M00263.AR.000366
MCRD PARRIS ISLAND
5090.3a

FINAL CORRECTIVE ACTION PLAN FOR DEPOT GAS STATION MCRD PARRIS ISLAND SC
7/11/2005
TETRA TECH NUS

Rev. 1
07/11/05

CORRECTIVE ACTION PLAN
for
DEPOT GAS STATION

SITE ID # 01386

MCRD Parris Island
Parris Island, South Carolina

Southern Division
Naval Facilities Engineering Command
Contract Number N62467-94-D-0888
Contract Task Order 0099

July 2005

CORRECTIVE ACTION PLAN
FOR
DEPOT GAS STATION
SITE ID # 01386

MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

Submitted to:

Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive
North Charleston, South Carolina 29406

Submitted by:

Tetra Tech NUS
661 Andersen Drive
Foster Plaza 7
Pittsburgh, Pennsylvania 15220

CONTRACT NO. N62467-94-D-0888
CONTRACT TASK ORDER 0099

JULY 2005

PREPARED UNDER THE SUPERVISION OF:

Paul E. Calligan

PAUL CALLIGAN, P.G.
TASK ORDER MANAGER
TETRA TECH NUS, INC.
TAMPA, FLORIDA

APPROVED FOR SUBMITTAL BY:

Debra M Humbert

DEBRA M. HUMBERT
PROGRAM MANAGER
TETRA TECH NUS, INC.
PITTSBURGH, PENNSYLVANIA

PROFESSIONAL CERTIFICATION

I hereby certify that this *Corrective Action Plan for Depot Gas Station* is true, accurate, and complete to the best of my knowledge, information, and belief.

Steven B. McCoy 7/11/05

Steven B. McCoy, P.E. / Date
South Carolina Registration No. 8885
Site Rehabilitation Certified Contractor No. 0024

TABLE OF CONTENTS

SECTION **PAGE**

TABLES ..... **iv**
FIGURES ..... **iv**
ACRONYMS ..... **v**
1.0 INTRODUCTION **1-1**
1.1 PURPOSE AND SCOPE 1-1
1.2 SITE DESCRIPTION 1-1
1.3 SITE HISTORY 1-5
1.4 RECEPTOR SURVEY RESULTS 1-5
2.0 TIER II ASSESSMENT INFORMATION **2-1**
2.1 GEOLOGY AND HYDROGEOLOGY 2-1
2.1.1 Regional Geology and Hydrogeology 2-1
2.1.2 Site Geology 2-2
2.1.3 Site Hydrogeology 2-7
2.2 AQUIFER CHARACTERISTICS AND EVALUATION 2-7
2.3 FIELD SCREENING ASSESSMENT 2-22
2.3.1 Soil Mobile Lab Results 2-22
2.3.2 Groundwater Mobile Lab Results 2-27
2.4 CHEMICALS OF CONCERN IN SOIL AND GROUNDWATER 2-27
2.4.1 Chemicals of Concern in Soil 2-27
2.4.2 Chemicals of Concern in Groundwater 2-31
2.5 FATE AND TRANSPORT MODEL DESCRIPTION 2-39
2.6 PREDICTED MIGRATION AND ATTENUATION OF CHEMICALS OF CONCERN 2-40
3.0 TIER 2 EVALUATION **3-1**
3.1 COMPARISON OF ANALYTICAL RESULTS WITH RBSLS 3-1
3.2 SITE CONCEPTUAL EXPOSURE MODEL 3-1
3.3 EXPOSURE PATHWAY ANALYSIS 3-2
3.3.1 Potable Water 3-2
3.3.2 On-Site Resident 3-2
3.3.3 Visitor 3-2
3.3.4 Utility/Construction Worker 3-2
3.3.5 Base Worker 3-5
3.3.6 Surface Water 3-5
3.4 IDENTIFICATION OF DATA REQUIREMENTS 3-5
3.5 SITE-SPECIFIC TARGET LEVELS 3-5
3.5.1 Utility/Construction Worker Groundwater SSTLs 3-6
3.5.2 Base Worker Groundwater SSTLs 3-7
3.5.3 Groundwater SSTLs Protective of Surface Water 3-8
3.5.4 Groundwater SSTLs Summary 3-9
3.5.5 Soil SSTLs 3-10
3.6 CONCLUSIONS AND RECOMMENDATIONS 3-11
4.0 REMEDIAL SYSTEM DESIGN **4-1**
4.1 SOIL EXCAVATION AND OFF-SITE DISPOSAL 4-2
4.2 GROUNDWATER REMEDIATION 4-3
4.2.1 Treatability Study 4-3
REFERENCES **R-1**

TABLE OF CONTENTS (CONTINUED)

APPENDICES

A ISOC™ USER GUIDE A-3
B ISOC™ TECHNOLOGY INFORMATION B-3

TABLES

NUMBER		PAGE
1	Groundwater Elevations	2-8
2	Summary of Mobile Laboratory Screening Results for Soil	2-25
3	Summary of Mobile Laboratory Screening Results for Groundwater	2-28
4	Summary of Fixed-base Laboratory Analytical Results for Chemicals of Concern in Soil	2-30
5	Summary of Fixed-base Laboratory Analytical Results for Chemicals of Concern in Groundwater	2-32
6	Current Land Use – Potential Receptors and Pathways within 1000-foot Radius	3-3
7	Future Land Use – Potential Receptors and Pathways within 1000-foot Radius	3-4

FIGURES

NUMBER		PAGE
1	Site Location Map	1-3
2	Site Map	1-7
3	Utility Map	1-9
4	Cross Section A-A'	2-3
5	Cross Section B-B'	2-5
6	Potentiometric Surface, August 8, 2000	2-11
7	Potentiometric Surface, June 20, 2001	2-13
8	Potentiometric Surface, October 5, 2001	2-15
9	Deep Potentiometric Surface, June 20, 2001	2-17
10	Deep Potentiometric Surface, October 5, 2001	2-19
11	Soil Removal Area and Fixed Base Soil Exceedances	2-23
12	Benzene in Groundwater	2-35
13	Naphthalene in Groundwater	2-37
14	ISOC™ Injection Well Study Area	4-5
15	ISOC™ Injection Well Construction	4-8

ACRONYMS

AST	aboveground storage tank
bgs	below ground surface
BTEX	Benzene, toluene, ethylbenzene, and xylenes
CAP	Corrective Action Plan
CLEAN	Comprehensive Long-term Environmental Action Navy
COC	chemical of concern
CTO	Contract Task Order
DPT	Direct Push Technology
DRO	diesel range organics
ISOC™	in situ submerged oxygen curtain
Koc	organic carbon partitioning coefficient
MCL	Maximum Contaminant Level
MCRD	Marine Corps Recruit Depot
msl	mean sea level
MTBE	methyl tert butyl ether
MW	monitoring well
NAVFAC	Naval Facilities Engineering Command
PAH	polynuclear aromatic hydrocarbon
PID	photoionization detector
PVC	polyvinyl chloride
RBSL	risk-based screening level
SCDHEC	South Carolina Department of Health and Environmental Control
SOUTHDIV	Southern Division
SSTL	site-specific target level
TPH	total petroleum hydrocarbons
TtNUS	Tetra Tech NUS, Inc.
USEPA	U.S. Environmental Protection Agency
UST	underground storage tank

1.0 INTRODUCTION

1.1 PURPOSE AND SCOPE

The former Depot Gas Station, Building 170, is located at the Marine Corps Recruit Depot (MCRD) Parris Island in Beaufort County, South Carolina (Figure 1). This Corrective Action Plan (CAP) was performed by Tetra Tech NUS, Inc. (TtNUS), on behalf of the U.S. Navy Southern Division (SOUTHDIV) Naval Facilities Engineering Command (NAVFAC). Authorization to prepare the CAP for the site was issued by NAVFAC under Contract Task Order (CTO) 0099, for the Comprehensive Long-term Environmental Action Navy (CLEAN III) Contract Number N62467-94-D-0888. The CAP was prepared in accordance with the South Carolina Department of Health and Environmental Control's (SCDHEC's) Corrective Action Guidance. This CAP was prepared to recommend proposed remedial alternatives to address soil and groundwater contamination.

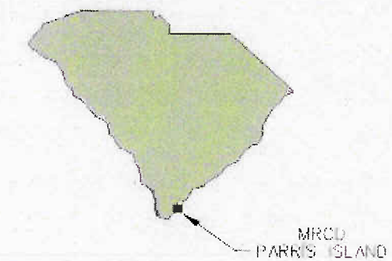
A Tier II Assessment report was prepared and submitted in April 2003 (TtNUS, 2003). The report summarized the results of field screening and confirmatory sampling of soil and groundwater at the site. Petroleum hydrocarbon contamination in both soil and groundwater exceeding SCDHEC risk-based screening levels (RBSLs) was found at the site.

The purpose of this CAP is to propose remedial alternatives to address impacted soil and groundwater exceeding site-specific target levels (SSTLs) in accordance with the SCDHEC Corrective Action Guidelines. This CAP will evaluate applicable alternatives that protect human health and the environment and reduce petroleum hydrocarbon constituent concentrations. This CAP will also provide a design for the selected remedial alternative.

1.2 SITE DESCRIPTION

The MCRD Parris Island is located approximately 5 miles south of the town of Beaufort in Beaufort County, South Carolina. The MCRD is located on an island north of Port Royal Sound between the Broad River and the Beaufort River (Figure 1). The Depot Gas Station is located at the northeastern end of the island. The MCRD Parris Island is an active facility. The mission of MCRD is to provide for the reception and recruit training of enlisted male personnel east of the Mississippi River and all female personnel upon their first entry into the Marine Corps. The MCRD also provides field and combat skills for training of recruits, schools to train enlisted Marines as Drill Instructors and Field Staff, rifle marksmanship training for Marine officers and enlisted personnel in the southeastern United States, and training for Marine reserves.

SOURCE:
TAKEN FROM U.S.G.S. TOPOGRAPHIC QUADRANGLE PARRIS ISLAND (1979 EDITION).



N

2000 0 2000
SCALE IN FEET

FIGURE 1

SITE LOCATION MAP
CORRECTIVE ACTION PLAN
DEPOT GAS STATION

MCRD PARRIS ISLAND
SOUTH CAROLINA

NAVFAC

CAD FILE NO./DATE: k:\cadd\navy\parrisis\depot station\ds 001.dgn 12 9 03

The Depot Gas Station is located at former Building 170, near former Building 139, and Building 155 at the northeastern part of MCRD Parris Island (Figure 2). The site is relatively flat with both grassy and paved areas being present.

1.3 SITE HISTORY

The site formerly provided both gasoline and diesel fuel to facility vehicles through two gasoline dispensers located at Building 170 and one diesel dispenser at the aboveground storage tanks (ASTs). The dispensers, tanks, and Building 170 were removed in March 2000.

In December 1983, approximately 97 gallons of gasoline spilled in the vicinity of Building 170 when a tank overflowed during filling operations. Contaminated soil was removed. Exact details of the removal activities are not known. There also may have been other past spills during offloading of fuels at the storage tanks.

The Depot Gas Station had been in service since the 1940s. During past operations a 2-inch-diameter dispenser line from the ASTs to dispensers at Building 157 also supplied fuel for facility vehicles. The fuel line reportedly had not been used for some time and the dispensers at Building 157 were later supplied by underground storage tanks (USTs). The dispensers and USTs at Building 157 have been removed and the fuel line was capped in late 1997. The dispenser line passed by the southern part of Buildings 139 and 155 (Figure 2) and may have contributed to the impacted soil and groundwater at Buildings 139 and 155. Building 139 was used as a warehouse before it was torn down at the end of 1997. Past activities at Building 139 may have included vehicle maintenance. Building 155 is the Depot vehicle maintenance facility.

1.4 RECEPTOR SURVEY RESULTS

A survey of the site vicinity was conducted by TtNUS personnel to identify potential receptors. Figure 3 depicts the utilities located within 250 feet of the site. Specific information concerning the depth of utilities below ground surface (bgs) is currently unavailable. However, according to facility personnel utility lines are typically located at approximately 3 to 5 feet bgs. The following utility receptors were located:

- Water utility: A water supply line runs along the southern portion of the site following Cape Gauffre Street. The water utility line lies a few feet south of monitoring well MW-15, one of the more impacted wells.

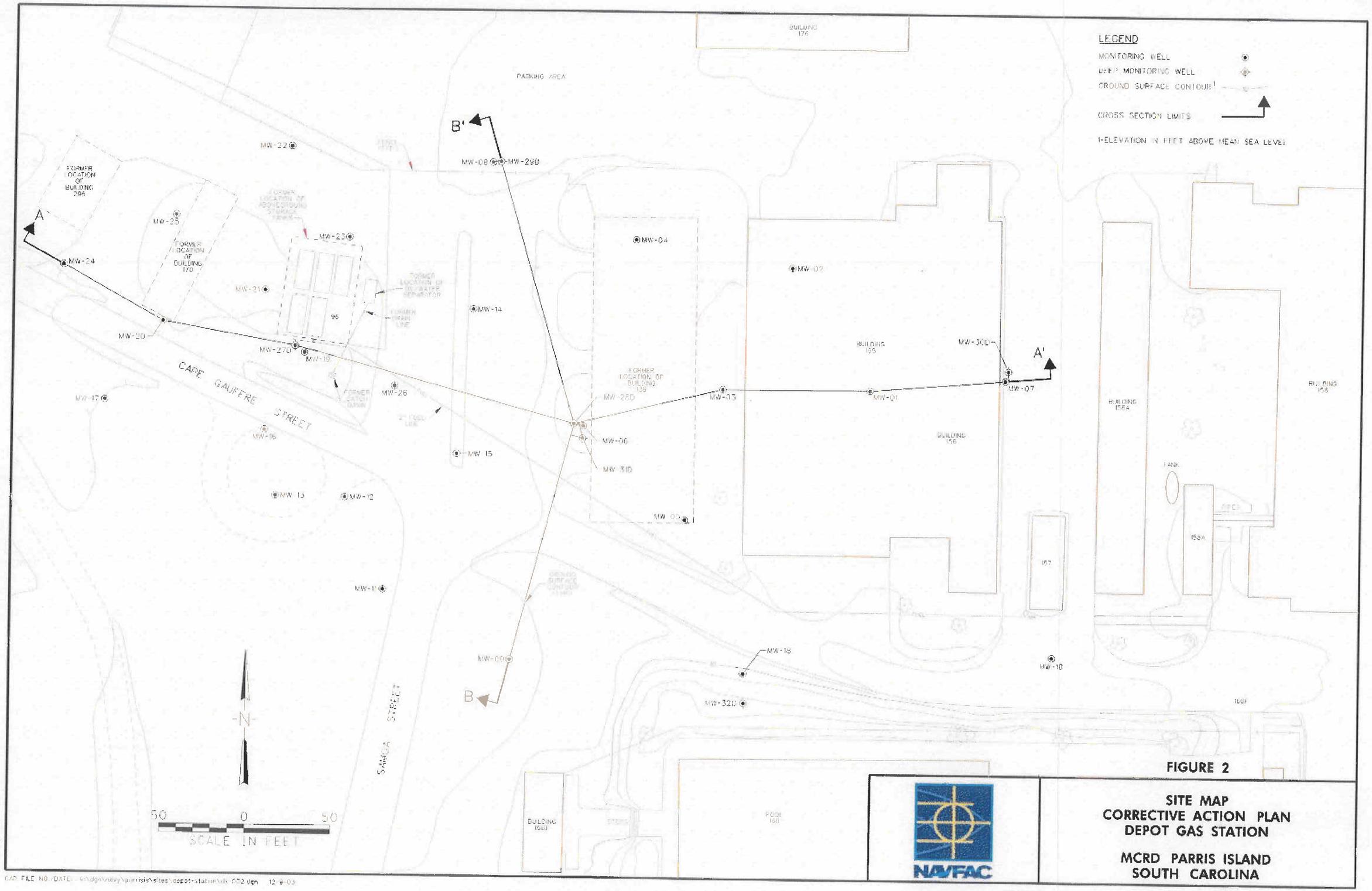


FIGURE 2

SITE MAP
CORRECTIVE ACTION PLAN
DEPOT GAS STATION

MCRD PARRIS ISLAND
SOUTH CAROLINA

NAVFAC

CAD FILE NO./DATE: c:\dgn\navy\parrisis\sites\depot-station\sb 072.dgn 12-9-03

CTO 0099

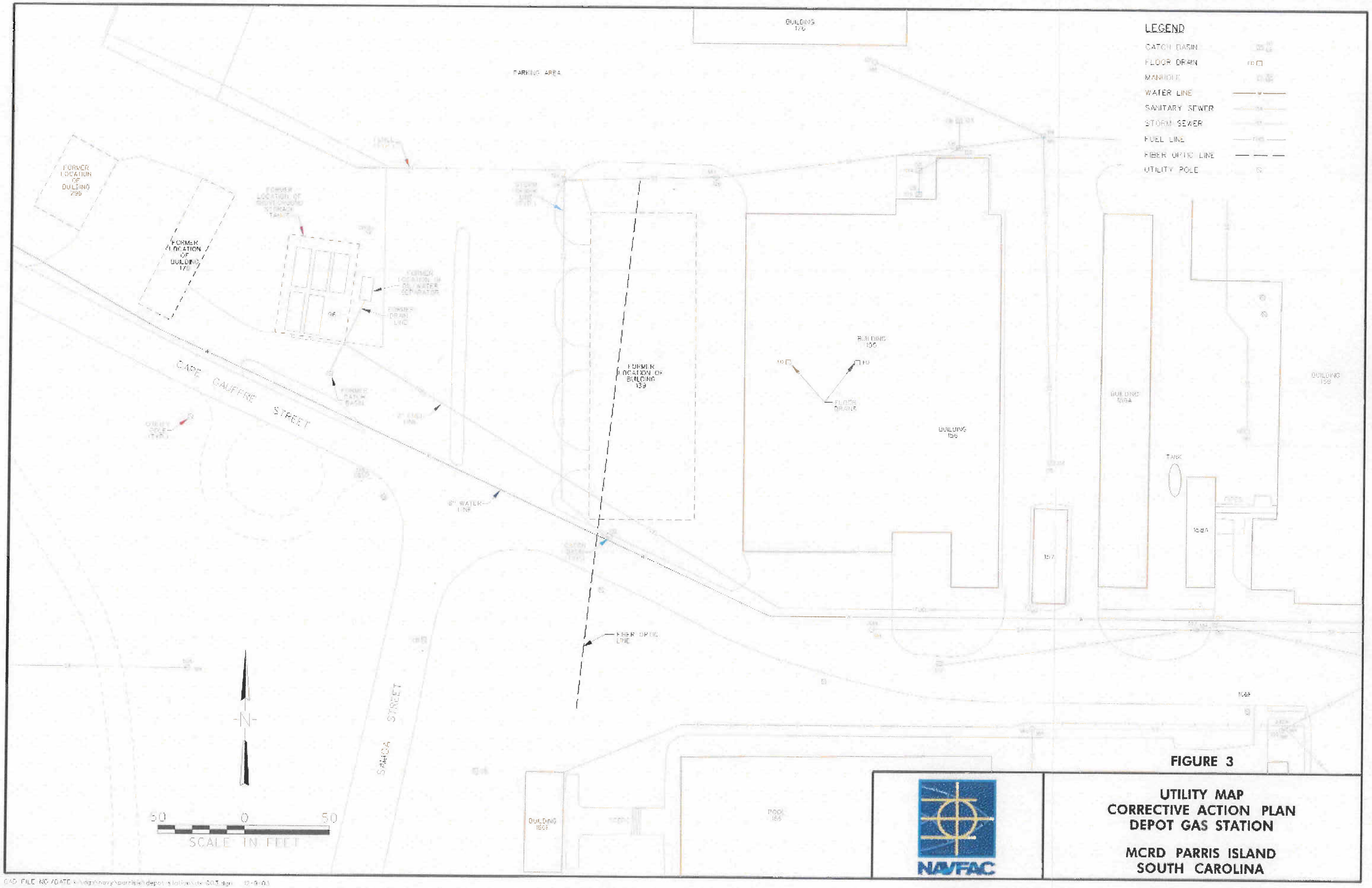


FIGURE 3

NAVFAC

UTILITY MAP
CORRECTIVE ACTION PLAN
DEPOT GAS STATION

MCRD PARRIS ISLAND
SOUTH CAROLINA

CAD FILE NO./DATE

- Storm sewer utility: A storm sewer line runs north of Building 155 and the former Building 139 and turns south to run along the western boundary of the former Building 139, ending in a catch basin at the southwest corner of the former Building 139 footprint.

- Electrical utility: The majority of the electrical utility lines in the site are overhead; however, a former underground electric line ran from the utility pole near MW-12 north-northwest to the ASTs. That underground electric line has been removed.

- Fuel line: This 2-inch line, which runs northwest to the former AST area has been capped and is no longer used.

- Oil/water separator (OWS) drain line: This line ran from the OWS to a catch basin in the area of the former ASTs. It has been removed.

- Several underground utilities, including a hot water pipe, run between Building 157 and the southeast corner of Building 155.

- Fiber optic line: A fiber optic line just east of MW-6 and MW-31D runs to the north and south.

Utility	On-Site or Distance/Direction from site	Depth to Utility
Water Main	10 feet south of the site along road	*
Storm Line	On-Site – not under building	*
Electric line	Formerly on-site – line has been removed	*
Fuel line	On-Site – not under building	*
OWS drain line	Formerly on-site – line has been removed	*
Hot water line	On-Site – not under building	*
Fiber optic line	On-Site – not under building	*

*Specific information concerning the depth of utilities is currently unavailable. However, according to facility personnel, utility lines are typically located approximately 3 to 5 feet bgs.

The potential receptors and preferential pathways within a 1,000-foot radius of the site are summarized here:

Description of Receptor	Distance/Direction from Site
Groundwater	On-Site. No complete pathways.
Resident	On-Site. No complete pathways.
Construction/ Utility Worker	On-Site – open areas
Personnel Training in open area	On-Site – open areas
Worker in Building	On-Site – in building
Surface Water	Marsh – approximately 600 feet north

There are no city, county, or state zoning ordinances because the property (MCRD Parris Island) is currently owned by the federal government. Information concerning zoning ordinances can be obtained from the NAVFAC Remedial Project Manager, 2155 Eagle Drive, North Charleston, South Carolina.

2.0 TIER II ASSESSMENT INFORMATION

2.1 GEOLOGY AND HYDROGEOLOGY

2.1.1 Regional Geology and Hydrogeology

The MCRD Parris Island is located in the Lower Coastal Plain Province of South Carolina and is characterized by flat terrain dissected by rivers and streams which flow into the Atlantic Ocean. Due to its location between two rivers, it is also surrounded by diverse ecosystems. There are many wetlands and tidal marsh areas with a variety of aquatic life as well as plants, birds, and animals.

The water table occurs within a few feet of the ground surface. The water table at Parris Island has been documented to vary by several feet depending upon the amount of recent precipitation. In general, the water table is deeper during the dry summer months and higher during the wetter winter months. There are two primary aquifers: the surficial aquifer and the Floridan Aquifer. These aquifers are generally separated by the Hawthorn Formation and Cooper Marl, which act as confining units to the underlying Floridan Aquifer.

The surficial or water table aquifer in the project area is restricted to the shallow, Pliocene to Holocene age, coarse grained sedimentary deposits of the Pamlico and Waccamaw Formations (Hughes et al., 1989), consisting primarily of fine sand and silty sand. Thin, discontinuous lenses of silty clay and clayey sand are also present. Pathways exist for contaminants to migrate via surface water runoff and infiltration into the shallow aquifer to adjacent ecosystems. The hydraulic characteristics of these formations are not particularly well known since the surficial aquifer is primarily used for domestic purposes. A few shallow monitoring wells on St. Helena and Ladies Islands have been hydraulically tested. An estimated transmissivity of 1,300 ft^2/day with a storage coefficient of 0.20 has been reported for coarse sands within the shallow deposits (Hassen, 1985). The direction of groundwater flow in the upper portion of the shallow surficial aquifer is generally toward the nearest surface water body, such as a pond, river, tidal creek, or the ocean. The hydraulic gradients are usually low and are nearly flat.

The surficial aquifer is underlain by the Miocene age Hawthorn Formation (Hughes et al., 1989). The Hawthorn Formation is significant in that it hydraulically separates the unconfined surficial aquifer from the underlying artesian Floridan aquifer. The thickness of the Hawthorn Formation in this area is reported to range from about 25 feet to as much as 40 feet near the confluence of the Beaufort and Broad Rivers (Hughes et al., 1989).

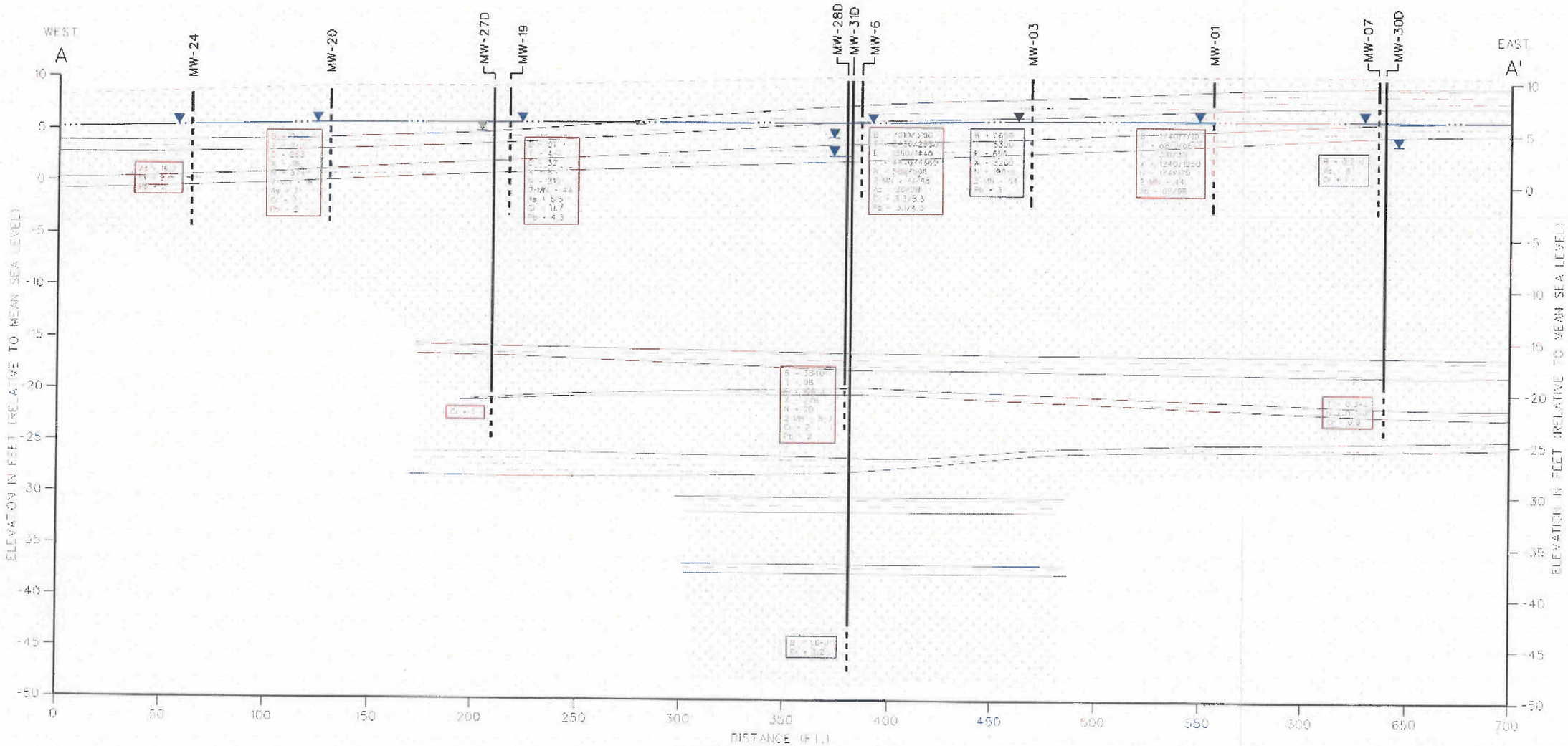
The Hawthorn Formation is reported to be breached in numerous locations throughout Beaufort County. Immediately adjacent to Parris Island, tidal scour and channel erosion may have breached the Hawthorn Formation beneath the Beaufort and Broad Rivers (Hughes et al., 1989). Smith (1987) reported a small area of recharge to the Upper Floridan at the southeastern end of Parris Island.

The principal source of groundwater used for consumption in the Beaufort County area is the Floridan aquifer (Smith, 1987). This artesian aquifer system has a total thickness of approximately 900 feet and is divided into the Upper Unit and the Lower Unit.

2.1.2 Site Geology

Seventy-eight direct push soil borings were advanced at the Depot Gas Station under the supervision of a TtNUS geologist between November 30 and December 9, 1999. These borings ranged in depth from 4 to 8 feet bgs and provided soil samples to characterize the subsurface lithology as well as samples for field screening of both soil and groundwater. Fifteen hand auger borings were completed on February 5-6, 2000, inside and near Building 155 to further define the extent of contamination. Soil and groundwater samples were collected and analyzed at a mobile laboratory. From April 27-30, 2000, twenty-six shallow monitoring wells were installed and on May 10-11, 2000, three deep monitoring wells were installed. Lithologic samples were collected and recorded during the drilling process to allow a vertical delineation of soils from land surface to a depth of approximately 60 feet bgs. Three additional deep monitoring wells were installed from May 21 to June 15, 2001, to further define the vertical extent of groundwater contamination at the site.

Based on lithologic descriptions from the above soil borings and monitoring wells, it appears that the subsurface soil consists of silty and clayey sands to a depth of approximately 4 to 5 feet bgs followed by clay and sandy clay from 5 feet bgs to approximately 10 feet bgs. The interval from 10 feet bgs to approximately 25 feet bgs consisted primarily of sand and silty sand with minor clay. At approximately 25 feet bgs, a clay layer varying from 1 to 3 feet thick was encountered across the site. Below this clay layer the soils consisted primarily of fine to medium sand with shell hash with thin, discontinuous lenses of finer-grained silty clay. At approximately 40 bgs a firm clay almost 2 feet thick was encountered with a thin layer of black ironstone deposit at well PAI-DGS-MW31D. This interval was followed by silty fine sand to 60 feet bgs with 1-foot-thick clay at 47 to 48 feet bgs. A generalized view of the subsurface lithology is presented in Figures 4 and 5.



CROSS SECTION A-A'

VERTICAL EXAGGERATION = 5 X HORIZONTAL

NOTE:
FOR COMPLETE LEGEND, SEE FIGURE 5.

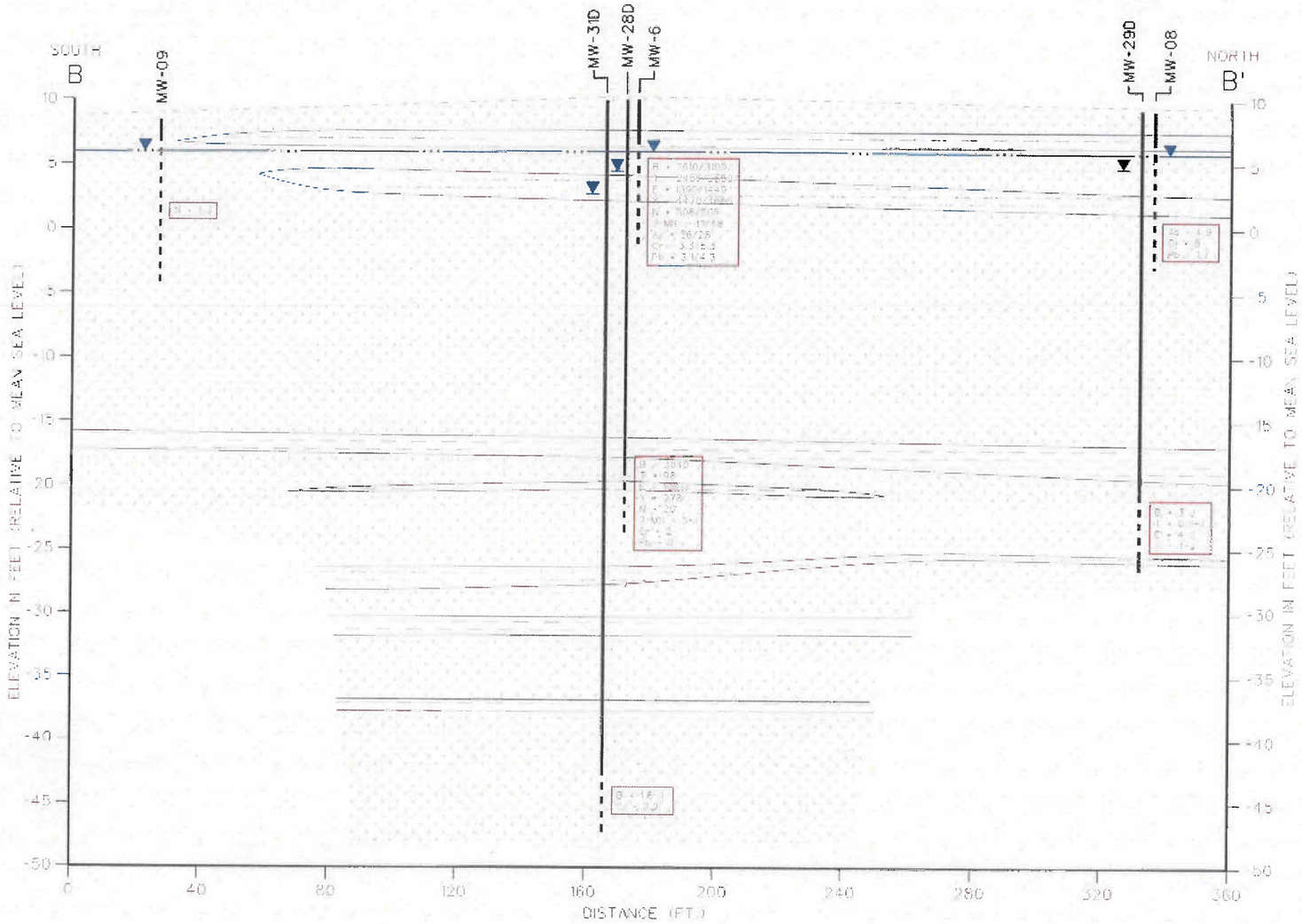
CAD FILE NO./DATE: K:\dgn\navy\parris\depot-station\ds-004.dgn 12-9-03

FIGURE 4

NAVFAC

CROSS SECTION A–A
CORRECTIVE ACTION PLAN
DEPOT GAS STATION

MCRD PARRIS ISLAND
SOUTH CAROLINA



CROSS SECTION B-B'

VERTICAL EXAGGERATION = 4 X HORIZONTAL

LEGEND

WELL

MW-09

WELL DESIGNATION

GROUND SURFACE

TOP OF SCREEN

WATER LEVEL ON 10-5-01

DEEP WELL WATER LEVEL ON 10-5-01

BOTTOM OF SCREEN

BOTTOM OF WELL

CHEMICALS OF CONCERN CONCENTRATIONS[1]

B = BENZENE
T = TOLUENE
E = ETHYLBENZENE
X = XYLENE
N = NAPHTHALENE
2-MN = 2-METHYLNAPHTHALENE
Cr = CHROMIUM
Pb = LEAD

ESTIMATED CONCENTRATION

1 = CONCENTRATION IN MICROGRAMS PER LITER (ug/L)

GEOLOGY

SAND

CLAY

SANDY CLAY

CLAYEY SAND

FIGURE 5

NAVFAC

CROSS SECTION B–B'
CORRECTIVE ACTION PLAN
DEPOT GAS STATION

MCRD PARRIS ISLAND
SOUTH CAROLINA

2.1.3 Site Hydrogeology

Six piezometers were installed at the Depot Gas Station as part of the assessment investigation. The piezometers were installed to determine the groundwater flow direction in the field and to assist in the placement of monitoring wells. The piezometers were located in former soil boring locations paired as follows: piezometer DGSP01 at soil boring DGSB07, DGSP02 at DGSB16, DGSP03 at DGSB14, DBSP04 at DGSB29, DGSP05 at DGSB44, and DGSP06 at DGSB60. The piezometers were abandoned after water level measurements were collected.

Thirty-two monitoring wells, PAI-DGS-MW01 through PAI-DGS-MW32D, were installed as part of the assessment. The monitoring well locations are shown on Figure 2. Twenty-six of the monitoring wells, PAI-DGS-MW01 through PAI-DGS-MW26, were completed as shallow wells to an approximate depth of 11-12 feet bgs. The monitoring wells were completed using 10 feet of polyvinyl chloride (PVC) well screen that bracketed the water table. Monitoring wells PAI-DGS-MW27D through PAI-DGS-MW30D and PAI-DGS-MW32D were completed as deep monitoring wells to depths ranging from approximately 34 to 37 feet bgs with screened intervals of 5 feet. Monitoring well PAI-DGS-31D was completed to a depth of approximately 58 feet bgs with 5 feet of screen to define the vertical extent of the plume.

In the site area, groundwater generally occurs at approximately 2 to 4 feet bgs. Groundwater elevation measurements were recorded in the monitoring wells from May 14-28, 2000, during development and sampling and on July 7 and August 29, 2000, as well as June 20 and October 5, 2001. No free product was observed in any well. The recorded water levels are presented in Table 1. Figures 6, 7, and 8 present the groundwater potentiometric surface on August 29, 2000, and June 20 and October 5, 2001, respectively. Based on the potentiometric map, shallow groundwater flow is toward the north-northwest. Figures 9 and 10 present the groundwater potentiometric surface for the deeper groundwater on June 20 and October 5, 2001, respectively, after all the deep monitoring wells had been installed. Groundwater flow in the deeper aquifer is to the southeast.

2.2 AQUIFER CHARACTERISTICS AND EVALUATION

Groundwater levels were measured in July and August of 2000 and June and October of 2001. Water level contours plotted on Figures 6, 7, and 8 indicate that the shallow groundwater flows to the north to northwest, with a hydraulic gradient of approximately 0.002 ft/ft. Water level contours plotted on Figures 9 and 10 indicated that the deep groundwater flows to the east or southeast with a hydraulic gradient of 0.0022 ft/ft.

TABLE 1

GROUNDWATER ELEVATIONS
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA

Well No.	Total Depth of Well (ft)	Top of Casing Elevation, ft (MSL)	Date Measured	Depth to Free Product (BTOC)	Depth to Water, ft (BTOC)	Groundwater Elevation, ft (MSL)
PAI-DGS-MW01	11.77	10.11	07/07/00	ND	4.07	6.04
			08/29/00	ND	3.66	6.45
			06/20/01	ND	3.60	6.51
			10/05/01	ND	3.80	6.31
PAI-DGS-MW02	12.00	9.99	07/07/00	ND	4.11	5.88
			08/29/00	ND	3.72	6.27
			06/20/01	ND	3.69	6.30
			10/05/01	ND	3.68	6.31
PAI-DGS-MW03	12.00	10.32	07/07/00	ND	4.59	5.73
			08/29/00	ND	4.10	6.22
			06/20/01	ND	3.94	6.38
			10/05/01	ND	4.13	6.19
PAI-DGS-MW04	12.00	9.99	07/07/00	ND	4.76	5.23
			08/29/00	ND	4.20	5.79
			06/20/01	ND	3.95	6.04
			10/05/01	ND	4.14	5.85
PAI-DGS-MW05	12.00	10.04	07/07/00	ND	4.11	5.93
			08/29/00	ND	3.58	6.46
			06/20/01	ND	3.44	6.60
			10/05/01	ND	3.82	6.22
PAI-DGS-MW06	12.50	10.04	07/07/00	ND	4.61	5.43
			08/29/00	ND	4.04	6.00
			06/20/01	ND	3.82	6.22
			10/05/01	ND	4.00	6.04
PAI-DGS-MW07	12.50	10.15	07/07/00	ND	4.13	6.02
			08/29/00	ND	3.74	6.41
			06/20/01	ND	3.62	6.53
			10/05/01	ND	3.88	6.27.
PAI-DGS-MW08	12.50	9.19	07/07/00	ND	4.04	5.15
			08/29/00	ND	4.50	4.69
			06/20/01	ND	3.26	5.93
			10/05/01	ND	3.35	5.84
PAI-DGS-MW09	12.50	8.55	07/07/00	ND	2.81	5.74
			08/29/00	ND	2.16	6.39
			06/20/01	ND	2.32	6.23
			10/05/01	ND	2.56	5.99
PAI-DGS-MW10	12.50	9.68	07/07/00	ND	3.21	6.47
			08/29/00	ND	2.97	6.71
			06/20/01	ND	2.95	6.73
			10/05/01	ND	3.85	5.83
PAI-DGS-MW11	12.50	9.03	07/07/00	ND	3.80	5.23
			08/29/00	ND	3.16	5.87
			06/20/01	ND	2.97	6.06
			10/05/01	ND	3.17	5.86
PAI-DGS-MW12	12.50	9.09	07/07/00	ND	3.97	5.12
			08/29/00	ND	3.37	5.72
			06/20/01	ND	3.04	6.05
			10/05/01	ND	3.23	5.86

TABLE 1

GROUNDWATER ELEVATIONS
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA

Well No.	Total Depth of Well (ft)	Top of Casing Elevation, ft (MSL)	Date Measured	Depth to Free Product (BTOC)	Depth to Water, ft (BTOC)	Groundwater Elevation, ft (MSL)
PAI-DGS-MW13	12.50	9.20	07/07/00	ND	4.20	5.00
			08/29/00	ND	3.55	5.65
			06/20/01	ND	3.15	6.05
			10/05/01	ND	3.40	5.80
PAI-DGS-MW14	12.50	9.09	07/07/00	ND	3.94	5.15
			08/29/00	ND	3.36	5.73
			06/20/01	ND	3.19	5.90
			10/05/01	ND	3.17	5.92
PAI-DGS-MW15	12.50	9.11	07/07/00	ND	3.80	5.31
			08/29/00	ND	3.25	5.86
			06/20/01	ND	2.97	6.14
			10/05/01	ND	3.11	6.00
PAI-DGS-MW16	12.50	9.36	07/07/00	ND	4.37	4.99
			08/29/00	ND	3.74	5.62
			06/20/01	ND	3.37	5.99
			10/05/01	ND	3.55	5.81
PAI-DGS-MW17	12.50	8.61	07/07/00	ND	3.92	4.69
			08/29/00	ND	3.11	5.50
			06/20/01	ND	2.88	5.73
			10/05/01	ND	3.05	5.56
PAI-DGS-MW18	12.50	10.56	07/07/00	ND	3.39	7.17
			08/29/00	ND	3.19	7.37
			06/20/01	ND	3.15	7.41
			10/05/01	ND	4.13	6.43
PAI-DGS-MW19	12.50	9.21	07/07/00	ND	4.17	5.04
			08/29/00	ND	3.54	5.67
			06/20/01	ND	3.10	6.11
			10/05/01	ND	3.30	5.91
PAI-DGS-MW20	12.50	8.92	07/07/00	ND	4.03	4.89
			08/29/00	ND	3.35	5.57
			06/20/01	ND	2.86	6.06
			10/05/01	ND	3.13	5.79
PAI-DGS-MW21	12.50	8.84	07/07/00	ND	3.91	4.93
			08/29/00	ND	3.23	5.61
			06/20/01	ND	2.79	6.05
			10/05/01	ND	3.05	5.79
PAI-DGS-MW22	12.50	8.61	07/07/00	ND	3.64	4.97
			08/29/00	ND	2.88	5.73
			06/20/01	ND	2.73	5.88
			10/05/01	ND	2.91	5.70
PAI-DGS-MW23	12.50	8.78	07/07/00	ND	3.70	5.08
			08/29/00	ND	3.06	5.72
			06/20/01	ND	2.91	5.87
			10/05/01	ND	2.96	5.82
PAI-DGS-MW24	12.50	8.56	07/07/00	ND	3.91	4.65
			08/29/00	ND	3.19	5.37
			06/20/01	ND	2.86	5.70
			10/05/01	ND	3.09	5.47

TABLE 1

GROUNDWATER ELEVATIONS
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA

Well No.	Total Depth of Well (ft)	Top of Casing Elevation, ft (MSL)	Date Measured	Depth to Free Product (BTOC)	Depth to Water, ft (BTOC)	Groundwater Elevation, ft (MSL)
PAI-DGS-MW25	12.50	8.97	07/07/00	ND	4.01	4.96
			08/29/00	ND	3.30	5.67
			06/20/01	ND	2.71	6.26
			10/05/01	ND	3.07	5.90
PAI-DGS-MW26	11.76	8.77	07/07/00	ND	3.54	5.23
			08/29/00	ND	2.98	5.79
			06/20/01	ND	2.72	6.05
			10/05/01	ND	2.88	5.89
PAI-DGS-MW27D	33.87	8.97	07/07/00	ND	4.67	4.30
			08/29/00	ND	4.25	4.72
			06/20/01	ND	4.12	4.85
			10/05/01	ND	3.99	4.98
PAI-DGS-MW28D	34.17	10.04	07/07/00	ND	6.25	3.79
			08/29/00	ND	6.14	3.90
			06/20/01	ND	5.80	4.24
			10/05/01	ND	5.50	4.54
PAI-DGS-MW29D	35.09	9.33	07/07/00	ND	5.19	4.14
			08/29/00	ND	5.07	4.26
			06/20/01	ND	4.55	4.78
			10/05/01	ND	4.50	4.83
PAI-DGS-MW30D	34.50	10.13	06/20/01	ND	6.40	3.73
			10/05/01	ND	6.10	4.03
PAI-DGS-MW31D	57.70	9.96	06/20/01	ND	7.85	2.11
			10/05/01	ND	7.16	2.80
PAI-DGS-MW32D	37.62	13.01	06/20/01	ND	10.27	2.74
			10/05/01	ND	8.63	4.38

Notes:
BTOC - Below Top of Casing
MSL - Mean Sea Level
ND - Not Detected

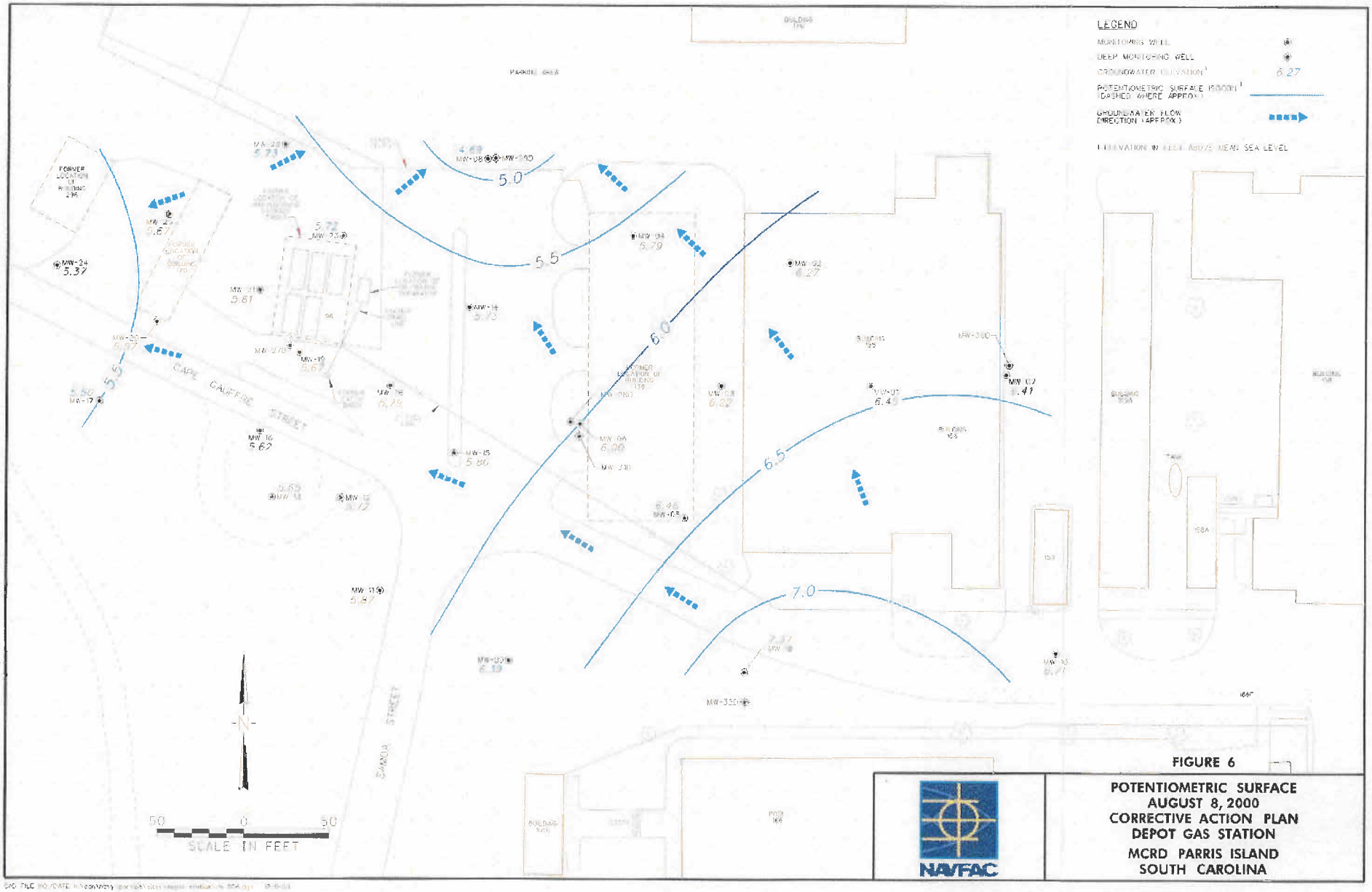


FIGURE 6

POTENTIOMETRIC SURFACE
AUGUST 8, 2000
CORRECTIVE ACTION PLAN
DEPOT GAS STATION
MCRD PARRIS ISLAND
SOUTH CAROLINA

NAVFAC

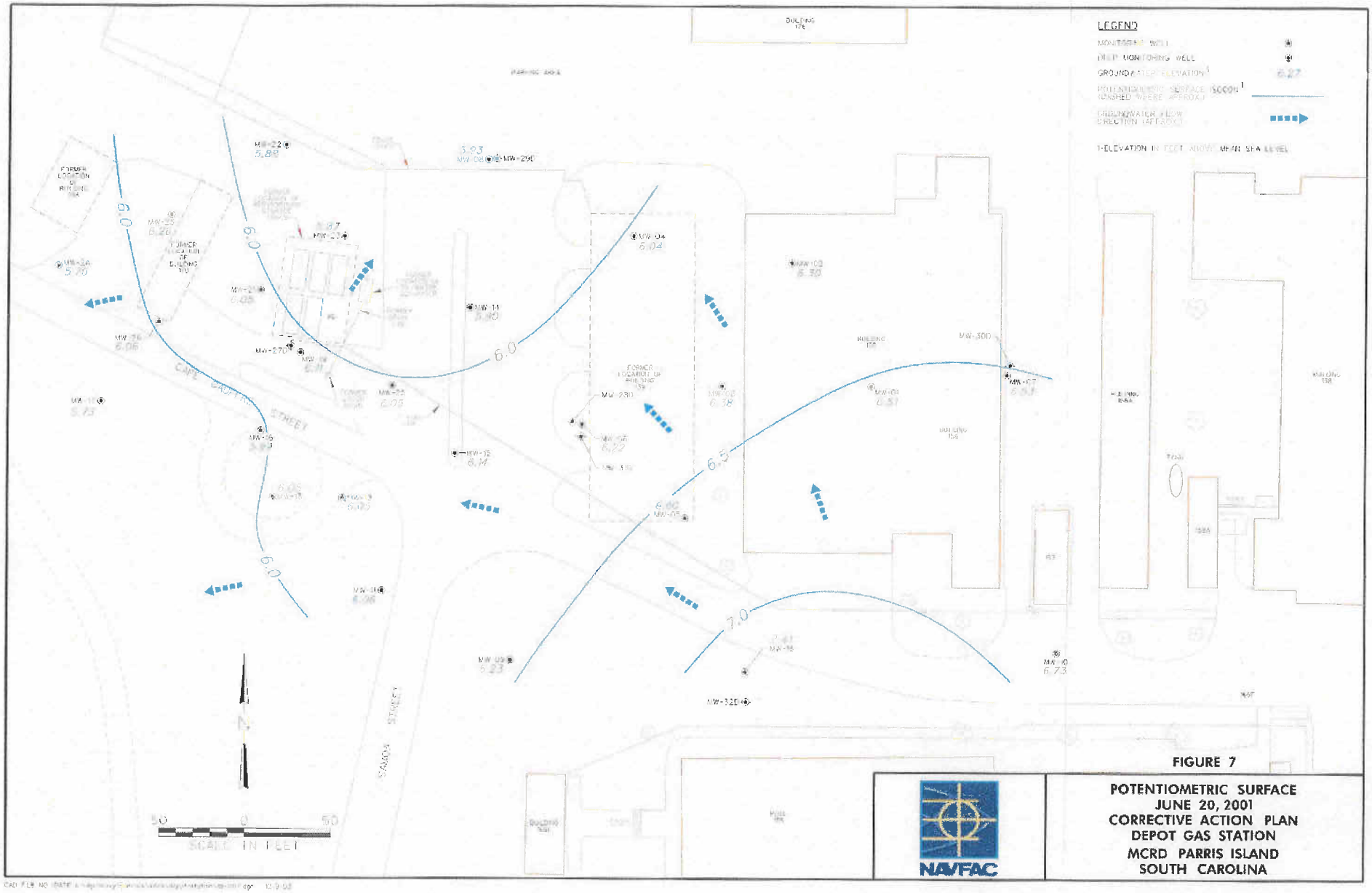


FIGURE 7

NAVFAC

POTENTIOMETRIC SURFACE
JUNE 20, 2001
CORRECTIVE ACTION PLAN
DEPOT GAS STATION
MCRD PARRIS ISLAND
SOUTH CAROLINA

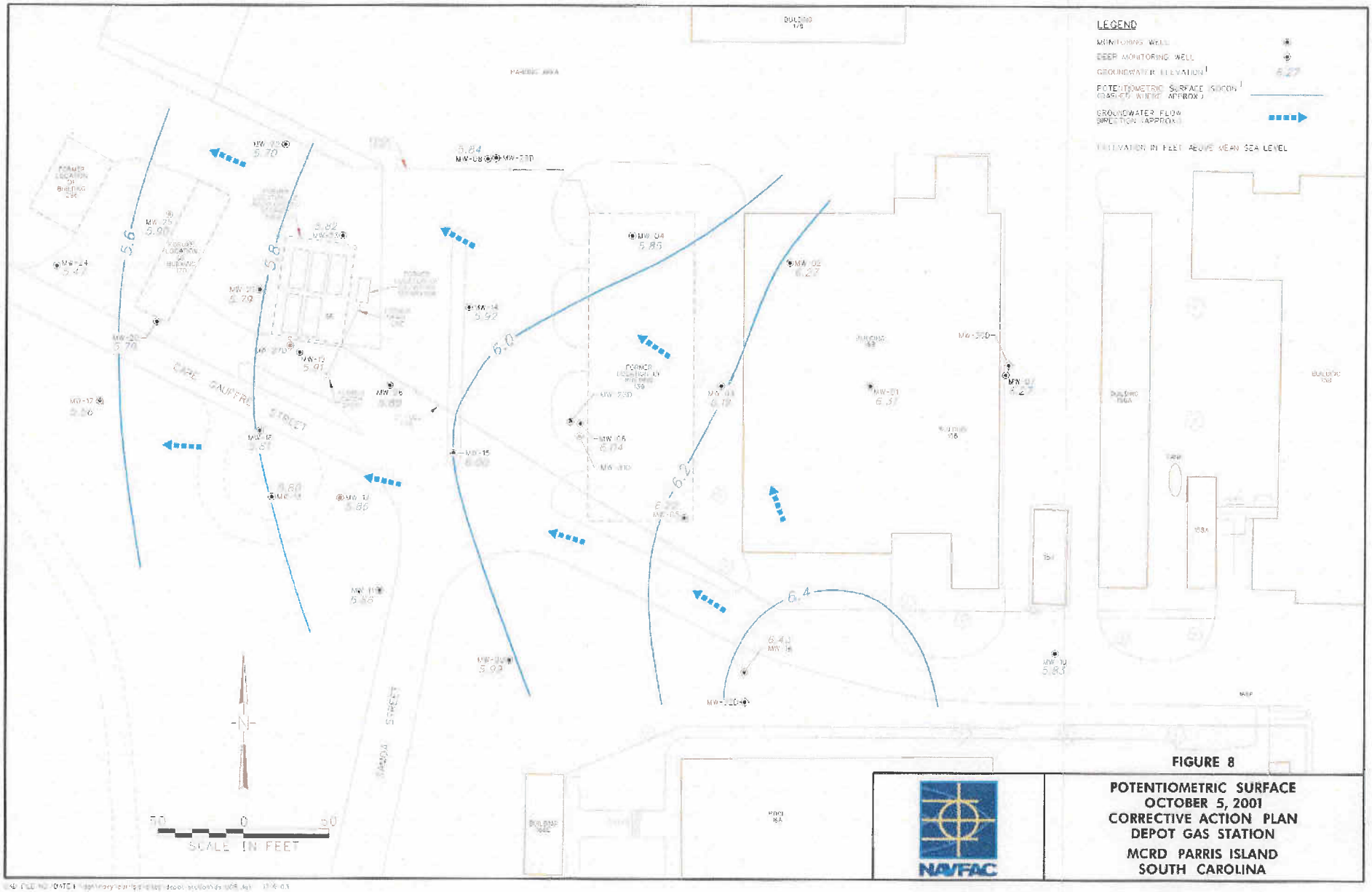


FIGURE 8

POTENTIOMETRIC SURFACE
OCTOBER 5, 2001
CORRECTIVE ACTION PLAN
DEPOT GAS STATION
MCRD PARRIS ISLAND
SOUTH CAROLINA

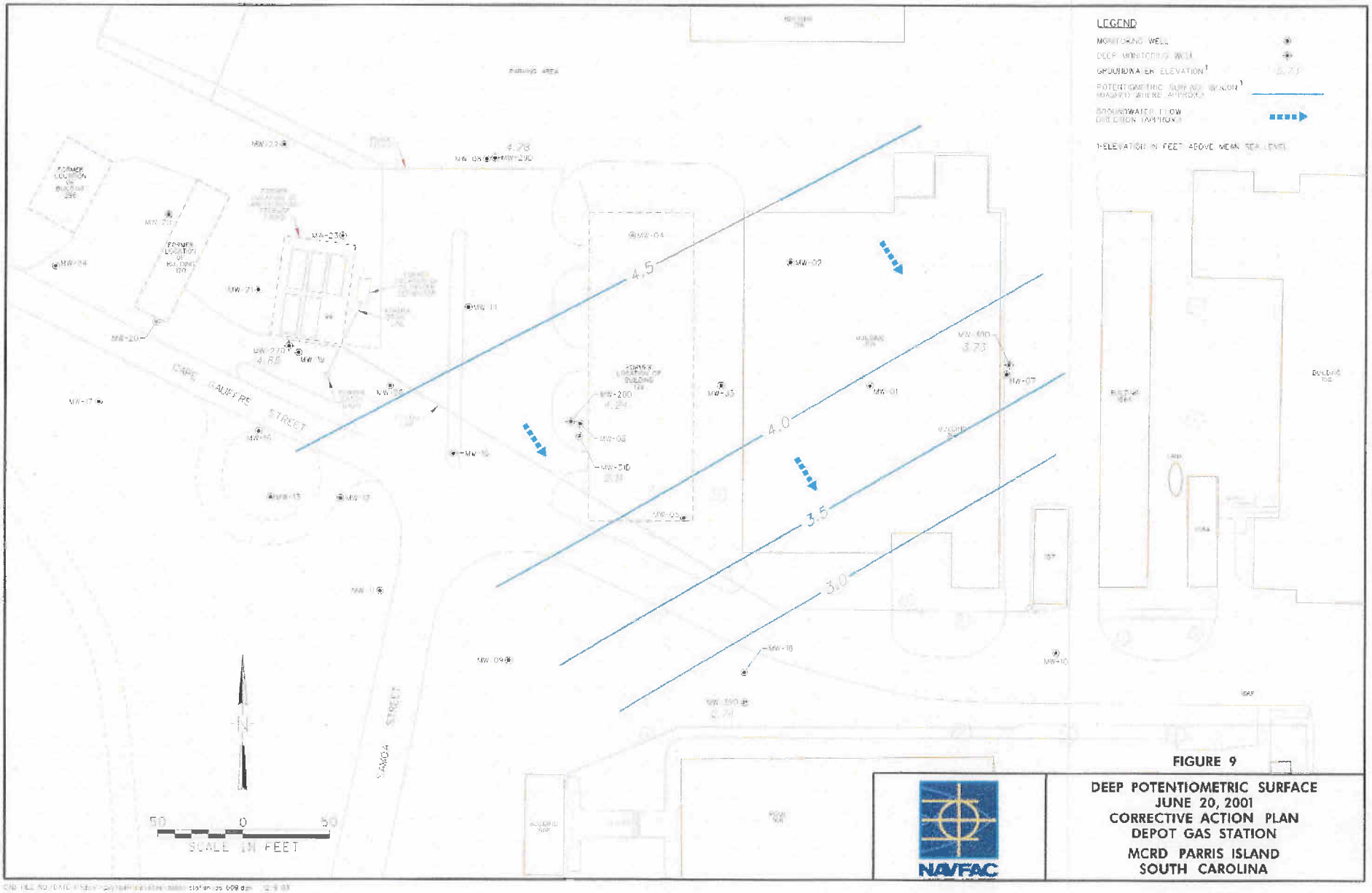
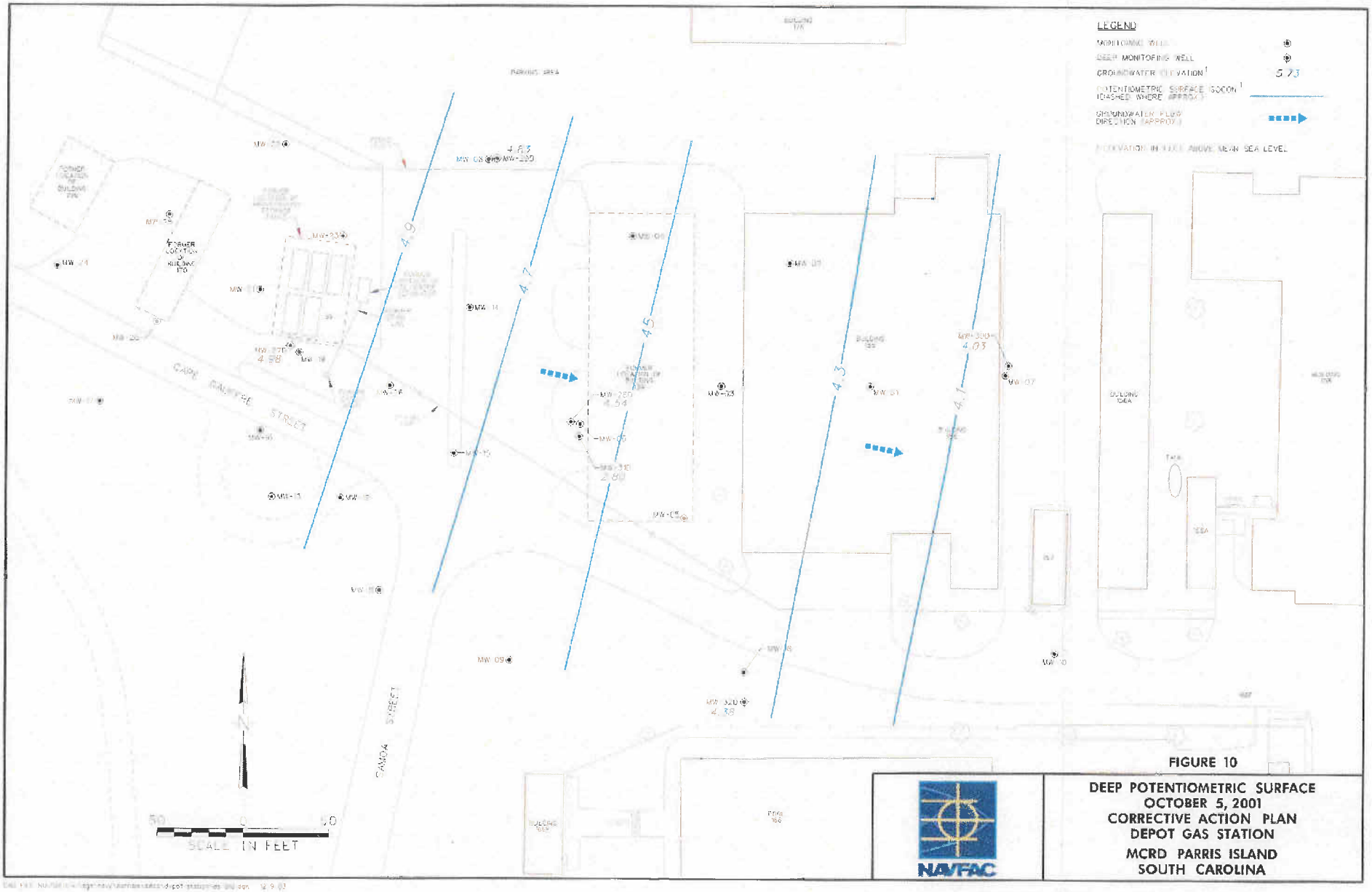


FIGURE 9

DEEP POTENTIOMETRIC SURFACE
JUNE 20, 2001
CORRECTIVE ACTION PLAN
DEPOT GAS STATION

MCRD PARRIS ISLAND
SOUTH CAROLINA

NAVFAC


LEGEND
MONITORING WELL
DEEP MONITORING WELL
GROUNDWATER ELEVATION[1] 5.73
POTENTIOMETRIC SURFACE (DOCON[1] (DASHED WHERE APPROX.)
GROUNDWATER FLOW DIRECTION (APPROX.)
[1] ELEVATION IN FEET ABOVE MEAN SEA LEVEL
PARKING AREA
BUILDING 1/K
FORMER LOCATION OF BUILDING 1/O
MW-23
MW-24
MW-22
MW-21
MW-20
MW-19
MW-18
MW-17
MW-16
MW-15
MW-14
MW-13
MW-12
MW-11
MW-10
MW-09
MW-08
MW-07
MW-06
MW-05
MW-03
MW-01
MW-03S
MW-05S
MW-07S
MW-08S
MW-09S
MW-10S
MW-320
4.33
MW-310
2.80
MW-280
4.54
MW-270
4.58
MW-300
4.03
MW-08
4.83
MW-300
4.9
4.7
4.5
4.3
4.1
CAPE RAVENEL STREET
CANOA STREET
BUILDING 1/A
BUILDING 1/B
BUILDING 1/C
BUILDING 1/D
BUILDING 1/E
BUILDING 1/F
BUILDING 1/G
BUILDING 1/H
BUILDING 1/I
BUILDING 1/J
BUILDING 1/K
BUILDING 1/L
BUILDING 1/M
BUILDING 1/N
BUILDING 1/O
BUILDING 1/P
BUILDING 1/Q
BUILDING 1/R
BUILDING 1/S
BUILDING 1/T
BUILDING 1/U
BUILDING 1/V
BUILDING 1/W
BUILDING 1/X
BUILDING 1/Y
BUILDING 1/Z
BUILDING 1/AA
BUILDING 1/AB
BUILDING 1/AC
BUILDING 1/AD
BUILDING 1/AE
BUILDING 1/AF
BUILDING 1/AG
BUILDING 1/AH
BUILDING 1/AI
BUILDING 1/AJ
BUILDING 1/AK
BUILDING 1/AL
BUILDING 1/AM
BUILDING 1/AN
BUILDING 1/AO
BUILDING 1/AP
BUILDING 1/AQ
BUILDING 1/AR
BUILDING 1/AS
BUILDING 1/AT
BUILDING 1/AU
BUILDING 1/AV
BUILDING 1/AW
BUILDING 1/AX
BUILDING 1/AY
BUILDING 1/AZ
BUILDING 1/BA
BUILDING 1/BB
BUILDING 1/BC
BUILDING 1/BD
BUILDING 1/BE
BUILDING 1/BF
BUILDING 1/BG
BUILDING 1/BH
BUILDING 1/BI
BUILDING 1/BJ
BUILDING 1/BK
BUILDING 1/BL
BUILDING 1/BM
BUILDING 1/BN
BUILDING 1/BO
BUILDING 1/BP
BUILDING 1/BQ
BUILDING 1/BR
BUILDING 1/BS
BUILDING 1/BT
BUILDING 1/BU
BUILDING 1/BV
BUILDING 1/BW
BUILDING 1/BX
BUILDING 1/BY
BUILDING 1/BZ
BUILDING 1/CA
BUILDING 1/CB
BUILDING 1/CC
BUILDING 1/CD
BUILDING 1/CE
BUILDING 1/CF
BUILDING 1/CG
BUILDING 1/CH
BUILDING 1/CI
BUILDING 1/CJ
BUILDING 1/CK
BUILDING 1/CL
BUILDING 1/CM
BUILDING 1/CN
BUILDING 1/CO
BUILDING 1/CP
BUILDING 1/CQ
BUILDING 1/CR
BUILDING 1/CS
BUILDING 1/CT
BUILDING 1/CU
BUILDING 1/CV
BUILDING 1/CW
BUILDING 1/CX
BUILDING 1/CY
BUILDING 1/CZ
BUILDING 1/DA
BUILDING 1/DB
BUILDING 1/DC
BUILDING 1/DD
BUILDING 1/DE
BUILDING 1/DF
BUILDING 1/DG
BUILDING 1/DH
BUILDING 1/DI
BUILDING 1/DJ
BUILDING 1/DK
BUILDING 1/DL
BUILDING 1/DM
BUILDING 1/DN
BUILDING 1/DO
BUILDING 1/DP
BUILDING 1/DQ
BUILDING 1/DR
BUILDING 1/DS
BUILDING 1/DT
BUILDING 1/DU
BUILDING 1/DV
BUILDING 1/DW
BUILDING 1/DX
BUILDING 1/DY
BUILDING 1/DZ
BUILDING 1/EA
BUILDING 1/EB
BUILDING 1/EC
BUILDING 1/ED
BUILDING 1/EE
BUILDING 1/EF
BUILDING 1/EG
BUILDING 1/EH
BUILDING 1/EI
BUILDING 1/EJ
BUILDING 1/EK
BUILDING 1/EL
BUILDING 1/EM
BUILDING 1/EN
BUILDING 1/EO
BUILDING 1/EP
BUILDING 1/EQ
BUILDING 1/ER
BUILDING 1/ES
BUILDING 1/ET
BUILDING 1/EU
BUILDING 1/EV
BUILDING 1/EW
BUILDING 1/EX
BUILDING 1/EY
BUILDING 1/EZ
BUILDING 1/FA
BUILDING 1/FB
BUILDING 1/FC
BUILDING 1/FD
BUILDING 1/FE
BUILDING 1/FF
BUILDING 1/FG
BUILDING 1/FH
BUILDING 1/FI
BUILDING 1/FJ
BUILDING 1/FK
BUILDING 1/FL
BUILDING 1/FM
BUILDING 1/FN
BUILDING 1/FO
BUILDING 1/FP
BUILDING 1/FQ
BUILDING 1/FR
BUILDING 1/FS
BUILDING 1/FT
BUILDING 1/FU
BUILDING 1/FV
BUILDING 1/FW
BUILDING 1/FX
BUILDING 1/FY
BUILDING 1/FZ
BUILDING 1/GA
BUILDING 1/GB
BUILDING 1/GC
BUILDING 1/GD
BUILDING 1/GE
BUILDING 1/GF
BUILDING 1/GG
BUILDING 1/GH
BUILDING 1/GI
BUILDING 1/GJ
BUILDING 1/GK
BUILDING 1/GL
BUILDING 1/GM
BUILDING 1/GN
BUILDING 1/GO
BUILDING 1/GP
BUILDING 1/GQ
BUILDING 1/GR
BUILDING 1/GS
BUILDING 1/GT
BUILDING 1/GU
BUILDING 1/GV
BUILDING 1/GW
BUILDING 1/GX
BUILDING 1/GY
BUILDING 1/GZ
BUILDING 1/HA
BUILDING 1/HB
BUILDING 1/HC
BUILDING 1/HD
BUILDING 1/HE
BUILDING 1/HF
BUILDING 1/HG
BUILDING 1/HH
BUILDING 1/HI
BUILDING 1/HJ
BUILDING 1/HK
BUILDING 1/HL
BUILDING 1/HM
BUILDING 1/HN
BUILDING 1/HO
BUILDING 1/HP
BUILDING 1/HQ
BUILDING 1/HR
BUILDING 1/HS
BUILDING 1/HT
BUILDING 1/HU
BUILDING 1/HV
BUILDING 1/HW
BUILDING 1/HX
BUILDING 1/HY
BUILDING 1/HZ
BUILDING 1/IA
BUILDING 1/IB
BUILDING 1/IC
BUILDING 1/ID
BUILDING 1/IE
BUILDING 1/IF
BUILDING 1/IG
BUILDING 1/IH
BUILDING 1/II
BUILDING 1/IJ
BUILDING 1/IK
BUILDING 1/IL
BUILDING 1/IM
BUILDING 1/IN
BUILDING 1/IO
BUILDING 1/IP
BUILDING 1/IQ
BUILDING 1/IR
BUILDING 1/IS
BUILDING 1/IT
BUILDING 1/IU
BUILDING 1/IV
BUILDING 1/IW
BUILDING 1/IX
BUILDING 1/IY
BUILDING 1/IZ
BUILDING 1/JA
BUILDING 1/JB
BUILDING 1/JC
BUILDING 1/JD
BUILDING 1/JE
BUILDING 1/JF
BUILDING 1/JG
BUILDING 1/JH
BUILDING 1/JI
BUILDING 1/JJ
BUILDING 1/JK
BUILDING 1/JL
BUILDING 1/JM
BUILDING 1/JN
BUILDING 1/JO
BUILDING 1/JP
BUILDING 1/JQ
BUILDING 1/JR
BUILDING 1/JS
BUILDING 1/JT
BUILDING 1/JU
BUILDING 1/JV
BUILDING 1/JW
BUILDING 1/JX
BUILDING 1/JY
BUILDING 1/JZ
BUILDING 1/KA
BUILDING 1/KB
BUILDING 1/KC
BUILDING 1/KD
BUILDING 1/KE
BUILDING 1/KF
BUILDING 1/KG
BUILDING 1/KH
BUILDING 1/KI
BUILDING 1/KJ
BUILDING 1/KK
BUILDING 1/KL
BUILDING 1/KM
BUILDING 1/KN
BUILDING 1/KO
BUILDING 1/KP
BUILDING 1/KQ
BUILDING 1/KR
BUILDING 1/KS
BUILDING 1/KT
BUILDING 1/KU
BUILDING 1/KV
BUILDING 1/KW
BUILDING 1/KX
BUILDING 1/KY
BUILDING 1/KZ
BUILDING 1/LA
BUILDING 1/LB
BUILDING 1/LC
BUILDING 1/LD
BUILDING 1/LE
BUILDING 1/LF
BUILDING 1/LG
BUILDING 1/LH
BUILDING 1/LI
BUILDING 1/LJ
BUILDING 1/LK
BUILDING 1/LL
BUILDING 1/LM
BUILDING 1/LN
BUILDING 1/LO
BUILDING 1/LP
BUILDING 1/LQ
BUILDING 1/LR
BUILDING 1/LS
BUILDING 1/LT
BUILDING 1/LU
BUILDING 1/LV
BUILDING 1/LW
BUILDING 1/LX
BUILDING 1/LY
BUILDING 1/LZ
BUILDING 1/MA
BUILDING 1/MB
BUILDING 1/MC
BUILDING 1/MD
BUILDING 1/ME
BUILDING 1/MF
BUILDING 1/MG
BUILDING 1/MH
BUILDING 1/MI
BUILDING 1/MJ
BUILDING 1/MK
BUILDING 1/ML
BUILDING 1/MM
BUILDING 1/MN
BUILDING 1/MO
BUILDING 1/MP
BUILDING 1/MQ
BUILDING 1/MR
BUILDING 1/MS
BUILDING 1/MT
BUILDING 1/MU
BUILDING 1/MV
BUILDING 1/MW
BUILDING 1/MX
BUILDING 1/MY
BUILDING 1/MZ
BUILDING 1/NA
BUILDING 1/NB
BUILDING 1/NC
BUILDING 1/ND
BUILDING 1/NE
BUILDING 1/NF
BUILDING 1/NG
BUILDING 1/NH
BUILDING 1/NI
BUILDING 1/NJ
BUILDING 1/NK
BUILDING 1/NL
BUILDING 1/NM
BUILDING 1/NN
BUILDING 1/NO
BUILDING 1/NP
BUILDING 1/NQ
BUILDING 1/NR
BUILDING 1/NS
BUILDING 1/NT
BUILDING 1/NU
BUILDING 1/NV
BUILDING 1/NW
BUILDING 1/NX
BUILDING 1/NY
BUILDING 1/NZ
BUILDING 1/OA
BUILDING 1/OB
BUILDING 1/OC
BUILDING 1/OD
BUILDING 1/OE
BUILDING 1/OF
BUILDING 1/OG
BUILDING 1/OH
BUILDING 1/OI
BUILDING 1/OJ
BUILDING 1/OK
BUILDING 1/OL
BUILDING 1/OM
BUILDING 1/ON
BUILDING 1/OO
BUILDING 1/OP
BUILDING 1/OQ
BUILDING 1/OR
BUILDING 1/OS
BUILDING 1/OT
BUILDING 1/OU
BUILDING 1/OV
BUILDING 1/OW
BUILDING 1/OX
BUILDING 1/OY
BUILDING 1/OZ
BUILDING 1/PA
BUILDING 1/PB
BUILDING 1/PC
BUILDING 1/PD
BUILDING 1/PE
BUILDING 1/PF
BUILDING 1/PG
BUILDING 1/PH
BUILDING 1/PI
BUILDING 1/PJ
BUILDING 1/PK
BUILDING 1/PL
BUILDING 1/PM
BUILDING 1/PN
BUILDING 1/PO
BUILDING 1/PP
BUILDING 1/PQ
BUILDING 1/PR
BUILDING 1/PS
BUILDING 1/PT
BUILDING 1/PU
BUILDING 1/PV
BUILDING 1/PW
BUILDING 1/PX
BUILDING 1/PY
BUILDING 1/PZ
BUILDING 1/QA
BUILDING 1/QB
BUILDING 1/QC
BUILDING 1/QD
BUILDING 1/QE
BUILDING 1/QF
BUILDING 1/QG
BUILDING 1/QH
BUILDING 1/QI
BUILDING 1/QJ
BUILDING 1/QK
BUILDING 1/QL
BUILDING 1/QM
BUILDING 1/QN
BUILDING 1/QO
BUILDING 1/QP
BUILDING 1/QQ
BUILDING 1/QR
BUILDING 1/QS
BUILDING 1/QT
BUILDING 1/QU
BUILDING 1/QV
BUILDING 1/QW
BUILDING 1/QX
BUILDING 1/QY
BUILDING 1/QZ
BUILDING 1/RA
BUILDING 1/RB
BUILDING 1/RC
BUILDING 1/RD
BUILDING 1/RE
BUILDING 1/RF
BUILDING 1/RG
BUILDING 1/RH
BUILDING 1/RI
BUILDING 1/RJ
BUILDING 1/RK
BUILDING 1/RL
BUILDING 1/RM
BUILDING 1/RN
BUILDING 1/RO
BUILDING 1/RP
BUILDING 1/RQ
BUILDING 1/RR
BUILDING 1/RS
BUILDING 1/RT
BUILDING 1/RU
BUILDING 1/RV
BUILDING 1/RW
BUILDING 1/RX
BUILDING 1/RY
BUILDING 1/RZ
BUILDING 1/SA
BUILDING 1/SB
BUILDING 1/SC
BUILDING 1/SD
BUILDING 1/SE
BUILDING 1/SF
BUILDING 1/SG
BUILDING 1/SH
BUILDING 1/SI
BUILDING 1/SJ
BUILDING 1/SK
BUILDING 1/SL
BUILDING 1/SM
BUILDING 1/SN
BUILDING 1/SO
BUILDING 1/SP
BUILDING 1/SQ
BUILDING 1/SR
BUILDING 1/SS
BUILDING 1/ST
BUILDING 1/SU
BUILDING 1/SV
BUILDING 1/SW
BUILDING 1/SX
BUILDING 1/SY
BUILDING 1/SZ
BUILDING 1/TA
BUILDING 1/TB
BUILDING 1/TC
BUILDING 1/TD
BUILDING 1/TE
BUILDING 1/TF
BUILDING 1/TG
BUILDING 1/TH
BUILDING 1/TI
BUILDING 1/TJ
BUILDING 1/TK
BUILDING 1/TL
BUILDING 1/TM
BUILDING 1/TN
BUILDING 1/TO
BUILDING 1/TP
BUILDING 1/TQ
BUILDING 1/TR
BUILDING 1/TS
BUILDING 1/TT
BUILDING 1/TU
BUILDING 1/TV
BUILDING 1/TW
BUILDING 1/TX
BUILDING 1/TY
BUILDING 1/TZ
BUILDING 1/UA
BUILDING 1/UB
BUILDING 1/UC
BUILDING 1/UD
BUILDING 1/UE
BUILDING 1/UF
BUILDING 1/UG
BUILDING 1/UH
BUILDING 1/UI
BUILDING 1/UJ
BUILDING 1/UK
BUILDING 1/UL
BUILDING 1/UM
BUILDING 1/UN
BUILDING 1/UO
BUILDING 1/UP
BUILDING 1/UQ
BUILDING 1/UR
BUILDING 1/US
BUILDING 1/UT
BUILDING 1/UU
BUILDING 1/UV
BUILDING 1/UW
BUILDING 1/UX
BUILDING 1/UY
BUILDING 1/UZ
BUILDING 1/VA
BUILDING 1/VB
BUILDING 1/VC
BUILDING 1/VD
BUILDING 1/VE
BUILDING 1/VF
BUILDING 1/VG
BUILDING 1/VH
BUILDING 1/VI
BUILDING 1/VJ
BUILDING 1/VK
BUILDING 1/VL
BUILDING 1/VM
BUILDING 1/VN
BUILDING 1/VO
BUILDING 1/VP
BUILDING 1/VQ
BUILDING 1/VR
BUILDING 1/VS
BUILDING 1/VT
BUILDING 1/VU
BUILDING 1/VV
BUILDING 1/VW
BUILDING 1/VX
BUILDING 1/VY
BUILDING 1/VZ
BUILDING 1/WA
BUILDING 1/WB
BUILDING 1/WC
BUILDING 1/WD
BUILDING 1/WE
BUILDING 1/WF
BUILDING 1/WG
BUILDING 1/WH
BUILDING 1/WI
BUILDING 1/WJ
BUILDING 1/WK
BUILDING 1/WL
BUILDING 1/WM
BUILDING 1/WN
BUILDING 1/WO
BUILDING 1/WP
BUILDING 1/WQ
BUILDING 1/WR
BUILDING 1/WS
BUILDING 1/WT
BUILDING 1/WU
BUILDING 1/WV
BUILDING 1/WW
BUILDING 1/WX
BUILDING 1/WY
BUILDING 1/WZ
BUILDING 1/XA
BUILDING 1/XB
BUILDING 1/XC
BUILDING 1/XD
BUILDING 1/XE
BUILDING 1/XF
BUILDING 1/XG
BUILDING 1/XH
BUILDING 1/XI
BUILDING 1/XJ
BUILDING 1/XK
BUILDING 1/XL
BUILDING 1/XM
BUILDING 1/XN
BUILDING 1/XO
BUILDING 1/XP
BUILDING 1/XQ
BUILDING 1/XR
BUILDING 1/XS
BUILDING 1/XT
BUILDING 1/XU
BUILDING 1/XV
BUILDING 1/XW
BUILDING 1/XX
BUILDING 1/XY
BUILDING 1/XZ
BUILDING 1/YA
BUILDING 1/YB
BUILDING 1/YC
BUILDING 1/YD
BUILDING 1/YE
BUILDING 1/YF
BUILDING 1/YG
BUILDING 1/YH
BUILDING 1/YI
BUILDING 1/YJ
BUILDING 1/YK
BUILDING 1/YL
BUILDING 1/YM
BUILDING 1/YN
BUILDING 1/YO
BUILDING 1/YP
BUILDING 1/YQ
BUILDING 1/YR
BUILDING 1/YS
BUILDING 1/YT
BUILDING 1/YU
BUILDING 1/YV
BUILDING 1/YW
BUILDING 1/YX
BUILDING 1/YY
BUILDING 1/YZ
BUILDING 1/ZA
BUILDING 1/ZB
BUILDING 1/ZC
BUILDING 1/ZD
BUILDING 1/ZE
BUILDING 1/ZF
BUILDING 1/ZG
BUILDING 1/ZH
BUILDING 1/ZI
BUILDING 1/ZJ
BUILDING 1/ZK
BUILDING 1/ZL
BUILDING 1/ZM
BUILDING 1/ZN
BUILDING 1/ZO
BUILDING 1/ZP
BUILDING 1/ZQ
BUILDING 1/ZR
BUILDING 1/ZS
BUILDING 1/ZT
BUILDING 1/ZU
BUILDING 1/ZV
BUILDING 1/ZW
BUILDING 1/ZX
BUILDING 1/ZY
BUILDING 1/ZZ
BUILDING 1/AA
BUILDING 1/AB
BUILDING 1/AC
BUILDING 1/AD
BUILDING 1/AE
BUILDING 1/AF
BUILDING 1/AG
BUILDING 1/AH
BUILDING 1/AI
BUILDING 1/AJ
BUILDING 1/AK
BUILDING 1/AL
BUILDING 1/AM
BUILDING 1/AN
BUILDING 1/AO
BUILDING 1/AP
BUILDING 1/AQ
BUILDING 1/AR
BUILDING 1/AS
BUILDING 1/AT
BUILDING 1/AU
BUILDING 1/AV
BUILDING 1/AW
BUILDING 1/AX
BUILDING 1/AY
BUILDING 1/AZ
BUILDING 1/BA
BUILDING 1/BB
BUILDING 1/BC
BUILDING 1/BD
BUILDING 1/BE
BUILDING 1/BF
BUILDING 1/BG
BUILDING 1/BH
BUILDING 1/BI
BUILDING 1/BJ
BUILDING 1/BK
BUILDING 1/BL
BUILDING 1/BM
BUILDING 1/BN
BUILDING 1/BO
BUILDING 1/BP
BUILDING 1/BQ
BUILDING 1/BR
BUILDING 1/BS
BUILDING 1/BT
BUILDING 1/BU
BUILDING 1/BV
BUILDING 1/BW
BUILDING 1/BX
BUILDING 1/BY
BUILDING 1/BZ
BUILDING 1/CA
BUILDING 1/CB
BUILDING 1/CC
BUILDING 1/CD
BUILDING 1/CE
BUILDING 1/CF
BUILDING 1/CG
BUILDING 1/CH
BUILDING 1/CI
BUILDING 1/CJ
BUILDING 1/CK
BUILDING 1/CL
BUILDING 1/CM
BUILDING 1/CN
BUILDING 1/CO
BUILDING 1/CP
BUILDING 1/CQ
BUILDING 1/CR
BUILDING 1/CS
BUILDING 1/CT
BUILDING 1/CU
BUILDING 1/CV
BUILDING 1/CW
BUILDING 1/CX
BUILDING 1/CY
BUILDING 1/CZ
BUILDING 1/DA
BUILDING 1/DB
BUILDING 1/DC
BUILDING 1/DD
BUILDING 1/DE
BUILDING 1/DF
BUILDING 1/DG
BUILDING 1/DH
BUILDING 1/DI
BUILDING 1/DJ
BUILDING 1/DK
BUILDING 1/DL
BUILDING 1/DM
BUILDING 1/DN
BUILDING 1/DO
BUILDING 1/DP
BUILDING 1/DQ
BUILDING 1/DR
BUILDING 1/DS
BUILDING 1/DT
BUILDING 1/DU
BUILDING 1/DV
BUILDING 1/DW
BUILDING 1/DX
BUILDING 1/DY
BUILDING 1/DZ
BUILDING 1/EA
BUILDING 1/EB
BUILDING 1/EC
BUILDING 1/ED
BUILDING 1/EE
BUILDING 1/EF
BUILDING 1/EG
BUILDING 1/EH
BUILDING 1/EI
BUILDING 1/EJ
BUILDING 1/EK
BUILDING 1/EL
BUILDING 1/EM
BUILDING 1/EN
BUILDING 1/EO
BUILDING 1/EP
BUILDING 1/EQ
BUILDING 1/ER
BUILDING 1/ES
BUILDING 1/ET
BUILDING 1/EU
BUILDING 1/EV
BUILDING 1/EW
BUILDING 1/EX
BUILDING 1/EY
BUILDING 1/EZ
BUILDING 1/FA
BUILDING 1/FB
BUILDING 1/FC
BUILDING 1/FD
BUILDING 1/FE
BUILDING 1/FF
BUILDING 1/FG
BUILDING 1/FH
BUILDING 1/FI
BUILDING 1/FJ
BUILDING 1/FK
BUILDING 1/FL
BUILDING 1/FM
BUILDING 1/FN
BUILDING 1/FO
BUILDING 1/FP
BUILDING 1/FQ
BUILDING 1/FR
BUILDING 1/FS
BUILDING 1/FT
BUILDING 1/FU
BUILDING 1/FV
BUILDING 1/FW
BUILDING 1/FX
BUILDING 1/FY
BUILDING 1/FZ
BUILDING 1/GA
BUILDING 1/GB
BUILDING 1/GC
BUILDING 1/GD
BUILDING 1/GE
BUILDING 1/GF
BUILDING 1/GG
BUILDING 1/GH
BUILDING 1/GI
BUILDING 1/GJ
BUILDING 1/GK
BUILDING 1/GL
BUILDING 1/GM
BUILDING 1/GN
BUILDING 1/GO
BUILDING 1/GP
BUILDING 1/GQ
BUILDING 1/GR
BUILDING 1/GS
BUILDING 1/GT
BUILDING 1/GU
BUILDING 1/GV
BUILDING 1/GW
BUILDING 1/GX
BUILDING 1/GY
BUILDING 1/GZ
BUILDING 1/HA
BUILDING 1/HB
BUILDING 1/HC
BUILDING 1/HD
BUILDING 1/HE
BUILDING 1/HF
BUILDING 1/HG
BUILDING 1/HH
BUILDING 1/HI
BUILDING 1/HJ
BUILDING 1/HK
BUILDING 1/HL
BUILDING 1/HM
BUILDING 1/HN
BUILDING 1/HO
BUILDING 1/HP
BUILDING 1/HQ
BUILDING 1/HR
BUILDING 1/HS
BUILDING 1/HT
BUILDING 1/HU
BUILDING 1/HV
BUILDING 1/HW
BUILDING 1/HX
BUILDING 1/HY
BUILDING 1/HZ
BUILDING 1/IA
BUILDING 1/IB
BUILDING 1/IC
BUILDING 1/ID
BUILDING 1/IE
BUILDING 1/IF
BUILDING 1/IG
BUILDING 1/IH
BUILDING 1/II
BUILDING 1/IJ
BUILDING 1/IK
BUILDING 1/IL
BUILDING 1/IM
BUILDING 1/IN
BUILDING 1/IO
BUILDING 1/IP
BUILDING 1/IQ
BUILDING 1/IR
BUILDING 1/IS
BUILDING 1/IT
BUILDING 1/IU
BUILDING 1/IV
BUILDING 1/IW
BUILDING 1/IX
BUILDING 1/IY
BUILDING 1/IZ
BUILDING 1/JA
BUILDING 1/JB
BUILDING 1/JC
BUILDING 1/JD
BUILDING 1/JE
BUILDING 1/JF
BUILDING 1/JG
BUILDING 1/JH
BUILDING 1/JI
BUILDING 1/JJ
BUILDING 1/JK
BUILDING 1/JL
BUILDING 1/JM
BUILDING 1/JN
BUILDING 1/JO
BUILDING 1/JP
BUILDING 1/JQ
BUILDING 1/JR
BUILDING 1/JS
BUILDING 1/JT
BUILDING 1/JU
BUILDING 1/JV
BUILDING 1/JW
BUILDING 1/JX
BUILDING 1/JY
BUILDING 1/JZ
BUILDING 1/KA
BUILDING 1/KB
BUILDING 1/KC
BUILDING 1/KD
BUILDING 1/KE
BUILDING 1/KF
BUILDING 1/KG
BUILDING 1/KH
BUILDING 1/KI
BUILDING 1/KJ
BUILDING 1/KK
BUILDING 1/KL
BUILDING 1/KM
BUILDING 1/KN
BUILDING 1/KO
BUILDING 1/KP
BUILDING 1/KQ
BUILDING 1/KR
BUILDING 1/KS
BUILDING 1/KT
BUILDING 1/KU
BUILDING 1/KV
BUILDING 1/KW
BUILDING 1/KX
BUILDING 1/KY
BUILDING 1/KZ
BUILDING 1/LA
BUILDING 1/LB
BUILDING 1/LC
BUILDING 1/LD
BUILDING 1/LE
BUILDING 1/LF
BUILDING 1/LG
BUILDING 1/LH
BUILDING 1/LI
BUILDING 1/LJ
BUILDING 1/LK
BUILDING 1/LL
BUILDING 1/LM
BUILDING 1/LN
BUILDING 1/LO
BUILDING 1/LP
BUILDING 1/LQ
BUILDING 1/LR
BUILDING 1/LS
BUILDING 1/LT
BUILDING 1/LU
BUILDING 1/LV
BUILDING 1/LW
BUILDING 1/LX
BUILDING 1/LY
BUILDING 1/LZ
BUILDING 1/MA
BUILDING 1/MB
BUILDING 1/MC
BUILDING 1/MD
BUILDING 1/ME
BUILDING 1/MF
BUILDING 1/MG
BUILDING 1/MH
BUILDING 1/MI
BUILDING 1/MJ
BUILDING 1/MK
BUILDING 1/ML
BUILDING 1/MM
BUILDING 1/MN
BUILDING 1/MO
BUILDING 1/MP
BUILDING 1/MQ
BUILDING 1/MR
BUILDING 1/MS
BUILDING 1/MT
BUILDING 1/MU
BUILDING 1/MV
BUILDING 1/MW
BUILDING 1/MX
BUILDING 1/MY
BUILDING 1/MZ
BUILDING 1/NA
BUILDING 1/NB
BUILDING 1/NC
BUILDING 1/ND
BUILDING 1/NE
BUILDING 1/NF
BUILDING 1/NG
BUILDING 1/NH
BUILDING 1/NI
BUILDING 1/NJ
BUILDING 1/NK
BUILDING 1/NL
BUILDING 1/NM
BUILDING 1/NN
BUILDING 1/NO
BUILDING 1/NP
BUILDING 1/NQ
BUILDING 1/NR
BUILDING 1/NS
BUILDING 1/NT
BUILDING 1/NU
BUILDING 1/NV
BUILDING 1/NW
BUILDING 1/NX
BUILDING 1/NY
BUILDING 1/NZ
BUILDING 1/OA
BUILDING 1/OB
BUILDING 1/OC
BUILDING 1/OD
BUILDING 1/OE
BUILDING 1/OF
BUILDING 1/OG
BUILDING 1/OH
BUILDING 1/OI
BUILDING 1/OJ
BUILDING 1/OK
BUILDING 1/OL
BUILDING 1/OM
BUILDING 1/ON
BUILDING 1/OO
BUILDING 1/OP
BUILDING 1/OQ
BUILDING 1/OR
BUILDING 1/OS
BUILDING 1/OT
BUILDING 1/OU
BUILDING 1/OV
BUILDING 1/OW
BUILDING 1/OX
BUILDING 1/OY
BUILDING 1/OZ
BUILDING 1/PA
BUILDING 1/PB
BUILDING 1/PC
BUILDING 1/PD
BUILDING 1/PE
BUILDING 1/PF
BUILDING 1/PG
BUILDING 1/PH
BUILDING 1/PI
BUILDING 1/PJ
BUILDING 1/PK
BUILDING 1/PL
BUILDING 1/PM
BUILDING 1/PN
BUILDING 1/PO
BUILDING 1/PP
BUILDING 1/PQ
BUILDING 1/PR
BUILDING 1/PS
BUILDING 1/PT
BUILDING 1/PU
BUILDING 1/PV
BUILDING 1/PW
BUILDING 1/PX
BUILDING 1/PY
BUILDING 1/PZ
BUILDING 1/QA
BUILDING 1/QB
BUILDING 1/QC
BUILDING 1/QD
BUILDING 1/QE
BUILDING 1/QF
BUILDING 1/QG
BUILDING 1/QH
BUILDING 1/QI
BUILDING 1/QJ
BUILDING 1/QK
BUILDING 1/QL
BUILDING 1/QM
BUILDING 1/QN
BUILDING 1/QO
BUILDING 1/QP
BUILDING 1/QQ
BUILDING 1/QR
BUILDING 1/QS
BUILDING 1/QT
BUILDING 1/QU
BUILDING 1/QV
BUILDING 1/QW
BUILDING 1/QX
BUILDING 1/QY
BUILDING 1/QZ
BUILDING 1/RA
BUILDING 1/RB
BUILDING 1/RC
BUILDING 1/RD
BUILDING 1/RE
BUILDING 1/RF
BUILDING 1/RG
BUILDING 1/RH
BUILDING 1/RI
BUILDING 1/RJ
BUILDING 1/RK
BUILDING 1/RL
BUILDING 1/RM
BUILDING 1/RN
BUILDING 1/RO
BUILDING 1/RP
BUILDING 1/RQ
BUILDING 1/RR
BUILDING 1/RS
BUILDING 1/RT
BUILDING 1/RU
BUILDING 1/RV
BUILDING 1/RW
BUILDING 1/RX
BUILDING 1/RY
BUILDING 1/RZ
BUILDING 1/SA
BUILDING 1/SB
BUILDING 1/SC
BUILDING 1/SD
BUILDING 1/SE
BUILDING 1/SF
BUILDING 1/SG
BUILDING 1/SH
BUILDING 1/SI
BUILDING 1/SJ
BUILDING 1/SK
BUILDING 1/SL
BUILDING 1/SM
BUILDING 1/SN
BUILDING 1/SO
BUILDING 1/SP
BUILDING 1/SQ
BUILDING 1/SR
BUILDING 1/SS
BUILDING 1/ST
BUILDING 1/SU
BUILDING 1/SV
BUILDING 1/SW
BUILDING 1/SX
BUILDING 1/SY
BUILDING 1/SZ
BUILDING 1/TA
BUILDING 1/TB
BUILDING 1/TC
BUILDING 1/TD
BUILDING 1/TE
BUILDING 1/TF
BUILDING 1/TG
BUILDING 1/TH
BUILDING 1/TI
BUILDING 1/TJ
BUILDING 1/TK
BUILDING 1/TL
BUILDING 1/TM
BUILDING 1/TN
BUILDING 1/TO
BUILDING 1/TP
BUILDING 1/TQ
BUILDING 1/TR
BUILDING 1/TS
BUILDING 1/TT
BUILDING 1/TU
BUILDING 1/TV
BUILDING 1/TW
BUILDING 1/TX
BUILDING 1/TY
BUILDING 1/TZ
BUILDING 1/UA
BUILDING 1/UB
BUILDING 1/UC
BUILDING 1/UD
BUILDING 1/UE
BUILDING 1/UF
BUILDING 1/UG
BUILDING 1/UH
BUILDING 1/UI
BUILDING 1/UJ
BUILDING 1/UK
BUILDING 1/UL
BUILDING 1/UM
BUILDING 1/UN
BUILDING 1/UO
BUILDING 1/UP
BUILDING 1/UQ
BUILDING 1/UR
BUILDING 1/US
BUILDING 1/UT
BUILDING 1/UU
BUILDING 1/UV
BUILDING 1/UW
BUILDING 1/UX
BUILDING 1/UY
BUILDING 1/UZ
BUILDING 1/VA
BUILDING 1/VB
BUILDING 1/VC
BUILDING 1/VD
BUILDING 1/VE
BUILDING 1/VF
BUILDING 1/VG
BUILDING 1/VH
BUILDING 1/VI
BUILDING 1/VJ
BUILDING 1/VK
BUILDING 1/VL
BUILDING 1/VM
BUILDING 1/VN
BUILDING 1/VO
BUILDING 1/VP
BUILDING 1/VQ
BUILDING 1/VR
BUILDING 1/VS
BUILDING 1/VT
BUILDING 1/VU
BUILDING 1/VV
BUILDING 1/VW
BUILDING 1/VX
BUILDING 1/VY
BUILDING 1/VZ
BUILDING 1/WA
BUILDING 1/WB
BUILDING 1/WC
BUILDING 1/WD
BUILDING 1/WE
BUILDING 1/WF
BUILDING 1/WG
BUILDING 1/WH
BUILDING 1/WI
BUILDING 1/WJ
BUILDING 1/WK
BUILDING 1/WL
BUILDING 1/WM
BUILDING 1/WN
BUILDING 1/WO
BUILDING 1/WP
BUILDING 1/WQ
BUILDING 1/WR
BUILDING 1/WS
BUILDING 1/WT
BUILDING 1/WU
BUILDING 1/WV
BUILDING 1/WW
BUILDING 1/WX
BUILDING 1/WY
BUILDING 1/WZ
BUILDING 1/XA
BUILDING 1/XB
BUILDING 1/XC
BUILDING 1/XD
BUILDING 1/XE
BUILDING 1/XF
BUILDING 1/XG
BUILDING 1/XH
BUILDING 1/XI
BUILDING 1/XJ
BUILDING 1/XK
BUILDING 1/XL
BUILDING 1/XM
BUILDING 1/XN
BUILDING 1/XO
BUILDING 1/XP
BUILDING 1/XQ
BUILDING 1/XR
BUILDING 1/XS
BUILDING 1/XT
BUILDING 1/XU
BUILDING 1/XV
BUILDING 1/XW
BUILDING 1/XX
BUILDING 1/XY
BUILDING 1/XZ
BUILDING 1/YA
BUILDING 1/YB
BUILDING 1/YC
BUILDING 1/YD
BUILDING 1/YE
BUILDING 1/YF
BUILDING 1/YG
BUILDING 1/YH
BUILDING 1/YI
BUILDING 1/YJ
BUILDING 1/YK
BUILDING 1/YL
BUILDING 1/YM
BUILDING 1/YN
BUILDING 1/YO
BUILDING 1/YP
BUILDING 1/YQ
BUILDING 1/YR
BUILDING 1/YS
BUILDING 1/YT
BUILDING 1/YU
BUILDING 1/YV
BUILDING 1/YW
BUILDING 1/YX
BUILDING 1/YY
BUILDING 1/YZ
BUILDING 1/ZA
BUILDING 1/ZB
BUILDING 1/ZC
BUILDING 1/ZD
BUILDING 1/ZE
BUILDING 1/ZF
BUILDING 1/ZG
BUILDING 1/ZH
BUILDING 1/ZI
BUILDING 1/ZJ
BUILDING 1/ZK
BUILDING 1/ZL
BUILDING 1/ZM
BUILDING 1/ZN
BUILDING 1/ZO
BUILDING 1/ZP
BUILDING 1/ZQ
BUILDING 1/ZR
BUILDING 1/ZS
BUILDING 1/ZT
BUILDING 1/ZU
BUILDING 1/ZV
BUILDING 1/ZW
BUILDING 1/ZX
BUILDING 1/ZY
BUILDING 1/ZZ
BUILDING 1/AA
BUILDING 1/AB
BUILDING 1/AC
BUILDING 1/AD
BUILDING 1/AE
BUILDING 1/AF
BUILDING 1/AG
BUILDING 1/AH
BUILDING 1/AI
BUILDING 1/AJ
BUILDING 1/AK
BUILDING 1/AL
BUILDING 1/AM
BUILDING 1/AN
BUILDING

Falling head slug tests were conducted on three shallow monitoring wells and one deep well throughout the site to determine the hydraulic conductivity of the surficial aquifer. A hydraulic conductivity value was then calculated for the tests.

The hydraulic conductivities from the three shallow wells (PAI-DGS-MW05, PAI-DGS-MW19, and PAI-DGS-MW25) were averaged for a shallow site conductivity of 1.4×10^{-05} ft/sec or 1.2 ft/day. The hydraulic conductivity from the deep well (PAI-DGS-MW27D) was 4.7×10^{-05} ft/sec or 4.05 ft/day.

Potential movement of groundwater at the site may be described in terms of transportation by natural flow system in the saturated zone, assuming groundwater flow follows Darcy's Law. Darcy's Law may be expressed as:

$$V = \left(\frac{K}{n}\right) x\, i$$

where:

V	=	average velocity
K	=	hydraulic conductivity = 1.2 ft/day
n	=	effective porosity = 0.45 (from charts in Appendix C of the SCDHEC 2001 guidance)
i	=	most recent hydraulic gradient measurement = 0.002 ft/ft

therefore:

$$V = \left(\frac{1.2\ \text{ft/day}}{0.45}\right) x\ 0.002\ \text{ft/ft}$$

$$= 0.0053\ \text{ft/day or } 1.9 \times 10^{-08}\ \text{m/sec.}$$

In summary, the seepage velocity of the surficial aquifer was calculated to be approximately 1.9 ft/year based on a hydraulic conductivity of 1.2 ft/day, a hydraulic gradient of 0.002 ft/ft, and a porosity of 45% for sandy soil. Likewise, the seepage velocity of the deeper groundwater was calculated to be approximately 7.3 ft/year based on a hydraulic conductivity of 4.05 ft/day, a hydraulic gradient of 0.0022 ft/ft, and a porosity of 45% for sandy soil.

2.3 FIELD SCREENING ASSESSMENT

Soil borings were completed as part of the screening portion of the soil investigation at the Depot Gas Station and to collect confirmation soil samples. Seventy-eight direct-push and 15 hand auger borings were advanced as part of the soil screening investigation at the Depot Gas Station. Sixteen soil borings were completed to collect soil samples for analysis at a fixed-base laboratory to confirm field screening concentrations and for the chemicals of concern (COC) evaluation. Except for one sample which was collected at 4 feet bgs, the field screening soil samples were collected from the upper 3 feet of each boring. The soil and groundwater samples collected for mobile laboratory screening were analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX); naphthalene; and diesel range organics at a mobile laboratory. The field screening soil boring locations are shown on Figure 11.

Initial borings were concentrated at Building 170 and the associated ASTs where the reported gasoline spill in December 1983 occurred. Additional borings to define lateral extent were installed along the 2-inch fuel line, at former Building 139, and later inside Building 155 through the concrete floor. Soil samples were collected from the surface down to the water table and screened with a photoionization detector (PID). The soil borings encountered the water table between 2 and 4 feet bgs.

2.3.1 Soil Mobile Lab Results

Eighty-nine soil samples were collected from 89 of 93 soil borings and analyzed at a mobile laboratory for BTEX, naphthalene, and diesel range organics using United States Environmental Protection Agency (USEPA) methods 8020 and 8015M. The soil samples were selected based on the soil headspace screening results with the additional criteria that the samples originate in the vadose zone above the water table. Table 2 presents a summary of the analytical data from the mobile laboratory.

As indicated in Table 2, benzene (11 borings), toluene (14 borings), ethylbenzene (14 borings), xylenes (14 borings), naphthalene (13 borings), and DRO (12 borings) were above the mobile laboratory detection limits. Benzene concentrations above detection limits ranged from 73.5 µg/kg (DGSSFB0801) to 2100 µg/kg (PAIDGSGB79). Benzene in soil exceeded the mobile laboratory capacity of the instrument at soil samples PAIDGSSB1803, PAIDGSSB2802, PAIDGSSB6901. Naphthalene concentrations above detection limits ranged from 360 µg/kg (DGSSFB1201) to 13,600 µg/kg (PAIDGSGB79). The soil boring locations with the highest BTEX and naphthalene concentrations were located adjacent to the 2-inch fuel line, at the former Building 139, and under Building 155.

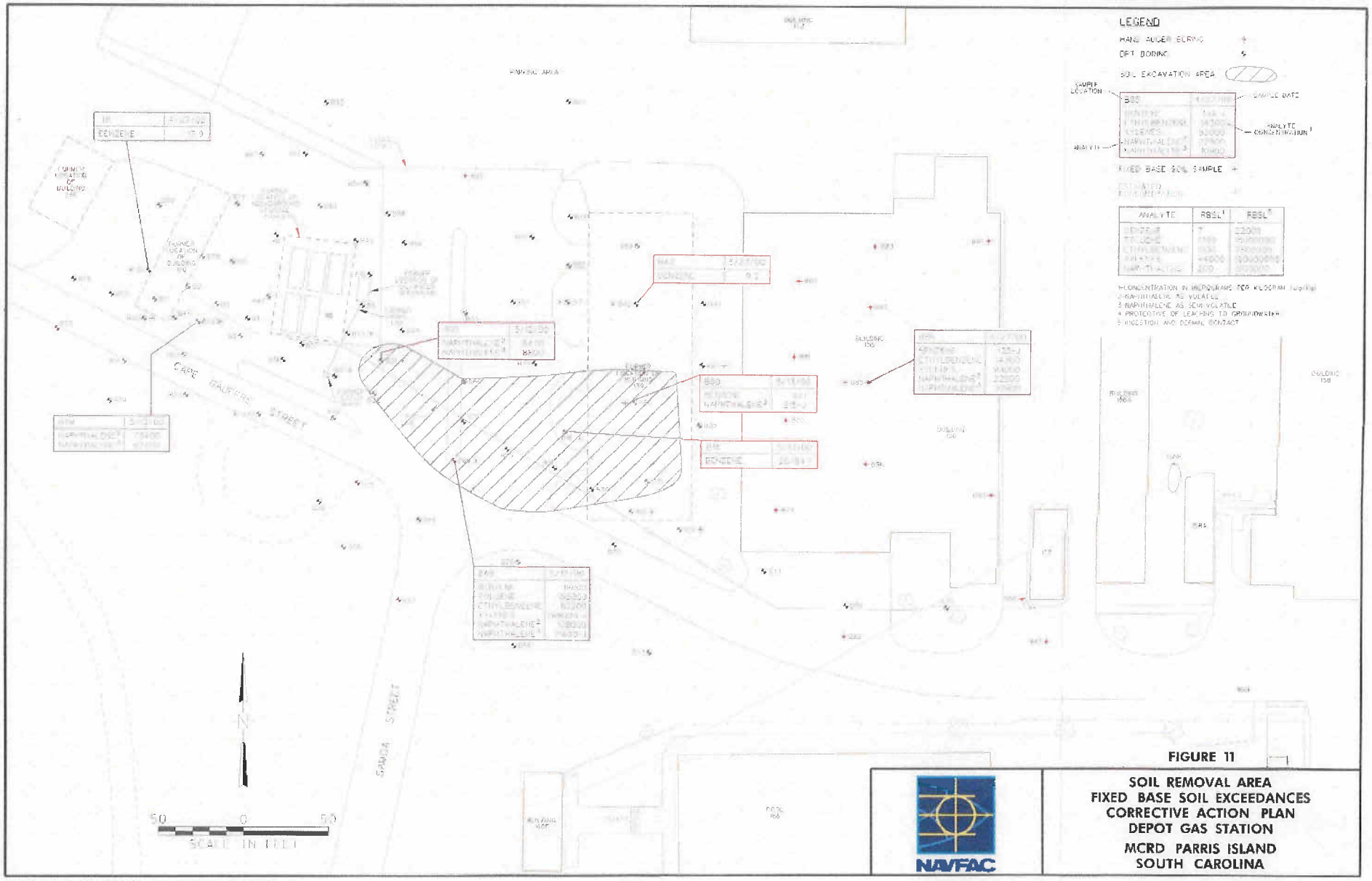

LEGEND
HAND AUGER BORING
DPT BORING
SOIL EXCAVATION AREA
SAMPLE LOCATION
SAMPLE DATE
ANALYTE CONCENTRATION
ANALYTE
FIXED BASE SOIL SAMPLE
ANALYTE
RBSL
RBSL
1 CONCENTRATION IN MILLIGRAMS PER KILOGRAM (mg/kg)
2 NAPHTHALENE AS VOLATILE
3 NAPHTHALENE AS SEMI-VOLATILE
4 PROTECTIVE OF LEACHING TO GROUNDWATER
5 INGESTION AND DERMAL CONTACT
BUILDING 158
BUILDING 159
BUILDING 160
BUILDING 166
BUILDING 167
BUILDING 168
BUILDING 169
BUILDING 170
BUILDING 171
BUILDING 172
BUILDING 173
BUILDING 174
BUILDING 175
BUILDING 176
BUILDING 177
BUILDING 178
BUILDING 179
BUILDING 180
BUILDING 181
BUILDING 182
BUILDING 183
BUILDING 184
BUILDING 185
BUILDING

TABLE 2

SUMMARY OF MOBILE LABORATORY SCREENING RESULTS FOR SOIL
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Sample Number	Benzene (µg/kg)	Toluene (µg/kg)	Ethylbenzene (µg/kg)	m&p-Xylene (µg/kg)	o-Xylene (µg/kg)	Naphthalene (µg/kg)	DRO (mg/kg)
Detection Limit	60	60	60	120	60	60	50
DGSSFB0101	ND	ND	ND	ND	ND	ND	ND
DGSSFB0201	ND	ND	ND	ND	ND	ND	ND
DGSSFB0301	ND	ND	ND	ND	ND	ND	ND
DGSSFB0401	ND	ND	ND	ND	ND	ND	ND
DGSSFB0501	ND	ND	ND	ND	ND	ND	ND
DGSSFB0601	ND	ND	ND	ND	ND	ND	ND
DGSSFB0701	85.4	7020E*	10620E*	5200*	5248*	771*	3687
DGSSFB0801	73.5	846^	218^	188	171	559	13519*
DGSSFB0901	ND	ND	ND	ND	ND	23.0	ND
DGSSFB1001	ND	ND	ND	ND	ND	ND	ND
DGSSFB1102	ND	ND	ND	ND	ND	ND	ND
DGSSFB1201	ND	1200*	2129*	11799*	3407*	360	417
DGSSFB1312	ND	ND	ND	ND	ND	ND	ND
DGSSFB1412	ND	ND	ND	132	ND	ND	ND
DGSSFB1512	ND	ND	ND	ND	ND	ND	ND
DGSSFB1612	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB1703	205+	88.0+	228+	596+	135+	26.7	ND
PAIDGSSB1803	U	U	U	U	U	5300E	11563E
PAIDGSSB2001	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB2101	ND	86.5	1000^	ND	138	300	4575
PAIDGSSB2201	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB2302	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB2402	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB2501	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB2601	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB2701	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB2802	U	U	U	U	U	432	6296
PAIDGSSB2901	79.8	ND	108	ND	ND	ND	ND
PAIDGSSB3001	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB3103	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB3201	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB3301	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB3402	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB3503	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB3601	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB3703	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB3802	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB3902	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB4002	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB4101	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB4202	131	ND	233	753	ND	ND	ND
PAIDGSSB4304	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB4403	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB4501	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB4601	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB4701	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB4801	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB4901	ND	2371*	2652*	2715*	8570E*	6020*	7383
PAIDGSSB5002	ND	177	5566E*	8557E*	8560*	2185E	7200
PAIDGSSB5201	ND	ND	ND	ND	ND	ND	ND

TABLE 2

SUMMARY OF MOBILE LABORATORY SCREENING RESULTS FOR SOIL
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Sample Number	Benzene (µg/kg)	Toluene (µg/kg)	Ethylbenzene (µg/kg)	m&p-Xylene (µg/kg)	o-Xylene (µg/kg)	Naphthalene (µg/kg)	DRO (mg/kg)
Detection Limit	60	60	60	120	60	60	50
PAIDGSSB5301	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB5401	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB5502	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB5601	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB5701	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB5902	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB6002	1430+	5620E+	1325+	21200E+	8260E+	1365+	728 G
PAIDGSSB6102	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB6202	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB6302	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB6402	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB6502	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB6602	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB6701	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB6801	ND	ND	34.9	105	33.2	ND	ND
PAIDGSSB6901	U	U	U	U	U	6430E*	15800
PAIDGSSB7103	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB7201	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB7301	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB7402	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB7502	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB7601	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB7702	ND	ND	ND	ND	ND	ND	ND
PAIDGSSB7801	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB79	2100	4280	2680	5770	2840	13600E	1250
PAIDGSGB80	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB81	ND	179	212	1260	1408E	3184E	ND
PAIDGSGB82	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB83	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB84	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB85	88.1	141	4320	11000	2110	1640E	655
PAIDGSGB86	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB87	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB88	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB89	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB90	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB91	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB92	ND	ND	ND	ND	ND	ND	ND
PAIDGSGB93	ND	ND	ND	ND	ND	ND	ND

^: Indicates the compound was run under a 2X Dillution
+: Indicates the compound was run under a 5X Dillution
* : Indicates the compound was run under a 10X Dillution
U: Indicates the compound exceeded the capacity of the instrument
E: Indicates the compound exceeded the upper calibration limit
ND: Nondetection

2.3.2 Groundwater Mobile Lab Results

Ninety-two groundwater-screening samples were collected analyzed in a mobile laboratory for BTEX, naphthalene, and diesel range organics using USEPA methods 8020 and 8015M. Groundwater screening samples from soil borings were typically collected at the water table at depths ranging from 3 to 8 feet bgs. Table 3 presents a summary of the analytical data from the mobile laboratory.

As indicated in Table 3, benzene (36 borings), toluene (42 borings), ethylbenzene (45 borings), xylenes (45 borings), naphthalene (41 borings), and diesel range organics (DRO) (33 borings) were above the mobile laboratory detection limits. Benzene concentrations above detection limits ranged from 13.1 µg/L (DGSGFB0204) to 22,900 µg/L (PAIDGSGB7107). Naphthalene concentrations above detection limits ranged from 22.4 µg/L (PAIDGSSGB7804) to 4,213 µg/L (PAIDGSGB1807). The groundwater screening samples with the highest benzene and naphthalene concentrations were located adjacent to the 2-inch fuel line, at the former Building 139, and under Building 155.

2.4 CHEMICALS OF CONCERN IN SOIL AND GROUNDWATER

2.4.1 Chemicals of Concern in Soil

Sixteen subsurface soil samples and two duplicate samples were collected from the Depot Gas Station area for determination of COCs. Soil samples collected for fixed-base laboratory analysis were analyzed for BTEX, naphthalene, polynuclear aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (TPH), and inorganics. The soil boring locations are shown on Figure 11. Table 4 summarizes the COCs detected in the soil samples. Because the receptors determined in Section 1.3 can be divided into two sets, those in open areas and those inside the building, the soil data collected from beneath Building 155, soil sample DGSSLM0103, were evaluated separately from the remaining soil samples collected from open areas. Benzene was detected in six of the samples at concentrations exceeding the risk-based screening level (RBSL) protective of leaching to groundwater of 7 µg/kg for sandy soil, including the sample DGSSLM0103. Naphthalene was detected in eight of the samples at concentrations exceeding the RBSL of 36 µg/kg. Soil sample DGSSLB6902, in the open area, had the highest concentrations of benzene (19,800 µg/kg) and naphthalene (128,000 µg/kg when analyzed as a volatile, estimated 71,600 µg/kg when analyzed as a semivolatile). Sample DGSSLB6902 also had toluene exceedances of 152,000 µg/kg (RBSL = 1,450 µg/kg), ethylbenzene at 82,200 µg/kg (RBSL = 1,150 µg/kg), and xylenes at an estimated 768,000 µg/kg (RBSL = 14,500 µg/kg) (Fig. 11). Sample DGSSLM0103 under the building had exceedances of benzene (estimated 135 µg/kg), ethylbenzene (14,300 µg/kg), xylenes (93,000 µg/kg), and naphthalene (22,900 µg/kg when analyzed as a volatile, 10,900 µg/kg when analyzed as a semivolatile).

TABLE 3

SUMMARY OF MOBILE LABORATORY SCREENING RESULTS FOR GROUNDWATER
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

Sample Number	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	m&p-Xylene (µg/L)	o-Xylene (µg/L)	Naphthalene (µg/L)	DRO (mg/L)
Detection Limit	10	10	10	20	10	20	1.7
DGSGFB0107	10	10	23.5	20	10	20	1.7
DGSGFB0204	13.1	34.8	77.2	99	86	65.7	8.54
DGSGFB0307	15.6	10	78.4	23.8	10.3	59.1	2.4
DGSGFB0404	10	10	10	20	10	20	1.7
DGSGFB0507	10	10	10.6	26.8	10	20	1.7
DGSGFB0604	24.34	10	151.2	25.9	12.7	48.1	8.1
DGSGFB0707	20.7	20.1	656.4	475.2	24.1	164	31.6
DGSGFB0804	23.5	16.7	10	20	11.5	846^	29.5
DGSGFB0903	10	10	10	20	10	20	1.7
DGSGFB1006	10	10	10	20	10	20	13.7
DGSGFB1108	10	102	202	5212E*	187	20	14.3
DGSGFB1208	10	1124*	160	9548E*	1071*	57.2	40.3
DGSGFB1324	10	10	116	20	10	31.4	1.7
DGSGFB1424	10	10	30.8	85.3	24.2	20	1.7
DGSGFB1534	10	10	10	17.1	10	20	1.7
DGSGFB1624	10	10	49.8	138	39.2	30.3	1.7
PAIDGSGB1707	5935E*	9582E*	2468E*	7010E*	1712*	867*	1.7
PAIDGSGB1807	16719"	2024"	4991"	1388"	7360"	4213"	1.7
PAIDGSGB1904	44.2	608E	295*	323	147	1540*	1.7
PAIDGSGB2004	10	10	10	20	10	20	1.7
PAIDGSGB2104	10	10	16.7	14.98	14.1	224	1.7
PAIDGSGB2204	10	10	10	20	10	20	1.7
PAIDGSGB2304	10	10	10	20	10	20	1.7
PAIDGSGB2404	10	10	10	20	10	20	1.7
PAIDGSGB2504	10	10	10	14.6	10	20	1.7
PAIDGSGB2604	10	10	10	20	10	20	1.7
PAIDGSGB2704	10	10	10	20	10	20	1.7
PAIDGSGB2804	1190**	1750**	1250**	3630**	2145**	668E	29.7
PAIDGSGB2904	3106E	4713E	2000^^	7020^^	3940^^	1778^^	11
PAIDGSGB3007	1811E	797E	1262E	1546E	395E	116	9.8
PAIDGSGB3107	U	U	U	U	U	1120E	27
PAIDGSGB3204	10	10	17.4	48	11.5	20	1.7
PAIDGSGB3304	10	10	10	20	10	20	1.7
PAIDGSGB3407	10	10	10	20	10	20	1.7
PAIDGSGB3503	U	U	2277E	5788E	2343E	575E	20.7
PAIDGSGB3604	27.6	28.3	10	20	10	20	1.7
PAIDGSGB3707	10	12.2	10	20	10	20	1.7
PAIDGSGB3807	10	10	10	20	10	20	1.7
PAIDGSGB3904	10	10	10	20	10	20	1.7
PAIDGSGB4004	10	10	10	20	10	20	1.7
PAIDGSGB4104	10	10	10	20	10	20	1.7
PAIDGSGB4207	934*	47.8	34.3	232	10	20	1.7
PAIDGSGB4307	10	10	10	20	10	20	1.7
PAIDGSGB4407	17.5	181	103	276	77.1	74.2	3.69
PAIDGSGB4504	1470*	43.5	254	33.9	10	95	1.7
PAIDGSGB4604	10	12.9	41	41.3	33.3	202	14.7
PAIDGSGB4704	23.6	10	52.9	43.6	45.9	146	20
PAIDGSGB4804	10	10	12.6	20	10	72.8	2.08
PAIDGSGB4904	10	20.3	353*	32.9	79.9	846*	10.4
PAIDGSGB5004	10	10	193	30	37.7	630*	25.4
PAIDGSSB5104	68.2	36.8	130	85.8	120	191	31.3
PAIDGSGB5204	10	10	10	20	10	20	1.7
PAIDGSGB5304	10	10	10	20	10	20	1.7
PAIDGSGB5404	10	10	10	20	10	20	1.7

TABLE 3

SUMMARY OF MOBILE LABORATORY SCREENING RESULTS FOR GROUNDWATER
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Sample Number	Benzene (µg/L)	Toluene (µg/L)	Ethylbenzene (µg/L)	m&p-Xylene (µg/L)	o-Xylene (µg/L)	Naphthalene (µg/L)	DRO (mg/L)
Detection Limit	10	10	10	20	10	20	1.7
PAIDGSGB5504	10	10	10	20	10	20	1.7
PAIDGSGB5604	10	10	10	20	10	20	1.7
PAIDGSGB5704	10	10	10	20	10	20	1.7
PAIDGSGB5807	10	10	10	20	10	20	1.7
PAIDGSGB5907	10	10	10	20	10	20	1.7
PAIDGSGB6007	17000"	31100"	3850"	11400"	5439"	2472"	63.5
PAIDGSGB6102	6520"	19100"	2980"	9520"	4922"	1530"	24.2
PAIDGSGB6207	157	527E	90.7	283	117	20	1.7
PAIDGSGB6304	196	886E	153	409	145	20	1.7
PAIDGSGB6408	23.3	94.4	21.2	56.9	26	20	1.7
PAIDGSGB6504	16.2	79.5	12.8	32	18.1	20	1.7
PAIDGSGB6604	196	305E	332E	748E	129	59.5	3.93
PAIDGSGB6704	10	10	10	20	10	20	1.7
PAIDGSGB6804	10	10	10	20	10	20	1.7
PAIDGSGB6904	11400"	1020"	7030"	4120E	1000"	2350"	30.8
PAIDGSGB7004	1623"	269E	1670"	4680"	1212E	755E	33.4
PAIDGSGB7107	22900"	10230"	8720"	26500"	12300"	2090"	46.9
PAIDGSGB7204	73.6	186	30.2	71.1	35.5	11.7	1.7
PAIDGSGB7305	10	31.5	34.2	81.5	80.6	150*	8.6
PAIDGSGB7404	13.7	32.2	10	20	10	31.2	1.7
PAIDGSGB7507	10	18.9	10	20	10	30.6	1.7
PAIDGSGB7604	10	10	10	20	10	20	1.7
PAIDGSGB7704	10	13.5	10	20	10	20	1.7
PAIDGSGB7804	10	21.1	10.3	64.4	14.9	22.4	8.7
PAIDGSGB79	7400E	1520	1670	3930	14450	1450	4.78
PAIDGSGB80	405	62.4	35.3	19.4	10	262	3.97
PAIDGSGB81	3990	186	2780	2450	136	2580	10.2
PAIDGSGB82	10	10	10	20	10	30	1.7
PAIDGSGB83	10	10	10	20	10	30	1.7
PAIDGSGB84	10	10	10	20	10	30	1.7
PAIDGSGB85	7920E	540	1100	3240	537	1710	3.72
PAIDGSGB86	1100E	109	19.8	20	14.9	107	3.23
PAIDGSGB87	10	10	10	20	10	30	1.7
PAIDGSGB89	10	10	10	20	10	30	1.7
PAIDGSGB90	10	10	10	20	10	30	1.7
PAIDGSGB91	10	10	10	20	10	30	1.7
PAIDGSGB92	10	10	10	20	10	30	1.7
PAIDGSGB93	10	10	10	20	10	30	1.7

^: Indicates the compound was run under a 2X Dillution
+: Indicates the compound was run under a 5X Dillution
* : Indicates the compound was run under a 10X Dillution
^^ : Indicates the compound was run under a 20X Dillution
** : Indicates the compound was run under a 30X Dillution
" : Indicates the compound was run under a 100X Dillution
U: Indicates the compound exceeded the capacity of the instrument
E: Indicates the compound exceeded the upper calibration limit
ND: Nondetection

TABLE 4

SUMMARY OF FIXED-BASE LABORATORY ANALYTICAL RESULTS FOR CHEMICALS OF CONCERN IN SOIL DEPOT GAS STATION MCRD PARRIS ISLAND PARRIS ISLAND, SOUTH CAROLINA

Sample No.	Sample Date	Benzene (µg/kg)	Toluene (µg/kg)	Ethylbenzene (µg/kg)	Xylenes (total) (µg/kg)	Naphthalene (µg/kg) as volatile	Naphthalene (µg/kg) as semivolatile
RBSL [1]		7	1450	1150	14500	36	36
RBSL [2]		12000	16000000	7800000	160000000	3100000	3100000
DGSLB0103	04/27/00	**7.9**	2.4 J	8.8	3.1 J	**133**	**62.6 J**
DGSSLB0802	05/27/00	0.57 J	3.9 J	0.98 J	4.8 J	5.7 U	3040 U
DGSSLB1202	05/27/00	5.4 U	5.4 U	5.4 U	5.4 U	5.4 U	718 U
DGSSLB1702	05/13/00	6.4 U	6.4 U	6.4 U	6.4 U	6.4 U	18.8 J
DGSSLB1802	05/13/00	**20**	0.96 J	3.5 J	1.1 J	1.4 J	**71.7 J**
DGSSLB1802-D	05/13/00	**84.1**	3.1 J	6.6	8.9	6.2	**52.9 J**
DGSSLB2102	05/12/00	658 U	51.6 J	825	127	**8470**	**8800**
DGSSLB3102	05/27/00	5.8 U	5.8 U	5.8 U	5.8 U	5.8 U	698 U
DGSSLB4002	05/27/00	5.5 U	5.5 U	5.5 U	5.5 U	5.5 U	703 U
DGSSLB4202	05/27/00	**9.2**	1.3 J	6.8 U	53.8	9.8	840 U
DGSSLB4902	05/13/00	5480 U	5480 U	5480 U	5480 U	**73400**	**62400**
DGSSLB5002	05/27/00	5.9 U	5.9 U	5.9 U	5.9 U	5.9 U	776 U
DGSSLB5002-D	05/27/00	5.6 U	5.6 U	5.6 U	5.6 U	5.6 U	746 U
DGSSLB6002	05/13/00	**114**	246 J	24.4	150	21.6	**215 J**
DGSSLB6102	05/27/00	5.2 U	5.2 U	5.2 U	5.2 U	5.2 U	722 U
DGSSLB6902	05/12/00	**19800**	**152000**	**82200**	**768000 J**	**128000**	**71600 J**
DGSSLB7302	05/27/00	6.1 U	6.1 U	6.1 U	6.1 U	6.1 U	746 U
DGSSLM0103	04/27/00	**135 J**	981	**14300**	**93000**	**22900**	**10900**

[1] Risk Based Screening Level protective of leaching to groundwater. (SCDHEC, 2001)
[2] Risk Based Screening Level for incidental ingestion and dermal contact with soil. (SCDHEC, 2001)
U = Analytical result is below detection limit.
J = Estimated value.

No chemicals, with the exception of benzene in soil sample DGSSLB6902, exceeded their RBSLs for ingestion and dermal contact with soil.

2.4.2 Chemicals of Concern in Groundwater

Table 5 presents the analytical results for COCs detected in the groundwater samples. Thirty-two groundwater samples and four duplicates were collected from the Depot Gas Station area for the determination of COCs. Groundwater samples were analyzed for BTEX, methyl tert butyl ether (MTBE), naphthalene, TPH, PAHs, and inorganics according to SCDHEC guidance documents. Five of the groundwater samples were also analyzed for the following natural attenuation parameters: dissolved oxygen, carbon dioxide, ferrous iron, nitrite, nitrogen/nitrate, sulfate, and methane. The monitoring well locations are shown on Figure 2. Because the receptors determined in Section 1.3 can be divided into two sets, those in open areas and those inside the building, the groundwater data collected from beneath Building 155, wells PAI-DGS-MW01 and PAI-DGS-MW02, were evaluated separately from the remaining wells located in the open areas.

In the shallow wells in the open areas, PAI-DGS-MW03 through PAI-DGS-MW26, benzene, toluene, ethylbenzene, MTBE, naphthalene, 2-methylnaphthalene, chromium, and lead were detected at concentrations exceeding their respective RBSLs or maximum contaminant levels (MCLs). The maximum concentrations of benzene (7,610 µg/L) and ethylbenzene (1,440 µg/L) were detected in well PAI-DGS-MW06. The maximum concentrations of naphthalene (612 µg/L), lead (205 µg/L), and chromium (314 µg/L) were detected in well PAI-DGS-MW15. The maximum concentrations of 2-methylnaphthalene (64.1 µg/L) and toluene (6,300 µg/L) were detected in well PAI-DGS-MW03.

In the shallow well, PAI-DGS-MW01, under Building 155, benzene (1,740 µg/L), naphthalene (179 µg/L), 2-methylnaphthalene (43.5 µg/L), and arsenic (98.2 µg/L) were detected at concentrations exceeding their respective RBSLs or MCLs. The extent of impact in the shallow groundwater is shown on Figures 12 and 13; note that for wells PAI-DGS-MW-03, -MW-06, and -MW-15, the values shown on the figures represent the average values for the samples and their duplicates.

In the deep wells, PAI-DGS-MW27D through PAI-DGS-MW32D, benzene was the only chemical detected at a concentration exceeding its RBSL (5 µg/L) at one well, PAI-DGS-MW28D (3,480 µg/L), at a depth of 34 bgs. Well PAI-DGS-MW28D is located adjacent to PAI-DGS-MW06, which has the highest concentration of benzene (7,610 µg/L) and the second highest naphthalene concentration (612 µg/L) in the surficial aquifer. Well PAI-DGS-MW31D was installed at this location at a depth of 58 feet bgs to further define the vertical extent of contamination. The benzene concentration was estimated at 1.6J µg/L

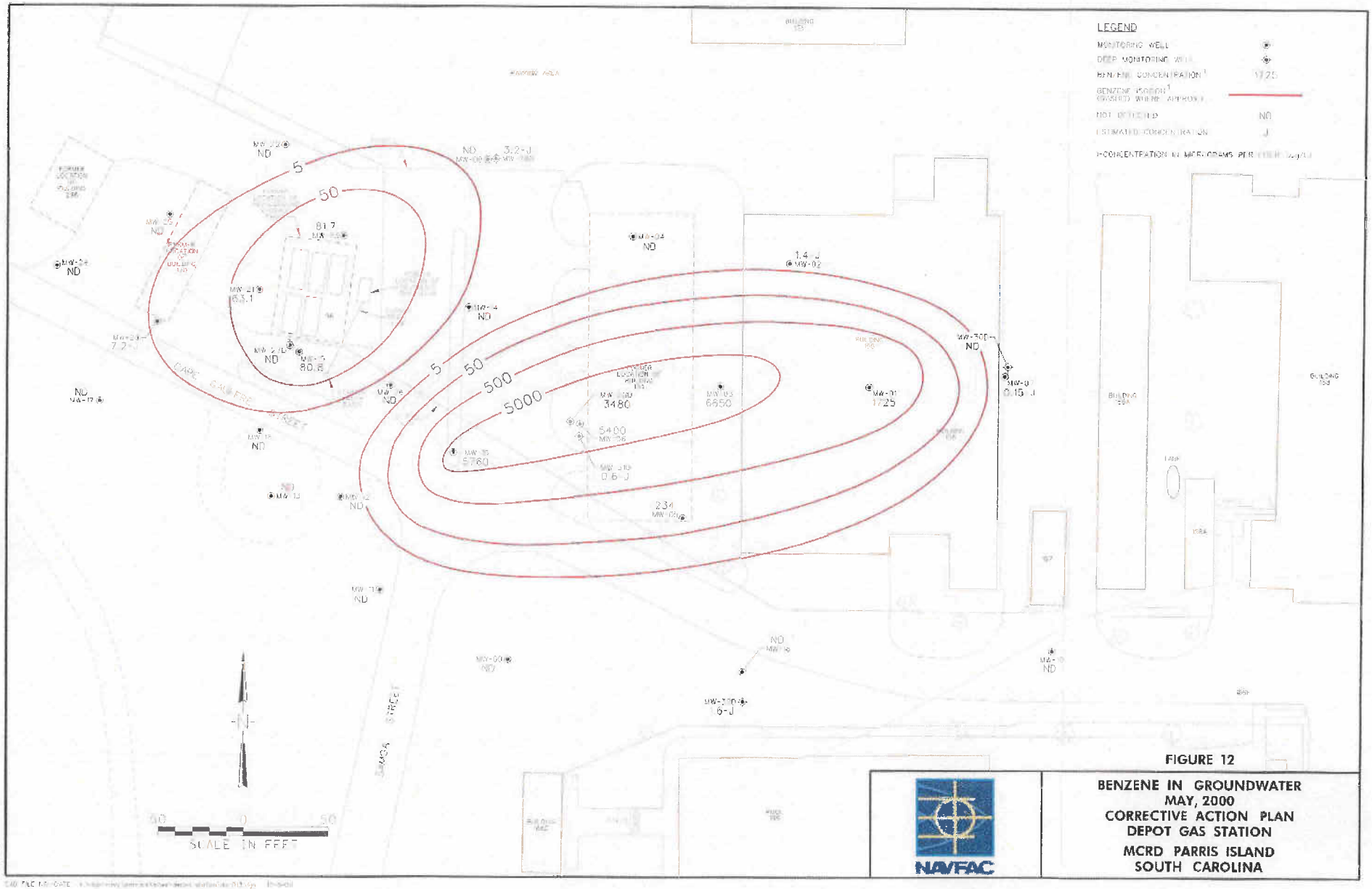
TABLE 5
SUMMARY OF FIXED-BASE LABORATORY ANALYTICAL RESULTS FOR CHEMICALS OF CONCERN IN GROUNDWATER
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA
PAGE 1 OF 2

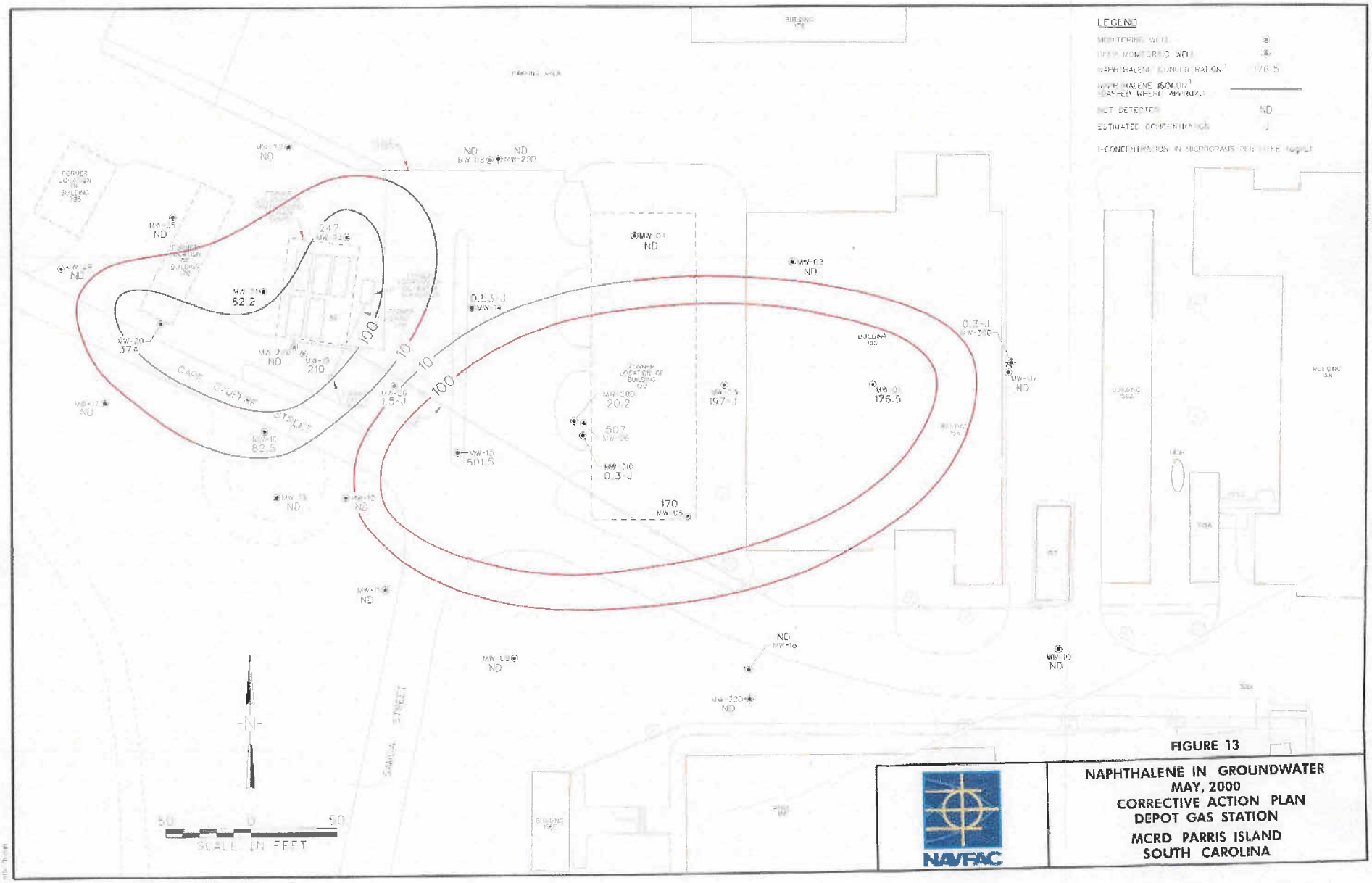
Monitoring Well/ Sample No.	Sample Date	Benzene (µg/L)	Toluene (µg/L)	Ethyl-benzene (µg/L)	Xylenes (total) (µg/L)	Naphthalene (µg/L)	Naphthalene (µg/L) as semivolatile	2-Methyl naphthalene (µg/L)	Acenaphthalene (µg/L)	Fluorene (µg/L)	Phenathrene (µg/L)	MTBE (µg/L)	Arsenic (µg/L)	Barium (µg/L)
RBSL[1]		5	1000	700	10000	25	25	25	25	25	25	40	50	2000
DGSGLMW0101	26-May-00	**1740**	68.5 J	310	1240	**174**	**130**	**43.5**	9.9 U	0.58 J	2.6 J	800 U	**67.8**	31.5
DGSGLMW0101-D	26-May-00	**1710**	66.5 J	311	1250	**179**	NA	NA	NA	NA	NA	800 U	**98.2**	27.5
DGSGLMW0201	26-May-00	1.4 J	5 U	0.068 J	5 U	5 U	9.9 U	9.9 U	9.9 U	9.9 U	9.9 U	40 U	2.9 U	111
DGSGLMW0301	14-May-00	**6650**	**6300**	699	3260	**197 J**	**338**	**64.1**	9.8 U	9.8 U	2.1 J	4000 U	NA	NA
DGSGLMW0401	14-May-00	5 U	5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	10 U	40 U	NA	NA
DGSGLMW0501	15-May-00	**234**	38 J	334	200	**170**	**68 J**	18.5 J	9.8 UJ	9.8 UJ	1.2 J	400 U	NA	NA
DGSGLMW0601	16-May-00	**7610**	**2480**	**1390**	4470	**508**	**280**	**41.3**	10 U	10 U	0.9 J	1600 U	26.1	13.4
DGSGLMW0601-D	15-May-00	**3190**	**2550**	**1440**	4660	**506**	**323**	**48**	10 U	10 U	0.92 J	1600 U	28.0	17.0
DGSGLMW0701	17-May-00	0.15 J	5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	10 U	40 U	4.0	32.9
DGSGLMW0801	17-May-00	5 U	5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	1 J	40 U	4.9	24.1
DGSGLMW0901	15-May-00	5 U	5 U	5 U	5 U	5 U	1 J	9.7 U	9.7 U	9.7 U	9.7 U	40 U	NA	NA
DGSGLMW1001	28-May-00	5 U	5 U	5 U	5 U	5 U	10.2 U	10.2 U	10.2 U	10.2 U	10.2 U	40 U	11.4	23.3
DGSGLMW1101	26-May-00	5 U	5 U	5 U	5 U	5 U	9.8 U	9.8 U	9.8 U	9.8 U	0.61 J	0.39 J	20.0	19.5
DGSGLMW1101-D	26-May-00	5 U	5 U	5 U	5 U	5 U	9.8 U	9.8 U	9.8 U	9.8 U	0.61 J	0.39 J	21.2	18.4
DGSGLMW1201	18-May-00	5 U	5 U	5 U	5 U	5 U	9.8 U	9.8 U	9.8 U	9.8 U	9.8 U	3.4 J	10.6	14.9
DGSGLMW1301	18-May-00	5 U	5 U	5 U	5 U	5 U	0.82 J	1.9 J	9.8 U	9.8 U	0.78 J	10.7 J	40.9	22.6
DGSGLMW1401	25-May-00	5 U	5 U	5 U	5 U	0.53 J	10 U	10 U	10 U	10 U	10 U	40 U	5.4	15.0
DGSGLMW1501	27-May-00	**5640**	425	**1000**	3080	**612**	**291**	**55.2**	10.5 U	10.5 U	10.5 U	400 U	30.8	462
DGSGLMW1501-D	27-May-00	**5880**	401	**925**	2920	**591**	**318**	**59.1**	9.8 U	9.8 U	0.5 J	400 U	29.0	504
DGSGLMW1601	25-May-00	10 U	10 U	0.38 J	1.8 J	**82.5**	**47.8**	14.3	0.57 J	9.8 U	9.8 U	30.5 J	4.3	29.1
DGSGLMW1701	19-May-00	5 U	5 U	5 U	5 U	5 U	9.8 U	9.8 U	9.8 U	9.8 U	9.8 U	1.2 J	2.9 U	16.4
DGSGLMW1801	27-May-00	5 U	5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	0.75 J	40 U	19.3	11.6
DGSGLMW1901	23-May-00	**80.8**	4 J	31.6	7.8 J	**210**	**37.6**	14.2	9.9 U	1.8 J	1.4 J	**152 J**	6.5	32.0
DGSGLMW2001	19-May-00	**7.2 J**	2.2 J	263	36.1	**374**	**104**	15.7	9.8 U	9.8 U	9.8 U	200 U	6.8	11.9
DGSGLMW2101	23-May-00	**63.1**	3.9 J	115	17.8 J	**62.2**	12.6	2 J	10 U	10 U	10 U	31.8 J	7.9	45.5
DGSGLMW2201	24-May-00	5 U	5 U	5 U	5 U	5 U	10.2 U	10.2 U	10.2 U	10.2 U	10.2 U	40 U	3.2	15.7
DGSGLMW2301	24-May-00	**81.7**	8.7 J	192	55.6	**247**	**130**	21.4	10.4 U	10.4 U	0.63 J	**62.8 J**	11.7	21.1
DGSGLMW2401	19-May-00	5 U	5 U	5 U	5 U	5 U	9.8 U	9.8 U	9.8 U	9.8 U	9.8 U	**53.1**	16.2	19.6
DGSGLMW2501	19-May-00	5 U	5 U	5 U	5 U	5 U	9.8 U	9.8 U	9.8 U	9.8 U	9.8 U	40 U	3.42	32
DGSGLMW2601	25-May-00	5 U	5 U	5 U	5 U	1.5 J	10 U	0.54 J	10 U	10 U	10 U	40 U	14.9	10.8
DGSGLMW27D01	24-May-00	5 U	5 U	5 U	5 U	5 U	10 U	10 U	10 U	10 U	0.53 J	0.74 J	2.1 U	96.8
DGSGLMW28D01	15-May-00	**3480**	97.8	106 J	278	20.2	11.7	4.6 J	10 U	10 U	1.4 J	40 U	2.9 U	468
DGSGLMW29D01	17-May-00	3.2 J	0.81 J	3.8 J	4.2 J	5 U	10 U	10 U	10 U	10 U	1.3 J	40 U	2.9 U	38.3
DGSGLMW30D01	15-Jun-01	5 U	0.3 J	5 U	5 U	0.3 JB	9.9 U	9.9 U	9.9 U	9.9 U	9.9 U	40 U	4.06 U	13.5
DGSGLMW31D01	16-Jun-01	0.59 J	0.26 J	0.22 J	0.87 J	0.27 JB	0.22 J	3.7 J	10 U	10 U	10 U	40 U	4.06 U	43
DGSGLMW32D01	16-Jun-01	1.6 J	5 U	5 U	5 U	5 U	9.8 U	9.8 U	9.8 U	9.8 U	9.8 U	40 U	4.06 U	18.5

TABLE 5
SUMMARY OF FIXED-BASE LABORATORY ANALYTICAL RESULTS FOR CHEMICALS OF CONCERN IN GROUNDWATER
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA
PAGE 2 OF 2

Monitoring Well/ Sample No.	Sample Date	Cadmium (µg/L)	Chromium (µg/L)	Iron (µg/L)	Lead (µg/L)	Mercury (µg/L)	Selenium (µg/L)	Silver (µg/L)
RBSL[1]		5	100	300 [3]	15 [3]	2	50	5
DGSGLMW0101	26-May-00	0.69 U	2.1	NA	3.7	0.14	5.8	0.94 U
DGSGLMW0101-D	26-May-00	0.69 U	0.87 U	NA	1.4 U	0.04 U	2.9	0.94 U
DGSGLMW0201	26-May-00	0.69 U	0.87 U	NA	1.4 U	0.04 U	2.1 U	0.94 U
DGSGLMW0301	14-May-00	NA	NA	NA	3.4	0.04 U	NA	NA
DGSGLMW0401	14-May-00	NA	NA	NA	1.4 U	0.04 U	NA	NA
DGSGLMW0501	15-May-00	NA	NA	NA	1.4 U	0.04 U	NA	NA
DGSGLMW0601	16-May-00	0.69 U	3.3	NA	3.1	0.04 U	8.1	0.94 U
DGSGLMW0601-D	15-May-00	0.69 U	5.3	NA	4.3	0.04 U	7.1	0.94 U
DGSGLMW0701	17-May-00	0.69 U	0.90	NA	1.4 U	0.04 U	3.0	0.94 U
DGSGLMW0801	17-May-00	0.69 U	5.0	NA	1.7	0.04 U	2.1 U	0.94 U
DGSGLMW0901	15-May-00	NA	NA	NA	1.4 U	0.04 U	NA	NA
DGSGLMW1001	28-May-00	0.69 U	0.87 U	**7030 J**	1.4 U	0.04 U	2.1 U	0.94 U
DGSGLMW1101	26-May-00	0.69 U	3.9	NA	1.4 U	0.04 U	2.1 U	0.94 U
DGSGLMW1101-D	26-May-00	0.69 U	3.5	NA	1.4 U	0.04 U	3.5	0.94 U
DGSGLMW1201	18-May-00	0.69 U	3.1	NA	1.4 U	0.04 U	2.1 U	4.3
DGSGLMW1301	18-May-00	0.69 U	2.3	NA	1.4 U	0.04 U	2.1 U	3.5
DGSGLMW1401	25-May-00	0.69 U	3.2	NA	1.6	0.04 U	3.7 U	0.94 U
DGSGLMW1501	27-May-00	0.75	**314**	NA	**205**	0.04 U	6.1	0.94 U
DGSGLMW1501-D	27-May-00	0.69 U	**293**	NA	**185**	0.04 U	5.9	0.94 U
DGSGLMW1601	25-May-00	0.69 U	1.2	NA	1.4 U	0.04 U	2.1 U	0.94 U
DGSGLMW1701	19-May-00	0.69 U	2.7	NA	1.4 U	0.04 U	2.1 U	2.3
DGSGLMW1801	27-May-00	0.69 U	0.87 U	33100 J	1.4 U	0.04 U	2.1 U	0.94 U
DGSGLMW1901	23-May-00	1.2	11.7	NA	4.3	0.04 U	3.7 U	0.94 U
DGSGLMW2001	19-May-00	0.69 U	1.7	NA	2.3	0.04 U	2.1 U	2.6
DGSGLMW2101	23-May-00	0.75	15.0	NA	6.3	0.04 U	3.7 U	0.94 U
DGSGLMW2201	24-May-00	0.69 U	5.7	NA	3.5	0.04 U	3.7 U	0.94 U
DGSGLMW2301	24-May-00	0.69 U	1.1	NA	4.1	0.04 U	3.7 U	0.94 U
DGSGLMW2401	19-May-00	0.69 U	9.4	NA	2.3	0.04 U	2.1 U	2.4
DGSGLMW2501	19-May-00	0.69 U	31.4	NA	9.97	0.043 U	2.14 U	2.86
DGSGLMW2601	25-May-00	0.69 U	1.8	NA	1.4 U	0.04 U	3.7 U	0.94 U
DGSGLMW27D01	24-May-00	0.69 U	1.4	NA	1.4 U	0.04 U	3.7 U	0.94 U
DGSGLMW28D01	15-May-00	0.69 U	2.0	NA	1.9	0.04 U	2.1 U	0.94 U
DGSGLMW29D01	17-May-00	0.69 U	0.87 U	NA	1.4 U	0.04 U	2.1 U	0.94 U
DGSGLMW30D01	15-Jun-01	0.42 U	0.93 B	589	1.98 U		2.8 U	0.94 U
DGSGLMW31D01	16-Jun-01	0.42 U	3.18 B	246	1.98 U		2.8 U	0.94 U
DGSGLMW32D01	16-Jun-01	0.42 U	2.21 B	1260	1.98 U		2.8 U	0.94 U

NA = Not analyzed
U = Analytical result is below detection limit.
J = Estimated vaule.
[1] South Carolina Department of Health and Environmental Control Risk Based Screening Levels for ground water.
[2] The Risk based screening level for individual PAH CoC is 10 ug/l or 25 ug/l for total PAHs.
[3] MCL published in the Environmental Protection Agency's Drinking Water Regulations.


LEGEND
MONITORING WELL
DEEP MONITORING WELL
BENZENE CONCENTRATION[1]
BENZENE ISOGEN[1] (DASHED WHERE APPROX.)
NOT DETECTED
ND
ESTIMATED CONCENTRATION
J
1-CONCENTRATION IN MICROGRAMS PER LITER (ug/L)
5
50
500
5000
MW-21
83.1
MW-27D
ND
MW-15
80.8
MW-24
ND
MW-25
ND
MW-17
ND
MW-13
ND
MW-12
ND
MW-14
ND
MW-04
ND
MW-02
1.4 J
MW-01
1725
MW-03
6650
MW-36
5400
MW-35
5760
MW-34
3480
MW-19
0.6 J
234
MW-00
ND
MW-16
ND
MW-200
16 J
MW-200
ND
MW-0
0.15 J
BUILDING 168
BUILDING 169
BUILDING 168A
BUILDING 169A
BUILDING 169B
BUILDING 169C
BUILDING 169D
BUILDING 169E
BUILDING 169F
BUILDING 169G
BUILDING 169H
BUILDING 169I
BUILDING 169J
BUILDING 169K
BUILDING 169L
BUILDING 169M
BUILDING 169N
BUILDING 169O
BUILDING 169P
BUILDING 169Q
BUILDING 169R
BUILDING 169S
BUILDING 169T
BUILDING 169U
BUILDING 169V
BUILDING 169W
BUILDING 169X
BUILDING 169Y
BUILDING 169Z
BUILDING 169AA
BUILDING 169AB
BUILDING 169AC
BUILDING 169AD
BUILDING 169AE
BUILDING 169AF
BUILDING 169AG
BUILDING 169AH
BUILDING 169AI
BUILDING 169AJ
BUILDING 169AK
BUILDING 169AL
BUILDING 169AM
BUILDING 169AN
BUILDING 169AO
BUILDING 169AP
BUILDING 169AQ
BUILDING 169AR
BUILDING 169AS
BUILDING 169AT
BUILDING 169AU
BUILDING 169AV
BUILDING 169AW
BUILDING 169AX
BUILDING 169AY
BUILDING 169AZ
BUILDING 169BA
BUILDING 169BB
BUILDING 169BC
BUILDING 169BD
BUILDING 169BE
BUILDING 169BF
BUILDING 169BG
BUILDING 169BH
BUILDING 169BI
BUILDING 169BJ
BUILDING 169BK
BUILDING 169BL
BUILDING 169BM
BUILDING 169BN
BUILDING 169BO
BUILDING 169BP
BUILDING 169BQ
BUILDING 169BR
BUILDING 169BS
BUILDING 169BT
BUILDING 169BU
BUILDING 169BV
BUILDING 169BW
BUILDING 169BX
BUILDING 169BY
BUILDING 169BZ
BUILDING 169CA
BUILDING 169CB
BUILDING 169CC
BUILDING 169CD
BUILDING 169CE
BUILDING 169CF
BUILDING 169CG
BUILDING 169CH
BUILDING 169CI
BUILDING 169CJ
BUILDING 169CK
BUILDING 169CL
BUILDING 169CM
BUILDING 169CN
BUILDING 169CO
BUILDING 169CP
BUILDING 169CQ
BUILDING 169CR
BUILDING 169CS
BUILDING 169CT
BUILDING 169CU
BUILDING 169CV
BUILDING 169CW
BUILDING 169CX
BUILDING 169CY
BUILDING 169CZ
BUILDING 169DA
BUILDING 169DB
BUILDING 169DC
BUILDING 169DD
BUILDING 169DE
BUILDING 169DF
BUILDING 169DG
BUILDING 169DH
BUILDING 169DI
BUILDING 169DJ
BUILDING 169DK
BUILDING 169DL
BUILDING 169DM
BUILDING 169DN
BUILDING 169DO
BUILDING 169DP
BUILDING 169DQ
BUILDING 169DR
BUILDING 169DS
BUILDING 169DT
BUILDING 169DU
BUILDING 169DV
BUILDING 169DW
BUILDING 169DX
BUILDING 169DY
BUILDING 169DZ
BUILDING 169EA
BUILDING 169EB
BUILDING 169EC
BUILDING 169ED
BUILDING 169EE
BUILDING 169EF
BUILDING 169EG
BUILDING 169EH
BUILDING 169EI
BUILDING 169EJ
BUILDING 169EK
BUILDING 169EL
BUILDING 169EM
BUILDING 169EN
BUILDING 169EO
BUILDING 169EP
BUILDING 169EQ
BUILDING 169ER
BUILDING 169ES
BUILDING 169ET
BUILDING 169EU
BUILDING 169EV
BUILDING 169EW
BUILDING 169EX
BUILDING 169EY
BUILDING 169EZ
BUILDING 169FA
BUILDING 169FB
BUILDING 169FC
BUILDING 169FD
BUILDING 169FE
BUILDING 169FF
BUILDING 169FG
BUILDING 169FH
BUILDING 169FI
BUILDING 169FJ
BUILDING 169FK
BUILDING 169FL
BUILDING 169FM
BUILDING 169FN
BUILDING 169FO
BUILDING 169FP
BUILDING 169FQ
BUILDING 169FR
BUILDING 169FS
BUILDING 169FT
BUILDING 169FU
BUILDING 169FV
BUILDING 169FW
BUILDING 169FX
BUILDING 169FY
BUILDING 169FZ
BUILDING 169GA
BUILDING 169GB
BUILDING 169GC
BUILDING 169GD
BUILDING 169GE
BUILDING 169GF
BUILDING 169GG
BUILDING 169GH
BUILDING 169GI
BUILDING 169GJ
BUILDING 169GK
BUILDING 169GL
BUILDING 169GM
BUILDING 169GN
BUILDING 169GO
BUILDING 169GP
BUILDING 169GQ
BUILDING 169GR
BUILDING 169GS
BUILDING 169GT
BUILDING 169GU
BUILDING 169GV
BUILDING 169GW
BUILDING 169GX
BUILDING 169GY
BUILDING 169GZ
BUILDING 169HA
BUILDING 169HB
BUILDING 169HC
BUILDING 169HD
BUILDING 169HE
BUILDING 169HF
BUILDING 169HG
BUILDING 169HH
BUILDING 169HI
BUILDING 169HJ
BUILDING 169HK
BUILDING 169HL
BUILDING 169HM
BUILDING 169HN
BUILDING 169HO
BUILDING 169HP
BUILDING 169HQ
BUILDING 169HR
BUILDING 169HS
BUILDING 169HT
BUILDING 169HU
BUILDING 169HV
BUILDING 169HW
BUILDING 169HX
BUILDING 169HY
BUILDING 169HZ
BUILDING 169IA
BUILDING 169IB
BUILDING 169IC
BUILDING 169ID
BUILDING 169IE
BUILDING 169IF
BUILDING 169IG
BUILDING 169IH
BUILDING 169II
BUILDING 169IJ
BUILDING 169IK
BUILDING 169IL
BUILDING 169IM
BUILDING 169IN
BUILDING 169IO
BUILDING 169IP
BUILDING 169IQ
BUILDING 169IR
BUILDING 169IS
BUILDING 169IT
BUILDING 169IU
BUILDING 169IV
BUILDING 169IW
BUILDING 169IX
BUILDING 169IY
BUILDING 169IZ
BUILDING 169JA
BUILDING 169JB
BUILDING 169JC
BUILDING 169JD
BUILDING 169JE
BUILDING 169JF
BUILDING 169JG
BUILDING 169JH
BUILDING 169JI
BUILDING 169JJ
BUILDING 169JK
BUILDING 169JL
BUILDING 169JM
BUILDING 169JN
BUILDING 169JO
BUILDING 169JP
BUILDING 169JQ
BUILDING 169JR
BUILDING 169JS
BUILDING 169JT
BUILDING 169JU
BUILDING 169JV
BUILDING 169JW
BUILDING 169JX
BUILDING 169JY
BUILDING 169JZ
BUILDING 169KA
BUILDING 169KB
BUILDING 169KC
BUILDING 169KD
BUILDING 169KE
BUILDING 169KF
BUILDING 169KG
BUILDING 169KH
BUILDING 169KI
BUILDING 169KJ
BUILDING 169KK
BUILDING 169KL
BUILDING 169KM
BUILDING 169KN
BUILDING 169KO
BUILDING 169KP
BUILDING 169KQ
BUILDING 169KR
BUILDING 169KS
BUILDING 169KT
BUILDING 169KU
BUILDING 169KV
BUILDING 169KW
BUILDING 169KX
BUILDING 169KY
BUILDING 169KZ
BUILDING 169LA
BUILDING 169LB
BUILDING 169LC
BUILDING 169LD
BUILDING 169LE
BUILDING 169LF
BUILDING 169LG
BUILDING 169LH
BUILDING 169LI
BUILDING 169LJ
BUILDING 169LK
BUILDING 169LL
BUILDING 169LM
BUILDING 169LN
BUILDING 169LO
BUILDING 169LP
BUILDING 169LQ
BUILDING 169LR
BUILDING 169LS
BUILDING 169LT
BUILDING 169LU
BUILDING 169LV
BUILDING 169LW
BUILDING 169LX
BUILDING 169LY
BUILDING 169LZ
BUILDING 169MA
BUILDING 169MB
BUILDING 169MC
BUILDING 169MD
BUILDING 169ME
BUILDING 169MF
BUILDING 169MG
BUILDING 169MH
BUILDING 169MI
BUILDING 169MJ
BUILDING 169MK
BUILDING 169ML
BUILDING 169MM
BUILDING 169MN
BUILDING 169MO
BUILDING 169MP
BUILDING 169MQ
BUILDING 169MR
BUILDING 169MS
BUILDING 169MT
BUILDING 169MU
BUILDING 169MV
BUILDING 169MW
BUILDING 169MX
BUILDING 169MY
BUILDING 169MZ
BUILDING 169NA
BUILDING 169NB
BUILDING 169NC
BUILDING 169ND
BUILDING 169NE
BUILDING 169NF
BUILDING 169NG
BUILDING 169NH
BUILDING 169NI
BUILDING 169NJ
BUILDING 169NK
BUILDING 169NL
BUILDING 169NM
BUILDING 169NN
BUILDING 169NO
BUILDING 169NP
BUILDING 169NQ
BUILDING 169NR
BUILDING 169NS
BUILDING 169NT
BUILDING 169NU
BUILDING 169NV
BUILDING 169NW
BUILDING 169NX
BUILDING 169NY
BUILDING 169NZ
BUILDING 169OA
BUILDING 169OB
BUILDING 169OC
BUILDING 169OD
BUILDING 169OE
BUILDING 169OF
BUILDING 169OG
BUILDING 169OH
BUILDING 169OI
BUILDING 169OJ
BUILDING 169OK
BUILDING 169OL
BUILDING 169OM
BUILDING 169ON
BUILDING 169OO
BUILDING 169OP
BUILDING 169OQ
BUILDING 169OR
BUILDING 169OS
BUILDING 169OT
BUILDING 169OU
BUILDING 169OV
BUILDING 169OW
BUILDING 169OX
BUILDING 169OY
BUILDING 169OZ
BUILDING 169PA
BUILDING 169PB
BUILDING 169PC
BUILDING 169PD
BUILDING 169PE
BUILDING 169PF
BUILDING 169PG
BUILDING 169PH
BUILDING 169PI
BUILDING 169PJ
BUILDING 169PK
BUILDING 169PL
BUILDING 169PM
BUILDING 169PN
BUILDING 169PO
BUILDING 169PP
BUILDING 169PQ
BUILDING 169PR
BUILDING 169PS
BUILDING 169PT
BUILDING 169PU
BUILDING 169PV
BUILDING 169PW
BUILDING 169PX
BUILDING 169PY
BUILDING 169PZ
BUILDING 169QA
BUILDING 169QB
BUILDING 169QC
BUILDING 169QD
BUILDING 169QE
BUILDING 169QF
BUILDING 169QG
BUILDING 169QH
BUILDING 169QI
BUILDING 169QJ
BUILDING 169QK
BUILDING 169QL
BUILDING 169QM
BUILDING 169QN
BUILDING 169QO
BUILDING 169QP
BUILDING 169QQ
BUILDING 169QR
BUILDING 169QS
BUILDING 169QT
BUILDING 169QU
BUILDING 169QV
BUILDING 169QW
BUILDING 169QX
BUILDING 169QY
BUILDING 169QZ
BUILDING 169RA
BUILDING 169RB
BUILDING 169RC
BUILDING 169RD
BUILDING 169RE
BUILDING 169RF
BUILDING 169RG
BUILDING 169RH
BUILDING 169RI
BUILDING 169RJ
BUILDING 169RK
BUILDING 169RL
BUILDING 169RM
BUILDING 169RN
BUILDING 169RO
BUILDING 169RP
BUILDING 169RQ
BUILDING 169RR
BUILDING 169RS
BUILDING 169RT
BUILDING 169RU
BUILDING 169RV
BUILDING 169RW
BUILDING 169RX
BUILDING 169RY
BUILDING 169RZ
BUILDING 169SA
BUILDING 169SB
BUILDING 169SC
BUILDING 169SD
BUILDING 169SE
BUILDING 169SF
BUILDING 169SG
BUILDING 169SH
BUILDING 169SI
BUILDING 169SJ
BUILDING 169SK
BUILDING 169SL
BUILDING 169SM
BUILDING 169SN
BUILDING 169SO
BUILDING 169SP
BUILDING 169SQ
BUILDING 169SR
BUILDING 169SS
BUILDING 169ST
BUILDING 169SU
BUILDING 169SV
BUILDING 169SW
BUILDING 169SX
BUILDING 169SY
BUILDING 169SZ
BUILDING 169TA
BUILDING 169TB
BUILDING 169TC
BUILDING 169TD
BUILDING 169TE
BUILDING 169TF
BUILDING 169TG
BUILDING 169TH
BUILDING 169TI
BUILDING 169TJ
BUILDING 169TK
BUILDING 169TL
BUILDING 169TM
BUILDING 169TN
BUILDING 169TO
BUILDING 169TP
BUILDING 169TQ
BUILDING 169TR
BUILDING 169TS
BUILDING 169TT
BUILDING 169TU
BUILDING 169TV
BUILDING 169TW
BUILDING 169TX
BUILDING 169TY
BUILDING 169TZ
BUILDING 169UA
BUILDING 169UB
BUILDING 169UC
BUILDING 169UD
BUILDING 169UE
BUILDING 169UF
BUILDING 169UG
BUILDING 169UH
BUILDING 169UI
BUILDING 169UJ
BUILDING 169UK
BUILDING 169UL
BUILDING 169UM
BUILDING 169UN
BUILDING 169UO
BUILDING 169UP
BUILDING 169UQ
BUILDING 169UR
BUILDING 169US
BUILDING 169UT
BUILDING 169UU
BUILDING 169UV
BUILDING 169UW
BUILDING 169UX
BUILDING 169UY
BUILDING 169UZ
BUILDING 169VA
BUILDING 169VB
BUILDING 169VC
BUILDING 169VD
BUILDING 169VE
BUILDING 169VF
BUILDING 169VG
BUILDING 169VH
BUILDING 169VI
BUILDING 169VJ
BUILDING 169VK
BUILDING 169VL
BUILDING 169VM
BUILDING 169VN
BUILDING 169VO
BUILDING 169VP
BUILDING 169VQ
BUILDING 169VR
BUILDING 169VS
BUILDING 169VT
BUILDING 169VU
BUILDING 169VV
BUILDING 169VW
BUILDING 169VX
BUILDING 169VY
BUILDING 169VZ
BUILDING 169WA
BUILDING 169WB
BUILDING 169WC
BUILDING 169WD
BUILDING 169WE
BUILDING 169WF
BUILDING 169WG
BUILDING 169WH
BUILDING 169WI
BUILDING 169WJ
BUILDING 169WK
BUILDING 169WL
BUILDING 169WM
BUILDING 169WN
BUILDING 169WO
BUILDING 169WP
BUILDING 169WQ
BUILDING 169WR
BUILDING 169WS
BUILDING 169WT
BUILDING 169WU
BUILDING 169WV
BUILDING 169WW
BUILDING 169WX
BUILDING 169WY
BUILDING 169WZ
BUILDING 169XA
BUILDING 169XB
BUILDING 169XC
BUILDING 169XD
BUILDING 169XE
BUILDING 169XF
BUILDING 169XG
BUILDING 169XH
BUILDING 169XI
BUILDING 169XJ
BUILDING 169XK
BUILDING 169XL
BUILDING 169XM
BUILDING 169XN
BUILDING 169XO
BUILDING 169XP
BUILDING 169XQ
BUILDING 169XR
BUILDING 169XS
BUILDING 169XT
BUILDING 169XU
BUILDING 169XV
BUILDING 169XW
BUILDING 169XX
BUILDING 169XY
BUILDING 169XZ
BUILDING 169YA
BUILDING 169YB
BUILDING 169YC
BUILDING 169YD
BUILDING 169YE
BUILDING 169YF
BUILDING 169YG
BUILDING 169YH
BUILDING 169YI
BUILDING 169YJ
BUILDING 169YK
BUILDING 169YL
BUILDING 169YM
BUILDING 169YN
BUILDING 169YO
BUILDING 169YP
BUILDING 169YQ
BUILDING 169YR
BUILDING 169YS
BUILDING 169YT
BUILDING 169YU
BUILDING 169YV
BUILDING 169YW
BUILDING 169YX
BUILDING 169YY
BUILDING 169YZ
BUILDING 169ZA
BUILDING 169ZB
BUILDING 169ZC
BUILDING 169ZD
BUILDING 169ZE
BUILDING 169ZF
BUILDING 169ZG
BUILDING 169ZH
BUILDING 169ZI
BUILDING 169ZJ
BUILDING 169ZK
BUILDING 169ZL
BUILDING 169ZM
BUILDING 169ZN
BUILDING 169ZO
BUILDING 169ZP
BUILDING 169ZQ
BUILDING 169ZR
BUILDING 169ZS
BUILDING 169ZT
BUILDING 169ZU
BUILDING 169ZV
BUILDING 169ZW
BUILDING 169ZX
BUILDING 169ZY
BUILDING 169ZZ
BUILDING 169AA
BUILDING 169AB
BUILDING 169AC
BUILDING 169AD
BUILDING 169AE
BUILDING 169AF
BUILDING 169AG
BUILDING 169AH
BUILDING 169AI
BUILDING 169AJ
BUILDING 169AK
BUILDING 169AL
BUILDING 169AM
BUILDING 169AN
BUILDING 169AO
BUILDING 169AP
BUILDING 169AQ
BUILDING 169AR
BUILDING 169AS
BUILDING 169AT
BUILDING 169AU
BUILDING 169AV
BUILDING 169AW
BUILDING 169AX
BUILDING 169AY
BUILDING 169AZ
BUILDING 169BA
BUILDING 169BB
BUILDING 169BC
BUILDING 169BD
BUILDING 169BE
BUILDING 169BF
BUILDING 169BG
BUILDING 169BH
BUILDING 169BI
BUILDING 169BJ
BUILDING 169BK
BUILDING 169BL
BUILDING 169BM
BUILDING 169BN
BUILDING 169BO
BUILDING 169BP
BUILDING 169BQ
BUILDING 169BR
BUILDING 169BS
BUILDING 169BT
BUILDING 169BU
BUILDING 169BV
BUILDING 169BW
BUILDING 169BX
BUILDING 169BY
BUILDING 169BZ
BUILDING 169CA
BUILDING 169CB
BUILDING 169CC
BUILDING 169CD
BUILDING 169CE
BUILDING 169CF
BUILDING 169CG
BUILDING 169CH
BUILDING 169CI
BUILDING 169CJ
BUILDING 169CK
BUILDING 169CL
BUILDING 169CM
BUILDING 169CN
BUILDING 169CO
BUILDING 169CP
BUILDING 169CQ
BUILDING 169CR
BUILDING 169CS
BUILDING 169CT
BUILDING 169CU
BUILDING 169CV
BUILDING 169CW
BUILDING 169CX
BUILDING 169CY
BUILDING 169CZ
BUILDING 169DA
BUILDING 169DB
BUILDING 169DC
BUILDING 169DD
BUILDING 169DE
BUILDING 169DF
BUILDING 169DG
BUILDING 169DH
BUILDING 169DI
BUILDING 169DJ
BUILDING 169DK
BUILDING 169DL
BUILDING 169DM
BUILDING 169DN
BUILDING 169DO
BUILDING 169DP
BUILDING 169DQ
BUILDING 169DR
BUILDING 169DS
BUILDING 169DT
BUILDING 169DU
BUILDING 169DV
BUILDING 169DW
BUILDING 169DX
BUILDING 169DY
BUILDING 169DZ
BUILDING 169EA
BUILDING 169EB
BUILDING 169EC
BUILDING 169ED
BUILDING 169EE
BUILDING 169EF
BUILDING 169EG
BUILDING 169EH
BUILDING 169EI
BUILDING 169EJ
BUILDING 169EK
BUILDING 169EL
BUILDING 169EM
BUILDING 169EN
BUILDING 169EO
BUILDING 169EP
BUILDING 169EQ
BUILDING 169ER
BUILDING 169ES
BUILDING 169ET
BUILDING 169EU
BUILDING 169EV
BUILDING 169EW
BUILDING 169EX
BUILDING 169EY
BUILDING 169EZ
BUILDING 169FA
BUILDING 169FB
BUILDING 169FC
BUILDING 169FD
BUILDING 169FE
BUILDING 169FF
BUILDING 169FG
BUILDING 169FH
BUILDING 169FI
BUILDING 169FJ
BUILDING 169FK
BUILDING 169FL
BUILDING 169FM
BUILDING 169FN
BUILDING 169FO
BUILDING 169FP
BUILDING 169FQ
BUILDING 169FR
BUILDING 169FS
BUILDING 169FT
BUILDING 169FU
BUILDING 169FV
BUILDING 169FW
BUILDING 169FX
BUILDING 169FY
BUILDING 169FZ
BUILDING 169GA
BUILDING 169GB
BUILDING 169GC
BUILDING 169GD
BUILDING 169GE
BUILDING 169GF
BUILDING 169GG
BUILDING 169GH
BUILDING 169GI
BUILDING 169GJ
BUILDING 169GK
BUILDING 169GL
BUILDING 169GM
BUILDING 169GN
BUILDING 169GO
BUILDING 169GP
BUILDING 169GQ
BUILDING 169GR
BUILDING 169GS
BUILDING 169GT
BUILDING 169GU
BUILDING 169GV
BUILDING 169GW
BUILDING 169GX
BUILDING 169GY
BUILDING 169GZ
BUILDING 169HA
BUILDING 169HB
BUILDING 169HC
BUILDING 169HD
BUILDING 169HE
BUILDING 169HF
BUILDING 169HG
BUILDING 169HH
BUILDING 169HI
BUILDING 169HJ
BUILDING 169HK
BUILDING 169HL
BUILDING 169HM
BUILDING 169HN
BUILDING 169HO
BUILDING 169HP
BUILDING 169HQ
BUILDING 169HR
BUILDING 169HS
BUILDING 169HT
BUILDING 169HU
BUILDING 169HV
BUILDING 169HW
BUILDING 169HX
BUILDING 169HY
BUILDING 169HZ
BUILDING 169IA
BUILDING 169IB
BUILDING 169IC
BUILDING 169ID
BUILDING 169IE
BUILDING 169IF
BUILDING 169IG
BUILDING 169IH
BUILDING 169II
BUILDING 169IJ
BUILDING 169IK
BUILDING 169IL
BUILDING 169IM
BUILDING 169IN
BUILDING 169IO
BUILDING 169IP
BUILDING 169IQ
BUILDING 169IR
BUILDING 169IS
BUILDING 169IT
BUILDING 169IU
BUILDING 169IV
BUILDING 169IW
BUILDING 169IX
BUILDING 169IY
BUILDING 169IZ
BUILDING 169JA
BUILDING 169JB
BUILDING 169JC
BUILDING 169JD
BUILDING 169JE
BUILDING 169JF
BUILDING 169JG
BUILDING 169JH
BUILDING 169JI
BUILDING 169JJ
BUILDING 169JK
BUILDING 169JL
BUILDING 169JM
BUILDING 169JN
BUILDING 169JO
BUILDING 169JP
BUILDING 169JQ
BUILDING 169JR
BUILDING 169JS
BUILDING 169JT
BUILDING 169JU
BUILDING 169JV
BUILDING 169JW
BUILDING 169JX
BUILDING 169JY
BUILDING 169JZ
BUILDING 169KA
BUILDING 169KB
BUILDING 169KC
BUILDING 169KD
BUILDING 169KE
BUILDING 169KF
BUILDING 169KG
BUILDING 169KH
BUILDING 169KI
BUILDING 169KJ
BUILDING 169KK
BUILDING 169KL
BUILDING 169KM
BUILDING 169KN
BUILDING 169KO
BUILDING 169KP
BUILDING 169KQ
BUILDING 169KR
BUILDING 169KS
BUILDING 169KT
BUILDING 169KU
BUILDING 169KV
BUILDING 169KW
BUILDING 169KX
BUILDING 169KY
BUILDING 169KZ
BUILDING 169LA
BUILDING 169LB
BUILDING 169LC
BUILDING 169LD
BUILDING 169LE
BUILDING 169LF
BUILDING 169LG
BUILDING 169LH
BUILDING 169LI
BUILDING 169LJ
BUILDING 169LK
BUILDING 169LL
BUILDING 169LM
BUILDING 169LN
BUILDING 169LO
BUILDING 169LP
BUILDING 169LQ
BUILDING 169LR
BUILDING 169LS
BUILDING 169LT
BUILDING 169LU
BUILDING 169LV
BUILDING 169LW
BUILDING 169LX
BUILDING 169LY
BUILDING 169LZ
BUILDING 169MA
BUILDING 169MB
BUILDING 169MC
BUILDING 169MD
BUILDING 169ME
BUILDING 169MF
BUILDING 169MG
BUILDING 169MH
BUILDING 169MI
BUILDING 169MJ
BUILDING 169MK
BUILDING 169ML
BUILDING 169MM
BUILDING 169MN
BUILDING 169MO
BUILDING 169MP
BUILDING 169MQ
BUILDING 169MR
BUILDING 169MS
BUILDING 169MT
BUILDING 169MU
BUILDING 169MV
BUILDING 169MW
BUILDING 169MX
BUILDING 169MY
BUILDING 169MZ
BUILDING 169NA
BUILDING 169NB
BUILDING 169NC
BUILDING 169ND
BUILDING 169NE
BUILDING 169NF
BUILDING 169NG
BUILDING 169NH
BUILDING 169NI
BUILDING 169NJ
BUILDING 169NK
BUILDING 169NL
BUILDING 169NM
BUILDING 169NN
BUILDING 169NO
BUILDING 169NP
BUILDING 169NQ
BUILDING 169NR
BUILDING 169NS
BUILDING 169NT
BUILDING 169NU
BUILDING 169NV
BUILDING 169NW
BUILDING 169NX
BUILDING 169NY
BUILDING 169NZ
BUILDING 169OA
BUILDING 169OB
BUILDING 169OC
BUILDING 169OD
BUILDING 169OE
BUILDING 169OF
BUILDING 169OG
BUILDING 169OH
BUILDING 169OI
BUILDING 169OJ
BUILDING 169OK
BUILDING 169OL
BUILDING 169OM
BUILDING 169ON
BUILDING 169OO
BUILDING 169OP
BUILDING 169OQ
BUILDING 169OR
BUILDING 169OS
BUILDING 169OT
BUILDING 169OU
BUILDING 169OV
BUILDING 169OW
BUILDING 169OX
BUILDING 169OY
BUILDING 169OZ
BUILDING 169PA
BUILDING 169PB
BUILDING 169PC
BUILDING 169PD
BUILDING 169PE
BUILDING 169PF
BUILDING 169PG
BUILDING 169PH
BUILDING 169PI
BUILDING 169PJ
BUILDING 169PK
BUILDING 169PL
BUILDING 169PM
BUILDING 169PN
BUILDING 169PO
BUILDING 169PP
BUILDING 169PQ
BUILDING 169PR
BUILDING 169PS
BUILDING 169PT
BUILDING 169PU
BUILDING 169PV
BUILDING 169PW
BUILDING 169PX
BUILDING 169PY
BUILDING 169PZ
BUILDING 169QA
BUILDING 169QB
BUILDING 169QC
BUILDING 169QD
BUILDING 169QE
BUILDING 169QF
BUILDING 169QG
BUILDING 169QH
BUILDING 169QI
BUILDING 169QJ
BUILDING 169QK
BUILDING 169QL
BUILDING 169QM
BUILDING 169QN
BUILDING 169QO
BUILDING 169QP
BUILDING 169QQ
BUILDING 169QR
BUILDING 169QS
BUILDING 169QT
BUILDING 169QU
BUILDING 169QV
BUILDING 169QW
BUILDING 169QX
BUILDING 169QY
BUILDING 169QZ
BUILDING 169RA
BUILDING 169RB
BUILDING 169RC
BUILDING 169RD
BUILDING 169RE
BUILDING 169RF
BUILDING 169RG
BUILDING 169RH
BUILDING 169RI
BUILDING 169RJ
BUILDING 169RK
BUILDING 169RL
BUILDING 169RM
BUILDING 169RN
BUILDING 169RO
BUILDING 169RP
BUILDING 169RQ
BUILDING 169RR
BUILDING 169RS
BUILDING 169RT
BUILDING 169RU
BUILDING 169RV
BUILDING 169RW
BUILDING 169RX
BUILDING 169RY
BUILDING 169RZ
BUILDING 169SA
BUILDING 169SB
BUILDING 169SC
BUILDING 169SD
BUILDING 169SE
BUILDING 169SF
BUILDING 169SG
BUILDING 169SH
BUILDING 169SI
BUILDING 169SJ
BUILDING 169SK
BUILDING 169SL
BUILDING 169SM
BUILDING 169SN
BUILDING 169SO
BUILDING 169SP
BUILDING 169SQ
BUILDING 169SR
BUILDING 169SS
BUILDING 169ST
BUILDING 169SU
BUILDING 169SV
BUILDING 169SW
BUILDING 169SX
BUILDING 169SY
BUILDING 169SZ
BUILDING 169TA
BUILDING 169TB
BUILDING 169TC
BUILDING 169TD
BUILDING 169TE
BUILDING 169TF
BUILDING 169TG
BUILDING 169TH
BUILDING 169TI
BUILDING 169TJ
BUILDING 169TK
BUILDING 169TL
BUILDING 169TM
BUILDING 169TN
BUILDING 169TO
BUILDING 169TP
BUILDING 169TQ
BUILDING 169TR
BUILDING 169TS
BUILDING 169TT
BUILDING 169TU
BUILDING 169TV
BUILDING 169TW
BUILDING 169TX
BUILDING 169TY
BUILDING 169TZ
BUILDING 169UA
BUILDING 169UB
BUILDING 169UC
BUILDING 169UD
BUILDING 169UE
BUILDING 169UF
BUILDING 169UG
BUILDING 169UH
BUILDING 169UI
BUILDING 169UJ
BUILDING 169UK
BUILDING 169UL
BUILDING 169UM
BUILDING 169UN
BUILDING 169UO
BUILDING 169UP
BUILDING 169UQ
BUILDING 169UR
BUILDING 169US
BUILDING 169UT
BUILDING 169UU
BUILDING 169UV
BUILDING 169UW
BUILDING 169UX
BUILDING 169UY
BUILDING 169UZ
BUILDING 169VA
BUILDING 169VB
BUILDING 169VC
BUILDING 169VD
BUILDING 169VE
BUILDING 169VF
BUILDING 169VG
BUILDING 169VH
BUILDING 169VI
BUILDING 169VJ
BUILDING 169VK
BUILDING 169VL
BUILDING 169VM
BUILDING 169VN
BUILDING 169VO
BUILDING 169VP
BUILDING 169VQ
BUILDING 169VR
BUILDING 169VS
BUILDING 169VT
BUILDING 169VU
BUILDING 169VV
BUILDING 169VW
BUILDING 169VX
BUILDING 169VY
BUILDING 169VZ
BUILDING 169WA
BUILDING 169WB
BUILDING 169WC
BUILDING 169WD
BUILDING 169WE
BUILDING 169WF
BUILDING 169WG
BUILDING 169WH
BUILDING 169WI
BUILDING 169WJ
BUILDING 169WK
BUILDING 169WL
BUILDING 169WM
BUILDING 169WN
BUILDING 169WO
BUILDING 169WP
BUILDING 169WQ
BUILDING 169WR
BUILDING 169WS
BUILDING 169WT
BUILDING 169WU
BUILDING 169WV
BUILDING 169WW
BUILDING 169WX
BUILDING 169WY
BUILDING 169WZ
BUILDING 169XA
BUILDING 169XB
BUILDING 169XC
BUILDING 169XD
BUILDING 169XE
BUILDING 169XF
BUILDING 169XG
BUILDING 169XH
BUILDING 169XI
BUILDING 169XJ
BUILDING 169XK
BUILDING 169XL
BUILDING 169XM
BUILDING 169XN
BUILDING 169XO
BUILDING 169XP
BUILDING 169XQ
BUILDING 169XR
BUILDING 169XS
BUILDING 169XT
BUILDING 169XU
BUILDING 169XV
BUILDING 169XW
BUILDING 169XX
BUILDING 169XY
BUILDING 169XZ
BUILDING 169YA
BUILDING 169YB
BUILDING 169YC
BUILDING 169YD
BUILDING 169YE
BUILDING 169YF
BUILDING 169YG
BUILDING 169YH
BUILDING 169YI
BUILDING 169YJ
BUILDING 169YK
BUILDING 169YL
BUILDING 169YM
BUILDING 169YN
BUILDING 169YO
BUILDING 169YP
BUILDING 169YQ
BUILDING 169YR
BUILDING 169YS
BUILDING 169YT
BUILDING 169YU
BUILDING 169YV
BUILDING 169YW
BUILDING 169YX
BUILDING 169YY
BUILDING 169YZ
BUILDING 169ZA
BUILDING 169ZB
BUILDING 169ZC
BUILDING 169ZD
BUILDING 169ZE
BUILDING 169ZF
BUILDING 169ZG
BUILDING 169ZH
BUILDING 169ZI
BUILDING 169ZJ
BUILDING 169ZK
BUILDING 169ZL
BUILDING 169ZM
BUILDING 169ZN
BUILDING 169ZO
BUILDING 169ZP
BUILDING 169ZQ
BUILDING 169ZR
BUILDING 169ZS
BUILDING 169ZT
BUILDING 169ZU
BUILDING 169ZV
BUILDING 169ZW
BUILDING 169ZX
BUILDING 169ZY
BUILDING 169ZZ
BUILDING 169AA
BUILDING 169AB
BUILDING 169AC
BUILDING 169AD
BUILDING 169AE
BUILDING 169AF
BUILDING 169AG
BUILDING 169AH
BUILDING 169AI
BUILDING 169AJ
BUILDING 169AK
BUILDING 169AL
BUILDING 169AM
BUILDING 169AN
BUILDING 169AO
BUILDING 169AP
BUILDING 169AQ
BUILDING 169AR
BUILDING 169AS
BUILDING 169AT
BUILDING 169AU
BUILDING 169AV
BUILDING 169AW
BUILDING 169AX
BUILDING 169AY
BUILDING 169AZ
BUILDING 169BA
BUILDING 169BB
BUILDING 169BC
BUILDING 169BD
BUILDING 169BE
BUILDING 169BF
BUILDING 169BG
BUILDING 169BH
BUILDING 169BI
BUILDING 169BJ
BUILDING 169BK
BUILDING 169BL
BUILDING 169BM
BUILDING 169BN
BUILDING 169BO
BUILDING 169BP
BUILDING 169BQ
BUILDING 169BR
BUILDING 169BS
BUILDING 169BT
BUILDING 169BU
BUILDING 169BV
BUILDING 169BW
BUILDING 169BX
BUILDING 169BY
BUILDING 169BZ
BUILDING 169CA
BUILDING 169CB
BUILDING 169CC
BUILDING 169CD
BUILDING 169CE
BUILDING 169CF
BUILDING 169CG
BUILDING 169CH
BUILDING 169CI
BUILDING 169CJ
BUILDING 169CK
BUILDING 169CL
BUILDING 169CM
BUILDING 169CN
BUILDING 169CO
BUILDING 169CP
BUILDING 169CQ
BUILDING 169CR
BUILDING 169CS
BUILDING 169CT
BUILDING 169CU
BUILDING 169CV
BUILDING 169CW
BUILDING 169CX
BUILDING 169CY
BUILDING 169CZ
BUILDING 169DA
BUILDING 169DB
BUILDING 169DC
BUILDING 169DD
BUILDING 169DE
BUILDING 169DF
BUILDING 169DG
BUILDING 169DH
BUILDING 169DI
BUILDING 169DJ
BUILDING 169DK
BUILDING 169DL
BUILDING 169DM
BUILDING 169DN
BUILDING 169DO
BUILDING 169DP
BUILDING 169DQ
BUILDING 169DR
BUILDING 169DS
BUILDING 169DT
BUILDING 169DU
BUILDING 169DV
BUILDING 169DW
BUILDING 169DX
BUILDING 169DY
BUILDING 169DZ
BUILDING 169EA
BUILDING 169EB
BUILDING 169EC
BUILDING 169ED
BUILDING 169EE
BUILDING 169EF
BUILDING 169EG
BUILDING 169EH
BUILDING 169EI
BUILDING 169EJ
BUILDING 169EK
BUILDING 169EL
BUILDING 169EM
BUILDING 169EN
BUILDING 169EO
BUILDING 169EP
BUILDING 169EQ
BUILDING 169ER
BUILDING 169ES
BUILDING 169ET
BUILDING 169EU
BUILDING 169EV
BUILDING 169EW
BUILDING 169EX
BUILDING 169EY
BUILDING 169EZ
BUILDING 169FA
BUILDING 169FB
BUILDING 169FC
BUILDING 169FD
BUILDING 169FE
BUILDING 169FF
BUILDING 169FG
BUILDING 169FH
BUILDING 169FI
BUILDING 169FJ
BUILDING 169FK
BUILDING 169FL
BUILDING 169FM
BUILDING 169FN
BUILDING 169FO
BUILDING 169FP
BUILDING 169FQ
BUILDING 169FR
BUILDING 169FS
BUILDING 169FT
BUILDING 169FU
BUILDING 169FV
BUILDING 169FW
BUILDING 169FX
BUILDING 169FY
BUILDING 169FZ
BUILDING 169GA
BUILDING 169GB
BUILDING 169GC
BU


LEGEND
MONITORING WELL
DEEP MONITORING WELL
NAPHTHALENE CONCENTRATION[1] 176.5
NAPHTHALENE ISOCON[1] (DASHED WHERE APPROX.)
NOT DETECTED ND
ESTIMATED CONCENTRATION J
1-CONCENTRATION IN MICROGRAMS PER LITER (ug/L)
MW-04 ND
MW-09 ND
MW-01 176.5
MW-05 197-J
MW-07 ND
MW-08 ND
MW-10 ND
MW-11 ND
MW-12 ND
MW-13 ND
MW-14 0.53-J
MW-15 601.5
MW-16 ND
MW-17 ND
MW-18 ND
MW-19 ND
MW-20 37.4
MW-21 ND
MW-22 62.2
MW-23 247
MW-24 210
MW-25 ND
MW-26 1.5-J
MW-27 ND
MW-28 ND
MW-29 ND
MW-30 ND
MW-32 ND
MW-33 ND
MW-34 ND
MW-35 ND
MW-36 ND
MW-37 ND
MW-38 ND
MW-39 ND
MW-40 ND
MW-41 ND
MW-42 ND
MW-43 ND
MW-44 ND
MW-45 ND
MW-46 ND
MW-47 ND
MW-48 ND
MW-49 ND
MW-50 ND
MW-51 ND
MW-52 ND
MW-53 ND
MW-54 ND
MW-55 ND
MW-56 507
MW-57 0.3-J
MW-58 20.2
MW-59 170
MW-60 0.3-J
MW-61 ND
MW-62 ND
MW-63 ND
MW-64 ND
MW-65 ND
MW-66 ND
MW-67 ND
MW-68 ND
MW-69 ND
MW-70 ND
MW-71 ND
MW-72 ND
MW-73 ND
MW-74 ND
MW-75 ND
MW-76 ND
MW-77 ND
MW-78 ND
MW-79 ND
MW-80 ND

and naphthalene was below detection limits at PAI-DGS-MW31D. The extent of impact in deeper groundwater is shown on Figures 4 and 5, as well as Figures 12 and 13.

2.5 FATE AND TRANSPORT MODEL DESCRIPTION

Soil and groundwater concentrations exceed the RBSL; therefore, evaluation of the Depot Gas Station continued beyond Tier II. The Domenico fate and transport model was used to determine groundwater site-specific target levels (SSTLs) in the risk analysis for the surface water receptors. The model was also used to estimate the distance downgradient the COCs may migrate in 10- and 20-year time periods. Separate SSTLs and migration distances were determined for the shallow and deep groundwater. The Domenico model is presented in the SCDHEC guidance document, *South Carolina Risk-Based Corrective Action for Petroleum Releases* (SCDHEC, 2001). This model is very conservative in that it assumes an infinite mass, areal source condition through which groundwater flows. The model incorporates biological decay effects through a first-order decay process; however, this mechanism was ignored because SCDHEC guidance specifies that the decay rate must be assumed to be zero if site-specific decay rates have not been determined.

The impacted groundwater source area was modeled as 50 feet (15.00 meters) wide and 6.56 feet (2.0 meters) deep; these values are conservative defaults suggested by the American Society for Testing and Materials (ASTM) *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (ASTM, 1997). The maximum source concentrations are assumed to exist throughout the source area, further compounding the conservatism of the estimate.

Site-specific data were used for saturated hydraulic conductivity (1.387×10^{-05} ft/sec or 4.227×10^{-06} m/sec in the shallow groundwater and 1.43×10^{-05} m/sec in the deep groundwater), hydraulic gradient (0.002 ft/ft in the shallow groundwater and 0.0022 ft/ft in the deep groundwater), and fraction of organic carbon in soil (0.0082 g-C/g-soil in the shallow soil and 0.0441 g-C/g-soil in the deep soil). The porosity (0.45) and soil bulk density (1.6 g/cm^3) were determined from the charts in Appendix C of the SCDHEC 2001 guidance. The organic carbon partitioning coefficient (Koc) was taken from the SCDHEC 2001 guidance for all organic chemicals except MTBE. A Koc of 11.2 was used for MTBE (Risk Assessment Information System, http://risk.lsd.ornl.gov).

For the shallow groundwater, the maximum concentrations of benzene (7,610 µg/L), toluene (6,300 µg/L), ethylbenzene (1,440 µg/L), MTBE (152 J µg/L), naphthalene (612 µg/L), arsenic (98.2 µg/L), lead (205 µg/L), and chromium (314 µg/L) were used as the source concentration. Because groundwater migration is modeled, separate maximums (to calculate separate SSTLs) were not used for shallow

groundwater from the open areas and shallow groundwater beneath Building 155. The naphthalene SSTL was also considered applicable for all naphthalenes; therefore, no SSTL was calculated for 2-methylnaphthalene. Likewise, for the deeper groundwater, the maximum concentration of benzene (3480 μg/L) was used as the source concentration.

The following estimates of dispersivity were used in the Domenico model as given in SCDHEC (2001):

Parameter	Estimate
Longitudinal Dispersivity, α_x	x/10, where x= distance between the point of exposure and the source or compliance point
Transverse Dispersivity, α_y	$\alpha_x/3$
Vertical Dispersivity, α_z	$\alpha_x/20$

2.6 PREDICTED MIGRATION AND ATTENUATION OF CHEMICALS OF CONCERN

The Domenico model was used to predict the distance at which the leading edges of both the shallow groundwater plume and the deeper groundwater plume are attenuated to SCDHEC RBSLs in 10 and 20 years without using degradation due to biological decay. This was done by adjusting the time to 10 years (3.15×10^8 sec) and 20 years (6.31×10^8 sec) and solving for distance (x) by trial and error. The source was assumed to be the impacted area on-site. The distance was changed until the required distance that is necessary for the concentration to attenuate to the RBSLs was determined. Model estimates for 10 and 20 years are provided in the following table:

Domenico Model Time Period	Chemical of Concern in Shallow Groundwater	Estimated Distance Traveled (feet)	Chemical of Concern in Deeper Groundwater	Estimated Distance Traveled (feet)
10 year	Benzene	81	Benzene	18.5
	Toluene	25		
	Ethylbenzene	13		
	MTBE	63.5		
	Naphthalene	3.65		
	Arsenic	57.5		
	Chromium	70.4		
	Lead	106		
20 year	Benzene	144	Benzene	36.5
	Toluene	46.9		
	Ethylbenzene	25.8		
	MTBE	92		
	Naphthalene	7.26		
	Arsenic	71		
	Chromium	93		
	Lead	156		

The Domenico 10-year and 20-year simulation spreadsheets are presented in Appendix F of the Tier II Assessment Report (TtNUS, 2003).

3.0 TIER 2 EVALUATION

3.1 COMPARISON OF ANALYTICAL RESULTS WITH RBSLs

Soil samples were collected from April 5 through May 27, 2000. The samples were analyzed for BTEX, naphthalene, PAHs, inorganics, and TPH. Benzene, toluene, ethylbenzene, xylenes, and naphthalene were found in the open area at concentrations exceeding their respective RBSLs for sandy soil. Benzene, ethylbenzene, xylenes, and naphthalene were found beneath Building 155 at concentrations exceeding their respective RBSLs for sandy soil. ***No chemicals exceeded the RBSLs for ingestion and dermal contact with surficial soil.***

Groundwater sampling was conducted on May 14-28, 2000, and June 15-16, 2001. The 32 wells were sampled and analyzed for BTEX, MTBE, naphthalene, PAHs, and inorganics. In the open areas, benzene, toluene, ethylbenzene, MTBE, naphthalene, 2-methylnaphthalene, chromium, and lead were detected at concentrations exceeding their respective RBSLs or MCLs in the shallow wells and benzene was detected at a concentration exceeding its RBSLs in the deep wells. In the wells beneath Building 155, benzene, naphthalene, 2-methylnaphthalene, and arsenic were detected at concentrations exceeding their respective RBSLs. A comparison of soil and groundwater concentrations to RBSLs is summarized in Tables 4 and 5.

3.2 SITE CONCEPTUAL EXPOSURE MODEL

This section focuses on the current and future land use issues concerning the site. The site includes the former gas station for base vehicles and a grassy area that formerly contained ASTs and dispensers. Figure 1 shows that the site is located in and surrounded by the MCRD Parris Island. The area surrounding the site is non-residential. Building 155 is expected to remain in use for vehicle maintenance and the former Building 170/AST area is expected to remain an open field used in training exercise.

Drinking water at the site and surrounding properties is supplied by the Beaufort-Jasper Water and Sewer Authority. The MCRD is located on an island north of Port Royal Sound between the Broad River and the Beaufort River. A marsh wetland is approximately 600 feet north of the site and the Beaufort River is approximately 1800 feet east of the site. Two former drinking water wells were identified on the island; however, they are no longer in use. Groundwater flow at the site is from north to northwest for the shallow groundwater and from east to southeast for the deeper groundwater.

3.3 EXPOSURE PATHWAY ANALYSIS

This section presents the receptor characterizations of the potentially exposed populations in the vicinity of the site and identifies the potentially complete exposure pathways for those receptors. SCDHEC requires that only those exposure pathways with COC concentrations exceeding Tier 1 RBSL concentrations are examined in a Tier II Risk-Based Corrective Action Report. Tables 6 and 7 present the exposure pathway assessments for current and future use scenarios.

3.3.1 Potable Water

The potable water for MCRD Parris Island is not obtained from facility water wells. MCRD Parris Island officials confirmed that Parris Island is supplied by the Beaufort-Jasper Water and Sewer Authority. Two former drinking water wells were identified on the island; however, they are no longer in use. Because of the availability of off-base potable water, the on-base drinking water wells were not evaluated as potential receptor pathways.

3.3.2 On-Site Resident

An on-site resident is defined as any person making his or her home at the site. The site is currently non-residential and expected to remain non-residential in the future. There are no complete residential pathways.

3.3.3 Visitor

A visitor is defined as any person occasionally on the site. Visitors would have the same exposure pathways as base workers, but their exposure duration would be much shorter. This receptor does not have to be quantified because a potential visitor's chemical intake would not drive risk or cleanup levels at the site.

3.3.4 Utility/Construction Worker

Utility or construction workers could be exposed to impacted groundwater by dermal contact, inhalation of volatiles from groundwater, and incidental ingestion of groundwater. Because the utilities, specifically the water line and the storm sewer line, are located near the plume, the construction worker is considered a potential future receptor to the shallow groundwater in the open areas. It is not expected that a utility or construction worker would have contact with the deeper groundwater (more than 30 feet bgs). The utility or construction worker could also be exposed to impacted surface soil in the open areas during

TABLE 6

CURRENT LAND USE - POTENTIAL RECEPTORS AND PATHWAYS WITHIN 1,000-FOOT RADIUS
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA

Media (for exposure)	Exposure Route	Pathway Selected for Evaluation? (Yes or No)	Exposure point or Reason for Non-Selection	Data Requirements (If pathway selected)
Air	Inhalation	No	No volatilization to enclosed space.	
	Explosion Hazard	No	No explosion hazard.	
Ground-Water	Ingestion	No	All water is supplied by city. Inhalation of vapors into building.	SSTLs for vapors in building.
	Dermal Contact	No		
	Volatile Inhalation	Yes		
Surface Water	Ingestion	Yes	Wetland marsh is 600 feet to the north (crossgradient).	SSTLs protective of surface water.
	Dermal Contact	Yes		
	Volatile Inhalation	Yes		
Surficial Soil	Ingestion	Yes	Base personnel training on the open grassy area near the former ASTs and former Building 170 could be exposed to surface soil.	SSTLs for leaching to groundwater.
	Dermal Contact	Yes		
	Volatile Inhalation	No		
	Leaching to Groundwater	Yes		
Subsurface Soil	Ingestion	No		
	Dermal Contact	No		
	Volatile Inhalation	No		
	Leaching to Groundwater	No		

TABLE 7

FUTURE LAND USE - POTENTIAL RECEPTORS AND PATHWAYS WITHIN 1,000-FOOT RADIUS
DEPOT GAS STATION
MCRD PARRIS ISLAND
PARRIS ISLAND, SOUTH CAROLINA

Media (for exposure)	Exposure Route	Pathway Selected for Evaluation? (Yes or No)	Exposure point or Reason for Non-Selection	Data Requirements (If pathway selected)
Air	Inhalation	No	No volatilization to enclosed space.	
	Explosion Hazard	No	No explosion hazard.	
Ground-Water	Ingestion	Yes (incidental)	All water is supplied by city. Construction worker may have contact in trench. Inhalation of vapors into building.	SSTLs for construction worker exposed to groundwater. SSTLs for vapors in building.
	Dermal Contact	Yes		
	Volatile Inhalation	Yes		
Surface Water	Ingestion	Yes	Wetland marsh is 600 feet to the north (crossgradient).	SSTLs protective of surface water.
	Dermal Contact	Yes		
	Volatile Inhalation	Yes		
Surficial Soil	Ingestion	Yes	Base personnel training on the open grassy area near the former ASTs and former Building 170 could be exposed to surface soil.	SSTLs for leaching to groundwater.
	Dermal Contact	Yes		
	Volatile Inhalation	No		
	Leaching to Groundwater	Yes		
Subsurface Soil	Ingestion	Yes	Construction worker in a utility trench could be exposed to subsurface soil.	
	Dermal Contact	Yes		
	Volatile Inhalation	No		
	Leaching to Groundwater	No	Sandy soils; groundwater is shallow: ~5 feet bls.	

excavation by incidental ingestion, dermal contact, or inhalation of volatiles. ***The soil concentrations of all detected chemicals were less than the RBSLs for ingestion and dermal contact with soil.*** The inhalation of volatiles pathway was considered insignificant for a construction worker because of the short duration of excavation work and because the work is performed outside.

3.3.5 Base Worker

An on-site base worker is defined as base personnel who work or train at the site. Building 155 is expected to remain in use for vehicle maintenance and the former Building 170/AST area is expected to remain an open field used for training exercise. Therefore, an on-site base worker was considered as a potential receptor. ***Incidental ingestion and dermal contact with impacted soil in the open areas are possible for base personnel training in unpaved areas at the site; however, no chemicals exceeded their RBSLs for ingestion and dermal contact with surficial soil. Ingestion and dermal contact with impacted soil is therefore not a complete exposure pathway.*** Drinking water at the site is provided by the city; therefore, ingestion of groundwater is not a complete exposure pathway. The building foundation will be an obstacle to volatilization into a commercial building but, because there are volatiles in the groundwater collected beneath Building 155 above RBSLs and the soil at the site is sandy, inhalation of vapors from impacted shallow groundwater beneath Building 155 was considered as a potential pathway to be conservative.

3.3.6 Surface Water

A marsh area lies approximately 600 feet north of the area of concern and was evaluated as a potential receptor. Monitoring well PAI-DGS-MW08, approximately 160 feet north of the area of highest impact, is considered as the compliance point for the shallow groundwater. The deeper groundwater is flowing east to southeast and the nearest surface water body is the river approximately 1800 feet to the east. Monitoring well PAI-DGS-MW30D, approximately 260 feet east of the area of highest impact, is considered as the compliance point for the deeper groundwater.

3.4 IDENTIFICATION OF DATA REQUIREMENTS

No additional data are required to calculate SSTLs for the site.

3.5 SITE-SPECIFIC TARGET LEVELS

The identified potential receptors for the shallow groundwater at the Depot Gas Station are the utility worker (open areas), the base worker (groundwater beneath Building 155), and the surface water body downgradient of the site (all groundwater). The identified potential receptor for the deeper groundwater at

the Depot Gas Station is the surface water body 260 feet east of the site. SSTLs were calculated for each receptor.

3.5.1 Utility/Construction Worker Groundwater SSTLs

For the construction worker, three pathways for shallow groundwater in the open areas were considered potentially complete: dermal contact, incidental ingestion, and inhalation of volatiles. A target cancer risk of 1×10^{-6} and a target hazard quotient of 1 were used in the calculations for the construction worker SSTL. Standard defaults were used when available and applicable to a construction worker. When no standard parameters were available, conservative assumptions were used. Where possible, site-specific parameters were used for site conditions. For all pathways, the exposure frequency was assumed to be 30 days/year and the exposure duration was assumed to be 1 year. These assumptions were considered conservative based on the nature of utility work.

The dermal contact SSTLs were calculated using procedures *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Part E Supplemental Guidance for Dermal Risk Assessment) Interim Guidance* (USEPA, 2000). Based on expected limited contact with groundwater, the event frequency was assumed to be 1 event/day and the event duration was assumed to be 1 hour/event. The skin surface area available for contact was 4500 cm^2, based on one-fourth the skin surface area given in the risk assessment guidance document for a swimming adult.

The incidental ingestion SSTLs were calculated using the equation given in *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Interim Final)*, (USEPA, 1989). An incidental ingestion rate of 0.01 L/day was assumed based on a fraction (12.5%) of the incidental ingestion rate for a wading adult (0.01 L/hour), considered for an 8-hour work day. The incidental ingestion rate for wading adults is given in *Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment* (USEPA Region 4, 1995).

Utility lines in the area are typically 3 to 5 feet deep. The average depth to groundwater at the site is 3.6 feet bgs. It was assumed that a construction worker might be exposed to chemicals volatilizing from standing groundwater. The inhalation SSTLs were calculated using Henry's Law:

$$SSTL_{WATER} = SSTL_{AIR}/H$$

Where H = Henry's Law constant [mg/L-air/mg/L-water]

The $SSTL_{AIR}$ for each chemical was calculated using the equation given in the ASTM *Standard Guide for Risk-Based Corrective Action Applied to Petroleum Release Sites, Designation E 1739-95e1* (1997). SCDHEC values were used for Henry's Law constants.

The minimum SSTL for the three pathways was chosen as the SSTL for the construction worker. The following table shows the calculated SSTLs for each pathway along with the selected (minimum) SSTL:

Chemical of Concern	Dermal SSTL (µg/L)	Incidental Ingestion SSTL (µg/L)	Inhalation SSTL (µg/L)	Selected (Minimum) SSTL (µg/L)	Maximum Concentration (µg/L)	Exceeds SSTL?
Benzene	18410	205600	500	500	**7610**	**Yes**
Toluene	558360	17033000	16100	16100	6300	No
Ethylbenzene	97020	8516000	43500	43500	1440	No
MTBE	NA	NA	1645200	1645200	152	No
Naphthalene	60000	3406000	32700	32700	612	No
Chromium	7100	255000	N/A	7100	314	No
Lead	NA	NA	N/A	NA	205	No

NA = Reference Doses not available
N/A = Not applicable.

3.5.2 Base Worker Groundwater SSTLs

For the base worker or personnel, the only complete pathway is by volatilization from groundwater beneath the building into Building 155. Groundwater SSTLs for the base worker were calculated for inhalation of vapors from groundwater in an enclosed space. SSTLs were calculated for benzene and naphthalene, COCs for shallow groundwater beneath Building 155. Inorganics were not of concern for inhalation of vapors. The SSTLs for groundwater protective of the inhalation of vapors were calculated using the Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings.

The Johnson and Ettinger model is a one-dimensional analytical solution for estimating the transport of contaminant vapors from either subsurface soils or groundwater into an indoor space (a building) located directly above or close to the source of contamination. The model assumes the volatilized contaminant moves by diffusion through the subsurface until it reaches the zone of influence of the building where convection moves the vapors through the cracks between the foundation and the floor. Results can be calculated with an infinite source (steady state) or a finite source (quasi-steady-state).

Inputs to the model include chemical properties of the contaminant, saturated and unsaturated zone soil properties, and structural properties of the building. The model was used to reverse-calculate a site-specific target concentration for groundwater given a target risk or target hazard quotient.

The model was run as a first-tier screening tool although it may be used as a more involved second-tier estimate. The first-tier screening model for groundwater contamination was run as steady state. In the screening models, the following model parameters were site-specific: initial groundwater concentration, soil type above water table (sandy), depth to enclosed space floor (the floor level was assumed to be approximately ground level (15 cm bgs) based on the surrounding buildings at MCRD Parris Island), and depth to water table (shallowest depth to groundwater measured (2.16 ft or 65.8 cm) used to be conservative). The SCDHEC default for sandy soil was used for the average groundwater temperature (10°C). The porosity (0.45), water-filled porosity (0.08), and soil bulk density (1.6 g/cm^3) were determined from the charts in Appendix C of the SCDHEC 2001 guidance. Standard model parameters for commercial workers were used for averaging times (25 years for non-carcinogens), exposure duration (25 years) and frequency (250 days/year), and target risk (1 x 10^{-6}) or target hazard quotient (1.0).

The SSTLs for the base worker for benzene and naphthalene were determined to be 7.92 μg/L and 31,000 μg/L, respectively. The maximum concentration detected beneath Building 155 of naphthalene (179 μg/L) was below its SSTL (31,000 μg/L). The maximum concentration detected beneath Building 155 of benzene (1,740 μg/L) exceeded its SSTL (7.92 μg/L).

3.5.3 Groundwater SSTLs Protective of Surface Water

The Domenico model and fate and transport parameters as described in Section 2.5 were used to determine groundwater SSTLs protective of the points of exposure: a marsh approximately 600 feet north of the site for the shallow groundwater and the river approximately 1800 feet east of the site. The wells with the highest impact, shallow monitoring well PAI-DGS-MW06 and deep monitoring well PAI-DGS-MW28D, were used as the respective sources. Monitoring well PAI-DGS-MW08, approximately 160 feet north of PAI-DGS-MW06, was chosen as the compliance point for the shallow groundwater and PAI-DGS-MW30D, approximately 260 feet east of PAI-DGS-MW28D was chosen as the compliance point for the deeper groundwater. A target cancer risk of 1 x 10^{-6} and a target hazard quotient of 1 were used in the calculations for the surface water SSTLs. Using the Domenico model, the SSTLs at the source were calculated and compared with the source concentrations. The SSTLs at the compliance wells (PAI-DGS-MW08 and PAI-DGS-MW30D) were also calculated using the values of the RBSLs at the point of exposure.

Groundwater concentrations and calculated SSTLs were:

Chemical of Concern	Maximum Concentration in Shallow GW (µg/L)	Source SSTL (µg/L)	Shallow GW Compliance Point Concentration (µg/L)	Shallow GW Compliance Point SSTL (µg/L)
Benzene	**7,610**	**455**	< 5	35
Toluene	6,300	90,994	< 5	7,005
Ethylbenzene	1,440	63,696	< 5	4,903
MTBE	152	3,640	< 10	280
Naphthalene	610	2,275	< 5	175
Arsenic	98	4,550	4.9	350
Chromium	314	9,099	5	700
Lead	205	1,365	1.7	105

Chemical of Concern	Maximum Concentration in Deep GW (µg/L)	Source SSTL (µg/L)	Deep GW Compliance Point Concentration (µg/L)	Deep GW Compliance Point SSTL (µg/L)
Benzene	3,480	4,072	< 5	88

3.5.4 Groundwater SSTLs Summary

Groundwater SSTLs were calculated for each of the receptors and compared to the maximum concentrations in groundwater of the COCs for each receptor scenario. The construction worker receptor SSTLs were compared to the maximum groundwater concentrations of COCs detected at wells in the open areas. The base worker receptor SSTLs were compared to the maximum groundwater concentrations of COCs detected at wells beneath Building 155. The surface water receptor SSTLs were compared to the maximum groundwater concentrations of COCs for the entire site. Benzene concentrations exceed its respective SSTLs for each receptor scenario as indicated in the following tables.

SSTLs for Groundwater in Open Area

Chemical of Concern in Shallow GW – Open Area	Maximum Concentration in Shallow Groundwater (µg/L)	Open Area Construction Worker SSTL µg/L)	All Groundwater Surface Water SSTL µg/L)	Limiting SSTL for Groundwater in Open Area (µg/L)	Exceeds SSTLs?
Benzene	7,610	500	455	**455**	**Yes**
Toluene	6,300	16,100	90,994	16,100	No
Ethylbenzene	1,440	43,500	63,696	43,500	No
MTBE	152	1,645,000	3,640	3,640	No
Naphthalene	610	32,700	2,275	2,275	No
Chromium	314	7,100	9,099	7,100	No
Lead	205	NA	1,365	1,365	No

SSTLs for Groundwater Beneath Building 155

Chemical of Concern in Shallow GW – Beneath Building 155	Maximum Concentration in Shallow Groundwater [µg/L]	Beneath Building 155 Base Worker SSTL [µg/L]	All Groundwater Surface Water SSTL [µg/L]	Limiting SSTL for Groundwater in Open Area µg/L)	Exceeds SSTLs?
Benzene	1,740	7.92	455	**7.92**	**Yes**
Naphthalene	179	31,000	2,275	2,275	No
Arsenic	98	N/A	4,550	4,550	No

SSTLs for Deep Groundwater

Chemical of Concern in Deep GW	Surface Water SSTL (µg/L)	Maximum Concentration in Deep GW (µg/L)	Exceeds SSTL?
Benzene	4,072	**3,480**	No

3.5.5 Soil SSTLs

SSTLs were calculated for soil using the SCDHEC leachability model and the applicable groundwater SSTLs: groundwater SSTLs protective of the construction worker receptor and groundwater SSTLs protective of the surface water. Soil SSTLs were calculated only for the soil in the open areas as the soil beneath Building 155 is protected from rain by the building and the impacted soil is above the water table so would therefore not be subject to leaching. An SSTL of 66,880 µg/L for xylenes in groundwater was calculated using the methods outlined above. Site-specific values were input for TPH (2,690 mg/kg),

percent sand (74.35%), percent clay (15.85%), Foc (8,200 mg/kg), porosity (0.45), residual water content (0.06), bulk density (1.6 g/ml), distance from highest soil impact to water table (49 cm), and hydraulic conductivity (4.23 x 10^{-04} cm/sec). SCDHEC default values were used for the remaining parameters. The leachability model predicted soil SSTLs as follows:

Soil Leachability SSTLs – Open Area

Chemical of Concern	Max Conc (µg/kg)	Protective of Construction Worker – Soil in Open Area SSTL (µg/kg)	Protective of Surface Water – Soil in Open Area SSTL (µg/kg)	Limiting SSTL for Soil in Open Area (µg/kg)	Exceeds SSTL?
Benzene	19,800	3,500	3,200	3,200	Yes
Toluene	152,000	180,270	1,019,000	180,270	No
Ethylbenzene	82,200	665,000	974,000	665,000	No
Xylenes	768,000	3,593,000	3,593,000	3,593,000	No
Naphthalene	128,000	4,337,000	302,000	302,000	No

3.6 CONCLUSIONS AND RECOMMENDATIONS

The downgradient extent of hydrocarbon impact to groundwater has been delineated. The maximum concentrations of benzene (7,610 µg/L in the open area and 1,740 µg/L beneath Building 155) in surficial groundwater exceeds the SSTLs determined in Section 3.5.4. No maximum concentrations of other COCs for any receptor pathway exceed their groundwater SSTLs. A summary of the shallow groundwater COCs and their respective SSTLs is presented below.

SSTLs for Groundwater in Open Area

Chemical of Concern in Open Areas	Maximum Conc. (µg/L)	RBSL (µg/L)	Exceeds RBSL?	SSTL (µg/L)	Exceeds SSTL?
Benzene	7,610	5	Yes	455	Yes
Toluene	6,300	1,000	Yes	16,100	No
Ethylbenzene	1,440	700	Yes	43,500	No
MTBE	152	40	Yes	3,640	No
Naphthalene	612	25	Yes	2,275	No
Chromium	314	100	Yes	7,100	No
Lead	205	15	Yes	1,365	No

SSTLs for Groundwater Beneath Building 155

Chemical of Concern	Maximum Conc. (µg/L)	RBSL (µg/L)	Exceeds RBSL?	SSTL (µg/L)	Exceeds SSTL?
Benzene	1,740	5	Yes	7.92	Yes
Naphthalene	179	25	Yes	2,275	No
Arsenic	98.2	50	Yes	4,550	No

No concentrations of any COC in the shallow groundwater compliance well PAI-DGS-MW-08 exceed the compliance well SSTLs for protection of surface water. The maximum concentration of benzene, the only COC in deep groundwater, does not exceed its SSTL for deep groundwater.

The maximum soil concentration of benzene exceeded the soil leachability SSTL. The maximum concentrations for all other soil COCs do not exceed the soil leachability SSTLs. A summary of the soil COCs and their respective SSTLs is presented below:

Soil Leachability SSTLs

Chemical of Concern	Maximum Conc. (µg/kg)	RBSL (µg/kg)	Exceeds RBSL?	SSTL (µg/kg)	Exceeds SSTL?
Benzene	**19,800**	**7**	**Yes**	**3,200**	**Yes**
Toluene	**152,000**	**1,450**	**Yes**	**180,270**	**No**
Ethylbenzene	**82,200**	**1,150**	**Yes**	**665,000**	**No**
Xylenes	**768,000**	**14,500**	**Yes**	**3,593,000**	**No**
Naphthalene	**128,000**	**36**	**Yes**	**302,000**	**No**

Benzene in shallow groundwater and in soil exceeds its respective SSTLs; therefore, this Corrective Action Plan recommends remedial alternatives to reduce benzene in soil and groundwater to below the formulated SSTLs.

4.0 REMEDIAL SYSTEM DESIGN

TtNUS conducted a screening of available technologies in order to determine the best remedial alternative for the Depot Gas Station. The objective of the remediation will be to reduce soil and groundwater benzene concentrations below the SSTLs developed in Section 3 of the report, specifically 455 µg/l for groundwater in the open areas, 7.92 µg/l for groundwater beneath Building 155, and 3,200 µg/kg for unsaturated soils. This will require remediation of both the unsaturated soil and the groundwater.

Potential remedial technologies and process options for soil and groundwater treatment have been identified and evaluated based on their ability to meet clean-up objectives (effectiveness), applicability based on site conditions, feasibility of implementation, reliability, and anticipated duration. The following remedial technologies were among those considered:

- Groundwater recovery – This option was not considered feasible because of the cost associated with the treatment of the relatively high groundwater flow rates expected, the expected duration of the remedy, and the difficulty in installing and maintaining the necessary infrastructure considering the facility uses in this area.

- Air sparging/bio-sparging – These options were not chosen based on the difficulty in effectively recovering hydrocarbon vapors created by the injection of air into the aquifer, considering the shallow water table at the site. Difficulties in installing and maintaining the infrastructure at the site were also considered.

- In-situ chemical oxidation – The injection of hydrogen peroxide, ozone, or other oxidant was considered. Ozone was rejected due to difficulties in recovery due to the shallow water table. The injection of large volumes of dilute oxidant (such as hydrogen peroxide) could cause mounding of the water table potentially leading to impacted groundwater and oxidant reacting at the ground surface. While this could be controlled by adjustment of injection rates, that type of adjustment may significantly limit the effectiveness of the remediation. This option has not been removed from consideration and may be utilized if the results of the treatability study detailed below are not positive.

- Enhanced bioremediation via oxygen addition – This option is considered viable for this site because it has been shown to be effective in reducing groundwater hydrocarbon concentrations at similar sites, does not require capture of vapors, and requires a limited amount of infrastructure (all components can be installed at the well heads). In order to confirm its effectiveness at this site and to

obtain a basis for full-scale design, an on-site treatability study is recommended; details on this study are provided below.

- Soil excavation – This option will provide for fast and effective removal of impacted soils which may present a continuing source of hydrocarbons to the site groundwater.

More information on the chosen alternatives, soil excavation and enhanced bioremediation via oxygen addition, is provided below.

4.1 SOIL EXCAVATION AND OFF-SITE DISPOSAL

Soil excavation and disposal provides the highest degree of overall protection to the environment by providing an immediate removal of hydrocarbons in soil that have the potential to leach to groundwater. Excavation should proceed prior to the selected groundwater remediation to help eliminate potential leaching from the soil to groundwater.

Soil excavation will be completed in the areas shown in Figure 11. Prior to excavation, all underground utilities will be marked. Soil will be excavated to the depth of the top of the water table, approximately 3 to 4 feet bgs. Excavated soil will be handled as petroleum contaminated soil and properly disposed off-site. Open excavations shall be protected with suitable barriers such as temporary fences along Cape Gauffre Street. In conjunction with the soil excavation, the 2-inch steel fuel line that runs from the ASTs to Building 157 will be removed; this will remove another potential continuing source of contamination.

The areas shown in Figure 11 are the initial excavation locations; visual observation and field instruments will be utilized to determine if additional excavation is necessary. Confirmation samples will be collected and analyzed as required. All activities associated with the excavation will be detailed in a work plan to be submitted prior to the start of field activities.

The total volume to be excavated for removal of petroleum contaminated soil is estimated at 1400 yd^3. Based on the actual water table at the time of excavation and potential additional excavation as detailed above, this volume may vary.

Backfill of excavated areas shall be performed simultaneously with soil removal once the limit of the excavation has been determined in that area. Backfill soil shall be obtained from a documented clean source. All disturbed areas shall be returned to original conditions including seeding grassed areas and replacing curbs and asphalt, as required.

4.2 GROUNDWATER REMEDIATION

A phased approach for the groundwater remediation using enhanced bioremediation via oxygen addition is proposed for the site. The first phase will be a treatability study conducted on a portion of the groundwater plume, approximately 50 feet wide by 65 feet long, near PAI-DGS-MW15. The results of the testing in this area will be used to evaluate the feasibility of this technology and determine design criteria prior to full-scale implementation. The treatability test area is shown in Figure 14. The area was chosen because it can provide data on the effectiveness of the process in areas of varying levels of petroleum impact, and the presence of existing wells downgradient that can be used to determine the area of influence of the injection. In addition to providing data for a full-scale implementation, the test should provide reduction of hydrocarbon concentrations in a highly contaminated portion of the plume.

The oxygen injection will be accomplished via the in situ submerged oxygen curtain (iSOC™) groundwater oxygenation system. This system, manufactured by inVentures Technologies, Inc. (iTi), utilizes a microporous mass transfer device to dissolve pure oxygen in to groundwater. This method has been shown to increase the dissolved oxygen levels in groundwater to 50 parts per million (ppm). Further information about ISOC™ Technology is provided in Appendices A and B. These consistently high dissolved oxygen concentrations increase the microbial activity in the subsurface and enhance the natural biodegradation of the petroleum hydrocarbons in the groundwater and saturated soils via aerobic respiration.

4.2.1 Treatability Study

The following sections provide detail on the baseline sampling, treatability testing procedure and follow-up sampling and reporting. More detail on each of these tasks will be provided in a work plan to be submitted prior to the initiation of activities.

4.2.1.1 Baseline Sampling of Existing Wells

In order to verify that the study area shown in Figure 14 is in the proper location based on current site conditions, all of the existing monitoring wells will be sampled prior to installation of the injection wells. The depth to groundwater in each well will also be measured to confirm the groundwater flow direction in the shallow and deep aquifers. This data will then be used to determine the placement of the injection wells.

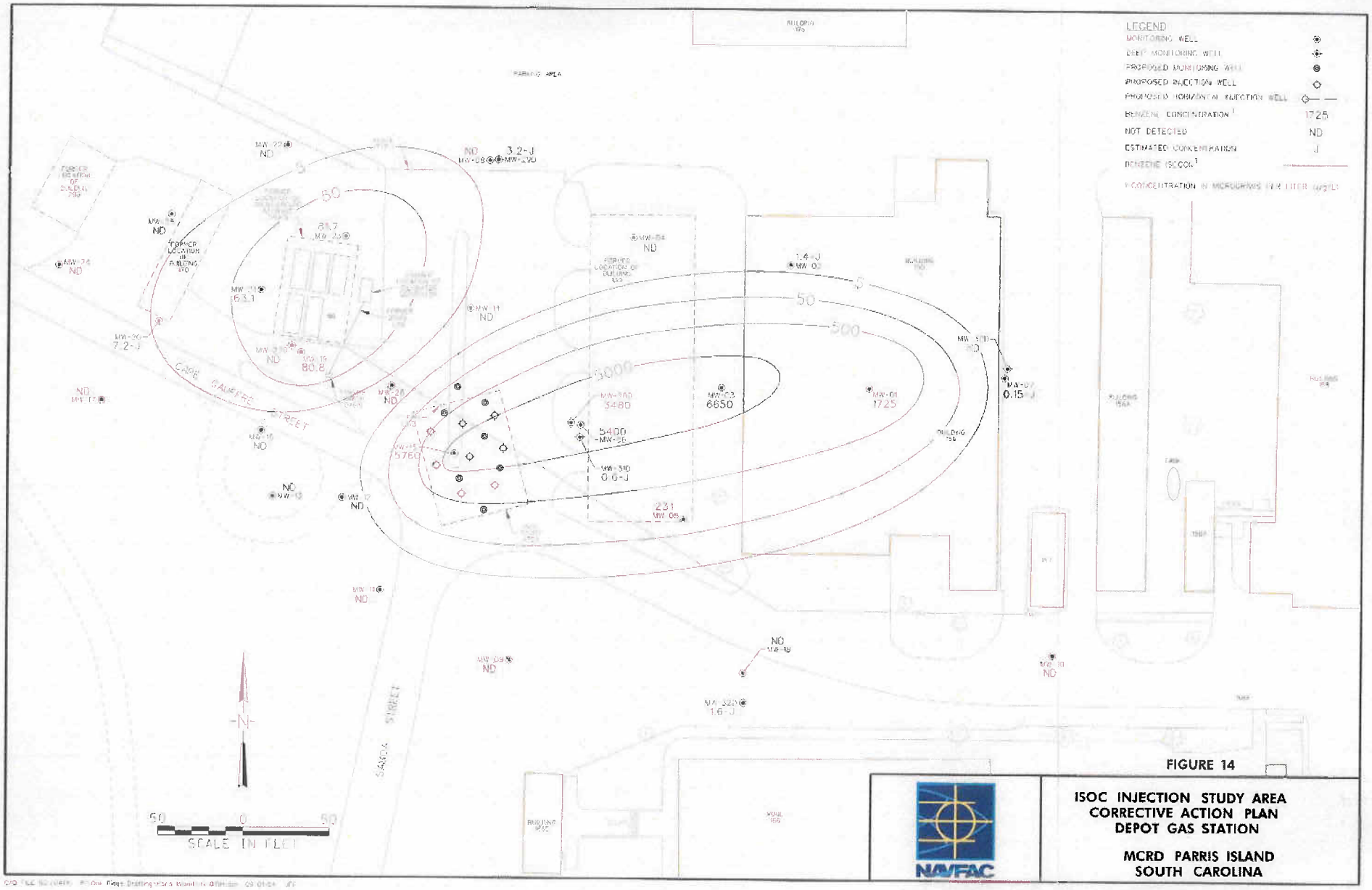


FIGURE 14

NAVFAC

ISOC INJECTION STUDY AREA
CORRECTIVE ACTION PLAN
DEPOT GAS STATION

MCRD PARRIS ISLAND
SOUTH CAROLINA

Samples from the 32 on-site wells will be analyzed for BTEX, MTBE, naphthalene, PAHs, iron, lead, nitrates, and sulfates per the SCDHEC requirements. Additionally, field measurements of temperature, pH, DO, oxidation-reduction potential (ORP), and specific conductance will be recorded during the sampling. Based on the results of this sampling, the location of the study area will be finalized. Also, for the purposes of evaluating the treatability test, this will be considered baseline data.

4.2.1.2 Injection Well and Additional Monitoring Well Installation and Baseline Sampling

As part of the treatability study a total of eight injection wells will be installed; one iSOC oxygenation system will be installed in each of the wells. The wells will be installed in a grid pattern on 20-foot centers in the chosen study area (Figure 14); using this spacing, it is expected that the system will create an area of oxygen-enriched groundwater and an aerobic reaction zone sufficient to reduce petroleum hydrocarbon concentrations throughout the entire study area. A cross sectional view of an injection well with the installed iSOC™ diffuser is presented as Figure 15.

The injection wells will be installed using hollow stem auger drilling techniques. The drilling subcontractor, prior to initiation of drilling activities at the site, will obtain well installation permits. The wells will be installed and constructed in general accordance with applicable guidelines from SCDHEC. Primary casing and screens of the monitoring wells will be constructed of 2-inch inside diameter, Schedule 40, flush-joint polyvinyl chloride riser and flush-joint 0.010-inch factory-slotted well screen. Each of the injection wells will be installed to a depth of 25 feet bgs and screened from 2 to 25 feet bgs (see Figure 15). The boring for each injection point will be terminated at 25.5 feet bgs to provided approximately 0.5 ft of sand pack under each well.

In order to provide data to determine the success of the treatability study, a total of seven additional shallow monitoring wells will be installed in the study area (Figure 14). The monitoring wells will be installed in a manner similar to the injection wells and will be approximately 17 feet deep with screened sections 15 feet in length. During the installation of these wells, saturated soil samples will be collected from three separate locations and analyzed for BTEX, naphthalene, PAH, and total petroleum hydrocarbons to determine the adsorbed source material in the study area. This information will be utilized when analyzing the results of the treatability study.

The monitoring and injection wells will be developed no sooner than 24 hours after placement of grout to remove fine sediment from around the screened interval of the well. Wells will be developed by bailing and surging, or by pumping, as determined by the field geologist. Field parameters (pH, temperature, turbidity, and specific conductance) will be measured at equally spaced time intervals during well

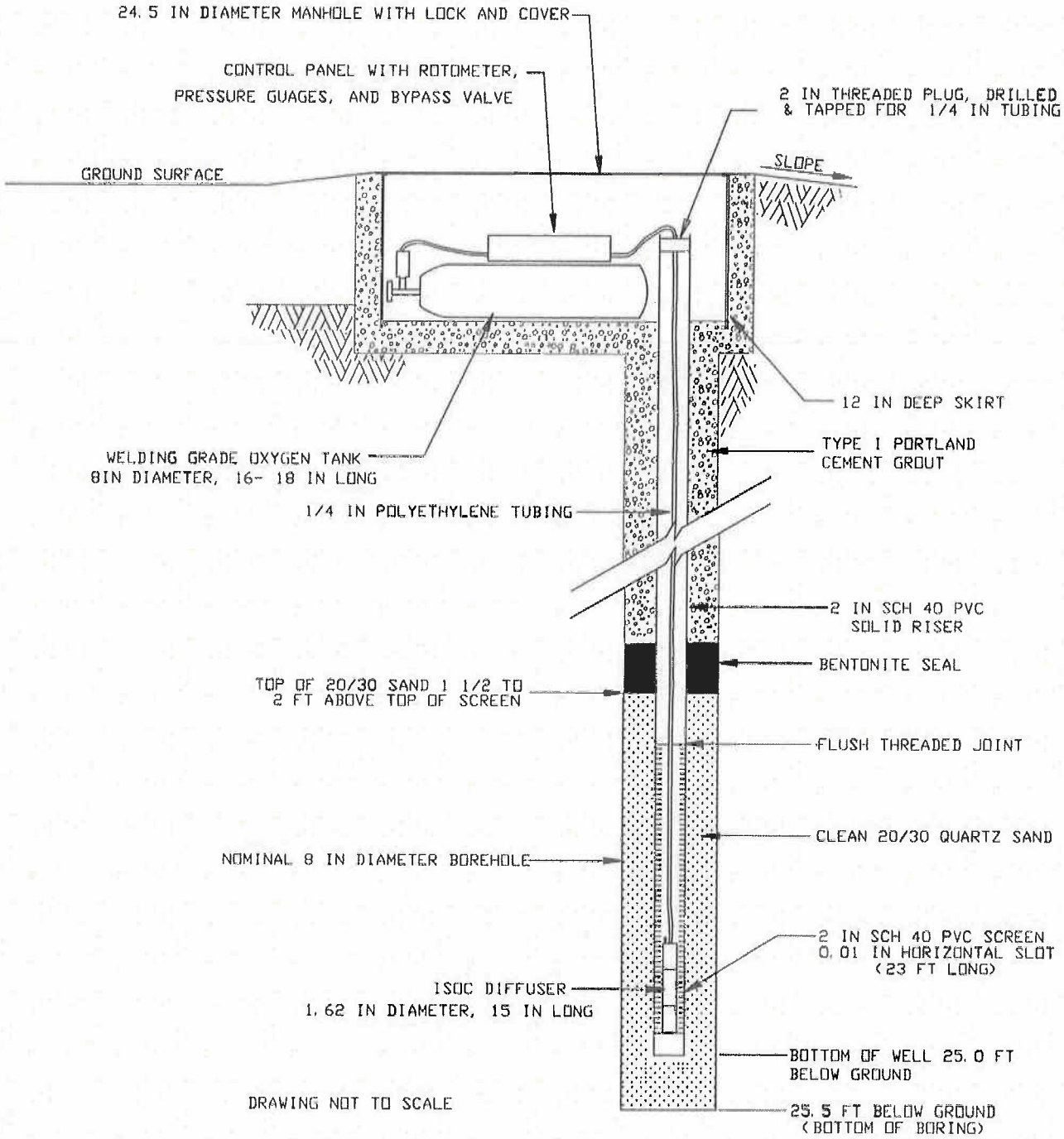


FIGURE 15

ISOC INJECTION WELL CONSTRUCTION
CORRECTIVE ACTION PLAN
DEPOT GAS STATION

MCRD PARRIS ISLAND
SOUTH CAROLINA

development. Wells will be developed a maximum of one hour or until the field measurements become stable and the development water is visibly clear.

Following installation and development of the monitoring wells, a groundwater sample will be collected from each well and analyzed for BTEX, MTBE, naphthalene, PAHs, iron, lead, nitrates, and sulfates per the SCDHEC requirements. Field measurements of pH, DO, ORP, temperature, and specific conductance will also be recorded during the sampling. In addition, four wells (one upgradient of the impact, two in the area of impact, and one downgradient of the impact) will be sampled for biological parameters, including total organic carbon, alkalinity, ammonia nitrogen, hydrocarbon degrading bacteria, and heterotrophic plate count. The results of this sampling will be used for evaluation of the results of the study as well as to determine if nutrient addition is required prior to the commencement of oxygen addition.

4.2.1.3 Feasibility Test Operation

Following installation of the injection and monitoring wells, the iSOC equipment will be installed in manholes at each well head. At each well head, an 18-inch oxygen tank, control panel, flow meter, and pressure gauges will be installed. Placing the equipment in the manholes eliminates the need to run piping from each well to a central location.

Prior to oxygen injection, nutrients will be injected in to each well, if necessary based on the results of the baseline sampling. Nutrients, at concentrations and volumes determined from the analytical results, will be injected in to each of the seven new monitoring wells either by gravity or at low pressure (10 pounds per square inch or less).

Then, the injection of oxygen will begin. The injection rates will be based on calculations which estimate the amount of oxygen that must be injected to provide for biodegradation of the petroleum contaminants based on contaminant concentration in the groundwater and saturated soils, site geochemical parameters, and other sources of oxygen demand.

The nutrient injection concentrations and volumes, oxygen injection rates, and specific operation and maintenance requirements for the iSOC equipment will be detailed in the work plan to be submitted prior to initiation of the study.

Following initiation of oxygen addition, monitoring of groundwater will take place on a weekly basis. During the monitoring visits, proper operation of the iSOC system will be confirmed and field

measurements of groundwater parameters will be collected. These measurements will be made at the seven newly installed monitoring wells as well as existing monitoring wells near the study area. For example, if the study area is as shown on Figure 14, measurements will be collected at the seven newly installed wells, MW-05 (in the plume), MW-09 (upgradient), MW-12 (sidegradient), MW-14 (downgradient) and MW-26 (downgradient). These measurements include depth to water, pH, DO, ORP, and specific conductance. After an appropriate period (approximately one month), the monitoring frequency will be reduced to twice per month.

Based on these results and the results of the quarterly sampling detailed below, the parameters of the test may be adjusted. This would include adjusting the oxygen flowrates at some or all of the wells, discontinuing injection at certain wells to test areas of influence, and/or adjusting the frequency and/or parameters of the scheduled monitoring.

4.2.1.4 Quarterly/Annual Groundwater Sampling

On a quarterly basis, groundwater samples will be collected from the wells associated with the test, including the seven newly installed monitoring wells and other nearby wells (for example, MW-09, MW-15 and MW-26). The samples will be analyzed for BTEX, MTBE, naphthalene, PAHs, iron, lead, nitrates, and sulfates per the SCDHEC requirements. Field measurements of pH, DO, ORP, temperature, and specific conductance will also be recorded during the sampling. In addition, four wells (one upgradient of the impact, two in the area of impact, and one downgradient of the impact) will be sampled for biological parameters, including total organic carbon, alkalinity, ammonia nitrogen, hydrocarbon degrading bacteria, and heterotrophic plate count. On an annual basis, a full round of groundwater samples will be collected from all site wells and analyzed for BTEX, MTBE, naphthalene, PAHs, iron, lead, nitrates, and sulfates per the SCDHEC requirements.

In conjunction with the annual sampling event, saturated soil samples will be collected from the three locations referred to in section 4.2.1.2 via DPT. The samples will be analyzed for BTEX, naphthalene, PAH, and total petroleum hydrocarbons; these data will be used in the analysis of the study's success.

This data will be utilized to determine the success of the test and if additional nutrient injection is or adjustments to the test protocol are needed. Based on this data, a quarterly Performance Evaluation shall be prepared and submitted to the SCDHEC.

4.2.1.5 Evaluation of Results and Full-Scale Remediation

Throughout the operation of the study, the data generated will be evaluated to determine the effectiveness of the iSOC system. After one year (or sooner if the data is adequate), the evaluation will be expanded to include design of the full-scale treatment system.

The evaluation of the success of the system will be based on the ability of the system to provide sufficient oxygen to provide an aerobic environment suitable for biodegradation, the reduction of benzene concentrations in the groundwater throughout the study period, whether the data collected shows evidence of biodegradation, and costs associated with the installation and operation of the system. If the study shows that the system was successful, a full-scale system will be designed and implemented. If not, consideration will be given to alternate technologies such as in-situ chemical oxidation.

Assuming that the study shows that the system is effective, the system will be expanded to the other areas of the site indicating benzene concentrations above the SSTLs. The full-scale system will include additional injection wells installed in a manner similar to those installed previously. The locations of these wells will be based on several factors, including:

- The location of the petroleum impact above SSTLs at the time of the design;
- The area of influence determined during the treatability study. If it is found that there is significant downgradient movement of the dissolved oxygen, it may be possible to install the wells in a row at the upgradient or downgradient edge of the plume rather than in a grid pattern;
- Surface and subsurface obstructions.

If required to monitor the full-scale system, additional monitoring wells may be installed; a maximum of three to four wells is anticipated. These wells and other existing monitoring wells may also be utilized for the injection of nutrients, if required.

The full-scale design will also include all monitoring and sampling requirements associated with the system.

The COC and geochemical data will be continuously analyzed to determine the success of the system and actions that can be taken to optimize system performance. As benzene concentrations are reduced, it may be possible to discontinue iSOC operation and move in to a period of monitored natural attenuation.

REFERENCES

ASTM (American Society for Testing and Materials), 1997. *Standard Guide for Risk-Based Corrective Action Applied at Petroleum Release Sites* (E-1739-95e1), American Society for Testing and Materials Annual Book of ASTM Standards, Conshohocken, PA.

Bioscreen Natural Attenuation Decision Support System Software, Version 1.3, June 1996. Technology Transfer Division, Air Force Center for Environmental Excellence.

Hassan, J. A., 1985. Groundwater Conditions in the Ladies and St. Helena Islands Area, South Carolina. South Caroline Water Resources Commission Report No. 147, p. 56.

Hayes, L. R.; 1979. The Groundwater Resources of Beaufort, Colleton, Hampton and Jasper Counties, South Carolina. South Carolina Water Resources Commission Report No. 9, pp. 91.

Hughes, W. B., M. S. Croch, and A. D. Park, 1989. Hydrogeology and Saltwater Contamination of the Floridan Aquifer in Beaufort and Jasper Counties, South Carolina. South Carolina Water Resources Commission Report No. 158. p. 52.

Johnson, P.C. and Ettinger, R.A.; 1991. Heuristic model for predicting the intrusion rate of contaminant vapors into buildings. Environ. Sci. Technology, 25: pp.1445-1452.

Shacklette, H. T.; Hamilton, J. C.; Boerngen, J. G.; and Bowles, J. M.; 1971. Elemental Composition of Surficial Materials in the Conterminous United States. Geological Survey Professional Paper 574-D. pp. 71.

Smith, B.S., 1987. Groundwater Flow and Saltwater Encroachment in the Upper Floridan Aquifer, Beaufort and Jasper Counties, South Carolina. U. S. Geological Survey Water Resources Investigations Report 87-4285, p. 61.

SCDHEC (South Carolina Department of Health and Environmental Control), 2001. *Risk-Based Corrective Action for Petroleum Releases.* May 15.

TtNUS (Tetra Tech NUS, Inc), 2003, *Tier II Assessment Report for Depot Gas Station, Marine Corp Recruit Depot Parris Island, Parris Island, South Carolina*. April.

USEPA (U.S. Environmental Protection Agency), 1989. *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual (Interim Final),* EPA/540/1-89/002 (USEPA 1989).

USEPA Region 4, 1995. *Supplemental Guidance to RAGS: Region 4 Bulletins, Human Health Risk Assessment.*

USEPA, June 2000. *Risk Assessment Guidance for Superfund: Volume I. Human Health Evaluation Manual, (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim Guidance,* Washington, D.C. June.

APPENDIX A

ISOC™ USER GUIDE

iSOC® Technology

User Guide

iSOC® Groundwater Oxygenation System

in situ Submerged Oxygen Curtain: Another innovation from iTi's patented Gas inFusion mass transfer Technology— 'elegance in simplicity'

United States Patent 6,209,855

Contact The Nearest iSOC® Representative for Sales & Service:
http://www.isocinfo.com/sales.aspx

iSOC® Technology

TABLE OF CONTENTS

Topics	Page Number
Introduction	1
Gas inFusion	1
iSOC® Unit	2
iSOC® Performance	3
iSOC® infusion of other gases	5
Equipment Setup	5
Installation & Startup Procedures	6
Trouble shooting	9

List of Figures

List of Figures	Page Number
iSOC® Unit	1
iSOC® Microporous Hollow Fibre	1
iSOC® Unit	2
Estimated iSOC® DO vs. Flow rate	3
iSOC® Performance Start-up	4
iSOC® Performance	4
iSOC® Dissolved Gas Concentrations in a Water Column	5
iSOC® Equipment Setup Schematic	6
iSOC® with Tubing & Recovery Line	7
iSOC® Well Head Connections	7
iSOC® Well Insertion	8
Measuring iSOC® DO	9
iSOC® Drain Plug	9

iSOC® Technology

User Guide

Introduction

iSOC® is a specially designed, highly structured, microporous mass transfer device invented and manufactured by inVentures Technologies incorporated (iTi) for use in enhanced groundwater remediation. iSOC®, or in situ Submerged Oxygen Curtain, is based on iTi's proprietary Gas inFusion technology, which is patented worldwide. Its inherently large surface area allows for intimate contact between any gas and groundwater, resulting in ultra efficient mass transfer.

Gas inFusion

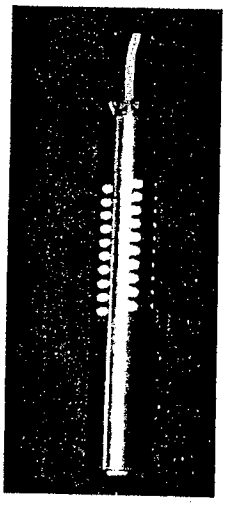


Figure 1: iSOC®

Gas infusion is a proprietary technology (patented worldwide) developed by inVentures Technologies incorporated (iTi) for dissolving gas into liquids **without sparging**. Figure 1 shows the iSOC® unit that will fit down any two-inch (50 mm) well.

Microporous hollow fibre, illustrated in Figure 2, is employed to provide the interfacial area needed to accomplish efficient mass transfer. The fibre provides an enormous surface area for mass transfer—in excess of 7000 m^2 per m^3—and is hydrophobic. Gas, fills the pores of the fibre. Maintaining a gas pressure, less than the liquid pressure ensures that ultra efficient mass transfer takes place without a bulk passage of gas into the liquid. Bulk transfer of gas creates bubbles. **Gas inFusion is mass transfer without bubbles**.

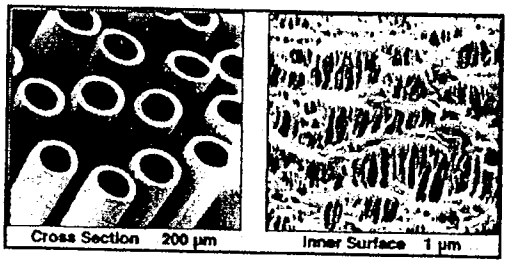


Figure 2: Microporous Hollow Fibre

Henry's Henry's Law governs the 'driving force' for this mass transfer. Increasing the pressure of the system raises the solubility of the gas and allows for greater levels of dissolved oxygen to be achieved. However, whereas conventional methods of oxygenation are limited to low atmospheric dissolved oxygen levels—typically ranging from about 15 ppm (mg/l) at 0°C (32°F) to about 7 ppm at 35°C (95°F) under1 atmosphere of pressure—achieves ultrasaturation dissolved oxygen concentrations of hundreds of ppm in water in a relatively stable condition. Rather than escaping from the water surface, Gas inFusion™ creates a supply of oxygen that remains in a dissolved state until utilized by a biomass. The decay of even very high dissolved oxygen concentrations in the hundreds of ppm has been demonstrated to be several days. Obviously, this unique method of

water oxygenation becomes ultra efficient in both biomass utilization and energy savings.

The iSOC® Unit

The iSOC® Unit is a specially designed, highly structured, microporous mass transfer device invented and manufactured by inVentures Technologies incorporated (iTi) for use in enhanced groundwater remediation. **iSOC®**, or in situ **S**ubmerged **O**xygen **C**urtain, is based on iTi's proprietary Gas inFusion technology. Its inherently large surface area allows for intimate contact between oxygen and groundwater, resulting in ultra efficient mass transfer.

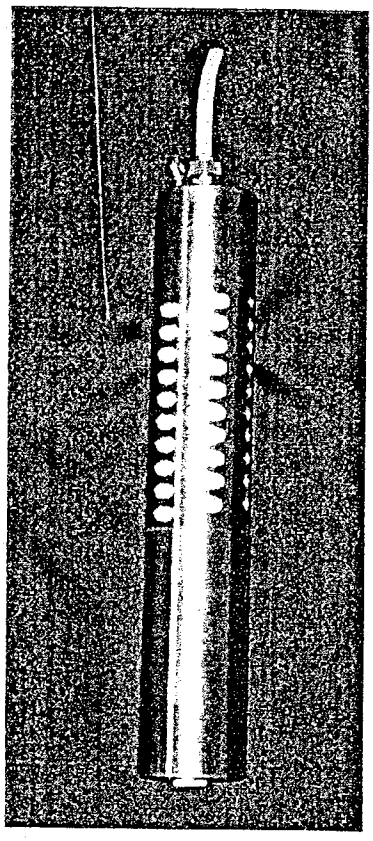


Figure 3: iSOC® Unit

Although used to enhance natural bioremediation of hydrocarbons in groundwater with oxygen, iSOC® can also be used to infuse any gas into groundwater, including gases used to enhance natural degradation of chlorinated solvents.

The iSOC® unit, illustrated in Figure 3, is made of stainless steel and is 1.62 inches (41 mm) in diameter and about 15 inches (380 mm) in length. The sizing is to allow the iSOC® to be placed inside 2 inch (50 mm) diameter groundwater monitoring wells.

The top of the unit is equipped with a steel barbed fitting to accommodate the 1/4" (6 mm) diameter polyurethane tubing used to connect the unit to a source of pressurized oxygen, usually a liquid oxygen cylinder. Although the tubing and fitting will support a considerable tensile strength, a 'lifting eye' is also installed on the top of the unit for attaching a lifting/security wire.

The bottom section of the iSOC® unit drains and collects any water which may occur in the infusion section due to improper operating conditions. The drain fitting on the bottom allows this water to be drained and the unit to be 'blown' clear.

iSOC® Performance:

Due to the enormous surface area presented by the iSOC® device, an oxygen saturated zone is quickly established around the device at the bottom of the groundwater well. The actual oxygen content achieved through use of the iSOC® is governed by the depth of water/gas pressure on the unit—Henry's Law.

This saturated zone spreads up and throughout the well, and diffuses out of the well. Higher in the well, the head pressure begins to fall. This results in water that is no longer saturated, but is now **supersaturated**. Conventionally produced supersaturation is unstable and effectively unattainable. However with Gas inFusion™, the release of oxygen from this supersaturated state is such an extremely slow process, from such a high dissolved concentration, that a relatively stable supersaturated state is created. This is especially true in the absence of other bubbles. An excess of bubbles actually works to strip out dissolved gas from a liquid, as bubbles tend to grow on bubbles.

Anything in nature is always working toward an equilibrium state. The supersaturation 'half-life', i.e., the time required for the level of saturation between normal solubility and this ultra-high level of Gas inFusion supersaturation to be reduced by one-half, was demonstrated to be up to 7 days in a 10' (3 m) by 2" (50 mm) column. This results in a supply of oxygen that is readily transferred to lower dissolved oxygen groundwater entering the well zone, or that is consumed for biological treatment by biomass.

As a function of the groundwater flow rate, the graph illustrated in Figure 4 indicates the expected dissolved oxygen concentration that each groundwater well equipped with an iSOC® can be expected to reach. This example assumes the water depth to be 10 feet (3 m) with the iSOC® located at the bottom of the well. Obviously, as the groundwater flow rate increases to very high levels, the achievable dissolved oxygen concentration is reduced.

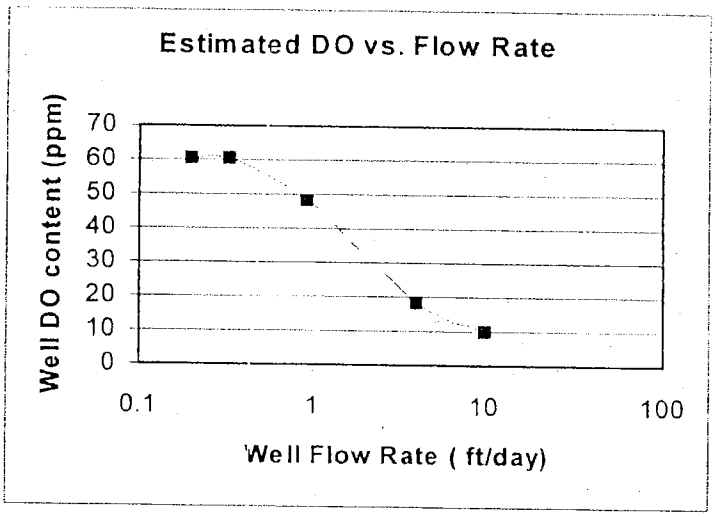


Figure 4: Estimated iSOC® DO vs. Flow Rate

Due to a natural mixing effect of the oxygenated water in the groundwater well, the dissolved oxygen concentrations should be relatively equal throughout the depth of the well. Once the iSOC® is first installed in a well, it takes a little while for the dissolved oxygen concentration to build up to maximum levels.
Figures 5 and 6 illustrate a short duration test of some 100 hours, recording the dissolved oxygen concentration at various depths in a well over time from start up. Figure 5 shows a log time scale to indicate that it took about 16 hours (~1000 minutes) for the iSOC® to maximize the dissolved oxygen concentration in the well to 35 ppm. Figure 6, with a conventional time scale, illustrates that once the maximum oxygen level

was attained, it remained relatively constant over time. Also, note that the oxygen concentrations at 1-foot intervals were roughly the same.

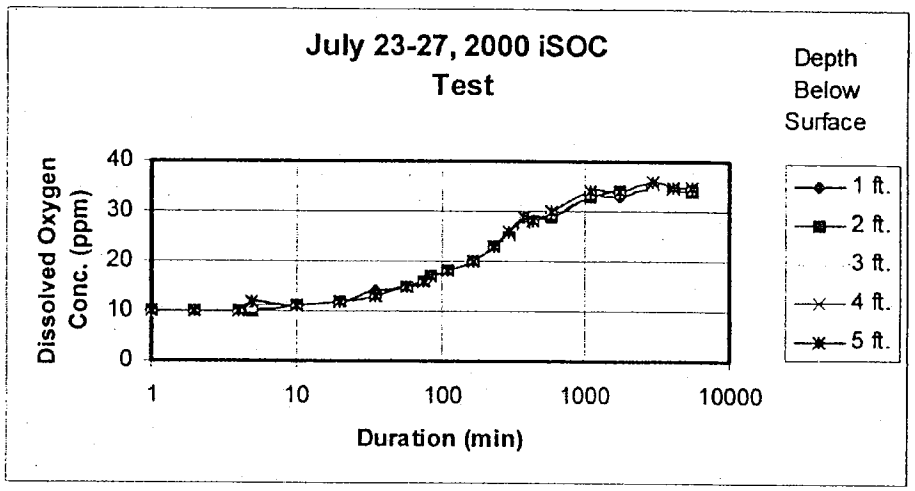


Figure 5: iSOC® Performance Start Up

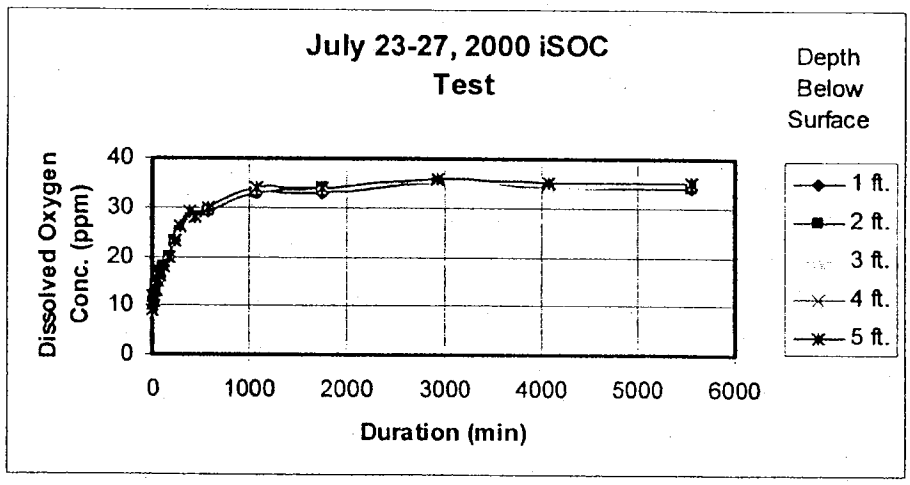


Figure 6: iSOC® Performance

As discussed earlier, the maximum attainable iSOC® dissolved oxygen concentration is determined by the gas and water depth pressure over the iSOC® unit—Henry's Law—and the groundwater flow rate. In the Installation & Start Up Procedures, an equation is provided to determine the maximum head pressure created by the depth of water over the iSOC® unit. The start up gas pressure from the oxygen cylinder is then adjusted to be slightly above this calculated maximum head.

iSOC® will deliver about 43 PPM of dissolved oxygen (DO) per atmosphere of head pressure on the iSOC® unit. Based on standard atmospheric pressure of 14.7 psi (1 bar) at sea level to about 10 psi (0.7 bar) at 10,000 feet elevation, an iSOC® unit positioned at the bottom of a well with a water depth of 35 feet (10 m) - roughly 2 atmospheres, can be expected to deliver in the order of 86 PPM DO. This is simply based on the

atmospheric pressure of 14.7 psi (1 bar) plus the water head pressure of 15.2 psi (1 bar) creating a total pressure of 29.9 psi (2 bar), or about 2 atmospheres.

iSOC® inFusion of Other Gases

The addition of oxygen has proven effective in the enhancement of biodegradation of hydrocarbon related compounds including MTBE. The iSOC® Gas inFusion technology is also effective in the infusion of any gas into groundwater. The controlled addition of gases such as methane and propane to groundwater has been successfully used to enhance the natural attenuation of chlorinated solvents such as TCE and PCE.

Figure 7 illustrates potential dissolved gas concentrations for five gases based on water column of different depths.

	Water Column Depth in Feet				
Gas Type	**5ft/1.5 m**	**10ft/3m**	**15ft/4.6m**	**20ft/6.1m**	**50ft/15.2m**
Oxygen	42	55	62	69	111
Methane	22	30	33	37	59
Propane	66	88	99	110	175
Ethane	57	75	85	95	150

Figure 7: iSOC® Dissolved Gas Concentrations in a Water Column

iSOC® Equipment Setup

iSOC® is a passive groundwater Gas inFusion device manufactured by iTi. The actual groundwater remediation system design and specification incorporating iSOC® devices is the responsibility of the remediation consultant.

Figure 8 illustrates a typical schematic for equipment setup for use of an iSOC®. For best results, the oxygen cylinder should be equipped with a two-stage, **low-flow** pressure regulator (0-50 psi / 0-3.5 bar). Where groundwater depths exceed 100 feet (30m), contact your iSOC® service representative for guidance in selecting an oxygen regulator.

In order to maintain accurate control over the very low oxygen flows, inVentures Technologies manufactures a control panel to adjust the rate of oxygen being infused into the groundwater and control the pressure between the iSOC® and the regulator.

The iTi control panel also contains a bypass valve to remove ambient air prior to startup and for blowing clear any water that may have entered the iSOC® Unit (See Figure 8). To ensure proper operation, the flow rotameter must deliver oxygen from a pressurized source (cylinder). The flow rate must be stable and on a continuous basis.

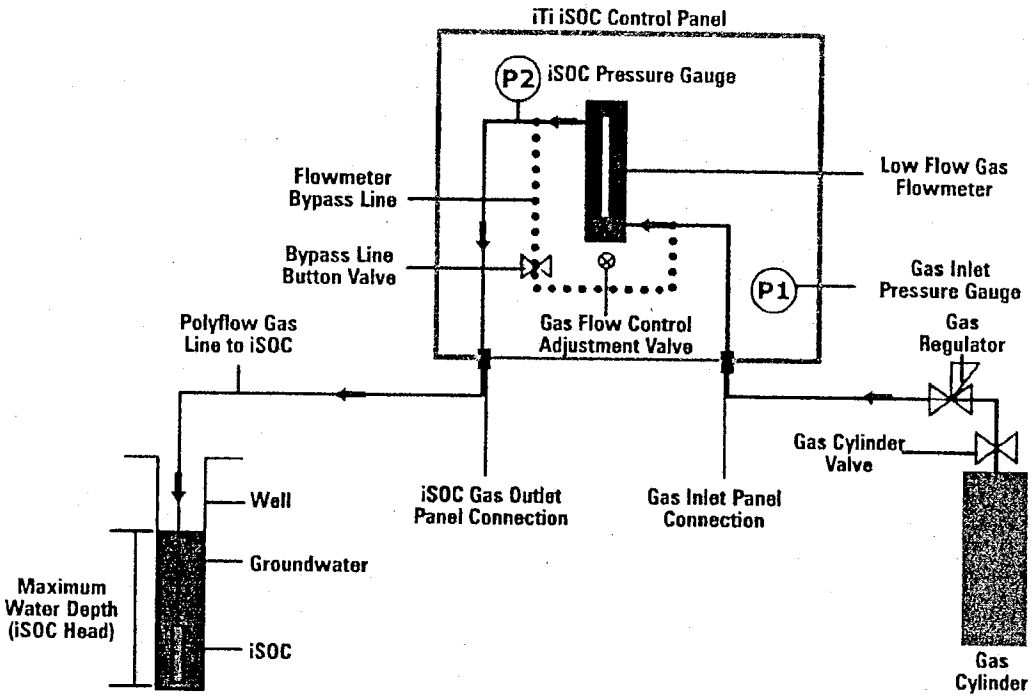


Figure 8: iSOC® Equipment Setup Schematic

The actual equipment setup design and specification varies with site conditions, number of iSOC®s employed, and the preference of the consultant and/or client. The control setup can be quite simple and inexpensive, or a little more comprehensive.

Innovative techniques are regularly used by consultants and contractors to install multiple iSOC® arrangements in busy sites. Normally, these installations can be handled in a matter of hours. To view, see our installation photos on the www.isocinfo.com website.

Again, these are examples only. The actual iSOC® installation details will be determined by the design remediation consultant. However, the installation should incorporate both equipment protection from vandalism and easy access features for maintenance and/or monitoring.

Installation & Start Up Procedures

1) **Place tape over ends of on site Polyurethane tubing before installation.** iSOC® and iSOC® control panel are supplied with tape covering the barb fittings. Keep tape on all fittings and tubing until final connections are made. The tape will help to prevent dirt and debris from entering the system internally. (**Note:** iSOC® system failure may occur if dirt enters the system via on site tubing, iSOC® or iSOC® Control Panel.)

2) **Make sure all on site tubing is installed correctly.** It should be well protected from, being crushed or severed. There should be no tight bend or kinks.

3) **Install iSOC® Control Panel, regulator and gas bottle in a clean, dry, well protected area** sheltered from the elements and safe from vandalism.

4) **Crack open new oxygen cylinder BEFORE attaching regulator** to purge out any debris such as sand and paint chips. Be sure to do so while wearing proper eye protection and making sure there are no open flames or combustibles in the area. Observe OSHA safety guidelines for handling and securing gas cylinders. (**Note:** Follow same procedure for routine changing of gas cylinders.) ***Failure to perform this procedure may cause iSOC® system failure.***

5) **Attach the two-stage low flow regulator to gas cylinder and once again, crack open oxygen cylinder** to purge regulator of any debris following same safety guidelines as in step 6.

6) **Be sure gas cylinder valve is opened completely, then backed off a slight amount.**

7) **Turn the regulator counterclockwise to make sure the pressure of the regulator is at zero.** At zero pressure there should be no gas flow.

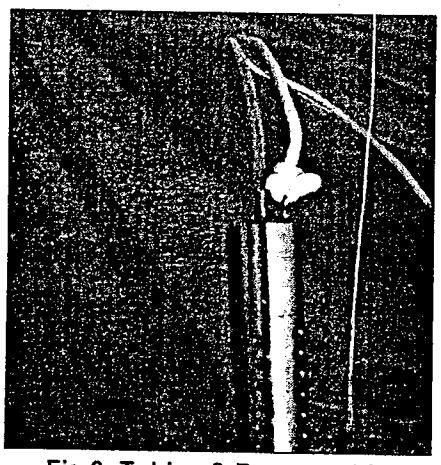


Fig 9: Tubing & Recovery Line attached to iSOC®

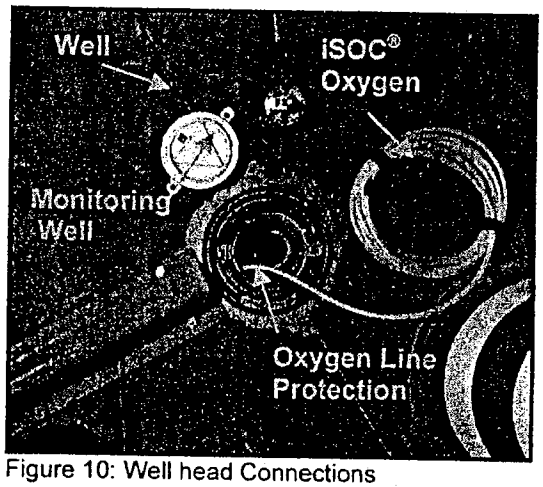


Figure 10: Well head Connections

Figures 9 and 10 illustrate iSOC® well connections.

Your installation may differ from these examples, but the essential points include:

- Protection of wellhead and iSOC® lines from damage and vandalism, especially on active sites.
- Secure, tight, accessible oxygen lines from control panel to individual iSOC®s.

8) **Attach all supplied black polyurethane tubing pieces with double barb fittings to the barb fittings on the control panel.** Remove tape protection as required. (**Note: Once attached, do not remove.** Make all future connections to the barbed end of the black tubing pieces to prevent scoring or cutting of the barbed rings on the control panel. If the barb on the tubing piece becomes scored at any given time, cut off and insert one of the extra supplied double barb fittings as necessary. A damaged barb is a potential source for a gas leak.)

9) **Connect the regulator to the black tubing piece on panel inlet labeled 'gas inlet'** using polyurethane tubing (0.250" OD x 0.170" ID OR 6mm OD x 4mm ID). Remove tape protection as required.

10) **Turn flow control valve on panel to off position (clockwise).** *Do not over tighten. Ensure the locknut is not interfering with the knob's rotation. (**Note:** You will damage the threads on the control knob if you attempt to turn while nut is fully tightened.)

11) **Set regulator on oxygen cylinder to 25 psi**. Gas inlet pressure gauge on panel should now read 25 lbs.

12) **Push panel by-pass button several times** to ensure panel is purged of any debris and that the by-pass button is not sticking. (**Note:** This is done before attaching iSOC®.)

13) **Drill two holes in well cap** - one for the iSOC® tubing and the other for the eyebolt used to secure the iSOC® lifting wire.

14) **Calculate injection wellhead pressure** in psi by dividing the height in feet of the water column by 2.306 (approx. 1 psi/ 2.3 ft water depth of iSOC®) and attach secure line to lifting eye on iSOC®.

15) **Attach iSOC® to black tubing piece on panel outlet labeled 'iSOC®'** using polyurethane tubing. Remove tape protection as required.

16) **Set inlet gas pressure at least 5 psi higher than wellhead pressure**.

17) **Set flow control to 40 cc/min**.

18) **Press by-pass valve on the control panel for 6-8 seconds** to purge ambient air.

19) **Submerge iSOC® unit in a bucket of water**.

20) **Adjust the flow control to 20 cc/min**. In 1-2 minutes you should observe one bubble every 1-2 seconds coming from the topside of the iSOC®. (**Note:** The single bubble release is normal and is designed to mix DO throughout the full vertical extent of the well and release nitrogen, assuring good mass transfer.)

21) While iSOC® is in the bucket of water, **use Snoop to test for leaks on all exposed fittings**. Make sure there are no leaks where the tube is connected to the barb fitting on top of the iSOC®. Key objective: if any leaks are found, repair before continuing.

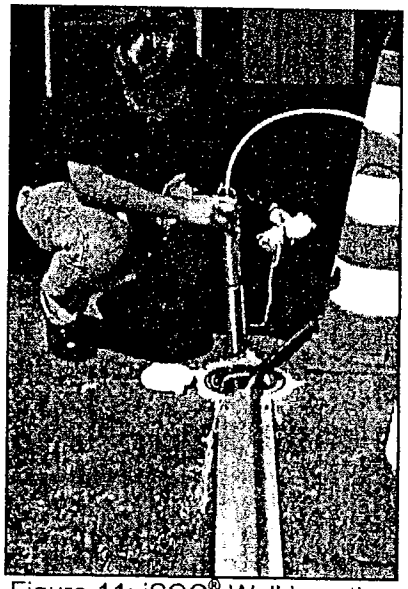


Figure 11: iSOC® Well Insertion

22) **Slowly lower the iSOC® into the well**. Note: Do not allow lifting wire and tubing to wrap around each other. This can cause kinking, cutting, loss of pressure in the outlet gas gauge and possible flooding of the iSOC®.

23) Once the iSOC® is at desired depth in well, **monitor the gas outlet gauge for the next 20-30 minutes.** It should stop at or near the psi calculated for the wellhead pressure.

24) **Adjust the flow control so the flow meter is set at 15 cc/min with the last adjustment being in the positive direction so as not to inadvertently shut it off.**

NOTE: If you are in need of assistance, please call your iTi representative **while on site** so that they can help with the above steps or any problem you may have encountered. Your iSOC® representative contact information can be found at **www.isocinfo.com** (iSOC® / sales).

Warnings:

1. **Do not allow gas cylinder to run out between site visits.** **NOTE: iSOC® failure may occur if gas supply to iSOC® is interrupted while iSOC® is in well. If this is allowed to happen, the iSOC® will have to be removed from well and allowed to dry.*
2. **Store the iSOC® unit in a clean, cool, dry place.** **NOTE: iSOC® failure may occur if the iSOC® unit is exposed to temperatures in excess of 60° C (140° F).*
3. **Do not use iSOC® in free phase Chlorinated Aliphatic Hydrocarbon product.**

Troubleshooting:

The unit will continue to operate as long as it is not deprived of oxygen. If it is, a vacuum in the iSOC® unit can occur. This can result in water being drawn into the microporous structure, effectively eliminating the large surface area, and reducing or stopping mass transfer. The two major causes are running out of oxygen due to miscalculation or a small system leak. As stated above, at very low pressures and very low flows, a series of adjustments over a few days following start up is often needed just to be sure that the regulator pressure has not dropped to below the head pressure, and that the rotameter is still reading on scale. Sometimes it is necessary to 'tap' the rotameter to make sure that the ball is not stuck in the tube.

Should the iSOC® unit be deprived of oxygen, pull it up to the surface to drain any water from the infusion structure. By removing the drain plug (See Figure 12), drain all water from the device. **With the plug still removed, and the bypass valve open**, set the regulator at 10-15 psi (0.7 – 1 Bar) and blow out any water still remaining in the unit. This will take several minutes. Reinstall the drain plug. The unit is now ready for start up.

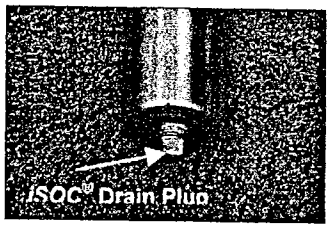


Figure 12: iSOC® Drain Plug

It is highly recommended that oxygen flow to the unit be confirmed on a weekly or biweekly schedule and that dissolved oxygen readings in the well be taken at this time as well (See Fig. 13).

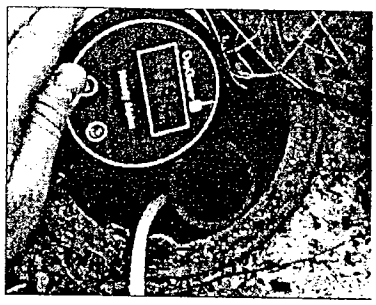


Figure 13: Measuring iSOC® DO

APPENDIX B

ISOC™ TECHNOLOGY INFORMATION

inVentures Technologies incorporated

Creating Value Through inNovation

Fredericton · Oakville · Ottawa

Introduction to *Gas inFusion* Technology

'elegance in simplicity'

Contact for Sales & Inquiry:

Performance Technologies

Advanced Environmental Solutions

Performance Technologies, Inc. • 337 Hunters Crossing • Tallahassee, FL USA 32312 • Tel: 850-385-7790 • Fax: 850-894-1067
Email: donrayoffice@home.com

TABLE OF CONTENTS

BACKGROUND	1
ITI VISION	1
ITI STRATEGY	1
OXYGENATION OF WATER 101	2
TECHNOLOGICAL BREAKTHROUGH	4
ELEGANT SIMPLICITY	4
MAGIC EFFECT—BUT SCIENCE BASED	5
FLEXIBILITY	6
UNCONVENTIONAL EFFICIENCY SAVES	7
OBVIOUS CONNECTION TO GROUNDWATER REMEDIATION	7
ISOC—PASSIVE 'NO POWER' GROUNDWATER OXYGENATION	8
PROOF IN DATA	9
ISOC PASSIVE DO PERFORMANCE	9
CONCEPT BECOMES FACT—*A/LINEAR*	10
OUTSTANDING A/LINEAR EFFICIENCY	10
ULTRA-HIGH GROUNDWATER GAS TRANSFER	11
CHLORINATED SOLVENTS	12
IMOX—POTENTIAL DNAPL EDGE	12
ZEGI - ZERO ENERGY GAS INFUSION	13
ITI CHALLENGE	14
ITI CONTACT	14

inVentures Technologies incorporated

Creating Value Through inNovation

Fredericton • Oakville • Ottawa

Introduction To *Gas inFusion*

Background

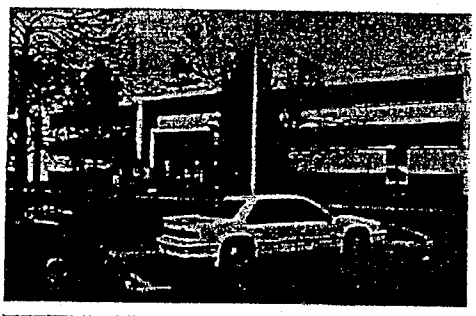
inVentures Technologies incorporated (iTi) has two platform world-class technologies that are based on a membrane-like polymer matrix barrier of microporous hollow fibre. The first technology, referred to as the *Organic Sieve* technology, effectively removes clean, dry organics from an aqueous stream—in-line, under pressure, instantaneously. The second, the *Gas inFusion* technology, infuses ultra-high levels of nascent dissolved gas into liquids. Both technologies have multiple market applications. *Gas inFusion* is patented worldwide, while *Organic Sieve* is patent pending. Both technologies are small, efficient, predictable, easy to use, and elegantly simple.

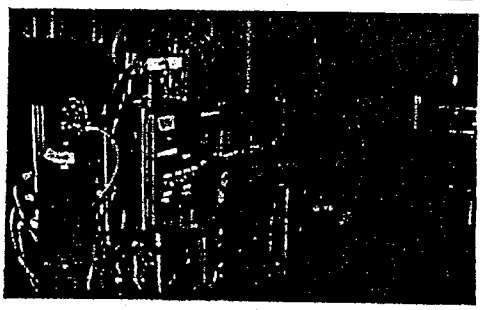
iTi Vision

The vision of iTi is focused solely on creating value, or enhancing the value of a product or process. Increased value that significantly exceeds the cost of enhancement tends to be an easy sell. The *Gas inFusion* and *Organic Sieve* technologies are platform, best in category and have several very significant market applications. Our clients have emphasized the importance of selling the 'elegant simplicity' of a technology having so many different applications while the technological concept remains the same.

iTi Strategy

inVentures associates itself with institutes and companies that are sound and that will help iTi develop its technology to its fullest potential. iTi recognizes the expertise required to enter these many markets and therefore has chosen not to go to market by itself. iTi always goes to market with industry partners who have a strong/dominant influence in a particular sector. We look to help a strong market player effect significant market growth through our technology. We either license or sell the technology or form some sort of strategic alliance with partners who are already successfully in the market and have a need for our technology. At all times, we have a research institute as a technical partner who helps with research. We have close ties with National Research Council Canada and continue ongoing research programs with them.





Oxygenation of Water 101

Dissolving a gas into a liquid is a 'mass transfer' operation. Mass transfer requires two things to occur:

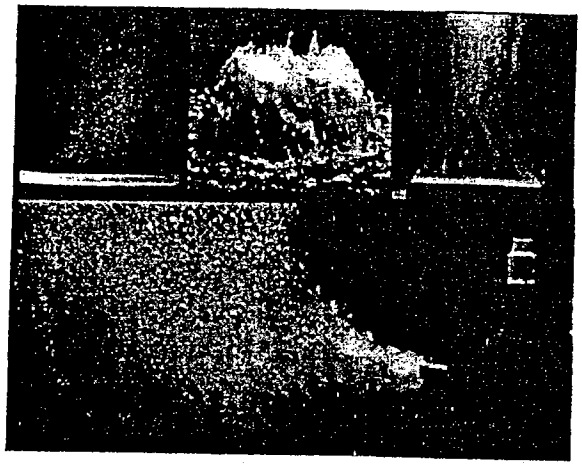
1. First, there must be a 'driving force'. The driving force in a gas/liquid system is the difference between the amount of gas currently in the liquid, and the maximum amount of gas that that liquid can hold, or take into solution, also known as the solubility. The solubility of a gas in a liquid is governed by Henry's Law and is unique to each gas/liquid system.

2. Second, there must be a means or pathway for the gas molecules to contact the liquid stream. This is also known as 'interfacial surface area'.

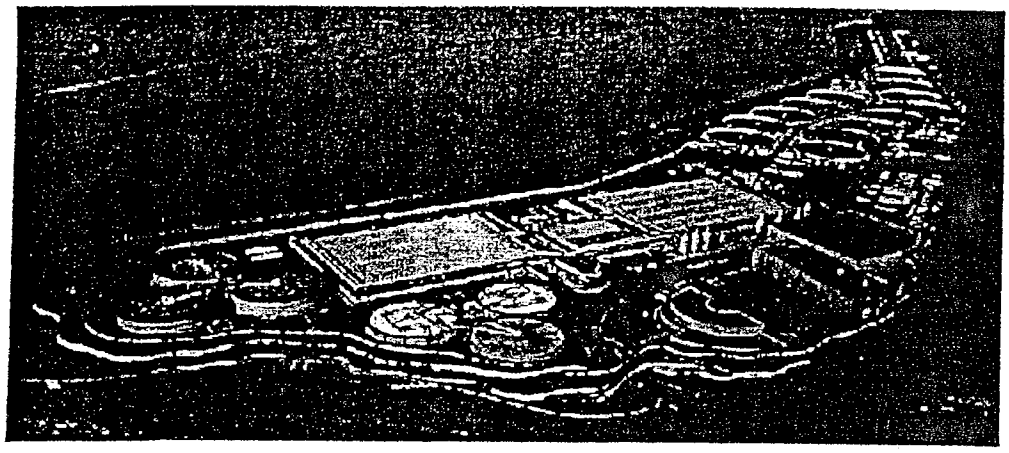
> ***Henry's Law** states: The weight of any gas that will dissolve in a given volume of liquid, at constant temperature, is directly proportional to the pressure that the gas exerts above the liquid.*
>
> *In equation form:* $C_{equil} = \alpha\, p_{gas}$
>
> *where:*
>
> *C_{equil} is the concentration of gas dissolved in the liquid at equilibrium;*
> *p_{gas} is the partial pressure of the gas above the liquid; and*
> *α is the Henry's Law constant for the gas at the given temperature.*

Conventional methods of oxygenation of water, as illustrated below, are energy intensive processes. This is due to the fact that oxygen is only sparingly soluble in water. The solubility of atmospheric oxygen in water ranges from about 15 ppm (mg/l) at 0°C to about 7 ppm at 35°C under 1 atmosphere of pressure. Most of the critical conditions related to dissolved oxygen deficiency in biological operations, including bioremediation, occur during the summer months when temperatures are higher and solubility of oxygen is at a minimum. For this reason, it is customary to think of dissolved oxygen levels of about 6 to 8 ppm being the maximum available under critical conditions.

Because of this low solubility, there is very little 'driving force'. In order to accomplish any mass transfer on a reasonable time scale, energy is expended to create interfacial surface area. Fine bubble diffusers, or chemical oxygen production compounds, release oxygen in the form of bubbles, usually in the range of 1 to 2 mm in diameter. These small bubbles create the interfacial surface area required for mass transfer.



Despite their small size, the vast majority of the oxygen (90 to 95%) created by these methods escapes from the water surface into the atmosphere. This escaping oxygen represents a high proportion of wasted energy and wasted money.



For example, the supply of oxygen to suspended biomass in wastewater treatment represents the largest single energy consumer in an activated sludge treatment facility. Recent studies indicate that the aeration system accounts for 50% to 90% of the total power demand. According to industry experts, only about 1% of all oxygen discharged from a fine bubble diffuser is absorbed per foot of tank depth. In a 10-foot deep tank, 90% of the applied oxygen escapes to the atmosphere. Along with the escaped oxygen and air are the noxious odors and VOC's that often require scrubbing at further energy cost.

In any biological treatment process, the limited solubility of oxygen is of great importance because it governs the rate at which oxygen will be absorbed by the medium and therefore, the cost of oxygenation.

Before we discuss how *Gas inFusion* differs from these conventional means of oxygenation, we need to address the concept of how much dissolved gas a liquid can 'hold'. Earlier we described 'solubility' as the maximum amount of gas a liquid can take into solution. This level of dissolved gas 'saturation' is also used extensively and is defined conventionally.

Saturation is defined as:

I. The condition of a liquid when it has taken into solution the maximum possible quantity of a given substance at a given temperature and pressure.

Supersaturation is conventionally defined as:

I. An unstable condition of a vapor in which its density is greater than that normally in equilibrium under the given conditions; or

II. An unstable condition of a solution in which it contains a solute at a concentration exceeding saturation.

Obviously, 'supersaturation' is an unstable condition and not in equilibrium. Now, let's look at why *Gas inFusion*™ redefines the concept of 'supersaturation' or more accurately, '***ultra**saturation*'.

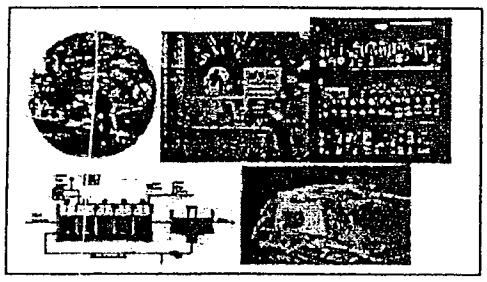
Technological Breakthrough

Gas inFusion technology is a unique method of infusing gas into liquids with demonstrated ability to:

- Effect rapid, no bubble, gas transfer (*inFusion*);
- Create ultra-saturation dissolved gas conditions, e.g., dissolved oxygen concentrations of hundreds of PPM;
- Allow long term retention of extremely high, nascent dissolved gas concentrations;
- Virtually eliminate dissolved gas losses into the atmosphere;
- Achieve gas transfer efficiencies with respect to power used, of 7 to 9 times that of the best conventional methods;
- Produce less dense liquids;
- Enhance performance and increase capacity of existing process infrastructures;
- Be flexible and comparatively small to be fitted into, or parallel to, conventional process technologies; and
- Be easily operated and maintained.

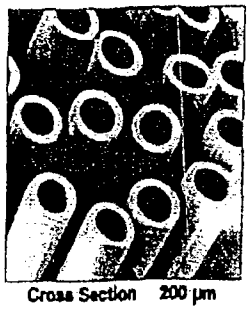
Gas inFusion technology is a global platform technology with numerous potential market uses, both stand alone and bundled with other technologies. iTi is currently focused on several market applications, including:

1. Aquaculture;
2. Live Fish/Seafood Transport;
3. Groundwater remediation;
4. Water/wastewater treatment;
5. Enhanced mineral leaching;
6. Hydroponics;
7. Food and beverage; and
8. Domestic products.



Elegant Simplicity

The infusion of ultra-high levels of nascent dissolved gas is all about mass transfer. Although iTi is definitely not expert in all of the potential market applications for *Gas inFusion*, iTi does have world class expertise in mass transfer.



Cross Section 200 µm

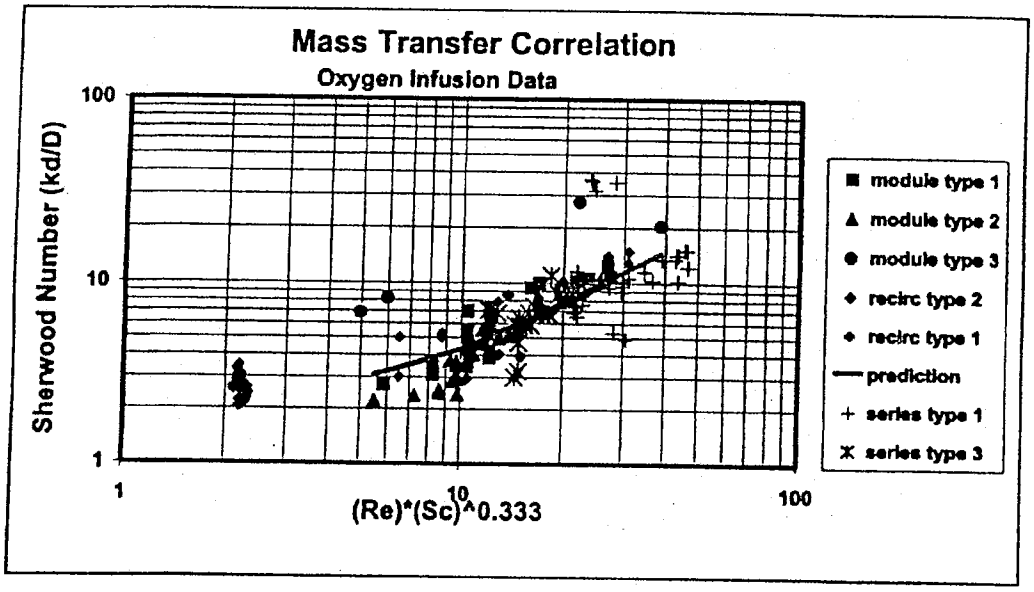
Inner Surface 1 µm

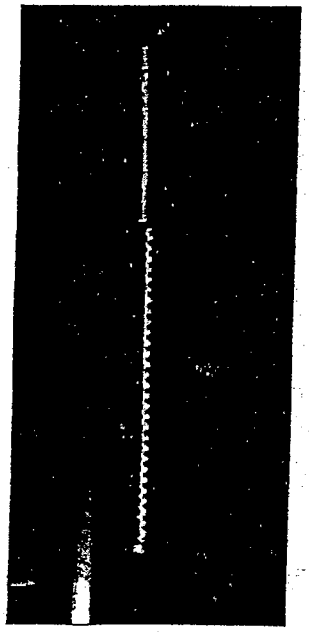
iTi's various *Gas inFusion* devices incorporate an inert polymer matrix barrier made of microporous hollow fibre (MHF). As illustrated, MHF is a type of fibre, about the outside diameter of fishing line, made of various materials, and essentially filled with holes. The size of the hole is controlled in the manufacturing process to produce different fibres with effective pathway diameters of typically 0.1 to 0.5 µm.

MHF produces a stable interface for mass transfer with more surface area, and holes, in the same space than any other material—in excess of 7000 m^2 per m^3—and is hydrophobic. The type and characteristics of the fibre, the size of micropore, and the proprietary designs and techniques developed by iTi determine its effective use in various applications.

Magic Effect—But Science Based

The Mass Transfer Correlation figure below shows that the *Gas inFusion* process is not black magic but is indeed based on solid science and engineering. Not only is the mass transfer predictable for any gas transfer device configuration and design, but custom systems design can also be employed to meet the requirements of any application. The iTi mass transfer predictive model has been proven out many times.



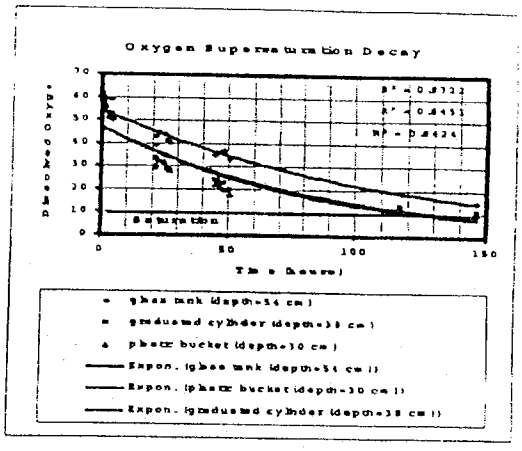


A gas-saturated liquid is produced under pressure within *Gas inFusion* devices, such as the one shown in a column to the left. These *inFusion* devices provide an extremely large interfacial area for gas transfer into a liquid. The transfer is performed such that there are no bubbles. The clear, open top column to the left contains roughly **70 PPM** of dissolved oxygen attached to a standard oxygen cylinder. While the device is actively infusing oxygen into the water, there are **no bubbles**.

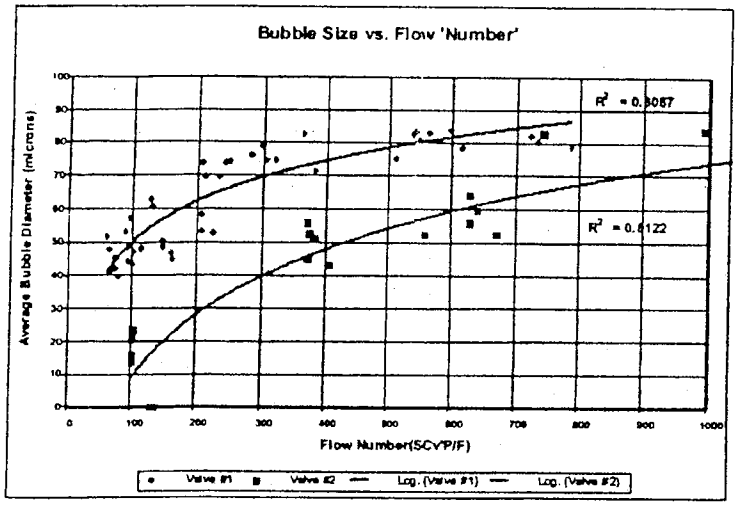
Both the liquid and the gas are under pressure. Henry's Law governs the limit that the liquid concentration can ultimately reach. When the liquid pressure is relieved for use, in an atmospheric tank or basin for example, the liquid is now supersaturated with gas. To prevent atmospheric loss, it is important that the liquid retain the gas as long as possible. When the liquid is introduced into a vessel in a 'bubbleless' fashion, the ultra-saturation condition remains in solution for many days, waiting to be used by process demand, such as biomass in wastewater or groundwater treatment systems.

Supersaturation Decay Test: 3" X 10' column

Time (hours)	DO Reading at Column Depth					
	9'	7'	6'	5'	3'	1'
0	52	53	53	53	52	50
50	42	43	43	43	39	34
100	40	41	41	40	36	32



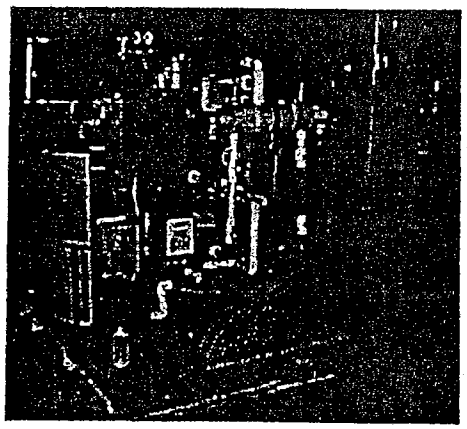
The supersaturation half-life correlates well with the depth of the vessel, as illustrated in the figure to the right. It correlates even better when other dimensional parameters of the vessel are taken into account. Half-lives in excess of a week are obtainable in 10 ft. deep open-top vessels, as shown above, **with oxygen feeds of <10 cc/min**.



As mentioned earlier, the ultra-high dissolved gas content liquid is produced without bubbles. The key to utilizing this gas most efficiently is the understanding of bubble size and growth once the pressure is relieved. As can be seen from the graph to the left, done correctly, extremely fine bubbles of up to 2 orders of magnitude smaller than achievable using the best diffusers on the market can be achieved, if desired.

Flexibility

The unique nature of the *Gas inFusion* technology allows it to be easily fit into an existing process to enhance performance and to increase capacity, or to design a 'grass roots' system around this 'better mouse trap'. Once iTi is aware of the specific needs of a market end use, a prototype gas transfer device can be fabricated to deliver the required results. The usual approach is to run an on-line pilot to test the performance enhancement and to determine the design requirements for a system solution. A typical *Gas inFusion* pilot skid being used for sulfide ore processing is shown on the right—always compact, always flexible.

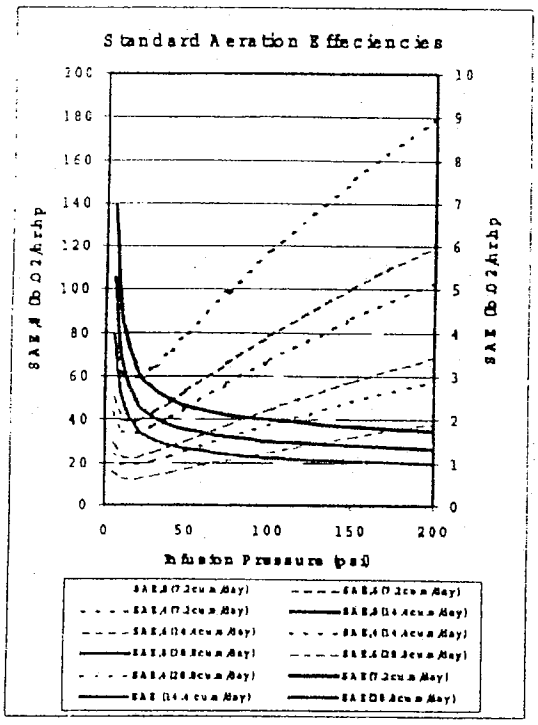


Unconventional Efficiency Saves

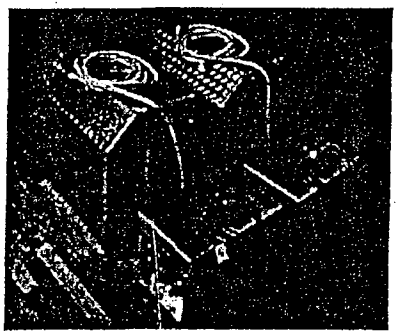
The bottom line is efficiency. In wastewater treatment, for example, enormous amounts of energy are needed to dissolve oxygen into the water. The standard unit of measure is the SAE, or Standard Aeration Efficiency, given in pounds O_2 per hour per horsepower. Conventional technologies achieve a SAE of about 2.0. At the same time, the oxygen concentration in the basin only reaches about 2 PPM. Higher dissolved oxygen concentrations will lower the SAE.

With iTi's *Gas inFusion* technology, and iTi's unique gas transfer devices and *A/Linear* valves, aeration efficiencies illustrated to the right become possible.

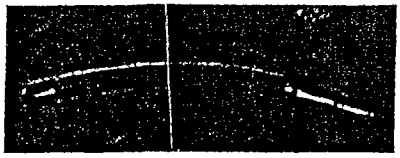
iTi is currently conducting an intensive R&D program in greenhouse gas reduction for wastewater treatment with Canadian federal government support.



Obvious Connection to Groundwater Remediation



iPRO Product Recovery Systems



iPRO Flexible Pump Unit

iTi naturally pursued groundwater remediation as an application for the *Gas inFusion* technology as it was already active in designing and manufacturing product recovery equipment. The two *iPRO* product recovery systems illustrated to the left, using iTi's proprietary *Organic Sieve* technology, clearly show the same efficient size approach as with the gas transfer technology. The same performance has also been demonstrated on many sites.

iPRO can be carried as baggage on a plane, or in the trunk of a car, and set up in full operation in a few minutes. *iPRO*, intrinsically safe, and pneumatic driven, recovers clean, dry hydrocarbon product only—absolutely no water—resulting in a product that can be re-used or re-sold. The pneumatic pump automatically seeks out the product/water interface continuously over any depth up to 250 feet. The product is removed down to a layer of 4 microns. Any accumulations of product are automatically recovered with little or no maintenance.

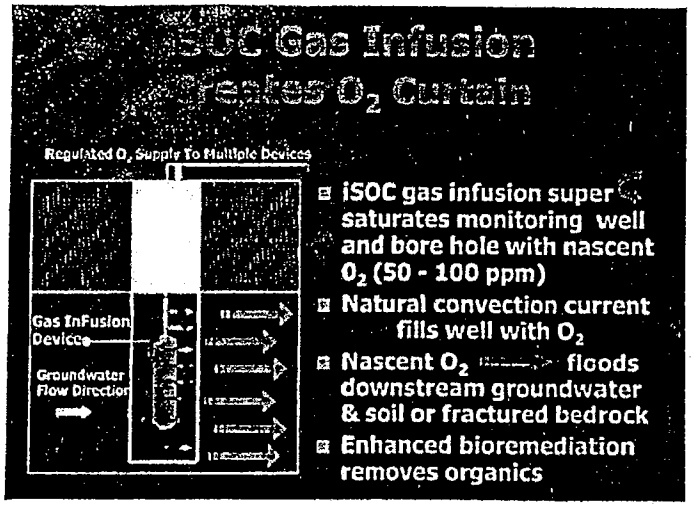
The combination of *iPRO* , *iSOC*, and *A/Linear* Valves (all described below) creates a one-two punch for both liquid phase LNAPL's and dissolved organics in the groundwater. This simple, inexpensive approach achieves immediate site remediation and an effective control of ongoing environmental liability exposure for contaminated property.

iSOC—Passive 'No Power' Groundwater Oxygenation

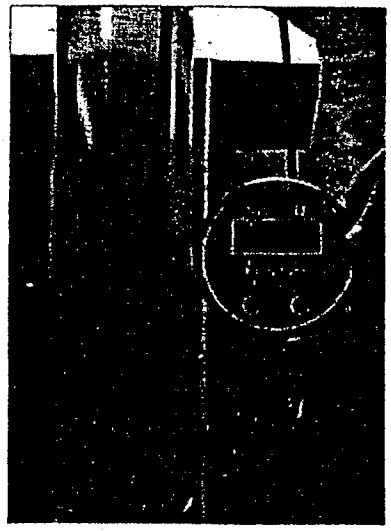
The benefits of enhanced biodegradation in cleaning up groundwater contaminated by organic components is well known, well documented, and widely used throughout the world. The addition of air, oxygen and oxidizing chemicals, as well as nutrients, has demonstrated successful results in enhancing natural attenuation.

iSOC—in situ Submerged Oxygen Curtain—is a *Gas inFusion* gas transfer device made to operate with no power, and a simple connection to a standard oxygen cylinder. The stainless steel *iSOC* is suspended down 2-inch diameter monitoring wells to create dissolved oxygen (DO) levels in the well of 50 to 300 PPM depending on well and groundwater characteristics, increasing with depth.

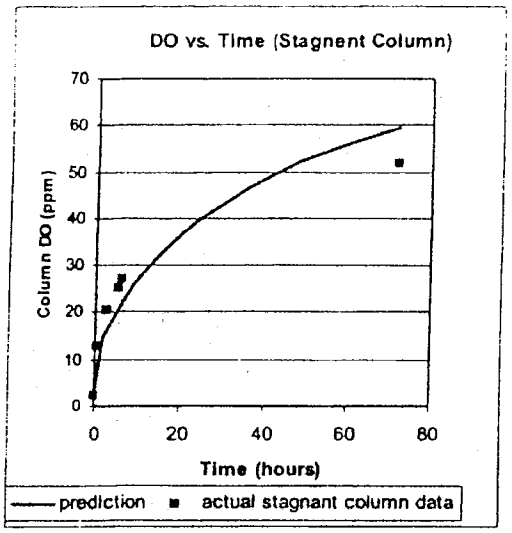
This state-of-the-art *Gas inFusion* mass transfer process delivers ultra-high, cost-efficient concentrations of dissolved oxygen directly into contaminated ground water. The greatly enhanced level of oxygenated ground water addresses dissolved-phase petroleum hydro-carbon contamination as well as sorbed material in the saturated, capillary fringe, and smear zones. The *iSOC* can create an enhanced O_2 curtain or barrier to prevent contamination migration thus making *iSOC Gas inFusion* an ideal enhancement to obtain approval for Monitored Natural Attenuation.



If seeing is believing, check the photograph to the right—the specially adapted high-range DO meter reads 51 PPM in a 10-foot, open top column. The blue line is the oxygen line to the *iSOC* located at the bottom of the column and the DO meter probe is shown in the bubble-free water. That's it, nothing else.



iSOC infuses an order of magnitude more DO than any competitive technology, and is the most cost effective solution to many hydrocarbon contamination problems. In many situations, a standard oxygen cylinder will supply an *iSOC* for about a year. Like everything else that iTi invents, *iSOC* is small, efficient, predictable, elegantly simple, and easy to use.

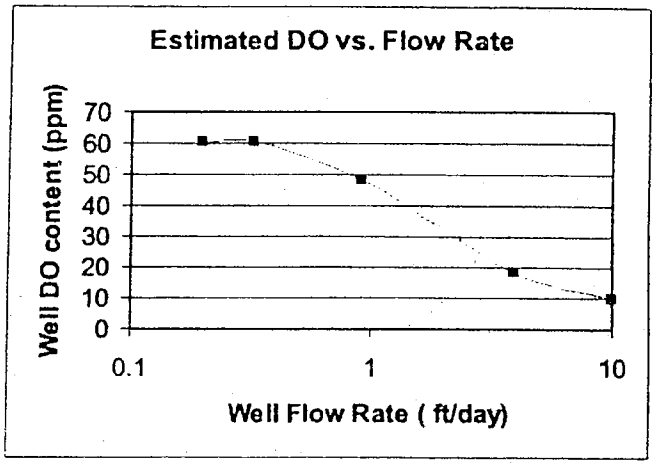


Proof In Data

If proof is in data, the graph illustrated on the left relates to 'passive' infusion of a gas into a column (or vessel) of liquid. No power is required for the mass transfer to occur. As shown, the iTi predictive model is accurately proven out.

In the 'real life' field, the *iSOC* and line are purged with oxygen once installed to overcome the natural boundary layer and to accelerate the creation of a fully oxygenated well.

The graph to the right is specific to the case of downhole groundwater remediation. As the groundwater flow rate increases, more super-saturated water is removed from the well, thus increasing the oxygen demand and lowering the DO level in the well. This is good. It is important to note that the mass transfer is generic to all gases, not just oxygen.



iSOC Passive Do Performance

iSOC will deliver about 43 PPM of dissolved oxygen (DO) per atmosphere of head pressure on the *iSOC* unit. Based on standard atmospheric pressure of 14.7 psi at sea level to about 10 psi at 10,000 feet elevation, an *iSOC* unit positioned at the bottom of a well with a water depth of 35 feet—roughly 2 atmospheres—can be expected to deliver in the order of 86 PPM DO. This is simply based on the atmospheric pressure of 14.7 psi plus the water head pressure of 15.2 psi creating a total pressure of 29.9 psi, or about 2 atmospheres.

Remember Henry's Law, which states: *the weight of any gas that will dissolve in a given volume of liquid, at constant temperature, is directly proportional to the pressure that the gas exerts above the liquid.*

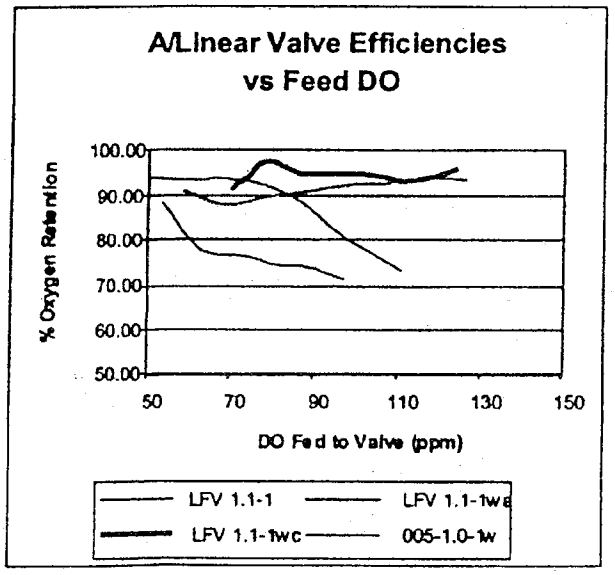
Concept Becomes Fact—*A/Linear*

As stated above, *iSOC* is capable of delivering very high levels of DO passively depending on the depth of water over the *iSOC*. Where higher DO levels are required, higher pressures must be used. This is where iTi employs small *Gas inFusion* skids equipped with larger gas transfer devices and a pump to create the required pressure.

In this 'active' form of *Gas inFusion*, it is essential that a laminar flow valve be used as part of the supersaturated flow discharge to eliminate immediate loss of dissolved gas across a normal valve. Once bubbles are formed in an uncontrolled fashion, the gas levels are quickly stripped to form larger bubbles. Since commercially available laminar flow valves did not allow the ultra-high performance possible with *Gas inFusion*, iTi invented a more efficient laminar flow valve capable of delivering even higher levels of dissolved gas into atmospheric pressure vessels or groundwater regimes.

As a result, and as part of its bubble size research with the National Research Council of Canada, iTi redefined the concept of linear laminar flow valves. iTi's patent pending 'valves' employ the same hollow fibre technology to drop the pressure of a gas saturated stream to produce a supersaturated stream containing controllable bubble sizes and quantities. The flow through the valve is always highly laminar and the pressure drop is absolutely linear, thus its name—***A/Linear***. By altering the valve's fibre characteristics, the valve can be sized for a wide variety of applications, including iTi's current application markets of wastewater treatment, aquaculture and groundwater remediation.

Outstanding A/Linear Efficiency



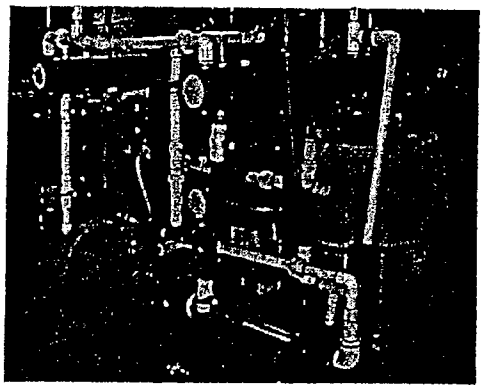
The efficiency of a valve, with respect to *Gas inFusion*, needs to be defined as the ability to retain the gas in a dissolved state. In a dissolved state, the gas will be more readily available to be utilized and less likely to escape to the atmosphere. Also, the ultra-saturated stream will mix with water with a low dissolved gas level with less loss to the atmosphere. This illustrates one of the prime functions of this infusion technology—to mix a small amount of ultra-saturated liquid with liquid deficient in dissolved gas—any gas.

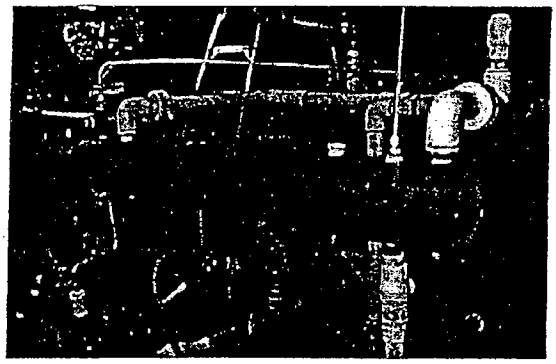
With no moving parts, the *A/Linear* valves not only relieve the liquid pressure linearly versus liquid throughput, but the *A/Linear* valve also makes it possible to retain

extremely high amounts of the dissolved gas. Naturally, each *A/Linear* valve design configuration produces its own unique bubble size distribution, and its own gas retention efficiency. The *A/Linear* laminar flow valve forms a basic part of all iTi 'active' *Gas inFusion* equipment solutions.

Ultra-High Groundwater Gas Transfer

Through the use of larger iTi gas transfer devices (shown below), and a small skid (shown at right) equipped with specific equipment for a specific application, dissolved gas concentrations can be attained that previously were considered impossible. A low-flow stream of water containing **hundreds of PPM of dissolved gas** can be injected downhole with the *A/Linear* valve directly into the contaminated groundwater through any well equal or greater than 2-inches in diameter.

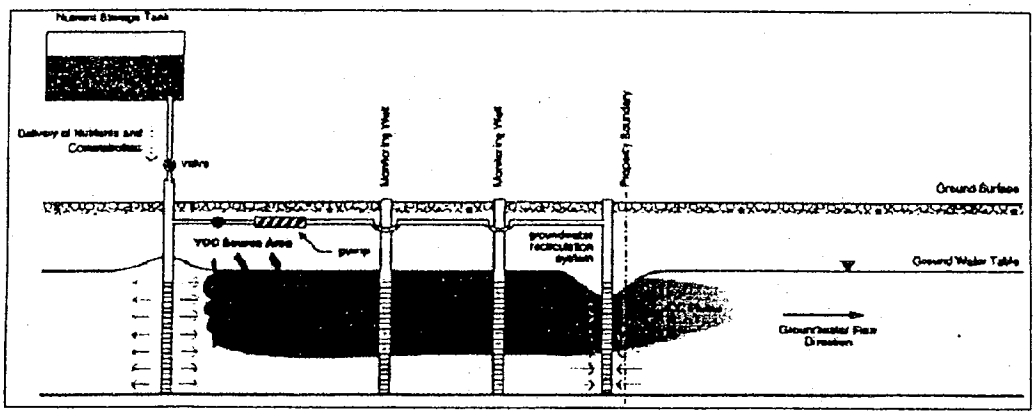




This ultra-saturated water, without bubbles or loss to the atmosphere, then mixes with the in situ groundwater to create a nascent oxygen (or any other gas) supply for extremely effective biodegradation.

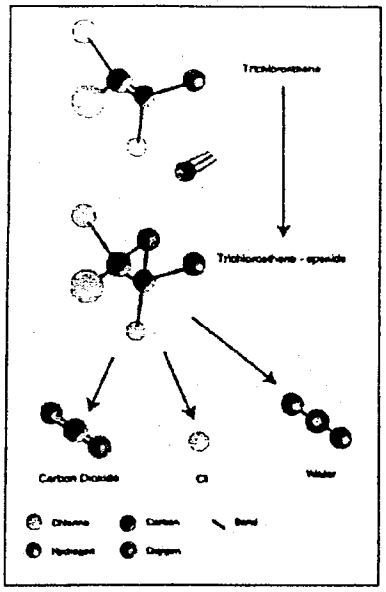
The only power involved is provided through pumping the ultra-saturated water stream—something that is normally available on any site.

The *Gas inFusion* equipment, usually a small, flexible skid, can be easily fit into most existing groundwater remediation systems to greatly enhance and accelerate contaminant cleanup, especially when nutrient addition is used, as shown below.



Chlorinated Solvents

Chlorinated organic chemicals such as trichloroethane, trichloroethylene, perchlorethylene, carbon tetrachloride and chloroform have been widely used as solvents in manufacturing, dry cleaning, and metal cleaning in the post-World War II era. Not surprisingly, chlorinated solvents have been identified as the most common industrial contaminants in groundwater in Europe and North America.

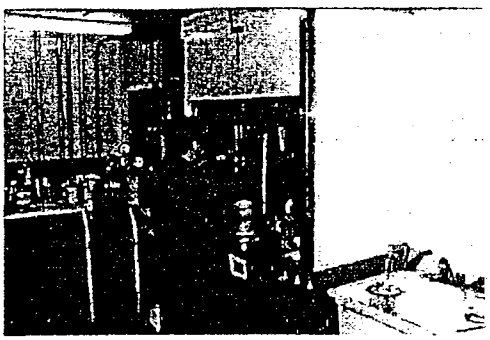


Since the first reporting of groundwater contamination from chlorinated solvents in the late 1970's and early 1980's, billions of dollars have been spent annually in North America and Europe in an attempt to restore groundwater systems beneath sites contaminated with chlorinated solvents. This generally has been unsuccessful.

iMOX—Potential DNAPL Edge

iTi's *Gas inFusion* technology applies to **all gases**. Although most of iTi's R&D thus far has been based on oxygen, the same performance can be achieved subject to the solubility of the gas in water. For example, since methane is about 60 per cent as soluble as oxygen, dissolved methane concentrations of 60 per cent of hundreds of PPM can be produced.

With the firm belief that iTi's unique gas transfer abilities will enable more effective remediation of chlorinated solvents, iTi has developed a prototype gas transfer device for DNAPL use.



iMOX—in situ coMetabolic OXidation— a device similar to *iSOC*, is capable of passive infusion of the necessary gas directly into the groundwater. The levels produced downhole are again dependent upon the solubility of the gas in water as compared to oxygen.

Combining an iTi *Gas inFusion* skid with the *A/Linear* valve installed downhole in 2-inch diameter wells creates the capability to introduce ultra-high gas transfer directly into the chlorinated solvent contaminated groundwater. This raises the following questions:

- Is it beneficial to deliver methane or natural gas directly to the DNAPL plume in concentrations of several hundred PPM?
- Is it beneficial to deliver hydrogen directly to the DNAPL plume in concentrations in the range of 20 PPM?
- Is it beneficial to deliver this dissolved gas concentration in a bubbleless, nascent form that does not readily decay and is immediately available to biomass?
- Is it acceptable to achieve this level of gas transfer by ultra-saturating a small volume of water and injecting it into the DNAPL plume?
- And/or, is it more acceptable to deliver somewhat lower dissolved gas concentrations through a passive *iMOX* device directly into the groundwater?

If any of the above questions are yes, we need to talk. The mass transfer expertise of iTi combined with the groundwater remediation expertise of a potential partner can redefine the cleanup industry. Right now, this is an iTi developmental concept.

ZEGi - Zero Energy Gas inFusion

One area that iTi is currently experimenting with is an innovative concept of using atmospheric air to raise the dissolved oxygen content of water—without any compression or air handling of any kind. We have named, and provisionally patented this concept, as ***ZEGi***, or ***Zero Energy Gas inFusion***.

Typically, water and wastewater systems requiring aeration already involve liquid movement as the liquid is pumped or flows from one unit process to another, or as water flows in a stream. *ZEGi* uses this 'energy' of movement to draw air (oxygen) into the liquid through a *ZEGi* gas transfer device. No other energy is used, but the transfer efficiency offered by the enormous interfacial surface area is impressive and exciting. At liquid flows of only 2 or 3 GPM, the dissolved oxygen in preliminary tests has been raised by about 30 PPM instantaneously with a single *ZEGi* device.

iTi is currently conducting intensive R&D work on *ZEGi* as part of a Canadian federal government supported greenhouse gas reduction program in wastewater treatment. The iTi program team includes wastewater treatment experts, one of the largest wastewater treatment plant owners in North America, and an international gas supplier.

The potential market opportunities for *ZEGi* are substantial.

iTi Challenge

iTi is, and always will be, a technology company. The challenge we face ourselves with each day is to 'push the envelope' of the *Gas inFusion* technology—both in its capabilities and its potential market applications.

The challenge we face our strategic partners with is to adopt this technology through a licensing arrangement and to create and redefine value enhancement through the development and application of *Gas inFusion* to these markets. Meeting this challenge can result in a win-win-win combination for the client, our partner, and iTi—creating value added success through innovation.

If you are a potential strategic partner, or you have a market application that may demand an innovative solution based on iTi's *Gas inFusion* or *Organic Sieve* technologies, contact iTi at the addresses listed in the following Contact section.

Gas inFusion *iPRO* *iSOC* *ZEGi* *A/Linear* *iMOX* *Organic Sieve*

Creating Value Through inNovation

iTi CONTACT

inVENTURES TECHNOLOGIES iNCORPORATED

Oakville, Ontario,
Office - Canada

John Archibald, P.Eng.
Managing Partner
2177 Oakmead Blvd.
Oakville, ON L6H 5N4
Canada

Tel: 905-339-1543
Fax: 905-339-1923
E-mail: jarch@attglobal.net

Creating Value Through inNovation

Fredericton • Oakville • Ottawa

Sales & Inquiries:

Performance Technologies

Advanced Environmental Solutions

Performance Technologies, Inc. • 337 Hunters Crossing • Tallahassee, FL USA 32312 • Tel: 850-385-7790 • Fax: 850-894-1067
Email: donrayoffice@home.com