered smear zone. The second phase will involve a vacuum extraction step test followed by a bioventing test, both using VEP-75 as the central test point. Test data will be collected to provide a basis for assessing the response of the vadose zone (including the dewatered smear zone) and the saturated zone (including the capillary fringe and upper groundwater) to vacuum-induced soil gas flow and injection-induced atmospheric air distribution. Of particular interest is the potential for LNAPL stranded in the dewatered smear zone to be mobilized and extracted under vacuum and to be remediated by enhanced volatilization and biodegradation.

3.5.1 Set-up of Vacuum Extraction and Bioventing Sub-systems

To the extent that the safety and integrity of the saturated smear zone testing activities are not compromised, the following sub-system components will be delivered to the site or otherwise prepared and assembled in parallel with the second round of water flushing and the final pilot point groundwater extraction activities:

- Electrical power supply, facility or portable generator (one);
- Vacuum/air injection manifolding of VEP-75 from top of casing to instrumentation manifold (one);
- Instrumentation manifold including vacuum and soil gas/air flow rate (one);
- Water moisture knock-out drum (one);
- Centrifugal Vacuum Pump, rated to at least 30 inches of Water Column (30 in WC), with integral vacuum gauge (one);
- Magnehelic vacuum gauges for manual monitoring of soil gas pressure (negative), ratings of 0.5, 10, and 30 in WC. (one of each measurement range);
- Barometer (one);
- Soil gas/air oxygen, carbon dioxide, and methane detector with digital read-out (one);
- PID (one).
- Soil gas sampling equipment.

Details for baseline monitoring, vacuum extraction test, and bioventing test are presented in the following sub-sections. The specific equipment and instrumentation and operational details presented herein will be reviewed following the completion of the first phase of pilot testing.

3.5.2 Baseline Monitoring

After the vacuum extraction and bioventing sub-system has been set-up and shake-down testing has concluded, a baseline monitoring round will be conducted to establish starting conditions for the vacuum extraction step test. Soil gas pressure and chemical composition will be monitored and compared to meterological conditions. Magnehelic gauges will be used to measure soil gas pressure at all test points and surrounding monitoring installations (within the general GMW-62 area) that have at least partial screen exposure to the vadose zone. Soil gas will be drawn from these same locations to measure oxygen, carbon dioxide, and methane content using hand-held instrumentation. Discrete samples will be obtained from selected test points using tedlar bags. The soil gas samples will be shipped off-site for laboratory analysis of hydrocarbon and fixed gases.

3.5.3 Vacuum Extraction Step Testing

A vacuum extraction step test will be conducted over an approximate one day period. A centrifigal vacuum pump will be used to establish a vacuum on test point VEP-75 at three tentative levels: 10 inches of water column (in WC), 20 in WC and finally 30 in WC. Test points and other wells surrounding VEP-75 will be capped to prevent atmospheric air short-circuiting. Vacuum and soil gas discharge flow will be measured at VEP-75 and vacuum will be measured at surrounding monitoring points SGP-76 through SGP-79. EP-71, IP-70, and pre-existing vacuum extraction and soil gas monitoring probes in the near vicinity will be monitored as well. The radius of effect of vacuum extraction at each vacuum level will be estimated. It is assumed that the vacuum differential of 0.1 in WC defines the limits of vacuum influence. Readings will be tagged by date and time and corrected for barometric pressure fluctuations.

Real-time information on hydrocarbons in soil gas effluent or soil gas at specific in-situ locations will be developed using a PID.

3.5.4 Bioventing Test

A bioventing test will be conducted after the vadose zone has recovered from vacuum extraction testing. The duration of the bioventing test is expected to be three months. The same test point used for vacuum extraction (VEP-75) will be used for the bioventing test. The same soil gas monitoring points used previously will be used for the bioventing test.

Atmospheric air will be injected into central test point VEP-75. Pressure and airflow will be monitored and recorded. In contrast to the vacuum extraction testing, enhanced volatilization or physical movement of LNAPL under elevated vacuum is not the goal but rather enhanced aerobic biodegradation of hydrocarbons constituents as LNAPL and sorbed or dissolved in the sediment. A relatively low rate of flow will be established with consideration given to promoting biological utilization of the oxygen and controlling the mass flux of volatile constituents moving upward through the vadose zone and to the ground surface. The injection rate will be established in the field based on monitoring results but it is expected that the injection rate will be on the order of 20 cfm.

Soil gas pressure and oxygen and carbon dioxide content of the soil gas are the measurement parameters of most importance. Changes in soil gas oxygen and carbon dioxide content will indicate the onset and progression of enhanced biodegradation. VOC concentration in soil gas will be monitored as well. An in-situ respirometry (ISR) test will be conducted to estimate the rate of aerobic biodegradation within the vadose zone, specifically the dewatered smear zone. Air injection will be stopped and oxygen, carbon dioxide, methane, and VOCs will be monitored versus time at selected soil gas monitoring locations. At least three ISR tests will be conducted during the bioventing test. The first one within two days of starting air injection to establish quasi-baseline, the second one after approximately one month of operation, and the third one to conclude the bioventing test (at approximately three months).

3.6 WDR Compliance Testing

The injection surfactants will be conducted under a specific WDR permit, which will include specific monitoring and reporting requirements.

4.0 EVALUATION OF LNAPL PRESENCE, MOBILITY, AND REMOVAL

4.1 Reporting

An integrated analysis of data from the various testings detailed in this work plan will provide an effective means of reducing the uncertainty in the LNAPL nature and extent in the GMW-62 area and of determining the most effective method to address the LNAPL at the site.

The LNAPL presence or absence will be further defined by data produced from UVOST-CPT, direct push sampling, baseline sampling and analysis including new test points and existing wells, and testing activities that stress the saturated and dewatered portions of the smear zone in the pilot test plot. The pilot activities that will stress the formation (groundwater extraction, water flushing, surfactant flushing, polymer flushing, and vacuum extraction) are intended to provide valuable insight into the presence, mobility, and recoverability of LNAPL at a scale that is relevant from a remedial action perspective. The bioventing test will provide additional information on in-situ reduction of hydrocarbon mass at a scale relevant to remedial planning.

The application of detailed sampling and analysis techniques described in this work plan will provide data to improve the CSM prior to finalization of planning for the two phases of pilot testing. The data collected from UVOST-CPT, continuous coring, use of the FLUTe ribbon sampler, discrete sampling for API RP40 analysis, discrete sediment and groundwater sampling for PHC profiling, and LNAPL characterization testing will be analyzed and integrated to provide a detailed understanding of the occurrence and condition of the LNAPL in the GMW-62 area.

An estimate of the LNAPL volume present in the GMW-62 area and in the pilot test plot prior to any removal testing will be calculated. Estimates of the LNAPL removed during simple pumping, water flushing, surfactant-enhanced flushing, polymer-enhanced flushing, and final water flushing will be calculated. The hydrocarbon mass removed at the termination of injection and after the termination of fluids extraction by the four extraction points will consist of LNAPL, dissolved-phase hydrocarbon mass (likely significantly elevated due to the surfactant use), and potentially emulsfied hydrocarbon mass (resulting from surfactant use if total fluids extraction occurs). The total mass of hydrocarbon constituents will be estimated and an estimate of the percentage of original LNAPL removed will be calculated.

The results of the extraction and bioventing of the dewatered smeared zone will be evaluated to determine the efficiency of the hydrocarbons removal and potential in reduction in residual hydrocarbon mass in the vadose/dewatered smear zone.

The integration of the newly collected and interpreted data will assist in development of a site-specific correlation relating lithology and LNAPL occurrence to the LNAPL recoverability and potential mobility.

A report detailing the completed scope of work, the data produced, data analysis results, and conclusions and recommendations for further testing or full-scale remedial action to address LNAPL in the GMW-62 area and site-wide will be prepared and presented to the LARWQB.

The report will include the following:

- UVOST-CPT and Direct Push Sampling
- Test point installation: installation methods, field observations and results of lab testing
- Surfactant bench testing
- Both pilot test phases including information on LNAPL presence, mobility, and recovery rates under the various test conditions in the saturated zone and dewatered smeared zone
- WDR Compliance
- Data Evaluation, Conclusions and
- Recommendations.

4.2 Schedule

The proposed pilot testing scope, including WDR permitting and data interpretation, will be completed and reported within 9 months of RWQCB approval of this work plan.

5.0 LIMITATIONS

This Work Plan was prepared for the exclusive use of Defense Logistics Agency Energy (DLA) for the express purpose of complying with regulatory directives for environmental investigation, in accordance with the scope of work, methodologies, and assumptions outlined in SGI's contract with DLA and as applicable to the location of the proposed investigation. Any re-use of this work product, in whole or in part, for a different purpose, or by others must be approved by SGI and DLA in writing. If any such unauthorized use occurs, it shall be at the user's sole risk without liability to SGI. To the extent that this plan is based on information provided to SGI by third parties, including DLA, their direct-contractors, previous workers, and other stakeholders, SGI cannot guarantee the completeness or accuracy of this information, even where efforts were made to verify third-party information. SGI has exercised professional judgment to collect and present a scope of work and opinions of a scientific and technical nature. The opinions expressed are based on the conditions of the site existing at the time of this plan preparation, current regulatory requirements, and any specified assumptions. Findings or conclusions presented in this plan are intended to be taken in their entirety to assist DLA and regulatory personnel in applying their own professional judgment in making decisions related to the property. SGI cannot provide conclusions on environmental conditions outside the completed scope of work. SGI cannot guarantee that future conditions will not change and affect the validity of the presented scope of work and any conclusions presented. No warranty or guarantee, whether expressed or implied, is made with respect to the data, observations, recommendations, and conclusions.

6.0 REFERENCES

Parsons, 2011 *Investigation Report for LNAPL Characterization and Vapor Monitoring Program*. January 14.

Parsons, 2013 *Conceptual Site Model and Remedial Action Evaluation for Soil, Groundwater and LNAPL*. September 30.

The Source Group, Inc, 2014a. *Soil Remedial Action Plan.* November 13.

The Source Group, Inc, 2014b. *Revised Workplan for Further Evaluation of GMW-62 LNAPL.* December 15.

FIGURES

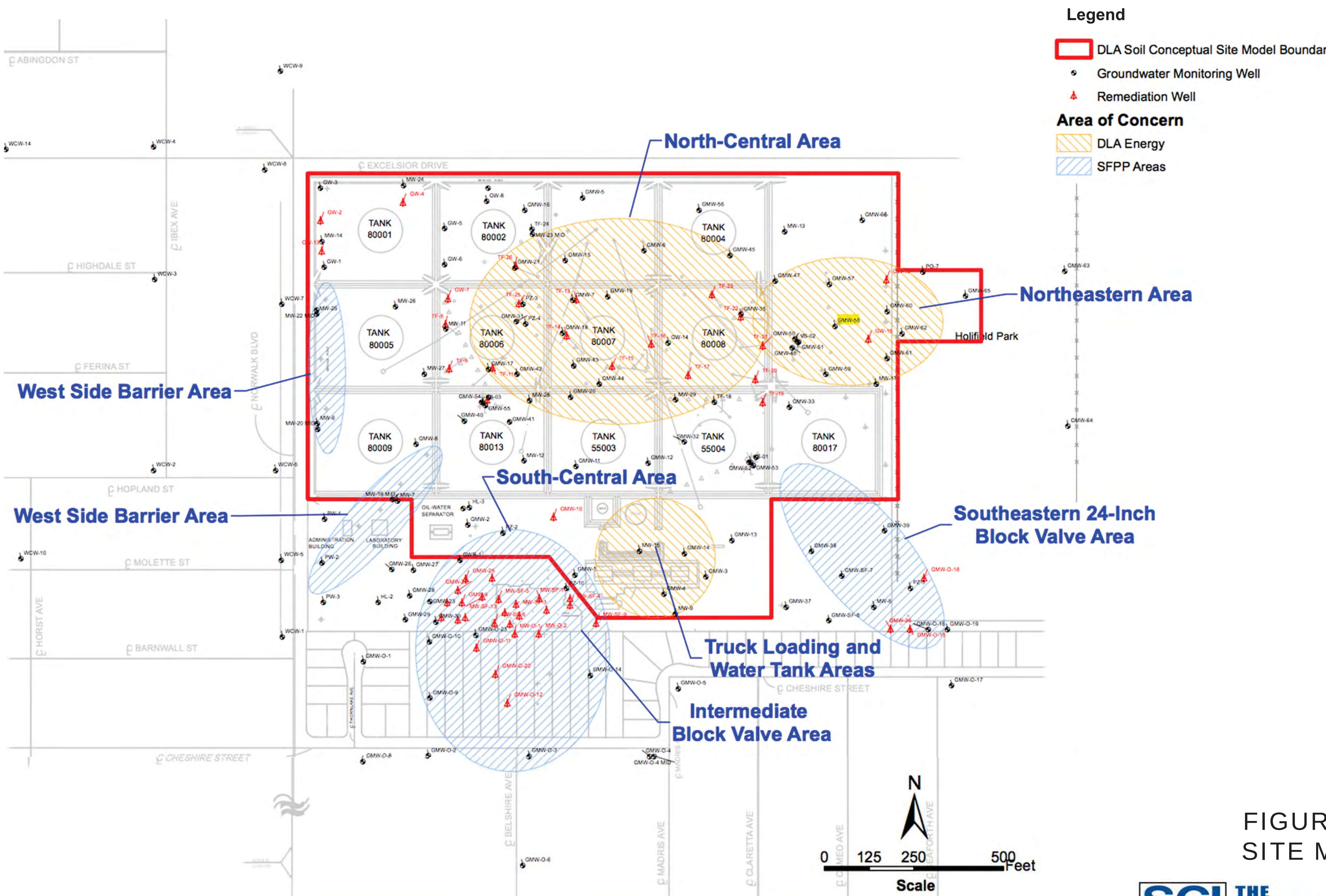
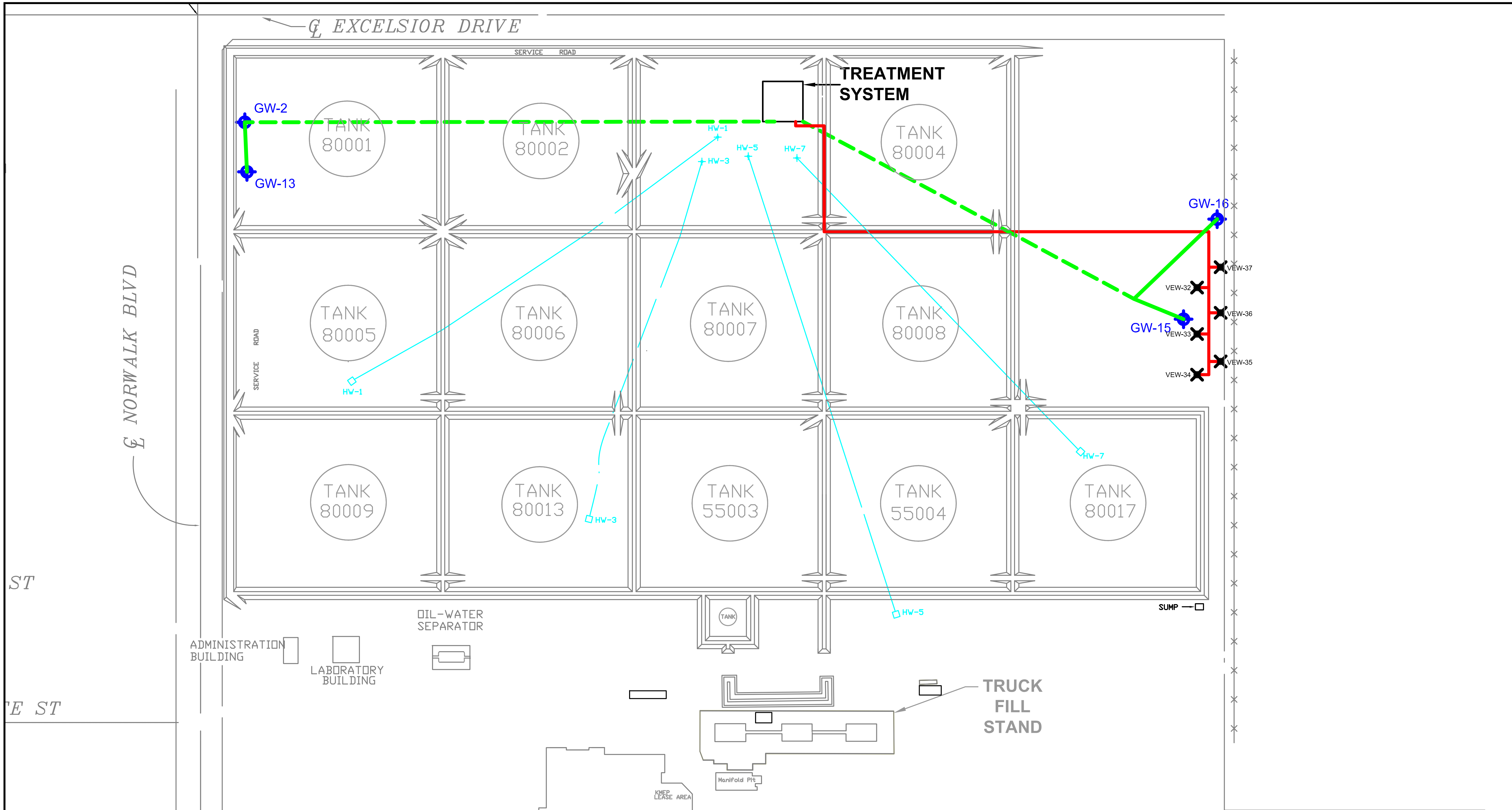


FIGURE 1
SITE MAP

SGI environmental THE SOURCE GROUP, INC.



LEGEND

- HW-1 HORIZONTAL VAPOR EXTRACTION WELL
- VEW-32 VERTICAL VAPOR EXTRACTION WELL
- GW-15 GROUNDWATER EXTRACTION WELL

NOTES

Base map and piping from Parsons' *First Quarter 2014 Remediation Progress Report*, dated May 15, 2014

DEFENSE FUEL SUPPORT POINT NORWALK
15306 NORWALK BOULEVARD
NORWALK, CALIFORNIA

PROJECT	DATE	DRAWN BY:	APPROVED BY:
04-NDLA-002	06/15/2015	SM	PP

0 160 320
HORIZONTAL SCALE IN FEET

SITE MAP SHOWING REMEDIATION WELLS AND PIPING LOCATIONS

SGI environmental THE SOURCE GROUP, INC.
1962 FREEMAN AVENUE
SIGNAL HILL, CA 90755

N

FIGURE 2

DFSP Norwalk / Figures & CAD / Remediation Layout Figures / Fig 2_Remediation System Logout2007_2015_06-15

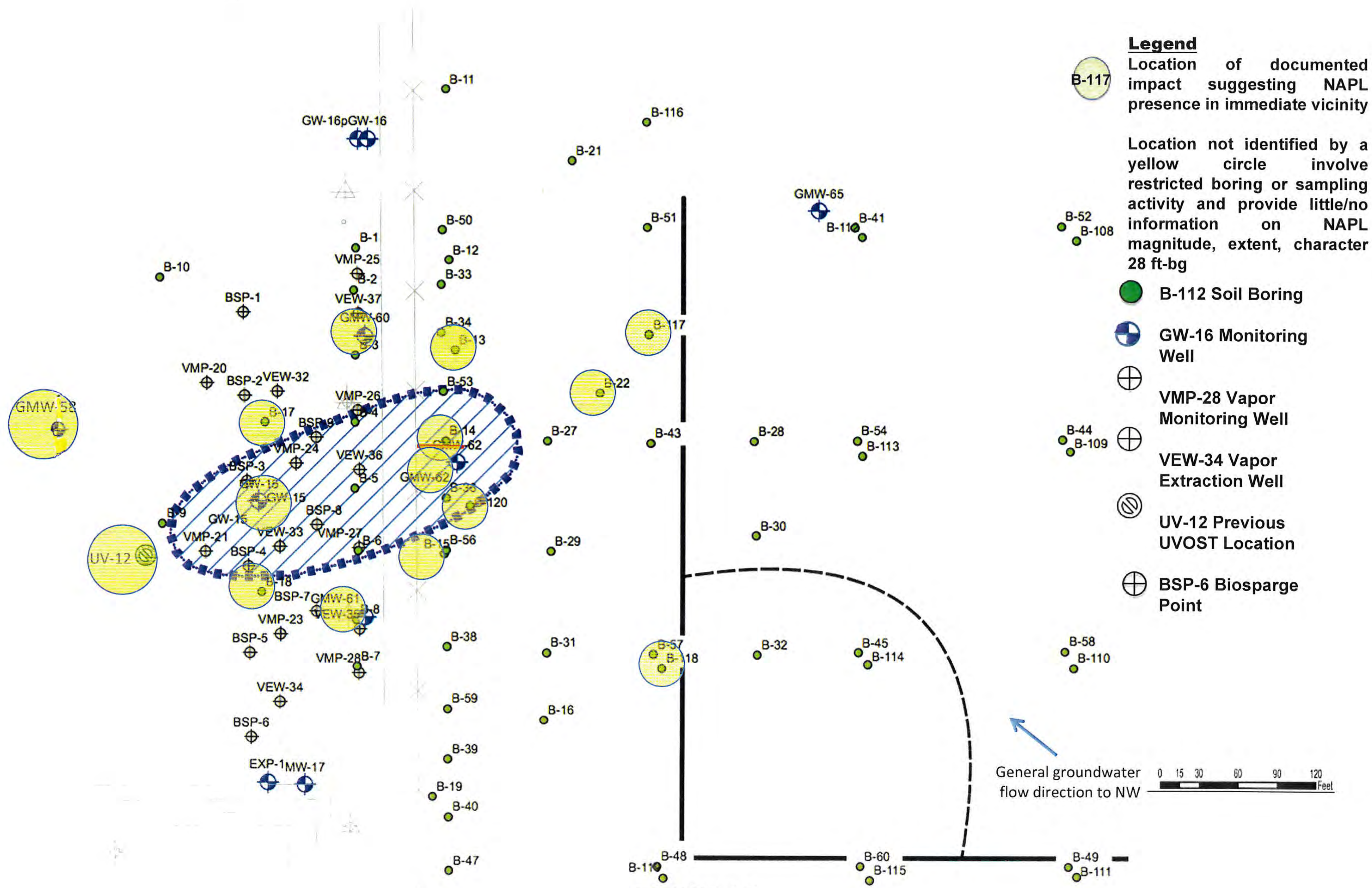


FIGURE 3

LOCATION OF DOCUMENTED HYDROCARBON IMPACT SUGGESTING NAPL PRESENCE, GWM-62 AREA

SGI environmental THE SOURCE GROUP, INC.

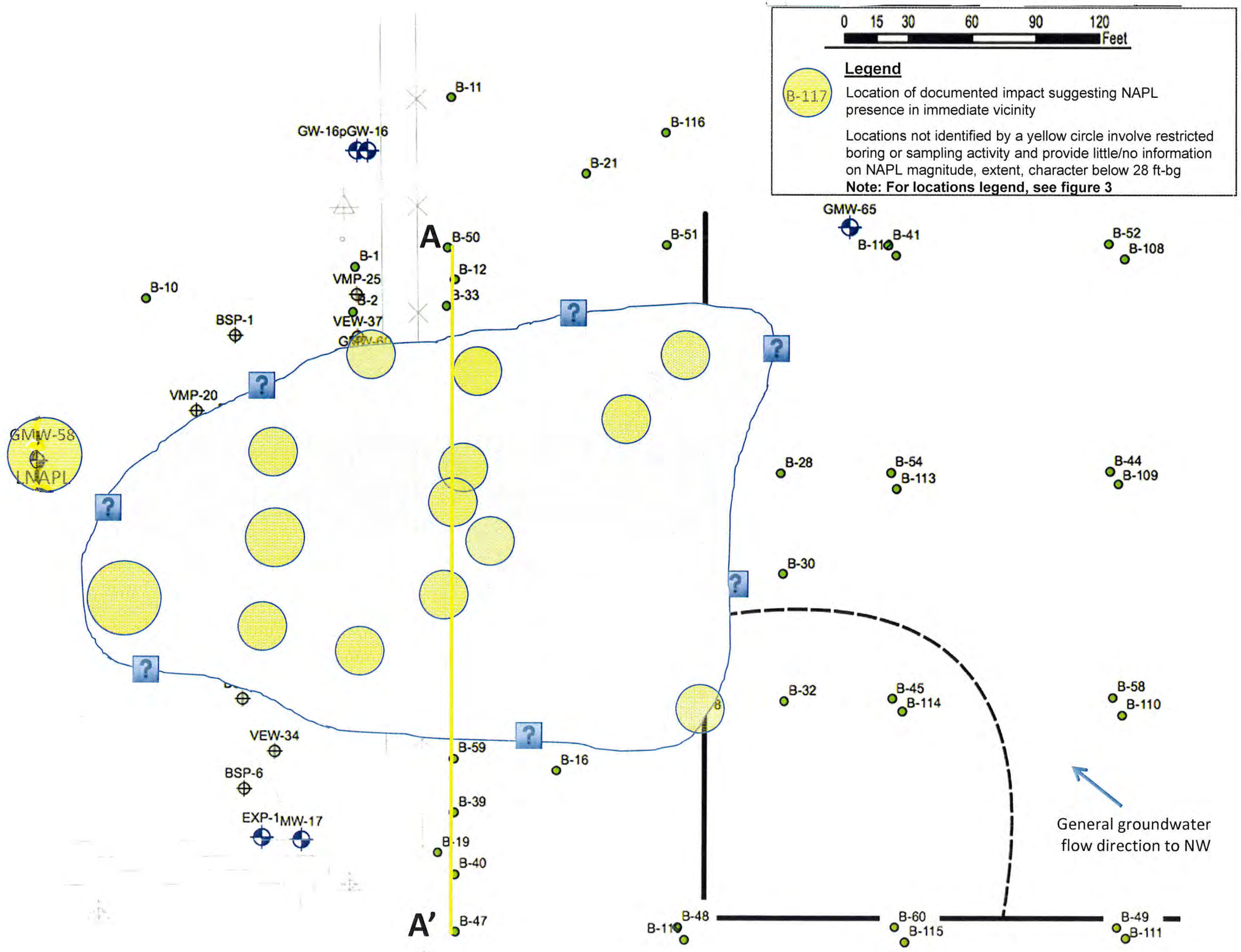
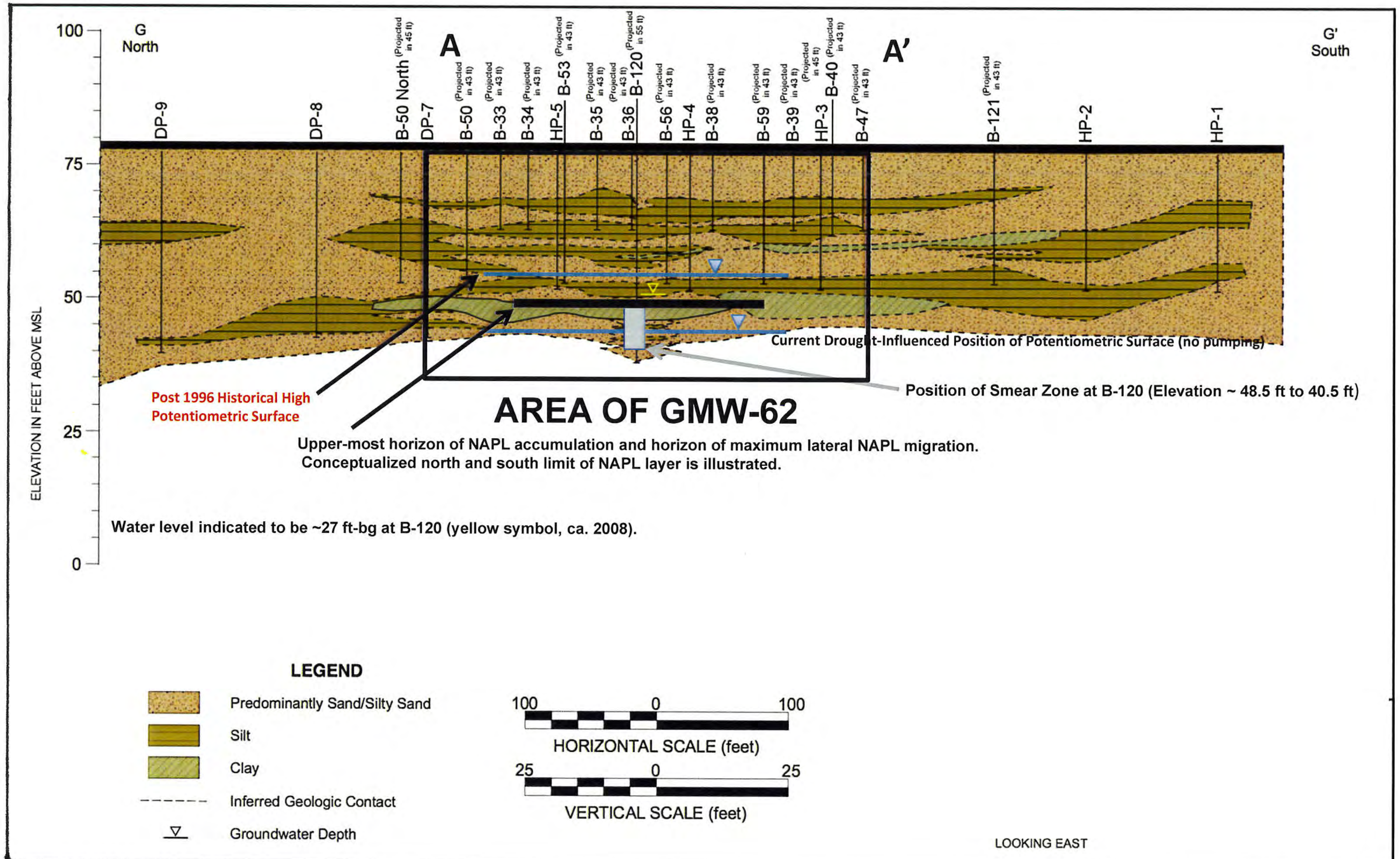


FIGURE 4

PLAN VIEW OF CONCEPTUALIZED LIMITS OF NAPL, GWM-62 AREA

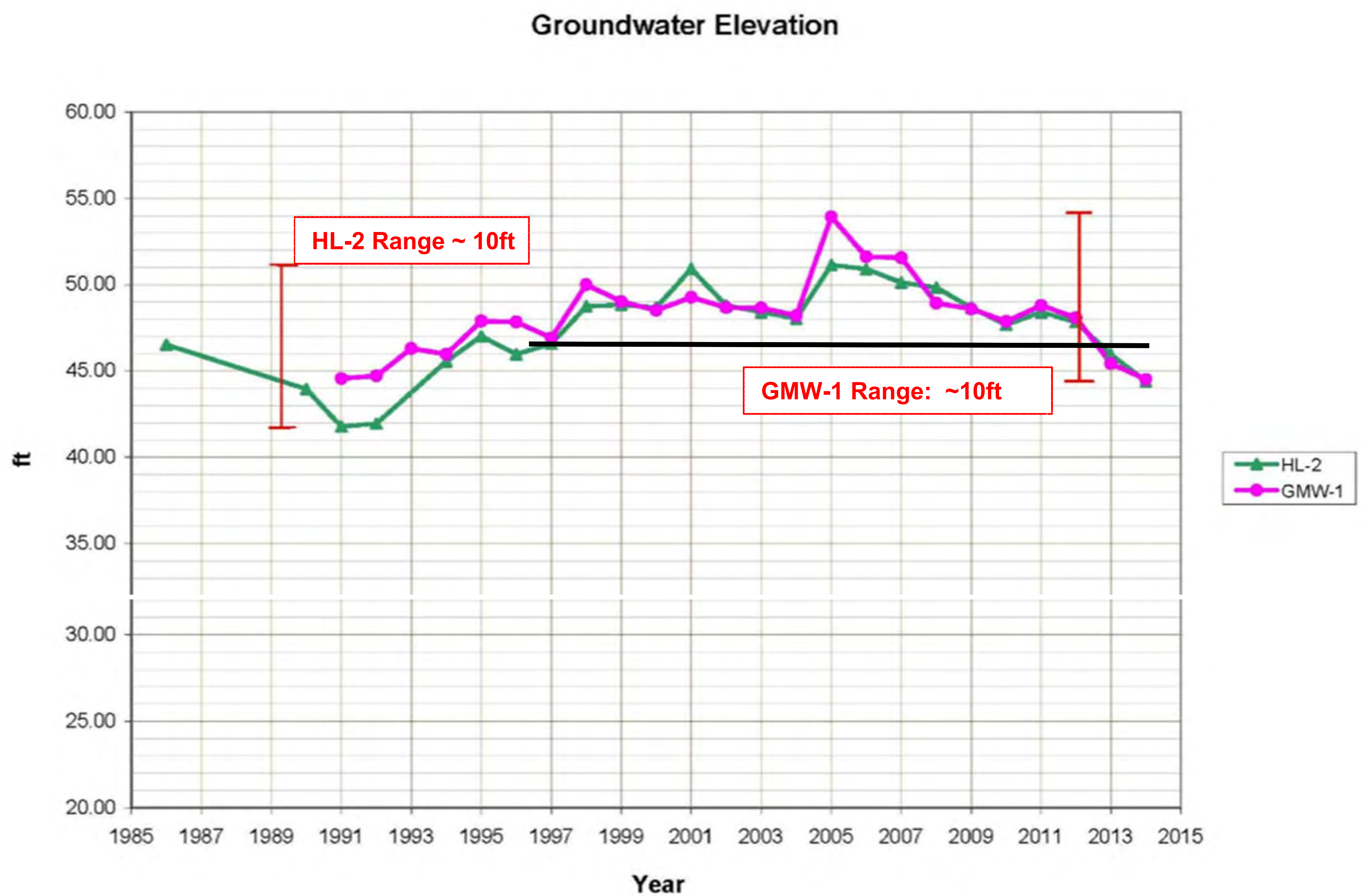
SGI environmental THE SOURCE GROUP, INC.



NOTE:
Lithologic Cross Section From Parsons Reports.

FIGURE 5
HYDROGEOLOGIC PROFILE A-A' WITH NAPL OCCURRENCE DETAILS, GWM-62 AREA

THE SOURCE GROUP, INC.

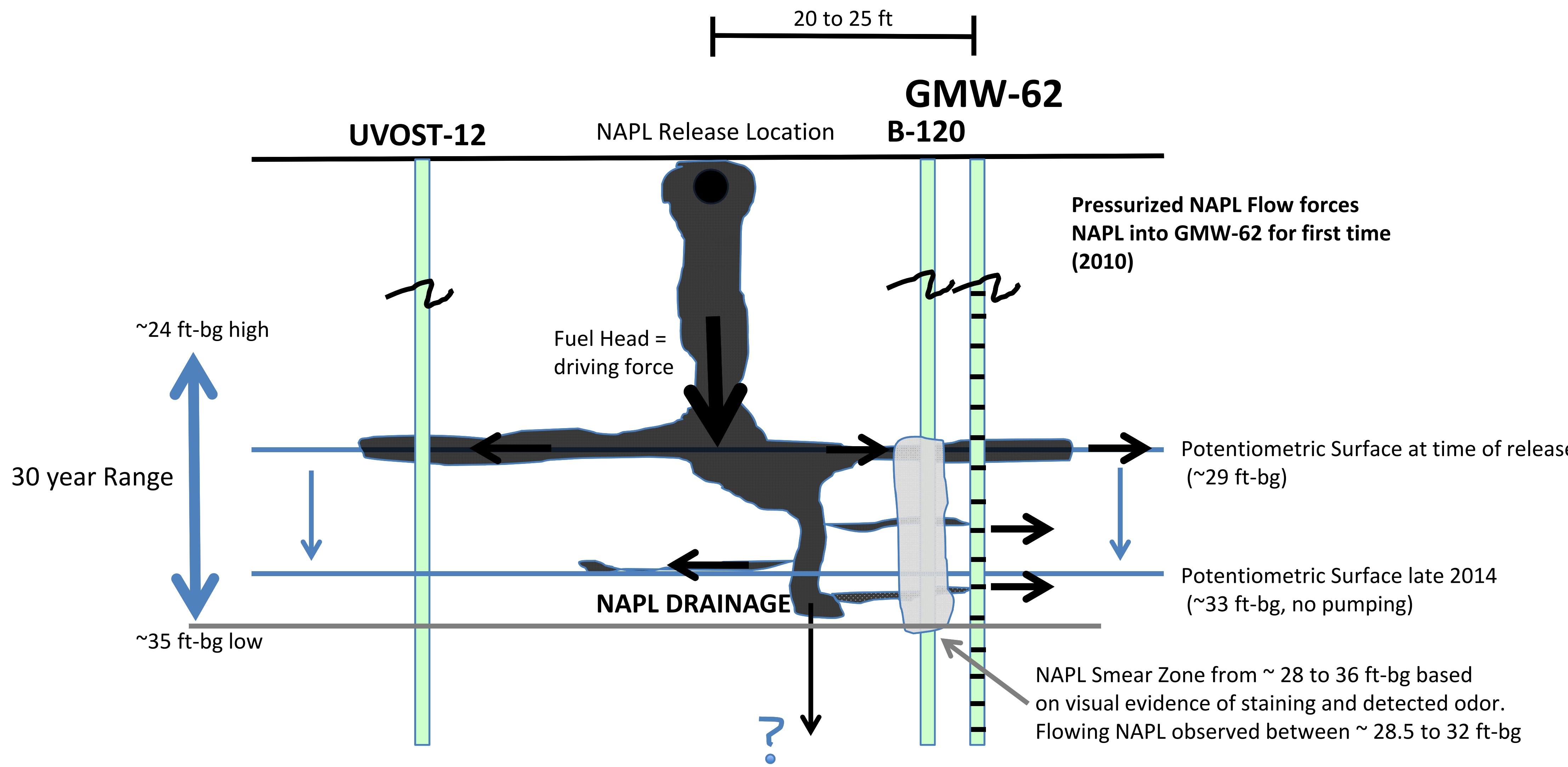


Not to Scale

FIGURE 6

HYDROGRAPH FOR WELLS HL-2 AND GMW-1 (1986 to 2014)

SGI environmental THE SOURCE GROUP, INC.



Detected Dissolved BTEX Concentration Data from HydroPunch Profiling suggests NAPL near 44 to 48 ft-bg in vicinity of B-120

Not to Scale

FIGURE 7
NAPL RELEASE AND MIGRATION CONCEPTUALIZATION PIPELINE RELEASE AREA NEAR GMW-62 DFSP NORWALK

THE SOURCE GROUP, INC.

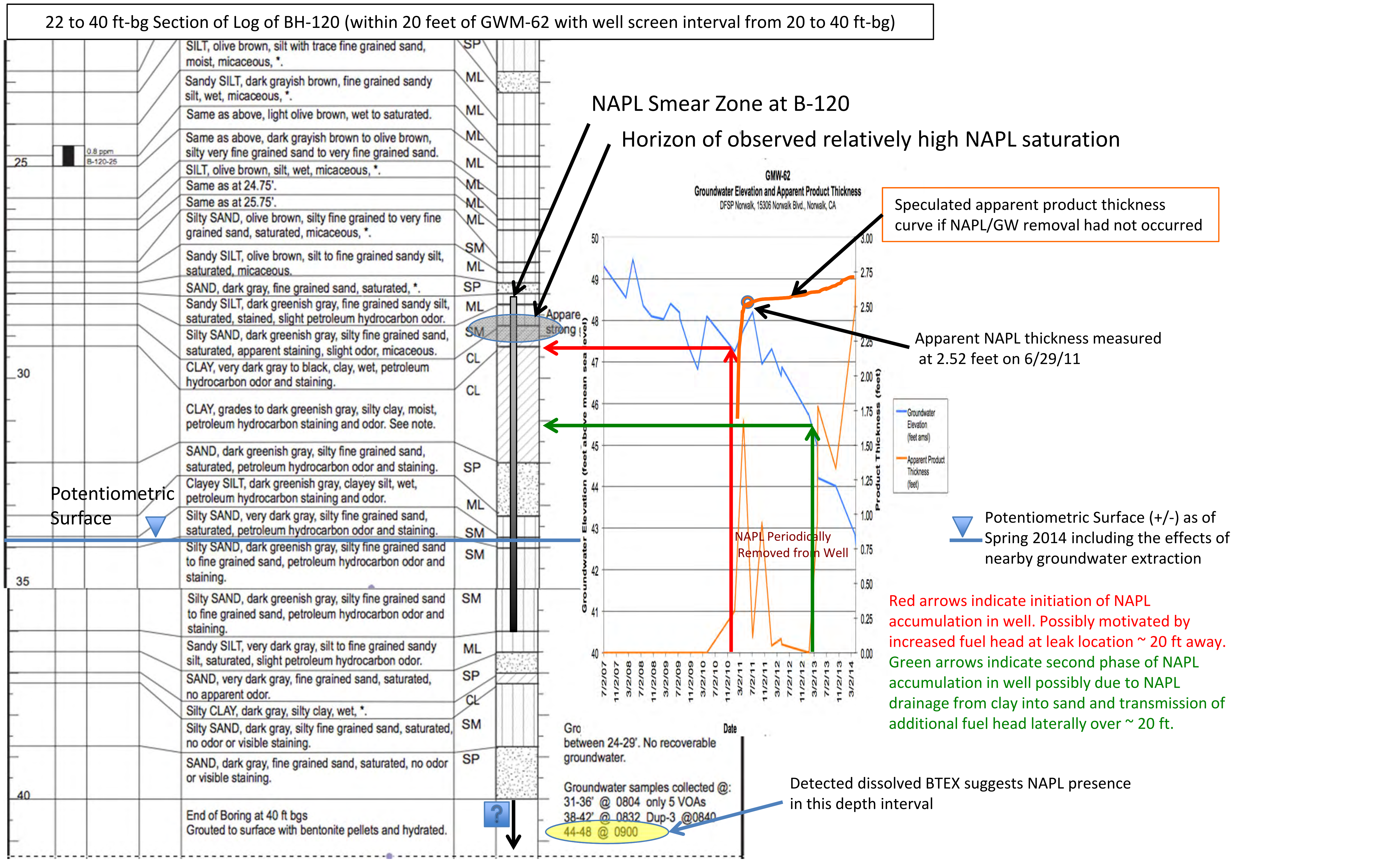
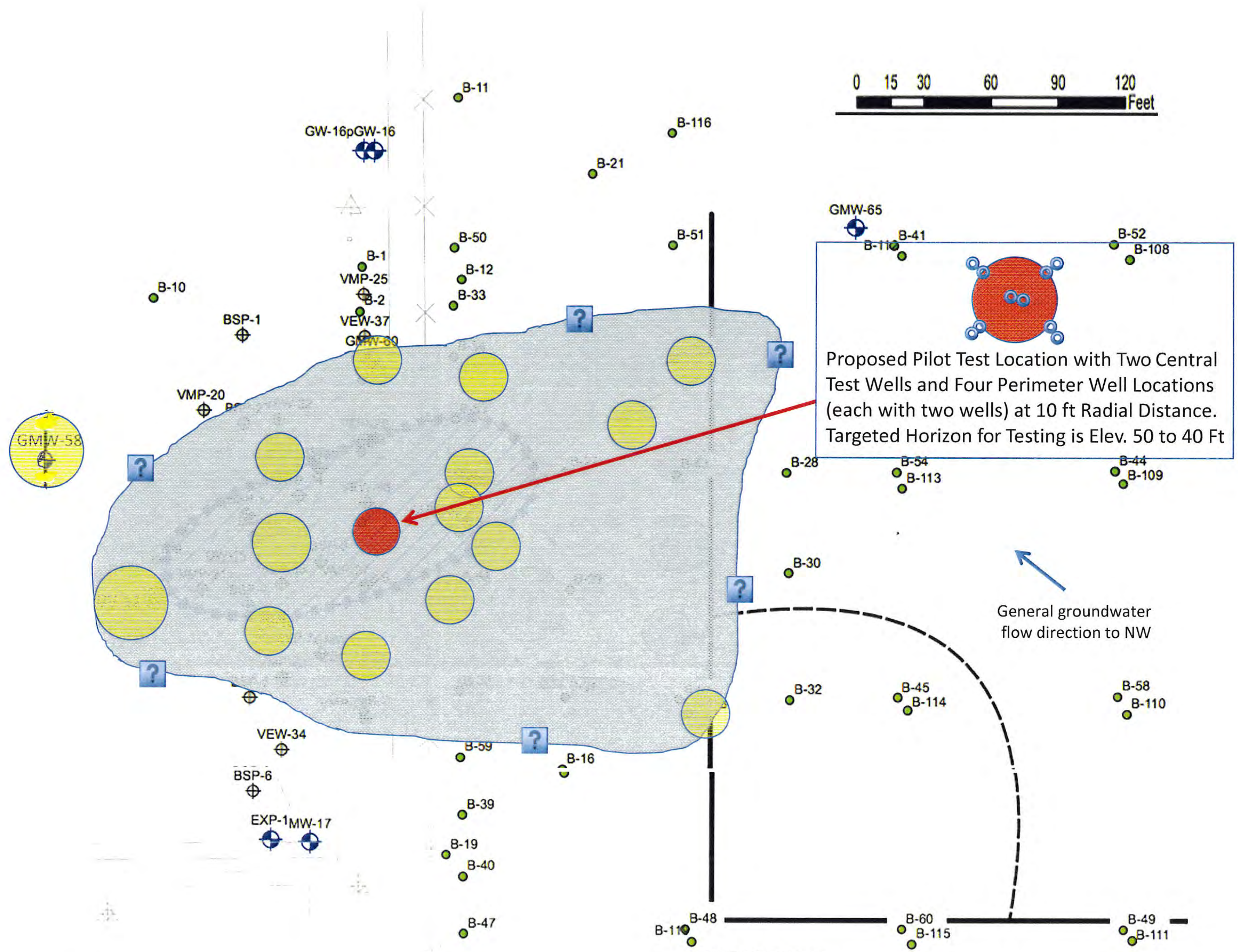


FIGURE 8

NAPL BEHAVIOR ANALYSIS FOR B-120 AND GMW-62 AREA

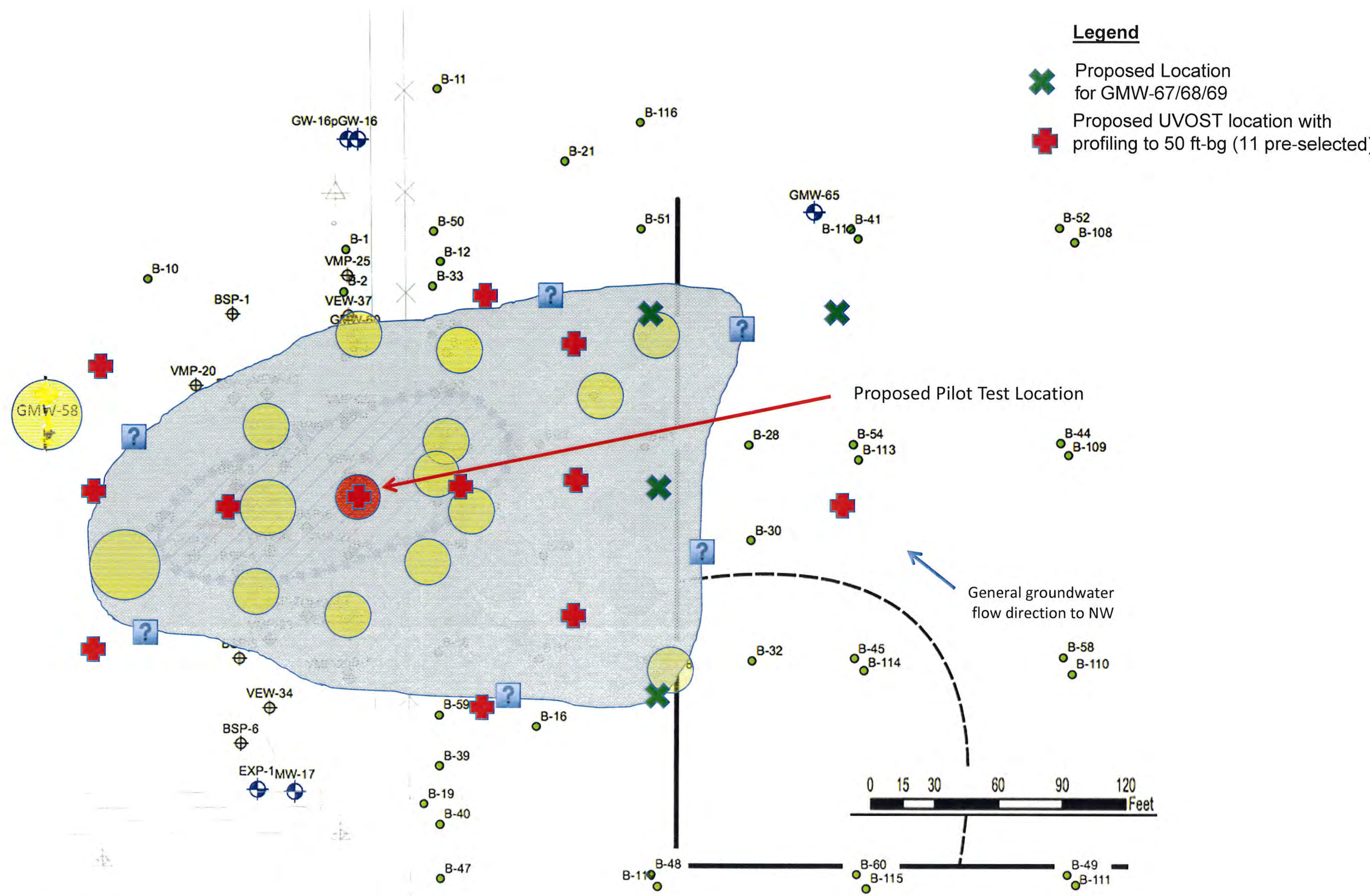
SGI environmental THE SOURCE GROUP, INC.



NOTE:
For location legend, see figure 3.

FIGURE 9
PLAN VIEW SHOWING PROPOSED PILOT TEST LOCATION

SGI environmental THE SOURCE GROUP, INC.



NOTE:
For location legend, see Figure 3.

FIGURE 10
PLAN VIEW OF PROPOSED UVOST LOCATIONS

THE SOURCE GROUP, INC.

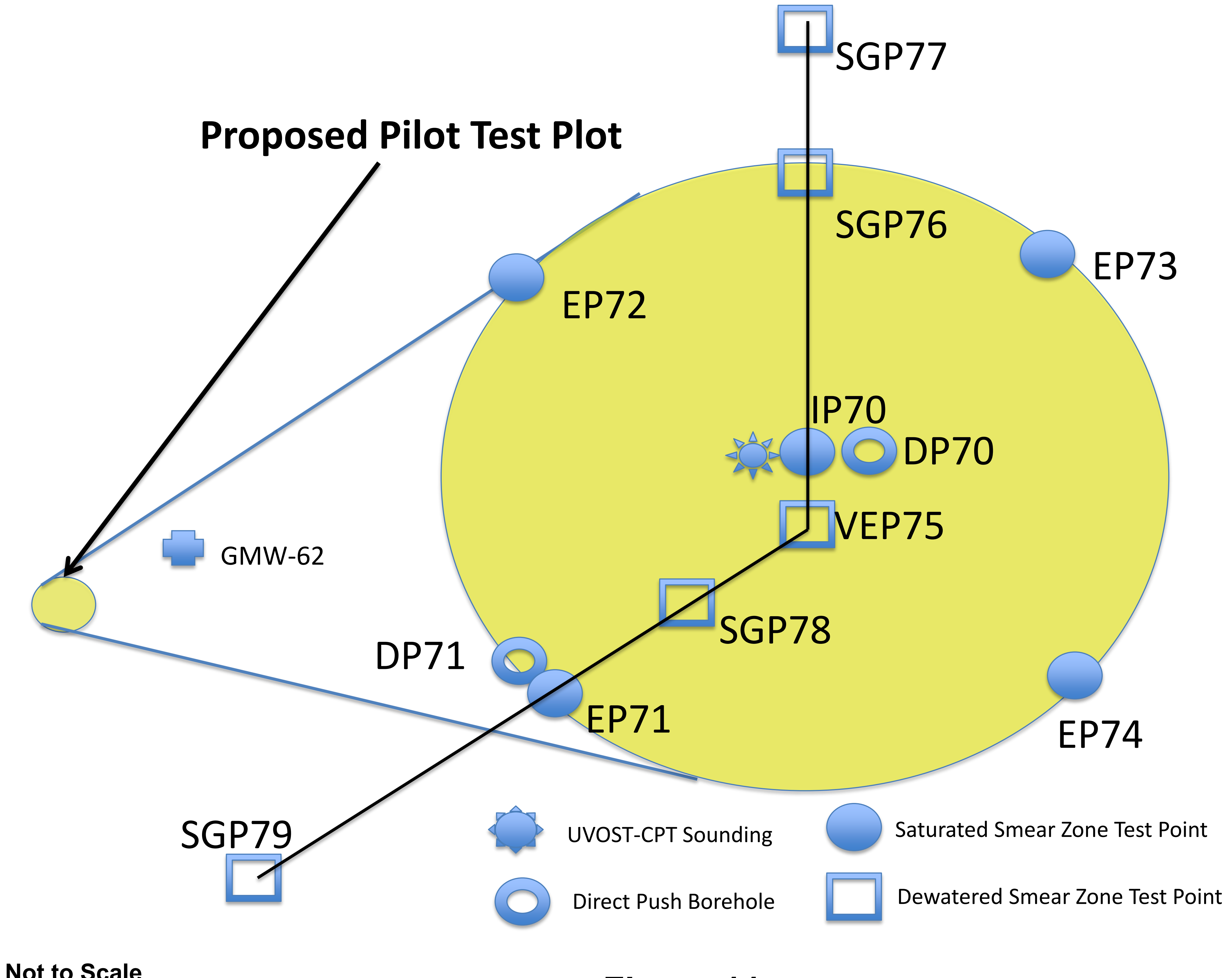


Figure 11
Plan View Showing Pilot Test Point Locations

SGI environmental THE SOURCE GROUP, INC.