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Summary and Status of DNAPL Characterization and Remediation Activities in the A/M Area, Savannah River Site

Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

Prepared for the United States Department of Energy under Contract No. DE-AC09-96-SR18500

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DISCLAIMER

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Abbreviations and Acronyms

CPT	cone penetrometer
DHEC	Department of Health and Environmental Control
DNAPL	dense non-aqueous phase liquid
DUS	Dynamic Underground Stripping
FY	fiscal year
GPR	ground penetrating radar
HPO	Hydrous Pyrolysis Oxidation
H_2O	water
NAPL	non-aqueous phase liquid
nd	below detection limit
PCE	tetrachloroethylene
PITT	Partitioning Tracer Tests
PVC	polyvinyl chloride
RCRA	Resource Conservation and Recovery Act
RF	radio frequency
SC	South Carolina
SRS	Savannah River Site
SVE	Soil Vapor Extraction
TA	Temporary Authorization
1,1,1-TCA	1,1,1-trichloroethane
TCE	trichloroethylene

bgs	below ground surface
ft msl	feet mean sea level
Kg	kilogram
lbs	pounds
ppb	parts per billion
ppbv	parts per billion volume
ppmw	parts per million weight
µg/g	micrograms per gram

EXECUTIVE SUMMARY

Characterizing and developing clean-up plans for residual undissolved industrial solvents, also known as dense non-aqueous phase liquids (DNAPLs), in the soil and groundwater beneath former “source areas” are key elements in the overall groundwater corrective action for the A/M-Area of the Savannah River Site (SRS). These activities support the goals of the A/M-Area Resource Conservation and Recovery Act (RCRA) permit. Based on ten years of data, SRS developed the A/M-Area DNAPL Strategy flowchart that lays out DNAPL characterization and clean-up activities in a logical and organized fashion. The flow chart consists of several steps – identification of suspect source areas, confirmation of the DNAPL status (presence or absence), delineation of location and quantity, and identification/permitting of clean-up activities. An important feature of the flow chart is that it is integrated with other activities within the corrective action. Completion of DNAPL related work does not signify that a site is clean, rather that the DNAPL source has been appropriately addressed and the remainder of the A/M-Area technology portfolio addresses remaining groundwater, vapor phase, or sorbed contamination. Removing pure phase DNAPL, to the extent possible, is a critical step in the A/M-Area solution. This step allows the other clean-up activities to work on suitable concentration levels and for a shorter time frame – a time frame that is less controlled by the slow dissolution of a large reserve of DNAPL.

SRS identified 16 possible or confirmed DNAPL source areas in the A/M-Area. We apply the general flowchart approach to each suspect area. One of these areas, notably the 321M Solvent Storage Tank, has been confirmed and is in the full-scale cleanup stage. Other suspect or confirmed DNAPL source areas (miscellaneous leakage from various former process buildings and the like) are in the confirmation, rapid response and/or characterization stages as noted below. A few of the DNAPL sources (e.g., M-Area Basin and its upstream Process Sewer, and the A-014 Outfall) have been confirmed and are being remediated by rapid response actions such as soil vapor extraction (SVE) or DNAPL removal/destruction pilot studies. These rapid responses have been implemented under RCRA while characterization efforts continue to delineate the DNAPL quantity, location and geometry and to develop a more complete DNAPL targeted solution. Based on the low concentrations observed in the data collected to date, a few potential sources are now being addressed under the general A/M-Area RCRA corrective action without additional planned DNAPL activities (e.g., the Upper 700 Area Building 703-A and the M-Area process sewer leading to the A-014 Outfall). This report summarizes historical A/M-Area DNAPL activities and data, and presents the overall A/M-Area strategy flowchart, the status work for each DNAPL source zone (or potential source zone), and future A/M-Area DNAPL plans.

1.0 INTRODUCTION

Metals fabrication and related industrial operations within the A/M-Area of the Savannah River Site (SRS) resulted in the releases of over $1.6x10^6$ Kg ($3.5x10^6$ pounds) of chlorinated solvents, primarily trichloroethylene (TCE) and tetrachloroethylene (PCE) into the subsurface. These wastes were discharged over the period from approximately 1955 through 1980. The releases have resulted in the contamination of the vadose zone (the upper 45 m, or approximately 135 ft, of interbedded sands and clays) underlying and adjacent to the disposal areas, as well as shallow groundwater over an area of approximately 5 km^2. The groundwater contamination was identified in 1980 and remediation strategies were rapidly developed and implemented for both the dissolved plume and contaminated soil vapor. During characterization activities in 1991, the presence of dense non-aqueous phase liquid (DNAPL) was confirmed by visual examination of liquid samples that were recovered with a bottom-filling bailer from groundwater monitoring wells. An active program to address DNAPL was initiated. The program has identified the strengths and weaknesses of various DNAPL technologies and DNAPL management approaches.

At large industrial sites like the A/M-Area, undissolved DNAPL in soil and groundwater is the most significant barrier to successful cleanup. DNAPL acts as a reservoir, generating contaminant levels above remediation concentration goals for an extended time period. Technical and operations personnel at SRS have developed and tested a variety of DNAPL characterization and remediation methods over the past ten years. We have refined the DNAPL strategy during this period based on the results of the various tests. The current SRS DNAPL strategy is documented in the form of a flow chart that defines our approach to DNAPL management. Importantly, the DNAPL strategy is integrated into the RCRA groundwater corrective action and is being developed within the context of an overall plan for clean up of this area. This allows us to select characterization and clean-up methods that are appropriate to character and distribution of the various zones within the contaminant plume (source zones, primary dissolved plume, and dilute fringe).

The DNAPL strategy that has evolved addresses the A/M-Area source zone(s). The strategy emphasizes detailed depth-discrete delineation of subsurface DNAPL to optimize remediation. This is particularly critical for DNAPL treatment technologies such as enhanced mobilization (e.g., using steam, cosolvents or surfactants) and in situ destruction methods (e.g., permanganate or Fenton's reagent) because the treatment costs are a strong function of target treatment volume (i.e., unit costs are $ per volume of soil treated). A sequence of complementary low cost characterization methods ("toolbox") is used for the characterization activities. The resulting approach, similar to exploration geochemistry, maximizes information to refine the conceptual model of target DNAPL at a minimum cost. A second key feature of the strategy is that DNAPL treatment methods are categorized based on cost, logistics and aggressiveness. We developed criteria, principally DNAPL mass and the treatment zone volume to assist in selecting the best technology for each discrete area of DNAPL accumulation. Large quantities of DNAPL are addressed with the most aggressive (i.e., expensive) methods; smaller quantities are addressed with less expensive methods. We also identified rapid response options for areas where DNAPL related modifications to existing operations/infrastructure are feasible. A final key feature of the strategy was development of criteria for identifying that a suspect DNAPL area does not have sufficient contamination to justify a DNAPL specific remediation – for these areas, the ongoing and planned future operation of the groundwater treatment system is the most appropriate action.

2.0 CONCEPTUAL MODEL OF DNAPL BEHAVIOR IN COASTAL PLAIN SEDIMENTS

Review of the literature regarding subsurface DNAPL migration and knowledge of soil physics led to the development of a conceptual model of DNAPL migration in the subsurface in A/M-Area (Jackson *et al*., 1996). As the DNAPL migrates in the subsurface, local heterogeneities of the sediments influence DNAPL movement and accumulation. DNAPL continues to migrate given a sufficient driving force in the form of continued disposal of solvent wastes. When the DNAPL source is exhausted and the driving force for movement removed, the DNAPL mass in the subsurface will reach a stable configuration based upon the applied gravitational, hydrodynamic, and capillary forces. At this stage, residual DNAPL remains in the pore throats along the migration path and in accumulation areas determined by geological structure. In the vadose zone, the DNAPL is often the wetting phase, and thus, residual DNAPL is held by capillary forces in the pores of layered fine-grained sediments typical of the Atlantic Coastal Plain. Below the water table, DNAPL tends to move vertically in narrow “fingers” and then accumulate in thin laterally extensive layers at the base of the affected aquifer. In contrast to the vadose zone, DNAPL accumulation below the water table is in coarse-grained sediments immediately above clayey intervals. After the source is removed, residual DNAPL is left throughout the entire migration pathway due to “snap-off” in pore throats as the DNAPL front moves away. Because of the relatively low solubility of DNAPL solvents, all of these types of residual and accumulated source material in the subsurface represent a large fraction of the original mass released at most sites. As a result, the DNAPL represents the primary long-term source for groundwater contamination over an extended period (circa 100s of years). (Jackson *et al*., 1996).

Current conceptual models indicate DNAPL will penetrate down into the water table when it has a high application rate over a small area. In these cases, the DNAPL obtains a large enough continuous (organic phase) head to penetrate the capillary fringe. Once the capillary fringe is penetrated the DNAPL flow is primarily controlled by the structure of any capillary barriers (clays and the like).

3.0 STATUS OF OVERALL A/M-AREA CORRECTIVE ACTION

Results of early work identified that approximately 3.5 million pounds of chlorinated solvents had been spilled or disposed through process sewers to the surface/subsurface in A/M-Area. This contamination has been addressed through the RCRA permit for A/M-Area (specifically related to the M-Area Settling Basin and Vicinity) and the RCRA postclosure requirements (defined in the A/M-Area Groundwater Corrective Action). In the 1980's and 1990's this has led to the:

a) closure of the M-Area Settling Basin through stabilization and the placement of a RCRA style cap,
b) operation of two full-scale groundwater pump-and-treat systems in the central A/M-Area and in the northern sector,
c) targeted air sparging, bioremediation, soil heating and oxidation remediations,
d) installation of in-well vapor stripping (recirculation well) systems to reduce the migration of the primary plume into the low concentration area in the southern sector,
e) installation of full-scale soil vapor extraction systems throughout the area from 1987 through 1995, and
f) operation of Dynamic Underground Stripping and Hydrous Pyrolysis (steam based) treatment in the soil and shallow groundwater underlying the former solvent storage tank.
g) Installation and operation of passive SVE (using barometric pumping and the BaroBall™ device) at the Metallurgical Laboratory and other lower concentration vadose zone sites.

These various systems have removed more than 1 million pounds (approximately 450,000 Kg) of chlorinated solvent from the soil and groundwater to date.

Much of the recent effort in the overall A/M-Area program addresses two portions of the plume, the source (DNAPL) areas and the low concentration (distal) areas. Contaminant conditions in these areas are not well suited to traditional treatments such as pump-and-treat. This process of matching the nature of the characterization treatment to the nature of the contaminant plume in various parts of the overall A/M-Area plume has been well documented (Looney, 2000; Harris *et al*., 2000). The approach has now been adopted for environmental restoration projects across SRS (each area publishes their groundwater strategy using this paradigm). In A/M-Area, the DNAPL strategy has been formalized to address technical issues of characterization and clean-up within the context of the overall corrective action. In the distal area, natural and sustainable methods that are consistent with the low concentrations are being evaluated.

4.0 STATUS OF A/M-AREA DNAPL ACTIVITIES

As part of the A/M-Area groundwater corrective action, SRS has actively identified facilities that may have contributed DNAPL to the subsurface during their operations, characterized the most significant potential sources, and initiated DNAPL targeted clean-up actions based on the data. The technical and management approach to A/M-Area DNAPL has now been formalized into a flowchart (submitted in the 2000 RCRA permit application) to clarify how the work is planned and carried out and to facilitate tracking of progress for each of the identified potential DNAPL sources. The flowchart defines the types of activities performed for each area and the basis for decision-making as the project moves through the various stages (screening, characterization, possible DNAPL specific clean-up, etc.). The identified potential sources were classified into three groups depending on the type of expected release scenario. The groups are storage areas (spills and leaks), use areas (spills and leaks) and disposal areas (documented as part of operations and often high volume releases). The suspect and confirmed DNAPL sources (Figure 4.1) that are currently being addressed by the A/M-Area groundwater corrective action include (letter designations on the map are the same as those used in Marine and Bledsoe, 1984):

STORAGE AREAS

- 321-M Solvent Storage Tank (shown as “C” on map)
- Rail Storage East of Building 313-M (shown as “A”)
- Drum Loading South of Building 313-M (shown as “E”)
- 713-A, Central Storage Facility

USE AREAS

- Buildings 313-M (Slug Manufacturing Facility), 320-M (Target Manufacturing Facility) and 321-M (Fuel Manufacturing Facility)
- Building 305-A
- Building 773-A (SRTC)
- Upper 700 Area
- Lower 700 Area

SOLVENT DISPOSAL AREAS

- M-Area Settling Basin Process Sewer (to M-Area Settling Basin) (shown as “F”)
- M-Area Settling Basin (shown as “D”)
- M-Area Process Sewer (to A-014 outfall)
- A-014 Outfall
- Swampy Area on which Building 321-M now sits (shown as “B”)

As the conceptual model implies, detecting the DNAPL zones in the subsurface is challenging. Improved characterization tools have been and continue to be used to allow for quicker, cheaper, more accurate characterization of the subsurface. DNAPL characterization activities began in 1992 with the ultimate goal to enable more precise targeting of DNAPL remediation efforts (Looney et al., 1992). The A/M-Area DNAPL flowchart is based on the results of the targeted characterization (see Cohen et al, 1993) and clean-up activities to date. Past characterization results have been documented in a series of reports and results for FY00 are summarized below. This is followed by an overview of the DNAPL results from all years, a description of the logic and details of the generic A/M-Area DNAPL flowchart and specific annotated flowcharts summarizing the status for each of the potential DNAPL source areas/groups.

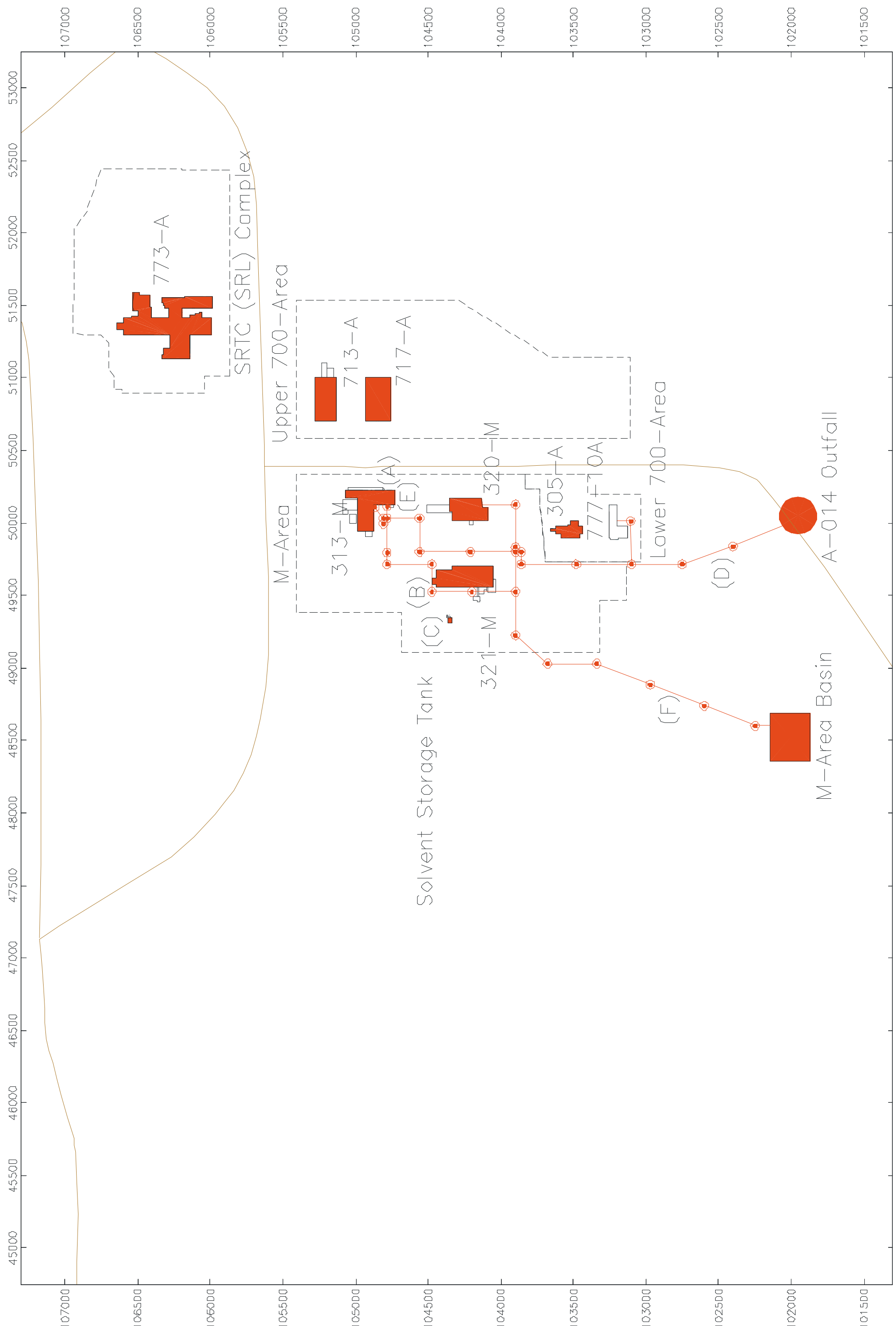


Figure 4.1 Base Map Showing A/M-Area and the Location of Suspect, or Confirmed, DNAPL Sources

5.0 CHARACTERIZATION ACTIVITIES AND DATA

5.1 Historical Information through FY 96

Historical A/M-Area data related to DNAPL is reported and interpreted in several technical reports and in the RCRA permit and related documents. The primary topical references from this period are *Assessing DNAPL Contamination, A/M-Area, Savannah River Site: Phase I Results* (Looney *et al*., 1992) and *Estimating the Thickness of DNAPL within the A/M-Area of the Savannah River Site* (Jackson *et al*., 1996). These reports discuss and present available information and the DNAPL implications and interpretation. In the 1992 report, Looney et al., reviewed process use and evaluated previous monitoring well data and soil core data with regard to potential DNAPL target areas. The investigators also performed a variety of screening activities, including, geophysical and caliper logs in existing wells, detailed analysis of collected DNAPL phases, a structure contour evaluation of the green clay, and additional activities. Important data generated for the report included a cone penetrometer study of lithology in the vicinity of the M-Area Settling Basin. The report also relied on sediment concentrations and vertical cross sections previously generated by Gordon *et al*. (1982), Marine and Bledsoe (1984), Pickett (1985) and the RCRA Part B permit. The 1996 report significantly extended this evaluation using a detailed time trend analysis for each monitoring well in the vicinity of potential DNAPL sources, additional interpretation related to the structure of critical clay layers in the vicinity of these sources, and a mathematical analysis of potential migration pathways. The two reports clarified the nature and distribution of DNAPL near the M-Area Settling Basin (the largest A/M-Area source) and provided indications of DNAPL behavior near the A-014 Outfall and other suspect areas. Based on the information, three pilot scale DNAPL targeted treatments were deployed. These included six phase heating and radiofrequency heating along the former process sewer line near the settling basin, and in situ oxidation using Fenton's reagent in a DNAPL accumulation zone west of the M-Area Settling Basin. As discussed below, the pre-test and post-test data from these activities provide additional information related to DNAPL behavior and distribution.

5.2 FY97 through FY99

Specific follow-on characterization activities were conducted in FY97 through FY99 to refine our knowledge of the extent of the VOC plume and the spatial distribution of DNAPL within the plume. The following activities were conducted and the documents in which the results were reported are listed below.

Characterization of the Vadose Zone at the A-014 Outfall using CPT based technologies as reported in "Characterization Activities to Determine the Extent of DNAPL in the Vadose Zone at the A-014 Outfall of A/M-Area (U), WSRC-RP-99-00569.

Characterization of a potential DNAPL transport pathway before and after a demonstration of a DNAPL remediation technology using rotosonic drilling as reported in “Final Report for Demonstration of In Situ Oxidation of DNAPL Using Geo-Cleanse Technology (U)”, WSRC-TR-97-00283.

Characterization below the water table at known DNAPL source areas using rotosonic drilling to complete 13 soil borings with soil plug samples as reported in “A/M-Area DNAPL Characterization Report for Cores Collected in FY97 and 1Q98 and 2Q98 (U)”, WSRC-TR-98-00296.

Characterization adjacent to and below the M-Area Settling Basin using rotosonic vertical and angle drilling to determine the spatial distribution of DNAPL adjacent to and below the basin as report in “A/M-Area DNAPL Characterization Report for Cores Collected in 2Q99”, WSRC-TR-99-00468.

5.3 FY00

Characterization activities in FY00 included depth discrete soil sampling of borings drilled using the rotosonic method, soil gas samples and lithology data gathered using cone penetrometer techniques. The depth discrete soil samples were collected adjacent and below the M-Area Settling Basin and adjacent to the A-014 outfall. The sampling locations are shown on Figure 5.1 and the results are summarized in Table 5.1. Depth discrete soil samples were also collected in FY00 to support the Lynntech demonstration and the Dynamic Underground Stripping (DUS) deployment. The results of those sampling events are reported in separate documents authored by Vangelas (2000b and 2000a, respectively).

Depth discrete soil borings were collected at 5 locations using the rotosonic drilling method during the months of March and April 2000. The core descriptions/geophysical logs and daily activity logs for these borings are included in Appendices A and B. The drilling activities occurred at the M-Area Settling Basin and the A-014 Outfall. At the M-Area Settling Basin one vertical boring was drilled adjacent to the western corner of the basin and one angle boring was drilled from the western corner of the basin towards the center of the basin. At the A-014 outfall two angle borings were drilled running parallel to the outfall stream. A third boring was drilled vertically above the location where PCE concentrations identified in one angle boring indicated the presence of DNAPL. All borings were sampled from surface to the top of the Green Clay.

The sampling to support the Lynntech demonstration Vangelas *et al*. (2000b).involved collecting soil samples using a Geo-Probe after the Lynntech soil ozone treatment demonstration was completed. The purpose was to determine the amount of PCE and TCE remaining in the soil to allow the Lynntech personnel to evaluate the effectiveness of the ozone in the destruction of DNAPL. This demonstration was conducted adjacent to the 321-M Solvent Storage Tank concrete pad. The sampling was conducted in March 2000. Three post-test soil borings were collected in the treatment cell, a 15 foot radial area. Sediment samples were collected from 340 ft msl to 330 ft msl (30 ft to 40 ft bgs). Of the 57 samples collected none contained TCE at DNAPL levels (> 200 μg/g) while 2 samples (3.5 %) contained PCE at DNAPL levels (> 50 μg/g).

The sampling to support the DUS deployment Vangelas *et al*. (2000a).involved collecting soil samples at 4 locations from mud rotary drilled soil borings. The purpose of this sampling was to provide additional data to the primary vendor on the pre-deployment soil conditions. Soil plug samples were collected from surface to the top of the Green Clay at approximately 20 foot intervals. Of the 98 samples collected none contained TCE at DNAPL levels (> 200 μg /g) while 2 samples (2%) contained PCE at DNAPL levels (>50 μg/g). The samples containing the PCE at DNAPL levels were located at elevations of 350 ft msl (20 ft bgs) and 349 ft msl (21 ft bgs).

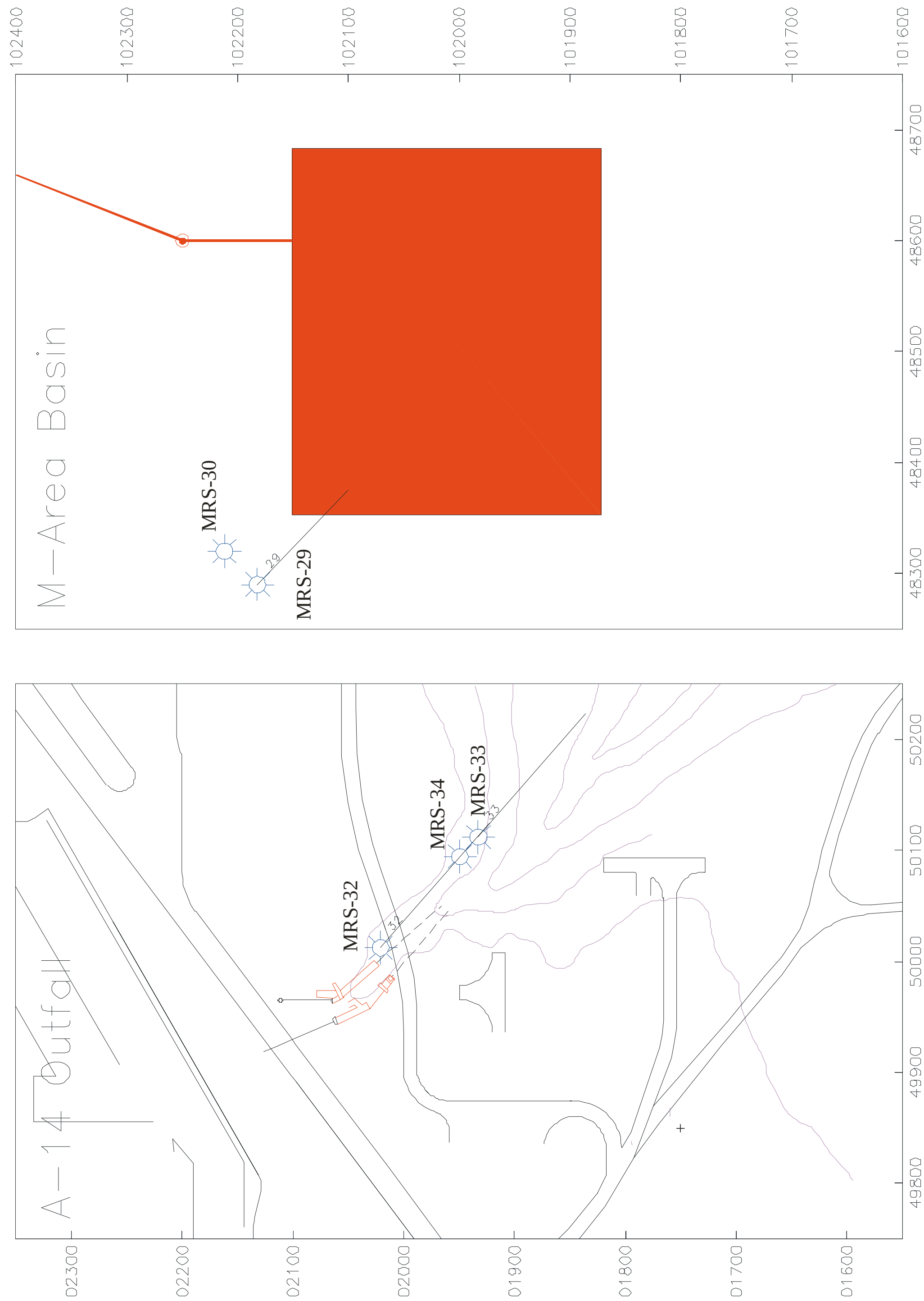


Figure 5.1 Map Showing Core Locations for the M Area Settling Basin and the A-014 Outfall in FY 2000 (Other FY 2000 activities are documented in Vangelas *et al.*, 2000a and 2000b)

Table 5.1. Identification of Elevations at which DNAPL and suspect DNAPL concentrations were reported for borings from the FY00 DNAPL investigations at the M-Area Basin

Elevation	MRS29	MRS30
343-307	nd	nd
307-305		nd
305-229 (231 H_2O table)	nd	nd
228		
227		nd
226-225		
224		
223		
222		
221-220		
219-216		
215		
214-213		
212	SD	
211-210		
209-208	SD	
207		SD
206	SD	
205		
204		
203		
202-201	SD	
200		SD
199-197		
196		SD
195		
194		Total Depth
193		
192		
191		
190		

D – DNAPL concentrations (45µg/g PCE or greater), SD – suspect DNAPL concentrations (between ½ the DNAPL concentration and the DNAPL concentration, 22.5 µg/g < x < 45 µg/g). nd – below detection limit of 0.001µg/g. Clear blocks indicate concentrations between suspect DNAPL and below detection. Shaded blocks indicate no samples collected at those elevations. H_2O table elevations based on information from GIMS database.

Table 5.2. Identification of Elevations at which DNAPL and suspect DNAPL concentrations were reported for borings from the FY00 DNAPL investigations at A-014 Outfall

Elevation	MRS32	MRS33	MRS34
353			
352 – 348			
347			
346 –345			
344			
343 – 341			
340	nd		Land Surface
339		Land surface	nd
338		nd	
337			
336	nd		
335			
334			
333	nd		nd
332			
331			
330			nd
329	nd		
328			
327			
326			
325			
324			
323		nd	
322			
321			
320			
319		nd	
318			
317			
316			
315			
314			
313			
312		nd	
311			
310			
309			
308			
307			
306			
305		nd	

Elevation	MRS32	MRS33	MRS34
304 – 303			
302			
301			
300			
299			
298 –296			
295			
294			
293 –291			
290			
289			
288			
287			
286			
285		nd	
284			nd
283			
282			
281			
280 – 278			
277			
276			nd
275			
274			
273			nd
272			
271			
270			
269	nd		
268			
267			
266			
265			
264 – 263			
262	nd		nd
261			
260	nd		
259			
258			
257			
256			nd
255			
254			
253			nd
252			

Elevation	MRS32	MRS33	MRS34
251		nd	
250			
249	D		
248	D		
247			nd
246			
245			
244			
243			
242			
241			
240			
239			
238			
237			
236			
235			
234			
233		nd	
232 (H_2O table)			
231			
230			
229			
228			
227 – 226			
225			
224			
223			
222 – 221			
220			
219			
218			
217			
216			
215			
214			
213			
212			
211			
210			
209			
208			
207	Total Depth		
206			
205			

Elevation	MRS32	MRS33	MRS34
204			
203			
202			
201 – 200			
199			
198			Total Depth
197 – 196			
195			

D – DNAPL concentrations (45µg/g PCE or greater), SD – suspect DNAPL concentrations (between ½ the DNAPL concentration and the DNAPL concentration, 22.5 µg/g < x < 45 µg/g). nd – below detection limit of 0.001µg/g. Clear blocks indicate concentrations between suspect DNAPL and below detection. Shaded blocks indicate no samples collected at those elevations. H_2O table elevations based on information from GIMS database.

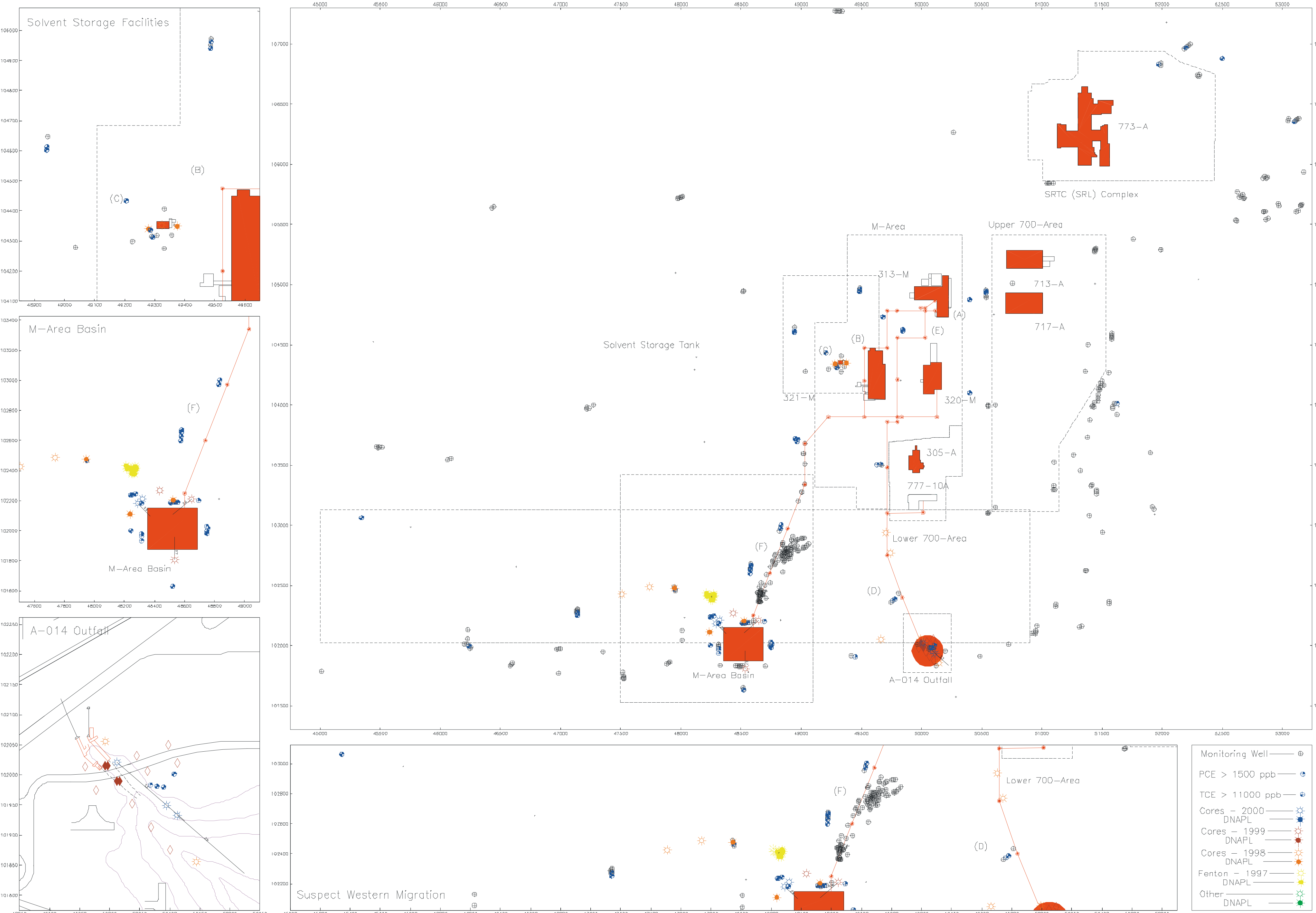
6.0 PRESENTATION OF CUMULATIVE A/M-AREA DNAPL DATA

The available data for the various DNAPL related studies has been assembled onto a map with symbols and colors that denote the different sample types and DNAPL relevant concentration ranges, respectively. This map is provided in Figure 6.1.

{see 11” x 17” insert sheet}

Figure 6.1 Summary of Cumulative DNAPL related Characterization Data from the A/M-Area, Savannah River Site

WSRC-RP-2001-00171
Figure 6.1
11" x 17" insert between pages 18 & 19



7.0 DNAPL STRATEGY - A/M-AREA CORRECTIVE ACTION

7.1 Overall A/M-Area DNAPL Characterization and Remediation Flowchart

In 1991, the presence of DNAPL in A/M-Area was confirmed by visual examination of liquid samples that were recovered with a bottom-filling bailer from monitoring wells MSB 3D and MSB 22. An active program to address DNAPL was initiated. The program has identified the strengths and weaknesses of various DNAPL technologies and DNAPL management approaches. The data collected since 1991 document that residual DNAPL in soil and groundwater is the most significant barrier to successful completing cleanup of large industrial sites like the A/M-Area. DNAPL acts as a reservoir, generating contaminant levels above remediation concentration goals for an extensive time period, thus prolonging clean up. During this period, SRS developed and tested a variety of DNAPL characterization and remediation methods. We have refined our DNAPL strategy during this period based on the results of the various tests and through advances in technology documented in the literature and in regulatory guidance. The current SRS DNAPL strategy is documented in the form of a flow chart (Figure 7.1) that defines our approach to DNAPL management. Importantly, the DNAPL strategy is integrated into the RCRA groundwater corrective action and is being developed within the context of an overall plan for clean up of this area. This allows us to select characterization and clean-up methods that are appropriate to the character and distribution of contaminants in the various portions of the overall A/M-Area contaminant plume. Technologies targeting DNAPL are applied to source areas. Less aggressive methods are proposed for primary dissolved plume (e.g., pump and treat, air sparging, and bioremediation), and sustainable-long term processes for the dilute-distal fringe (e.g., phytoremediation and other types of natural attenuation).

The DNAPL strategy that has evolved addresses source zone(s). The strategy emphasizes detailed depth-discrete delineation of subsurface DNAPL to optimize remediation. This is particularly critical for DNAPL treatment systems such as enhanced mobilization (e.g., using steam, cosolvents or surfactants) and in situ destruction methods (e.g., permanganate or Fenton's reagent) because the treatment costs are a strong function of target treatment volume (i.e., unit costs are $/volume). A sequence of complementary low cost characterization methods ("toolbox") is used for the characterization activities. The resulting approach, similar to exploration geochemistry, maximizes information to refine the conceptual model of target DNAPL at a minimum cost. A second key feature of the strategy is that DNAPL treatment methods are categorized based on cost, logistics and aggressiveness. SRS developed criteria, principally based on DNAPL mass and the treatment zone volume, to assist in selecting the best technology for each discrete area of DNAPL accumulation. Large quantities of DNAPL are addressed with the most aggressive (i.e., expensive) methods; smaller quantities are addressed with less expensive methods. We also identified rapid response options for areas where DNAPL related modifications to existing operations/infrastructure are feasible. A final key feature of the strategy was development of criteria for identifying that a potential DNAPL area does not have sufficient contamination to justify a DNAPL specific remediation – this does not mean we are proposing no action for these sites. Such areas will still have high (but not DNAPL) concentration levels. They are near the center of A/M-Area and will continue to be cleaned up by the groundwater and vadose zone systems until permitted levels are achieved.

The DNAPL strategy flowchart (Figure 7.1) can be divided into several inter-related modules:

- Characterization (Figure 7.2) – This module covers the initial identification of potential (or suspect) DNAPL sources based on process data, monitoring data and "rules of thumb". The characterization modules also includes follow up activities for each suspect area to "confirm" the presence of DNAPL and to support remediation by delineating the quantity and location of residual DNAPL. Many of the technologies are selected as described in Cohen et al (1993). DNAPL behaviors (and ultimately the optimal remediation strategies) are different in the vadose zone versus the saturated zone. These differences are accounted for in the selection from the available technologies in the flow chart as each site is addressed. Within characterization, complementary approaches are used. For example, "screening" level headspace analysis provides vertically dense data in a cost effective manner. This information helps determine the most appropriate placement for monitor well screens or follow up DNAPL testing.
- Rapid Response (Figure 7.3) – This module provides a mechanism to implement a DNAPL targeted clean-up action by reconfiguring or modifying existing infrastructure. The availability of a rapid response option will allow SRS and the South Carolina Department of Health and Environmental Control (SCDHEC) to maintain and improve the performance of the on-going corrective action. Rapid response is for cases where the response is already described in the RCRA permit and for activities that do not involve new or substantial permit issues (e.g., no new types of underground injections, etc.). Note that the selection and operation of a rapid response is typically done in parallel to continued characterization and possible implementation of a more robust treatment later. A good example of this is the operation of SVE at the 321-M Solvent Storage Tank followed later by Dynamic Underground Stripping (steam enhancement to SVE).
- Technology (Figure 7.4) – This module outlines the process for identifying appropriate DNAPL remediation activities and developing plans and schedules. Importantly, we have identified two categories of remediation targeting "large" volume source areas and "low" volume DNAPL sources. This structure clearly captures the important concept that the type of technology that can be implemented for large sources (e.g., steam) is not practical for small areas of DNAPL accumulation. A group of technologies appropriate to such sites has been identified based on our data.
- Regulatory (Figure 7.5) – This module identifies the proposed steps in implementing DNAPL targeted clean up activities.

The flowchart consists of boxes and diamonds. Each of the boxes describes an activity or action, and each of the diamonds represents a decision. Within each activity, several technologies/approaches are used to obtain the information for the next decision. More detail on the approaches and technologies in each box are provided in Table 7.1 and the logic/basis of the various decisions represented by each diamond are discussed in Table 7.2. Characterization technologies, for example, are listed with brief descriptions of their capabilities and applicability and references that document their performance in implementation as we propose. This generic flowchart, implemented for each potential DNAPL area, will improve our ability to document our progress, scope, schedule and plans. We can set goals to be at specific decision points and discuss the status for each source area in a standard and structured fashion. The DNAPL strategy identifies where technology limitations currently exist and provides a framework that allows demonstration of new technologies. The structure of the flowchart provides a framework for and simplifies inclusion of new characterization and remediation methods as they prove valuable in the future.

A/M Area DNAPL Program Flowchart

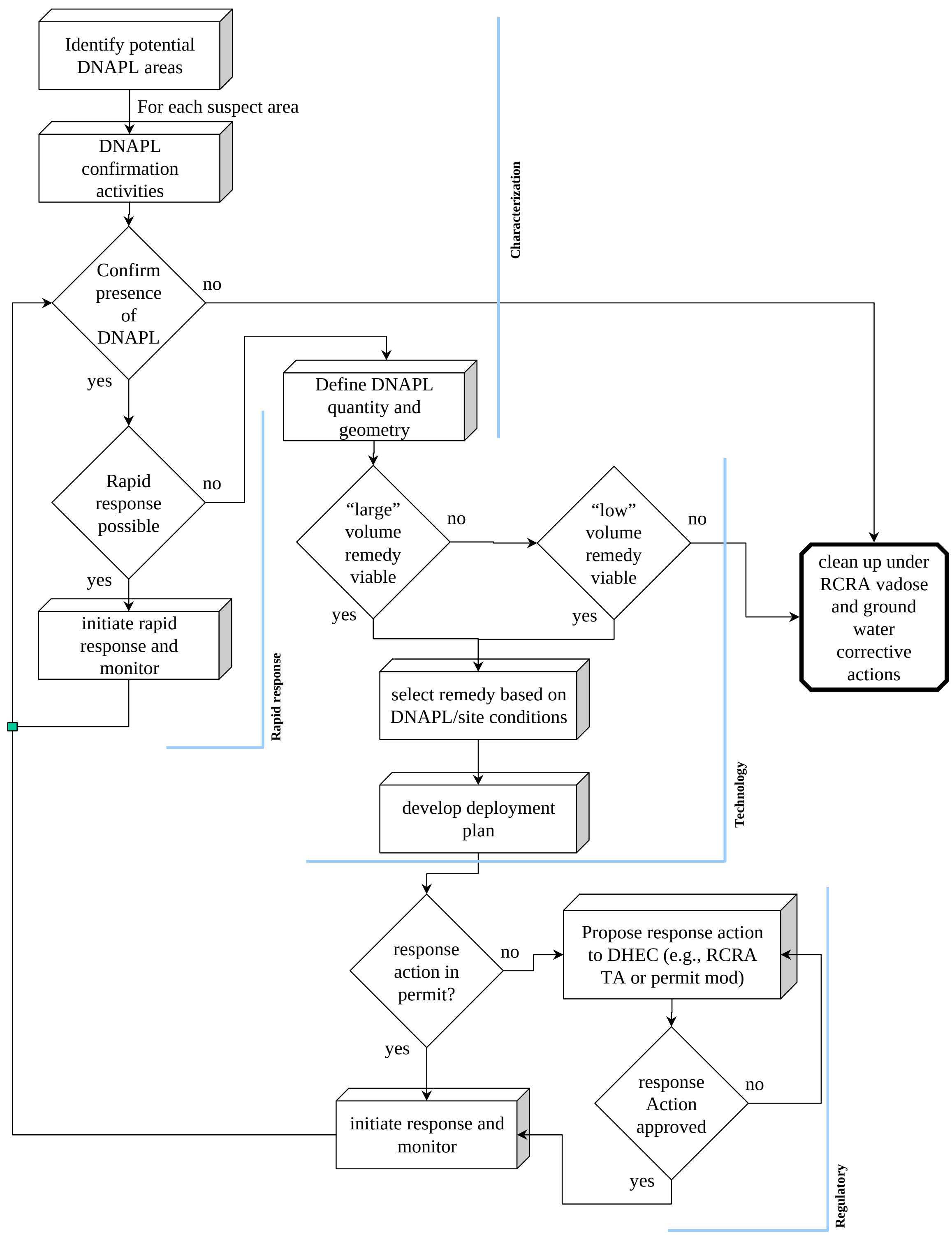


Figure 7.1. Overall A/M-Area DNAPL Strategy

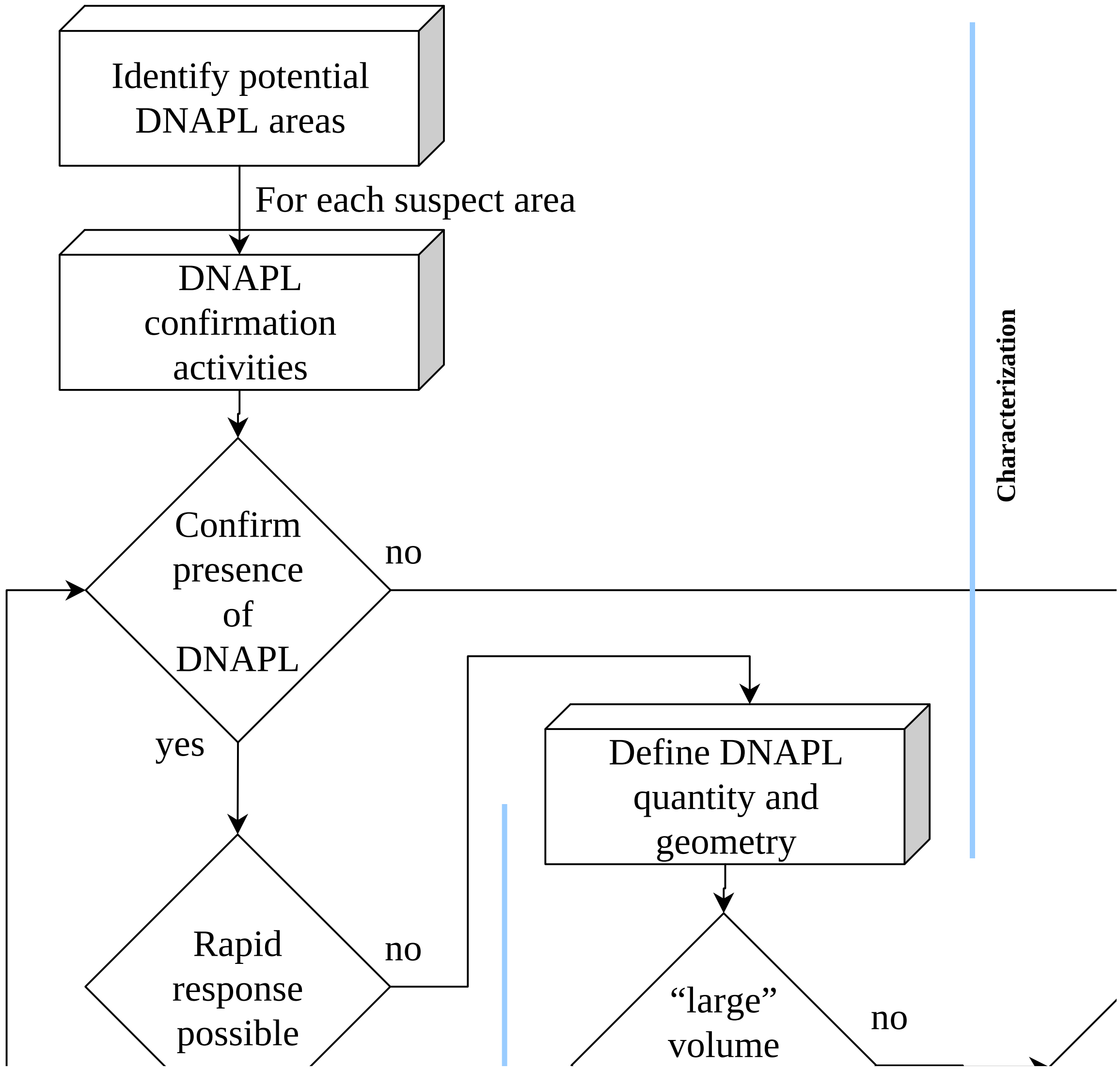


Figure 7.2. Characterization Module of the A/M-Area DNAPL Strategy

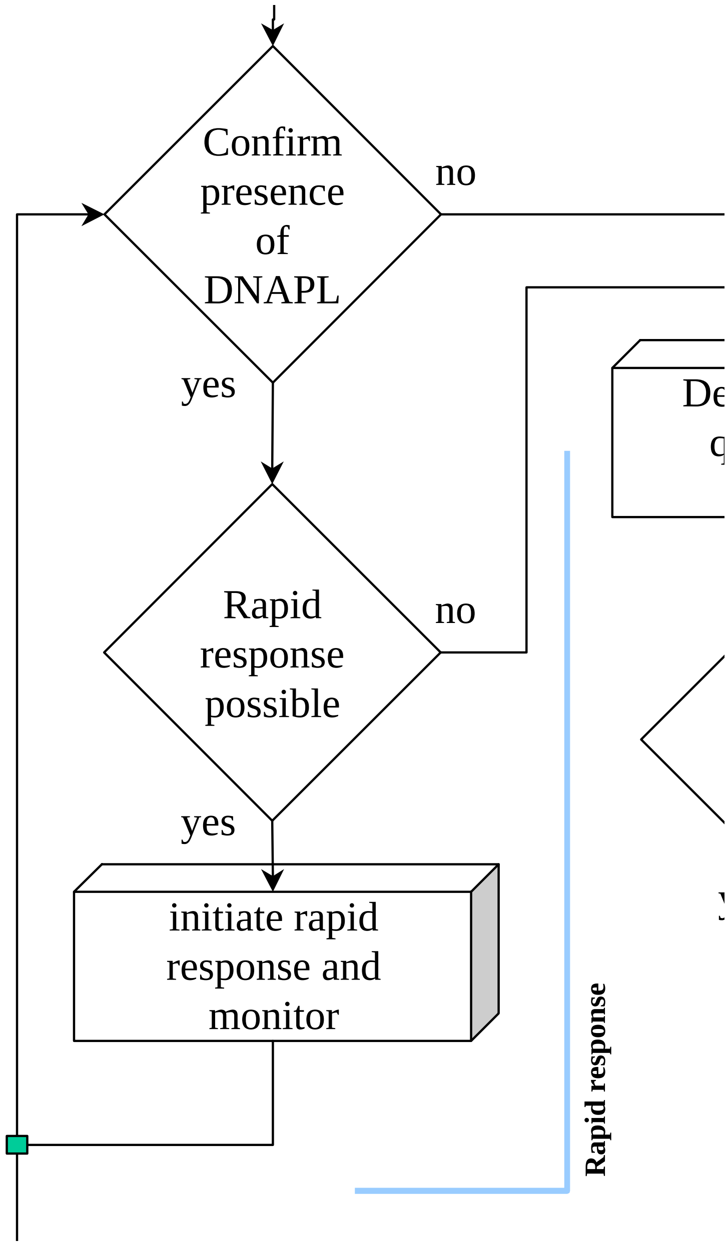


Figure 7.3. Rapid Response Module of the A/M-Area DNAPL Strategy

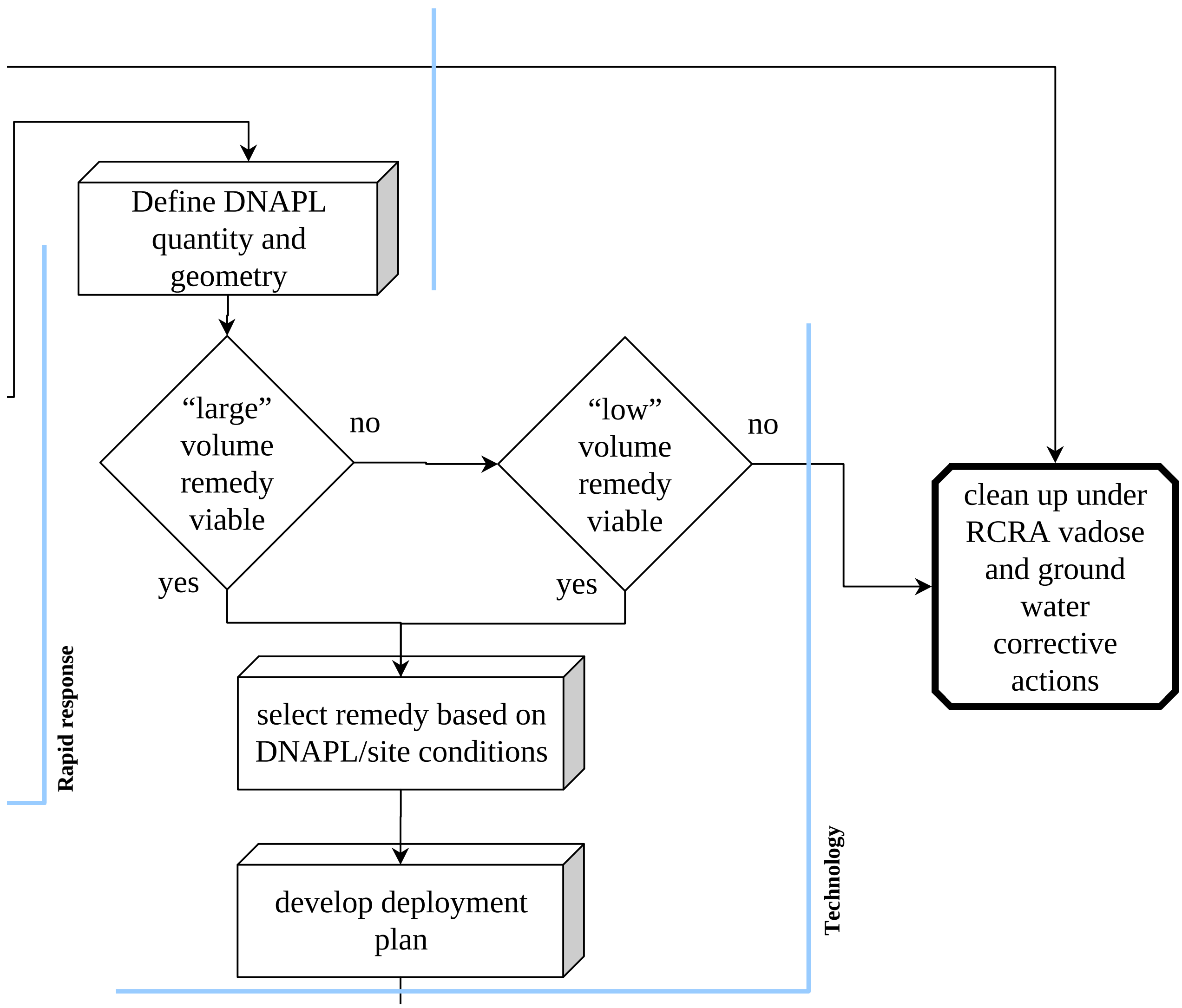


Figure 7.4. Technology Module of the A/M-Area DNAPL Strategy

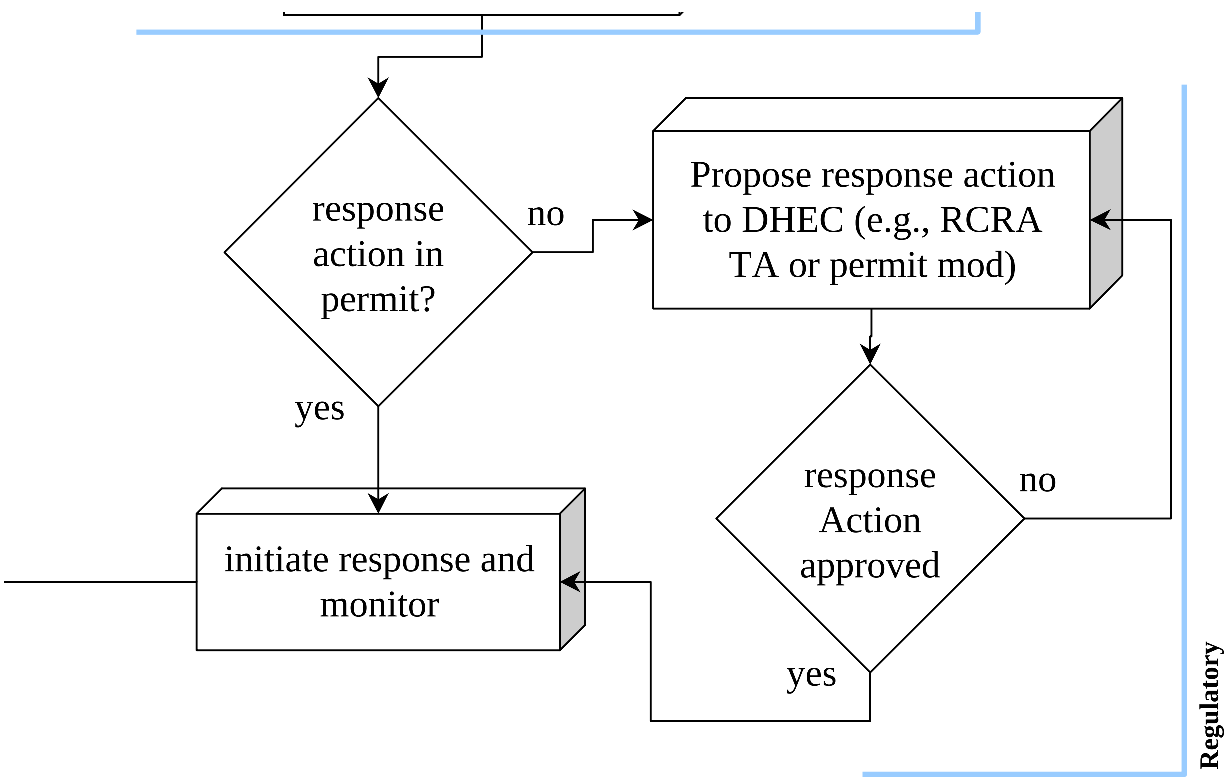


Figure 7.5. Regulatory Module of the A/M-Area DNAPL Strategy

TABLE 7.1. Detail of the Activities and Techniques Used to Support the A/M-Area DNAPL Program	
Identify Possible / Suspect DNAPL Areas (Identification based on at least one of the following)	
Historical Information and Process Records (see Looney et al., 1992; Jackson et al., 1996; Jarosch et al., 1997; Marine and Bledsoe, 1984, and others)	- Recorded discharge of DNAPL solvents to the environment. - Recorded leakage of DNAPL solvents to the environment - Documented DNAPL solvent storage area or DNAPL solvent usage facility - Other potential DNAPL release areas that can be inferred from process records or interviews.
DNAPL indicators in Groundwater Monitoring Database (see Looney et al., 1992; Jackson et al., 1996)	- Groundwater concentrations > 1% or 10% of solubility from traditional monitoring wells (wells with 5' screen interval or longer). Two different screening levels are used to help prioritize follow up confirmation activities. - Monitoring well concentrations that exhibit high variability between sampling intervals or that change rapidly in concentration
Miscellaneous indicators (see Looney et al., 1992; Cohen et al, 1993, and others)	- Caliper logs in existing monitoring wells (deformation of PVC casing may indicate the influence of DNAPL) - Unexpected intervals of high readings in natural gamma geophysical logs (due to partitioning of radon into NAPL from both water and air phases) - Unexpected intervals if low or high readings in electrical geophysical logs (due to presence of either low conductivity NAPL or high conductivity co-disposed aqueous wastes)
DNAPL Confirmation Activities	
Direct DNAPL Observation (see Cohen et al, 1993; Rossabi et al., 2000; Looney et al., 1992; and others)	- Identification of DNAPL in the sumps of groundwater monitoring wells using clear bottom filling bailer or similar method (useful for wells installed with intake screens and sumps near potential DNAPL controlling aquitards) - Drainage of separate NAPL phase from collected core. - In situ visualization of DNAPL using remote video system such as the GeoVis. - If DNAPL is collected, it's composition is analyzed for DNAPL constituents and co-contaminants (inorganics and trace organics such as polychlorinated biphenyls) to assist in technology decisions

TABLE 7.1. Detail of the Activities and Techniques Used to Support the A/M-Area DNAPL Program (continued)	
Indirect DNAPL Detection (see Rossabi et al., 2000; Cohen et al, 1993; and others)	Ribbon NAPL sampler (hydrophobic fabric that wicks NAPL from the formation and indicates location with oil soluble dye marking) DNAPL spectra on Raman spectrometer (normally deployed using fiber optics in a cone penetrometer (CPT) tip) NAPL and/or codisposed hydrocarbon spectra on laser induced fluorescence spectrometer (normally deployed using fiber optics in a CPT tip) Solubilization of oil soluble dye in collected liquid sample
Depth discrete sampling (see Cohen et al, 1993; Looney et al., 1992; Rossabi et al., 2000, and others)	- Collect and analyze depth discrete (point) water samples using CPT or during standard drilling. In A/M-Area, samples are collected using several commercially available samplers (e.g., hydropunch, conesipper, BAT sampler, and others) and analyzed by standard methods. - Collect and analyze depth discrete (point) soil samples using CPT or during standard drilling. In A/M-Area, samples are collected using available split spoon or wireline core devices, immediately sealed and preserved in the field, and analyzed by standard methods. - Collect and analyze depth discrete (point) soil gas samples using CPT or during standard drilling. In A/M-Area, samples are collected using a cone sipper or similar gas permeable access device and by photoacoustic infrared spectrometry confirmed by gas chromatography. - Obtain depth discrete water/soil gas concentrations using investigational methods such as membrane interface probe (concentration in gas or water is related to diffusion through membrane and concentration inside probe system), colorometric or optical concentration sensor (e.g., sensor based on fujiwara reaction where TCE causes color change in pyridine based reagent), and others.
Geophysical and geotechnical confirmation activities (see Looney et al., 1992, and others)	- Define lithological and geological (structural) controls on DNAPL movement to optimize sampling strategy using CPT logs, ground penetrating radar (GPR), shallow seismic reflection profiles, etc. (routine activity) - Direct geophysical detection of DNAPL using amplitude and frequency variations and offsets in GPR and shallow seismic reflection profiling (investigational).
In-situ Solubilization Tests (see Jackson and Pickens., 1994; Jerome et al., 1996, and others)	- Inject and extract solution of cosolvent or surfactants and look for significantly elevated concentration in extracted fluid from dissolution of DNAPL. This technique has had limited success but may be useful in carefully selected scenarios.

TABLE 7.1. Detail of the Activities and Techniques Used to Support the A/M-Area DNAPL Program (continued)	
Define DNAPL Quantity and Geometry	
Depth discrete sampling (see Cohen et al, 1993; Looney et al., 1992; Rossabi et al., 2000, and others)	Utilize depth discrete methods described above and supplement confirmation data to improve understanding of the type, quantity, distribution and extent of residual DNAPL in DNAPL contaminated area.
Geological and Geostatistical Data Interpretation (see Marine and Bledsoe, 1984; Looney et al., 1992; Jackson et al., 1996; Parker et al., 1999, and others	Generate 2D (cross section and plan view) and 3D (e.g., Earthvision) descriptions of DNAPL source zone concentrations and mass.
Partitioning Tracer Tests - PITT (see Mariner et al., 1999)	Test injects multiple tracers in a well and extracts in a second well. Estimates the presence and quantity of DNAPL between the wells by examining the difference in behavior of the various tracers. This is a relatively expensive, but potentially useful, technique that has not been used to date in A/M-Area. PITT may have most utility in pre-test and post-test characterization of an active DNAPL cleanup.
Initiate Rapid Response and Monitor	
Optimize existing treatment systems to address residual DNAPL	Operate or modify existing remediation system, such as a vadose zone treatment SVE unit, to target or better address residual DNAPL. This action is contingent on appropriate regulatory concurrence, either through an existing permit or other authorization.
Perform Limited Pilot Testing of Innovative Treatment System.	Install and operate limited pilot test on well-defined DNAPL target. These actions are contingent on appropriate regulatory concurrence, either through an existing permit or other authorization. These tests are intended to facilitate understanding of performance and design and to treat an isolated or well-defined portion of the DNAPL associated with one of the A/M-Area source zones. Examples of pilot tests to date include In Situ Oxidation Using Fenton's Reagent, Six-Phase Heating, and Radio Frequency Heating.

TABLE 7.1. Detail of the Activities and Techniques Used to Support the A/M-Area DNAPL Program (continued)
Select Remedy Based on DNAPL / Site Conditions
This step considers the quantity and nature of the DNAPL target (concentrated pool versus diffuse ganglia) and the target geometry (thin laterally extensive layer versus vertically extensive laterally defined source. An example of the latter case is the 321-M Solvent Storage Tank where steam flushing of the vadose zone and shallow groundwater was selected. Existing clean up methods to be considered are classified into three groups to facilitate consideration: - Enhanced Removal (examples include Dual Media Extraction, Surfactant Flushing, Cosolvent Flushing, Six Phase Heating, and Steam Flushing). - In Situ Destruction: In Situ Bioremediation (normally anaerobic for PCE containing DNAPL), In Situ Oxidation (Fenton's), and In Situ Oxidation (Permanganate). - Source Zone Isolation Methods: Capping may be useful as a temporary action that provides some benefit prior to identification and implementation of DNAPL specific remediation. In general, however, this is not normally recommended as a sole response since isolation is difficult and has not been successfully performed even under well-controlled experimental conditions. Classifying the technologies by their primary mode of action encourages consideration of a large number of options and provides a structure to rapidly compare and contrast the options in a rapidly developing and competitive commercial market. The various commercial exemplars are constantly being evaluated and improved.
Develop Deployment Plan
This step consists of defining and describing the planned action, including: design basis, proposed operational protocol, monitoring plan, contingencies, potential technical problems/issues and actions taken to monitor or mitigate them, and regulatory plan.
Propose Response Action to DHEC
Propose the response action to DHEC. If action is deemed appropriate, develop an appropriate strategy to permit and implement the activity. This might entail a RCRA permit modification, a Temporary Authorization, or another appropriate type of regulatory approval. For DNAPL clean-up methods, other types of regulatory approval (notably underground injection control permits are often needed to approve addition of the reagents necessary to enhance removal of or destroy DNAPL)
Initiate Response and Monitor
Perform clean-up action (operate and monitor) and report to the regulators as agreed in the regulatory approval process.

TABLE 7.2. Detail of the Decisions and Logic within the A/M-Area DNAPL Flowchart
Confirm Presence of DNAPL
Yes = collection and/or observation of separate phase liquid, or concentrations in water sample >= solubility, or concentration in soil gas sample >= vapor pressure, or concentration in bulk soil sample >= calculated DNAPL level (based on porosity, expected water content, etc.), or staining on ribbon NAPL sampler, or solubilization of oil soluble dye in liquid sample, or Raman (or similar) spectrometer confirmation of DNAPL, or direct *in-situ* visualization of DNAPL (using video visualization system such as GeoVis), or DNAPL solubilization during cosolvent/surfactant injection-extraction testing, or observation of other NAPL specific diagnostic phenomena (e.g., differential tracer partitioning).
No = very low concentrations (e.g., less than 1 ppmv soil gas concentrations for TCE and PCE) in depth discrete samples or negative findings from at least two methods listed above. Methods to be selected to provide maximum DNAPL sensitivity under site specific conditions.
Rapid Response Possible
Yes = Existing permitted remedy is in place that can be modified to provide improved DNAPL targeted performance (e.g., SVE system), or innovative/pilot scale DNAPL treatment possible that is within scope of RCRA permit or that can be implemented in a straightforward manner using an expedited Temporary Authorization (TA).
No = No existing or rapidly implementable treatment available for identified DNAPL
Large Volume Remedy Viable
Yes = 1) Target DNAPL zone is sufficiently defined to allow safe-robust design and engineering of treatment (i.e., to avoid inadvertent spread of contamination or other adverse collateral environmental damage), and 2) target zone contains, or is believed to contain, sufficient DNAPL to justify aggressive treatment action. See Jerome (*et al*., 1997) who documents that several hundred pounds of target DNAPL are needed to justify large volume remedies under A/M-Area conditions. Aggressive treatments use large amounts of energy and/or strong chemical reagents that should be used only if sufficient source material is present.
No = Poorly defined target zone and/or insufficient DNAPL mass (< 100's of pounds) to justify aggressive remediation technology.
Low Volume Remedy Viable
Yes = 1) Target DNAPL zone contains lower quantities than listed above, and 2) DNAPL is accessible and amenable to available less aggressive (lower energy, less corrosive chemistry, etc.) methods such as periodic pumping or bailing of accumulated separate phase material.
No = "Small" quantities of diffuse or inaccessible DNAPL that are not amenable to available recovery/removal options.

TABLE 7.2. Detail of the Decisions and Logic within the A/M-Area DNAPL Flowchart (continued)
Response Action in Permit
Yes = Proposed Response Action is listed in RCRA Part B Permit or approved modification or existing RCRA Temporary Authorization. Note that additional permit approvals are often required for DNAPL treatment (notably underground injection control permits or air permits) that must be obtained prior to initiating activities.
No = self explanatory
Response Action Approved
Yes = Approval of proposed activity as a modification to the RCRA Permit, a Temporary Authorization, or by any other valid direction from SCDHEC.
No = self explanatory

7.2 DNAPL Strategies for Individual Source Terms

The three largest DNAPL sources in the A/M-Area are the A-014 Outfall, the M-Area Settling Basin and the 321-M Solvent Storage Tank. A former confirmed source that is approaching clean-up levels is the process sewer leading to the M-Area Settling Basin. Additional potential sources are the process facilities, buildings 313-M, 320-M, 321-M and 305-A, their associated storage facilities, the M-Area process sewer leading to the A-014 outfall, releases in SRTC, maintenance areas and related A/M-Area facilities. All of these areas can be classified into one of three categories: Storage Areas, Use Areas and Disposal Areas. One of the three primary sources is included in Storage Areas. This is the 321-M Solvent Storage Tank, where solvent was received from railroad cars and stored until needed by the processing facilities within M-Area and other locations on SRS. Other storage areas include the rail storage east of building 313-M, the drum loading area south of 313-M, and building 713-A. The Use Areas consist of the majority of the potential sources. These are buildings 305-A, 313-M, 320-M and 321-M, maintenance areas, potential release sites in SRTC and the 700 Area. The Disposal Areas contain two of the three primary sources, the M-Area Settling Basin and the A-014 Outfall, as well as the M-Area process sewer, the M-Area Settling Basin process sewer and the swampy area where building 321-M now stands. In the sections below we summarize key information and work through the flowchart for each of these facilities.

7.2.1 STORAGE AREAS

The storage areas consist of 321-M Solvent Storage Tank, rail storage east of building 313-M, drum loading south of 313-M, and building 713-A which was the Central Stores Facility.

7.2.1.1 321-M Solvent Storage Tank

This is a known source of DNAPL. Identification activities involved researching SRS records to determine use, duration and records of spills. The solvent storage tank is located west of the 321-M facility and began operation in 1957. This facility consisted of a 17,000 gallon storage tank with associated piping and equipment necessary to off-load solvent from rail-cars to the storage tank and to distribute solvent to the other process facilities in the M-Area and across the SRS. This facility served as the primary point for the storage and distribution of solvent in the M-Area except for the period between 1962 and 1970, during which PCE was introduced into the 313-M process and would have required local storage. According to Marine and Bledsoe (1984), numerous undocumented spills and leaks occurred in the vicinity of the solvent storage tank from off-loading the railroad cars. At the 321-M Solvent Storage Tank one spill of significance is reported to have occurred in October 1975. A cracked ceramic seal on a transfer pump resulted in an estimated 1,200 gallons of PCE being released to the environment. The incident report states that there was no evidence of PCE puddling on the ground.

This information provided sufficient evidence to conduct DNAPL confirmation activities. The initial characterization data are available from chemical analysis of soil plugs collected and analyzed in 1984 during the installation of monitoring well clusters MSB-

23, -26, -27 and –28 (Marine and Bledsoe, 1984). Total solvent concentrations in soil samples collected at MSB-23 were elevated, with concentrations exceeding 6,000 ppb at an elevation of 300.4 ft msl (70 ft bgs) and reaching 28,000 ppb at an elevation of 260.4 ft msl (110 ft bgs) immediately above the water table. Additional characterization of this area was performed by CH2M Hill (CH2M Hill, 1990). A total of 28 shallow soil gas samples were taken around the tanks and railroad tracks. TCE was detected in approximately 67% of the samples, with concentrations ranging from 0.11 to 4,200 parts per billion in vapor (ppbv). PCE was detected in all of the samples, with concentrations ranging from 0.12 to 570,000 ppbv. TCA was detected in all but one of the samples, with concentrations ranging from 0.90 to 3,000 ppbv. Four soil borings (SRM-101-B through SRM-104-B) were drilled in the immediate vicinity of the solvent storage area. Significant concentrations of TCE and PCE were detected in soil samples collected from numerous intervals within each of the four borings. The overall highest concentrations of solvents were detected in soil samples collected from 356.7 ft msl to 335.7 ft msl (14 to 35 ft bgs) at boring SRM-101-B. PCE was detected in this interval at concentrations as high as 3,000 parts per million (ppm). Significant concentrations ranged in elevation from 365 ft msl (5 ft bgs) to the top of the water table (approximately 235 ft msl [135 ft bgs]) at each boring. As a result of this data an active soil vapor extraction (SVE) system was installed and began operation in 1995. The SVE system represents a rapid response for DNAPL in the vadose zone and has removed 28,238 pounds of solvent during its operation.

Characterization investigations from 1992 through 1997 were conducted to evaluate the lateral extent of (primary emphasis) and change in vertical contaminant distribution (secondary emphasis) (Jarosch et al, 1998). The results of the soil gas and soil plug samples indicated very high soil concentrations (>1000 ppmw) at shallow depths (< 50 ft bgs) and consisting primarily of PCE. This shallow contamination is confined to the immediate vicinity of the tanks on the eastern and southern sides of the pad. The shallow concentrations showed very little change since the CH2M Hill report of 1990. Concentrations less than 10 ppmw were observed down to the water table where TCE predominates. Coring in 1999 indicated that DNAPL concentrations are still present in pockets within the shallow vadose zone. The zone selected for a source zone remediation was determined to be 100 feet by 100 feet by 160 feet deep. This area encompasses the area of the solvent storage tank and associated pad and transfer facilities located to the south east of the pad. The depth includes the vadose zone and the water table down to the Green Clay, considered the first confining zone in that immediate area. The action chosen for this location is steam flushing combined with hydrous pyrolysis, also known as Dynamic Underground Stripping. This DNAPL treatment will supplement the ongoing SVE and groundwater pump and treat system. The DUS treatment plan has been submitted to SCDHEC and approval has been granted. Deployment of this technology began in April 2000. The active steaming is scheduled to be complete in May 2001.

The activities described above represent a relatively complete implementation of the A/M-Area DNAPL Strategy as shown in Figure 7.6. The flowchart depicts the SVE implementation as a rapid response and the subsequent additional characterization and implementation of DUS.

Source Specific DNAPL Flowchart - 321M Solvent Storage Tank

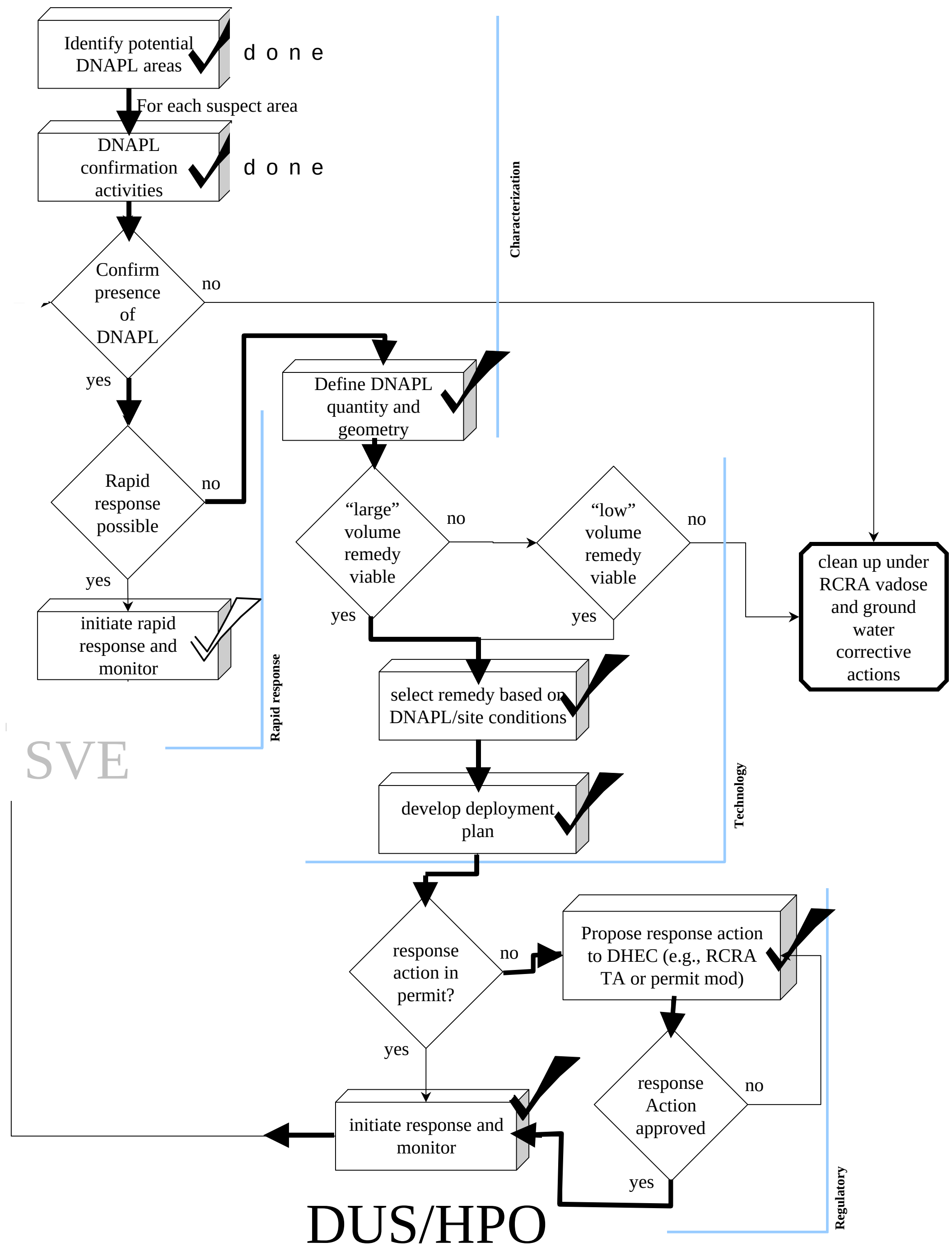


Figure 7.6. A/M-Area DNAPL Strategy applied to the 321-M Solvent Storage Tank Area

7.2.1.2 Rail Storage East of Building 313-M

Historical information indicates the TCE was shipped to the 313-M facility in rail tank cars. These tank cars were used for a storage facility while located on the railroad siding, which is located east of the building. The TCE was pumped from the tank cars into the pipeline to 313-M. Spills are likely to have occurred during tank car unloading operations, but none are documented (Marine and Bledsoe, 1984). Due to the uncertainty of the presence or absence of DNAPL, the next step is to perform DNAPL confirmation activities at this location. This activity can be conducted in conjunction with the DNAPL confirmation sampling of Building 313-M. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar storage areas discussed herein) is shown in Figure 7.7.

7.2.1.3 Drum Loading South of Building 313-M

As M-Area was the primary user of chlorinated solvents at SRS, many of the shipments came to this area. To accommodate shipping of these solvents to other use areas at SRS, a drum loading facility was established at the south end of building of 313-M. As with the rail storage area described above, there is no documented evidence of spills (Marine and Bledsoe, 1984). Due to the uncertainty of the presence or absence of DNAPL, the next step is to perform DNAPL confirmation activities at this location. This activity can be conducted in conjunction with the DNAPL confirmation sampling of Building 313-M. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar storage areas discussed herein) is shown in Figure 7.7.

7.2.1.4 Central Storage Facility, 713-A

This facility dispensed small quantities of chlorinated solvents to buildings 773-A and 717-A from the mid-1960’s through May 1978. The transition from TCE to PCE came in August 1977. The solvents were stored in 55-gallon drums from which it was pumped into smaller containers for distribution. This storage facility was in a small building at the north end of building 713-A, where paint was also stored (Marine and Bledsoe, 1984). There is no documented evidence of spills at this location. Due to the uncertainty of the presence or absence of DNAPL, the next step is to perform DNAPL confirmation activities at this location. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar storage areas discussed herein) is shown in Figure 7.7.

Source Specific DNAPL Flowchart -

Rail Storage East of Building 313-M, Drum Loading South of Building 313-M, 713-A Central Storage Facility

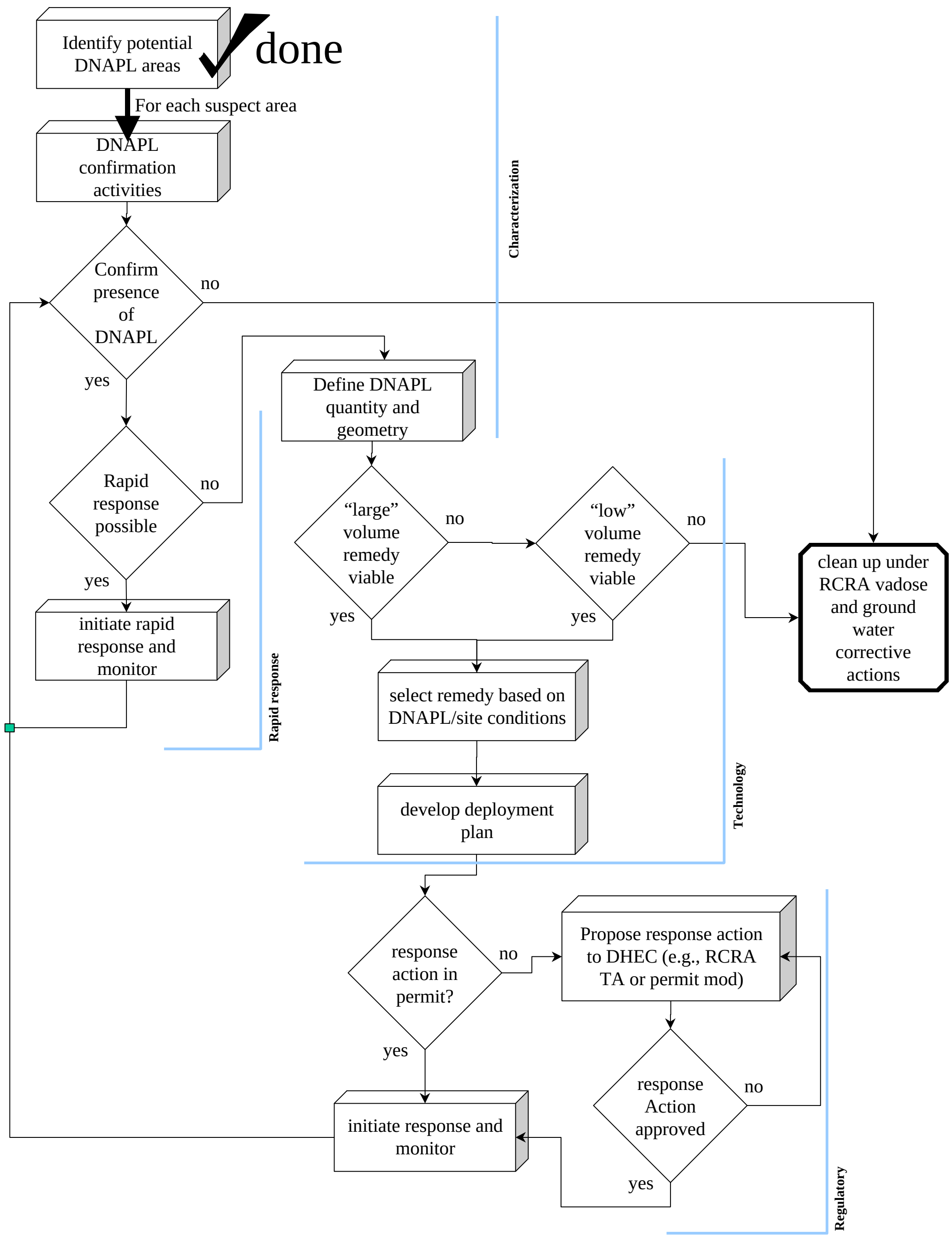


Figure 7.7. A/M-Area DNAPL Strategy applied to the several smaller storage areas

7.2.2 USE AREAS

The Use Areas comprise the largest number of the potential DNAPL sources, but they represent a relatively small release quantity (compared to the large disposal areas – the M-Area Settling Basin and the A-014 Outfall). The Use Areas are buildings 305-A, 313-M, 320-M and 321-M, 773-A, 717-A, 703-A and 777-10A. These buildings are located within SRTC, M- Area, Upper 700 and Lower 700 Areas.

7.2.2.1 313-M (Slug Manufacturing Facility), 320-M (Target Manufacturing Facility) and 321-M (Fuel Manufacturing Facility)

Degreasing facilities were located in each of these three buildings. An estimated quantity of 13 millions pounds of chlorinated degreasing solvents were used in these three buildings between 1952 and 1982. The degreasing solvent use changed from TCE to PCE to 1,1,1-TCA through this period, with the changeover occurring at different times in different facilities. The spent solvents were either drained into the process sewers, or pumped into drums and then distilled for reuse. In the 1970s, still bottoms, degreaser sludges, and some solvent were collected in drums and stored on concrete pads awaiting distillation recovery. Based on review of the design drawings for these buildings, the primary locations of interest are the degreasing rooms and the sumps where solvent may have accumulated. DNAPL confirmation activities are planned for the end of FY00 and through FY02 for these three facilities.

7.2.2.2 Building 305-M

During 2000, review of historical documentation (Plumlee, *et al*., 1953) led to the identification of building 305-M as a potential source of DNAPL. The next step will be to initiate DNAPL confirmation activities. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar use areas discussed herein) is shown in Figure 7.8.

7.2.2.3 Building 773-A (SRTC)

Building 773-A has been identified as a potential release site for DNAPL. Historical documentation (Marine and Bledsoe, 1984) indicates building 773-A is a potential source of DNAPL. As with building 305-A, the next step is to initiate DNAPL confirmation activities. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar use areas discussed herein) is shown in Figure 7.8.

7.2.2.4 Lower 700 Area

Historical information led to the identification of building 777-10A as a potential release site for DNAPL. Conversations with former employees who worked in this building indicate that chlorinated solvents were used to wipe down the walls of some rooms. The next step is to initiate DNAPL confirmation activities. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area (and the similar use areas discussed herein) is shown in Figure 7.8.

7.2.2.5 Upper 700 Area

During 1999, review of historical documentation led to the identification of the former print shop facilities in building 703-A as a potential release site for DNAPL. Shallow soil gas sampling was completed using the CPT truck in 1999. The results did not indicate the presence of DNAPL. A site specific version of the A/M-Area DNAPL Strategy for this suspect DNAPL Area is shown in Figure 7.9.

Source Specific DNAPL Flowchart -
Buildings 313-M , 320-M, 321-M, 305-A, 773-A
and the Lower 700 Area

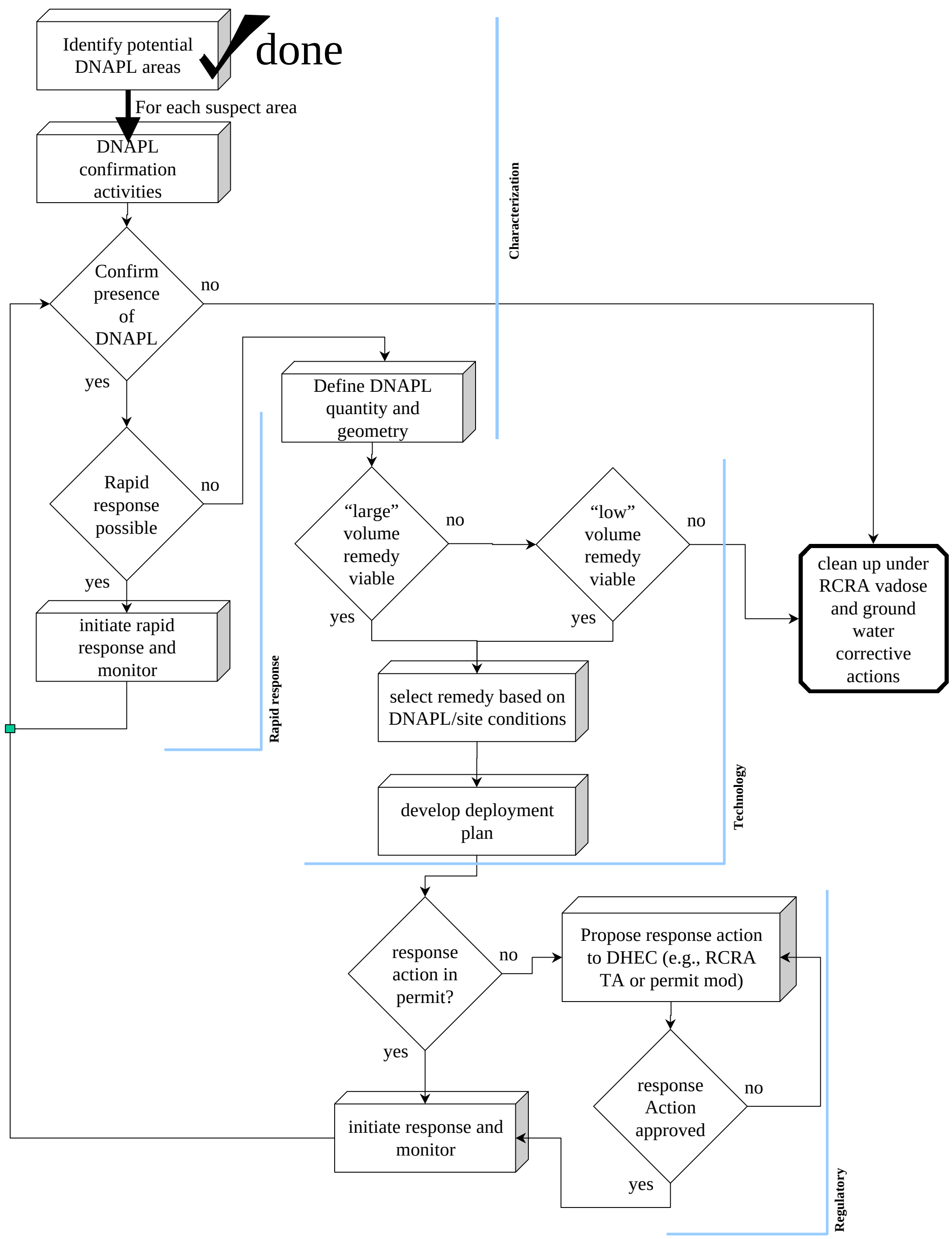


Figure 7.8. A/M-Area DNAPL Strategy applied to the DNAPL use areas (excluding Upper 700 Area)

Source Specific DNAPL Flowchart -
Upper 700 Area

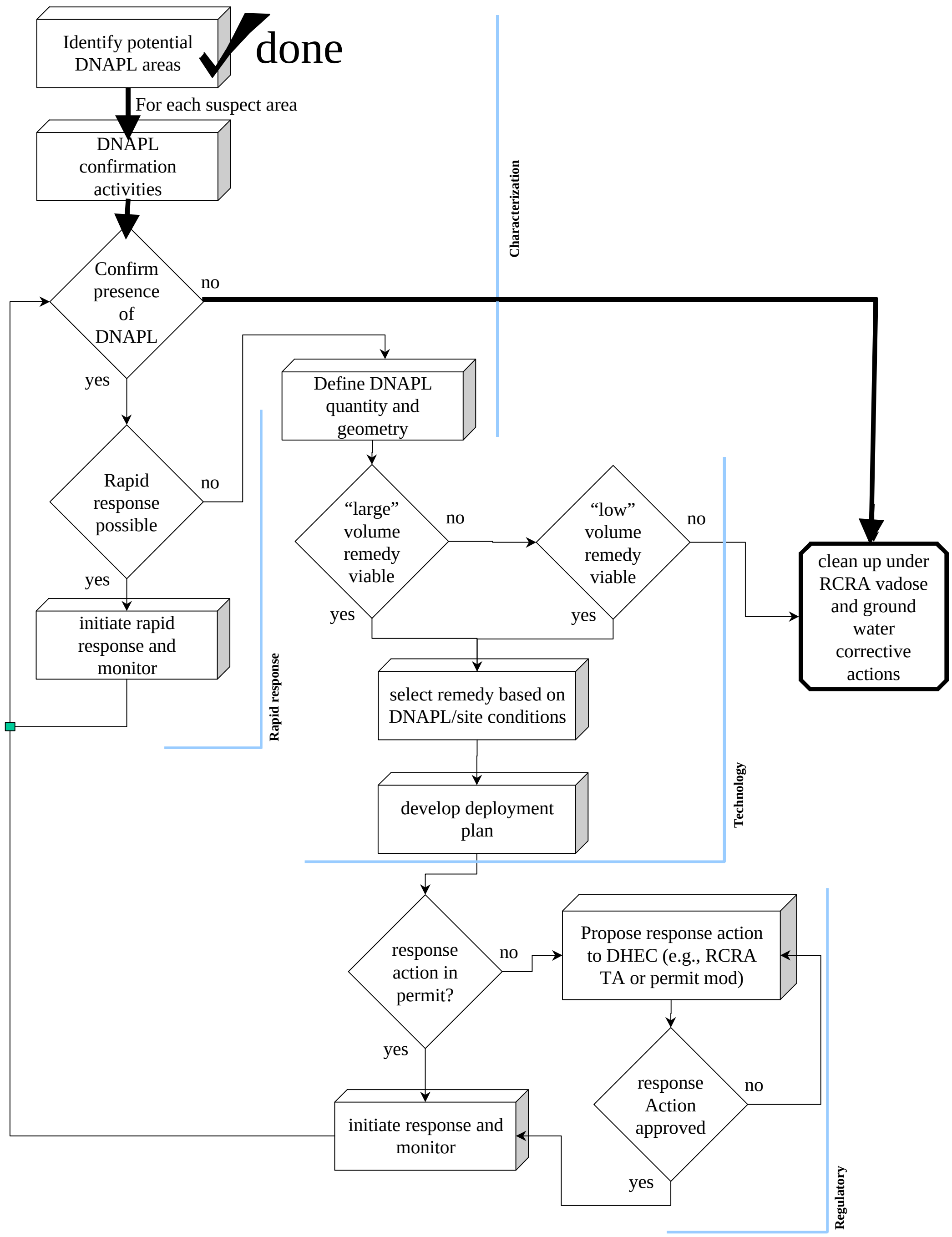


Figure 7.9. A/M-Area DNAPL Strategy applied to the Upper 700 DNAPL use area

7.2.3 SOLVENT DISPOSAL AREAS

The Solvent Disposal Areas were the primary sources of DNAPL to the environment in A/M-Area. These areas consist of the M-Area Settling Basin, M-Area Settling Basin process sewer, A-014 outfall, M-Area process sewer (leads to A-014 outfall), and the swampy area on which building 321-M now sits. Waste effluents from the Use Areas were discharged to the Disposal Areas process sewers beginning in 1952. The M-Area settling basin was built and began receiving waste in 1958.

7.2.3.1 M-Area Settling Basin Process Sewer

M-Area process wastewaters were discharged from buildings 313-M, 320-M and 321-M to the M-Area Settling Basin from 1958 to 1985 via a 30-inch diameter terra cotta underground sewer line. It is estimated that 2 million pounds of chlorinated solvents may have been released to the M-Area Settling Basin through this sewer line. A television survey made in 1982 of the process sewer line to the M-Area Settling Basin showed cracks in the terra cotta pipe. In places fine plant roots penetrated into the sewer (Marine and Bledsoe, 1984). This pipe was relined with a 12-inch PVC liner in December 1983 (Pickett, 1985). Characterization of the process sewer line was conducted from November 1984 through March 1985 consisting of soil gas and soil samples. The locations with the highest soil gas numbers were the basis for selecting the sites for collecting the soil samples. Soil samples were collected to a depth of 8 feet below the bottom of the process sewer line (approximately 356 ft msl). Three locations were selected with one location at the manhole closest to the basin. Four soil cores were collected at each location, with two additional cores collected at one location. These two additional cores were slanted underneath each side of the sewer line to enable collection of samples directly under the line. The results indicated levels as high as 765 ug/g (ppmw) PCE directly below the sewer line at a depth of 3 feet (approximately 361 ft msl). The data indicated no significant lateral spread of the contamination (Pickett, 1985). The early data and later characterization work (cone penetrometer work conducted in 1992 and the like) suggested that a significant fraction the original released DNAPL solvents remained trapped in the vadose zone along the sewer line (Looney, 1992).

Based on the available data, we performed a variety of DNAPL related actions. Several pilot and research studies, as well as full scale soil vapor extraction were implemented in the high concentration areas – all serving as rapid responses that address residual source DNAPL in these areas.

A soil vapor extraction pilot test conducted along a portion of the sewer line by Terra Vac and SRS in 1987 confirmed the vadose zone in the vicinity of the sewer was contaminated with large quantities of residual solvent, verified the viability of SVE, and provided design data for subsequent full scale implementation. The SVE pilot system was operated for 21 days to provide sufficient data to meet these objectives. Over 1500 pounds of chlorinated solvent were removed during the test. In 1989 as part of the M-Area Settling Basin closure, this process sewer was excavated. In 1988, a pair of horizontal wells was installed – one above the water table and one below the water table. These wells were used as an SVE and sparge well, respectively, provided a system for combined remediation of the vadose zone and shallow groundwater. Further, these particular wells represented an early, and key, step in the use of horizontal drilling in environmental applications. The pilot study of the system, known as the In Situ Air Stripping Demonstration, was operated between July 27 and December 13, 1990. This test removed approximately 16,000 pounds of chlorinated solvent during the 3 month test (CH2M Hill, 1990).

Based on the data collected during the In Situ Air Stripping Demonstration (measured increases in microorganisms including TCE degraders) an In Situ Bioremediation pilot test was initiated. This test used natural gas (methane) and other nontoxic nutrients to stimulate organisms that have the capability to degrade moderate concentrations of residual solvent. An additional 17,000 pounds of solvent were removed from (or destroyed in) the subsurface during this 14 month test (Hazen et al., 1994).

We performed two additional pilot tests along this sewer line. The objective of these tests, both heating technologies, was to speed up the removal of residual solvent trapped in vadose zone clays. The two heating technologies employed were radio frequency (RF) heating and direct resistive (joule) heating. In the former, low frequency radio waves interact with the atoms of water and sediment to generate heat (Jarosch et al, 1994), while in the latter, the block of earth acts as the resistor (heating element) in the process (Gauglitz, et al).

In 1995, a full-scale RCRA vadose zone SVE treatment was initiated in the area of the process sewer line. This effort, utilizing the original horizontal wells, three new horizontal wells, and vertical extraction wells, providing contaminated vapors to two SVE units has provided significant additional removal of residual DNAPL solvent. The full scale operation has removed an additional 57,000 pounds of chlorinated solvents.

The total contaminant mass removal from the various pilot scale, research and full scale rapid response actions along the M Basin Process Sewer line is approximately 91,500 pounds (sum of above numbers). A site specific version of the A/M-Area DNAPL Strategy for this particular suspect DNAPL Area is shown in Figure 7.10. Work continues to characterize the nature and extent of residual source along the process sewer. Post-test characterization reports and vadose zone characterization data suggest that the rapid response actions have been successful in addressing residual source DNAPL. Nonetheless, as discussed in Section 8.0, additional characterization work on this source continues to support orderly close-out of this particular former DNAPL source.

Source Specific DNAPL Flowchart -

M Basin Sewer Line

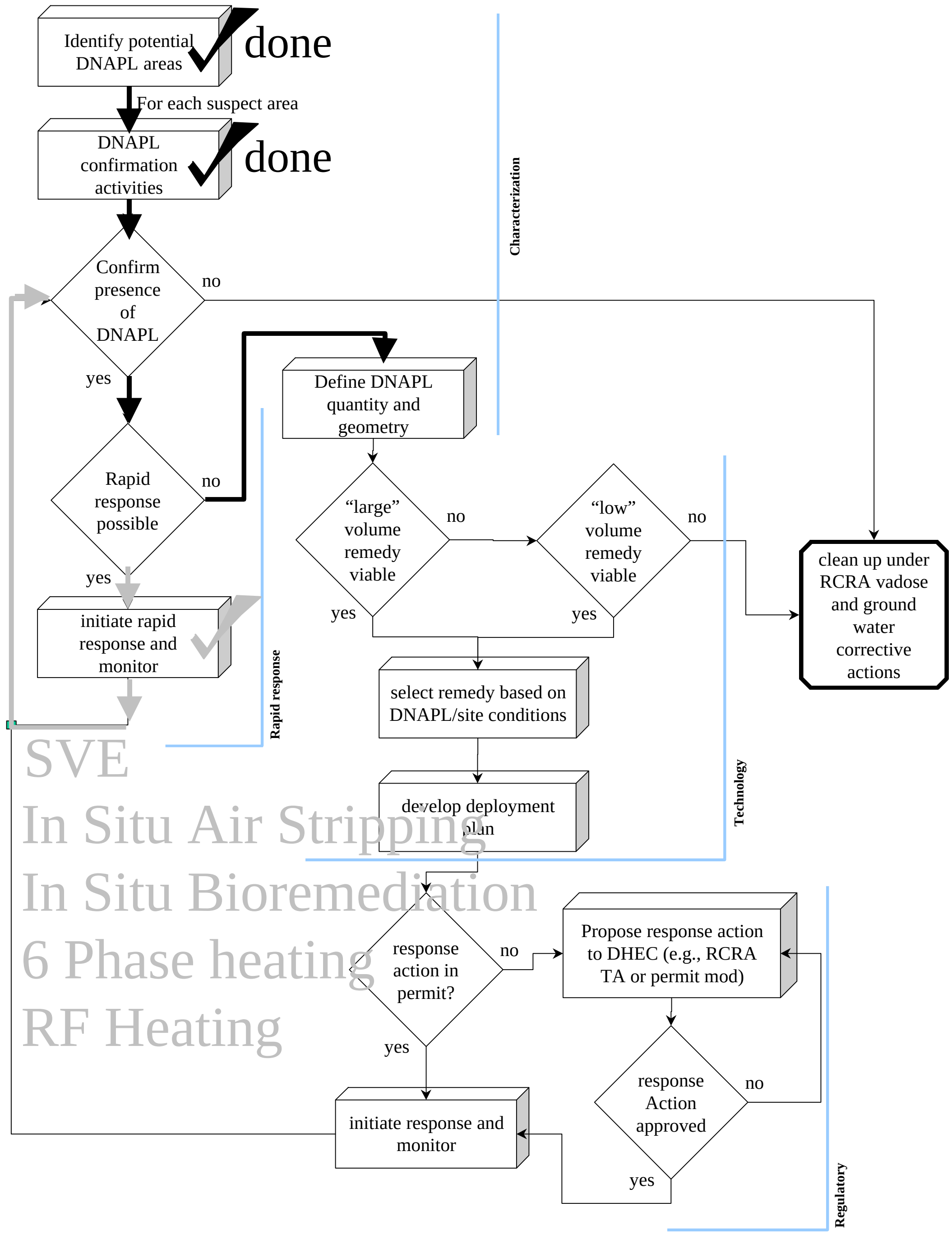


Figure 7.10. A/M-Area DNAPL Strategy applied to process sewer leading to the M-Area Basin

7.2.3.2 M-Area Settling Basin

M-Area process wastewaters were discharged from buildings 313-M, 320-M and 321-M to the M-Area Settling Basin from 1958 to 1985 via a 30-inch diameter terra cotta underground sewer line (discussed above). The receiving facility, the M-Area Settling Basin, was an eight million gallon capacity, unlined surface impoundment designed to settle and contain uranium and other dissolved metals discharged from fuels and target fabrication processes. The M-Area waste stream contained metals (nickel, aluminum, uranium, lead), acids, caustics, and solvents from the aluminum-forming and electroplating processes. Under the RCRA Hazardous Waste Listings promulgated in 1980, the waste stream was classified as F006-electroplating waste (Looney, 1992). It is estimated that 2 million pounds of chlorinated solvents may have been released to the M-Area Settling Basin through this sewer line (Marine and Bledsoe, 1984).

Initial characterization activities involved construction of exploratory wells. RCRA type wells were installed from November 1979 through February 1981 around several of the facilities associated with the M-Area groundwater plume as part of the interim status requirements under the RCRA Part A Permit. Clusters MSB-1 through MSB-4 were installed around the M-Area Settling Basin. On June 28, 1981 analytical results from initial well sampling confirmed the presence of degreaser solvents around the M-Area Settling Basin. Soil and fluid sample analyses showed organic concentrations as high as 500 mg/L. In March 1982, 5 core holes were drilled inside the perimeter of the M-Area Settling Basin. The core holes were drilled to a depth of 15 ft beneath the bottom of the basin from a floating barge. The core holes were drilled at the 4 corners of the basin and at the center. The concentration in the eastern part of the basin opposite the inflow was much higher than in the remainder of the basin. The concentrations indicate the presence of pure solvent at the inflow and in the eastern part of the basin opposite the inflow. PCE levels as high as 2,000 μg/g (ppmw) were found in the upper 3 feet of soil and ranged from 10 μg/g to 500 μg/g to depths of 15 feet (Gordon, 1982). In 1985, 4 additional soil borings were drilled inside the perimeter of the M-Area Settling Basin with 4 borings drilled adjacent to the basin in the basin berm. The borings inside the basin were drilled to a depth of 6 feet and those outside the perimeter were drilled to a depth of 21 feet. The highest PCE concentration measured was 24.1 μg/g in the 0 to 1.0 foot sample located in the eastern part of the basin opposite the inflow. The average PCE concentration in the upper 2 feet was 1 μg/g. Neither PCE, TCE, nor 1,1-TCA was detected above detection limits in any soil sample from 2 to 6 feet deep inside the basin perimeter. The analysis showed no evidence of chlorinated solvents in the berm material. Analysis for inorganic contaminants was also conducted on the liquid and sludge in the basin and shallow underlying soil. Results indicated the metal contaminants (Al, Ni, U, Pb, Na) had been held in the sludge and shallow basin sediments (Pickett, 1985).

Based on the results of the characterization activities a closure plan was prepared, submitted to SCDHEC in 1984 and approved by SCDHEC in 1987 to close the M-Area Settling Basin by placement of a RCRA cap (Looney, 1992). As part of the closure the basin was dewatered and the liquid treated and sent to a permitted outfall. This was followed by stabilization of the sludge, which contained the majority of the inorganic contaminants. The stabilized sludge and cement mixture was placed back in the basin and the low-permeability cap was then placed atop this material (Colven et al., 1985). In 1985 SRS submitted a RCRA Part B Permit Application to include M-Area HWMF post-closure maintenance, groundwater monitoring, and corrective-action systems. SCDHEC approved and issued the Part B permit in September 1987 with a periodic renewal required (Looney, 1992). Basin closure activities began in 1988 with completion in 1990.

In early 1990, 40 soil gas samples were collected along the fence perimeter of the closed M -Area Settling Basin. TCE was detected in one-fourth of the samples, with concentrations ranging from 0.02 to 3.8 ppbv. PCE was detected in all of the samples, with concentrations ranging from 0.03 to 2,700 ppbv. TCA was detected in every sample, with concentrations ranging from 0.07 to 75 ppbv. Based on the soil gas results, four locations were proposed for soil sampling using hollow-stem auger drilling. Of the four locations proposed, three locations were drilled with two of these completed as monitoring wells. These borings were located adjacent to the basin inlet, at the corner adjacent to the overflow ditch, and at the western corner of the basin. Two sample points measured TCE above 50 ppb. These were at the location adjacent to the basin inlet at sampling intervals of 45 to 50 feet below ground surface (bgs) and 95 to 110 feet bgs. The concentrations were 75 ppb at 45 ft, 68 ppb at 50 feet, 103 ppb at 95 ft, 112 ppb at 105 ft and 81 ppb at 110 ft (CH2M Hill, 1990).

Monitoring well MSB-3D, located adjacent to the northwest side of the closed basin, was installed in September 1990. This well is screened from 230.7 ft msl to 211.2 ft msl (128 to 147.5 ft bgs). During the first sampling in January 1991 a strong solvent odor was detected and a small amount of separate phase residue was observed in the bottom of a filtering apparatus. This well was resampled in February1991 to obtain a separate phase liquid sample. The analytical results from that sampling indicated TCE and PCE concentrations of 160 and 560 mg/L, respectively for the groundwater sample. Analysis of the separate phase indicated the presence of an organic liquid comprised almost exclusively of high concentration of PCE and TCE. In May 1991, 12 additional wells, within the vicinity of the M-Area Settling Basin, were sampled as had been done with well MSB-3D to obtain separate phase material, if present. No separate phase material was observed in any of these 12 wells. In September 1991 well MSB 3D was sampled again and 1.8 L of DNAPL were recovered. In December 1991 and February 1992 15 wells, identified as potential or known DNAPL wells, were sampled. A visible-dense phase was collected only in wells MSB-22 and MSB-3D (Looney, 1992).

In 1992 cone penetrometer studies were conducted that strengthened early work suggesting that a structural feature on the surface of the “green clay” -- in the form of a trough -- may serve as a pathway for DNAPL transport to the west and the north of the M-Area Settling Basin passing through the area near well MSB-76 (Looney, 1992). Additional characterization and data analysis, primarily aimed at “defining DNAPL quantity and geometry”, were performed during the following years and summarized in Jackson et al., 1996. These efforts identified the presence of isolated DNAPL targets below the water table to the north and west of the basin. One of these was selected for a pilot study of in situ oxidation using Fenton’s Reagent (Jerome et al., 1997).

In January 1997, pre-demonstration characterization activities were initiated for the purpose of final site selection then pretest characterization for a small-scale demonstration of an in situ oxidation technology for destruction of DNAPL. Two borings were drilled, one north of the inlet to the basin and one along a suspected DNAPL flow pathway west of the basin. The highest concentration in the boring north of the basin inlet was 4.48 ug/g PCE at an elevation of 258.6 ft msl (90 ft bgs). The boring along the suspected DNAPL flow pathway west of the basin indicated higher levels of PCE and TCE than the boring north of the basin inlet. Additional characterization along this suspected flow pathway identified concentrations indicative of pure solvent (PCE) at elevations ranging from 216 ft msl to 211 ft msl (138 to 143 ft bgs). Upon completion of the technology demonstration, post-demonstration characterization showed a marked decrease in PCE and TCE concentrations in the treatment zone. The oxidation of DNAPL by Fenton's Reagent was estimated to have destroyed 600 lbs of solvent. Continued monitoring of the wells installed for the demonstration showed a rebound of TCE and PCE in the aqueous phase. Subsequent soil plug sampling has confirmed that separate phase DNAPL solvents are not present and have not re-entered the test site. This suggests a continuing upgradient DNAPL contaminant source reintroducing contaminated water across the test zone (Jerome, 1997). The upgradient source is the vadose zone and shallow groundwater immediately beneath and downgradient of the former M-Area Settling Basin. These were highlighted as the focus of recent characterization efforts to support implementation of an appropriate DNAPL treatment technology.

Other miscellaneous studies that were performed during this time period included an alcohol injection extraction characterization test in existing wells to determine the presence or absence of DNAPL in the immediate vicinity of the well (Jerome et al., 1996) and a small scale study of a hydrophobic lance (Tuck et al., 1998). The lance concept used teflon (a hydrophobic surface) to slowly collect solvent from zones that have a continuous phase, but low quantities, of residual DNAPL. These two tests were equivocal and both technologies require additional development for any potential application.

From 1997 through 2000 characterization activities have continued around the M-Area Settling Basin to delineate the vertical and horizontal extent of contamination from this source. Soil borings were drilled adjacent to the basin and beneath the basin. Most borings were drilled to the top of the Green Clay to elevations of approximately 195 ft msl (160 ft bgs) with one boring drilled to the top of the Crouch Branch Confining Unit at an elevation of 128 ft msl (227 ft bgs). All borings beneath the basin were drilled to the top of the Green Clay. The borings beneath the basin were drilled at an angle to allow access below the basin without the need to compromise the existing RCRA cap. The data suggest contaminants are migrating from the basin toward the west and also to the southwest along structural "depressions" on the surfaces of low permeability intervals. The concentrations in the soil plug samples indicate the highest DNAPL source concentrations are present immediately below and adjacent to the source and do not indicate that a large volume of DNAPL is present at locations further from the source. The highest concentrations were detected in the angle boring drilled beneath the inlet for the basin within the lower vadose zone. In the water table below the basin, TCE and PCE concentrations indicate the presence of contamination, but do not suggest DNAPL presence. The highest concentrations in this boring were 22.1 μg/g of TCE and 198.3 μg/g of PCE, at elevations of 262 ft msl and 240 ft msl, respectively. The angle boring on the southeastern and vertical boring on the western side of the basin did not have concentrations suggesting DNAPL. However, TCE and PCE are present in both locations (Jerome, 1998; Jerome, 1999). The data collected in FY2000 further substantiate the data gathered the past 3 years. The data from the vicinity of the M-Area Settling Basin have demonstrated the complexity of determining the quantity and location of DNAPL, especially distant or deep pockets below the water table. Future plans include continuing this activity and implementing source treatment as viable target accumulation zones are identified.

In 1995, a full-scale RCRA vadose zone SVE treatment was initiated in the area of the basin, utilizing two horizontal wells that are installed in the deep vadose zone beneath the capped area. This effort has provided significant removal of residual DNAPL solvent. The full scale SVE operation at the M-Area Settling Basin has removed 115,700 pounds of chlorinated solvents.

The total contaminant mass removal from the various pilot scale, research and full scale rapid response actions along the M- Area Settling Basin is approximately 116,300 pounds (sum of above numbers). A site-specific version of the A/M-Area DNAPL Strategy for this particular suspect DNAPL Area is shown in Figure 7.11. Work continues to characterize the nature and extent of residual source near the basin. As discussed in Section 8.0, additional DNAPL related work on this source area will continue.

Source Specific DNAPL Flowchart -

M Area Settling Basin

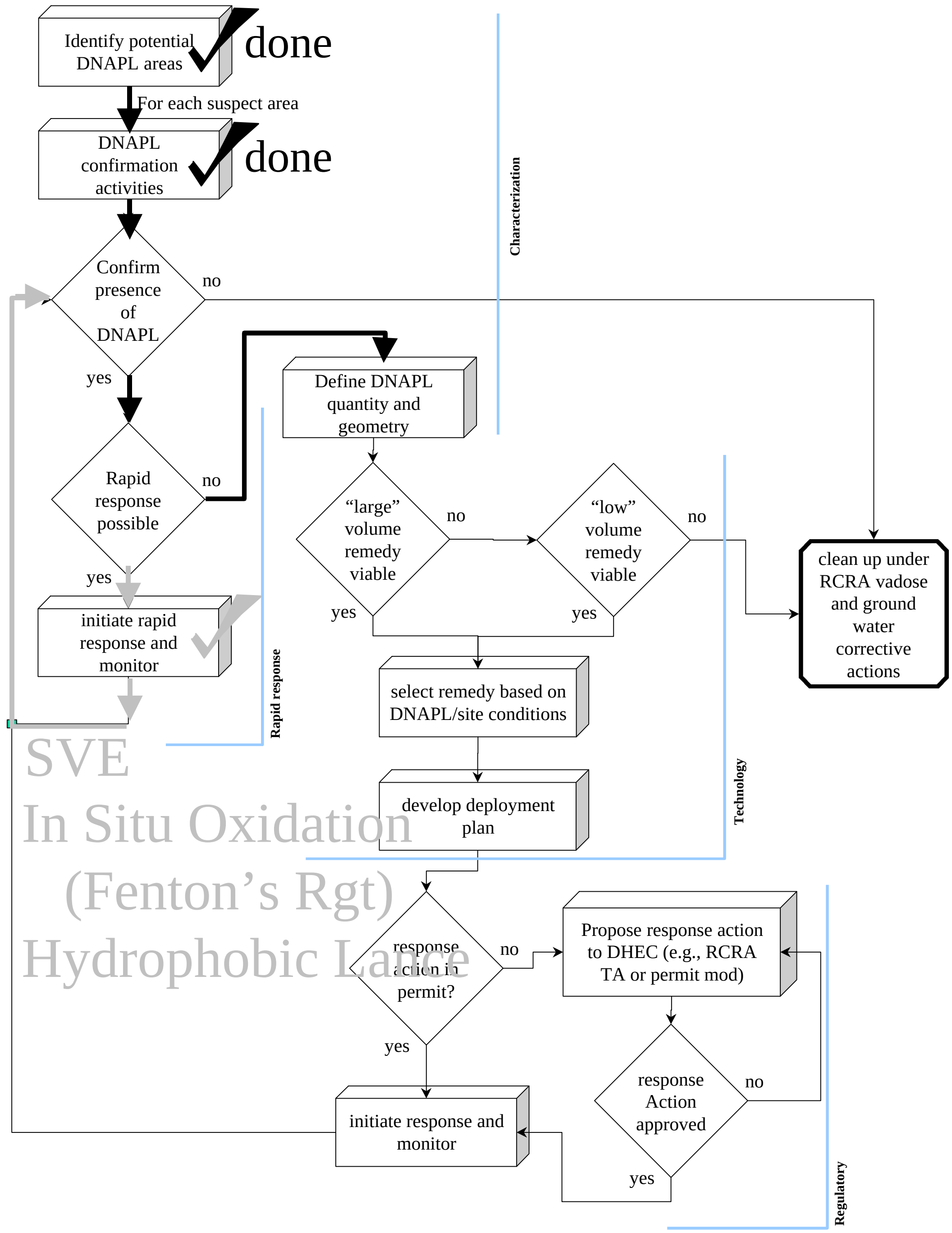


Figure 7.11. A/M-Area DNAPL Strategy applied to the M-Area Settling Basin

7.2.3.3 M-Area Process Sewer (leads to A-014 outfall)

M-Area process wastewaters were discharged from buildings 313-M and 320-M to the A-014 outfall from 1952 through 1980 via a 30-inch diameter terra cotta underground sewer line. It is estimated that 1.5 million pounds of chlorinated solvents may have been released to the A-014 Outfall through this sewer line. A television survey made in 1982 of the process sewer line to the A-014 Outfall showed small cracks along most of the length of the terra cotta pipe. Also, the pipe near the discharge to the outfall was heavily corroded. This sewer line was relined in 1983 (Marine and Bledsoe, 1984). The process sewer line had numerous manholes located approximately 350 ft apart along the entire length of the system. In 1997 and 1998 two borings were drilled along the A-014 outfall using rotosonic drilling. The resulting data showed contaminated intervals, primarily TCE, below the water table. This suggests lateral dissolved plume migration at depth rather than vertical migration from an overlying source (Jerome, 1998). No significant levels of DNAPL solvent were identified in the vadose zone along this sewer line – closely spaced vertical samples were collected from the several representative manholes and from M-Areas underlying straight runs of the sewer line. Limited additional sampling of this potential source area is not currently planned unless new information is generated that suggests a particular location to study. As shown in Figure 7.12, this source is currently being remediated by the baseline RCRA groundwater corrective action and no additional DNAPL targeted work is scheduled.

Source Specific DNAPL Flowchart -
Process Sewer leading to A-014 Outfall

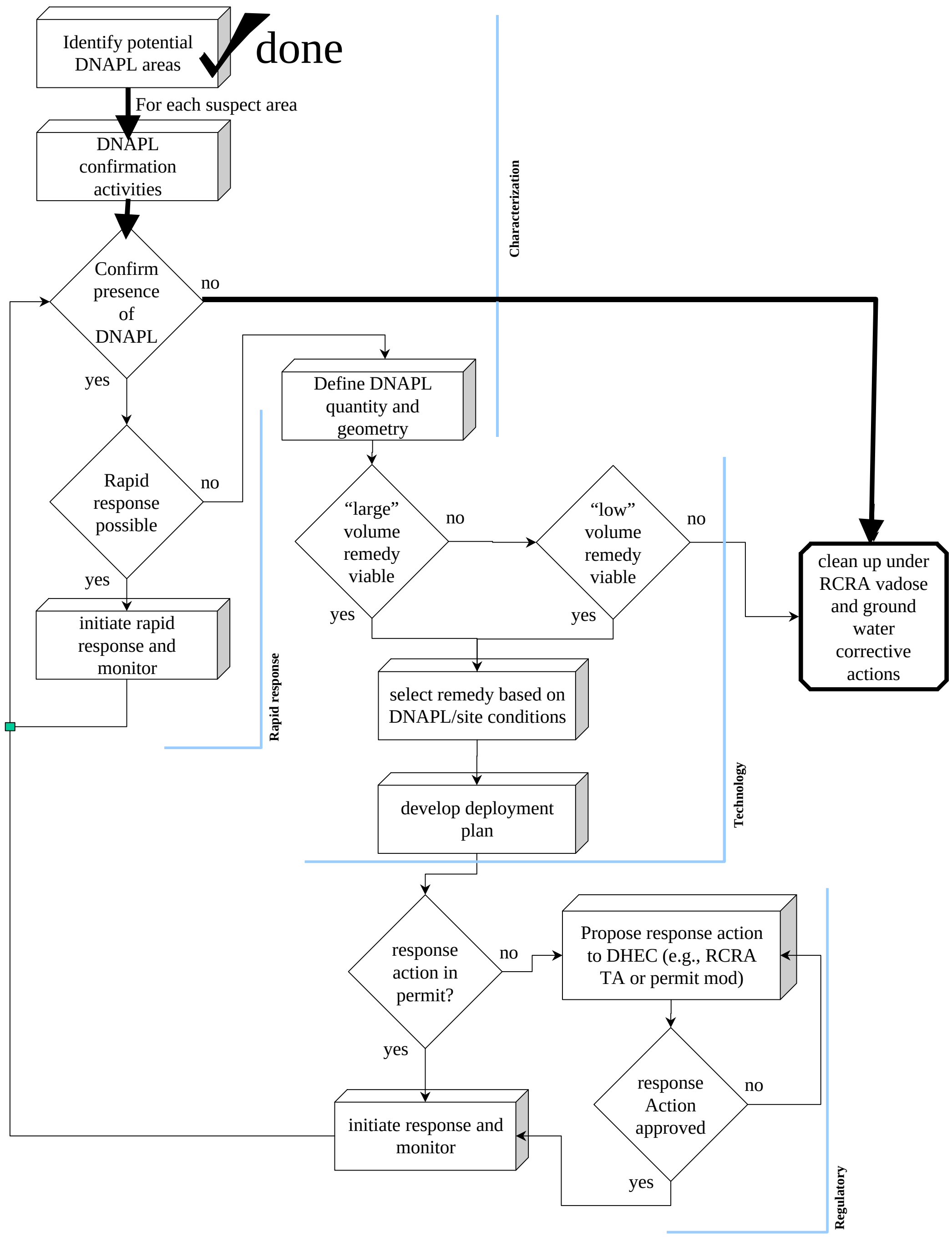


Figure 7.12. A/M-Area DNAPL Strategy applied to the process sewer leading to the A-014 Outfall

7.2.3.4 A-014 Outfall

M-Area process wastewaters were discharged from buildings 313-M and 320-M to the A-014 outfall from 1952 through 1980. It is estimated that 1.5 million pounds of chlorinated solvents may have been released to the A-014 Outfall through the sewer line (Marine and Bledsoe, 1984). Of this quantity, 72 % was PCE, 27% was TCE, along with a small quantity of 1,1,1-TCA. The release rates and distributions were not constant over the active disposal period from the buildings. It is believed this may effect the distribution of the TCE and PCE in the subsurface (Jackson, 1999). Groundwater monitoring well data indicate a source of chlorinated solvents in the area of the present water discharge (CH2M Hill, 1990). In 1997 and 1998 three borings (MRS 11, 14 and 18) were drilled at the A-014 outfall using rotosonic drilling. The resulting data suggested the soil vapor extraction units are effectively remediating the vadose zone and the contaminants are being transported along the middle clay of the water table aquifer and then penetrating deep into water bearing zones. The relatively thin intervals (approximately 10 ft thick) of elevated PCE concentrations below the water table indicate that DNAPL accumulation areas in the vicinity are probable (Jerome, 1998). In 2000, two angle borings (MRS 32 and 33) and one vertical boring (MRS 34) were drilled along the outfall. The angle borings were drilled in an effort to detect vertical movement into the subsurface along a greater front than is possible with one vertical boring. MRS 32 detected concentrations of PCE indicative of DNAPL in the zone of 251 ft msl to 247 ft msl (107 to 110 ft bgs). A vertical boring was drilled, sampled for verification purposes and a vadose zone well installed in the contaminated zone.

In mid-1990 24 soil gas samples plus 5 duplicates were taken at the headwall of the A-014 outfall and along the stream. TCE was detected in 23 samples, will concentrations ranging from 0.38 to 25,000 ppbv. PCE was detected in every sample, with concentrations ranging from 1.4 to 230,000 ppbv. This work was followed up by drilling 3 soil borings that were sampled at 5-foot intervals. TCE and PCE were detected in most of the soil samples. Detectable concentrations above 50 ppb occurred consistently from approximately 266 ft msl to 261 ft msl (80- to 85- foot bgs) interval down to an elevation of 221 ft msl (125 ft bgs). One vapor extraction well and two vapor monitoring clusters were installed at the outfall area (CH2M Hill, 1990).

In 1995, a full-scale RCRA vadose zone SVE treatment was initiated in the area of the outfall. This effort has provided significant removal of residual DNAPL solvent. The full scale SVE operation at the A-014 Outfall has removed 166,100 pounds of chlorinated solvents.

In February and April 1999 cone penetrometer based characterization activities were conducted to evaluate shallow vadose zone contamination at the headwater of the A-014 outfall. Twenty-two locations were selected for the characterization. Techniques used were soil gas sampling, cone penetrometer probes for determining lithology and in-situ DNAPL detection Ribbon NAPL Sampler. The results indicate that DNAPL is present in the shallow (337-322 ft msl [10-25 ft bgs]) vadose zone near the headwater of the outfall.

The data indicate that although the DNAPL is within the radius of influence of ongoing remediation systems, the interval is not adequately being addressed due to the clayey-interbedded nature of the sediments of the shallow vadose zone at this particular site. To address this limitation and specifically target the identified DNAPL, a series of vertical extraction wells were installed in these zones for connection and configuration into the existing, permitted soil vapor extraction system located at the outfall. Based on the results of the characterization, it is postulated the infiltration associated with the headwaters of the outfall may impact the distribution and subsequent removal of DNAPL in the shallow vadose zone. Additional information is needed on the possible effects of this infiltration and on the effects of co-disposed liquids released to the outfall in the transport and distribution of DNAPL in the subsurface (Jackson, 1999).

The total contaminant mass removal from full scale rapid response actions along the A-014 Outfall is approximately 166,100 pounds (sum of above numbers). A site-specific version of the A/M-Area DNAPL Strategy for this particular suspect DNAPL Area is shown in Figure 7.13. Work continues to characterize the nature and extent of residual source near the outfall. A-014 Outfall is one of the earliest DNAPL sources in A/M-Area (receiving solvents prior to the construction of the M-Area Settling Basin). Because of this, planned work to "define the DNAPL quantity and geometry" will include both the shallow source (vadose zone), as well as an expanded program to identify deeper discrete DNAPL accumulation zones below the water table. As discussed in Section 8.0, additional DNAPL related work on this source area will continue.

Source Specific DNAPL Flowchart -

A-014 Outfall

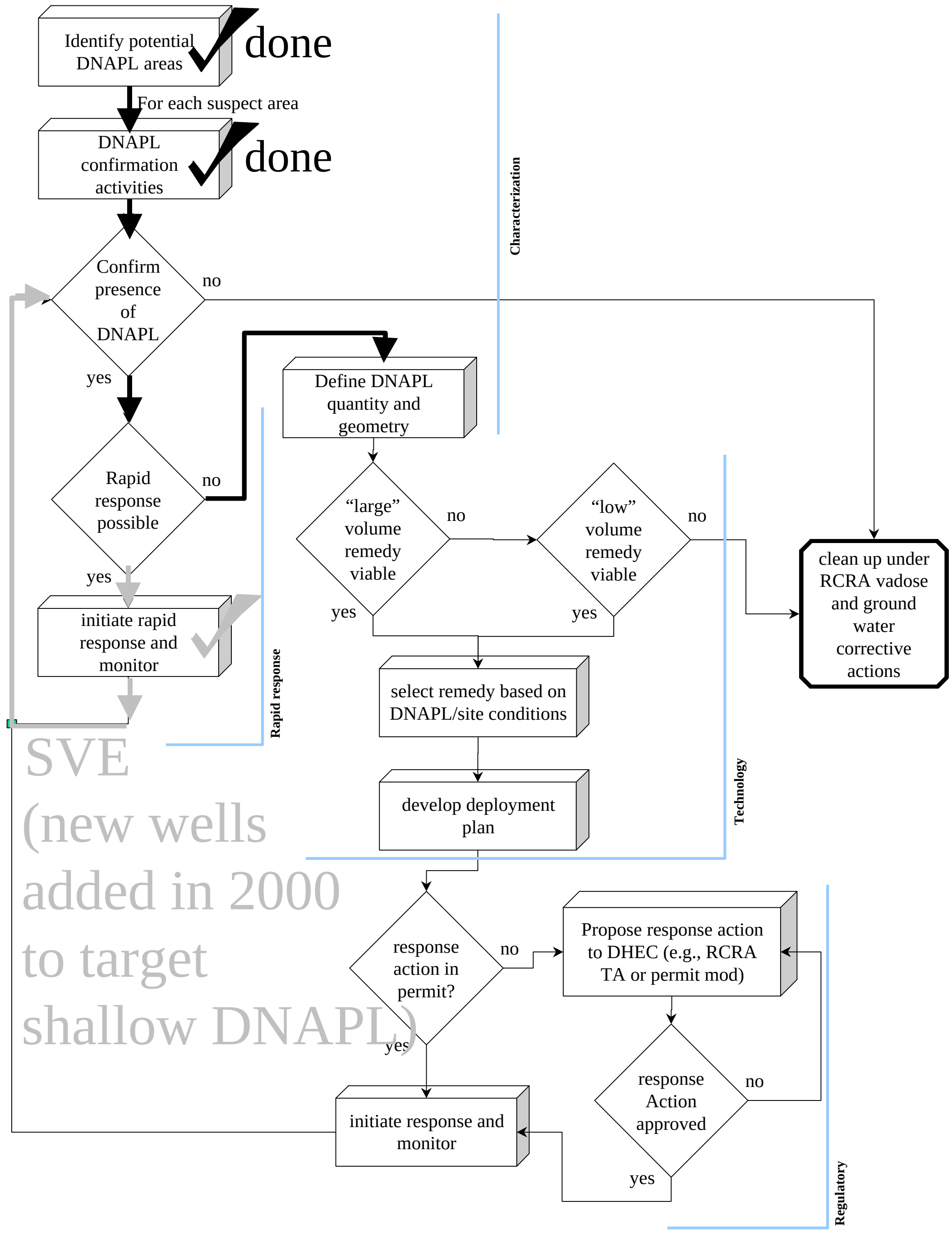


Figure 7.13. A/M-Area DNAPL Strategy applied to the A-014 Outfall

7.2.3.5 Swampy Area on which Building 321-M now sits

Before construction of M-Area there was a draw or depression that passed beneath 321-M and then turned northward past 320-M and thence northwestward. One of the first operations of construction in 1952 was to grade the area and fill in this draw. Thus extensive earth moving equipment was employed. After operations in M-Area began a ditch drained the vicinity of 313-M to the back of 320-M and then to a low swampy spot where 321-M was built. When 321-M was completed in 1957 a drainfield was installed that discharged to the south and west of the facility but most drainage was still to the natural draw over the head of which 321-M had been built (Marine and Bledsoe, 1984).

The swampy spot where 321-M now sits is a potential DNAPL site because it was a drainage area for 313-M and 320-M as identified in Marine and Bledsoe and because building 321-M now sits on that location. This area will be characterized per the characterization of building 321-M (see Figure 7.8).

The drainfield installed when building 321-M was completed has undergone limited characterization. During the 1990 soil gas investigation, six soil gas probe locations were sampled and 1 vapor extraction well was installed with soil samples collected. The results of the soil gas probe shown concentrations of TCE ranging from below detection limits to 7.6 ppbv and of PCE ranging from 0.12 ppbv to 45 ppbv. The highest soil sample concentrations were at elevations of 270 ft msl and 268 ft msl (100' and 102' bgs). The concentrations were 300 ppb TCE and 197 ppb PCE at 270 ft msl and 828 ppb TCE and 663 ppb PCE at 268 ft msl. (CH2MHill).

8.0 FUTURE PLANS AND SCHEDULE

Table 8.1 summarizes the status and proposed schedule for all of the currently identified suspected and known DNAPL source areas.

Table 8.1. Future Plans and Schedule for A/M Area DNAPL Activities as Part of the A/M Area RCRA Corrective Action

STORAGE AREAS	Current Status	FY 01 activities	FY 01 decisions	FY 02 activities	FY 02 decisions	FY 03 activities	FY 03 decisions	Comments
321-M Solvent Storage Tank	h / 4	h	1	(c&d) or (X)	(2) or (none)	tbd	tbd	Dynamic Underground Stripping (and Hydrous Pyrolysis) currently underway
Rail Storage Area East of Building 313-M	a	b	1	(c&d) or (X)	(2) or (none)	tbd	tbd	Work conducted in conjunction with Building 313-M (Use Area)
Drum Loading Area South of Building 313-M	a	b	1	(c&d) or (X)	(2) or (none)	tbd	tbd	Work conducted in conjunction with Building 313-M (Use Area)
713-A Central Storage Facility	a	b	1	(c&d) or (X)	(2) or (none)	tbd	tbd	
USE AREAS	Current Status	FY 01 activities	FY 01 decisions	FY 02 activities	FY 02 decisions	FY 03 activities	FY 03 decisions	Comments
313-M (Slug Manufacturing Facility)	a/b	b	1	(c&d) or (X)	(2) or (none)	tbd	tbd	
320-M (Target Manufacturing Facility)	a	b	1	(c&d) or (X)	(2) or (none)	tbd	tbd	
321-M (Fuel Manufacturing Facility)	a	b	1	(c&d) or (X)	(2) or (none)	tbd	tbd	
305-A	a	b	1	(c&d) or (X)	(2) or (none)	tbd	tbd	
773-A (SRTC)	a	b	1	(c&d) or (X)	(2) or (none)	tbd	tbd	
Lower 700 Area (777-10A)	a	b	1	(c&d) or (X)	(2) or (none)	tbd	tbd	
Upper 700 Area (703-A)	b/1	X	none	X	none	X	none	DNAPL not confirmed, no additional DNAPL program activities planned
SOLVENT DISPOSAL AREAS	Current Status	FY 01 activities	FY 01 decisions	FY 02 activities	FY 02 decisions	FY 03 activities	FY 03 decisions	Comments
M-Area Basin Process Sewer	c&d / 2	d	(1) & (3 or 4)	tbd	tbd	tbd	tbd	rapid responses to date: SVE, installation of horizontal wells, in situ air stripping, in situ bioremediation, 6 phase heating and RF heating.
M-Area Basin	c&d / 2	d	3 or 4	tbd	tbd	tbd	tbd	rapid responses to date: SVE, installation of horizontal wells, in situ oxidation using Fenton's Reagent, and hydrophobic lance. Evaluating possible DNAPL treatment of vadose zone and shallow groundwater beneath and adjacent to original basin location.
M-Area Process Sewer to A-014 Outfall	b/1	X	none	X	none	X	none	DNAPL not confirmed, no additional DNAPL program activities planned
A-014 Outfall	c&d / 2	d	3 or 4	tbd	tbd	tbd	tbd	rapid responses to date: SVE and recent DNAPL targeted modification to SVE.

Key:

Activities……..
a = identify potential DNAPL source areas
b = DNAPL confirmation activities
c = initiate rapid response
d = define DNAPL quantity and geometry
e = select remedy based on DNAPL and site conditions
f = develop deployment plan
g = propose respnse action to DHEC
h = Initiate DNAPL specific response and monitor
X = no further DNAPL actions planned, clean up under RCRA vadose zone and groundwater correction actions
tbd = to be determined, depends on prior year results

Decisions ………
1 = Confirm presence of DNAPL
2 = Rapid Response possible
3 = Large volume or low volume remedy viable
4 = response action in permit or response action approved
tbd = to be determined, depends on prior year results

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Appendix A

Core Descriptions and Logs from FY 2000 Drilling

OSR 30-27# (2-12-97)

Field Geologic Log

Project		Date	Sheet
A/M DNAPL / 45° Angle boring		4/4/00	1 of 12
Well Number: MRS 29	Location: M Area Basin	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery %	Sample Description	Drilling Comments/Remarks
	0–4	(no recovery)				
1	4		0		Sandy clay, Clay 70%, red 2.5YR 4/8, [illegible], sand med-coarse,	
1	6		0			
1	8		0			
1	10	(no recovery)	0			
2	11				Sandy clay, Clay 70-75%, dark red 2.5YR 3/6 to red 2.5YR 4/8, yellow & white mottling throughout, sand med-coarse	
2	12		34			
2	13		20			
2	15		8			
2	17		16			
2	18		17			
2	20		35			

OSR 30-27# (2-12-97)

Field Geologic Log

Project: K/M DNAPL/45° Angle Boring	Date: 4/4/08
Sheet: 2 of 12	
Well Number: MRS-29	Location: M Basin
Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester	Driller: M. Coleman
Company: WSRC	Drilling Method: rotosonic/3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery		Sample Description	Drilling Comments/Remarks
2	20			100		
	1					
3	2		3		Sandy Clay, Clay % 65-75, red 2.5YR 4/8 To reddish brn. 2.5YR 4/4 with mottling throughout of gray, yellow, and white, Sand % increasing down, coarse.	
	3		5			
	4					
	5		12	100		
	6		7		Clayey sand, Clay 50-20% decreasing down, reddish brn 10YR 4/6, fine-coarse, muscovite present.	sampled @ 26'
	7		27			
	8		13			
	9		54			sample 29'
	30		23			sample 30'
	1		11			
4	2		1		Clayey sand, clay % 25, lt. red 2.5YR 6/8, soft, coarse	
	3		3			sampled @ 33
	4		2			
	5		1			
	6		9		Silty sand, silt ≈ 25%, lt. red 2.5YR 6/8, To reddish brn. 2.5YR 5/4.	
	7		46			sampled @ 37'
	8		25			
	9		23			sampled @ 39'
	40		32			

Field Geologic Log

Project	Date	Sheet
A/M DNAPL/45° Angle Boring	4/4/06	3 of 12

Well Number	Location	Drilling Subcontractor
MRS-27	M Basin	AEI

Logs Prepared By	Driller
Jay Noonkester	M. Coleman

Company	Drilling Method
WSRC	Rotosonic / 7" core

Run Number	Depth Below Ground Surface (Feet)	Lithology		Percent Recovery	Sample Description	Drilling Comments/Remarks
4	40		22			
	1					
5					Silty Clayey Sand, Silt/Clay 25%, several colors of reddish brn 5YR5/4, red 2.5YR 4/8 and yellowish red 5YR5/8 muscovite abundant throughout, sand v. fine-fine, soft.	
	2		13			
	3		15			Sample 43'
	4		27			sampled @ 45'
	5		34	90		
	6		11			
	7		13			
			14			
	8		12			
	9					sampled @ 50'
	50		31			
	1					
6					Clayey Sand, Clay 25%, weak red 10R5/2 some yellow mottling, med-coarse grading to v. fine-fine, muscovite abundant throughout, soft.	
	2		6			
	3		10			
	4		12	100		sampled @ 55'
	5		15			
	6		11			
	7		3			sampled 58'
	8		20			
	9		6			
	60		8			

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
H/M Area DNAPL/45° Angle Boring	4/4/00	4 of 12

Well Number	Location	Drilling Subcontractor
MRS-29	M-Basin	AEI

Logs Prepared By	Driller
Jay Noonkester	Michael Coleman

Company	Drilling Method
WSRC	Rotosonic/3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery		Sample Description	Drilling Comments/Remarks
6	60		31		See above	
	1					Sampled 61'
7	2		6	95	Silty Sand, silt/clay 15-20%, reddish brn. 2.5YR 5/3 with mottling of dk. red and yellow, v. fine - med, soft.	sample 63'
	3		11			
	4		3			
	5					
	6		2			Sampled @ 67'
	7		9			
	8					
	9		12			
	70		13			Sampled @ 70'
	1					
8	2		3	100	Silty Sand, silt/clay 30%, Fine banded colors of 5 strong brn. 7.5YR 5/8, gray 7.5YR 6/1, drk brn. 7.5YR 3/4, sand v. Fine - fine, muscovite abundant.	Sampled @ 73'
	3		16			
	4		7			
	5		3		Clayey Silt, silt 60%, clay 20%, some v. fine sand, mainly weak red 10R 5/3, firm - hard, muscovite abundant	
	6		9			Sampled @ 76'
	7		5			
	8		3			
	9		15		Silty Sand, silt 20, 17, reddish brn. 5YR 6/4, v. fine - fine, soft, muscovite abundant.	Sampled @ 79'
	80					

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / 45° Angle boring	Date: 4/5/00
	Sheet: 5 of 12
Well Number: MRS-29	Location: M-Basin
Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester	Driller: M. Coleman
Company: WSRC	Drilling Method: Rotosonic

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
8	80		100 / 100	See above	
	1				
9	2		4	~~Clayey~~ Sand, ~~Clay 20%~~ Sand 85%, reddish brn. 5/4, and reddish yellow 7.5YR 6/8, fine-med.	
	3				sampled @ 83'
	4		2	Clayey Sand, clay 25%, weak red 10R 5/4, sand fine-med.	
	5		14		
	6				
	7		2	Sand 90%, yellow 10YR 7/8, weak red 10R 5/4, fine-med. with occasional v. coarse	
	8				sampled @ 88'
	9		3		
	90		7		
	1				
10	2		3	Sand, 88%, weak red 10R 5/4 and yellowish red 5YR 5/8, med-coarse, soft.	
	3		5		
	4		11		sampled @ 94'
	5		5 / 70		
	6		6	Same as above, but yellow 10YR 7/8	
	7				
	8		7		sampled @ 98'
	9				
	100				

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / 45° Angle boring		Date: 4/5/00	Sheet: 6 of 12
Well Number: MRS 27	Location: M-Basin	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic	

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
10	100					
	1					
11	2		7		Sand, 90%, reddish yellow 7.5YR6/8, med-coarse with occasional v. coarse.	
	3		5			sampled at 103'
	4					
	5		3	60		
	6		7			
	7		14			sampled at 107'
	8					
	9					
	110					
	1					
12	2		0		Sand, 90%, brownish yellow 10YR6/8, coarse with some v. fine and occasional v. coarse, soft	
	3		0			
	4		2			sampled @ 114'
	5		6	65		
	6		3			
	7		5		Clayey sand, clay % 25, yellowish red 5YR4/6, Fine - v. coarse with granules and pebbles	sampled @ 117'
	8					
	9					
	120					

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / 45° Angle Boring		Date: 4/5/00	Sheet 7 of 12
Well Number: MRS-29	Location: M-Basin	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
12	120			65	see above	
	1					
13	2		5		Clayey sand, clay 25-30%, strong brn. 7.5YR5/8, fine - v. coarse with granules and pebbles	
	3		3		Sand, 85%, strong brn 7.5YR5/8 to red 10R4/8, med-coarse grading to fine-med., occasional granules	
	4		9, 18			Sampled @ 124'
	5		12		Clayey sand grading to sand, clay 25-5, strong brn 7.5YR5/8 to red 2.5YR4/8, several thick clay lamina present strong brn, fine - coarse	sampled @ 125.5
	6		3			
	7		5, 2			
	8		5			
	9		6			sampled @ 129
	130					
	1					
14	2		1, 3		Sand, 95%, red 2.5YR 4/8, fine-med.	
	3		5			
	4		3	50	Clayey sand, clay 25%, drk. red 2.5YR 3/6, fine-coarse	
	5		10		Sand, 95%, yellow 10YR7/8, fine-coarse, thin clayey zone at 135.7.	
	6		5			
	7					
	8					
	9					
	140					

QSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / 45° Angle Boring
Date: 3/5/00
Sheet: 8 of 12
Well Number: MRS-29
Location: M-Basin
Drilling Subcontractor: AEI
Logs Prepared By: Jay Noonkester
Driller: M. Coleman
Company: WSRC
Drilling Method: Rotosonic

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
14	140				See above	
	1					
15			2		Sand, 95-99%, brownish yellow 10YR6/8,	
	2		5		mod-well sorted	
						sample @ 143'
	3		9			
	4		6			
			7	60		
	5		5			sample @ 146'
	6					
			3			
	7					
	8					
	9					
	150					
	1					
16			2		Sand, 95-90% yellow 10YR7/8,	
	2				v. fine - granules with occasional pebbles.	
	3		9			
	4		18	75		
	5		53			sample @ 155'
	6		13			sample 156.5'
	7		27		Clayey sand grading into sand, strong brn. 7.5YR5/6, coarse - v. coarse grading into fine - med., thin lt. gray clay lamina at 156.5 ft	sample @ 158'
	8		13			
	9					
	160					

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL /45° Angle Boring	Date: 3/5/00
Sheet: 9 of 12	
Well Number: MRS 29	Location: M-Basin
Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester	Driller: M. Coleman
Company: WSRC	Drilling Method: Rotosonic

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery %	Sample Description	Drilling Comments/Remarks
16	160					
	1		6		Sand, 95%, yellowish red 5YR5/8, med-coarse with occasional v. coarse, several lt gray clay laminae one	
	2		0		thick at 165' and several v. thin at	
	3		.5		168', soft.	
	4					
	5		.1	90		
17	6		0			Sampled @ 166'
	7		0			
	8		14			Sampled @ 168'
	9		2			
	170		1			
	1				Silty Sand, silt 25%, dk yellowish brn 10YR3/4,	
	2		15		v. fine-med., several v. thin lt gray clay laminae at 171.5,	
	3		38		soft, 1 ft. of brownish yellow 10YR6/8 sand at 174', v. fine-fine.	Sampled @ 173'
	4		177			Sampled @ 175'
18	5		186 [illegible]	50		
	6		50			
	7					
	8					
	9					
	180					

OSR 30-27# (2-12-97)

Field Geologic Log

Project		Date	Sheet
A/M DNAPL/45° Angle Boring		3/5/00	10 of 12
Well Number: MRS-29	Location: M Basin	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
18	180			50	see above	
	1		0		Sand, 95%, strong brown 7.5YR 4/6 to brownish yellow 10YR 6/8, coarse-v. coarse grading to fine-v. fine, occasional muscovite, several v. thin lt. gray clay laminae present.	
19	2		0			Sampled @ 182
	3		30			
	4		170			Sampled @ 184
	5		285	50		Sampled @ 185
	6		111			
	7					
	8					
	9					
	190					
	1				Sand, 95%, strong brown 7.5YR 5/8 and reddish yellow 7.5YR 6/6, fine-coarse, with many v. coarse and occasional granules, several v. thin lt gray clay laminae present	
20	2		113			
	3		350			Sampled @ 192'
	4		70			Sampled @ 193'
	5		70	70		
	6		20			Sampled @ 197'
	7		20			
	8		20			
	9					
	200					

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / 45° Angle Boring	Date: 4/7/00
Sheet: 11 of 12	
Well Number: MRS-29	Location: M-Basin
Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester	Driller: M. Coleman
Company: WSRC	Drilling Method: Rotosonic / 3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
20	200			10	See above	
	1					Sampled 201'
21					~~Sandy Clay~~ Clayey Sand To Sandy Clay, clay % 70 To 65, brownish yellow 10YR6/8 with thin banding colors of yellow, red, and white, Fine-coarse with some v. coarse and occasional granules	
	2		95			
	3		60			Sampled 203' Sampled 204'
	4		71			
	5		25	100		
	6		12			Sampled 207'
	7		6			
	8		10			
	9		16			Sampled 209'
	210		279		Clayey Sand quickly grading To sand, Strong brown 7.5YR5/8, med.-v. coarse with granules	Sampled 210'
	1		26			Sampled 211'
22			55		Clayey Sand Clay 15%, reddish yellow 7.5YR6/8 with some thin bands of red and white, med-v. coarse with many granules and some pebbles.	
	2		100			Sampled 212'
			300			
	3		240			Sampled @ 213'
	4				Sand, ~~90%~~ 70%, reddish yellow 7.5YR6/8 with white mottling, v Fine-Fine, some silt, abundant muscovite pebbles at 216'.	Sampled @ 214'
	5		92	100		Sampled @ 215'
	6		436		Sand, ~~~~ 98%, reddish yellow 7.5YR 6/8, med-v. coarse, very clean, muscovite present.	Sampled @ 216'
	7		138			Sampled @ 217'
	8		100			Sampled @ 218'
	9		150			Sampled 219'
	220		30			

Field Geologic Log

Project	Date	Sheet
A/M DNAPL FY00	4/7/00	12 of 12

Well Number	Location	Drilling Subcontractor
MRS 29	M Basin	AEI

Logs Prepared By	Driller
J. Noonkester	M. Coleman

Company	Drilling Method
WSRC	Rotosonic / 3" Core

Fm Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
22	220		30	100	See above	
	1					
23	2		0		Sand, 95-85%, ~~sand~~ clay% increasing down, brownish yellow 10YR6/8,	
	3		0		v. pale brn streaks, Trace mica, v.fine-med, at 224' grading into ~~sandy~~	sampled @ 223'
	4		0	100	clayey sand, v. coarse & granules present near 225'	
	5		0			sampled @ 225'
	6		0		Sandy clay grading to clay, clay 65%-85%, Thinly banded colors of yellow, lt. gray, red 2.5YR 4/6, and brn.	Sample @ 228'
	7		0			
	8		0		Clay, mainly lt gray with thin laminae of sand red and brn. some laminae indurated	S
	9		0			sample @ 231'
	230		0		grading to clayey sand, clay 35-45%, yellow 10YR7/8 and v. pale brn, Trace mica, v. fine-med.	
	T.D. 1					T.D.
	2					
	3					
	4					
	5					
	6					
	7					
	8					
	9					
	0					

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL FY00 / Flute	Date: 4/10/00	Sheet 1 of 8
Well Number: MRS-30	Location: M basin	Drilling Subcontractor: AEI
Logs Prepared By: Jay Noonkester		Driller: M. Coleman
Company: WSRC		Drilling Method: Rotosonic / 3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery		Sample Description	Drilling Comments/Remarks
1	0		6	100	Sandy Clay, clay 75%, red 10R 4/8 with some reddish yellow mottling. Fine - v. coarse, hard - v. hard.	
	1		0			
	2					
	3		5			
	4		15			
	5		20			
	6		19			
	7		6			
2	8		7	100	Sandy Clay, Clay 75%, red 10R 4/8 with reddish yellow mottling, hard - v. hard, fine - v. coarse with granules present	
	9		20			
	10		20			sampled 10'
	11		20		Dense mottling of Blue, white and olive yellow.	
	12		22			
	13		14			
	14		15		less mottling, coarse and less clay (60%).	
	15		4			sampled @ 17'
	16					
	17		7			
3	18		3	100	Clayey Sand, clay 20-25%, red 2.5YR 4/8, some yellow and blue mottling. Trace of muscovite, fine - V. coarse. Fining down to a v. fine - med. muscovite increasing.	
	19					
	20		5			

Field Geologic Log

Project: A/M DNAPL / Flute	Date: 4/10/00
Sheet: 2 of 8	
Well Number: MRS 30	Location: M Basin
Drilling Subcontractor: AEI	
Logs Prepared By: J Noonkester	Driller: M. Coleman
Company: WSRC	Drilling Method: Rotosonic / 3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology		Percent Recovery	Sample Description	Drilling Comments/Remarks
3	20		7			
	1		7			
	2		8	100		
	3					
	4		32			sampled @ 24'
			23			
	5					
	6		20			
	7		35			
4	8				Silty Sand, silt 25%, reddish brn. 2.5YR 5/4, muscovite abundant, v. fine-fine	
	9		44			Sampled @ 29
	30		17			
	1		16			
	2		20		grading into clayey sand, weak red 10R 5/4 to weak red 10R 5/3 v. fine - coarse	
	3		1			
	4		2			
	5					
	6		5			
	7		19			
5	8		6		Clayey Sand, Clay 20%, weak red 10R 5/2, muscovite presen v. fine - coarse with occasional granules, some yellow mottling.	
	9		1	100		
	40		3			

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / Flute		Date: 4/10/00	Sheet: 3 of 8
Well Number: MRS-30	Location: M Basin	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: RotoSonic/3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
3	40		3	see above	
	1		2		
	2		100	Sand, 90%, reddish brn 5YR5/4, v. fine - med,	
	3		15		
	4		5		Sampled @ 44'
	5		3	colors become v. thin banding of reddish brn, white, pink, dk. brn.	
	6				
	7				
4	8		7	Clayey Sand grading to Sandy Clay, Clay % 20-60, weak red, 10R5/2 with strong brn. mottling near top, fine - med, firm - hard.	
	9		3		
	50		100		
	1		5		
	2		7		
	3				
	4		10	Sand, Clay 15%, weak red 10R5/2 to brownish yellow 10YR6/8, fine - med, with granules near bottom	
	5				
	6		12		
	7		48		Sample @ 57'
5	8			Sand, 95%, mult colors, yellow, pink, lt brn, v. pale brn, fine - coarse with occasional granules.	
	9		70		
	60				

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / FLUTE	Date: 4/11/00	Sheet: 4 of 8
Well Number: MRS-30 / Location: M-Basin	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester	Driller: M. Coleman	
Company: WSRC	Drilling Method: Rotosonic	

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
	60			See above	
	1				
5	2				sampled @ 62'
	3		70		
	4				
	5				
	6				
	7				
	8		3	Sand, 95%, reddish yellow 7.5YR6/8 and yellow 10YR7/8, Fine - v. coarse with occasional granules, several v. thin lt gray clay laminae present.	
	9		5		
	70				
	1		3		
6	2		2 / 70		
	3				
	4		1		
	5				
	6				
	7				
	8		3	Sand, 95%, reddish yellow 5YR6/8 to yellow 10YR 7/8, Fine - v. coarse with occasional granules, several v. thin lt. gray clay laminae.	
7	9		80		
	80		2		

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/m DNAPL / FLUTE		Date: 4/11/00	Sheet 5 of 8
Well Number: MRS 30	Location: M-Basin	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
7	80		1		see above	
	1		2			
	2					no samples
	3		1	80		
	4		3			
	5		4		Clayey Sand, clay 20%, red 2.5YR 4/8, v. fine - v. coarse, many granules.	
	6					
	7					
8	8		4		Sand 90% with thin clayey sand zones throughout, red 10R 4/8 with some reddish yellow sand, v. fine - v. coarse with many granules and occasional granules.	
	9		8			no samples
	90		17			
	1		2			
	2		14			
	3		3			
	4					
	5					
	6					
	7					
9	8		2		Clayey sand, clay 20%, brn. 7.5YR 4/4, v. fine - v. coarse.	
	9		1			
	100		2			

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / FLUTE		Date: 4/11/00	Sheet 6 of 8
Well Number: MRS-30	Location: M Basin	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic/3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
9	100		7			
	1		8			
	2		10		Sand, 95%, yellow 10YR 7/8, v. fine-med.	
	3		3	80		
	4		1		Clayey Sand, clay 20%, Strong brn. 7.5YR 5/8, v. fine-granules with many pebbles.	
	5		5			
	6		0			
	7					
10	8		9		Sand, 95%, reddish yellow 7.5YR 6/8, med.-coarse grading to v. coarse-granules with pebbles several v. thin lt. gray clay laminae present mainly at 112'.	
	9		5			
	110					no samples
	1		6			
	2		10	100	Clayey sand, clay 20%, brn. 7.5YR 4/4, one thick (40 mm) strong brn. lamina at 112, med.-v. fine - fining down	
	3					
	4		5		Sand, 99%, yellow 10YR 7/8, v. fine-fine, v. clean, v. well sorted, v. dry, occasional v. coarse	
	5		15			
	6					
	7		6			
11	8		0		Sand, 90%, yellowish red 5YR 5/8, fine-v. coarse with granules, 2 thin clayey zones as shown in lith.	
	9		0	100		
	120		0			

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL Flute		Date:	Sheet 7 of 8
Well Number: MRS 30	Location: M Basin	Drilling Subcontractor:	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery		Sample Description	Drilling Comments/Remarks
11	120		8			
	1		21			
	2		38			
	3		78	100	very dry, no moisture at all in core from 123'-125'. Also silty fine sand	sampled @ 123'
	4		28			
	5		58			sampled @ 125'
	6		17			
	7		0			
12	8		47		Sand, 95%, reddish yellow 7.5YR6/8, fine - v. coarse, from 128.5' To 129.5' grades To silty sand, several lt gray clay laminae present.	sampled @ 128'
	9		0			" 129'
	130		15			" 130'
	1		185	100		" 131'
	2		177			" 132'
	3		147			" 133'
	4		76			" 134'
	5		60			" 135'
	6		90			" 136'
	7		137			" 137'
13	8		23		Silty Sand, Silt 20%, yellowish red 5YR5/8, v. fine - med.	" 138'
	9		6	100		" 140'
	140		8			" 141"

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL Flute		Date: 4/11/00	Sheet 8 of 8
Well Number: MRS-30	Location: M Basin	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery		Sample Description	Drilling Comments/Remarks
	140		57		See above	
13	1		60		Clayey sand, Clay 30-35%, multi banded colors of yellowish red 5YR 5/8, red, yellow and v. pale brn. med-v. coarse with occasional granules.	Sampled @ 141'
	2		40			142'
	3		30	100		143'
	4		93			144'
	5		87			145'
	6		139			146'
	7		114		Sand, reddish yellow 5YR 5/8, clay 10%, med. - v. coarse.	147'
14	8		205		Sand, 90%, brownish yellow 10YR 6/8, v. fine + med. many v. thin - thin - one thick lt gray clay laminae. Some banding colors of red, yellow, yellowish brn.	148'
	9		409			149'
	150		385			150'
	1		264			151'
	2		335	100		152'
	3		695			153'
	4		260			154'
	5		81		Clay, 85%, v. pale brn, brn, reddish yellow and a little red, Thin sand lamina throughout, grading to clayey sand at bot	155'
	6		41			156'
	7		252			157' T.D.
	8					
	9					
	160					

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/m DNAPL / Angle Drill ~ 45°		Date: 3/29/00	Sheet 1 of 11
Well Number: MRS-32	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	PID	Percent Recovery %	Sample Description	Drilling Comments/Remarks
	0	0		Sand/Gravel, 80%, dk brn 7.5YR3/3,	
	1	1.2		gravel grading down to a coarse sand.	
		0			
	2	0		~~Clay~~ Sandy Clay, Clay 85-90%, red 2.5YR 4/8,	
				firm-hard, sand med.-v. coarse.	
	3				
		1.5			
1	4	6		Sand, 90%, lt yellowish brn 10YR6/4,	
	5	0		v. fine - med. from 4 FT to 4.5 FT.	
	6	2.0			
		0			sampled @ 7
	7				
	8				
	9				
	10				
	1				
		0		Sandy Clay, Clay 80-90%, red 10R 4/8,	
	2	0		hard, sand med - v. coarse with occasional	
				granules	
	3	4			
	4	0			
2	5	0	100		sample @ 15'
	6	0			
	7	0			
	8	2			
	9	0			
	20	2			sampled @ 20'

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
A/M DNAPL / Angle Drill @ 45°	3/27/00	2 of 4

Well Number	Location	Drilling Subcontractor
MRS-32	A-14	AEI

Logs Prepared By	Driller
J Noonkester	M. Coleman

Company	Drilling Method
WSRC	Rotosonic / 3" core

Run Number	Depth Below Ground Surface (Feet)	PID	Percent Recovery %	Sample Description	Drilling Comments/Remarks
2	20	0	100		
		2			
3	21	0	100	Sandy clay down to 34', 75-80%, red 10R 4/6, sand coarse with pebbles up to 50 mm at ~22', Firm-hard.	
	22	3			
		3			
	23	3			
	24	0		grading into a clayey sand, clay 50%, red 2.5YR 4/8, sand coarse, firm,	
		3			
	25	3			Sampled @ 25'
	26	3			
	27	3			
	28	3			
	29	3			
		7			
	30	0		sand at 30', sand 80%, yellowish red 5YR 4/6, med - coarse.	Sampled @ 30'
		2.5			
4	31	0	100	Clayey sand, clay 35%, red 2.5YR 5/8, sand coarse, firm.	
	32	0			
		0			
	33	0			
	34	0			
		4		grading into sandy clay at 36'	
	35			Sandy clay, clay 65%, red 2.5YR 4/8, sand is fine-med. hard-firm.	Sampled @ 35'
		0			
	36	2.5			
	37	0			
	38	0		grading into clayey sand at 38'	
		0		Clayey sand, clay 40%, red 2.5YR 5/8 and yellowish red 5YR 5/8, firm,	
	39	0		sand med - coarse.	
	40	2			Sampled @ 40'

OSR 30-27# (2-12-97)

Field Geologic Log

Project		Date	Sheet
A/M DNAPL / Angle Drill @ 45°		3/27/00	3 of 11
Well Number: MRS-32	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology		Percent Recovery	Sample Description	Drilling Comments/Remarks
4	40		6	100	see above	
			3			
	1		0			
5			0	55	Clayey Sand, clay 20-25%, pale red 10R6/4	
	2		0		with gray mottling, fine-coarse, soft.	
			0		Sand, 85-90%, mottled colors of	
	3		9		white, pink, brn, yellow, v. fine-med.,	
					soft	
	4		8			sampled @ 44'
			15		Clayey Sand clay 20-30% yellowish	44.5'
	5		20		red 5YR4/6 - strong brn 7.5YR4/6, soft-	45'
			0		firm, fine-med	45.5'
	6		38		Sandy clay, clay 50% weak red 2.5YR5/2	46
			35		with some strong brn 10YR4/6, firm.	
	7					
	8					
	9					
	50					save/boxed core
	1					from 0' - 51'
6				70%	Clayey Sand, clay 15-20%, reddish gray	
	2		20		2.5YR6/1 with some red mottling,	
					firm-soft, last 0.5 ft. is a lt. brn.	
	3				med. sand.	sampled @ 53'
			52			
	4					
						55'
	5		18			
						56.5'
	6		89			
	7		98			
						58'
	8		49			
	9					
	60					

OSR 30-27# (2-12-97)

Field Geologic Log

Project		Date	Sheet
A/M DNAPL / Angle Drill 45°		3/27/00	4 of 11
Well Number: MRS-32	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core barrel	

Fm Number	Depth Below Ground Surface (Feet)	Lithology	PID ppm	Percent Recovery %	Sample Description	Drilling Comments/Remarks
6	60				see above	
7	1					
	2		32		Sand, clay 10%, multicolors of mainly reddish gray, some red and strong brn, sand fine - coarse, soft.	
	3		62			sampled @ 63'
	4		34	75%		
	5		33			
	6		18			sampled @ 66'
	7		38			
	8		36			sampled @ 68'
	9		14			
	70					
8	1					
	2		6		Clayey Sand, clay 30%, brownish yellow 10YR 6/8 with mottling of white and red and lt. red, sand is v. fine - fine, firm.	
	3		5			
	4		16			sampled @ 74'
	5		46			
	6		47	80		sampled @ 76'
	7		40			
	8		31			sampled @ 78'
	9		47			
	80		23			

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
A/m DNAPL / Angle Drill 45°	3-27-00	5 of 11

Well Number	Location	Drilling Subcontractor
MRS-32	A-14	AEI

Logs Prepared By	Driller
J. Noonkester	M. Coleman

Company	Drilling Method
WSRC	Rotosonic / 3" core

Fm Number	Depth Below Ground Surface (Feet)	Lithology	PID ppm	Percent Recovery %	Sample Description	Drilling Comments/Remarks
8	80			80	see above	
9	81–83		2, 3, 0	80	Clayey Sand, Clay % 30, banded colors of reddish yellow 7.5YR 6/8, strong brn, pale yellow, med. coarse, firm-soft.	sampled @ 83'
	83–87		10, 0, 0, 1, 2		Sand, Clay % 10, multi colors/mottled reddish yellow, strong brn, pink, lt brn, white, med-v. coarse, occasional granules, soft	
	87–89		0, 0, 0		Clayey Sand, Clay % 25-30, strong brn, and coarse-med with v. coarse & some granules, soft	sampled @ 88'
	89–91					
10	91–96		0, 0, 0, 0, 0, 0, 0, 0, 0	50	Sand, 95-98 %, strong brn 7.5YR 5/6, med-coarse with many v. coarse and occasional granules, one thin light gray clay lamina at 91.3'.	sampled @ 96'
	96–100					

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / Angle Drill 45°	Date: 3-27-00
	Sheet 6 of 11
Well Number: MRS 32	Location: A-14
Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester	Driller: M. Coleman
Company: WSRC	Drilling Method: Rotosonic / 3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID NA	Percent Recovery %	Sample Description	Drilling Comments/Remarks
10	100				see above vertical depth - 70.7 FT.	
	1					
11	2		0		Sand, 90-95%, brownish yellow 10YR 6/8, med. - v. coarse with occasional granules and some pebbles at 108', 2-3 v. Thin lt gray clay lamina present near end of run.	
	3		2, 4			
	4		0			sampled @ 105'
	5			75		
	6		1			
	7		0			sampled @ 108'
	8		0			
	9					
	110					
	1					
12	2		0, 0		Clayey Sand, clay% 25, brownish yellow 10YR 6/8 and yellowish brn 10YR 5/8, med.-v. coarse with zones of granules, several zone of Thin lt. brn clay laminae, from 111' To 112.5' sand is v. fine - Med.	
	3		0			
	4		0	65		sampled @ 114'
	5		20, 6			sampled @ 115'
	6		32			sampled @ 116'
	7		60, 24			sampled @ 117'
	8					
	9					
	120					

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/m DNAPL / Angle Drill 45°		Date: 3/28/00	Sheet 7 of 11
Well Number: MRS-32	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
12	120 – 121			See above.	
13	121 – 130		50	Sand, 90%-95%, brownish yellow 10YR 6/8, med-coarse, occasional v. coarse mainly around 125', several v. thin lt gray clay laminae at 123.4'.	Sampled @ 125'
14	131 – 140		75	Clayey sand grading into sand, clay 25%, brownish yellow 10YR 6/8 with some reddish yellow and white mottling, sand v. fine-med grading to coarse-v. coarse, with many granules and occasional pebbles Clayey sand grading into sand, clay 25%, red 2.5YR 4/8 with yellow & white mottling grading to yellow 10YR 7/8, sand med-v. coarse with many granules and pebbles.	sampled @ 135' sampled @ 138'

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / Angle Drill 45°		Date: 3/28/00	Sheet 8 of 11
Well Number: MRS-32	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: rotosonic / 3" Core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
14	140			see above	
	1				
15	2		0, 1	Sand, 85-95%, yellow, 10YR 7/8, med.-v. coarse, coarsing down to v. coarse with many granules & pebbles.	
	3		25	Sandy Clay grading to Clayey sand, Clay % 80 at Top to 70 at bottom, yellowish red 5YR 4/6, several lt gray clay lamina present, med.-v. coarse with many granules & pebbles throughout	
	4		2		
	5		6		
	6		95		
	7		0		
	8		0		
	9		1, 0	Sand, 85-90%, mult colors, white, yellow mainly, med.-coarse with occasional granules.	
	150				
	1				
16	2		450	Silty-Clayey sand, Silt-Clay 20-30%, brownish yellow 10YR 6/8, v. fine-fine, several thin lt gray clay laminae present concentrated in zones	sampled 152'
	3		540		153'
					153.5'
	4		540, 75		154'
	5		540		155'
	6		300		156'
	7		95	Clayey sand grading into sand, Clay % 20-5%, strong brown 7.5YR 5/8, med.-coarse, well sorted	157'
	8		14, 21		158'
	9				
	160				

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
A/M DNAPL/Angle Drill 45°	3/28/00	9 of 11

Well Number	Location	Drilling Subcontractor
MRS-32	A-14	AEI

Logs Prepared By	Driller
J. Noonkester	M. Coleman

Company	Drilling Method
WSRC	rotasonic / 3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology		Percent Recovery	Sample Description	Drilling Comments/Remarks
16	160			75		
	1		2		Sand, 70%, Strong brn 7.5YR5/8, Fine-coarse.	
17	2		60			
	3		40			sampled @ 164'
	4		30		Silty Sand, Strong brn 7.5YR5/8, v. Fine-Fine, Sand 85%.	sampled @ 165.5'
	5		138	100	Sand, 90%, brownish yellow 10YR6/8 To pale brn 10YR6/3, coarse-v. coarse with occasional granules.	
	6		8			
	7		6			sampl 168'
	8		0			
	9		0			
	170		0			sample 171'
	1		2		Sand, 90%, reddish yellow 7.5YR6/8 and Strong brn 7.5YR5/8, med-v. coarse with granules & occasional pebbles, several Thin clay laminae Tan and lt. gray.	
	2		0			
18	3		3			sampled 183'
	4		20 / 17	100	Silty Sand grading into a clayey Sand, Clay/silt %20-25, Sand v. Fine-Fine grading into med-v. coarse with granules & pebbles present yellowish red 5YR5/8 and Strong brn 7.5YR5/8.	184'
	5		0			
	6		6			
	7					
	8		0			
	9		1			189'
	180		0			191'

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / Angle Drill 45°	Date: 3/28/00	Sheet: 10 of 11
Well Number: MRS-32 — Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester	Driller: M. Coleman	
Company: WSRC	Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
18	180		100	see above	
	1				
19	1			Sandy Clay grading into a clayey sand. Clay % 50 To 20%, banded colors of Strong brn 7.5YR 5/8 and v. pale brn 10YR 7/4, sand v. fine - v. coarse with granules & pebbles present	
	3				sample 183'
	5		93	Clayey sandy shell fragments, whitish pink sandy clay grading into clayey sand banded colors of Strong brn 7.5YR 5/8 and v. pale brn 10YR 7/4 coarse - v. coarse grading down to fine, granules & pebbles present around 186'.	
	8				sample at 188'
	190				
20	191			Clayey sand, clay 15-20%, banded colors of reddish yellow 7.5YR 6/8 and v. pale brn 10YR 7/4, several lt gray clay lamin. present, sand v. fine - coarse	
	4		100		
	4.5			Sand 90-95%, reddish yellow 7.5YR 6/8 and v. Pale brn 10YR 7/4, one clayey zone at 199.5, v. fine - med with much muscovite present.	sampled @ 196
	200				

OSR 30-27# (2-12-97)

Field Geologic Log

Project		Date	Sheet
A/M DNAPL / Angle Drill 45°		3/28/00	11 of 11
Well Number: MRS-32	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
20	200		100	see above	
	1				Sampled @ 201
21	1		100	Sand Clay - Clay - To Sandy Clay	Green Clay
	2			Thinly banded colors of reddish yellow, v. Pale brn, and dark reddish brn.	
	3			Some cemented material - v. thin dark red brn.	
	4				
	5			Sandy Clay grading To sand, brownish yellow 10YR6/8 and v. Pale brn,	
	6			Sand med-coarse, colors banded.	Sampled @ 206'
	7				
	8				
	9				
	210				Sample at 211
	1			T.D.	
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	0				

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
A/M Area DNAPL / 45° Angle Boring	3-29-00	1 of 11

Well Number	Location	Drilling Subcontractor
MRS-33	A-14	AEI

Logs Prepared By	Driller
Jay Noonkester	M. Coleman

Company	Drilling Method
WSRC	Rotosonic / 3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
1	0				Sand, 95%, reddish yellow 7.5YR 6/6, med., well sorted.	
	1			100		
	2				Sandy Clay, clay 70%, red 2.5YR 5/8 to red 10R 4/8 with yellow mottling from 6' to 9', hard - firm, sand coarse	
	3		1			
	4					
	5					
	6					
	7					
	8					Sampled @ 8 FT
	9					
2	10		1		Sandy Clay, clay 75%, red 10R 4/6, some yellow mottling, sand med - v. coarse, hard.	
	11		0			
	12		1			Sampled at 12'
	13			100		
	14		2			
	15		4			
	16		3			
	17		4			
	18		5			Sampled @ 18'
	19					
3	20		0, 0	100	Sandy Clay, clay 65-75%, red 10R 4/8, med., some yellow & white mottling, hard.	

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
A/M Area DNAPL / 45° Angle boring	3-29-00	2 of 11

Well Number	Location	Drilling Subcontractor
MRS-33	A-14	AET

Logs Prepared By	Driller
Jay Noonkester	M. Coleman

Company	Drilling Method
WSRC	Rotosonic

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
	20			see above.	
3	1				
	2		100		
	3				
	4				
	5				
	6				
	7			Clayey Sand, clay 20-30%, red 10R 4/8, firm-soft, med.-coarse, some strong brn. mottling.	
	8				
	9				sampled @ 29'
4	30			Clayey sand, clay 20-30%, clay% decreasing down, red 2.5YR 4/8 to lt. red 2.5YR 6/8, with reddish brn. mottling, sand v.fine-med., hard-firm.	Sampled @ 30'
	1				
	2			Silty Sand, silt 15-25%, decreasing down, lt. red 2.5YR 6/8 with mult color variation, v.fine-fine, soft.	
	3		60		sampled @ 34
	4				
	5				
	6				
	7				
	8				
	9				
5	40		90	Clayey Sand, clay 20-30%, dk red 10R 3/6, with many other colors pale red, lt. brn, several v. thin dk gray (cont. next page)	

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
A/m DNAPL / 45° Angle	3/31/00	3 of 11

Well Number	Location	Drilling Subcontractor
MRS-33	A-14	AEI

Logs Prepared By	Driller
J. Noonkester	M. Coleman

Company	Drilling Method
WSRC	rotosonic / 3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
	40		5	and lt. gray clay laminae, sand v. fine-med.	
	1				
5	2		3		
	3		90		
	4		5		sample @ 44'
	5				
	6		5		sampled @ 47'
	7		4		
	8				
	9		6	Sand, 85%, multi-banded colors of	
	50		1	weak red, pale red, reddish, purple,	
			2	yellow, with some white sand,	
	1		0 / 50	several v. thin lt. gray clay laminae at 53.5', sand v. fine-med.	sampled @ 51'
	2		5		
6	3		6		sampled @ 54'
7	4				
	5				
	6				
	7				
	8				
	9		4	Clayey sand, Clay 30-40%, multi-colors	
8	60		100	mainly Strong brn 7.5YR 5/8 and	
			3	pink 5YR 7/4 other colors white (cont)	

OSR 30-27# (2-12-97)

Field Geologic Log

Project		Date	Sheet
A/M DNAPL / 45° Angle		3/31/00	4 of 11
Well Number: MRS-33	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology		Percent Recovery	Sample Description	Drilling Comments/Remarks
7	60		22	100	lt. reddish brn, many v. thin clay laminae present mainly near end of run, firm, v. fine - med.	
	1		18			
	2		23			sampled @ 62'
	3		18			
	4		20			Sampled @ 64'
	5		17			
	6		9			
	7		8			
	8		9			sampled @ 67'
	9		12			
8	70		3	95	Sand to Clayey Sand to Sand, 15% - 30% 15% clay, very fine banding colors of reddish yellow and white, fine - med.	
	1		5			
	2		7			Sampled @ 73'
	3					
	4		3			
	5					
	6		1			
	7		3		clayey sand, clay 25%, yellowish brn 10YR5/8, v. fine - coarse, firm.	
	8		2			Sampled @ 78'
9	9		5	35	Sand, 95%, brownish yellow 10YR 6/8, v. fine - v. coarse, soft.	
	80		3			Sampled @ 80'

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL/45° Angle		Date: 3/31/00	Sheet 5 of 11
Well Number: MRS-33	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: rotosonic	

Fm Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery		Sample Description	Drilling Comments/Remarks
9	80		3		see above.	
	1		2			
	2		4	35		Sampled @ 82'
	3					
	4					
	5					
	6					
	7					
	8					
10	9		2		Sand, 95%, yellow 10YR7/8 and brownish yellow 10YR6/8, Fine-med grading down to med-v. coarse with granules & occasional pebbles at 96'-97'.	
	90		0			
	1		1			
	2					Sampled @ 92'
	3		7	80		
	4		2			
	5		3			
	6		10			Sampled @ 96'
	7		14			
	8					
	9					
11	100		1 50	100	Sand, 90-95%, brownish yellow 10YR 6/8, med-coarse grading to coarse-v. coarse with granules & pebbles	Sampled @ 100.5'

OSR 30-27# (2-12-97)

Field Geologic Log

Project		Date	Sheet
A/M DNAPL / 45° angle		3/31/00	6 of 11
Well Number: MRS-33	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: rotosonic	

Fin Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery HD	Percent Recovery %	Sample Description	Drilling Comments/Remarks
11	100		9		Clay, 98%, brownish yellow 10YR 6/6, several v. thin black cemented material.	
	1		50			sampled @ 101'
	2		50		Sandy Clay, clay 35%, ~~brownish yellow~~ 10YR 6/8, fine - v. coarse with granules, several thin gray clay laminae.	sampled @ 102'
	3		5	100		
	4		8		Clay 70%, brownish yellow 10YR 6/6, several thin-thick layers of clayey sand same color.	sampled @ 104'
	5		34			
	6		3		Clayey Sand grading to Sand, brownish yellow 10YR 6/6, med-coarse.	
	7		5			sampled @ 108'
	8		9			
	9		8			
12	110		2		Sand, 85-95%, yellow 10YR 7/8, v. fine-med with occasional v. coarse.	
	1		3			sampled @ 111'
	2		12			
	3		1	70%		
	4		3			
	5		3			sampled @ 115'
	6		5			
	7					
	8					
	9					
13	120		20		Sand, 85%, brownish yellow 10YR 6/8, some black sandy v. thin layers present, v. fine - coarse with (continued)	sampled @ 120
			15			

Field Geologic Log

Project: N/M DNAPL / 45° Angle		Date: 3/31/00	Sheet 7 of 11
Well Number: MRS-33	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: rotosonic/3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID ppm	Percent Recovery %	Sample Description	Drilling Comments/Remarks
	120		20		many granules and occasional pebbles; several zone That are silty.	
13	1		20			sampled at 121'
	2		5			
	3		3	80		
			0			
	4		0			sampled at 125'
	5		1			
	6		6			
	7					
	8					
	9				Sand, 90%, brownish yellow 10YR6/8 Fine-coarse, couple v. Thin clay laminae present	
	130					sampled @ 13Ø
	1					
14	2					
	3			95		
	4					sampled @ 185'
	5				Clayey Sand, clay 20%-30%, Strong brn. 7.5YR5/8, coarse-granules with many pebbles, clay lamina present at 138.5'.	
	6					
	7					
	8					
	9				Sand grading into Clayey Sand, yellowish red 5YR4/6, Fine-coarse, clay% 5-25%, several lamina at 144'.	
15	140		20			sampled @ 140
			14			

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
A/M DNAPL / 45° Angle	3/31/00	8 of 11

Well Number	Location	Drilling Subcontractor
MRS 33	A-14	AEI

Logs Prepared By	Driller
J. Noonkester	M. Coleman

Company	Drilling Method
WSRC	rotosonic / 3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery		Sample Description	Drilling Comments/Remarks
15	140		10		See above	
	1		10			
	2		6			
	3					
	4		10	70	Sand, 98%, yellow 10YR7/8, v. fine-med.	sampled @ 144'
	5		10			sampled @ 146'
	6		8			
	7					
	8					
16	9				Sand, 90-95%, Strong brn 7.5YR5/8 with some white mottling and some reddish yellow, med.-coarse	
	150		20			
	1		5			sampled @ 151'
	2		7			
	3		3			
	4		5	80		
	5		8			sampled @ 155'
	6		1			
	7		1			
	8					
17	9				Sand 98% reddish yellow 7.5YR6/8 To yellowish red 5YR4/6 Fine-med. grading To coarse, (continue)	
	160			100		

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL / 45° Angle			Date: 3/31/00	Sheet 9 of 11
Well Number: MRS 33	Location: A-14		Drilling Subcontractor: AEI	
Logs Prepared By: J. Noonkester			Driller: M. Coleman	
Company: WSRC			Drilling Method: rotosonic/3" core	

Fm Number	Depth Below Ground Surface (Feet)	Lithology	PID ppm	Percent Recovery %	Sample Description	Drilling Comments/Remarks
17	160		0	100	several thin lt gray clay laminae present	
	1		1			
	2		2			
	3		4			
	4		1			
	5		3			
	6					
	7		6			
	8		1		Clayey Sand, clay 35-40%, reddish yellow 7.5YR 6/8, fine-coarse.	
	9		1			
18	170		0	100	Sand, 95%, reddish yellow 7.5YR6/8, fine-v. fine grading to coarse-v. coarse with occasional granules.	sampled @ 170'
	1		10			
	2		5			
	3		15		Silty sand grading into a clayey sand, clay/silt 20-25%, strong brn 7.5YR5/8 and reddish yellow 7.5YR6/8 fine-v. coarse occasional granules	sampled @ 174'
	4		6			
	5		1			
	6					
	7		6			sampled @ 177'
	8		1			
	9				sand (60-80%) clay & silt (20-40%) strong brn to white	
	180					

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
A/M DNAPL / 45° Angle	4-3-00	10 of 11

Well Number	Location	Drilling Subcontractor
MRS-33	A-14	AEI

Logs Prepared By	Driller
Noonkester / Jones	Michael Coleman

Company	Drilling Method
WSRC	Rotosonic / 3" Core

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
19	180		100	Sand (60-80%) Silt & Clay (40-20%) Strong brn & lt. greenish gray	sampled @ 180.0
				small ~1 in zone of pink & white w/ shell fragments	PID 0 ppm
	1			sand fn-crs	
				interlaminated brn & lt. greenish gray (laminae 2mm	
	2			to ~1cm)	
	3				Sampled 183.0
					PID 3 ppm
	4				
	5				
	6				Sampled 186.5 &
	7				187.5 PID 146 ppm
	8				
	9				
20			100	Sand fn-med, slightly silty, interlaminated	
	190			strong brown & lt. gray; trace mica (laminae 1mm	sampled 190.5' PID 184 ppm
				to ?1cm thick)	
	1				sampled 192.0' PID 198 ppm
				sand fining downward to fn-v.fn.	
	2				Sampled 193.0' PID 112 ppm
				trace mica	
	3			silt content increasing	
				Silt & clay, interlaminated brown & lt. gray	
	4			Sand 100% med-crs, mod. sorted, white to	
	5			strong brown	sampled 195.0' PID 17 ppm
				clayey laminae (~2mm thick) zone	
	6				
	7			coarse grained strong brown sand 5YR 5/8	
				tr. mica	sampled 198.0' PID 12 ppm
	8			Sand (40-60%) Silt & Clay (40-60%) interlaminated	
				gray & brown changing to interlaminated, gray,	
	9			brown & red 188.5 ft w/ red granules	
21	200			color primarily lt. olive gray 10YR 8/1 w/ red & brn	sampled @ 200.0'
				laminae clay content increased	PID 4 ppm

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
A/M DNAPL / 45° Angle	4-3-00	11 of 11

Well Number	Location	Drilling Subcontractor
MRS-33	A-14 Outfall	AEI

Logs Prepared By	Driller
W. Jones	M. Coleman

Company	Drilling Method
SRTC	Rotosonic

Fin Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
	200			Clay & silt (40-60%) fine sand (40-60%) trace mica, lt olive gray 10Y 8/1 w/ red & brown laminae 2mm to 7mm thick	
	1				
21	2			tough clay (~80% cly)	
	3			red coloration ceases, sand content increases	
	4				sampled @ 204.0' PID 2.0 ppm
	5			Sand & clay interlaminated, gray & brownish tan 10YR 7/6 & 10YR 8/2 fn-crs	
	6				sampled @ 206.0' PID 27 ppm
	7			sand content increasing downward.	
	8			Sand (70-90%) silty; fn-crs, poorly sorted brownish tan 10YR 7/6	
	9				sampled @ 208.0' PID 120 ppm
end	210	end core	end		
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	0				

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL FY00	Date: 4/13/00
Sheet: 1 of 8	
Well Number: MRS 34	Location: A-14
Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester	Driller: M. Coleman
Company: WSRC	Drilling Method: Rotosonic / 3" core

Run Number	Depth Below Ground Surface (Feet)	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
1	0	0	100	Sandy Clay, Clay 75%, red 2.5YR 4/8 with yellow mottling, sand fine-coarse, hard.	
	1	0			
	2	1			
	3	3			
	4	5			
	5	15			
	6				Sampled @ 6'
2	7	1	100	Sandy Clay, Clay 75%, red 10R 4/8, sand fine-coarse grading into a Clay Sand at 15.5' sand coarse to v. coarse with yellow mottling	
	8	2			
	9	3			
	10	1			
	11	0			Sampled @ 12'
	12	15			
	13	1			Sampled @ 15'
	14	2			
	15	15		grading into clayey sand.	
	16	16			
3	17	0	100	Clayey Sand grading into silty sand clay/silt 25%, red 10R 5/8 to lt. red 2.5YR 6/8, v. fine-med, grading to v. fine-fine	Sampled @ 18'
	18	28			
	19	42			
	20	133			Sampled 20'

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL FY00		Date: 4/13/00	Sheet 2 of 8
Well Number: MRS 3[illegible]	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
	20		[illegible]		see above.	
	1		24			
	2		55	100	Sand, 85-95% increasing down, reddish yellow 7.5YR6/6, v. fine-fine.	sampled @ 22'
3	3		76			" 24'
	4		59			
	5		74			" 26'
	6		20			
	7		0		Sand, 85%, reddish yellow 7.5YR 6/8 and lt. red 2.5YR6/8, v. fine-med. with occasional v. coarse, several thin clay lamina present.	
	8		0			Sampled @ 29
	9		42	100	Clayey sand, clay 20%, multi-colors of brn., dk red, brownish yellow, pink, and many other colors, fine-v. coarse with granules and occasional pebbles.	
4	30		47			" 31'
	1		13			" 33'
	2		9			
	3		16			
	4		10			
	5		20			" 36'
	6		35			
	7		0		Sand, 85-90%, multi-colors of brn, dk red, brownish yellow, red, pink and more, v. fine-med., several sandy clay laminae present.	
	8			86		
5	9		0			sampled @ 39'
	40		16			

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/m DNAPL FY00	Date: 4/13/00	Sheet 3 of 8
Well Number: MRS-3	Location: A-14	Drilling Subcontractor: AEI
Logs Prepared By: J. Noonkester		Driller: M. Coleman
Company: WSRC		Drilling Method: Rotosonic/3" core

Fm Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
	40		9		see above	
5	41		12			
	42		6	80		
	43					
	44		25			sampled @ 44'
	45	X				
	46	X				
	47		0		Clayey Sand To Sandy Clay, clay% 30-70, pale red 2.5YR6/2 with many other colors in thin bands, v. fine - med, several thin pale red clay laminae present mainly near bottom	
	48		0			
	49		0			
	50		8			
	51			100		
6	52		8		Sand with clayey sand zones, lt yellowish brn 10YR6/4 and brownish yellow 10YR6/8, fine-coarse, Clay% 15-35,	
	53		13			
	54		0			
	55		8			
	56		15			
	57		3		Clayey Sand, Clay 30%, lt. brn 7.5YR6/4 and lt. reddish brn 5YR6/4, fine-v. coarse with occasional granules	
	58		10			sampled @ 58'
7	59		5		Sand, 90%, reddish brn 2.5YR5/4 to reddish yellow 7.5YR6/8, fine-v. coarse,	
	60		0			

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL FY00		Date: 4/13/00	Sheet 4 of 8
Well Number: MRS 34	Location: A-14	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Roto sonic / 3" core	

Fill Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
7	60		5		see above	
			15			
	1			50		sampled @ 61'
	2					
	3					
	4					
	5					
	6					
8	7		0		Sand, 85%, brownish yellow 10YR 6/8, med-coarse with occasional v. coarse and granules and pebbles at 71' to 72'.	
	8					sampled @ 69
	9		0			
	70		0			
	1		8	80		" 72'
	2					
	3		10		Clayey Sand, Clay 25% with several clay laminae, yellow 10YR 7/8, v. fine - med., clay laminae also yellow.	" 74'
			3			
	4		15			
	5					
	6					
9	7		0		Clayey Sand, Clay 35%, yellowish brown 10YR 5/8, Thin layer of Black, fine - v. coarse with granules & pebbles.	
	8		6	65	Sand, 90%, brownish yellow 10YR 6/8 to yellow 10YR 7/6, v. fine - coarse,	sampled @ 78'
	9					
	80		0			

OSR 30-27# (2-12-97)

Field Geologic Log

Project: A/M DNAPL FY00		Date: 4/13/00	Sheet 5 of 8
Well Number: MRS 34	Location: A-M	Drilling Subcontractor: AEI	
Logs Prepared By: Jay Noonkester		Driller: M. Coleman	
Company: WSRC		Drilling Method: Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	PID	Percent Recovery	Sample Description	Drilling Comments/Remarks
9	80		0	65	see above.	
	1		0			
	2		0			
	3					sampled @ 83'
	4					
	5					
	6					
10	7		0		Clayey sand - Sandy Clay, clay 35-50%, brownish yellow 10YR 6/6, fine-coarse with occasional v. coarse	
	8		0			
			0		Sand, 70%, yellow 10YR 7/8, v. fine - coarse with granules and occasional pebbles	
	9		0			
	90		0			
	1		0			
	2					
	3					
	4					
	5					
	6					
11	7		0		Sand, 90%, reddish yellow 7.5YR 6/8, med - v. coarse with many granules + pebbles at 97'	
	8					sampled 98
	9		0		Clayey sand, clay 20%, strong brown 7.5YR 5/8, fine - v. coarse with granules and pebbles throughout.	
	100		0			

OSR 30-27# (2-12-97)

Field Geologic Log

Project	A/m DNAPL FY00		Date	4/13/00	Sheet	6 of 8
Well Number	MRS 34	Location: Ar 14	Drilling Subcontractor	AEI		
Logs Prepared By	Jay Noonkester		Driller	M Coleman		
Company	WSRC		Drilling Method	RoTosonic / 3" core		

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery		Sample Description	Drilling Comments/Remarks
	100		0		See above	
11	1		0		Sand, 95%, Strong brn. 7.5YR 5/8, Fine - Coarse	sampled @ 101'
	2		0			
	3		52		Silty Sand, silt 20%, yellow 10YR 7/8, v. Fine - fine	sampled 103'
	4					
	5					
	6					
	7		0		Sand, 90%, reddish yellow 7.5YR 6/8, med - v. coarse with occasional granules	
	8		26			
	9		50			sampled 109'
12	110		100			sampled 110.5'
	1		85	85		111'
	2		15			
	3		10			
	4		5			
	5		5			end of 20' screen
	6					
	7		0		Sand, 90%, reddish yellow 7.5YR 6/8, med. - v. coarse, several v. thin lt. gray clay laminae	
13	8		0	70		
	9		0			
	120		0			

OSR 30-27# (2-12-97)

Field Geologic Log

Project	Date	Sheet
A/M DNAPL FY00	4/13/00	7 of 8

Well Number	Location	Drilling Subcontractor
MRS-34	A-14	AEI

Logs Prepared By	Driller
Jay Noonkester	M. Coleman

Company	Drilling Method
WSRC	Rotosonic/3" core

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
13	120 – 126		100	see above. Silty Sand, silt 30% Strong brn 7.5YR5/6, v. fine-coarse. Clayey Sand, clay 35%, banded colors of reddish yellow, ltgray, and strong brn. Fine-coarse grains to coarse-v. coarse. Several thin layers of shelly fragments pinkish white.	
14	127 – 136		100	Sandy Clay, clay 50%, Strong brn 7.5YR5/8 and v. pale brn 10YR7/4, colors are thinly banded, sand med.-v. coarse with granules. Sand, 90%, v. pale brn and brownish yellow, v. fine-fine, trace of muscovite.	Sampled @ 132'
15	136 – 140		100	Sand, 85%, lt. yellowish brn. 10YR6/4 with white and lt. gray, fine-v. fine grading to coarse with granules and pebbles. Sandy Clay to Clay, Clay 85%, Thinly banded colors of reddish yellow, v. pale brn, drk red (cont.)	Sampled @ 136.8; Sample @ 139'

OSR 30-27# (2-12-97)

Field Geologic Log

Project	A/M DNAPL FY00		Date	4/13/00	Sheet 8 of 8
Well Number	MRS-34	Location A-14	Drilling Subcontractor	AEI	
Logs Prepared By	J. Noonkester		Driller	M. Coleman	
Company	WSRC		Drilling Method	Rotosonic / 3" core	

Run Number	Depth Below Ground Surface (Feet)	Lithology	Percent Recovery	Sample Description	Drilling Comments/Remarks
15	140		5	and strong brn, sand med-coarse, v. good clay from 140-142'. Sandy clay above and below	
	1				sample 142'
	2		5		
	3		30		144'
	4		30 100		145'
	5		30	Sand, 95%, yellow 10YR7/8 and v. Pale brn 10YR 8/2, v.fine-med.	146.5
	6		18	T.D.	
	7				
	8				
	9				
	150				
	1				
	2				
	3				
	4				
	5				
	6				
	7				
	8				
	9				
	0				

Appendix B

Daily Activities from FY 2000 Drilling

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL Characterization			
Driller: M. Coleman		Drilling Subcontractor: AEI	
Well Number: MRS-29	Technical Oversight: J Noonkester	Oversight Firm: WSRC	
Location: M seepage basin		Date: 4/4/00	Page 1 of 5

Start	Stop	Description of Activities/Remarks
8:00		Drillers & oversight on location. Setting up on MRS-29.
8:30		Skip pan ER-24. The first one we used has been moved to basin but was not emptied. I have paged Theron twice to find out the deal, but he has not returned page.
12:00		I have contacted Fletcher Brown and e-mailed him the results from the skip pan. They are dispositing. We are also waiting on a clean skip pan before we start drilling. Should arrive around 1:00
2:00		First run 4-11 ft. We have skip pan and starting to drill.
4:30		Drilled 71 ft today. Fletcher Davis came by. He is trying to decide how to handle skip pan ER-24.
	5:00	Finished

Technical Oversight Signature: [signature]	Date: 4/4/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL FY00			
Driller: M. Coleman		Drilling Subcontractor: AEI	
Well Number: MRS-29	Technical Oversight: J. Noonkester	Oversight Firm: WSRC	
Location: M Basin		Date: 4/5/00	Page 2 of 5

Start	Stop	Description of Activities/Remarks
7:30		warm up truck - Cold - 32°.
		Drillers started at 8:30 (Drilling.
		Drillers take break at 10:00 15 mins.
10:00		Mary Harris and Dani Jackson visited at 10:00.
11:00		Drillers mix up a batch of gel, drilling getting
		difficult. oversight to
12:00		Bob Lasswitz, ER waste Management and Fletcher Davis
		sampled skip pan then pumped water off
		into Drums.
2:30		Truck pick up skip pan and hauled it
		to the staging area.
2:45		drill rig broke down: 2 gears need replacing.
		They will do repairs on location. J. Rinder
		will order parts from Ohio. The plan is
		the parts will be here in the morning and we
	4	will make repairs and start drilling by lunch time.
	4:00	Finished

Technical Oversight Signature: [signature]

Date: 4/5/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL FY00			
Driller: M. Coleman		Drilling Subcontractor: AEI	
Well Number: MRS 29	Technical Oversight: J. Noonkester	Oversight Firm: WSRC	
Location: M-Basin		Date: 4/6/00	Page 3 of 5

Start	Stop	Description of Activities/Remarks
8:00		Oversight on location
8:45		Drillers not here.
9:30		I called J. Rinder for update and he said part will be in at 10:00 then and Then Drillers will be on Their way To job site.
11:00		Drillers are on the rig and making repairs. yesterday I sent analytical results on The other A-14 skip pan To Fletcher Davis. This morning I call Fletcher and he said results are negative and we could dump The skip Pan and move it To M-Basin.
1:30		Skip Pan has arrived. Repairs are going good. Should be ready To drill at 2:30 - 3:00.
3:10		Repairs complete and Tested. Drillers mixing another batch of mud To tub casing.
3:40		Drilling To 171' Now, run #17.
		Finished run #17
	4:15	end.

Technical Oversight Signature: Jay Noonkester

Date 4/6/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/m DNAPL FY00	
Driller: M. Coleman	Drilling Subcontractor: AEI
Well Number: MRS 29 / Technical Oversight: J. Noonkester	Oversight Firm: WSRC
Location: M basin / 45° Angle	Date: 4/7/00 / Page 4 of 5

Start	Stop	Description of Activities/Remarks
7:30		Drillers and oversight on location.
8:10		waiting on water Truck
8:40		water Truck arrived.
8:55		Problem with rig or rod connects, not sure.
9:10		The rod connector broke and has been fix.
11:00		Driller is still having trouble advancing core barrel
		more rods broken. Mixing 3 batches of gel
		with hope this will help. we have drilled 5'
		so far This morning.
11:20		Driller had to face 6" casing to advance Through hard
		material which was at approximately 176'.
1300		Finished run # 19, 181'-191'. Drilling is slow.
1525		Drillers pulling up run #22, 211'-221'.
1550		Finished coring, we have not finished yet but Driller
		will pull out several 6" casing so it will not
	4:30	be stuck when we come back on Monday.

Technical Oversight Signature: Jay Noonkester

Date: 4/7/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL FY00			
Driller: M. Coleman		Drilling Subcontractor: AEI	
Well Number: MRS 29 & 30	Technical Oversight: J. Noonkester	Oversight Firm: WSRC	
Location: M Basin / 45° Angle boring		Date: 4/10/00	Page 5 of 5

Start	Stop	Description of Activities/Remarks
7:00		oversight & Drillers on location
8:30		I Talked to Joe Rossabi about The next boring where we will put The NAPL Ribbon in. Joe said To try To get To 110' Today.
10:00		Went To office To Email lab results from Skip pan To Fletcher Davis
12:00		run #23 completed, 221-231', Caree clay was hit.
2:00		grouting and pulling 6" casing. 140' pulled so far
3:00		All 6" and 20' of 7" have been pulled out. Drillers are now breaking down platform they built.
		32 bags of grout used in This hole
		30 bags used in MRS 31
		30 bags used in MRS 32
4:00		Set up and drilling on MRS-30
4:15		run #1, 0-7.5', 100% recovery. PID Field screening showed 20 ppm at one area, could have been from heated core causing false reading. Johnny was not here so I could not sample. Johnny just brought Sampling kit To leave with me, he had To leave.
	5:30	Core 67.5'. I need To describe 2 runs in The morning

Technical Oversight Signature: Jay Noonkester

Date: 4/10/00

R 30-28# (2-13-97)

Daily Activities Report

Project: M/M DNAPL FY00			
Driller: M. Coleman		Drilling Subcontractor: AEI	
Well Number: MRS 29 & 30	Technical Oversight: J. Noonkester	Oversight Firm: WSRC	
Location: M Basin / 45° Angle boring		Date: 4/10/00	Page 1 of 3

Start	Stop	Description of Activities/Remarks
7:00		oversight & Drillers on location
8:30		I Talked to Joe Rossiba about The Next boring where we will put The NAPL Ribbon in. Joe said To try To get To 110' Today.
10:00		Went To Office To E-mail lab results from Skip pan to Fletcher Davis
12:00		run #23 completed, 221-231', Core Clay was hit.
2:00		grouting and pulling 6" casing. 140' pulled so far
3:00		All 6" and 20' of 7" have been pulled out. Drillers are now breaking down platform They built. 32 bags of grout used in This hole 30 bags used in MRS 31 30 bags used in MRS 32
4:00		Set up and drilling on MRS-30
4:15		run #1, 0-7.5', 100% recovery. PID Field screening showed 20ppm at one area, could have been from heated core causing false reading. Johnny was not here so I could not sample. Johnny just brought Sampling Kit to leave with me, he had to leave.
	5:30	Core 67.5'. I need To describe 2 runs in The morning

Technical Oversight Signature: Jay Noonkester

Date: 4/10/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL FY00			
Driller: M. Coleman		Drilling Subcontractor: AEI	
Well Number: MRS 30	Technical Oversight: J Noonkester	Oversight Firm: WSRC	
Location: M-Basin / Flute		Date: 4/11/00	Page 2 of 3

Start	Stop	Description of Activities/Remarks
8:00		Drillers & Oversight on location
9:00		Joe Rossabi & Carl Keller are on location. They
		will deploy FLUTe membrane in MRS-30 6" casing.
		have done safety briefing for Carl and Joe.
10:00		Tom Kenite & Jim Kupar stopped by for a 15 min visit.
12:20		run # 14, 147.5' – 157.5' is coming up.
		Tagged bot. of hole at 161.2 to TOC
		casing above ground surface ~~2.8~~ 2.8
		from ground surface to bot. of hole 158.4'
		Total depth cored was 157.5'.
2:30		Joe & Carl are deploying the FLUTe.
		John Bradley stopped by to speak to Joe. He is
		ER Reactors team.
	7:00	The FLUTe came out

Technical Oversight Signature: [signature] Date: 4/11/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL FY 00			
Driller: M. Coleman		Drilling Subcontractor: AEI	
Well Number: MRS ~~29~~ 34/30	Technical Oversight: J. Noonkester	Oversight Firm: WSRC	
Location: M Basin		Date: 4/12/00	Page 3 of 3

Start	Stop	Description of Activities/Remarks
12:28		Drillers were waiting on me when I arrived at MRS 30,
		This morning They grouted holes while I
1:30		was in Diversity Training.
2:30		AT A-14 looking for next location.
3:00		Set up on MRS 33
	715	ready To start drilling in morning

Technical Oversight Signature: [signature] Date: 4/12/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: N/M Area DNAPL Characterization	
Driller: Michael Coleman	Drilling Subcontractor: AEI
Well Number: MRS-~~29~~ 32 · Technical Oversight: J. Noonkester	Oversight Firm: WSRC
Location: A-14	Date: 3/24/00 · Page 1 of 4

Start	Stop	Description of Activities/Remarks
7:30		oversight at Demo Trailer. Driller are to arrive at 8:00.
8:30		Driller on location
9:00		Prejob briefing completed
10:00		The rig & all casing & rods deconned.
11:00		set up on first location at A-14. Rig is setup and 45° angle has been determined using a level.
~~11:20~~ 1:20		drillers are leaving the site to pick up material to build platform.
1:10		Drillers returned with plywood & 2X10s to build platform. We will not work Tomorrow (Fri) because Karen is ill & ~~we~~ I am not here either. Michael Colemans medical has expired and he has a Dr. appointment Fri morning so we would not get a lot of work done. We are not going to start today but will start Monday morning instead.
	2:30	Drillers Done for the day

Technical Oversight Signature: [signature] Date: 3/3/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M Area DNAPL - Characterization			
Driller: Michael Coleman		Drilling Subcontractor: AEI	
Well Number: MRS-32	Technical Oversight: J. Noonkester	Oversight Firm: WSRC	
Location: A-14		Date: 3/28/00	Page 2 of 4

Start	Stop	Description of Activities/Remarks
7:30		Oversight on location preparing paperwork.
7:45		Drillers arrive on location.
8:00		Karen Vangelder stopped by and gave me a message To Call Dave Harver Site Utilities, 5-3705, pager #5363 before we begin drilling because of concerns about the powerline. I called and paged him and am now waiting for him to return my call.
8:30		Dave Harver came down and oked us To Drill and Signed off on WCP.
9:40		run #1, 11FT, 7FT recovery
9:50		Drillers can not get The mud pan sealed and iT's leaking. They are leaving site to go To Shop To pick up 7" casing To use To seal Tube.
11:00		Drillers back on site and placing 7" casing.
11:40		run 2, 11-21 FT, 100% recovery
12:00		run #3 21-31 FT, 100% recovery.
2:15		we are now at 91 FT. Drillers left site To pick up more pipe.
3:00		Drillers on site with 6" casing. Core was boxed from 0-51'.
4:00		Finished for The day

Technical Oversight Signature: J. Noonkester

Date: 3/28/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M Area DNAPL characterization			
Driller: Michael Coleman		Drilling Subcontractor: AEI	
Well Number: MRS 32	Technical Oversight: J. Noonkester	Oversight Firm: WSRC	
Location: A-14		Date: 3/28/00	Page 3 of 4

Start	Stop	Description of Activities/Remarks
7:30		Oversight on location
8:15		Drillers arrive.
9:00		run #11, first run today.
11:00		J. Rider & Blake stopped by for a visit.
12:30		Johnny Simmons left to go to chemistry class at 12:00
		Drillers have mixed up bentonite mud because drilling is getting difficult. we are at 161 ft of angle drilling. The last run (run #16) had v. high hits on PID. The PID pegged out several times. All samples received red dots to indicate they had high levels of contamination.
12:45		~~drill~~ The pump is plugged with bentonite gel, Drillers are repairing pump.
4:00		Completed boring to 211 ft.
4:30	4:30	finish for the day

Technical Oversight Signature: [signature]	Date: 3/28/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project A/M DNAPL Characterization			
Driller Michael Coleman		Drilling Subcontractor AEI	
Well Number MRS-32 & 33	Technical Oversight J. Noonkester	Oversight Firm WSRC	
Location A-14		Date 3/29/00	Page 4 of 4

Start	Stop	Description of Activities/Remarks
8:00		Drillers on location and beginning to grout.
8:30		Pick up Christine Rust at badge office. She
		is going to take samples for her ~~masters~~ at
		USC. ~~doctorial~~ Degree
		Total depth yesterday was 211 at 45°. 211' = 149.4
1:30		Christine Rust left site at 10:30
1:50		Drillers have pulled all casing and grouted up
		the bore hole. Now setting up on
		MRS-32.
3:00		Drillers are set up and ready to start drilling
3:20		Cheked the angle on drill rods and it is at 45°,
		accually running a little ~~shallower~~ shallower the 45°.
	4:30	Finished completed run 3 to 29 ft.

Technical Oversight Signature: [signature] Date 3/29/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL Characterization			
Driller: Michael Coleman		Drilling Subcontractor: AEI	
Well Number: MRS-32 & 33	Technical Oversight: J. Noonkester	Oversight Firm: WSRC	
Location: A-14		Date: 3/29/00	Page 1 of 4

Start	Stop	Description of Activities/Remarks
8:00		Drillers on location and beginning to grout MRS32
8:30		Pick up Christine Rust at badge office. She
		is going to take samples for her ~~masters at~~ doctoral Degree
		USC.
		Total depth yesterday was 211 at 45°. 211' = 149.4
1:30		Christine Rust left site at 10:30.
1:50		Drillers have pulled all casing and grouted up
		the bore hole. Now setting up on
		MRS-33.
3:00		Drillers are set up and ready to start drilling
3:20		Checked the angle on drill rods and it is at 45°,
		actually running a little shallower the 45°.
	4:30	Finished - completed run 3 to 29 ft.

Technical Oversight Signature: [signature] Date: 3/29/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL Characterization			
Driller: M. Coleman		Drilling Subcontractor: AEI	
Well Number: MRS-33	Technical Oversight: Jay Noonkester	Oversight Firm: WSRC	
Location: A-14		Date: 3-30-00	Page 2 of 4

Start	Stop	Description of Activities/Remarks
7:30		oversight on location. Tim Grooms called & say skip truck drive should arrive soon to move skip pan to MRS 33 location. Johnny Rinder called and said 2 of the Drillcrew had to take CAT Trading this morning and would not be on location until around 10:30. we may not get started today anyway because of the threat of rain.
9:00		M. Coleman on location. Skip Pan Truck driver here to move skip pan to MRS-33. beginning to rain.
	9:30	Rained out.

Technical Oversight Signature: [signature] Date: 3-30-00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL Characterization	
Driller: M. Coleman	Drilling Subcontractor: AEI
Well Number: MRS-33 / Technical Oversight: J. Noonkester	Oversight Firm: WSRC
Location: A-14	Date: 3/31/00 / Page 3 of 4

Start	Stop	Description of Activities/Remarks
7:30		Oversight on location. Drillers on location
8:00		run# 4 29-39'
9:30		completed run#9 79'-89', Drillers Took 15 min. break at 9:00.
10:30	—	Kim Wierbicki, Chris Bergren, and Tom Kiernan stopped by to visit for about 15 mins.
1:20		we are down 169 FT. Drillers are mixing mud To help drill because of The clean sand we are in now.
2:00	3:00	Finished

Technical Oversight Signature: Jay Noonkester

Date: 3/31/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project A-14 45° Angle .			
Driller M. Coleman		Drilling Subcontractor AEI	
Well Number MRS-33	Technical Oversight W. Jones	Oversight Firm SRTC	
Location A-14 Outfall		Date 4-3-00	Page 4 of 4

Start	Stop	Description of Activities/Remarks
0800		Writer & J. Simmons onsite w/ M. Coleman & J. Hall, Jr. Watertruck
		departed site.
0830		Watertruck returned to site. Drillers began to trip in drill string. H&S
		briefing w/ Brian Giesecke (AEI), driller's helper/watertruck driver
11:15		completed drilling. Drillers departed site to pick up grout.
12:30		Drillers returned to site.
13:05		Skid-pan mover on site.
13:10		Writer offsite w/ skid-pan mover to relocate pan to M-Basin
13:25		Writer returned to site. Drillers mixing cement/bentonite.
13:10		J.S. onsite to sample skidpan.

Technical Oversight Signature [signature]	Date 4/24/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL FY 00		
Driller: M. Coleman	Drilling Subcontractor: AEI	
Well Number: MRS ~~29~~ 34/30 — Technical Oversight: J. Noonkester	Oversight Firm: WSRC	
Location: M Basin	Date: 4/12/00	Page 1 of 3

Start	Stop	Description of Activities/Remarks
12:00		Drillers were waiting on me when I arrived at MRS 30.
		This morning They grouted holes while I
1:30		was in Diversity Training.
2:30		AT A-14 looking for next location.
3:00		Set up on MRS 33.
	7:15	ready To start drilling in morning

Technical Oversight Signature: Jay Noonkester

Date: 4/12/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL FY00			
Driller: M. Coleman		Drilling Subcontractor: AEI	
Well Number: MAS 34	Technical Oversight: Jay Noonk	Oversight Firm: WSRC	
Location: A-14		Date: 4/13/00	Page 2 of 3

Start	Stop	Description of Activities/Remarks
8:00		Oversight on location
9:00		Driller to well hose for water - beginning to
10:00		Drill.
10 00		Driller (M. Coleman) notified me that the creek
		bank developed a leak and mud is running to
		A-14 outfall. We decided to continue with the
		hope it will seal it's self. If not, then we
		will stop and reevaluate the situation.
11:15		I have paged Tim Greene twice this morning for
		the skip pan which I asked for yesterday.
		He has not responded. I also spoke to him
		This morning and everything seemed to be in order.
		We have not received the skip pan yet.
12:00		Tim called and said he was being held up. They
		may have to pump off water before they can
		move skip pan to our location
2:00		Down to 136.5'
2:30		hit green clay on run #15 136.5-146.5'
3:30		Drillers started to set well and, after the two
		10 ft screens were lower into hole, they
		dropped them. Now fishing out screens.
4:00		Successfully fished out screens, we are now
		setting well.
		hole plug to 120' - 8 bags.
		4 centralizers used
		Sand tagged at 72' - They ran out of filter sand
	5:30	finished

Technical Oversight Signature: Jay Noonkeser   Date: 4/13/00

OSR 30-28# (2-13-97)

Daily Activities Report

Project: A/M DNAPL FY00	
Driller: M. Coleman	Drilling Subcontractor: AEI
Well Number: MRS 34 / Technical Oversight: J. Noonkester	Oversight Firm: WSRC
Location: M-Basin	Date: 4/14/00 / Page 3 of 3

Start	Stop	Description of Activities/Remarks
8:00		Oversight on location
		yesterday we set the well and poured sand filter
		pack up to 99' when we ran out of sand.
		Top of filter sand - 92'
		Top of fine sand - 91.2' 1 bag
		Top of bentonite pellets - 82' 2 buckets
8:30		waiting for bentonite pellets to hydrate.
12:00	—	Completed grout

Technical Oversight Signature: [signature] Date: 4/14/00