Draft

DETAILED ANALYSIS OF ALTERNATIVES REPORT

SITE 10 - CAMP FOGARTY DISPOSAL AREA
SITE 11 - FIRE FIGHTING TRAINING AREA

NAVAL CONSTRUCTION BATTALION CENTER
DAVISVILLE, RHODE ISLAND

Contract No. N62472-86-C-1282
May, 1994

Prepared For:
Northern Division
Naval Facilities Engineering Command
Lester, Pennsylvania

TRC
TRC Environmental Corporation

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U.S. DEPARTMENT OF THE NAVY
INSTALLATION RESTORATION PROGRAM

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EXECUTIVE SUMMARY

At the request of the U.S. Navy, TRC Environmental Corporation (TRC) has prepared this Detailed Analysis of Alternatives (DAA) Report for Site 10 - Camp Fogarty Disposal Area and Site 11 - Fire Fighting Training Area, at the Naval Construction Battalion Center in Davisville, Rhode Island (NCBC Davisville). The DAA is part of the Feasibility Study (FS) process and is being conducted under the Navy's Installation Restoration Program and in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA).

Introduction

Twelve sites at the NCBC facility are being investigated under a Remedial Investigation/Feasibility Study (RI/FS) program. Phase I and Phase II Remedial Investigations (RIs) have been conducted to investigate the physical characteristics of the sites, as well as to identify potential sources of contamination, determine the nature and extent of contamination, and characterize potential health risks and environmental impacts. Detailed site background information, results of the investigations, and a characterization of the potential risks to human health and the environment posed by the sites are presented within several separate Remedial Investigation Reports (TRC, 1993). Initial screenings of potential remedial alternatives were also conducted for the sites on the basis of Phase I RI results only within two Initial Screening of Alternatives (ISA) Reports (TRC, 1993). This DAA Report, which addresses only Sites 10 and 11, builds upon the analyses conducted within the ISA report, presenting remedial alternatives developed based on the results of the Phase I and Phase II RIs, and detailed analyses of those alternatives. A summary of the DAA Report for each site follows.

SITE 10 - CAMP FOGARTY DISPOSAL AREA

Background

Camp Fogarty is a 347-acre parcel of land located about 3 miles west of the Main Center of NCBC Davisville, in East Greenwich, Rhode Island. Camp Fogarty, which has been excessed to the U.S. Army, includes an active firing range. The Site 10 study area, the Camp Fogarty Disposal Area, is located west of the firing range, between the firing range berm and a steeply rising hill. Access to the entire area, including the portion of the area referred to as Site 10, is restricted by fences and facility personnel. Since this property has been excessed to the Army, its future use is not impacted by the closure of NCBC Davisville. The southern portion of Site 10 is located within the capture zone of a proposed water supply well location and private potable wells may exist downgradient of the site.

A plan of the study area is provided in Figure ES-1. Three depressions filled with construction debris are present within the site area. The vicinity of the study area is heavily wooded, interspersed with meadow areas. Seasonal flooding occurs in the low lying regions of Site 10 during periods of heavy rain.

Cans of rifle- and weapon-cleaning oils and preservatives, as well as miscellaneous municipal-type garbage, were reportedly occasionally disposed of in a shallow, sandy excavation just west of the firing ranges at Camp Fogarty. Approximate disposal area locations, corresponding to surface depressions at the site, are shown in Figure ES-1. Previous studies have estimated the disposal volume to be approximately 50,000 cubic feet. Waste materials noted during previous studies have included rusted, empty paint cans, 55-gallon drums, and miscellaneous metal parts. Reportedly, thousands of cans of rifle-bore oils were removed from the site and relocated at NCBC Davisville.

Site investigations have consisted of an Initial Assessment Study (Hart, 1984), a Confirmation Study (TRC, 1987), the Phase I RI (TRC, 1991), and the Phase II RI (TRC, 1993). These investigations have included the collection of surface soil, subsurface soil and ground water samples for chemical analysis. Surface water and sediment samples have also been collected from the Hunt River Watershed, in which the site is located.

Based on the results of site investigations, the nature and extent of site contamination were defined, as were potential risks to human health and the environment. Surface soil contamination is limited to a small portion of the site where lead is present at three sample locations (10-SS08, 10-SS09 and 10-SS10 - see Figure ES-1) at levels which exceed the Rhode Island Department of Environmental Management (RIDEM) action level of 300 ppm but which fall within or below the federal action level range of 500 to 1,000 ppm. Lead levels in adjacent surface soil samples (10-SS07 and 10-SS11) did not exceed regulatory action levels. Surface soils present no unacceptable risks to human health under a future commercial/industrial site use scenario and no unacceptable ecological risks were identified for the site based on surface soil data. Subsurface soil contamination does not appear to present a potential risk through contaminant leaching, based on the application of a leaching model. Only one surface soil sample (10-SS09) contained a single semivolatile organic compound (benzo(a)anthracene) at a level exceeding the modeled maximum accepted level, indicating that leaching of contamination from surface soils is also not expected to be a major concern at the site. No semivolatile organics were detected in the ground water during either phase of remedial investigation.

When ground water was sampled using a low-flow methodology to minimize the presence of suspended sediments, lead was detected in an upgradient deep well (10-MW5D) at a level of 16.5 parts per billion (ppb), which slightly exceeds the drinking water action level of 15 ppb, and manganese was detected at levels exceeding the risk-based preliminary remediation goal (PRG) of 510 ppb at shallow well 10-MW5S and deep well 10-MW5D. Ground water at Site 10 is classified as GAA-NA, which includes those ground water resources which RIDEM has designated to be suitable for public drinking water without treatment. Areas classified as non-attainment (NA) areas are those which are known or presumed to be out of compliance with the standards of the assigned classification. The goal for non-attainment areas is restoration to a quality consistent with the classification. While ingestion of ground water is not a current exposure pathway at Site 10, the southern portion of Site 10 is located in the ground water capture zone of a proposed public water supply well location and private potable wells may be used in nearby residential areas. Also to be considered in the evaluation of ground water quality at the site is the possibility that lead and manganese are not site-related contaminants, based on the presence of lead within the upgradient well and the presence of manganese in upgradient wells at all NCBC Davisville sites evaluated during the RI.

Feasibility Study Summary

The first step of the Feasibility Study process, the ISA, was conducted for Site 10 on the basis of Phase I RI information only. The ISA report included the development of remedial action objectives, the screening of potential remedial technologies and process options, and the development and initial screening of remedial alternatives. This report incorporates the results of the Phase II RI, and presents the refinement of remedial response objectives, the refinement of remedial alternatives, and detailed individual and comparative analyses of the remedial alternatives.

Based on the nature and extent of contamination at Site 10 as well as potential human health and ecological risk considerations, remedial action objectives were developed as follows:

For soils:

- Prevent residential exposures to surface soil contaminants at levels which exceed ARARs/TBCs, as presented in Table 3-1 of the report.

Specifically, the remedial action objective for surface soils is to prevent potential residential exposures to lead at a level exceeding the RIDEM guidance level of 300 ppm.

For ground water:

- Prevent exposure, due to ground water ingestion, to contaminants which are present at levels exceeding acceptable ARARs/TBCs, as indicated in Table 3-2 of the report, or which exceed risk-based preliminary remediation goals, as indicated in Table 3-3 of the report.

Specifically, the remedial action objective for ground water is to prevent exposures due to ingestion of lead in ground water at levels exceeding the drinking water action level of 15 ppb or ingestion of manganese in ground water at levels exceeding the risk-based preliminary remediation goal of 510 ppb.

Remedial alternatives were developed for both soil and ground water and were evaluated in detail with respect to the evaluation criteria specified in the National Contingency Plan [40 CFR 300.430(e)(9)]. A list of the individual soil and ground water alternatives for which detailed analyses were conducted is presented in Table ES-1. The alternatives included:

- No Action (soil and ground water)
- Limited Action (soil and ground water)
- Extraction/Treatment/Discharge (ground water only)

Although the soil and ground water alternatives were evaluated separately within the report, the limited number of alternatives considered allows for a presentation of combined alternatives herein. A summary of the components which are included in each of the combined soil/ground water alternatives is presented in Table ES-2.

<u>Alternative 1 - No Action</u>

A comprehensive no action alternative would consist of no action with respect to soil and ground water. It would provide the least overall protection of human health and the environment because it would not prevent future residential exposures to surface soil contaminants and would not prevent future installation of an on-site potable well, which could result in ingestion of ground water. It would not achieve remedial action objectives.

<u>Alternative 2 - Limited Action (Institutional Controls with Long-Term Ground Water Monitoring)</u>

A comprehensive limited action alternative would consist of institutional controls for soil and ground water. It would consist of the following:

- Deed restrictions to prevent future residential exposures to surface soil contaminants and to prevent future use of ground water as a potable water supply; and
- Long-term monitoring of ground water quality

This alternative would be protective of human health by preventing residential exposures to the limited area of surface soil lead contamination which exceeds the RIDEM guidance level and by preventing the potential installation of a potable well on-site, thereby precluding the development of a potential ground water ingestion pathway at the site. Long-term monitoring would provide a means of further defining ground water quality and identifying potential contaminant migration towards potential off-site receptors. Due to the lack of significant ecological risks associated with the site, the limited action alternative would also be protective of the environment. The alternative would be compatible with continued military use of the site. Deed restrictions would be implemented upon transfer of the property from government control.

Alternative 3 - Ground Water Extraction/Treatment/Discharge with Institutional Controls

This active remedial alternative would consist of ground water extraction, treatment and discharge actions combined with institutional controls and long-term ground water monitoring. The alternative would consist of the following:

- Deed restrictions to prevent future residential exposures to surface soil contaminants;
- Ground water extraction, inorganic ground water treatment and discharge of the treated water to surface water (a tributary to Frenchtown Brook, which discharges to the Hunt River); and
- Long-term monitoring of ground water quality

This alternative would provide overall protection of human health and the environment during its operation by providing active treatment of ground water contaminants. However, the presence of lead in the upgradient well at a level exceeding the drinking water action level indicates a potential for the re-occurrence of lead once the treatment is discontinued. Similarly, the apparent presence of manganese in ground water throughout all portions of the NCBC Davisville facility indicates that ground water treatment at Site 10 may not permanently address the potential human health risks associated with the ingestion of manganese in ground water. Residential exposures to contaminated surface soil materials would be addressed through the implementation of deed restrictions upon transfer of the property from government control. Due to the lack of significant ecological risks associated with the site, the extraction/treatment/ discharge alternative would also be protective of the environment. Long-term monitoring would allow for the identification of any changes in ground water quality. Implementation of this alternative would be compatible with continued military site use.

Comparative Evaluation of Comprehensive Alternatives

A comparison of the three comprehensive remedial alternatives described above against the alternative evaluation criteria specified under the National Contingency Plan [40 CFR 300.430(e)(9)] is presented in Tables ES-3 through ES-9. Two of the criteria, State Acceptance and Community Acceptance, are evaluated later in the remedial decision-making process.

Recommendations and Conclusions

Based on the evaluation of soil and ground water remedial alternatives, the recommended remedial alternative for Site 10 consists of a limited action consisting of the following:

- Deed restrictions to prevent future residential exposures to surface soil and to prevent ground water from being used as a potable water source; and
- Long-term monitoring of ground water to identify any future changes in ground water quality.

This alternative would be protective of human health and the environment under the present military site use or potential future commercial/industrial site use based on the lack of unacceptable human health risks and the lack of unacceptable environmental risks associated with the site.

While there are no chemical-specific ARARs applicable to soil contamination at the site, the limited action alternative could be considered to comply with federal and state chemical-specific TBCs for lead, which are based on residential exposures to soils, by preventing future residential site use. It would also use institutional controls to limit exposures to ground water contaminants at levels exceeding drinking water action levels, which would be consistent with EPA's expectations for Superfund that allow the use of institutional controls when active remediation measures are determined not to be practicable, based on the balancing of trade-offs among alternatives. Based on the minimal exceedance of the lead drinking water action level detected in only one well (16.5 parts per billion detected versus the action level of 15 parts per billion), and the apparent presence of manganese in ground water throughout the facility, the balancing of trade-offs conducted among the ground water remedial alternatives indicates that active ground water treatment would not be practicable to implement and may not be permanent with respect to maintaining ARARs or preliminary remediation goals upon discontinuation of treatment. The lack of ground water treatment at Site 10 is not expected to adversely affect the environment. The long-term monitoring would provide a means of defining the presence of lead in ground water at the site and the potential impacts of the presence of lead on the proposed installation and operation of a public water supply well to the east-southeast of the site.

Implementing a mechanism to ensure deed restrictions are applied to the site if the U.S. Army ever excesses the property would be an administrative effort; thus no short-term effects would result from implementation. The ground water monitoring program would have minimal short-term risks associated with its implementation and the limited action alternative would be effective in the long-term, provided deed restrictions are enforced. Due to the continued presence of contaminants at the site at levels which do not allow for unrestricted use, five-year reviews of the limited action decision would be required. If the results of the ground water monitoring program indicated that ground water quality was deteriorating or contaminants were migrating towards the proposed public water supply well location, additional remedial measures could be implemented in the future. Similarly, if the monitoring program consistently indicates that ground water quality does not pose a threat to human health or the environment, the monitoring period could be shortened.

SITE 11 - FIRE FIGHTING TRAINING AREA

Background

Site 11, the Former Fire Fighting Training Area, consists of an open, grassy field surrounded by roadways, measuring approximately 200 feet by 300 feet. A general site location map is provided in Figure ES-2. There are no trees on the site, although a few border the northeast edge of the site. Several large, devegetated areas exist and may be attributable to the incineration of accelerant during historic fire training exercises. Site 11 is bound by Moscrip Avenue, Building 390 and Warehouses W-1 to W-3 to the south, and by Middletown Street to the west, and is located approximately one mile west of Narragansett Bay. The ground surface slopes gradually to the southwest, and small, shallow, eroded drainage swales are evident in the central portion of the study area. The swales drain to a catch basin on the western side of the study area, which is part of a storm drain system which runs under the site. The storm drainage system discharges into a tributary of Mill Creek, approximately 2,200 feet south-southwest of the site. The assumed destination of ground water flowing from Site 11 is Mill Creek, located approximately one-half mile from the site to the southwest. The area in which Site 11 is located has been designated for economic/industrial development under the Comprehensive Base Reuse Plan.

Between the mid-1940s and 1955, fire fighting training exercises were held in the field which constitutes Site 11. Waste oils contaminated with solvent and paint thinners were reportedly poured on the ground, ignited and subsequently extinguished. The total amount of wastes destroyed in this manner is not known (Hart, 1984).

Site investigations have consisted of an Initial Assessment Study (Hart, 1984), a Confirmation Study (TRC, 1987), the Phase I RI (TRC, 1991), and the Phase II RI (TRC, 1993). These investigations have included the collection of surface soil, subsurface soil, ground water, and catch basin sediment samples for chemical analysis. Surface water and sediment samples have also been collected from Mill Creek Watershed, in which the site is located.

Based on the results of site investigations, the nature and extent of site contamination were defined, as were potential risks to human health and the environment. No surface soil contaminants were detected at levels which exceed guidance levels and surface soils do not present unacceptable human health risks under a future commercial/industrial site use scenario. No unacceptable ecological risks were identified for the site based on surface soil data and no significant risks were identified for the Mill Creek Watershed, in which Site 11 is located. Subsurface soil contamination does not appear to present a potential risk due to contaminant leaching, based on the application of a leaching model.

When ground water was sampled using a low-flow methodology to minimize the presence of suspended sediments, bis(2-ethylhexyl)phthalate and antimony were the only contaminants detected at levels which exceed the Maximum Contaminant Levels (MCLs). The detection of bis(2-ethylhexyl)phthalate is thought to be attributable to the tubing used during the low-flow sampling effort. The presence of antimony in well 11-MW6D does not appear to be attributable to soil contamination at the site. Manganese was detected at levels exceeding the risk-based preliminary remediation goal (PRG) of 510 ppb at several wells located throughout the site, including upgradient shallow wells. Ground water at Site 11 is classified as GB, which indicates that it is not suitable for public or private drinking water use without treatment due to known or presumed degradation. Therefore, ingestion of ground water is not anticipated to be a significant potential exposure pathway, although there is no regulatory mechanism which prohibits the installation of an on-site potable well. Also to be considered is the potential that manganese is not a site-related contaminant, based on its presence in upgradient wells at all NCBC Davisville sites evaluated during the RI.

Sediments within the on-site catch basins exhibited PCBs, pesticides and inorganic contaminants, although no ARARs/TBCs were identified for the catch basin sediments. No significant potential ecological risks were identified for the Mill Creek Watershed, in which Site 11 is located, however.

Feasibility Study Summary

The first step of the Feasibility Study process, the ISA, was conducted for Site 11 on the basis of Phase I RI information only. The ISA report included the development of remedial action objectives, the screening of potential remedial technologies and process options, and the development and initial screening of remedial alternatives. This report incorporates the results of the Phase II RI, and presents the refinement of remedial response objectives, the refinement of remedial alternatives, and detailed individual and comparative analyses of the remedial alternatives.

Based on the nature and extent of contamination at Site 11 as well as potential human health and ecological risk considerations, remedial action objectives were developed for the environmental media at the site, as described in the following paragraphs.

Based on the absence of soil contaminants at levels exceeding federal or state action levels, the lack of significant human health risks associated with exposures to surface soil contaminants under future commercial/industrial site use, the lack of environmental risks associated with Site 11 soil contaminants, and the lack of potential impact to ground water as indicated by the results of the leaching model evaluation, no remedial action objectives were developed for Site 11 soils.

While ground water is classified GB and would not provide a suitable potable water source, no regulatory means of preventing installation of a potable well and subsequent exposures exist. Based on the detection of contaminants at levels exceeding ARARs/TBCs and PRGs, the remedial action objective for ground water is as follows:

- Prevent exposure, due to ground water ingestion, to contaminants which are present at levels exceeding acceptable ARARs/TBCs as indicated in Table 3-2 of the report, or which exceed risk-based preliminary remediation goals as indicated in Table 3-3 of the report.

Specifically, the only ground water contaminant detected at levels exceeding ARARs/TBCs not attributable to the presence of sediments in the ground water sample or the sampling methodology was antimony. Manganese is the only ground water contaminant detected at a level exceeding the risk-based preliminary remediation goal.

For catch basin sediments, considering the presence of pesticides in facility background samples at levels exceeding the catch basin sediment levels, the lack of PCBs at levels exceeding the ER-M value in the most downgradient catch basin sediment sample, the distance of the site from the point of discharge to the watershed (approximately 2,200 feet), and the lack of identification of significant existing ecological risks to the Mill Creek Watershed, the catch basin sediments and their potential for off-site migration are not expected to present significant potential impacts to the watershed. Therefore, no remedial action objectives were developed for catch basin sediments at Site 11.

Remedial alternatives were developed for ground water and evaluated in detail with respect to the evaluation criteria specified in the National Contingency Plan [40 CFR 300.430(e)(9)]. A list of the individual ground water alternatives, including a summary of components or options evaluated with the alternatives, is presented in Table ES-10. The alternatives included:

- No Action
- Limited Action
- Extraction/Treatment/Discharge

While these alternatives were evaluated separately within the report, a combination of alternatives may be appropriate for comprehensive evaluation. A summary of the components included in each comprehensive alternative is presented in Table ES-11.

Alternative 1 - No Action

The no action alternative would consist of no action with respect to ground water. It would provide the least overall protection of human health and the environment because it would not prevent future installation of an on-site potable well, which could result in ingestion of ground water. It would not achieve remedial action objectives.

Alternative 2 - Limited Action (Institutional Controls and Ground Water Monitoring)

The limited action alternative would consist of institutional controls for ground water. It could consist of the following:

- Deed restrictions to prevent future use of on-site ground water as a potable water supply; and
- Long-term monitoring of ground water quality

This alternative would be protective of human health by preventing the potential installation of a potable well on-site, thereby precluding the development of a potential ground water ingestion pathway at the site. Due to the lack of significant ecological risks associated with the site and downgradient watershed, the limited action alternative would also be protective of the environment. The alternative would be compatible with future commercial/industrial site use.

Alternative 3 - Ground Water Extraction/Treatment/Discharge and Long-Term Ground Water Monitoring

This active remedial alternative would consist of ground water extraction, treatment and discharge actions combined with long-term ground water monitoring. The alternative would consist of the following:

- Ground water extraction, inorganic ground water treatment and discharge of the treated water to surface water (a tributary which discharges to Mill Creek); and
- Long-term monitoring of ground water quality

This alternative would provide overall protection of human health and the environment during its operation by providing active treatment of ground water contaminants. However, the apparent presence of manganese in ground water throughout all portions of the NCBC Davisville facility indicates that ground water treatment at Site 11 may not permanently address the potential human health risks associated with the ingestion of manganese in ground water. Due to the lack of significant ecological risks associated with the site and downgradient watershed, the extraction/treatment/discharge alternative would also be protective of the environment. Long-term monitoring would allow for the identification of any changes in ground water quality. Implementation of this alternative would be compatible with future commercial/industrial site use.

Comparative Evaluation of Comprehensive Alternatives

A comparison of the three comprehensive remedial alternatives described above against the alternative evaluation criteria specified under the National Contingency Plan [40 CFR 300.430(e)(9)] is presented in Tables ES-12 through ES-18. Two of the criteria, State Acceptance and Community Acceptance, are evaluated later in the remedial decision-making process.

Recommendations and Conclusions

Based on the evaluation of ground water remedial alternatives, the recommended remedial alternative for Site 11 consists of a limited action consisting of the following:

- Deed restrictions to prevent ground water from being used as a potable water source; and
- Long-term monitoring of ground water to identify any future changes in ground water quality.

This alternative would be protective of human health and the environment under the proposed future commercial/industrial site use based on the lack of unacceptable human health risks associated with such a future site use and the lack of unacceptable environmental risks associated with the site.

This alternative would use institutional controls to limit exposures to ground water contaminants at levels exceeding maximum contaminant levels, which would be consistent with EPA's expectations for Superfund that allow the use of institutional controls when active remediation measures are determined not to be practicable, based on the balancing of trade-offs among alternatives. Considering the site's GB ground water classification which indicates that the ground water is not suitable for consumption without treatment and the apparent presence of manganese in ground water throughout the facility, the balancing of trade-offs conducted among the ground water remedial alternatives indicates that active ground water treatment would not be practicable to implement and may not be permanent with respect to maintaining ARARs or preliminary remediation goals upon discontinuation of treatment. The lack of ground water treatment at Site 11 is not expected to adversely effect the environment. The long-term monitoring would provide a means of identifying any changes in ground water quality in the future.

Implementation of deed restrictions requires an administrative effort which would be incorporated into the base closure property transfer process; thus no short-term effects would result from implementation. The monitoring program would have minimal short-term risks associated with its implementation and the limited action alternative would be effective in the long-term, provided deed restrictions are enforced. Due to the continued presence of contaminants at the site at levels which do not allow for unrestricted use, five-year reviews of the limited action decision would be required. The alternative would complement future use of the site for commercial/industrial purposes, as specified in the Comprehensive Base Reuse Plan.

TABLE ES-1
ALTERNATIVES UNDERGOING DETAILED ANALYSIS
SOIL/GROUND WATER
SITE 10 – CAMP FOGARTY DISPOSAL AREA

Soil	Ground Water
Alternative S-1 No Action	Alternative GW-1 No Action
Alternative S-2 Limited Action (Institutional Control) A. Fencing/Deed Restrictions	Alternative GW-2 Limited Action (Institutional Control) A. Deed Restrictions/Ground Water Monitoring
	Alternative GW-3 Extraction/Treatment/Discharge A. Extraction Wells B. Precipitation C. Ion Exchange D. Discharge to Surface Water

TABLE ES-2
DESCRIPTIONS OF GENERAL COMPREHENSIVE ALTERNATIVES
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 – No Action	• No action
Alternative 2 – Limited Action (Institutional Controls with Long-Term Ground Water Monitoring)	• Deed restrictions to limit future residential exposures to surficial soil and to prevent future use of ground water as a potable water supply • Long-term monitoring of ground water quality
Alternative 3 – Extraction/Treatment/Discharge with Long-Term Monitoring	• Deed restrictions to limit future residential exposures to surficial soil • Ground water extraction, inorganic ground water treatment and discharge of the treated water to surface water (a tributary of Frenchtown Brook, which discharges to the Hunt River) • Long-term monitoring of ground water quality

TABLE ES – 3
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC – DAVISVILLE, RI

ACTION	COMPARISON OF OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
Alternative 1 – No Action	Least protective alternative; Does not limit future potable use of ground water and does not monitor ground water quality; Provides protection of human health under current military use or a potential future commercial/industrial site use scenario; However, should the U.S. Army excess the property, no control of potential residential exposures to soil contamination is provided; Effective in the short–term and long–term provided residential exposures to soil and ingestion of ground water do not occur; Does not meet remedial response objectives
Alternative 2 – Institutional Controls with Long–Term Ground Water Monitoring	Provides protection of human health by limiting potential future exposures to ground water and soil contaminants through the establishment of institutional controls limiting potable ground water use and residential site use; Does not provide compliance with the state chemical–specific TBC for lead in surface soil or drinking water standards through treatment of ground water; However, would prevent the development of a ground water ingestion exposure pathway on–site and provides long–term monitoring to identify any potential off–site impacts; Effective in the short–term and long–term provided residential exposures and ground water ingestion do not occur; Uses institutional controls to meet remedial action objectives
Alternative 3 – Extraction/Treatment/Discharge with Institutional Controls	Provides active treatment to reduce potential future risks to human health associated with ground water ingestion; Would comply with chemical–specific, location–specific, and action–specific ARARs; Some increased short–term risks would result during implementation; Would be effective in the long–term as long as the treatment system is operational but permanence is not ensured

TABLE ES – 4
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
COMPLIANCE WITH ARARS
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC – DAVISVILLE, RI

ACTION	CHEMICAL–SPECIFIC	LOCATION–SPECIFIC	ACTION–SPECIFIC
Alternative 1 – No Action	Lead present in ground water at a level exceeding the lead drinking water action level; Does not meet state chemical–specific TBC for lead, but falls within the acceptable federal range for lead	Does not meet criteria related to ground water quality; Would comply with location–specific ARARs	Not applicable
Alternative 2 – Institutional Controls with Long–Term Ground Water Monitoring	Lead present in ground water at a level exceeding the lead drinking water action level; Does not meet state chemical–specific TBC for lead, but falls within the acceptable federal range for lead	Compliance with location–specific criteria would be maintained	Monitoring would comply with RIDEM's Rules and Regulations for Ground Water Quality
Alternative 3 – Extraction/Treatment/Discharge with Institutional Controls	Treatment would meet drinking water criteria; Does not meet state chemical–specific TBC for lead, but falls within the acceptable federal range for lead	Construction would be conducted in accordance with location–specific criteria	Extraction/Treatment/Discharge systems would comply with action–specific criteria

TABLE ES – 5
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
LONG–TERM EFFECTIVENESS AND PERMANENCE
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC – DAVISVILLE, RI

ACTION	COMPARISON OF LONG–TERM EFFECTIVENESS AND PERMANENCE
Alternative 1 – No Action	Protective in long–term under existing military use or potential future commercial/industrial site use based on lack of identified unacceptable risks due to soil exposures; Would be effective in the long–term as long as the site remains in control of the U.S. Army and ground water is not used as a drinking water supply; Provides no long–term monitoring of ground water quality; Requires five–year reviews
Alternative 2 – Institutional Controls with Long–Term Ground Water Monitoring	Protective in long–term since no unacceptable risks due to soil exposures were identified under existing military use or potential future commercial/industrial site use; Utilizes a mechanism for establishing deed restrictions to limit future residential exposures to the site should the property ever be transferred from federal ownership; Effective in minimizing the long–term risks associated with the potential construction and use of an on–site well as a source of drinking water; Monitoring program provides a means of monitoring potential changes in ground water quality or potential contaminant migration and off–site impacts; Requires five–year reviews
Alternative 3 – Extraction/Treatment/Discharge with Institutional Controls	Treatment effective in treating contaminants which exceed ARARs or risk–based PRGs and in preventing off–site migration of contaminants during operation; Permanent contaminant reduction would not necessarily result if ground water treatment is discontinued in the future; Requires long–term maintenance; Requires five–year reviews

TABLE ES – 6
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
REDUCTION OF TOXICITY, MOBILITY OR VOLUME THROUGH TREATMENT
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC – DAVISVILLE, RI

ACTION	COMPARISON OF REDUCTION IN TOXICITY, MOBILITY OR VOLUME
Alternative 1 – No Action	Provides no reduction in toxicity, mobility or volume through treatment
Alternative 2 – Institutional Controls with Long–Term Ground Water Monitoring	Provides no reduction in toxicity, mobility or volume through treatment; Site access or development restrictions would limit the potential contaminant exposure pathways associated with residential future site use
Alternative 3 – Extraction/Treatment/Discharge with Institutional Controls	Provides a reduction in ground water toxicity, mobility and volume through treatment

TABLE ES - 7
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
SHORT-TERM EFFECTIVENESS
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	COMPARISON OF SHORT-TERM EFFECTIVENESS
Alternative 1 - No Action	No remedial activities conducted; Therefore, no short-term risks result; Five-year reviews would provide the only means of ensuring compliance with remedial action objectives
Alternative 2 - Institutional Control with Long-Term Ground Water Monitoring	Implementation of deed restrictions would result in no short-term risks; Implementation of the monitoring program would have minimal short-term adverse impacts based on the use of existing wells for ground water monitoring purposes; Would meet remedial response objectives related to preventing ingestion of contaminated ground water by preventing on-site potable well installation and providing ground water monitoring to assess potential off-site migration; Would meet remedial action objectives
Alternative 3 - Extraction/Treatment/Discharge with Institutional Control	No significant risks to on-site workers or off-site risks are anticipated; Degree of short-term risk would be dependent upon the individual options employed; Remedial response objectives would be achieved during operation of the treatment system but may not be maintained if treatment is discontinued

TABLE ES - 8
COMPARISON BETWEEN COMPREHENSIVE ALTERNATIVES
IMPLEMENTABILITY
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	COMPARISON OF IMPLEMENTABILITY
Alternative 1 - No Action	Requires no implementation other than five-year reviews; Would not limit the implementation of other remedial actions
Alt rnative 2 - Institutional Controls with Long-Term Ground Water Monitoring	A mechanism for establishing deed restrictions should the U.S. Army ever excess the property would need to be established; Deed restrictions limiting future installation of on-site potable wells would not be expected to impact the present use of the site; Implementation of deed restrictions or ground water monitoring would not limit the implementation of future remedial actions
Alt rnative 3 - Extraction/Treatment/Discharge with Institutional Controls	Relatively easy to implement; Technical implementability would be dependent upon the individual alternative options selected; Some treatment technologies are more easily implemented than others; Services and materials should be readily available for the implementation of all options

TABLE ES – 9
COMPARISON AMONG COMPREHENSIVE ALTERNATIVES
COST
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC – DAVISVILLE, RI

ACTION	TOTAL CAPITAL COST	ANNUAL O&M COST	PRESENT WORTH O&M COST (1)	TOTAL PRESENT WORTH (2)
Alternative 1 – No Action	--	--	--	Nominal (3)
Alternative 2 – Institutional Controls with Long–Term Ground Water Monitoring(4)	--	$8,300	$130,000	$150,000
Alternative 3 – Extraction/Treatment/Discharge with Institutional Controls				
Precipitation(5)	$210,000	$70,000	$1,100,000	$1,500,000
Ion Exchange(6)	$290,000	$29,000	$450,000	$880,000

(1) – Based on 5% discount rate
(2) – Includes 20% contingency on all components
(3) – The only cost associated with the implementation of Alternative GW–1 would be that associated with conducting five–year reviews of the no action decision.
(4) – For costing purposes, Alternative 2 consists of Alternative GW–2. Deed restrictions would be implemented only if the property was transferred from federal ownership in the future.
(5) – For costing purposes, the precipitation option consists of Alternatives GW–2, GW–3A, GW–3B, and GW–3D. Deed restrictions would be implemented only if the property was transferred from federal ownership in the future.
(6) – For costing purposes, the ion exchange option consists of Alternatives GW–2, GW–3A, GW–3C, and GW–3D. Deed restrictions would be implemented only if the property was transferred from federal ownership in the future.

TABLE ES-10

GROUND WATER REMEDIAL ALTERNATIVES UNDERGOING DETAILED ANALYSIS
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

Alternative 1

No Action

Alternative 2

Limited Action (Institutional Controls)

A. Deed Restrictions/Ground Water Monitoring

Alternative 3

Extraction/Treatment/Discharge

A. Interceptor Trench/Extraction Wells
B. Precipitation
C. Electrochemical Treatment
D. Discharge to Surface Water

TABLE ES-11
DESCRIPTIONS OF GROUND WATER REMEDIAL ALTERNATIVES
SITE 11 – FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	DESCRIPTION
Alternative 1 – No Action	• No action
Alt rnative 2 – Limited Action (Institutional Controls and Ground Water Monitoring)	• Deed restrictions to prevent future use of on-site ground water as a potable water supply • Long-term monitoring of ground water quality
Alternative 3 – Ground Water Extraction/Treatment/ Discharge and Long-Term Ground Water Monitoring	• Ground water extraction, inorganic ground water treatment and discharge of the treated water to surface water (a tributary of Mill Creek) • Long-term monitoring of ground water quality

TABLE ES-12
COMPARISON AMONG GROUND WATER ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	COMPARISON OF OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
Alternative 1 - No Action	Least protective alternative; Does not limit future potable use of ground water and does not monitor ground water quality; Does not present any short-term impacts; Does not meet remedial response objectives
Alternative 2 - Limited Action (Institutional Controls and Gr und Water Monitoring)	Provides protection of human health by limiting potential future exposures to inorganics in ground water through the institution of deed restrictions limiting potable ground water use; Does not provide compliance with drinking water standards through treatment; However, would prevent the development of a ground water ingestion exposure pathway; Uses institutional controls to meet remedial action objectives
Alternative 3 - Extraction/Treatment/ Discharge with Long-Term Ground Water Monit ring	Provides a reduction in potential future risks to human health associated with ground water ingestion through active treatment; Would comply with chemical-specific and action-specific ARARs; Some increased short-term risks would result during implementation; Would be effective in the long-term as long as the treatment system is operational although permanence is not ensured

TABLE ES-13
COMPARISON AMONG GROUND WATER ALTERNATIVES
COMPLIANCE WITH ARARS
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	CHEMICAL-SPECIFIC	LOCATION-SPECIFIC	ACTION-SPECIFIC
Alternative 1 - No Action	Does not meet criteria	Not applicable	Not applicable
Alternative 2 - Limited Action (Institutional Controls and Gr und Water Monitoring)	Does not meet criteria	Not applicable	Monitoring would comply with RIDEM's Rules and Regulations for Ground Water Quality
Alternative 3 - Extraction/Treatment/ Discharge with Long-Term Ground Water Monitoring	Treatment would meet criteria	Not applicable	Extraction/Treatment/Discharge systems would comply with action-specific criteria

TABLE ES-14
COMPARISON AMONG GROUND WATER ALTERNATIVES
LONG-TERM EFFECTIVENESS AND PERMANENCE
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	COMPARISON OF LONG-TERM EFFECTIVENESS AND PERMANENCE
Alternative 1 - No Action	Effective in the long-term provided ground water is not used as a drinking water supply; Provides no long-term monitoring of ground water quality; Requires five-year reviews
Alternative 2 - Limited Action (Institutional Controls and Ground Water Monitoring)	Effective in minimizing the long-term risks associated with the potential construction and use of an on-site well as a source of drinking water; Monitoring program provides a means of monitoring potential changes in ground water quality; Requires five-year reviews
Alternative 3 - Extraction/Treatment/ Discharge with Long-Term Ground Water M nitoring	Treatment effective in treating contaminants which exceed ARARs or risk-based PRGs and in preventing off-site migration of contaminants during operation; Permanent contaminant reduction would not necessarily result if ground water treatment is discontinued in the future; Requires long-term maintenance and monitoring; Requires five-year reviews

TABLE ES-15
COMPARISON AMONG GROUND WATER ALTERNATIVES
REDUCTION OF TOXICITY, MOBILITY OR VOLUME THROUGH TREATMENT
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	COMPARISON OF REDUCTION IN TOXICITY, MOBILITY OR VOLUME
Alternative 1 - No Action	Provides no reduction in toxicity, mobility or volume through treatment
Alternative 2 - Limited Action (Institutional Controls and Ground Water Monitoring)	Provides no reduction in toxicity, mobility or volume through treatment; Site access or development restrictions would limit the potential ground water ingestion exposure pathway
Alternative 3 - Extraction/Treatment/ Discharge with Long-Term Ground Water Monitoring	Provides a reduction in ground water toxicity, mobility and volume through treatment

TABLE ES-16
COMPARISON AMONG GROUND WATER ALTERNATIVES
SHORT-TERM EFFECTIVENESS
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	COMPARISON OF SHORT-TERM EFFECTIVENESS
Alternative 1 - No Action	No remedial activities conducted; Therefore, no short-term risks result; Five-year reviews would provide the only means of ensuring compliance with remedial action objectives
Alternative 2 - Limited Action (Institutional Controls and Ground Water Monitoring)	Implementation of deed restrictions would result in no short-term risks; Implementation of the monitoring program would have minimal short-term adverse impacts based on the use of existing wells for ground water monitoring purposes; Would meet remedial response objectives related to preventing potential human exposures to contaminated ground water by prohibiting on-site potable well installation
Alternative 3 - Extraction/Treatment/ Discharge with Long-Term Ground Water M nitoring	No significant risks to on-site workers or off-site risks are anticipated; Degree of short-term risk would be dependent upon the individual options employed; Remedial response objectives would be achieved during operation of the treatment system but may not be maintained if treatment is discontinued

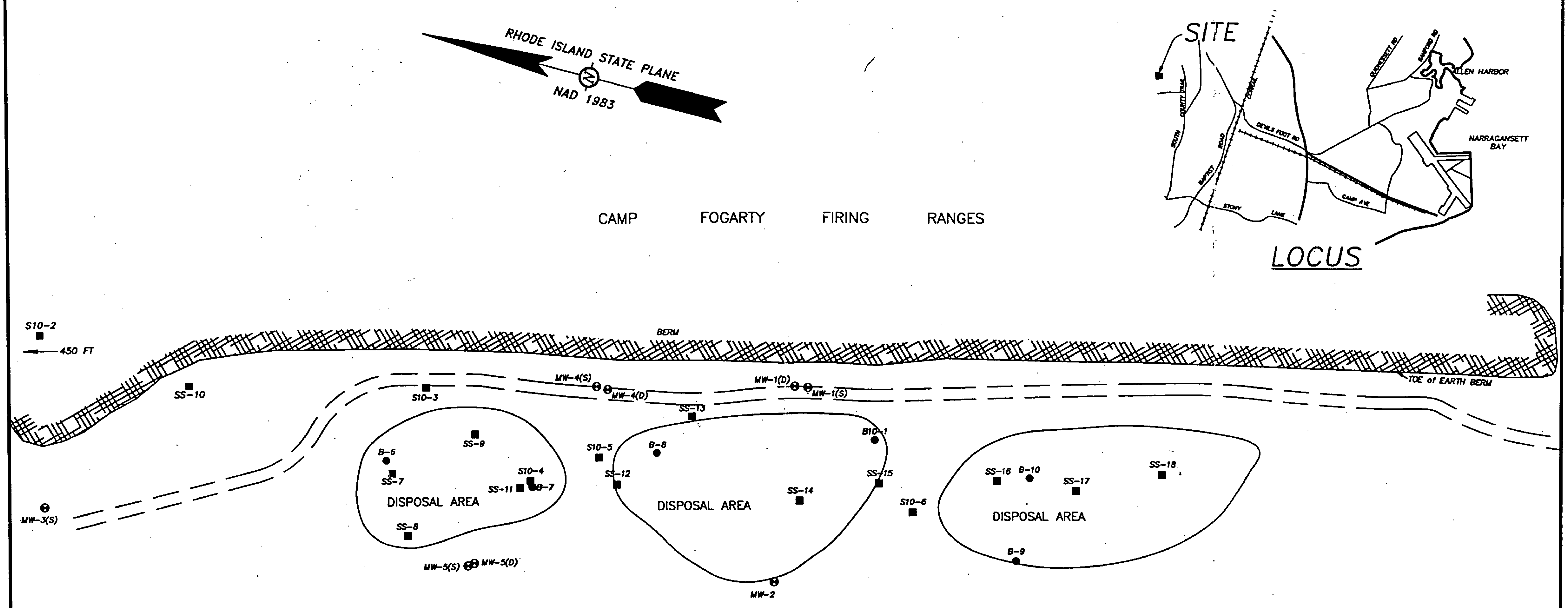
TABLE ES-17
COMPARISON AMONG GROUND WATER ALTERNATIVES
IMPLEMENTABILITY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	COMPARISON OF IMPLEMENTABILITY
Alternative 1 - No Action	Requires no implementation other than five-year reviews; Would not limit the implementation of other remedial actions
Alternative 2 - Limited Action (Institutional Controls and Ground Water Monitoring)	Deed restrictions would have to be implemented as part of the base closure property transfer process; Deed restrictions limiting future installation of on-site potable wells would not be expected to prevent future commercial/industrial use of the site; Implementation of deed restrictions or ground water monitoring would not limit the implementation of future remedial actions
Alternative 3 - Extraction/Treatment/ Discharge with Long-Term Ground Water Monit ring	Relatively easy to implement; Technical implementability would be dependent upon the individual alternative options selected; Some treatment technologies are more easily implemented than others; Services and materials should be readily available for the implementation of all options; Implementation of ground water remediation or ground water monitoring would not significantly limit future site use or the implementation of future remedial actions, if necessary

TABLE ES-18
COMPARISON AMONG GROUND WATER ALTERNATIVES
COST
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	TOTAL CAPITAL COST	ANNUAL O&M COST	PRESENT[1] WORTH O&M COST	TOTAL[2] PRESENT WORTH
Alternative 1 - No Action	--	--	--	Nominal[3]
Alternative 2 - Limited Action (Institutional Controls and Ground Water Monitoring)	--	$12,000	$190,000	$220,000
Alternative 3 - Extraction/Treatment/ Discharge with Long-Term Ground Water Monitoring	--	--	--	--
Precipitation[4]	$242,000	$78,200	$1,204,000	$1,750,000
Electrochemical Treatment[5]	$272,000	$48,200	$754,000	$1,220,000

(1) - Based on 5% discount rate
(2) - Includes 20% contingency on all components
(3) - The only cost associated with the implementation of Alternative 1 would be that associated with conducting five-year reviews of the no action decision. Deed restrictions would be implemented under the base closure property transfer process.
(4) - For costing purposes, the precipitation option consists of Alternatives 2, 3A, 3B and 3D.
(5) - For costing purposes, the electrochemical treatment option consists of Alternatives 2, 3A, 3C and 3D.



LEGEND:

- ● .... TEST BORING LOCATION
- ⊖ .... MONITORING WELL LOCATION
- ■ .... SURFACE SOIL SAMPLE LOCATION
- (S) .... SHALLOW WELL
- (D) .... DEEP WELL

NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

60 0 60 120 180 240 FEET

20 0 20 40 60 METERS

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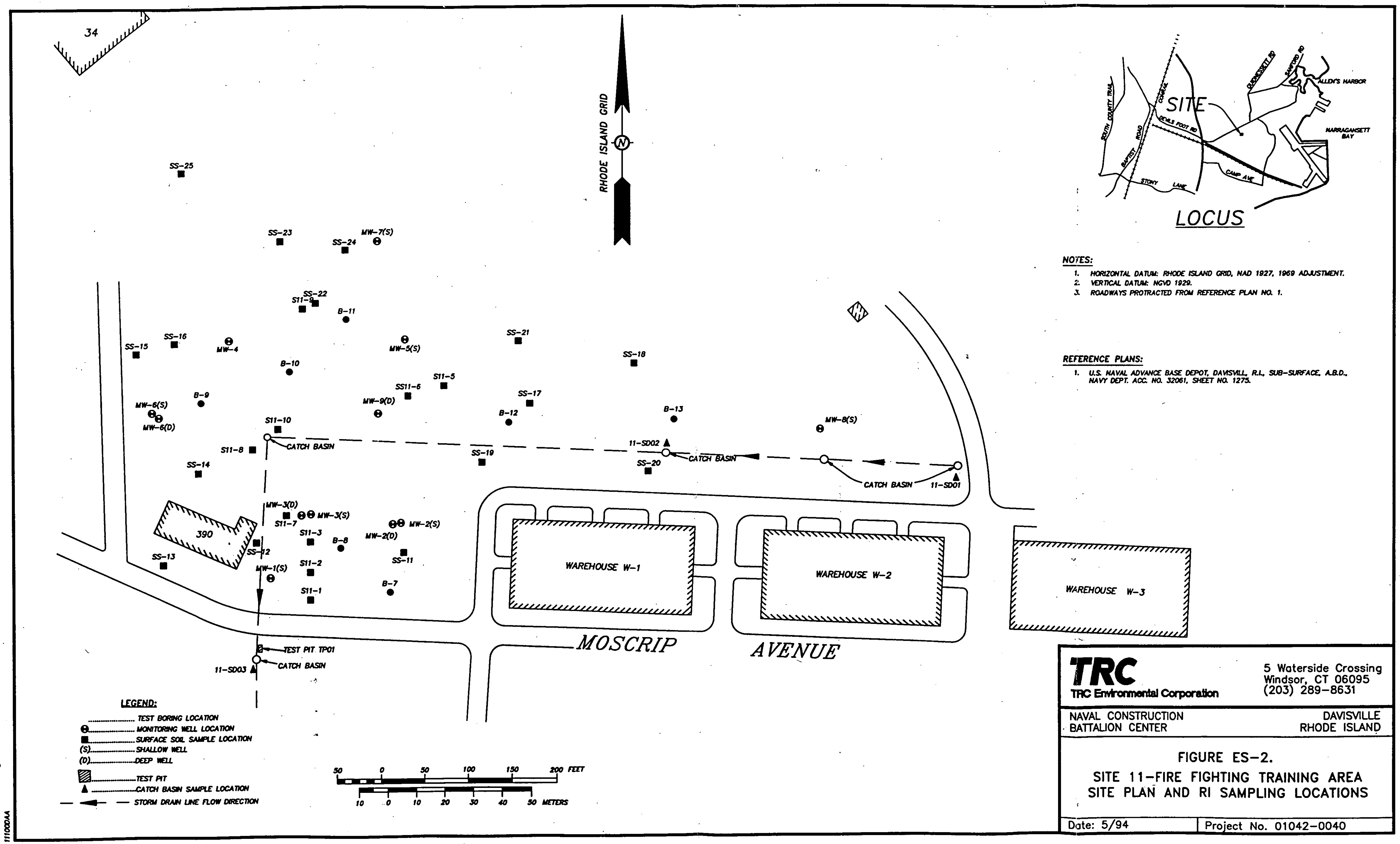
NAVAL CONSTRUCTION BATTALION CENTER — DAVISVILLE RHODE ISLAND

FIGURE ES-1.
SITE 10-CAMP FOGARTY DISPOSAL AREA
SITE PLAN AND RI SAMPLING LOCATIONS

Date: 5/94 | Project No. 01042-0040



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NAVAL CONSTRUCTION BATTALION CENTER — DAVISVILLE RHODE ISLAND

FIGURE ES-2.
SITE 11-FIRE FIGHTING TRAINING AREA
SITE PLAN AND RI SAMPLING LOCATIONS

Date: 5/94 | Project No. 01042-0040

Detailed Analysis of Alternatives
Site 10 - Camp Fogarty Disposal Area
Site 11 - Fire Fighting Training Area
Naval Construction Battalion Center

Volume I
Introduction

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1.0 INTRODUCTION

TRC Environmental Corporation (TRC) is conducting a Remedial Investigation/Feasibility Study (RI/FS) at the Naval Construction Battalion Center, located in the northeast section of the town of North Kingstown, Rhode Island (NCBC Davisville). The RI/FS is being conducted under the Navy's Installation Restoration Program and in accordance with the requirements of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). The study is being performed by TRC under Contract N62472-85-C-1026 for NORTHNAVFACENGCOM.

The Feasibility Study process was formulated by the U.S. Environmental Protection Agency (USEPA) to properly implement CERCLA. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP, 40 CFR Part 300) establishes the framework for performing Feasibility Studies. Further definition of the FS process is provided in the Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA (USEPA, 1988).

Previous investigations under which environmental data for the NCBC Davisville facility were developed include the following:

- Initial Assessment Study (IAS) (Hart, 1984a);
- Verification Step Report (part of a Confirmation Study) (TRC, 1987); and
- Phase I RI Draft Final Report (TRC, 1991).

Based on these studies, twelve sites were identified at NCBC Davisville for which Feasibility Study efforts were initiated. The site numbers were assigned during the IAS and have been retained under this investigation for consistency. The twelve sites were initially grouped for the purposes of conducting Feasibility Studies as follows:

- Group I Sites
  - Site 05 - Transformer Oil Disposal Area
  - Site 06 - Solvent Disposal Area
  - Site 13 - Disposal Area Northwest of Buildings W-3, W-4 and T-1
- Group II Sites
  - Site 08 - DPDO Film Processing Disposal Area

- Group III Sites
    - Site 12 - Building 316, DPDO Transformer Oil Spill Area
    - Site 14 - Building 38, Transformer Oil Leak Area

- Group IV Sites
    - Site 02 - CED, Battery Acid Disposal Area
    - Site 03 - CED, Solvent Disposal Area

- Group V Sites
    - Site 07 - Calf Pasture Point
    - Site 09 - Allen Harbor Landfill

- Group VI Sites
    - Site 10 - Camp Fogarty Disposal Area

- Group VII Sites
    - Site 11 - Fire Fighting Training Area

Figure 1-1 provides a summary of the approach being used in this investigation to formulate appropriate remedial responses for the NCBC Davisville sites.. The FS is being conducted in phases. The first step of the Feasibility Study process, the Initial Screening of Alternatives or ISA, was conducted for the twelve sites on the basis of Phase I RI information. Two ISA reports were prepared (TRC, 1993a and 1993b), one which addressed the Group I, Group II, Group III and Group VI sites and the second which addressed the remaining groups of sites. The ISA reports incorporate the following steps:

- Introduction/Background Information
- Assessment of Applicable or Relevant and Appropriate Requirements (ARARs)
- For each group of sites:
    - Site-Specific Information
    - General Response Actions
    - Identification and Screening of Technologies
    - Development and Initial Screening of Alternatives
- References

Subsequent to the initiation of the Feasibility Study activities, the Group III Sites, Sites 12 and 14, were addressed separately through the development of a Risk Assessment Technical

Memo (TRC, 1993c), a Proposed Plan for additional remedial activities, and the development and signature of a Record of Decision (ROD).

Also subsequent to the development of the ISA Reports, the Phase II Remedial Investigation was conducted, with the results presented in a series of draft reports (TRC, 1993d, 1993e, 1993f). Included in the Phase II RI are a Human Health Risk Assessment, which considers both Phase I and Phase II RI data in the evaluation of potential risks to human health, and an Ecological Risk Assessment, which evaluates the potential risks to the environment posed by the investigated sites.

This document, the Detailed Analysis of Alternatives (DAA), assesses the need for the application of potential remedial technologies at Site 10 - Camp Fogarty Disposal Area and Site 11 - Fire Fighting Training Area, as defined by existing site information. It builds upon the evaluation conducted in the ISA (TRC, 1993a) and incorporates the results of the Phase II RI in the evaluation of potential remedial technologies for Sites 10 and 11. The format followed within this DAA generally follows the original ISA format, with facility background information followed by a site-specific evaluation of the nature and extent of contamination, and the potential risks to human health and the environment posed by the site. The report presents the refinement of remedial response objectives, originally proposed within the ISA, the refinement of remedial alternatives, and detailed individual and comparative analyses of the remedial alternatives.

1.1 Facility Location and Description

NCBC Davisville is located in the northeast section of the town of North Kingstown, Rhode Island, approximately 18 miles south of Providence. A site location map is provided in Figure 1-2. NCBC Davisville is composed of three areas including the Main Center, the West Davisville storage area, and Camp Fogarty, a training facility located approximately 4 miles west of NCBC Davisville. A significant portion of NCBC Davisville is contiguous with Narragansett Bay. These areas are noted in Figure 1-3.

Adjoining NCBC Davisville's boundary on the south is the decommissioned Naval Air Station (NAS) Quonset Point that was declared excess to the Navy in April, 1973. The Quonset Point area is currently owned by the Rhode Island Port Authority (RIPA) and the Rhode Island

Department of Transportation (RIDOT), along with some private companies. Hereafter, this area will be referred to as NAS Quonset Point, to distinguish it from NCBC Davisville.

1.2 NCBC Davisville History

Quonset Point was the location of the first annual encampment of the Brigade Rhode Island Militia in 1893. During World War I, it was designated for the mobilization and training of troops and later was the home of the Rhode Island National Guard. In the 1920s and 1930s, Quonset Point functioned as a summer resort.

In 1939, Quonset Point was acquired by the Navy to establish a Naval Air Station (NAS), and construction began in 1940. During construction, millions of cubic yards of sediment were dredged to create a ship basin and channel.

By 1942, the operations at NAS Quonset Point had expanded into what is now called NCBC Davisville. Land at Davisville adjacent to NAS Quonset Point was designated the Advanced Base Depot, and the first of two piers was constructed. Later that year the Naval Construction Training Center (NCTC), known as Camp Endicott, was established to train the newly established construction battalions.

After World War II, activities at NAS Quonset Point remained the same, providing an operating base for aircraft and ships. After 1947, NAS Quonset Point was a site of carrier-based jet aviation. The Antarctic Development Squadron Six was moved to NAS Quonset Point in 1956. A Naval Air Rework Facility (NARF) was created there in 1967. The Naval Hospital was established in 1968.

The NCBC Davisville area was inactive between World War II and the Korean Conflict. In 1951 it became the Headquarters Construction Battalion Center (CBC). In 1974, the NAS and NARF at Quonset Point were decommissioned, and operations at Davisville were greatly reduced. In 1980, RIPA purchased NAS Quonset Point and the two Davisville piers from the Navy. In 1989, the closure of Davisville was announced, and all operations at Davisville were phased down to the present staffing levels for Public Works, Maintenance, Security and Navy Personnel. The facility was officially closed on April 1, 1994, and is subsequently being held under caretaker status by the Naval Facilities Engineering Field Division (Northern Division).

Under caretaker status, a civilian presence will be maintained at or near NCBC Davisville to monitor and provide oversight for all identified hazardous waste sites.

A Base Reuse Committee was established to develop a Comprehensive Reuse Plan to guide future use and development of the NCBC Davisville facility following closure. The proposed land uses defined under the Reuse Plan have been used as the basis for evaluation of future site uses in the RI/FS evaluations.

1.3 History of Facility Response Actions at NCBC Davisville

1.3.1 Previous Investigations - U.S. Navy

In 1983, Fred C. Hart Associates, Inc. (Hart) conducted an Initial Assessment Study (IAS) under contract to the Navy Assessment and Control of Installation Pollutants (NACIP) Office, with the purpose of identifying areas where potential contamination from past waste storage, handling or disposal practices at NCBC Davisville could pose threats to human health and the environment. The IAS identified a total of 14 potentially contaminated sites at NCBC Davisville (Hart, 1984a). Based on regulatory review of the IAS report, seven additional areas were added for a total of 21 potential areas of contamination at NCBC Davisville.

A Confirmation Study (CS) - Verification Step was initiated by TRC Environmental Consultants, Inc. (TRC) in March 1985. The purpose of the CS was to assess the nature and extent of contamination at 13 of the 21 sites identified in the IAS. The sites investigated during the Verification Step program included:

- Site 02 - CED Battery Acid Disposal Area;
- Site 03 - CED Solvent Disposal Area;
- Site 04 - CED Asphalt Disposal Area;
- Site 05 - Transformer Oil Disposal Area;
- Site 06 - Solvent Disposal Area;
- Site 07 - Calf Pasture Point;
- Site 08 - DPDO Film Processing Disposal Area;
- Site 09 - Allen Harbor Landfill;
- Site 10 - Camp Fogarty Disposal Area;
- Site 11 - Fire Fighting Training Area;
- Site 12 - DPDO Transformer Oil Spill Area;
- Site 13 - Disposal Area Northwest of Buildings W-3, W-4 and T-1; and
- Site 14 - Building 38, Transformer Oil Leak Area.

1.3.2 Previous Investigations - USEPA

NCBC Davisville was proposed by the USEPA for inclusion on the National Priorities List (NPL) in July 1989. NCBC Davisville was added to the NPL on November 21, 1989. USEPA developed a Hazard Ranking System (HRS) scoring package to support the proposed and final listings. The HRS package was based on existing information; a Preliminary Assessment/Site Investigation was not performed.

The HRS package noted that of the 24 potential sites which were identified in a combined study of NCBC Davisville, West Davisville, Camp Fogarty, and the decommissioned Quonset Point, the most serious sites of concern, and the sites which were aggregated to form the basis of the ranking package, are Site 09 - Allen Harbor Landfill and Site 07 - Calf Pasture Point.

Of the 24 potential sites listed in the HRS package, the areas designated 1 through 14 coincide with the 14 areas identified in the Navy's IAS. The remaining potential areas, 15 through 24, were identified by the EPA from an "Off-Site Activity Investigation" report (Hart, 1984b). The HRS package notes that areas 15 through 24 are on property not currently owned or operated by the U.S. Navy and are not included as part of the NPL site. Several of these areas are being investigated by the Army Corps of Engineers' program aimed at former defense facilities.

1.3.3 Current Remedial Investigation

In 1988, the Navy's three-phase NACIP Program was restructured to conform with USEPA's four-phase program. This change was predicated by the Superfund Amendments and Reauthorization Act (SARA) of 1986. The U.S. Navy changed its NACIP Program to closely parallel the USEPA requirements for remedial actions at Superfund sites. The Navy's program is now called the Installation Restoration (IR) Program. Under the IR Program, current investigations at NCBC Davisville are in the Remedial Investigation/Feasibility Study (RI/FS) phase.

In March 1988, TRC was tasked by the Navy to implement recommendations of the Confirmation Study - Verification Step by developing a Plan of Action as a NACIP Confirmation Study - Characterization Step to conduct more extensive sampling. Shortly after initiating this task, the Navy requested TRC to develop a Remedial Investigation (RI) Work Plan conforming to the newly-established Navy IR Program, and to the extent possible, conforming to current EPA requirements under the NCP and the USEPA draft RI guidance (USEPA, 1988). The resulting Phase I RI/FS Work Plan included a Field Sampling Plan, a Health and Safety Plan, a Quality Assurance Project Plan and a Data Management Plan (TRC, 1988). The Phase I RI field investigations were conducted from September 1989 to March 1990 and the Phase I RI Draft Final Report was submitted to the Navy in May 1991.

A Phase II RI/FS Work Plan was developed by TRC in 1992 and was implemented in the field over a period spanning from December 1992 through September 1993. The results of the Phase I and Phase II RIs are presented in a series of technical reports for the various sites (TRC, 1993d, 1993e, 1993f).

1.4 Regional Geology, Hydrogeology and Hydrology

The regional and site-specific geology, hydrogeology and hydrology are briefly discussed in the following sections. More comprehensive descriptions are provided in the Remedial Investigation Technical Report (TRC, 1993d).

1.4.1 Regional Geology

The area of Narragansett Bay, including the surrounding lowlands and islands in the Bay, overlies the Narragansett Basin. This geologic structure is a complex syncline of Pennsylvanian Age metasedimentary rocks about 12 miles wide and up to 12,000 feet deep. The Narragansett Basin's western limit is about 3 miles west of NCBC Davisville, and its eastern edge is close to Fall River, Massachusetts. All of the NCBC Davisville sites, except Site 10 - Camp Fogarty, overlie the Narragansett Basin. The bedrock is overlain by various glacial deposits up to 200 feet thick that have left the basin area relatively flat compared to the surrounding areas (Schafer, 1961).

The bedrock forming the basin is comprised of five formations which consist chiefly of non-marine conglomerates, sandstones, and shales. The principal unit is the Rhode Island Formation, which consists of a gray-greenish fine to coarse conglomerate, sandstone, lithic graywacke, graywacke, arkose, shale, and a minor amount of meta-anthracite and anthracite.

According to Johnson and Marks (1959), in the vicinity of NCBC Davisville, the bedrock is more than 90 feet below sea level in the West Passage of Narragansett Bay, greater than 70 feet below sea level just west of Frys Pond, nearly 50 feet below sea level near the West Davisville facility, and nearly 100 feet above sea level near Camp Fogarty. The Geologic Map and Sections of the Wickford Quadrangle, Rhode Island (Williams, Bulletin 1158-C, 1964) and visual observations identify a major bedrock outcrop just west of Frys Pond (approximately 300 yards east of Site 05).

The unconsolidated soils overlying the bedrock consist of three general types of glacial deposits: till, water-laid deposits, and wind-deposited material. In the Davisville area, till is exposed along highlands such as Lippitt Hill, the hillside due west of the rifle and pistol range at Camp Fogarty, and along the hillside of the ridge between West Davisville and NCBC Davisville. Just northeast of Site 02, there is an end moraine deposit which controlled the pro-glacial melt water drainage system.

Most of the surficial geologic soils in the Davisville area are water-laid deposits. Melt water streams flowing along the west side of the end moraine near Site 02 deposited a sequence of sands and silts over most of NCBC Davisville, including Sites 02, 03, 05, 06, 11, 13, and 14. Melt water streams also deposited layers of sand and silt near West Davisville (Sites 08 and 12) and the Allen Harbor Landfill (Site 09). Fine-grained glaciolacustrine soils underlie Calf Pasture Point (Site 07). At Camp Fogarty (Site 10), the rifle and pistol range overlies a kame terrace consisting of sand and gravel deposited by melt water streams which flowed alongside the glacier which moved through the Hunt River valley.

Wind deposited materials in the Davisville area are loose, heterogeneous, and relatively thin in comparison to the other glacial deposits in the area [10 feet at the higher elevations, and over 150 feet thick in some portions of the bedrock valleys (Schafer, 1961)].

1.4.2 Regional Hydrogeology

Ground water hydrogeology in the Davisville area is controlled by the geographic and geologic setting. The underlying bedrock units have primary porosities (pore openings between the grains of mineral crystals forming the rock) of less than 1 percent and very low secondary porosities (joints, fractures and openings along bedding planes). The only openings capable of yielding significant amounts of ground water are the secondary openings. In general, well yields from the bedrock formations are generally low, about 22 gallons per minute (gpm) from an average depth of approximately 225 feet. Flow from the secondary openings is greatest in the top 250 to 300 feet of bedrock (Rhode Island Development Council, 1952). In the Davisville area, the bedrock is not the principal aquifer and, therefore, is penetrated by only a small portion of wells.

The glacial soils in the Davisville area generally consist of stratified sand/gravel interbedded with very fine sand and silt, glacial till (a heterogeneous mixture of silt, sand, clay, and gravel), and stratified sand or gravel interbedded with varying amounts of glacial till. All of these materials will yield ground water, but only the stratified sands or gravels are permeable enough to yield large quantities of water for development. These very permeable materials form the Hunt Ground Water Reservoir or Hunt River Aquifer (previously known as the Potowomut-Wickford Aquifer), which is the principal source of potable water in the area. The specific yield capacities can range between 5 and 300 gallons per minute per foot drawdown (gpm/ft), with some wells yielding as much as 2,700 gpm. A hydrologic review of the aquifer recharge and discharge shows the long-term sustained safe yield of the entire Hunt Ground Water Reservoir is about 8 million gallons per day (mgd) (GZA, 1992).

Ground water in the Davisville area is unconfined; therefore, movement of the ground water is in direct response to gravity. The direction of regional ground water flow in the Davisville area is west to east, from the highlands towards Narragansett Bay. For small localized areas, the direction of ground water flow will be to the nearest downhill discharge area.

Ground water quality beneath the Davisville area is classified by the RIDEM as GAA-NA (Sites 08, 10, and 12) and GB (Sites 02, 03, 05, 06, 07, 09, 11, 13 and 14). GAA ground water is considered to be suitable for public drinking water use without treatment. Non-attainment areas (NA) are those areas that have pollutant concentrations greater than ground water quality standards for the applicable classification; a goal of restoration to ground water quality consistent with the standards is applicable to such areas. GB ground water is not suitable for public or private drinking water use. Areas were classified as GB because of known or presumed ground water degradation due to urbanization and/or identified waste disposal sites.

Rhode Island regulations do not require cleanup to drinking water standards, but if RIDEM determines resultant impacts need to be addressed or if contaminant levels pose a risk or contaminants migrate off-site, the Department can require remediation. The need for cleanups are determined on a site-by-site basis.

The ground water quality of the Hunt Ground Water Reservoir is suitable for most purposes. It generally contains less than 70 ppm of dissolved solids and the pH is slightly acidic to neutral, with a range of 5.5 to 7.0. The principal anions in the ground water are bicarbonate, sulfate, chloride and nitrate, all usually present at concentrations less than 25 ppm. In the vicinity of Narragansett Bay, the chloride concentration may exceed 250 ppm, due to salt water intrusion. The principal cations in the ground water are calcium, sodium, magnesium and potassium, each generally present at concentrations less than 10 ppm, resulting in soft water. Iron and manganese usually do not exceed drinking water standards (Rosenshein, Gonthiel and Allen, 1968).

1.4.3 Area Water Use

Available information (Personal Communication, Cohen, Smith, 1992) indicates that potable water in the Davisville area is supplied by either the North Kingstown Water Department or the Rhode Island Port Authority.

The North Kingstown Water Department supplies the non-military portion of Davisville and North Kingstown with water. North Kingstown operates three wells located in the Hunt Ground Water Reservoir and has proposed an additional well location (GZA, 1992). The locations of these wells are indicated in Figure 1-4.

The Rhode Island Port Authority (RIPA) supplies water on a wholesale basis to the Navy and some private users on Quonset Point (Personal Communication, Cohen, 1992). RIPA obtains its water from a series of three ground water supply wells located in the Hunt Ground Water Reservoir, as indicated in Figure 1-4. The Kent County Water Authority, which supplies water to towns north of North Kingstown, also maintains a ground water production well in the Hunt Ground Water Reservoir, also shown in Figure 1-4.

No active ground water supply wells exist at NCBC Davisville on Navy property (Personal Communication, Cohen, 1992).

Wellhead protection areas have been defined for the production wells which are part of community water systems in the vicinity of NCBC Davisville. Community water systems are defined as public water systems which serve at least 15 service connections used by year-round residents or which regularly serve at least 25 year-round residents. The refined wellhead protection areas for the community wells in the immediate vicinity of NCBC Davisville are indicated in Figure 1-4A. Also indicated are the capture zones of the wells, as presented in the Phase I Report, Hunt River Aquifer Wellhead Recharge Area Study (GZA, 1992). As indicated, none of the NCBC Davisville sites fall within the wellhead protection areas. The southern portion of Site 10 is located within the capture zone of the proposed North Kingstown production well. Site 08 is also located in the general vicinity of the proposed well's capture zone.

Two production wells which are not part of community water systems (referred to as non-community water systems) are also located in the vicinity of NCBC Davisville. One of these well locations is indicated in Figure 1-4A. The other non-community well is not indicated in the figure but is located in the vicinity of the Rhode Island Port Authority well in the northern portion of the figure. Refined wellhead protection areas have not been defined for the non-community wells. Therefore, the default value of 2,000 feet, as defined in the Rhode Island Rules and Regulations for Ground Water Quality, is used as the wellhead protection area for these wells. None of the NCBC Davisville sites fall within 2,000 feet of a non-community well.

As part of the Phase II RI, a search of potential private well locations was conducted within one-mile radii of the main center of NCBC Davisville, of Camp Fogarty and of the vicinity of Sites 07 and 09. The search area was located within the Town of North Kingstown and within the Town of East Greenwich (Camp Fogarty). Following an identification of street names within the study areas, specific street addresses were identified based upon a review of town tax records, and addresses at which water service is provided were identified based upon a review of town water department records. To identify potential addresses where private wells could be in use, the town tax addresses were compared with the water service addresses. From this comparison, an initial list of potential private well users was compiled. Tax codes noted for each address on the town tax list indicate the use of the property. These codes were used to eliminate all vacant lots from further consideration, thereby reducing the list of potential addresses where private wells could be in use. All tax codes that described property uses that could potentially utilize a potable water source were retained.

For Sites 02, 03, 06, 11 and 13, and Sites 07 and 09, addresses located on twelve streets were identified as potentially using private wells in this evaluation. The street locations are highlighted in Figure 1-5. As shown, three of the streets, Mountview Avenue, Pettee Avenue and Coolidge Avenue are located to the north of Sites 07 and 09. Fletcher Road, Newcomb Road, Northrup Road, and Signal Rock Road are located west of Sites 07 and 09 and north of Sites 02, 03, 06, 11 and 13. Boyer Street and Tidal Drive are located southeast of the Sites 07 and 09 and northeast of Sites 02, 03, 06, 11 and 13, adjacent to the eastern side of Allen Harbor. Genoa Drive, Smith Street, and Spinnaker Street are located south of Sites 02, 03, 06, 11 and 13.

For Site 10, addresses located on ten streets were identified as potentially using private wells in this evaluation. The street locations are highlighted in Figure 1-6. Cartier Court, Cavalier Drive, Ezechiel Carre Road and Frenchtown Road are all located north of Site 10. Meadowbrook Road, King Phillip Trail, Pequot Trail and South County Trail are located east and northeast of Site 10. South Road and Tillinghast Road are located south and west of Site 10, respectively.

1.4.4 Regional Hydrology

All of the investigated sites lie within the Hunt River drainage basin. The basin is about 60 square miles in area and is divided into four smaller sub-basins (Figure 1-7). Camp Fogarty and West Davisville lie within the Potowomut River basin, and the Main Center of NCBC Davisville lies within the Coastal River basin. All stream flow and river flow eventually discharge into Narragansett Bay (Figure 1-7). Surface water features in the immediate vicinity of NCBC Davisville are indicated in Figure 1-8. During most of the year, a part of the stream flow consists of water discharged from detention storage in natural as well as man-made impoundments. The remaining flow is from direct runoff of precipitation and from base runoff consisting largely of ground water discharge. The ground water contributes close to 50 percent of the average annual stream flow.

Annual precipitation in the area has ranged from 24.8 to 66.2 inches with an average of 42.3 inches. The frequency of measurable precipitation events (0.01 inch or greater) averages once every 3 days and is evenly distributed throughout the year. The average snowfall is almost 40 inches and has varied from 11.3 to 75.6 inches. Roughly 36 percent of the precipitation actually recharges the ground water system; the other 64 percent runs off into streams or is lost through evapotranspiration (GZA, 1992).

The surface water and ground water quality are similar since ground water contributes a major portion to stream flow. The principal anions are bicarbonate, sulfate, chloride, and nitrate. The principal cations are calcium, sodium, magnesium, and potassium. The pH ranges between 5.5 and 7.0. The iron concentrations in stream water vary from 0.03 to 3.7 ppm with the higher concentrations detected in Sandhill Brook, the lower reach of Hunt River, and the Potowomut River. Manganese concentrations range between less than 0.01 and 0.54 ppm (Rosenshein, Gonthiel, and Allen, 1968).

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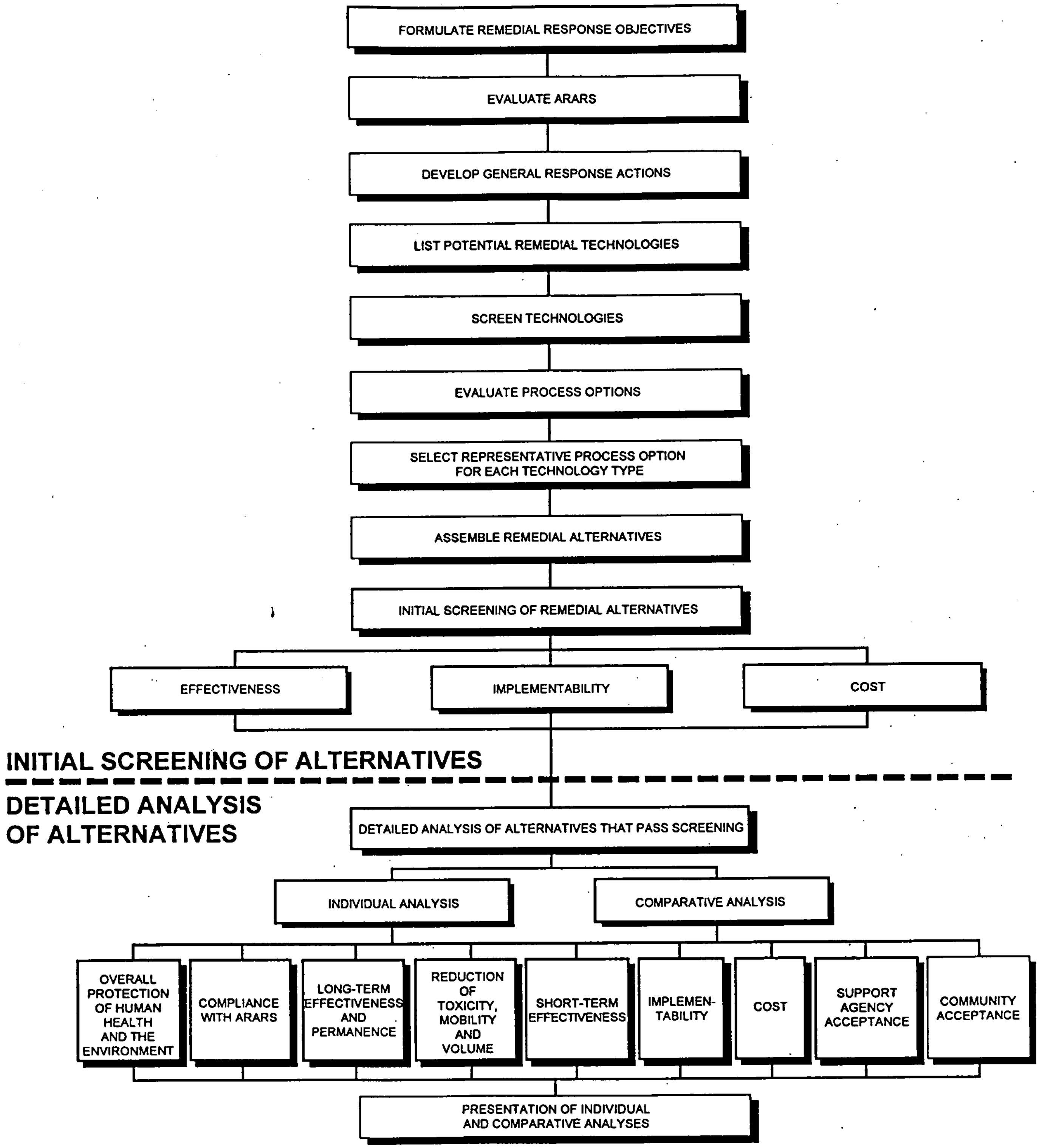

SOURCE: USEPA

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NAVAL CONSTRUCTION BATTALION CENTER — DAVISVILLE RHODE ISLAND

FIGURE 1-1.

FEASIBILITY STUDY APPROACH

Date: 4/94 | Project No. 01042-0040

01042020

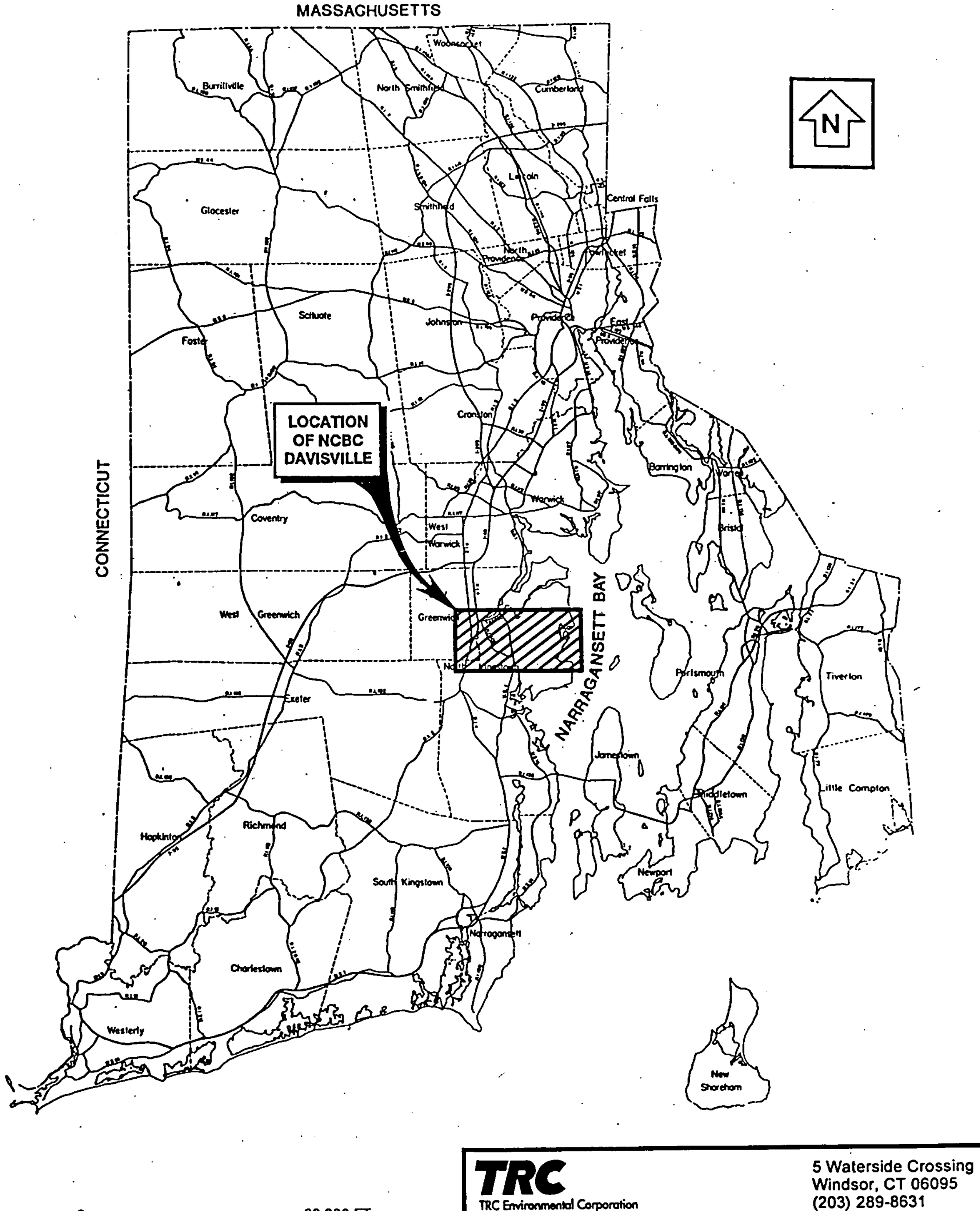

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FIGURE 1-2.

NCBC FACILITY LOCATION PLAN

Date 4/94 | Project No. 01042-0040

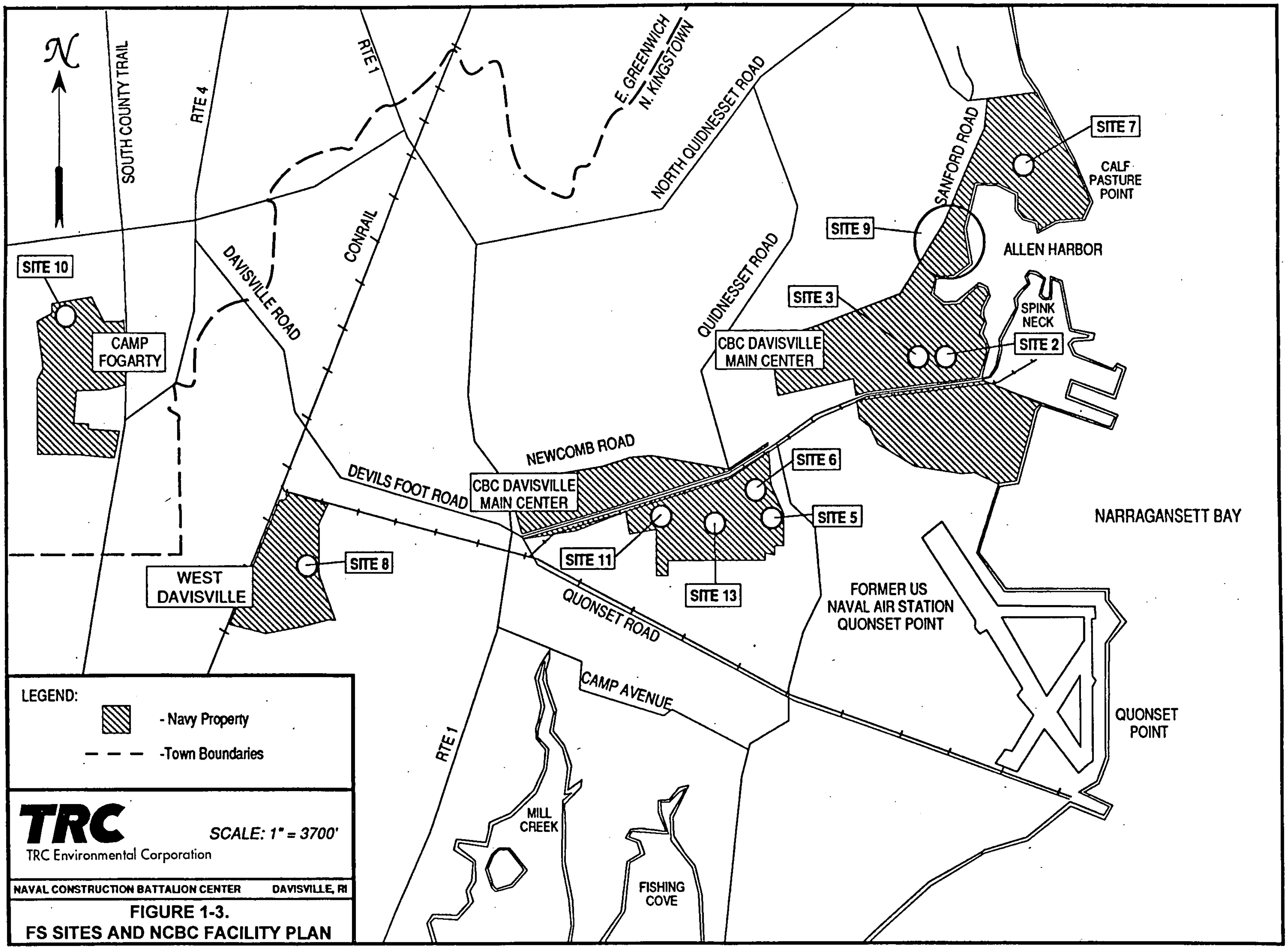

FIGURE 1-3.
FS SITES AND NCBC FACILITY PLAN

MS22/3/P

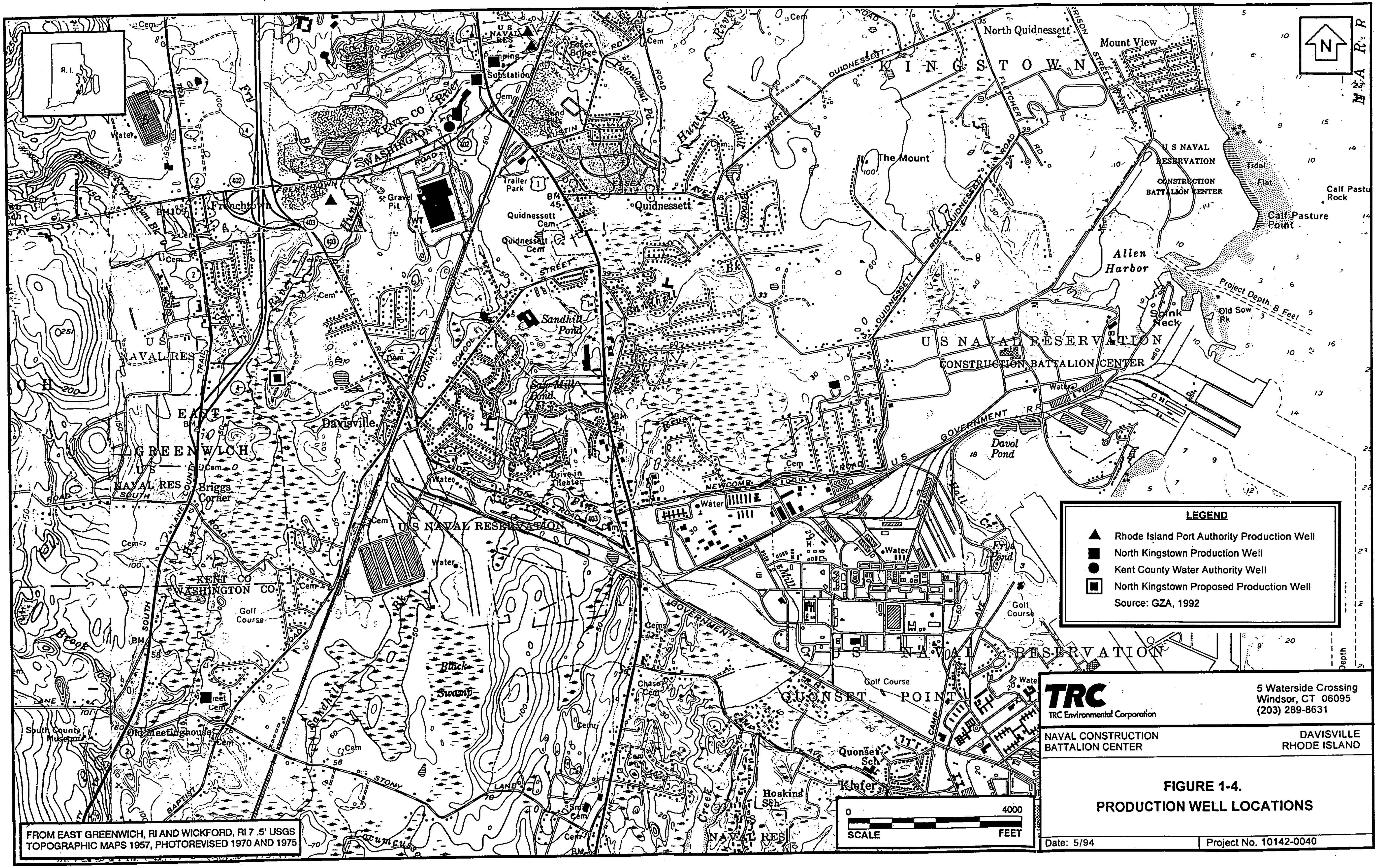

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FIGURE 1-4.
PRODUCTION WELL LOCATIONS

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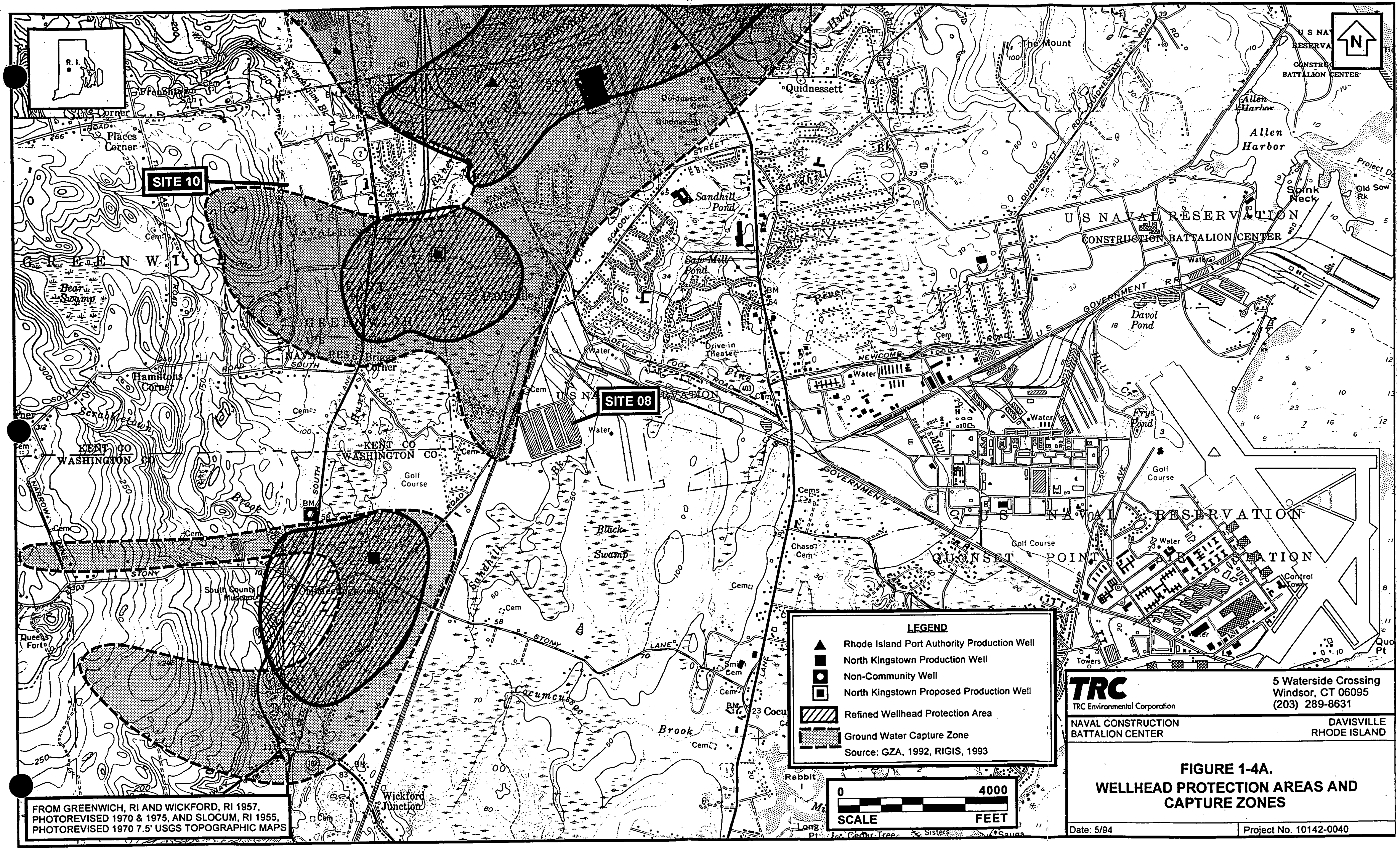
Project No. 10142-0040


SITE 10
SITE 08
LEGEND
Rhode Island Port Authority Production Well
North Kingstown Production Well
Non-Community Well
North Kingstown Proposed Production Well
Refined Wellhead Protection Area
Ground Water Capture Zone
Source: GZA, 1992, RIGIS, 1993
0 4000
SCALE FEET
FROM GREENWICH, RI AND WICKFORD, RI 1957, PHOTOREVISED 1970 & 1975, AND SLOCUM, RI 1955, PHOTOREVISED 1970 7.5' USGS TOPOGRAPHIC MAPS
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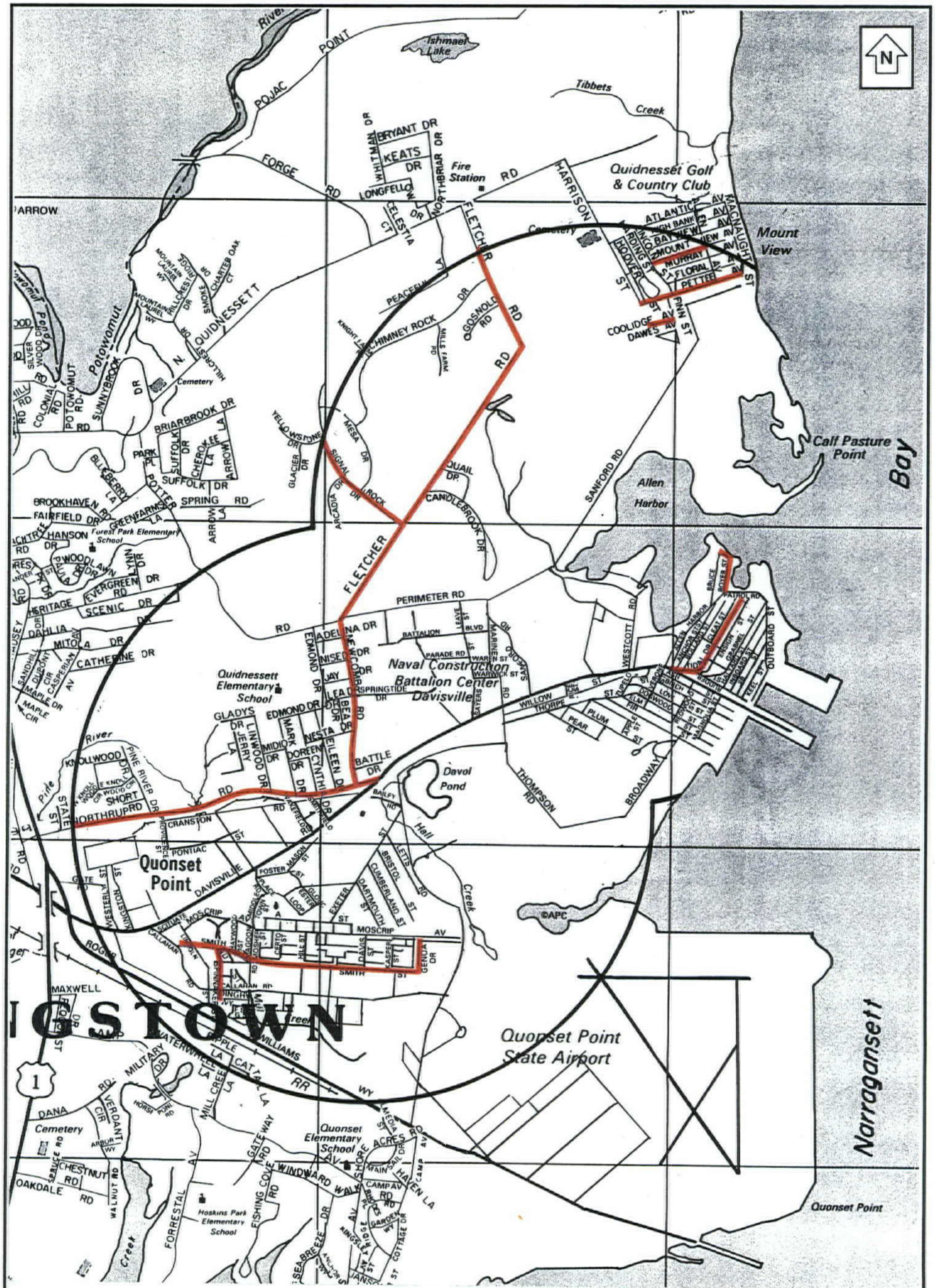
NAVAL CONSTRUCTION BATTALION CENTER
DAVISVILLE RHODE ISLAND
FIGURE 1-4A.
WELLHEAD PROTECTION AREAS AND CAPTURE ZONES
Date: 5/94
Project No. 10142-0040
U S NAVAL RESERVATION
CONSTRUCTION BATTALION CENTER
QUONSET POINT
Quidnessett
Allen Harbor
Sandhill Pond
Davol Pond
Black Swamp
Wickford Junction
Hamiltons Corner
Places Corner
KENT CO
WASHINGTON CO
Golf Course
N



0 .5 1 MILE

SCALE

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**FIGURE 1-5.
NCBC DAVISVILLE
STREET LOCATIONS FOR
POTENTIAL PRIVATE WELL USERS**

Date 4/94

Project No. 01042-0040

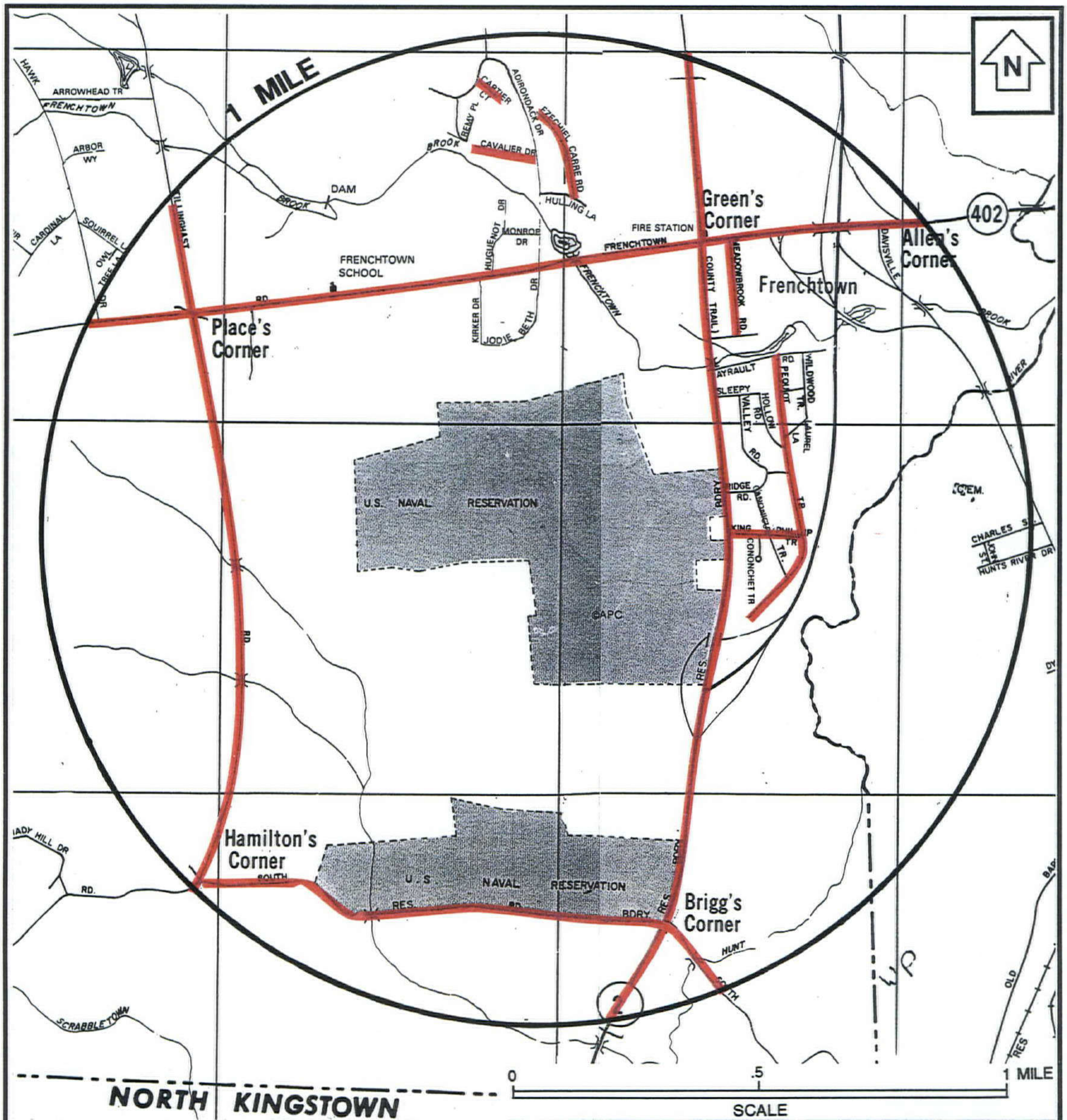

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**FIGURE 1-6.
SITE 10 - CAMP FOGARTY
STREET LOCATIONS FOR
POTENTIAL PRIVATE WELL USERS**

Date 4/94 | Project No. 01042-0040

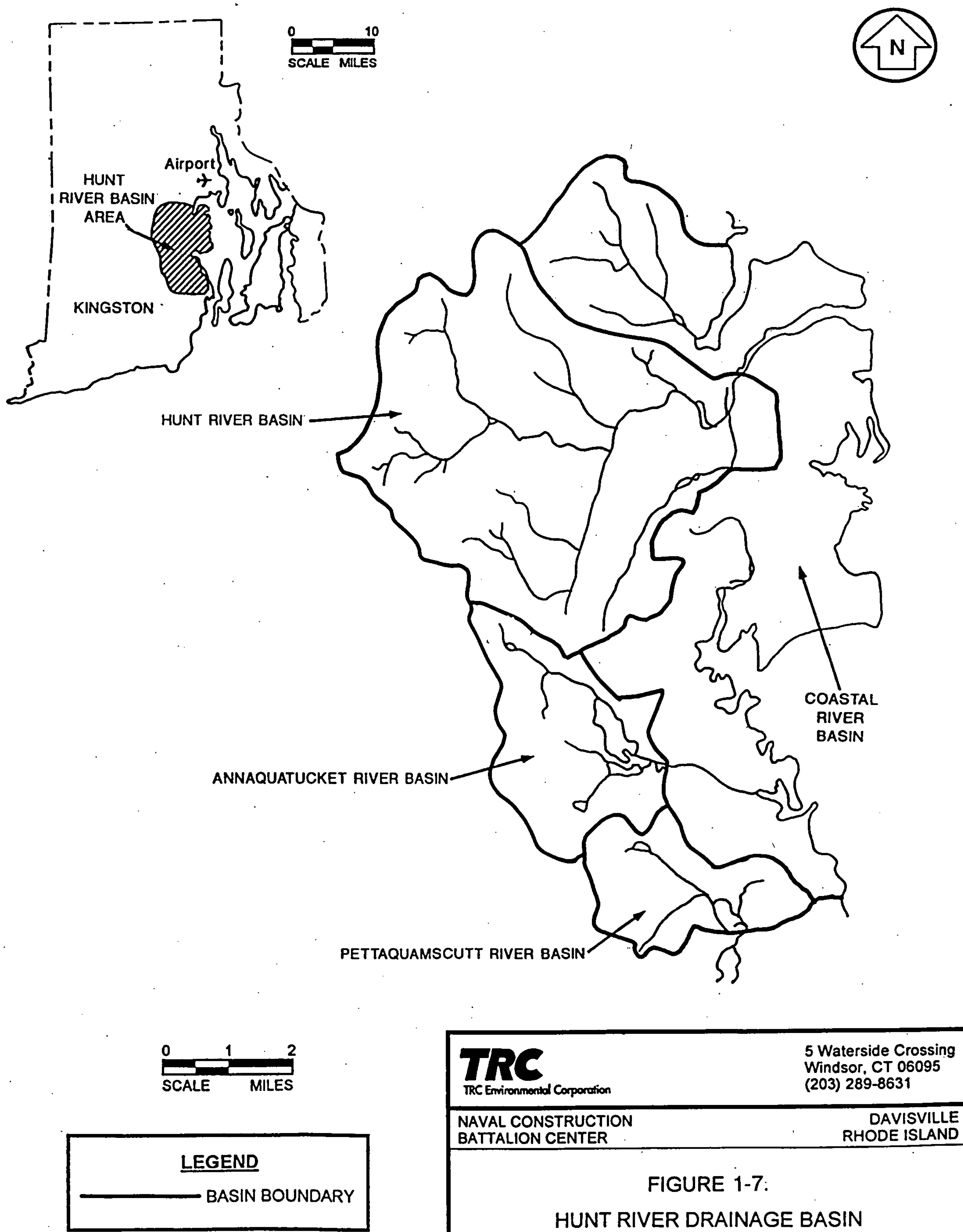

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FIGURE 1-7:
HUNT RIVER DRAINAGE BASIN

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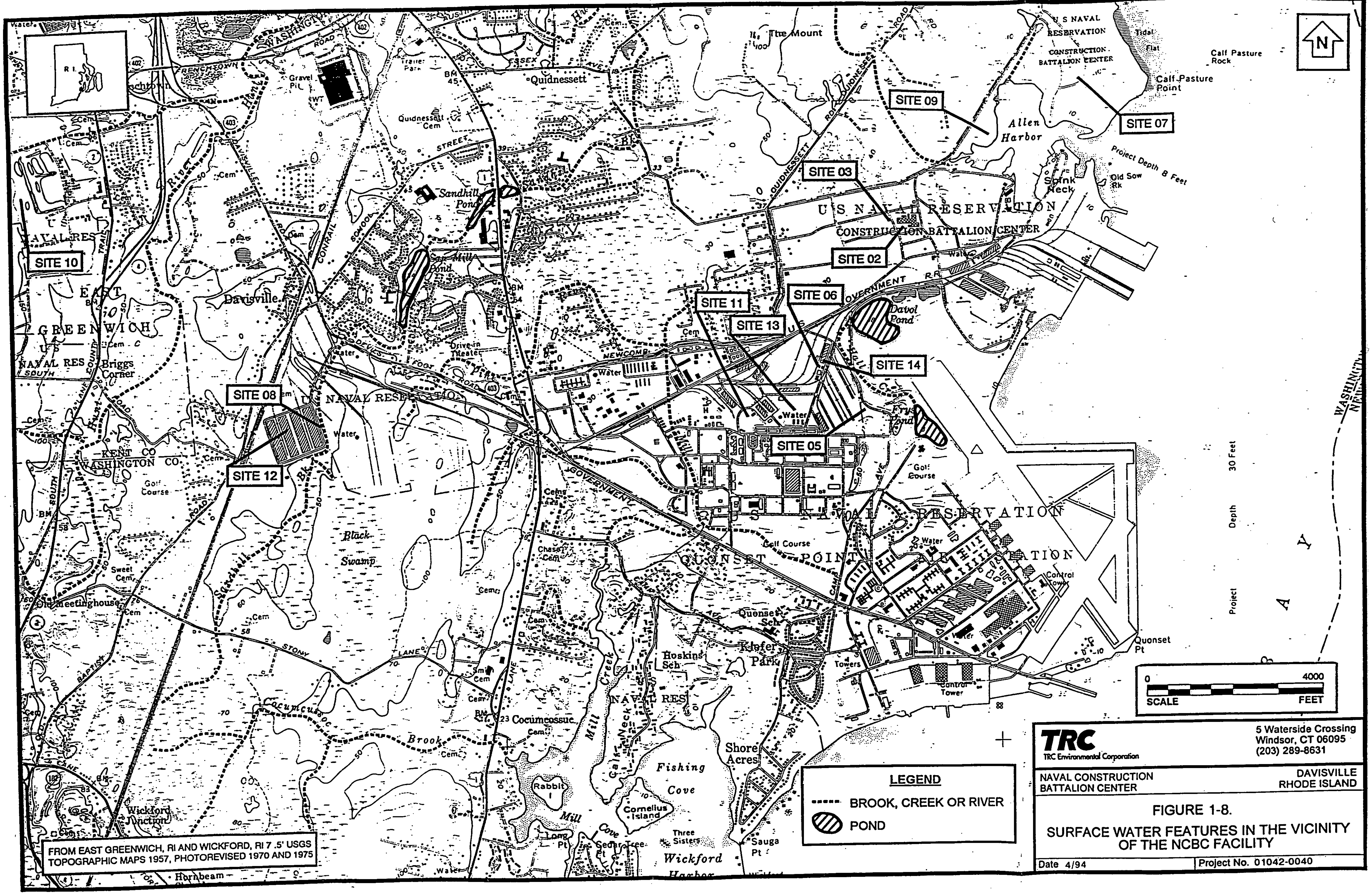

FIGURE 1-8.
SURFACE WATER FEATURES IN THE VICINITY OF THE NCBC FACILITY

Detailed Analysis of Alternatives
Naval Construction Battalion Center

Volume II
Site 10 - Camp Fogarty Disposal Area

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TABLE

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FIGURE

1.0 INTRODUCTION

Volume II addresses the Detailed Analysis of Alternatives for Site 10 - Camp Fogarty Disposal Area. The location of Site 10 relative to the Davisville facility is shown on Figure 1-1. The following sections provide background information and a description of the site, followed by a summary of remedial response objectives and cleanup criteria, general response actions, identification and screening of technologies and process options, a refinement of remedial alternatives previously developed in the ISA, and a detailed analysis of remedial alternatives. It builds upon the evaluation conducted in the ISA (TRC, 1993a) and incorporates the results of the Phase II RI in the evaluation of potential remedial technologies for Site 10.

2.0 SITE CHARACTERIZATION

2.1 Site Location and Description

Camp Fogarty is a 347-acre parcel of land located about 3 miles west of the Main Center, in East Greenwich, Rhode Island. A plan of Camp Fogarty is presented in Figure 2-1. Camp Fogarty includes an active firing range. The Site 10 study area, the Camp Fogarty Disposal Area, is located west of the firing range, between the firing range berm(s) and a steeply rising hill. Access to the entire area, including the portion of the area referred to as Site 10, is restricted by fences and facility personnel. This property has been excessed to the U.S. Army and remains an active facility which is not impacted by the closure of NCBC Davisville.

A plan of the study area is provided in Figure 2-2. Three depressions filled with construction debris are present within the site area. The vicinity of the study area is heavily wooded, interspersed with meadow areas. Seasonal flooding occurs in the low lying regions of Site 10 during periods of heavy rain.

2.2 Site History Overview

Cans of rifle- and weapon-cleaning oils and preservatives, as well as miscellaneous municipal-type garbage, were occasionally disposed of in a shallow, sandy excavation just west of the firing ranges at Camp Fogarty. Approximate disposal area locations, corresponding to surface depressions at the site, are shown in Figure 2-2. The disposal volume is estimated at 50,000 cubic feet in the IAS (Hart, 1984). Waste materials noted during the IAS included rusted, empty paint cans, 55-gallon drums, and miscellaneous metal parts. Reportedly, thousands of cans of rifle-bore oils were removed from the site and relocated at NCBC Davisville.

2.3 Site Geology, Hydrogeology and Hydrology

2.3.1 Site Geology

The soil boring activities performed during the RI provided information on the site geology. The subsurface soil investigation activities included drilling at seven soil boring locations and five monitoring well locations during the Phase I RI and Phase II RI. The locations of the Phase I and Phase II RI borings and monitoring wells are shown on Figures 2-3 and 2-4, respectively.

Surface soils on this site consist predominantly of native silt and fine to medium sand with variable artificial fill, clay, coarse sand and gravel content. Site 10 is not included in the area covered by the "Interim Soil Survey Report for North Kingstown, Rhode Island" (USDA, 1973).

According to the USGS surficial geologic map of the Wickford, Rhode Island quadrangle (Schafer, 1961), overlying the bedrock in the eastern portion of Site 10 are surficial overburden deposits of Pleistocene glacial water-laid ice-contact (kame terrace) sediments, consisting of sand, gravel and silt. The western portion of Site 10 is mapped as underlain by Pleistocene glacial ground moraine deposits, consisting of till with thin layers and lenses of gravel and sand in some places. The Phase II soil boring results indicate that the overburden deposits on this site consist of native fine to coarse sand with variable silt and gravel content, with fine sandy silt layers. Fill was encountered at borings 10-B06 and 10-B09 to depths of up to six feet below ground surface. However, fill material was not encountered in other site borings, suggesting that low areas have been filled in the past. In addition, a boulder layer was encountered at every soil boring and monitoring well boring location, at approximate depths of nine to twelve feet below grade. The descriptions of the soil boring samples were consistent with the mapped surficial overburden materials at Site 10. Overburden thicknesses ranged from 22.0 feet (10-MW4D) to 31.0 feet (10-MW5D).

Competent bedrock was encountered at the three Site 10 deep monitoring well locations at elevations ranging from 100.3 feet above mean sea level (msl) to 104.0 feet msl. The bedrock surface appears to slope downward from 10-MW5S/D to the east to form a fairly horizontal surface in the area of 10-MW1S/D and 10-MW4S/D. A weathered bedrock layer was not encountered in any of the Phase II deep monitoring well borings.

One seismic refraction survey line was completed in a north-south direction, adjacent to the access road at Site 10; this investigation indicated that the competent bedrock at Site 10 is located from approximately 24 to 40 feet below ground surface, and appears to dip slightly to the north and south from a high point located approximately 250 feet south of 10-MW1S/D.

According to the USGS bedrock geologic map of the Wickford, Rhode Island quadrangle (Williams, 1964), Site 10 is underlain at depth by biotite gneiss bedrock possibly belonging to the Precambrian Blackstone Series. Nx rock cores were collected of competent bedrock at the three deep monitoring well borings. The bedrock cores at Site 10 consisted of massive and competent, light to dark grey, fine- to coarse-grained meta-sandstone gneiss. The gneiss contained several quartz vein-healed and/or iron oxide-stained natural fractures.

2.3.2 Site Hydrogeology

Contour maps of the shallow and deep ground water elevations as measured in Site 10 monitoring wells on August 13, and September 17, 1993 are presented as Figures 2-5 through 2-8. The ground water contour maps indicate site shallow ground water flow converges toward the topographically low, north-central portion of the site. The northernmost depression/disposal area, located between monitoring well pairs 10-MW4 and 10-MW5, has the lowest elevation and appears to dominate shallow ground water flow. In the southern portion of the site, the contour lines indicate that shallow ground water flow is generally toward the north-northeast, and in the northern portion of the site, shallow ground water flow is generally to the south-southwest. Based on the deep ground water levels measured at Site 10, the site deep ground water potentiometric surface indicates flow generally to the north-northeast.

Vertical hydraulic gradients were calculated at the three sets of paired monitoring wells at the site (10-MW1S/D, 10-MW4S/D and 10-MW5S/D), as presented in Table 2-1. A positive hydraulic gradient indicates a potential for upward flow and a negative gradient indicates a potential for downward flow of ground water. For the two monitoring events, the calculated vertical gradients ranged from -4.93×10^{-3} ft/ft to 1.18×10^{-2} ft/ft. Positive vertical gradients (upward) were measured at 10-MW5S/D during both events, negative vertical gradients (downward) were measured at 10-MW1S/D during both events, and zero vertical gradients were measured at 10-MW4S/D during both events. The positive and negative vertical hydraulic gradients observed at Site 10 are low in magnitude; this indicates that vertical transport would appear to have little impact on contaminant migration at the site.

Horizontal hydraulic gradients were also calculated from the water level measurements and the resulting water level elevations at the site. Representative average horizontal hydraulic gradients for both the shallow and deep ground water were determined for several areas on the site, and are provided in Table 2-2. Average horizontal gradients for shallow ground water ranged from 9.40×10^{-4} ft/ft to the southeast to 4.70×10^{-3} ft/ft to the northwest. Average deep ground water horizontal gradients ranged from 1.58×10^{-3} ft/ft to the northwest to 5.04×10^{-3} ft/ft to the northwest.

The calculated average horizontal hydraulic gradients, hydraulic conductivity and estimated effective porosity values, were used to calculate average ground water flow linear velocity values at the site. The average linear velocity values, calculated on the basis of the shallow and deep hydraulic conductivities of 13.7 and 5.9 ft/d (derived from Phase II slug tests) and an assumed effective porosity of 20% for the silty sands, are presented in Table 2-2. Average linear velocities of the shallow ground water ranged from 0.06 ft/d to 0.32 ft/d. Average deep linear velocities ranged from 0.05 ft/d to 0.15 ft/d.

Ground water at Site 10 is classified as GAA-NA by RIDEM. Ground water classified as GAA includes those ground water resources which RIDEM has designated to be suitable for public drinking water without treatment. Areas classified as non-attainment (NA) areas are those which are known or presumed to be out of compliance with the standards of the assigned classification. The goal for non-attainment areas is restoration to a quality consistent with the classification.

A Wellhead Recharge Area Study of the Hunt River Aquifer was conducted by GZA GeoEnvironmental, Inc. in 1992 (GZA, 1992). The study was conducted to provide local municipalities and water departments with technical information necessary to estimate the direction and rate of ground water migration under a variety of pumping conditions and to identify wellhead recharge areas at seven existing wells and one proposed public well site (see Figure 1-4 in Volume I for well locations). The study indicated that the area in which Site 10 is located is included in the ground water capture zone of the proposed public well site.

2.3.3 Site Hydrology

Site 10 is characterized by the presence of three depressions located between the firing range berms and a steeply rising hill. The vicinity of the study area is heavily wooded, interspersed with meadow areas. Site soils consist of fine- to coarse-grained sands with varying amounts of gravel and silt, thus suggesting the soils are well-drained. Runoff is expected to be minimal since the site consists of depression areas and the soils are well-drained. No surface water bodies exist within Camp Fogarty.

2.4 Ecological Setting

The ecological assessment activities conducted as part of the Phase II RI for NCBC Davisville included the assessment of both terrestrial and aquatic risk for Site 10 and the watershed in which it is located. The terrestrial risk was assessed at individual sites, while aquatic risk was assessed for the watershed. Camp Fogarty and the surrounding area are located within the Hunt River/Frenchtown Creek Watershed.

The Hunt River drainage system drains much of the western portion of the NCBC facility. The location of the Hunt River relative to Site 10 is indicated in Figure 1-1. The system includes the Hunt River which flows to the north, associated swamps over the southwestern portion of the watershed, and Frenchtown Brook and nearby streams, which flow east into the Hunt River north of Site 10. Surface water runoff and ground water from Camp Fogarty flow east toward the Hunt River.

Based on a RIDEM endangered species survey report for Camp Fogarty (RIDEM, 1989), red maple and mixed oaks occur throughout the site. Red maples are generally in the marshy regions, while mixed oaks occur in the higher areas. This deciduous forest supports about 50 bird species. The RIDEM report states that no occurrence records of rare species were identified for the Camp Fogarty property. However, based on the identification of two listed amphibians, the marbled salamander (*Ambystoma opacum*) and the four-toed salamander (*Hemidactylium scutatum*), within a two-mile radius of the site, the report concludes that impacts to wetland systems should be avoided and that small, temporary pools of water potentially used as salamander breeding sites should not be disturbed.

The Hunt River Watershed itself appears to support a diverse, nesting, avian fauna, exhibits evidence of small and large mammals, and exhibits a diverse second growth vegetation with no observable signs of vegetative stress. The far downstream benthos appears to be at least as diverse and abundant as the upstream area.

2.5 Site Investigation Overview

2.5.1 Initial Assessment Study and Confirmation Study

In 1983, Site 10 was identified in the IAS as a possible receptor of hazardous wastes. However, the IAS concluded that the risk posed by Site 10 to human health and the environment was minimal and that no further investigation was necessary. At the request of RIDEM, Site 10 was included in the Verification Step of the Confirmation Study.

The Verification Step field investigations consisted of two phases which included a site walk-over with an organic vapor analyzer (OVA) and surface soil sampling. One composite surface soil sample was collected from four discrete sampling locations and scanned for EPA Priority Pollutants. Another surface soil sample (grab sample) was taken during the second phase of sampling and also scanned for EPA Priority Pollutants.

2.5.2 Phase I Remedial Investigation

The Phase I RI, conducted from September 1989 to March 1990, included a limited soil gas survey, the collection of six surface soil samples, two soil borings, and the installation and sampling of three ground water monitoring wells. A sample location map is provided on Figure 2-3. All soil and ground water samples were submitted for full TCL/TAL analyses.

2.5.3 Phase II Remedial Investigation

The purpose of the Phase II Remedial Investigation at Site 10 was to further delineate the horizontal and vertical extent of contamination associated with the disposal activities and to verify the Phase I RI conclusion that there is no significant source of contamination at the site. The investigations also provided a basis for the evaluation of contaminant fate and transport mechanisms and data for use in quantitatively evaluating human health risks and ecological risks.

The Phase II RI field investigation activities were conducted at Site 10 from December 1992 to August 1993. They included a soil gas survey, geophysical survey, surface soil sampling, soil boring sampling, and ground water sampling. The geophysical investigation at Site 10 consisted of a seismic refraction survey and an electromagnetic conductivity survey.

The soil gas survey focused on the three large depressions and included the collection of 46 soil gas samples. All of the Phase II soil gas samples were subjected to dual analyses on a portable gas chromatograph (GC). One analysis was conducted according to EPA Method 601 (modified) and the other analysis was conducted according to EPA Method 602 (modified).

Nineteen surface soil samples were collected from twelve surface soil sample locations, five test boring locations (0- to 2- feet), and two monitoring well boring locations (0- to 2- feet). Five subsurface soil samples were taken from one monitoring well boring and four test borings. The surface and subsurface soil samples were analyzed for full TCL and TAL parameters, less pesticides/PCBs. Two surface soil samples from Site 10 were also collected for TCLP analyses. The Phase II sampling locations are shown on Figure 2-4.

After the completion of the monitoring well borings, two shallow wells and three deep wells (two shallow/deep clusters and one deep well adjacent to an existing shallow well) were installed at Site 10. In addition, three bedrock cores were collected during the drilling activities. Ground water samples were collected from each of the eight monitoring wells (five shallow wells and three deep wells). Ground water samples were analyzed in the field for the water quality parameters of pH, specific conductance, Eh, temperature, and turbidity, and in the laboratory for full TCL and TAL parameters, less pesticides/PCBs. In addition, three ground water samples were analyzed for filtered metals, BOD, COD, and TSS.

Eighteen background surface soil samples were also collected across NCBC Davisville during the Phase II RI to provide a range of background soil quality for NCBC Davisville soils. All eighteen samples were analyzed for full TCL and TAL compounds. Only inorganic and semi-volatile background results are applicable to Site 10. The applicable background soil quality results are summarized in Table 2-3 and considered in the evaluation of contaminant levels presented below.

2.5.4 Other Investigations

A separate investigation is being conducted in the firing range area of Camp Fogarty to evaluate the potential for soil lead contamination as a result of firing range exercises. The results of this investigation are being reported separately and are not considered within this DAA Report.

2.6 Nature and Extent of Contamination

The nature and extent of contamination based on the RI results are presented by chemical class below. Where appropriate, Confirmation Study results are also referenced.

2.6.1 Volatile Organic Compounds (VOCs)

Surface Soils

The composite surface soil sample collected during the Verification Step field investigations contained less than 80 ppm of petroleum-based hydrocarbons and about 10 ppm of total volatile organic compounds, of which the major compound was not identified. Benzene, 1,2-dichloroethane, 1,1,2,2-tetrachloroethane, and 1,3-transdichloropropane were all detected at low levels. The EPA Priority Pollutant scan performed during the second round of sampling, which consisted of one surface soil sample, indicated slightly elevated levels of toluene.

No volatile organic compounds were detected in Site 10 surface soils during the Phase I RI.

Acetone, 1,1,1-trichloroethane and toluene were each detected in at least one of the Phase II RI surface soil samples. Acetone was detected in two surficial soil boring samples, 10-B6-01 and 10-B7-01, at concentrations of 12 ppb and 24 ppb, respectively. 1,1,1-Trichloroethane was detected in surface soil samples 10-SS09, 10-SS12, 10-SS14, 10-SS15, and 10-SS17 at estimated concentrations ranging from 3 to 8 ppb. Toluene was detected in surface soil samples 10-SS07 through 10-SS13 and sample 10-SS15 at estimated concentrations ranging from 3 to 12 ppb. Both acetone and toluene are common laboratory contaminants (USEPA, 1989a) and were present in the surface soils at low concentrations. Therefore, their actual presence in Site 10 surface soils is questionable. The source of the 1,1,1-trichloroethane detected in Site 10 surface soils is unknown and those surface soil samples which had detectable levels of 1,1,1-trichloroethane are scattered throughout the site, with no apparent pattern or trend.

Subsurface Soils

Chloroform was the only VOC detected in Phase I RI subsurface soil samples at Site 10. Chloroform was detected at an estimated concentration of 1 ppb in soil boring sample B-10-01-04, collected from the 6- to 8-foot interval.

Results of the Phase II subsurface soil analyses indicated the presence of low levels of acetone in one of the subsurface soil samples. Acetone was detected in soil boring sample 10-B6-02 (2- to 4-feet) at a concentration of 13 ppb.

Ground Water

No volatile organic compounds were detected in samples collected from the three shallow monitoring wells present during the Phase I RI or the five shallow and three deep monitoring wells present during the Phase II RI.

2.6.2 Semi-Volatile Organic Compounds (SVOCs)

Surface Soils

During the Verification Step of the Confirmation Study, pyrene was detected at 0.048 ppm and benzo(b)/benzo(k)fluoranthene was detected at 2.5 ppm in the grab surface soil sample.

Analyses of the Phase I RI surface soil samples indicated that polynuclear aromatic hydrocarbons (PAHs), a subset of SVOCs, were present in six of the eight samples. The highest total PAH concentration of 6,651 ppb was detected at surface soil sample S-10-03. Benzoic acid was also detected in surface soil sample S-10-01 and in soil boring sample B-10-01 at estimated concentrations of 610 ppb and 250 ppb, respectively.

During the Phase II RI, PAH compounds were detected in six of the nineteen surface soil samples collected at Site 10. In addition, bis(2-ethylhexyl)phthalate was detected in three of the surface soil samples and one duplicate surface soil sample. There were no other SVOCs detected in the Phase II RI surface soil samples. PAHs were detected in surface soil samples 10-SS09, 10-SS12, and 10-SS19 (duplicate of 10-SS17) and in soil boring samples 10-B06-01, 10-B08-01, and 10-B09-01. Total PAH concentrations ranged from 470 ppb at surface soil sample 10-SS19 to 28,350 ppb at surface soil sample 10-SS09. Based on the locations of these six samples, there does not appear to be any consistent distribution or source of SVOC contamination across the Site 10 surface soils.

Bis(2-ethylhexyl)phthalate was detected in surface soil samples 10-SS07, 10-SS10, 10-SS17, and 10-SS19 (duplicate of 10-SS17). The concentrations of bis(2-ethylhexyl)phthalate in the four surface soil samples ranged from 250 ppb to 710 ppb.

SVOC analyte concentrations detected in Site 10 surface soils were compared to NCBC background concentration ranges, as shown on Table 2-3. Background levels were exceeded in at least one surface soil sample for every contaminant detected.

Subsurface Soils

During the Phase I RI, only one SVOC was detected in one of the two subsurface soil samples collected at the site. Di-n-octyl phthalate was detected at an estimated concentration of 46 ppb at soil boring B-10-02-04. No other SVOCs were detected in Phase I RI subsurface soil samples.

During the Phase II RI, SVOCs were detected at one subsurface sample location. Four PAH compounds were detected in soil boring sample 10-B09-05 at a total concentration of 1,140 ppb. The sample was collected from the 8- to 10-foot interval within the southernmost depression area at the site. PAHs were also detected at this location in the surface soil sample.

Ground Water

No SVOCs were present in the Site 10 ground water samples during either the Phase I or the Phase II RIs.

2.6.3 Pesticides/PCBs

No pesticides/PCBs were detected in Phase I surface soil, subsurface soil, or ground water samples. Surface soil, subsurface soil, and ground water samples were not analyzed for pesticides/PCBs during the Phase II RI at Site 10.

2.6.4 Inorganic Analytes

Surface Soils

The Verification Step of the Confirmation Study identified slightly elevated levels of lead in surface soils. Beryllium, chromium, copper, lead, and zinc were among the inorganics detected in each of the Phase I RI surface soil samples.

The inorganics detected in Phase II RI surface soil samples were compared with background sample results from surface soil samples collected throughout the NCBC Davisville facility. A comparison of the observed surface soil concentration ranges at Site 10 to the NCBC background samples is presented in Table 2-3.

Nineteen inorganic analytes were detected in Site 10 surface soils at concentrations above background concentration ranges. These inorganics include aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, mercury, nickel, potassium, silver, sodium, thallium, zinc and cyanide. The highest levels of inorganics were detected in surface soil samples collected from the northernmost disposal area (samples 10-SS08, 10-SS09, 10-SS10, and 10-B06-01).

Subsurface Soils

The inorganic analytes detected in the surface soils during the Phase I RI were also detected in the subsurface soils, but generally at lower concentrations.

Soil sample results for the subsurface soil samples collected during the Phase II RI were compared to the background samples collected through the NCBC facility. Fifteen inorganic analytes were detected at concentrations above the NCBC background ranges. The analytes include aluminum, antimony, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, zinc and cyanide. The highest level of inorganic contamination was detected at soil boring sample 10-B06-02 collected from the 2- to 4-foot interval, and located in the depression area in the northern portion of the site.

Ground Water

Results of the Phase I ground water sampling indicated that beryllium and lead were present in Site 10 ground water at elevated levels. Beryllium was detected in monitoring well 10-MW2S at a concentration of 5.3 ppb. Lead was detected at concentrations ranging from 13.3 ppb to 140 ppb.

The inorganic analytes detected in the Phase II RI ground water sampling include aluminum, arsenic, barium, beryllium, cadmium, calcium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, selenium, sodium, zinc, and cyanide. Comparison of the Phase I and Phase II analytical data reveals a significant reduction in analyte concentrations, which may be attributed to the low-flow sampling methodology employed during the Phase II ground water sampling program. Comparison of the Phase II RI filtered and non-filtered analytical sample results indicates that the inorganic concentrations in the filtered samples are primarily equivalent to or slightly less than the concentrations of the non-filtered samples.

2.6.5 TCLP Analyses

During the Phase II RI, low leachable levels of methylene chloride, acetone, 4-methyl-2-pentanone, toluene, ethylbenzene, and total xylenes were detected in the TCLP samples 10-B10-01 and 10-B8-01. One inorganic constituent, cadmium, was detected in TCLP sample 10-B10-01 at a concentration of 60 ppb.

2.7 Summary of Contaminant Fate and Transport

A contaminant fate and transport analysis was initially conducted as a part of the Phase I RI and incorporated in the Initial Screening of Alternatives (TRC, 1993a). Subsequently, information obtained during the Phase II RI was incorporated into the contaminant fate and transport analysis and a revised discussion was presented in the Draft Phase II RI Technical Report (TRC, 1993b).

Potential routes of migration, contaminant persistence and observed contaminant migration were considered in evaluating the fate and transport of the site contaminants identified during the RI. Typically, contaminants in surface soils can migrate or be carried off-site by surface runoff (resulting from precipitation), by windblown dust, and by site visitors via adherence to vehicle tires, shoes, etc. Based on current site use, dust generation and surface runoff at Site 10 are not expected to be significant, given the vegetated cover over the site and the depressions located within the site area. Contaminants can also migrate from the surface soils through leaching (by the infiltration of precipitation) and subsequent transport by ground water, by volatilization to ambient air, or by uptake by plants or animals. Subsurface contaminants can migrate through leaching and ground water transport. Regional ground water migration in the vicinity of Site 10 would be to the north-northeast, towards the Hunt River.

The following sections examine the presence of Constituents of Concern (COCs), as identified during the Human Health Risk Assessment (HHRA) process (TRC, 1993b), across the site in combination with the potential migration pathways to provide an understanding of contaminant persistence and potential for migration at the site. The discussions below are presented with respect to individual contaminants or contaminant groups based on environmental fate data such as water solubility, vapor pressure, Henry's Law constants, organic carbon-water partition coefficients (K_{oc}), octanol-water partition coefficients (K_{ow}), and half-life in water. COCs identified in the HHRA for Site 10 include VOCs, SVOCs, and inorganics.

Volatile Organic Compounds

In general, VOCs were detected infrequently and at low concentrations in soils at Site 10. Four VOCs (1,1,1-trichloroethane, acetone, toluene, and chloroform) detected in surface or subsurface soil samples were identified as COCs. The principal mechanism for the natural removal of VOCs is through volatilization, based on vapor pressures (@ approximately 25°C) ranging from 28 mmHg (toluene) to 270 mmHg (acetone), and Henry's Law Constants for these VOCs ranging from 4.3×10^{-5} atm-m^3/mol (acetone) to 5.9×10^{-3} atm-m^3/mol (toluene).

The role of biodegradation in the natural attenuation of these compounds is compound-specific. Similarly, the role of adsorption is compound-specific. The volatile COCs are fairly soluble in water, with solubilities of 520 mg/l (toluene) to being miscible (acetone). The tendency of these constituents to partition from organic media into water varies, with log K_{ow}s ranging from 2.69 (for toluene) to -0.24 (for acetone, which is highly water soluble). The volatile COCs in surface and subsurface soil are not expected to persist in these media. The primary migration pathways from soil for these constituents are expected to be volatilization and leaching through soil into water.

No VOCs were identified as COCs in ground water.

Semi-Volatile Organic Compounds

Seventeen SVOCs were identified as COCs in surface soil at Site 10. In subsurface soil, an additional SVOC was selected as a COC. The SVOC COCs include fourteen PAHs, two phthalates, benzoic acid and carbazole. Benzoic acid, carbazole, nine PAHs and one phthalate were identified as COCs in surface but not subsurface soil. In general, the PAHs and phthalates were detected at the highest frequencies and concentrations. It should be noted that phthalates are common laboratory contaminants and are widespread in the environment (ATSDR, 1987; ATSDR, 1989b).

SVOCs, particularly PAHs, are persistent in the environment due to their complex chemical nature. While some of the lighter PAHs (with fewer aromatic rings) are subject to biodegradation or volatilization, chemical persistence generally increases with increasing number of aromatic rings. SVOCs are generally characterized by high boiling point, low vapor pressure, and low solubility (except for lower molecular weight PAHs).

PAHs generally exhibit a very low solubility (i.e., as low as 1 x 10^{-4} mg/l), with higher solubilities for the smaller PAHs (e.g., 30 mg/l for naphthalene). The solubility of the phthalate COCs ranges from 0.4 mg/l for bis(2-ethylhexyl)phthalate to 3 mg/l for di-n-octyl phthalate.

SVOCs, in general, have moderate to high log K_{oc} and log K_{ow} values, indicating a relative affinity for organic materials in solid (e.g., soil) and liquid (e.g., octanol) phases. The log K_{oc}s and log K_{ow}s of PAHs and phthalates are generally greater than 3, with many greater than 5.

Based on these characteristics, migration of SVOCs from soil to ground water is not likely to be a primary route of concern. Off-site transport of these less soluble SVOCs could be possible through soil transport in surface water runoff but runoff from the Site 10 area is expected to be minimal. SVOCs in soil are more likely to persist than VOCs, but are less likely to persist than pesticides/PCBs or inorganics.

No SVOCs were identified as COCs in ground water.

Pesticides/PCBs

No pesticides/PCBs were detected in soils or ground water at Site 10.

Inorganic Analytes

Many metals have a strong affinity for soils (particularly clay particles and organic matter in soils) which reduces their mobility. Under extremes of pH, some metals can be rendered mobile. The presence of the inorganic analytes at Site 10, particularly the naturally occurring elements, were examined in the context of facility background concentrations, as presented in Table 2-3. Site background samples were collected as composite samples from background locations at Sites 02, 07, 09, 10 and from wooded areas east of Sites 06, 11 and 13 during the Phase II RI. Inorganic COCs in surface soil at Site 10 include aluminum, antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, nickel, and zinc. The inorganic COCs in subsurface soil include antimony, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, cyanide, lead, manganese, nickel and zinc.

The inorganic COCs in ground water include aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, selenium, vanadium, and zinc. The presence of a number of these inorganics in surface and subsurface soils indicates migration from soil to ground water may have occurred. However, it is important to note that a comparison of Phase I and Phase II RI ground water analytical results indicates a considerable decrease in the concentration of inorganics in the Phase II RI samples. This decrease is believed to be due to the sampling methodology utilized in Phase II which incorporated a low-flow sampling rate, which decreased the turbidity of the ground water samples. Thus, the Phase II ground water data are thought to be more reflective of the actual concentrations of inorganics than the Phase I data.

TCLP Analyses

The results of the TCLP analyses indicate that there were no samples which exhibited contaminants above the regulatory action levels as identified on the TCLP list (40 CFR 261.24).

2.8 Summary of Human Health and Environmental Risk

The Human Health Risk Assessment conducted for Site 10 (TRC, 1993b) evaluated the contaminants of potential concern, assessed potential exposure pathways and chemical toxicity, and characterized potential risks to human health posed by the site. Both Phase I RI and Phase II RI data were used to characterize the human health risks. Exposure doses were developed based on the geometric mean of chemical concentrations (mean) as well as on the basis of the maximum detected chemical concentration (Reasonable Maximum Exposure or RME). Potential human health exposure scenarios evaluated include the following:

- Scenario 1 (Future Construction Worker) - Exposure of adult workers to subsurface soils (via dermal contact, ingestion and inhalation) for a one-year period, assuming construction of commercial buildings; and

- Scenario 2 (Future Commercial/Industrial Worker) - Exposure of adult employees to surface soils (via dermal contact and ingestion) and to ground water (through ingestion) under future commercial/industrial use of the site.

Human health risks were presented with regard to potential cancerous or non-cancerous (systemic) effects from the contaminants of concern. Cancer risks are presented in scientific notation, where a lifetime risk of 1×10^{-4} represents a lifetime risk of one in ten thousand. The calculated cancer risk is compared to the acceptable cancer risk range (1×10^{-4} to 1×10^{-6}) for evaluating the need for remediation, as stated in 40 CFR Part 300. A cancer risk of 1×10^{-6}

is considered as the point of departure for determining risk-based remediation goals. For non-carcinogens a summation of hazard quotients, referred to as the hazard index (HI), which exceeds unity (1) indicates there may be concern for potential non-cancer health effects. Therefore, the cancer risk and HI ratios that constitute a potential concern are those greater than 1×10^{-6} and 1, respectively.

Cancer and non-cancer risks for Site 10 are summarized in Table 2-4. Subsurface soil exposures under Scenario 1 (construction scenario) indicated a potential cancer risk range due to incidental ingestion of 9×10^{-7} (mean) to 2×10^{-6} (RME). Cancer risks associated with inhalation of suspended subsurface soil particulates are approximately three orders of magnitude less than 1×10^{-6}, and no risks were quantified for dermal exposure based on a lack of verified dermal absorption values for the carcinogenic COCs. Exposure to beryllium accounts for the majority of the estimated risks. The non-cancer hazard index values for each of the exposure pathways were below 1.

Under Scenario 2 (commercial/industrial), surface soil exposures resulted in a potential cancer risk range of 4×10^{-6} (mean) to 2×10^{-5} (RME) and non-cancer hazard index values of less than 1. Ingestion of arsenic, beryllium, and carcinogenic PAHs accounted for the majority of the estimated cancer risks.

Ground water exposures under Scenario 2 (commercial/industrial scenario) indicated a potential cancer risk range of 3×10^{-5} (mean) to 9×10^{-5} (RME) and a non-cancer hazard index value range of 0.4 (mean) to 5 (RME). Ingestion of arsenic and beryllium accounted for the majority of the estimated cancer risks, while manganese is the major contributor to the non-cancer hazard index values.

2.9 Summary of Ecological Risk Assessment

Ecological risks were assessed based on an evaluation of potential receptors identified through the ecological characterization of the Hunt River Watershed, and the detected levels and bioavailability of contaminants in environmental media. Terrestrial risks were characterized based on site-specific biological observations and surface soil data. Aquatic risk was assessed for the watershed. A "weight of evidence" approach was used in which information generated from exposure and ecological effects assessments, field observations and a toxicity quotient (TQ) evaluation are used to provide an overall weight of evidence concerning the nature of risks. As with the human health HI ratios, when the calculated TQ value exceeds unity (one), a potential for environmental risk exists. Risks to benthic organisms were assessed based on direct observations of the freshwater benthos in the watershed while risks to water column organisms were estimated based on a comparison to ambient water quality criteria. Risks to small mammals and birds were estimated on the basis of calculated TQ values.

The ecological assessment concluded that Site 10 does not pose an ecological risk to aquatic or terrestrial populations in the Hunt River watershed because:

- organic and inorganic constituents in the sediments of Hunt River were generally within natural levels;
- modeled doses of contaminants to birds and shrew near Site 10 do not indicate toxicity quotients greater than 1;
- the wildlife and benthic observations in the system indicate a taxonomically and functionally diverse ecosystem; and
- RIDEM does not recommend any specific precautions in regard to state endangered species.

3.0 SCREENING OF TECHNOLOGIES AND DEVELOPMENT OF ALTERNATIVES

Based on the available site information, potential remedial actions can be identified. Remedial action objectives are developed in order to set goals for protecting human health and the environment early in the alternative development process. General response actions are then developed to address the objectives. Remedial technologies and process options associated with the general response actions are identified and screened to eliminate those that are not technically implementable and to identify those that offer the optimum combination of effectiveness, implementability and cost. Remedial alternatives are then developed for detailed analysis.

3.1 Development of Preliminary Remediation Goals (PRGs)

Prior to the development of remedial action objectives, preliminary remediation goals (PRGs) are developed and evaluated with respect to site contaminant levels. Existing contaminant levels are compared to Applicable or Relevant and Appropriate Requirements (ARARs), To-Be-Considered guidance (TBCs), and risk-based PRGs to identify the extent of contamination requiring remediation. Also included in the evaluation is the role of environmental risks and the application of models to predict the potential for migration of soil contaminants to ground water.

3.1.1 Comparison of Contaminants to ARARs/TBCs

Soil and ground water quality are considered in the identification of potential remedial actions at Site 10. The soil and ground water contaminants are evaluated separately against appropriate chemical-specific ARARs/TBCs below. A more detailed identification and evaluation of potential chemical-specific ARARs/TBCs is presented in Appendix A.

Soil Contamination

In evaluating soil contaminant levels, available state and federal standards and guidance levels were used as ARARs/TBCs. Only a limited number of standards are applicable to soil contamination. The only identified standards and guidance levels applicable to soils were those associated with PCB and lead contamination. Therefore, these levels were used as the basis for this evaluation.

As presented in Table 3-1, TSCA includes a PCB Spill Cleanup Policy (Subpart G, 40 CFR 761.120 through 761.135) which establishes a PCB cleanup level of 10 ppm for soils to a minimum depth of 10 inches in nonrestricted access areas. This level is applicable to spills of materials containing PCBs at concentrations of 50 ppm or greater which occurred after May 4, 1987. While not applicable to Site 10, this cleanup level is to be considered in the remedial evaluation of surface soils at the site. The State of Rhode Island Department of Environmental Management (RIDEM) Rules and Regulations for Solid Waste Management Facilities define solid waste as including any soil, debris, or other material with a concentration of 10 ppm or greater PCBs, while the Rules and Regulations for Hazardous Waste Management define Type 6 - extremely hazardous waste as including waste which contains 50 ppm or greater PCBs. These definitions are also considered with respect to soil contamination at Site 10.

With respect to lead contamination, the USEPA has developed an Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02) which sets forth an interim lead soil cleanup level of 500 to 1,000 ppm, based on residential exposures. RIDEM considers a safe lead level in soil to be under 300 ppm. These guidance values will be considered in the evaluation of surface soil contamination at the site.

Table 3-1 provides a comparison of maximum detected surface soil contaminant levels to associated guidance levels. Concentrations of lead in three Phase II RI surface soil samples, 10-SS08 (343 ppm), 10-SS09 (305 ppm), and 10-SS10 (655 ppm), exceeded the RIDEM action level of 300 ppm and one Phase II RI surface soil sample (10-SS10) fell within the federal interim cleanup level range of 500 to 1,000 ppm. No other samples exhibited lead at concentrations exceeding the state or federal guidance levels. With respect to PCBs, Phase I surface soil samples exhibited no detectable levels of PCBs. The Phase II RI soil samples were not analyzed for PCBs.

The locations of the surface soil samples which contained lead at levels exceeding regulatory guidance levels are presented on Figure 3-1.

Ground Water Contamination

For ground water which is a potential source of drinking water, MCLs, MCLGs, state drinking water requirements or other health-based levels generally are appropriate for consideration as PRGs. Also considered in the evaluation are the Rhode Island Ground Water

Quality Standards as amended by RIDEM in July 1993 for Class GAA and Class GA ground waters. For those detected contaminants for which RIDEM Maximum Contaminant Levels and Ground Water Quality Standards have been established, the standards mirror the federal MCLs.

The maximum concentrations of ground water contaminants that exceed state and federal MCLs for the Phase I and Phase II RIs are presented by well location on Figure 3-2. Table 3-2 presents a comparison of maximum detected ground water contaminant levels to associated federal and state standards and guidelines.

Two inorganic contaminants were detected in ground water samples at levels exceeding either federal or state standards. During the Phase I RI, the beryllium concentration exceeded the federal MCL of 4 ppb in monitoring well 10-MW2S (5.3 ppb). However, during the Phase II RI, in which the low-flow sampling methodology was used to minimize the presence of suspended sediments in the samples, beryllium was not detected in any of the monitoring wells. The federal and state action levels for lead in drinking water are each 15 ppb, and the state Ground Water Quality Standard for lead is also 15 ppb. The concentrations of lead from two of the three ground water samples collected during the Phase I RI exceeded 15 ppb (10-MW1S at 30.5 ppb and 10-MW2S at 140 ppb). One sample from the Phase II RI exceeded the 15 ppb standard (10-MW5D at 16.5 ppb). Well 10-MW5D is located upgradient of the northernmost disposal area.

3.1.2 Human Health Risk-Based Considerations

As described in the National Contingency Plan [40 CFR 300.43(e)(2)(i)(A)(2)], "The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available...". The 10^{-6} starting point indicates U.S. EPA's preference for setting cleanup levels at the more protective end of the acceptable 10^{-4} to 10^{-6} risk range for Superfund remedial actions. Site-specific and remedy-specific factors are then taken into consideration in the determination of where within the 10^{-4} to 10^{-6} risk range the cleanup standard for a given contaminant will be established. For the purposes of this evaluation, preliminary remediation goals (PRGs) which correspond to a 10^{-6} risk are calculated. Site-specific and remedy-specific factors which may affect the determination of the final cleanup level will be addressed in subsequent portions of this document.

Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), Interim, RAGs, Volume I, Part B, (USEPA, 1991a) provides additional guidance on the development of preliminary remediation goals (PRGs). One of the initial steps in development of PRGs is the identification of the most appropriate future land use for the site so that the appropriate exposure pathways, parameters, and equations can be used to calculate PRGs. Site 10 was recently excessed to the Army and continuation of its present military use is expected. Therefore, the risk assessment scenario (Scenario 2) which evaluated risks to commercial/industrial workers based on exposures to surface soils and ground water will be used in the development of PRGs.

As a further guide to determining the media and chemicals of potential concern at a site, the OSWER directive "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (USEPA, 1991b) states that "where the cumulative site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted unless there are adverse environmental impacts." At Site 10, the cumulative carcinogenic risk to an individual based on reasonable maximum exposure to surface soils under the future commercial/industrial development scenario does not exceed 10^{-4} and the cumulative hazard index (HI) value does not exceed unity (1). Therefore, risk-based preliminary remediation goals were not calculated for Site 10 surface soils.

For ground water, the cumulative carcinogenic risk to an individual based on reasonable maximum exposure to ground water under the future commercial/industrial site use scenario is 9×10^{-5} and the non-cancer HI value is 5. Therefore, risk-based preliminary remediation goals were calculated for non-carcinogenic ground water contaminants only. The ground water contaminants which present a non-cancer hazard quotient greater than 1 under the reasonable maximum exposure scenario for future commercial/industrial use, as presented in the Human Health Risk Assessment portion of the Phase II RI Report (TRC, 1993b), were evaluated to identify those for which an ARAR/TBC has not been identified. For non-carcinogens, the presence of manganese in ground water is associated with an estimated non-cancer hazard quotient of 4.4, exceeding the point of departure of unity (1). No other compounds or analytes detected in the ground water for which no ARARs/TBCs have been identified pose a hazard quotient greater than 1. A ground water risk-based PRG of 510 ppb was calculated for manganese based on an HI of 1, as presented on Table 3-3. Additional information used in the development of risk-based PRGs is presented in Appendix B.

The Phase I and Phase II RI manganese levels for each monitoring well location at Site 10 were compared to the risk-based PRG presented in Table 3-3. The monitoring well locations at which the manganese PRG was exceeded are shown on Figure 3-3. During the Phase I RI, the PRG of 510 ppb was exceeded in only one ground water sample (10-MW2S at 1,120 ppb). Two of the eight monitoring wells sampled during the Phase II RI also had manganese concentrations which exceeded the 510 ppb limit. The sample locations and associated concentrations were 10-MW5S at 2,240 ppb and 10-MW5D at 732 ppb. Well 10-MW5D, located west of the northernmost disposal area, is located upgradient of the disposal area. Based on the presence of manganese in this monitoring well upgradient of the disposal area at levels exceeding the PRG, the elevated concentrations detected in other site wells may not be site-related. Further indicating that manganese is not site-related is the fact that manganese was found to be associated with an elevated hazard index value (i.e., greater than 1) at each site for which risks were characterized (i.e., Sites 02, 03, 06, 07, 09, 10, 11, and 13). Also, the manganese PRG is within the range of manganese concentrations detected in upgradient wells during the Phase II RI at these sites.

3.1.3 Environmental Risk-Based Considerations

As discussed in the ecological risk assessment (TRC, 1993b), Site 10 does not pose an environmental risk to the Hunt River Watershed based on the weight of evidence approach to risk evaluation. Therefore, ecological considerations will not play a significant role in the development of PRGs for the site.

3.1.4 Contaminant Migration Considerations

Another consideration in the development of remedial response objectives is the potential for contaminant migration, especially as it applies to soil contamination. Since exposures to subsurface soils are not included in the expected future use exposure scenario (commercial/industrial use) for the site, potential leaching of contaminants to the ground water is the greatest concern with respect to subsurface soil contamination. To evaluate the potential for contaminant leaching to be a major factor in contaminant migration, the "Unnamed Model" described in Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples (USEPA, 1989b) was applied to existing site data. The unnamed model is a variation of the Summers Model, also described in the above-referenced document. Both models utilize a mass balance approach in estimating the maximum allowable soil contaminant levels, assuming that the maximum allowable ground water contaminant concentration is equal to the Maximum Contaminant Level. A detailed description of both models is provided in Appendix C. Data used in the model include the volumetric flow rate of infiltration, estimated based on known precipitation and infiltration values, and the volumetric flow rate of ground water entering the site, estimated based on information obtained during the Phase I and II RIs. Using published octanol-water partition coefficients (K_{OW}) and organic carbon soil concentrations measured during the RI, the maximum allowable concentration of a contaminant in the ground water (equal to the MCL) can be related to the maximum allowable contaminant concentration in the soil in the saturated zone. The maximum concentration of a contaminant adsorbed to the soil in the unsaturated zone can then be back-calculated using a mass-balance approach. The calculations conducted for Site 10 are described in detail in Attachment C.

The results of the unnamed model calculations for Site 10, as presented in Appendix C and summarized in Table 3-4, indicate that only one contaminant detected in unsaturated soil samples was detected at a level which exceeded the estimated maximum allowable contaminant concentration in unsaturated soils which is protective of ground water quality. Benzo(a)anthracene was detected at a level of 3.4 ppm in surface soil sample 10-SS09, which exceeds the modeled maximum allowable unsaturated concentration of 3.1 ppm (based on use of the proposed MCL as the maximum allowable ground water concentration). It should be noted, however, that the model calculations are based on subsurface TOC values. TOC values for surface soil samples such as 10-SS09 could be expected to be higher than for subsurface soil samples (due to increased organic matter near the surface) and would therefore be expected to be more resistant to contaminant leaching. Even a slight increase in the TOC value (e.g., an increase from the 0.0205% used to 0.0226%) would result in the conclusion that the detected level of benzo(a)anthracene in surface soil sample 10-SS09 was not unacceptable in terms of potential leaching to the ground water.

No soil samples were collected from the saturated zone in either the Phase I RI or Phase II RI for TCL/TAL analysis; therefore, a comparison of saturated soil contaminant levels to maximum allowable saturated soil contaminant concentrations could not be made.

Another consideration in the potential migration of contaminants from site soils is the information provided by the Toxicity Characteristic Leaching Procedure (TCLP) analyses conducted during the Phase II RI on surface soil samples. Of the two samples collected and analyzed for TCLP (samples 10-B10-01 and 10-B08-01), no constituent exceeded maximum allowable TCLP levels. Therefore, available TCLP analyses support the unnamed model results in indicating that minimal leaching of contaminants from soils could be expected, especially considering that the leaching conditions at Site 10 would be expected to be less severe than those employed in the TCLP analysis.

3.2 Remedial Action Objectives

The remedial action objectives developed to guide the implementation of a remedial response at Site 10 are presented by environmental medium below.

3.2.1 Soils

The Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02) states that the federal guidance level for lead, 500 to 1,000 ppm, is protective for direct contact at residential settings. Only one surface soil sample (10-SS10) exhibited a lead concentration (655 ppm) within the guidance level range. The OSWER Directive also adopts the recommendation contained in the 1985 Centers for Disease Control (CDC) statement that reads, "... lead in soil and dust appears to be responsible for blood levels in children increasing above background levels when the concentration in the soil or dust exceeds 500 to 1000 ppm." Since the most likely future site use is military (commercial/industrial), not residential, long-term exposures to children would not be anticipated. Concentrations of lead detected in three surface soil samples (10-SS08, 10-SS09, 10-SS10) exceeded the RIDEM guidance level of 300 ppm.

One surface soil sample also exhibited a contaminant which slightly exceeds the maximum allowable contaminant concentration indicated by the leaching model as being protective of ground water quality. Sample 10-SS09 contained benzo(a)anthracene at a level of 3.4 ppm, which exceeds the maximum allowable modeled concentration of 3.1 ppm. Considering the limited nature and extent of contamination detected at levels exceeding the maximum modeled concentrations, the presence of the elevated contaminant level in a surface soil sample, which would tend to have a higher organic content than the subsurface soil samples used in the model (and would tend to leach less), and the lack of detection of any semivolatile organic compounds in either phase of ground water investigations at Site 10, leaching of contaminants from unsaturated soils to the ground water does not appear to pose a significant concern at the site.

Therefore, based on the analysis presented above, the lack of human health risks associated with exposures to surface soil contaminants under future commercial/industrial site use, the lack of environmental risks associated with Site 10 soil contaminants, and the minimal potential impact to ground water as indicated by the results of the leaching model evaluation, the remedial action objective for Site 10 is as follows:

- Prevent residential exposures to surface soil lead levels which exceed 300 ppm, as presented in Table 3-1.

3.2.2 Ground Water

Ground water at Site 10 is classified as GAA-NA, indicating a ground water resource suitable for public drinking water without treatment but located in a non-attainment area which is known or presumed to be out of compliance with the assigned ground water quality standards. The southern portion of Site 10 is also located within the ground water capture zone for a proposed well location identified in the Phase I Report, Hunt River Aquifer Wellhead Recharge Area Study (GZA, 1992) and private potable wells may be located downgradient of the site. Based on the presence of inorganic contaminants in ground water at levels exceeding ARARs/TBCs and PRGs, the remedial action objective for ground water is as follows:

- Prevent exposure, due to ground water ingestion, to contaminants which are present at levels exceeding acceptable ARARs/TBCs as indicated in Table 3-2, or which exceed risk-based preliminary remediation goals as indicated in Table 3-3.

3.3 General Response Actions

General response actions are those remedial actions which will satisfy the remedial response objectives. The first step in determining appropriate general response actions for Site 10 is an initial determination of the areas or volumes to which the general response actions may be applied. In determining these volumes/areas of media, consideration has been given to site conditions, the nature and extent of contamination, acceptable exposure levels and potential exposure routes.

3.3.1 Soils

As indicated in Section 3.2.1, the remedial action objective for soils at Site 10 is to eliminate potential residential exposures to contaminated surface soils. Existing soil quality does not pose a significant concern under continued military use or potential commercial/industrial site use. As indicated in Figure 3-1, only three surface soil samples (two located in the northernmost disposal area and an additional sample located at the base of the berm separating Site 10 from the firing range area) exceeded the 300 ppm RIDEM lead guidance level. Based on the limited exceedances of the 300 ppm level and the improbability of residential site use, the general response actions identified for site soils are as follows:

- No Action
- Institutional Control

3.3.2 Ground Water

In order to provide a preliminary estimate of the volume of ground water requiring remediation, the extent of ground water contamination at levels exceeding ground water ARARs/TBCs and risk-based cleanup standards must be evaluated. As discussed in Section 3.1.1 and 3.1.2, inorganic constituents present in ground water samples at Site 10 exceed MCLs or risk-based PRGs. The area of ground water containing inorganics at levels exceeding MCLs and risk-based PRGS was estimated to encompass approximately 214,000 square feet. Using an estimated average saturated thickness of 15 feet, and assuming a conservative effective porosity of 20%, the volume of ground water containing inorganics at levels exceeding MCLs or risk-based PRGs at Site 10 is on the order of 4.8 million gallons. The uncertainty associated with the estimate is high, based on the presence of both lead (at a level which exceeds the drinking water action level) and manganese (at a level which exceeds the risk-based PRG) in the upgradient deep well.

A listing of general response actions developed for ground water at Site 10 is provided below.

- No Action
- Institutional Control
- Extraction/Treatment/Discharge

3.4 Identification and Screening of Technologies and Process Options

The general response actions are developed further through the identification and screening of remedial technologies which could potentially meet the remedial action objectives and PRGs. Following a screening of the remedial technologies on the basis of technical implementability, the process options associated with each technology are screened based on effectiveness, implementability and cost. Representative process options are chosen for inclusion in the remedial alternatives developed for the site.

While technology and process option screenings were conducted in the Initial Screening of Alternatives Report (TRC, 1993a), the screening process is re-evaluated herein based on the results of the Phase II RI and the impact of those results on the remedial action objectives for the site.

3.4.1 Technology Screening

The technology screening performed for Site 10 is presented for soil in Table 3-5 and for ground water in Table 3-6. The table includes brief descriptions of the individual technologies or process options, and comments on their technical implementability. Technologies which are screened from further consideration are shaded in the technology screening tables. More detailed descriptions of the screening process and the technologies considered are provided in Appendix D.

3.4.2 Process Option Screening

Upon identification of those technologies which are technically implementable, the process options are further evaluated to allow the selection of representative process options to be used in the development of remedial alternatives. The process options are evaluated on the basis of effectiveness, implementability, and cost. The process option screening is presented for soil and ground water in Tables 3-7 and 3-8, respectively. The selected representative process options are indicated with a bullet in the process option screening tables. Table 3-9 summarizes the technologies and process options which passed the technology screening, with selected representative process options indicated with a bullet. More details on the representative process option selection process are provided in Appendix D.

3.5 Remedial Alternative Development

The selected technologies and process options identified in Section 3.4.2 are combined as appropriate in this section to form remedial alternatives. The developed range of alternatives is intended to provide a streamlined evaluation of possible remedial actions. The alternatives presented herein have been developed in accordance with the expectations of the Superfund program, as outlined within the NCP. Rather than combining alternatives for the various media, the alternatives developed for each media will be evaluated separately to allow greater flexibility in determining the overall remedial action for the site. The remedial alternatives developed for soil and ground water at Site 10 are presented in Table 3-10.

4.0 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

Each of the remedial alternatives developed for the site, as presented in Section 3.5, is further defined and then undergoes a detailed analysis. Following the detailed analysis of individual alternatives, a comparative analysis is conducted between alternatives.

4.1 Evaluation Criteria

The NCP defines nine evaluation criteria to be considered in the detailed analysis of alternatives. The evaluation criteria are divided into three groups; threshold criteria, which relate to statutory requirements that each alternative must satisfy; balancing criteria, which are the technical criteria that are considered during the detailed analysis; and modifying criteria, which are formally assessed after the public comment period. The nine criteria include the following:

Threshold Criteria

- Overall protection of human health and the environment;
- Compliance with applicable or relevant and appropriate requirements (ARARs);

Balancing Criteria

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability;
- Cost;

Modifying Criteria

- Community acceptance; and
- State acceptance.

When evaluating alternatives in terms of overall protection of human health and the environment, consideration is given to the manner in which site-related risks are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls. Long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs are given major consideration in determining the overall protection offered by each alternative.

The alternatives are assessed to determine whether they attain applicable or relevant and appropriate requirements (ARARs) under federal environmental laws and state environmental laws and state environmental or facility siting laws. The identification of ARARs in a site-specific process which is dependent on the specific hazardous substances, pollutants, and contaminants at a site, the physical characteristics of a site, and the remedial actions under consideration at a site. Therefore, it is an iterative process which requires re-examination throughout the RI/FS process, until a Record of Decision (ROD) is issued. A preliminary ARARs analysis is presented in Appendix A of this document. In the following alternative analysis, the individual remedial alternatives will be evaluated in detail to determine their compliance with ARARs/TBCs which are applicable to the specific media being addressed by the remedial action, and the potential impacts of ARARs/TBCs on the alternative's implementation.

An alternative that does not meet an ARAR may be selected as a remedial action under several circumstances, including the following:

- If the alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement;
- If compliance with the requirement will result in greater risk to human health and the environment than other alternatives;
- If compliance with the requirement is technically impracticable from an engineering perspective;
- If the alternative will attain an equivalent standard of performance through the use of another method or approach; or
- If the ARAR is a state requirement that the state has not consistently applied in similar circumstances.

Each alternative is also evaluated for long-term effectiveness and permanence, in which the magnitude of residual risk remaining from untreated waste or treatment residuals and the adequacy and reliability of containment systems and institutional controls is evaluated. The degree to which alternatives employ recycling or treatment to reduce toxicity, mobility, or volume is assessed, including how treatment is used to address the principal threats at the site.

The short-term effectiveness evaluation takes into consideration the short-term risks that might be posed to on-site workers, the surrounding community, or the environment during implementation, as well as the time until protection is achieved. The analysis of implementability considers the technical feasibility and administrative feasibility of implementation, as well as the availability of required materials and services. The cost analysis evaluates capital (direct and indirect) costs and annual operation and maintenance (O&M). The net present value of capital and O&M costs is presented for each alternative.

In selecting a remedial action, the following criteria must be considered. Each selected remedial action shall meet the threshold criteria, and thereby be protective of human health and the environment. Provided the remedy meets the threshold criteria, it shall also be cost effective. The overall effectiveness of an alternative is determined by evaluating long-term effectiveness and permanence, reduction of toxicity, mobility, or volume through treatment, and short-term effectiveness. The alternative is then evaluated with regard to cost to ensure that it is cost-effective. Each remedial action shall also utilize permanent solutions and alternative treatment technologies to the maximum extent practicable. This requirement is fulfilled by selecting the alternative that satisfies the threshold criteria and provides the best balance of trade-offs among alternatives in terms of the five balancing criteria, with an emphasis on long-term effectiveness and reduction of toxicity, mobility, and toxicity through treatment.

4.2 Soil Alternative Individual Descriptions and Evaluations

4.2.1 Alternative S-1 - No Action Alternative Description

The NCP requires consideration of the no action alternative to, at a minimum, provide a baseline for comparison with other alternatives. The no action alternative would involve no remedial response activities with respect to soil at Site 10. The three surface soil sample locations, located in the northernmost disposal area and adjacent to the firing range berm, where lead concentrations were detected at levels exceeding the RIDEM guidance level, would remain. The need for five-year reviews of the no action decision would require a risk management decision, since these areas of contamination which exceed the RIDEM lead guidance level will remain on-site.

An evaluation of the no action alternative with respect to federal and state chemical-specific and location-specific ARARs/TBCs is presented in Tables 4-1 and 4-2, respectively. Since there are no actions involved with this alternative, action-specific ARARs do not apply.

An evaluation of the no action alternative with respect to the evaluation criteria is presented below.

4.2.2 Alternative S-1 - No Action Alternative Evaluation

Overall Protection of Human Health and the Environment - The no action alternative would be protective of human health and the environment under the proposed future commercial/industrial site use based on the lack of identified human health risks and environmental risks associated with the site soils and the minimal potential for impacts to ground water, as indicated by the leaching model evaluation. The present use of the site by the U.S. Army makes future residential use improbable, although a potential could exist for future residential exposures if the Army ever excesses the property. If the site were to be developed for residential use, the limited areal extent of soil lead contamination would limit the risks associated with future residential use. Alternative S-1 does not meet state chemical-specific TBCs for lead but falls within the federal TBC lead range.

Compliance with ARARs - Since this alternative does not address lead in soils, it does not meet state chemical-specific TBCs; contaminant levels wold fall within the federal action level range for lead, however. Since there are no actions involved in this alternative, action-specific ARARs/TBCs do not apply, and compliance with location-specific ARARs, as noted in Table 4-2, would be maintained.

Long-Term Effectiveness and Permanence - The no action alternative would be effective in the long-term, as long as the site remains under control of the U.S. Army. This alternative would also be effective in the long-term if the site was ever developed for commercial/industrial purposes, based on the lack of identified unacceptable risks to human health and the environment. The need for five-year reviews of the no action decision would require a risk management decision, since a limited area of contamination exceeds the RIDEM lead guidance level.

Reduction of Toxicity, Mobility, or Volume through Treatment - The no action alternative does not include any treatment methods. The alternative offers no significant reductions in the toxicity, mobility, or volume of contamination through treatment. However, based on the limited extent and nature of contamination, reduction of toxicity, mobility, or volume may not be required.

Short-Term Effectiveness - The no action alternative does not result in any increased short-term risks due to the lack of activities associated with its implementation and the minimal potential risks to human health and the environment posed by the site soils.

Implementability - The no action alternative would require no implementation other than potential five-year reviews of the no action decision. Its implementation would not limit the future implementation of additional remedial actions.

Cost - The cost associated with the no action alternative would be the nominal cost associated with conducting the five-year reviews, if necessary.

4.2.3 Alternative S-2 - Limited Action Alternative Description

Alternative S-2 was developed as a limited action option which provides no active source control but limits potential risks to human health through the construction of a fence around the contaminated portions of the site and/or implementation of a mechanism for establishing deed restrictions should the U.S. Army ever transfer the property to another owner. A chain-link fence would be placed around the perimeter of the northernmost disposal area and the area immediately surrounding SS-10 to limit access to those soils with elevated levels of lead. Additional sampling may be appropriate to further define surface soil quality between these two areas. Approximate fence locations are indicated in Figure 4-1. Warning signs would be placed on the fence to warn any trespassers of the potential hazards associated with existing site conditions. Deed restrictions would be implemented to restrict future site use should the site ever be transferred from federal ownership.

An evaluation of Alternative S-2 with respect to federal and state chemical-specific and location-specific ARARs/TBCs is presented in Tables 4-1 and 4-2, respectively. No action-specific ARARs/TBCs are associated with this alternative.

An evaluation of the limited action alternative with respect to the evaluation criteria is presented below.

4.2.4 Alternative S-2 - Limited Action Alternative Evaluation

Overall Protection of Human Health and the Environment - Alternative S-2 would protect human health and the environment under the present military site use or potential future commercial/industrial site use, based on the lack of identified human health risks and environmental risks. The limited action would also limit the potential for future residential exposures by restricting the future use of the site through fencing or future site use restrictions. Through fencing, the action would limit potential exposures due to direct contact with the soils at the site. Deed restrictions would be implemented to prevent future residential site use and development, should the property be excessed by the U.S. Army, and would thereby prevent the residential exposures upon which the chemical-specific TBCs are based.

Compliance with ARARs - Alternative S-2 complies with federal and state chemical-specific TBCs for lead, as noted in Table 4-1, by preventing potential future residential site development. Implementation of the fencing component of the alternative would be conducted in accordance with applicable location-specific ARARs, as noted in Table 4-2. No action-specific ARARs/TBCs were identified for the construction of a perimeter fence or implementation of site use restrictions.

Long-Term Effectiveness and Permanence - Alternative S-2 relies on the limitation of future residential site use to limit contact with lead contamination which will remain on-site at a level above the state TBC. Since no unacceptable human health risks or environmental risks were identified under a commercial/industrial site use scenario and given the site's federal ownership and present use as a firing range, the limited action alternative would have good long-term effectiveness in protecting human health and the environment. Long-term effectiveness could be impacted if the U.S. Army ever excesses the property. Establishment of deed restrictions on site development at that time would ensure continued protectiveness. A risk management evaluation would be required to determine if five-year reviews of Alternative S-2 are necessary.

Reduction in Toxicity, Mobility, or Volume through Treatment - Alternative S-2 provides no treatment of site contamination and therefore no associated reduction in contaminant toxicity, mobility, or volume. Site access or development restrictions would prevent the potential for exposure associated with future residential site use.

Short-Term Effectiveness - Minimal short-term risks would result from the implementation of Alternative S-2. Routine construction activities would be required to install the fence. Since no unacceptable human health risks have been identified under the construction future use scenario at Site 10, no short-term risks would be expected due to construction of the fence. No increased off-site risks would result from the implementation activities. Implementation is expected to take less than one month.

Implementability - The construction of a fence would be fairly easy to implement, since associated materials and equipment are readily available, and the contaminated area is small in areal extent. The construction of the fence would not limit the activities presently conducted at Camp Fogarty by the U.S. Army. A mechanism, such as modification of the existing transfer of custody and maintenance agreement established when Camp Fogarty was transferred from the Navy to the Army, would be required to ensure implementation of deed restrictions should the Army ever excess the property from federal ownership. Implementation of Alternative S-2 would not be expected to limit the implementation of future remedial actions, if necessary.

Cost - Costs associated with the implementation of S-2 would be those associated with fence placement and the establishment of land use restrictions. The cost of implementation for Alternative S-2 is estimated to include $10,000 in direct capital costs, $1,500 in indirect capital costs, and $300 in annual operation and maintenance costs ($4,600 net present value). The net present worth value of this alternative, including contingency, is estimated at $20,000. A detailed cost estimate is presented in Appendix E.

4.3 Soil Alternatives Comparative Evaluation

A comparative analysis is conducted to evaluate the differences between the soil remedial alternatives based on the threshold and balancing criteria. Tabular comparisons of the two alternatives based on the seven evaluation criteria are presented in Tables 4-3 through 4-9.

4.3.1 Overall Protection of Human Health and the Environment

A comparative analysis of the remedial alternatives with respect to their overall protection of human health and the environment is presented in Table 4-3.

Based on existing site contamination and existing site use, Alternative S-2 would provide protection of human health by limiting potential exposures to site soils through fencing and/or deed restrictions. While fencing would limit access to the site, the implementation of future deed restrictions would prevent the potential for future residential site use should the Army relinquish ownership of the site, thereby reducing the potential for residential exposures to lead in site surface soils. Alternative S-2 is effective in both the short-term and the long-term.

The no action alternative would also be considered protective of human health under the present use of the site as a firing range. However, Alternative S-1 would not provide a means of limiting future use of the site if the U.S. Army ever excesses the property. Alternative S-1 is effective in both the short-term and the long-term, provided residential exposures do not occur.

4.3.2 Compliance with ARARs

A comparative analysis of the remedial alternatives with respect to their compliance with ARARs is presented in Table 4-4.

Neither alternative provides direct remediation of site soils; therefore, lead would remain on-site at levels which do not meet the state chemical-specific TBC for lead, but which fall within the acceptable federal TBC range. Alternative S-2 provides greater compliance with the chemical-specific TBCs by preventing future residential site development. Implementation of the fencing component of Alternative S-2 would be conducted in accordance with location-specific ARARs. No action-specific ARARs/TBCs were identified as being applicable to these alternatives.

4.3.3 Long-Term Effectiveness and Permanence

A comparative analysis of the remedial alternatives with respect to long-term effectiveness and permanence is presented in Table 4-5.

Both alternatives would be effective in the long-term under the current ownership of the site by the U.S. Army, based on the lack of identified unacceptable risks to human health and the environment under commercial/industrial site use. Alternative S-2 relies on institutional controls to limit potential future residential exposures to site contamination if the U.S. Army ever excesses the property. The alternative would require long-term maintenance of site fencing and/or deed restrictions to maintain its effectiveness. Alternative S-1 would not provide the same degree of long-term effectiveness as Alternative S-2 since no fencing or deed restrictions would be implemented to limit potential future residential exposures to site contamination, in the event that the Army transfers ownership of the property to another party.

4.3.4 Reduction of Toxicity, Mobility and Volume Through Treatment

A comparative analysis of the remedial alternatives with respect to reduction of toxicity, mobility and volume through treatment is presented in Table 4-6.

Alternative S-1 and Alternative S-2 provide no active remediation of site soils; therefore neither alternative offers reductions in the toxicity, mobility or volume of contamination on-site through treatment. However, based on the limited extent and nature of soil contamination, a reduction of toxicity, mobility or volume may not be required.

4.3.5 Short-Term Effectiveness

A comparative analysis of the remedial alternatives with respect to short-term effectiveness is presented in Table 4-7.

Alternative S-1 would not result in any increased short-term risks due to the lack of activities associated with its implementation. While it would meet remedial action objectives in the short-term (based on current site use), it would not ensure compliance in the long-term. Minimal short-term risks are associated with the implementation of fence installation under Alternative S-2, since only routine construction activities would be required. Alternative S-2 would meet remedial action objectives and ensure long-term compliance within a short time frame.

4.3.6 Implementability

A comparative analysis of the remedial alternatives with respect to implementability is presented in Table 4-8.

Alternative S-1 requires no implementation other than five-year reviews (as required). Alternative S-2 is easily implemented from a technical standpoint, requiring the implementation of deed restrictions and/or construction and maintenance of site fencing. The restriction of access due to site fencing would not hinder the use of the remainder of Camp Fogarty as a firing range. From an administrative standpoint, a mechanism would have to be established to ensure the implementation of deed restrictions should the U.S. Army relinquish ownership of the site. Alternative S-2 would also require five-year reviews (as necessary). Neither alternative would limit the implementation of other remedial actions.

4.3.7 Cost

A comparative analysis of the remedial alternatives with respect to cost is presented in Table 4-9.

The no action alternative is the least costly alternative, the only cost being the nominal cost associated with the five-year reviews (as necessary). Alternative S-2 has a total estimated present worth cost of $20,000.

4.4 Ground Water Alternative Individual Descriptions and Evaluations

Three ground water remedial alternatives were developed, as described below.

4.4.1 Alternative GW-1 - No Action Alternative Description

The NCP requires consideration of the no-action alternative; at a minimum, it provides a baseline for comparison with other alternatives. This alternative would involve no remedial response activities with respect to ground water. No removal or treatment of ground water which contains lead at levels exceeding the drinking water action level or manganese at levels exceeding the risk-based PRG would be conducted. Because remaining contamination would not allow for unlimited future use of the site, five-year reviews of the no action decision would be required.

An evaluation of the no action alternative with respect to federal and state chemical-specific and location-specific ARARs/TBCs is presented in Tables 4-10 and 4-11, respectively. Since the alternative involves no actions, no action-specific ARARs/TBCs were identified for this alternative.

4.4.2 Alternative GW-1 - No Action Alternative Evaluation

Overall Protection of Human Health and the Environment - The no action alternative does not address the presence of lead, which was detected in one well (using the low-flow sampling methodology) at a level slightly exceeding its drinking water action level. Similarly, the presence of manganese at levels exceeding risk-based preliminary remediation goals would not be addressed; manganese appears to be present facility-wide, however, and may not be directly attributable to the site. Based on the minimal exceedance of the lead action level and the lack of unacceptable environmental risks identified within the Hunt River Watershed, the lack of ground water treatment is not expected to result in significant risks to human health and the environment. While a public water supply well has been proposed to be located near the site, such that the southern portion of the site would be located within its capture zone, the potential risks associated with the detected presence of lead if such a well should be constructed are difficult to evaluate based on the limited amount of data collected using the low-flow sampling methodology. A search of potential private potable well users also identified several streets to the east and north of Site 10 where private potable wells may be located (see Section 1.4.3 and Figure 1-6 of Volume I). Therefore, the degree of long-term protection of human health offered by the no action alternative is difficult to evaluate. Implementation of this alternative results in no short-term impacts to the site or surrounding areas.

Compliance with ARARs - Based on the presence of lead at a level exceeding the lead drinking water action level in an upgradient deep well during the Phase II RI, this alternative would not meet chemical-specific ARARs, as listed in Table 4-10. The lack of monitoring or remediation activities associated with this alternative would not provide a means of monitoring continued compliance with state location-specific ARARs related to ground water quality, as indicated in Table 4-11. No action-specific ARARs/TBCs were identified for this alternative.

Long-Term Effectiveness and Permanence - The no action alternative would be effective in the long-term provided ground water is not used as a drinking water supply on-site. The no action alternative would not bring ground water into compliance with Class GAA ground water standards, and, if the proposed public water supply well is installed in the vicinity of Site 10, potential impacts to off-site ground water quality are difficult to predict on the basis of existing data. Potential impacts to the environment are not expected based on the current lack of significant environmental risks attributable to metals within the Hunt River Watershed. Due to the presence of lead and manganese at levels which do not allow for unrestricted ground water use, five-year reviews of the no action decision would be required under the NCP.

Reduction of Toxicity, Mobility, or Volume through Treatment - The no action alternative does not include any treatment methods other than naturally occurring degradation or attenuation processes. Therefore, the alternative offers no significant reductions in the toxicity, mobility, or volume of ground water contaminants through treatment.

Short-Term Effectiveness - The no action alternative does not present any increased short-term risks due to the lack of activities associated with its implementation. The five-year review would provide the only means of ensuring continued compliance with remedial action objectives.

Implementability - The no action alternative would require no implementation other than the five-year reviews of the no action decision. Its implementation would not limit the future implementation of additional remedial actions.

Cost - The cost associated with the no action alternative would be the nominal cost associated with the five-year reviews.

4.4.3 Alternative GW-2 - Limited Action Alternative Description

Alternative GW-2 consists of the institution of ground water use restrictions and/or ground water monitoring. Ground water use restrictions would not provide active ground water remediation but would limit potential risks to human health through the implementation of institutional controls, such as deed restrictions, to limit future potable ground water use on-site. Deed restrictions would only be implemented if the U.S. Army were to transfer the property to a non-federally-owned entity.

Long-term (30-year) ground water monitoring, consisting of annual monitoring of the existing monitoring wells, is included in the limited action alternative. The long-term monitoring would provide a means of further defining ground water quality at the site and of identifying any ground water quality changes over time.

Rhode Island Rules and Regulations for Ground Water Quality include methods of establishing for a facility a point of compliance, which is used to determine compliance with ground water quality standards. They also define appropriate responses to a violation of a ground water quality standard at the point of compliance. The establishment of a ground water monitoring program is included in the regulations' list of potential responses to a ground water quality standard violation. Seeing as lead was present in only one well (when using the low-flow sampling methodology) at a level slightly exceeding its ground water quality standard, the definition of a facility-specific point of compliance and the establishment of a ground water monitoring program could be a potential means of further defining the presence of lead in ground water at the site and of further defining if a violation of the ground water quality standard exists. The proposed monitoring time frame (30 years) could be reduced if subsequent monitoring indicates that ground water quality at the point of compliance is acceptable.

An evaluation of Alternative GW-2 with respect to federal and state chemical-specific, location-specific, and action-specific ARARs/TBCs is presented in Tables 4-10 through 4-12.

4.4.4 Alternative GW-2 - Limited Action Alternative Evaluation

Overall Protection to Human Health and the Environment - Implementation of the limited action option would protect human health by limiting potential future exposures to lead in the ground water which could occur should a drinking water supply well be installed on-site. This alternative is not expected to result in adverse impacts to the environment, based on the current lack of significant environmental risks identified for the Hunt River Watershed. The ground water monitoring component would provide a means of further defining the presence of lead in ground water at the site and the potential impacts of the presence of lead on the proposed installation and operation of a public water supply well to the east-southeast of the site or on potential private well users who may exist in the vicinity of Site 10. It would also provide a means of monitoring the long-term effectiveness of the alternative. Implementation of this alternative results in no short-term impacts to the site or surrounding areas.

Compliance with ARARs - Based on the presence of lead at a level exceeding the lead drinking water action level in the upgradient deep well during the Phase II RI, this alternative would not achieve chemical-specific ARARs, as listed in Table 4-10. Ground water monitoring activities would be conducted in compliance with location-specific ARARs, as indicted in Table 4-11. Ground water monitoring would be conducted in accordance with RIDEM's Rules and Regulations for Ground Water Quality, as indicated in Table 4-12.

Long-Term Effectiveness and Permanence - Provided deed restrictions are implemented and enforced, they can be effective in minimizing the long-term risks associated with the potential construction and use of an on-site well as a source of drinking water. Since contaminants will remain on site at levels which do not allow for unlimited use and unrestricted exposure, five-year reviews of Alternative GW-2 would be required. The monitoring program would provide a means of monitoring potential changes in ground water quality at Site 10. If monitoring indicated that ground water quality was deteriorating or contaminants were migrating, additional remedial measures could be implemented, as necessary.

Reduction of Toxicity, Mobility or Volume through Treatment - Alternative GW-2 provides no treatment nor associated reduction of contaminant toxicity, mobility or volume.

Short-Term Effectiveness - Since implementation of deed restrictions is an administrative effort, no short-term risks would result from implementation of this option. This option would meet remedial response objectives related to minimizing potential human exposure to contaminated ground water due to on-site potable well installation. Implementation of the monitoring program would have minimal short-term adverse impacts based on the use of existing wells for ground water monitoring purposes.

Implementability - A mechanism would have to be established to ensure the implementation of deed restrictions should the U.S. Army relinquish ownership of the site. The prohibition of future installation of a water supply well on-site would not impact the present use of the site as a firing range. Implementation of this alternative would not limit the implementation of future remedial actions.

Cost - The costs associated with the implementation of deed restrictions would primarily be limited to legal costs. The costs associated with ground water monitoring include the long-term sampling, analysis, and reporting costs. The overall cost includes $8,300 in annual operation and maintenance costs ($130,000 net present value). The present worth value of this alternative, including contingency, is estimated at $150,000. A detailed cost estimate is provided in Appendix E.

4.4.5 Alternative GW-3 - Extraction/Treatment/Discharge Alternative Description

Alternative GW-3 consists of active remediation of the ground water to meet the chemical-specific ARARs for lead and risk-based PRG for manganese. The alternative would provide hydraulic control of the ground water at the site, thereby reducing potential off-site migration, but would not address the unidentified source of lead detected in the upgradient well.

The extraction/treatment/discharge alternative would consist of separate options which would be combined to form a complete alternative. These options are described in detail in Sections 4.4.7 through 4.4.14. This discussion and the evaluation presented in Section 4.4.6 focus on the extraction/treatment/discharge alternative in general terms, and will provide a basis for alternative comparisons.

The main contaminants of concern in ground water at Site 10 are lead and manganese. The results of the Phase I RI ground water sampling also indicated the presence of beryllium in one sample at a level exceeding the MCL. However, during the Phase II RI, in which the low-flow sampling methodology was used to minimize the presence of suspended sediments in the samples, beryllium was not detected above the MCL in any of the Phase II monitoring wells. Therefore, the evaluation of the extraction/treatment/discharge options will focus on the treatment of lead and manganese.

Lead was detected at levels exceeding the drinking water action level of 15 ppb in two of the three wells sampled during the Phase I RI; however, it was present only in an upgradient well (10-MW5D) at a level (16.5 ppb) exceeding the federal action level during the Phase II RI, when the low-flow sampling methodology was used. Although lead contamination may not be site-related, it will be considered in the evaluation of the extraction/treatment/discharge options.

Manganese, the other inorganic contaminant of concern, was present in one of the three wells sampled during the Phase I RI at a level exceeding the risk-based PRG, and was present in two of the eight wells (10-MW5S and 10-MW5D) sampled during the Phase II RI at levels exceeding the PRG. However, as previously discussed in Section 3.1.2, the manganese PRG is within the range of manganese concentrations detected in upgradient wells at all of the Davisville sites and, therefore, is not considered to be a site-related contaminant. Treatment of manganese will be considered in the evaluation of extraction/treatment/discharge options, however.

An evaluation of Alternative GW-3 and its associated options with respect to federal and state chemical-specific, location-specific and action-specific ARARs/TBCs is presented in Tables 4-13 through 4-15, respectively.

4.4.6 Alternative GW-3 - Extraction/Treatment/Discharge Alternative Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-3 would provide active treatment of ground water at Site 10, and therefore, would provide a reduction in potential future risks to human health and the environment which could be associated with contaminated ground water migration. Its long-term effectiveness would be good as long as the treatment system was operational. If treatment was discontinued, lead or manganese could return to the site, based on their presence in the upgradient deep well. The extraction/treatment/discharge options would be designed to comply with location-specific and action-specific ARARs/TBCs.

Compliance with ARARs - Alternative GW-3 would be designed to treat ground water contaminants present at levels exceeding ARARs, as indicated in Table 4-13. The extraction, treatment, and discharge systems would be operated in accordance with location-specific and action-specific ARARs as indicated in Tables 4-14 and 4-15, respectively. A more detailed identification of the action-specific and location-specific ARARs applicable to this alternative is provided in the individual options evaluations which follow.

Long-Term Effectiveness and Permanence - Ground water treatment would be effective in treating lead and manganese and in preventing off-site migration of inorganic contaminants during operation. Effective ground water treatment could return the ground water at Site 10 to

Class GAA quality, but would not necessarily result in a permanent contaminant reduction if ground water treatment is discontinued at some point in the future. Long-term ground water monitoring would be required to evaluate the effectiveness of the alternative after operations cease. Since contaminants would be present on-site during the operating period at levels which do not allow for unlimited use and unrestricted exposure, five-year reviews of Alternative GW-3 would be required.

Reduction of Toxicity, Mobility or Volume through Treatment - Alternative GW-3 would utilize treatment to reduce the toxicity and mobility of existing ground water contaminants.

Short-Term Effectiveness - No significant risks to on-site workers or off-site risks are anticipated as a result of implementation of this alternative. The degree of short-term risk would be dependent upon the individual options employed. Remedial response objectives would be achieved during operation of the treatment system but may not be maintained if treatment is discontinued.

Implementability - Implementation of a ground water extraction, treatment, and discharge system would be fairly easy, with the possible exception of the discharge component. The technical implementability would be dependent upon the individual alternative options selected, with some treatment technologies more easily implemented than others. Services and materials should be readily available for the implementation of all options.

Cost - The cost of this alternative is dependent on the operational period as well as the individual options utilized in the final alternative. Based on the individual option evaluations presented in the following sections, the total cost of Alternative GW-3 is estimated to range from $730,000 for ion exchange to $1,400,000 for chemical precipitation.

4.4.7 Alternative GW-3A - Ground Water Extraction via Extraction Wells Option Description

Initial modeling was conducted to evaluate a potential ground water extraction system design, as described in detail in Appendix F. The computer ground water flow model FLOWPATH was used to simulate the flow regime at the site in order to arrive at an optimal configuration of extraction wells. The aquifer was assumed to be comprised of native fine to coarse sand with variable silt and gravel content with a boulder layer overlying the bedrock surface. After the initial model calibration, an extraction scenario was simulated.

The extraction simulation indicated that four extraction wells pumping at 0.75 gallons per minute (gpm) are necessary to provide capture and extraction of the ground water at the site. The extraction wells would be installed at the locations of 10-MW1S, 10-MW2S, 10-MW3S, and 40 feet north of 10-MW5S, as indicated in Figure 4-2. Ground water would be extracted at a total rate of 3 gpm, although the treatment system will be designed to allow for up to 10 gpm flow rate. It has been assumed that the ground water extraction system would operate for thirty years, which would allow for the removal of a minimum of ten pore volumes of ground water.

4.4.8 Alternative GW-3A - Ground Water Extraction via Extraction Wells Option Evaluation

Overall Protection of Human Health and the Environment - Use of extraction wells to remove ground water for treatment would be protective of both human health and the environment. Ground water would be extracted from the wells and piped directly to an on-site treatment system. The treatment system would be designed to comply with applicable ARARs, would be effective and reliable in the long-term, and would have minimal short-term risks associated with its installation and operation.

Compliance with ARARs - The proposed ground water extraction system has been developed to capture ground water containing lead at levels exceeding the drinking water action level and manganese at levels exceeding the risk-based PRG. Therefore, it has been developed to provide compliance with chemical-specific ARARs, as presented in Table 4-13. Ground water extraction activities would be conducted in compliance with location-specific ARARs, as indicated in Table 4-14. Extraction wells will be constructed and operational in accordance with RIDEM Site Remediation Regulations, as indicated in Table 4-15.

Long-Term Effectiveness and Permanence - Extraction wells are an effective and reliable means of extracting ground water. They are well-proven in their performance and generally can function with minimal maintenance.

Reduction of Toxicity, Mobility or Volume through Treatment - The ground water extraction option does not provide treatment although it would be combined with a treatment option in a final alternative. By extracting contaminated ground water, the contaminants' potential mobility is reduced.

Short-Term Effectiveness - Installation of extraction wells would present minimal short-term risks to on-site workers and would not be expected to result in any increased off-site risks to human health or the environment. Extraction wells could be implemented within a minimal time frame.

Implementability - The implementability of a ground water extraction system is expected to be good. Materials and services are readily available and minimal technical or administrative obstacles to implementation would be anticipated.

Cost - The major cost component associated with implementation of Alternative GW-3A is the cost of installation of the extraction wells. The estimated cost of Alternative GW-3A consists of $43,000 in direct capital costs and $6,000 in indirect capital costs. The present worth value of this alternative, including contingency, is estimated at $58,000. A detailed cost estimate is presented in Appendix E.

4.4.9 Alternative GW-3B - Precipitation Inorganic Treatment Option Description

Alternative GW-3B involves the treatment of inorganic ground water contaminants using chemical reduction and precipitation. Chemical precipitation is an inorganic removal method often used in industrial as well as ground water remediation applications.

For this evaluation, it is assumed that the chemical precipitation treatment system will include a filtration unit to remove gross solids prior to treatment and a flow equalization tank. The provision of an initial filtration system could result in reduced reagent costs and smaller equipment sizing for the remainder of the treatment system. A typical precipitation system includes the following:

- Reaction tank including mixers and pH control instrumentation;
- Chemical feed system, including a storage tank, mixers, level instrumentation, and metering equipment;
- Clarifier;
- pH adjustment tank;

Filter; and
Solidification/stabilization system.

A schematic of a typical system is provided on Figure 4-3.

The extracted ground water flows from the filtration system, through the equalization tank, and into the reaction tank. In the reaction tank, a reagent is added to adjust the pH of the wastestream to the level required for optimum precipitation. The selection of an applicable precipitation reagent is dependent upon the flow rate, pH, pollution loading, and waste/reagent compatibility.

Following the reaction tank, a flocculent such as anionic or cationic polymer is added and the solution flocculated to aid in the settling of the metal precipitate. In the clarifier, flow is decreased to the point where solids with a specific gravity greater than that of the liquid settle to the bottom. The supernatant is drawn off and discharged to a pH adjustment tank for neutralization. The solids are discharged to a holding tank for subsequent dewatering. Dewatering is accomplished using mechanical dewatering equipment such as a filter press. Once dewatered, the sludge is stabilized prior to off-site landfill disposal in accordance with federal and state disposal requirements.

In precipitation processes, lead is normally precipitated as a carbonate ($PbCO_3$) or as a hydroxide ($Pb(OH)_2$). These compounds have low solubilities at elevated pHs and the formation of these compounds is effective in reducing lead concentrations. Lime is commonly used as a lead treatment chemical. Manganese can also be removed at a pH above 9.4 using lime soda type treatment. Removal of manganese generally results in the simultaneous removal of iron, since the conditions under which high soluble iron levels occur are essentially the same as those for soluble manganese.

4.4.10 Alternative GW-3B - Precipitation Inorganic Treatment Option Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-3B is expected to provide overall protection of human health and the environment through treatment of inorganic ground water contaminants. The long-term effectiveness and permanence and short-term effectiveness are expected to be good, and the system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs - The ability of a chemical precipitation treatment system to treat lead and manganese is expected to be good. Treatment system operation would be conducted in compliance with action-specific ARARs, as listed in Table 4-15. Chemical precipitation generates a sludge which requires subsequent disposal off-site. If the sludge is characterized as a hazardous waste, federal RCRA hazardous waste generator and transporter requirements as well as state hazardous waste management regulations will be followed in the handling of the sludge. If not hazardous, the residuals would be handled in accordance with state solid waste management regulations. The treatment system would be required to treat the inorganic contaminants sufficiently to meet the applicable discharge requirements, also listed in Table 4-15. Treatment system construction would be conducted in accordance with location-specific ARARs, as listed in Table 4-14.

Long-Term Effectiveness and Permanence - The long-term risks associated with chemical precipitation will be minimal based on the system's ability to treat lead and manganese contamination. However, the treatment system does produce a sludge that will require hazardous waste characterization and appropriate disposal. Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties.

Reduction of Toxicity, Mobility or Volume Through Treatment - This alternative will provide a reduction in the toxicity of identified inorganic ground water contaminants through treatment. The volume of contaminated media is reduced through removal of contaminants from the ground water and subsequent production of a concentrated sludge residual.

Short-Term Effectiveness - Short-term risks to workers under Alternative GW-3B are not expected to be significant. Maintenance of chemical supplies and sludge handling are the major operation and maintenance activities associated with the chemical precipitation system. No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation.

Implementability - A chemical precipitation system should be easily implemented. Start-up is not expected to result in unanticipated technical problems. Its implementation is not expected to impact the implementation of any future remedial actions. Operational activities include maintenance of the chemical supplies and sludge handling. Administrative feasibility is also expected to be good.

Cost - The major costs associated with the precipitation treatment system are the capital costs associated with the construction of a chemical precipitation unit and associated operation and maintenance costs, including chemical supply costs. The overall estimated cost includes $130,000 in direct costs, $26,000 in indirect capital costs, and $54,000 in annual operation and maintenance costs ($830,000 net present value). The present worth value of this alternative, including contingency, is estimated at $1,200,000. A detailed cost estimate is provided in Appendix E.

4.4.11 Alternative GW-3C - Ion Exchange Inorganic Treatment Option Description

Ion exchange is a reversible chemical separation process in which a resin is used to remove metal ions from solutions such as wastewaters or leachate. As a solution passes through a bed of resin, ions attached to the surface of the resin are replaced by ions in the solution that have similar charge. The ions removed from the solution may either be positively charged cations or negatively charged anions depending on the nature of the resin. After the exchange capacity of the resin is exhausted, a regenerant solution is pumped through the bed to restore the resin to its original condition. The metal ions desorb from the resin and are flushed from the system for subsequent recovery or disposal.

Ion exchange is sensitive to interference from competing ions, dissolved or suspended solids, and organics. Therefore, pretreatment of the wastewater stream using filtration may be required. Metal removal efficiencies of greater than 95% are typically achieved in properly operated ion exchange systems. See Figure 4-4 for a schematic of a typical ion exchange system.

For the treatment of lead, strongly acid cation exchange resins have been demonstrated to be effective. The non-selective removal of other ions, however, can rapidly increase operational costs. Also, if air is present, manganese and iron can oxidize and clog the ion exchange bed. A filtration pre-treatment system has been assumed to minimize the potential for clogging of the ion exchange bed.

4.4.12 Alternative GW-3C - Ion Exchange Inorganic Treatment Option Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-3C would provide overall protection of human health and the environment when combined with ground water extraction and discharge. The long-term effectiveness and permanence of this option are expected to be good and the treatment system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs - An ion exchange system is expected to be able to treat the lead and manganese contamination in ground water at Site 10. Treatment system operation would be conducted in compliance with action-specific ARARs, as listed in Table 4-15. Backwash of the treatment system would result in the production of a concentrated brine solution which would require off-site disposal/treatment. If the brine is characterized as a hazardous waste, it will be handled in accordance with the applicable federal and state hazardous waste management regulations. The treatment system would be required to treat the inorganics contaminants sufficiently to meet the applicable discharge requirements, also listed in Table 4-15. Treatment system construction would be conducted in accordance with location-specific ARARs, as listed in Table 4-14.

Long-Term Effectiveness and Permanence - The long-term effectiveness of this alternative is expected to be good, with the addition of a filtration pretreatment process, based on the system's ability to treat inorganic contaminants. However, the regeneration of the resin material produces strong acids and bases as a waste material which would require hazardous waste characterization and appropriate disposal. Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties, although manganese and iron can cause clogging of the exchange resin.

Reduction of Toxicity, Mobility or Volume through Treatment - This alternative will provide a reduction in the toxicity of inorganic ground water contaminants through treatment. The volume of contaminated media is reduced through the removal of the inorganic ions from the ground water and subsequent production of a concentrated brine residual. Also, the addition of the filtration pretreatment process would produce a sludge/filter cake that would require disposal.

Short-Term Effectiveness - Short-term risks to workers under this alternative are not expected to be significant. Maintenance of chemical supplies and brine handling are the main operation and maintenance activities associated with the ion exchange treatment system. No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation.

Implementability - The technical implementability of Alternative GW-3C is good, based on the availability of the technology, although it requires the construction of an on-site treatment facility. Start-up is not expected to result in any unanticipated technical problems. Its implementation is not expected to impact the implementation of any future remedial actions. Operational activities include maintenance of the chemical supplies and sludge handling. Administrative feasibility is also expected to be good.

Cost - The major costs associated with the ion exchange treatment system are the capital costs associated with the construction of an ion exchange unit, the installation of a pretreatment filtration unit, and associated operation and maintenance costs, including chemical supply costs. The overall estimated cost includes $190,000 in direct costs, $38,000 in indirect capital costs, and $13,000 in annual operation and maintenance costs ($200,000 net present value). The present worth value of this alternative, including contingency, is estimated at $520,000. A detailed cost estimate is provided in Appendix E.

4.4.13 Alternative GW-3D - Discharge to Surface Water Option Description

Alternative GW-3D involves the discharge of treated ground water to surface water, which in this case would be a tributary of Frenchtown Creek, which flows into Hunt River. The discharge would be piped north from the site to the discharge location, an approximate distance of 500 feet. The discharge rate would be equal to the extraction rate, estimated at 3.0 gpm, although the system would be designed to handle up to 10 gpm. Implementation of discharge to the surface water is expected to have little, if any, effect on the ground water extraction and treatment system.

4.4.14 Alternative GW-3D - Discharge to Surface Water Option Evaluation

Overall Protection of Human Health and the Environment - Alternative GW-3D would provide overall protection of human health and the environment when combined with ground water extraction and treatment. The long-term effectiveness and permanence of this option are expected to be good, due to its simplicity, and the treatment system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs/TBCs - The water quality of the treatment process effluent would be required to comply with state and federal surface water discharge criteria, including ambient water quality criteria as listed in Table 4-13 and surface water discharge regulations listed in Table 4-15. The discharge system would be constructed in accordance with location-specific requirements, as listed in Table 4-14.

Long-Term Effectiveness and Permanence - The long-term risks associated with the discharge to surface water will be minimal, provided the treatment system is operating properly. Long-term operation and maintenance of the discharge piping is not expected to pose any major technical problems. Long-term monitoring of the discharge water quality will be required.

Reduction in Toxicity, Mobility or Volume through Treatment - This alternative is not expected to significantly impact the extraction or treatment system; therefore, it has little impact on the toxicity, mobility or volume of contamination.

Short-Term Effectiveness - Short-term risks to workers under this alternative are not expected to be significant, involving only the construction of the discharge piping. Maintenance of the system will require maintenance of the piping and discharge monitoring. No significant added risks to the adjacent community or the environment are anticipated.

Implementability - The technical implementation of a discharge to surface water system is affected by the distance to a discharge point. The estimated distance to a tributary of Frenchtown Creek from Site 10 is approximately 500 feet to the north. Maintenance of the system will be limited. Continued monitoring of the discharged water quality will be required. The administrative feasibility of discharging treated ground water to surface water depends on the treatment system's ability to meet surface water discharge criteria.

Cost - The major costs associated with Alternative GW-3D are the on-going maintenance and discharge monitoring costs associated with its implementation. The overall estimated cost includes $5,800 in direct capital costs, $800 in indirect capital costs, and $7,400 in annual operation and maintenance costs ($110,000 net present value). The present worth value of this alternative, including contingency, is estimated at $150,000. A detailed cost estimate is provided in Appendix E.

4.5 Ground Water Alternative Comparative Evaluation

A comparative analysis of the ground water alternatives is conducted to evaluate the significant differences between the alternatives based on the threshold and balancing criteria. Tables 4-16 through 4-22 comparatively summarize the alternative evaluations conducted strictly on the basis of ground water considerations for each of the evaluation criteria.

4.5.1 Overall Protection of Human Health and the Environment

A comparative analysis of the remedial alternatives with respect to their overall protection of human health and the environment is presented in Table 4-16.

The no action alternative would be considered protective of human health under the present use of the site by the U.S. Army, provided ground water is not utilized for potable use. However, Alternative GW-1 would not provide a means of limiting future use of the site should the U.S. Army excess the site and does not limit the potential for future installation of a potable well on-site. Therefore, remedial action objectives are not met.

Alternative GW-2 also provides protection of human health and the environment under the present site use by the U.S. Army. In addition, Alternative GW-2 would also provide future protection of human health and the environment by applying deed restrictions, should the Army excess the site, which would not allow the future installation of a potable well on-site. The ground water monitoring component would provide a means of further defining the presence of inorganics in ground water at the site and the potential impacts of the presence of lead on the proposed installation and operation of a public water supply well to the east-southeast of the site. It would also provide a means of monitoring the long-term effectiveness of the alternative. Implementation of this alternative results in no short-term impacts to the site or surrounding areas and would meet remedial action objectives.

Alternative GW-3, ground water extraction/treatment/discharge, would provide the greatest degree of overall protection of human health and the environment through its active remediation of ground water contamination; however its permanence once treatment is discontinued is not ensured. For the treatment options evaluated under this alternative, both options provided relatively comparable protection of human health and the environment. The extraction and discharge options would also be protective of human health and the environment.

4.5.2 Compliance with ARARs

A comparative analysis of the remedial alternatives with respect to their compliance with ARARs is presented in Table 4-17.

Alternatives GW-1 and GW-2 would not comply with chemical-specific ARARs since neither alternative provides for the treatment of inorganic ground water contaminants. By providing direct remediation of contaminated ground water, Alternative GW-3 would achieve chemical-specific ARARs. The precipitation and ion exchange options would be effective in meeting chemical-specific ARARs. However, long-term maintenance of reduced levels for these contaminants is not guaranteed once operation of the treatment system is discontinued.

Alternative GW-2 and Alternative GW-3 would be implemented in accordance with action-specific criteria. The construction of the remedial components of Alternative GW-3 would be conducted in accordance with location-specific ARARs/TBCs.

4.5.3 Long-Term Effectiveness and Permanence

A comparative analysis of the remedial alternatives with respect to long-term effectiveness and permanence is presented in Table 4-18.

Alternative GW-2 would be expected to be effective in the long-term. The limited action alternative would provide a means of monitoring the site over the long-term to identify any changes in ground water quality and associated off-site impacts, and would limit the potential for future on-site use of the ground water as a potable water supply. The extraction, treatment, and discharge options are all expected to be effective in the long-term. Both the precipitation (GW-3B) and ion exchange (GW-3C) options are effective and easily operated and maintained. However, after treatment operations cease, ground water monitoring would be required to evaluate the permanence of Alternative GW-3. The no action alternative offers the least long-term effectiveness and permanence.

4.5.4 Reduction of Toxicity, Mobility and Volume through Treatment

A comparative analysis of the remedial alternatives with respect to reduction of toxicity, mobility and volume through treatment is presented in Table 4-19.

Alternative GW-3 is the only alternative which provides for a reduction in contaminant toxicity, mobility, and volume through treatment. Alternatives GW-1 and GW-2 provide no reduction in contaminant toxicity, mobility, or volume through treatment.

4.5.5 Short-Term Effectiveness

A comparative analysis of the remedial alternatives with respect to short-term effectiveness is presented in Table 4-20.

Alternative GW-2 is the most effective alternative in the short-term, providing a means of monitoring compliance with remedial action objectives but resulting in no increase in short-term risks. The limited action alternative allows for the long-term monitoring of ground water and meets remedial action objectives with respect to minimizing future human exposures to contaminated ground water. Alternative GW-1 also poses no increased short-term risks, but does not ensure compliance with remedial action objectives.

Alternative GW-3 also provides a means of complying with remedial action objectives within a short time frame with minimal risk incurred. The precipitation (GW-3B) and ion exchange (GW-3C) options would be effective in the short-term since both treatment systems are readily available. Both options would require the handling of waste materials. The ion exchange process would also require the handling and use of strong acids and bases in the operation of the ion exchange treatment system. Both ground water extraction (GW-3A) and discharge to surface water (GW-3D) could be quickly implemented and effective in the short-term.

4.5.6 Implementability

A comparative analysis of the remedial alternatives with respect to implementability is presented in Table 4-21.

Alternative GW-1 would be the most implementable since it requires no action other than five-year reviews. Alternative GW-2 would be next in terms of implementability, requiring initiation of long-term monitoring and the establishment of a mechanism to implement deed restrictions, should the Army transfer the property in the future, but requiring no on-site construction activities. Neither Alternatives GW-1 nor GW-2 would limit the implementation of other remedial actions at the site.

Alternative GW-3 would require the disruption of the site for implementation. However, from a technical standpoint, none of the options of Alternative GW-3 would pose difficulty in implementation. For Alternative GW-3, precipitation (GW-3B) and ion exchange (GW-3C) would both be easily implemented due to their commercial availability, although the precipitation option would be more easily operated than the ion exchange option. Ground water extraction (GW-3A) and discharge to surface water (GW-3D) would both be easily implemented.

4.5.7 Cost

A comparative analysis of the remedial alternatives with respect to cost is presented in Table 4-22.

The no action alternative is the least costly alternative, with the only cost being the nominal cost associated with five-year reviews. Alternative GW-2 follows, with a total estimated present worth cost of $150,000. Alternative GW-3 would be the most costly. The total estimated present cost for combined ground water extraction/treatment/discharge ranges from $730,000 (ion exchange) to $1,400,000 (chemical precipitation). The present worth costs for individual options include: $58,000 for extraction (GW-3A); $1,200,000 for chemical precipitation (GW-3B); $520,000 for ion exchange (GW-3C); and $150,000 for discharge to surface water (GW-3D).

4.6 Sensitivity Analysis

A sensitivity analysis was conducted to assess the effect that variations in specific assumptions made during alternative development and assessment could have on the total estimated remedial cost. The main uncertainty factors which are applicable to the remedial alternatives and associated options are the uncertainties associated with the discount factor over the life of the remedy and over the remediation period for the ground water treatment alternatives. The resultant impacts to remedial costs are summarized in Table 4-20.

The discount rate can vary from the 5% rate used in the cost evaluation. Alternatives with large O&M cost components and extended remedial periods can be significantly impacted by a variation in the discount rate. The sensitivity analysis has been conducted assuming a variation in the annual discount rate, with total present worth costs estimated for each alternative at annual discount rates of 3% and 10%. The long-term ground water monitoring option (GW-3A) and long-term treatment options with high operation and maintenance (GW-3B) are impacted the greatest by variations in the discount rate.

Variations in the estimated remediation period also impacted the ground water remedial alternatives. Option GW-3B was the most affected due to its high operation and maintenance costs.

5.0 RECOMMENDATIONS AND CONCLUSIONS

Based on the evaluation of soil and ground water remedial alternatives presented in Section 4, the recommended remedial alternative for Site 10 is a limited action, consisting of the following:

- A mechanism for establishing deed restrictions to prevent potential future residential exposures to surface soil and to prevent ground water from being used as a potable water source.

- Long-term monitoring of ground water to identify any future changes in ground water quality or determine potential ground water migration.

The alternative would be protective of human health and the environment based on the lack of unacceptable human health risks associated with future site use and the lack of unacceptable environmental risks associated with the site. This alternative would be protective under the existing military use of the site and potential future commercial/industrial site use.

While there are no chemical-specific ARARs applicable to soil contamination at the site, the limited action alternative could be considered to comply with federal and state chemical-specific TBCs for lead, which are based on residential exposures to soil, by preventing future residential site use. It would also use institutional controls to limit exposures to ground water contaminants at levels exceeding drinking water levels, which would be consistent with EPA's expectations for Superfund that allow use of institutional controls when active remediation measures are determined not to be practicable, based on the balancing of trade-offs among alternatives.

Ground water at Site 10 is classified as GAA-NA, indicating a water resource suitable for public drinking water without treatment but located in a non-attainment area which is known or presumed to be out of compliance with the assigned ground water quality standards. The southern portion of Site 10 is located within the ground water capture zone for a proposed well location identified in the Phase I Report, Hunt River Aquifer Wellhead Recharge Area Study (GZA, 1992). Potential locations of private potable wells have also been identified downgradient of the site.

To ensure the protection of ground water quality and potable well users, Rhode Island Rules and Regulations for Ground Water Quality include methods of establishing for a facility a point of compliance, which is used to determine compliance with ground water quality standards. They also define appropriate responses to a violation of a ground water quality standard at the point of compliance. The establishment of a ground water monitoring program is included in the regulations' list of potential responses to a ground water quality standard violation. Seeing as lead was present in only one well (when using the low-flow sampling methodology) at a level slightly exceeding its ground water quality standard, the definition of a facility-specific point of compliance and the establishment of a ground water monitoring program could be a potential means of further defining the presence of lead in ground water at the site and identifying the potential impacts of the presence of lead on the proposed installation and operation of the public water supply well to the east-southeast of the site. The proposed monitoring time frame (30 years) could be reduced if subsequent monitoring indicates that ground water quality at the point of compliance is acceptable and potential risks to any downgradient potable water supplies are minimal.

No short-term effects would result from the implementation of a mechanism to ensure the establishment of deed restrictions should the U.S. Army relinquish ownership of the site. The monitoring program would have minimal short-term risks associated with its implementation and, provided deed restrictions are enforced, the limited action alternative would be effective in the long-term. Due to the continued presence of contaminants at the site at levels which do not allow for unrestricted use, five-year reviews of the limited action decision would be required. If results of the ground water monitoring program indicated that ground water quality was deteriorating or contaminants were migrating towards the proposed public water supply well location, additional remedial measures could be implemented.

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TABLE 2–1

Site 10 – Camp Fogarty Disposal Area
Vertical Hydraulic Gradients

Well Cluster Number	Vertical Distance (ft) [1]		Head Difference (ft) [2]		Gradient (ft/ft)	
	8/13/93	9/17/93	8/13/93	9/17/93	8/13/93	9/17/93
10–MW1	10.14	8.38	–0.05	–0.04	-4.93×10^{-3}	-4.77×10^{-3}
10–MW4	9.23	7.71	0.00	0.00	0	0
10–MW5	5.91	4.40	0.07	0.05	1.18×10^{-2}	1.14×10^{-2}

NOTES: (1) The vertical distance is the difference in elevation between the water table in the shallow well and the middle of the screened interval in the deep well.

(2) The head difference is the elevation of the deep well piezometric level minus the water table elevation. Thus, negative signs represent downward gradients.

TABLE 2-2

Site 10 – Camp Fogarty Disposal Area
Average Horizontal Hydraulic Gradients and Linear Velocities

Location	Average Horizontal Gradient (ft/ft) 8/13/93	Average Horizontal Gradient (ft/ft) 9/17/93	Average Linear Velocity (ft/d) 8/13/93	Average Linear Velocity (ft/d) 9/17/93
Shallow Wells				
10–MW1S to 10–MW4S	4.70×10^{-3}	3.56×10^{-3}	0.32	0.24
10–MW2S to 10–MW4S	4.10×10^{-3}	3.54×10^{-3}	0.28	0.24
10–MW2S to 10–MW5S	3.32×10^{-3}	2.80×10^{-3}	0.23	0.19
10–MW3S to 10–MW4S	1.21×10^{-3}	9.40×10^{-4}	0.08	0.06
10–MW3S to 10–MW5S	1.43×10^{-3}	1.06×10^{-3}	0.10	0.07
Deep Wells				
10–MW1D to 10–MW4D	5.04×10^{-3}	3.81×10^{-3}	0.15	0.11
10–MW1D to 10–MW5D	2.18×10^{-3}	1.58×10^{-3}	0.06	0.05

NOTES: The shallow and deep hydraulic conductivities for the site (13.7 ft/d and 5.9 ft/d, respectively) are the median values derived from the Phase II RI slug tests.
An effective porosity of 0.20 for silty sands (EPRI, 1985) was assumed.

TABLE 2-3

Site 10 – Camp Fogarty Disposal Area
Comparison of Background Soils to Surface and Subsurface Soil Samples
Range of Semivolatile Organic Compounds Detected

Compound	Surface Soil Range (µg/kg)	Subsurface Soil Range (µg/kg)	Background Range[1] (µg/kg)
Phenol	ND	ND	ND
bis(2-Chloroethyl)ether	ND	ND	ND
2-Chlorophenol	ND	ND	ND
1,3-Dichlorobenzene	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	ND
2-Methylphenol	ND	ND	ND
2,2'-Oxybis(1-chloropropane)	ND	ND	ND
4-Methylphenol	ND	ND	ND
N-Nitroso-di-n-propylamine	ND	ND	ND
Hexachloroethane	ND	ND	ND
Nitrobenzene	ND	ND	ND
Isophorone	ND	ND	ND
2-Nitrophenol	ND	ND	ND
2,4-Dimethylphenol	ND	ND	ND
bis(2-Chloroethoxy)methane	ND	ND	ND
2,4-Dichlorophenol	ND	ND	ND
1,2,4-Trichlorobenzene	ND	ND	ND
Naphthalene	ND	ND	ND
4-Chloroaniline	ND	ND	ND
Hexachlorobutadiene	ND	ND	ND
4-Chloro-3-methylphenol	ND	ND	ND
2-Methylnaphthalene	ND	ND	ND
Hexachlorocyclopentadiene	ND	ND	ND
2,4,6-Trichlorophenol	ND	ND	ND
2,4,5-Trichlorophenol	ND	ND	ND
2-Chloronaphthalene	ND	ND	ND
2-Nitroaniline	ND	ND	ND
Dimethyl phthalate	ND	ND	ND
Acenaphthylene	ND	ND	ND
2,6-Dinitrotoluene	ND	ND	ND
3-Nitroaniline	ND	ND	ND
Acenaphthene	ND-670	ND	ND
2,4-Dinitrophenol	ND	ND	ND
4-Nitrophenol	ND	ND	ND
Dibenzofuran	ND-240	ND	ND
2,4-Dinitrotoluene	ND	ND	ND
Diethyl phthalate	ND	ND	ND
4-Chlorophenyl phenyl ether	ND	ND	ND
Fluorene	ND-530	ND	ND
4-Nitroaniline	ND	ND	ND
4,6-Dinitro-2-methylphenol	ND	ND	ND
N-Nitrosodiphenylamine(1)	ND	ND	ND
4-Bromophenyl phenyl ether	ND	ND	ND
Hexachlorobenzene	ND	ND	ND
Pentachlorophenol	ND	ND	ND
Phenanthrene	ND-3,700	ND-260	ND
Anthracene	ND-820	ND	ND
Carbazole	ND-780	ND	ND
Di-n-butyl phthalate	ND	ND	ND - 41
Fluoranthene	ND-4,000	ND-330	ND - 250
Pyrene	ND-4,200	ND-290	ND - 260
Butyl benzyl phthalate	ND	ND	ND - 51
3,3'-Dichlorobenzidine	ND	ND	ND
Benzo(a)anthracene	ND-3,400	ND	ND
Chrysene	ND-2,900	ND	ND - 190
bis(2-Ethylhexyl)phthalate	ND-710	ND	ND
Di-n-octyl phthalate	ND	ND	ND
Benzo(b)fluoranthene	ND-5,100	ND-260	ND - 270
Benzo(k)fluoranthene	ND-2,200	ND	ND - 73
Benzo(a)pyrene	ND-2,600	ND	ND
Indeno(1,2,3-cd)pyrene	ND-940	ND	ND
Dibenzo(a,h)anthracene	ND-430	ND	ND
Benzo(g,h,i)perylene	ND-860	ND	ND

ND = Not Detected

(1) – Background surface soil samples which exhibited 1,1,1 – trichloroethane or PCBs have not been included within the background range.

TABLE 2–3, continued

Site 10 – Camp Fogarty Disposal Area
Comparison of Background Soils to Surface and Subsurface Soil Samples
Range of Inorganics Detected

Element	Surface Soil Ranges (mg/kg)	Subsurface Soil Ranges (mg/kg)	Background Ranges(1) (mg/kg)
Aluminum	2,490–13,000	3,240–10,600	1,170 – 8,560
Antimony	ND–35.8	ND–14	ND
Arsenic	ND–3.6	ND–1.8	0.59 – 8.1
Barium	11.2–192	14.5–135	5.6 – 15.5
Beryllium	0.41–2.9	1–3.8	0.12 – 0.66
Cadmium	ND–4.7	ND–0.58	ND – 0.46
Calcium	114–3,990	893–1,920	62.7 – 628
Chromium	1.5–10.9	2.4–11.3	ND – 9.6
Cobalt	1.1–6.9	2.1–5.9	ND – 4.6
Copper	1.6–330	3–73.6	ND – 15
Iron	5,090–23,100	8,120–71,200	3,810 – 10,700
Lead	10.2–655	5.8–207	3.4 – 53.8
Magnesium	410–1,550	696–1,380	325 – 1,220
Manganese	78.2–507	200–449	21.8 –150
Mercury	ND–0.15	ND	ND
Nickel	ND–11.9	1.6–12.4	ND – 6.2
Potassium	258–1,710	716–1,960	ND – 728
Selenium	ND–0.52	ND	ND – 0.77
Silver	ND–0.89	ND	ND – 0.16
Sodium	ND–2,780	42.3–103	ND – 119
Thallium	ND–0.28	ND	ND – 0.19
Vanadium	2.7–19.5	4–12.3	3.3 – 24.6
Zinc	30.6–566	74.1–325	10.3 – 172
Cyanide	ND–0.9	ND–0.4	ND

ND – Not Detected
(1) – Background surface soil samples which exhibited 1,1,1–trichloroethane or PCBs have not been included within the background range.

TABLE 2–4

Site 10 – Camp Fogarty Disposal Area
Summary of Cancer and Non–Cancer Risk Estimates For All Scenarios

Pathway	CANCER RISKS			
	Scenario 1 (Construction Worker)		Scenario 2 (Commercial/Industrial Worker)	
	Geometric Mean	RME	Geometric Mean	RME
Incidental ingestion of soil	9E–07	2E–06	4E–06	2E–05
Dermal contact with soil	NA	NA	NA	NA
Inhalation of particles	1E–09	3E–09	––	––
Ingestion of ground water	––	––	3E–05	9E–05

[shaded] = Cancer risk > 1E–6

Pathway	NON–CANCER HAZARD INDICES			
	Scenario 1 (Construction Worker)		Scenario 2 (Commercial/Industrial Worker)	
	Geometric Mean	RME	Geometric Mean	RME
Incidental ingestion of soil	8E–02	2E–01	8E–03	6E–02
Dermal contact with soil	5E–05	6E–05	3E–05	2E–04
Inhalation of particles	2E–03	4E–03	––	––
Ingestion of ground water	––	––	4E–01	5E+00

[shaded] = Cancer risk > 1E+0

TABLE 3-1

Site 10 – Camp Fogarty Disposal Area
Comparison of Soil Contaminant Levels to Action Levels

Parameter	Maximum Concentration Detected (ppm)		Federal Action Level (ppm)	State Action Level (ppm)
	Surface Soils (0–2')			
	Phase I RI	Phase II RI		
LEAD	118	655	500–1,000[1]	300[2]
PCBs	ND	NA	10[3]	10/50[4]

(1) USEPA, OSWER Directive 9355.4–02, Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites.
(2) RIDEM and RI Dept. of Health–Risk Assessment Guidance Level.
(3) TSCA (40 CFR 761); Requirements for decontaminating spills in nonrestricted areas.
(4) RIDEM Rules and Regulations for Solid Waste Management Facilities defines solid waste as including any soil debris or other material with a concentration of 10 ppm or greater PCBs.
RIDEM Rules and Regulations for Hazardous Waste Management defines Type 6 – extremely hazardous waste as including waste which contains 50 ppm or greater PCBs.

NA – No Phase II soil samples were analyzed for pesticides/PCBs

ND – Parameter was not detected in any surface soil samples.

TABLE 3–2

Site 10 – Camp Fogarty Disposal Area
Comparison of Detected Ground Water Contaminants to
Applicable or Relevant and Appropriate Requirements (ARARs) or To–be–Considered Requirements (TBCs)

Parameter	Maximum Concentration Detected in Ground Water: Phase I (ppb)	Phase II (ppb)	FEDERAL ARARs/TBCs: MCL[1] (ppb)	MCLG[2] (ppb)	RHODE ISLAND ARARs/TBCs: MCL[3] (ppb)	Ground Water[4] Quality Standards (ppb)
Volatiles						
None Detected						
Semivolatiles						
None Detected						
Inorganics						
Arsenic	ND	0.95	50	–	50	50
Beryllium	5.3	1.9	4	4		
Cadmium	ND	2.7	5	5	5	5
Chromium	80.8	ND	100	100	100	100
Copper	22.2	4.6	1300*		1300	
Lead	140	16.5	15*		15	15
Mercury	0.31	ND	2	2	2	2
Nickel	48	8.8	100	100		
Zinc	203	67				
Barium	115	14.3	2000	2000	2000	2000
Iron	7950	4350				
Manganese	1120	2240				
Vanadium	6.4	ND				
Aluminum	6080	1430				
Cobalt	7	4				
Magnesium	1540	3260				
Calcium	6390	27000				
Sodium	3290	8540				
Potassium	1330	7340				
Selenium	NA	1.8	50	50	50	50
Cyanide	ND	ND				

1. MCL – Maximum Contaminant Level. National Primary Drinking Water Regulations.
2. MCLG – Maximum Contaminant Level Goal, based on health considerations only.
3. Rhode Island Maximum Contaminant Level. Rules and Regulations Pertaining to Public Drinking Water (R46–13–DWQ) Sections 6.80(c), 16.1, 16.2(a), and 16.2(b).
4. Water Quality Standards, Class GAA and Class GA ground waters, Rhode Island Regulation DEM–GW–01–92, July 1993. Site 10 is located in a Class GAA–NA area and, therefore, the listed standards are directly applicable to Site 10 ground water contaminants.

*–Action levels representative of drinking water quality at the tap, U.S. EPA, May 7, 1991.
ND – Not detected
NA – Not analyzed

TABLE 3-3

Summary of Risk-Based Preliminary Remediation Goals - Ground Water
Site 10 - Camp Fogarty Disposal Area

Parameter	Ground Water Maximum Detected Concentration (ppm)	Estimated [(1)] Non-Cancer Based Hazard Index	Risk-Based [(2)] Preliminary Remediation Goal (ppm)
Manganese	2.2	4.4	0.51

(1) - Risk estimate represents total non-cancer hazard index ratio due to ingestion of manganese in ground water under future commercial/industrial use, as presented in the Draft Remedial Investigation Report (TRC, 1993b).
(2) - See Appendix B for discussion of risk-based preliminary remediation goal calculations.

TABLE 3-4

Site 10 – Camp Fogarty Disposal Area
Comparison of Soil Contaminant Levels to Calculated Leaching Model Levels

Constituent	Maximum Modeled [1] Unsaturated Concentration (ppm)	Maximum Concentration Detected in Unsaturated Soils (ppm)
Volatile Organics		
Chloroform	0.70	0.001
1,1,1-Trichloroethane	4.5	0.008
Toluene	37.0	0.012
Semivolatile Organics		
Bis(2-ethylhexyl)phthalate	90.9	0.71
Chrysene	6.5	2.9
Indeno(1,2,3-cd)pyrene	1408	0.94
Dibenzo(a,h)anthracene	21.1	0.43
Benzo(a)anthracene	3.1	3.4
Benzo(a)pyrene	14.7	2.6
Benzo(b)fluoranthene	58.7	5.1
Benzo(k)fluoranthene	105.6	2.2

Notes:
(1) See Appendix C for model description and associated calculations.
Shaded contaminants indicate maximum detected concentration exceeds modeled concentration.

TABLE 3–5
SOIL REMEDIAL TECHNOLOGY SCREENING
SITE 10 – CAMP FOGARTY DISPOSAL AREA

░ Screened on Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
No Action	None	Not Applicable	No action.	Required for consideration under the NCP.
Institutional Control	Site Use Restrictions	Deed Restrictions	Deed for site would be revised to include restrictions on future site use or development, limiting future exposures to soil contaminants.	Site 10 has previously been excessed to the Army; deed restrictions would be implemented if and when the property is transferred from federal ownership.
		Fencing	Fencing and posting of warning signs to limit public access and exposure to soil contaminants.	Access to Camp Fogarty is limited due to its active use by the Army for firing range purposes; access to the area in which lead has been identified at levels exceeding the RIDEM action level could be further limited through additional fencing.

TABLE 3-6
GROUND WATER REMEDIAL TECHNOLOGY SCREENING
SITE 10 – CAMP FOGARTY DISPOSAL AREA

Screened On Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
No Action	None	Not Applicable	No action.	Fulfills NCP requirement for consideration of no action alternative.
Institutional Control	Ground Water Monitoring	Not Applicable	Continued ground water monitoring.	Would provide monitoring of water quality and any potential contaminant migration.
	Ground Water Use Restrictions	Deed Restrictions	Legal restrictions on ground water use in the contaminated area.	Would prevent future exposures to existing ground water contamination by restricting future installation of on–site potable wells should the property ever be excessed by the Army.
		Alternate Water Supply	Provision of alternate water supply to receptors impacted by ground water contamination.	No potable water receptors have been impacted.
Extraction/ Treatment/ Discharge	Extraction	Extraction Wells	Wells and pumping system used for extraction of contaminated ground water.	Potentially viable, proven technology. Presence of subsurface boulders and cobbles could complicate installation of wells.
		Well Points	Manifold system of closely–spaced extraction points connected to common collection source.	Potentially viable, proven technology. Presence of subsurface boulders and cobbles could complicate installation of well points.
		Interceptor Trench	Placement of trench with high permeability materials, used to divert ground water flow.	Potentially viable, proven technology, suitable for shallow ground water extraction only. Viability limited by depth to bedrock and subsurface boulders and cobbles.
	Off–Site Treatment	Off–site POTW	Extracted ground water discharged to local POTW for treatment.	Regulations often prohibit discharge of subsurface water to sewer systems; preliminary evaluation indicates POTW will not be amenable to accepting extracted ground water.
		Off–site RCRA Facility	Extracted ground water discharged to licensed RCRA facility for treatment and/or disposal.	High ground water extraction rates can prohibit feasibility of this treatment option.

TABLE 3–6
GROUND WATER REMEDIAL TECHNOLOGY SCREENING
SITE 10 – CAMP FOGARTY DISPOSAL AREA

(shaded box) Screened On Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
Extraction/ Treatment/ Discharge (cont)	Inorganic Treatment	Ion Exchange	Contaminants removed from aqueous phase by exchanging places with ions held by ion exchange material.	Effective for inorganics; ineffective for organics, which are not readily ionized.
		Precipitation	Contaminants removed by decreasing solubility.	Effective for inorganics; ineffective for organics, which generally have solubilities less affected by pH adjustments.
		Membrane Microfiltration	Solid particles removed from liquids using pressure filter.	SITE program technology; applicable to ground water contaminated with suspended heavy metals; would not remove dissolved inorganics.
		Filtration	Suspended particles are removed from the ground water stream using conventional filtration methods.	Effective for removal of suspended solids contaminated with heavy metals; would not remove dissolved inorganics.
		Electrochemical	Utilizes the oxidation/reduction properties of ferrous ions for removing heavy metals from aqueous solutions.	Proven for treatment of heavy metals; ineffective for organics, which are not readily ionized.
	Discharge	Ground Water	Treated water is recharged to the ground water via wells and/or infiltration galleries.	Potentially viable.
		Surface Water	Treated water is discharged directly or indirectly (via storm sewer) into surface water.	Potentially viable.
		Sanitary Sewer/ POTW (shaded: screened)	Treated water is discharged indirectly to surface water body via sanitary sewer and POTW.	Regulations may prohibit discharge of ground water to sewer system; preliminary evaluation indicates POTW will not be amenable to accepting treated ground water.

TABLE 3-7
SOIL PROCESS OPTION SCREENING
SITES 10 – CAMP FOGARTY DISPOSAL AREA

● Representative Process Option

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
No Action	None	Not Applicable	● Effective under current site use.	No implementation is required.	No cost.
Institutional Control	Site Use Restrictions	Deed Restrictions	● Limits future disturbance of existing contamination, unacceptable future site use, or introduction of additional contaminated materials.	Requires appropriate legal authority; would require the establishment of a mechanism (e.g. signed agreement) between the Navy and the Army which would ensure the implementation of deed restrictions should the property ever be transferred from federal ownership.	Low capital cost.
		Fencing	● Limits human exposure to site.	Fairly easily implemented.	Low capital cost; low maintenance cost.

TABLE 3-8
GROUND WATER PROCESS OPTION SCREENING
SITE 10 – CAMP FOGARTY DISPOSAL AREA

● Representative Process Option

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
No Action	None	Not Applicable	● Not effective in prohibiting or monitoring contaminant migration.	No implementation required.	No cost.
Institutional Control	Ground Water Monitoring	Not Applicable	● Would provide means of monitoring potential contaminant migration but provides no treatment.	Easily implemented.	Low capital; moderate O&M.
	Ground Water Use Restrictions	Deed Restrictions	● Effective in limiting public ingestion of ground water contaminants by eliminating installation of potable wells in contaminated areas.	Requires legal authority; may be difficult to implement due to the fact that the site has previously been excessed to the Army.	Low capital.
Extraction/ Treatment/ Discharge	Extraction	Extraction Wells	● Effective; best suited for steep hydraulic gradients, miscible contaminants, and greater extraction depths.	Easily implemented.	Moderate capital; moderate O&M.
		Well Points	Effective; best suited to shallow aquifers.	Easily implemented.	Moderate capital; moderate O&M.
	Inorganic Treatment	Ion Exchange	● Effective for inorganic removal; requires selection of resin suitable for contaminants of concern.	Fairly easily implemented;; operation is relatively simple.	Moderate capital; moderate O&M.
		Precipitation	● Effective for removal of dissolved inorganics; precipitate must be disposed of.	Readily implemented.	Low to moderate capital; moderate O&M.
		Electrochemical	Effective in producing metal hydroxide precipitates of such inorganic species as arsenic, cadmium, zinc and copper.	Newly developing technology; may not be widely available; more complicated than other inorganic treatment systems.	Moderate capital, moderate O&M.
	Discharge	Ground Water	Effective with permeable soils and relatively low flow rates.	Requires construction of a recharge system; requires compliance with discharge criteria.	Moderate capital; low to moderate O&M.
		Surface Water	● Effective for discharge of treated ground water.	Requires installation of a discharge pipe; requires compliance with discharge criteria.	Moderate capital; low O&M.

TABLE 3–9
TECHNOLOGIES WHICH PASSED SCREENING
SOIL/GROUND WATER
SITE 10 – CAMP FOGARTY DISPOSAL AREA

Soil	Ground Water
No Action	No Action
No Action	• No Action
Institutional Control	Institutional Control
Deed Restrictions	• Ground Water Monitoring
Fencing	• Deed Restrictions
	Treatment/Disposal/Discharge
	• Extraction Wells
	Well Points
	• Ion Exchange
	• Precipitation
	Electrochemical
	Discharge to Ground Water
	• Discharge to Surface Water

• – Process Technology Used to Formulate Remedial Alternatives

TABLE 3–10
ALTERNATIVES UNDERGOING DETAILED ANALYSIS
SOIL/GROUND WATER
SITE 10 – CAMP FOGARTY DISPOSAL AREA

Soil	Ground Water
Alternative S–1	Alternative GW–1
No Action	No Action
Alternative S–2	Alternative GW–2
Limited Action (Institutional Control)	Limited Action (Institutional Control)
A. Fencing/Deed Restrictions	A. Deed Restrictions/Ground Water Monitoring
	Alternative GW–3
	Extraction/Treatment/Discharge
	A. Extraction Wells B. Precipitation C. Ion Exchange D. Discharge to Surface Water

TABLE 4-1
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE S-1 - NO ACTION
ALTERNATIVE S-2 - LIMITED ACTION
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL Soils/Surfaces--				
	Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02)	To Be Considered	Sets forth an interim soil cleanup level for lead at 500 to 1000 ppm.	Will be considered at Site 10 with respect to soil lead contamination.
STATE Soils/Surfaces--				
	Lead Soil Cleanup Standards (Guidance)	To Be Considered	RIDEM and the Rhode Island Department of Health-Risk Assessment consider a safe lead level in soil (total) to be under 300 ppm.	To be considered with respect to lead soil contamination.

TABLE 4-2
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE S-1 - NO ACTION
ALTERNATIVE S-2 - LIMITED ACTION
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Wetlands/Water Resources--	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	Will be applicable if implementation of fencing impacts wetland areas.
Endangered Species--	Endangered Species (16 USC 1531) Protection of Endangered Species	Applicable	Restricts activities in areas inhabited by registered endangered species.	Will be applicable if the presence of rare species is identified at Site 10. ARAR for fencing.
Cultural Resources--	National Historic Preservation Act of 1966 (16 USC 470, et seq.) Protection of Historic Lands and Structures; Archaeological and Historic Preservation Act of 1974 (132 CFR 229 & 229.4, 43 CFR 7 & 7.4); Historic Sites, Building and Antiquities Act.	Applicable	Several statutes which govern the preservation at historic, scientific and archaeological sites and resources. Includes action to recover and preserve artifacts, preserve historic properties and minimize harm to National Historic Landmarks.	Will be applicable if significant scientific, prehistoric, historic or archaeological resources exist at the site. ARAR for fencing.

TABLE 4–2(continued)
FEDERAL AND STATE LOCATION–SPECIFIC ARARs AND TBCs
ALTERNATIVE S–1 – NO ACTION
ALTERNATIVE S–2 – LIMITED ACTION
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
STATE Wetlands– –				
	Rhode Island Wetlands Laws (RIGL 2–1–18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh–water Wetlands Act – As Amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	Will be applicable if construction of fencing impacts a wetland area.

TABLE 4-3
COMPARISON AMONG SOIL ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC – DAVISVILLE, RI

ACTION	COMPARISON OF OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
Alternative S-1 – No Action	Least protective alternative; Provides protection of human health under present site use or potential future commercial/industrial site use scenario; However, should the U.S. Army ever excess the property, no control of potential residential exposures to soil contamination is provided; Does not comply with state chemical-specific TBC for lead; Effective in the short-term and the long-term provided residential exposures do not occur; Does not meet remedial action objectives
Alternative S-2 – Limited Action	Provides protection of human health under the present military site use or potential future commercial/industrial site use by limiting potential exposures to soil contaminants through fencing and/or institutional controls; Protective against future residential site use; Does not comply with state chemical-specific TBC for lead; Effective in the short-term and in the long-term; Meets remedial action objectives

TABLE 4-4
COMPARISON AMONG SOIL ALTERNATIVES
COMPLIANCE WITH ARARs/TBCs
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	CHEMICAL-SPECIFIC	LOCATION-SPECIFIC	ACTION-SPECIFIC
Alternative S-1 - No Action	Does not meet state chemical-specific TBC for lead, but falls within the acceptable federal range for lead	Compliance with location-specific ARARs would be maintained	Not applicable
Alternative S-2 - Limited Action	Does not meet state chemical-specific TBC for lead, but falls within the acceptable federal range for lead; prevents future residential exposures to lead	Compliance with location-specific ARARs would be maintained	Not applicable

TABLE 4-5
COMPARISON AMONG SOIL ALTERNATIVES
LONG-TERM EFFECTIVENESS AND PERMANENCE
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	COMPARISON OF LONG-TERM EFFECTIVENESS AND PERMANENCE
Alternative S-1 - No Action	Protective in long-term under existing military use or potential future commercial/industrial site use based on lack of identified unacceptable risks; Would be effective in the long-term as long as the site remains in control of the U.S. Army; Necessity of five-year reviews requires risk management decision
Alternative S-2 - Limited Action	Protective in long-term since no unacceptable risks were identified under existing military use or potential future commercial/industrial site use; Utilizes a mechanism for establishing deed restrictions to limit future residential exposures should the property ever be transferred from federal ownership; deed restrictions would require long-term enforcement to ensure their protectiveness; Fencing requires long-term maintenance; Necessity of five-year reviews requires risk management

TABLE 4-6
COMPARISON AMONG SOIL ALTERNATIVES
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC – DAVISVILLE, RI

ACTION	COMPARISON OF REDUCTION IN TOXICITY, MOBILITY AND VOLUME THROUGH TREATMENT
Alternative S-1 – No Action	Provides no reduction of toxicity, mobility or volume through treatment
Alternative S-2 – Limited Action	Provides no treatment of soil contamination and therefore no associated reduction of contaminant toxicity, mobility, or volume; Site access and/or development restrictions would prevent the potential contaminant exposure pathways associated with future residential site use

TABLE 4-7
COMPARISON AMONG SOIL ALTERNATIVES
SHORT-TERM EFFECTIVENESS
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	COMPARISON OF SHORT-TERM EFFECTIVENESS
Alternative S-1 - No Action	No remedial activities conducted; Therefore, no short-term risks result; Remedial response objectives not achieved
Alternative S-2 - Limited Action	Minimal short-term risks associated with fence construction; No increased off-site risks would result from the implementation activities; Short implementation time frame; Remedial response objectives would be achieved

TABLE 4-8
COMPARISON AMONG SOIL ALTERNATIVES
IMPLEMENTABILITY
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	COMPARISON OF IMPLEMENTABILITY
Alternative S-1 - No Action	Requires no implementation other than five-year reviews; Would not limit the implementation of other remedial actions
Alternative S-2 - Limited Action	Fencing construction easily implemented; A mechanism for establishing deed restrictions should the Army ever excess the property would need to be established; The presence of fencing would not limit the activities presently conducted at Camp Fogarty by the U.S. Army; Would not limit the implementation of other remedial actions

TABLE 4-9
COMPARISON AMONG SOIL ALTERNATIVES
COST
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC – DAVISVILLE, RI

ACTION	TOTAL CAPITAL COST	ANNUAL O&M COST	PRESENT WORTH O&M COST [1]	TOTAL PRESENT WORTH [2]
Alternative S-1 – No Action	--	--	--	Nominal [3]
Alt mative S-2 – Limited Action	$12,000	$300	$4,600	$20,000

[1] – Based on 5% discount rate.
[2] – Includes 20% contingency on all components.
[3] – The only cost associated with the implementation of Alternative S-1 would be that associated with conducting five-year reviews of the no action decision.

TABLE 4-10
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-1 - NO ACTION
ALTERNATIVE GW-2 - LIMITED ACTION
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL Ground Water--				
	Safe Drinking Water Act (40 CFR 141.11-.16 and 141.60-.63) Maximum Contaminant Levels (MCL's)	Relevant and Appropriate	MCL's directly apply to "public water systems", defined as systems with at least 15 connections which service a minimum of 25 persons.	Ground water at Camp Fogarty is not a current source of drinking water, but is classified as GAA-NA at Site 10; therefore, MCLs are relevant and appropriate. Contaminant concentrations are compared to MCLs to assess potential risks associated with ingestion of ground water.
	Safe Drinking Water Act (40 CFR 141.50-.52) Maximum Contaminant Level Goals (MCLGs)	Relevant and Appropriate	Non-enforceable health goals for public water supply systems, set at levels which result in no known or anticipated adverse health effects.	Ground water at Camp Fogarty is not a current source of drinking water, but is classified as GAA-NA at Site 10; therefore, MCLGs are relevant and appropriate. Non-zero MCLGs are to be used as remedial goals for current or potential sources of drinking water, per the NCP (40 CFR 300). Contaminant concentrations are compared to MCLGs to assess potential risks associated with ingestion of ground water.
	USEPA Risk Reference Doses (RfDs)	To Be Considered	Toxicity values for evaluating noncarcinogenic effects resulting from exposures to contamination.	USEPA RfDs are used to characterize risks due to noncarcinogens in ground water.
	Lifetime Health Advisories	To Be Considered	Guidelines developed based on toxicity for noncarcinogenic compounds	TBC criteria due to the presence of contaminants in ground water.
STATE Ground Water--				
	RI Ground Water Protection Act (RIGL, 46-13 et seq.) Public Drinking Water Regulations	Relevant and Appropriate	Establishes provisions for the protection and management of potable drinking waters, including the development of ground water classifications and associated standards which specify maximum contaminant levels for each classification.	Ground water at Camp Fagarty is not a current source of drinking water, but is classified as GAA-NA at Site 10; therefore, these regulations are relevant and appropriate and contaminant concentrations will be compared to the established ground water quality standards.

TABLE 4-11
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-1 - NO ACTION
ALTERNATIVE GW-2 - LIMITED ACTION
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL Wetlands/Water Resources--	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	May be applicable if wetland areas are present on-site. Due to the lack of site disturbance under these alternatives, the alternatives would comply with this ARAR.
Endangered Species--	Endangered Species (16 USC 1531) Protection of Endangered Species	Applicable	Restricts activities in areas inhabited by registered endangered species.	Due to the lack of site disturbance under these alternatives, the alternatives would comply with this ARAR.
Cultural Resources--	National Historic Preservation Act of 1966 (16 USC 470, et seq.) Protection of Historic Lands and Structures; Archaeological and Historic Preservation Act of 1974 (132 CFR 229 & 229.4, 43 CFR 7 & 7.4); Historic Sites, Building and Antiquities Act.	Applicable	Several statutes which govern the preservation at historic, scientific and archaeological sites and resources. Includes action to recover and preserve artifacts, preserve historic properties and minimize harm to National Historic Landmarks.	Due to the lack of site disturbance under these alternatives, the alternatives would comply with this ARAR.

TABLE 4-11 (continued)
FEDERAL AND STATE LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-1 - NO ACTION
ALTERNATIVE GW-2 - LIMITED ACTION
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
<u>STATE</u> Wetlands--				
	Rhode Island Wetlands Laws (RIGL 2-1-18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh-water Wetlands Act - As Amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	May be applicable if wetland areas are present on-site. Due to the lack of site disturbance under these alternatives, the alternatives would comply with this ARAR.
Wellhead Protection Areas--				
	RI Water Pollution Control Act; RI Rules and Regulations for Groundwater Quality	Applicable	Specific requirements for delineating and refining wellhead protection areas.	While the refined wellhead protection area for a proposed water supply well, if constructed, does not encompass Site 10, its proximity to the site may require continued monitoring of pumping rates and capture zones. Ground water monitoring would be conducted in accordance with these regulations.

TABLE 4-12
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-2 - LIMITED ACTION
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
STATE Monitoring	Rules and Regulations for Ground Water Quality	Applicable	Rules and regulations intended to protect and restore the quality of the State's ground water. Includes ground water program monitoring requirements and monitoring well construction and abandonment.	Ground water monitoring programs and well construction/abandonment methodologies will comply with these regulations.

TABLE 4-13
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - EXTRACTION/TREATMENT/DISCHARGE
INCLUDING OPTIONS GW-3A THROUGH GW-3D
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Ground Water--				
	Safe Drinking Water Act (40 CFR 141.11-.16 and 141.60-.63) Maximum Contaminant Levels (MCL's)	Relevant and Appropriate	MCL's directly apply to "public water systems", defined as systems with at least 15 connections which service a minimum of 25 persons.	Ground water at Camp Fogarty is not a current source of drinking water, but is classified as GAA-NA at Site 10; therefore, MCLs are relevant and appropriate. Contaminant concentrations are compared to MCLs to assess potential risks associated with ingestion of ground water.
	Safe Drinking Water Act (40 CFR 141.50-.52) Maximum Contaminant Level Goals (MCLGs)	Relevant and Appropriate	Non-enforceable health goals for public water supply systems, set at levels which result in no known or anticipated adverse health effects.	Ground water at Camp Fogarty is not a current sourceof drinking water, but is classified as GAA-NA at Site 10; therefore, MCLGs are relevant and appropriate. Non-zero MCLGs are to be used as remedial goals for current or potential sources of drinking water, per the NCP (40 CFR 300). Contaminant concentrations are compared to MCLGs to assess potential risks associated with ingestion of ground water.
	USEPA Risk Reference Doses (RfDs)	To Be Considered	Toxicity values for evaluating noncarcinogenic effects resulting from exposures to contamination.	USEPA RfDs are used to characterize risks due to noncarcinogens in ground water.
	Lifetime Health Advisories	To Be Considered	Guidelines developed based on toxicity for noncarcinogenic compounds	TBC criteria due to the presence of contaminants in ground water.
Surface Water --				
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	Applicable	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms.	AWQC will be applicable to remedial alternatives which involve discharges to surface water.
	Clean Water Act (40 CFR 401.15) Effluent Discharge Limitations	Applicable	Regulates the discharge of contaminants from an industrial point source.	Regulations will be applicable to remedial alternatives which involve discharges to surface water.

TABLE 4-13(continued)
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - EXTRACTION/TREATMENT/DISCHARGE
INCLUDING OPTIONS GW-3A THROUGH GW-3D
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
STATE				
Ground Water--	RI Ground Water Protection Act (RIGL, 46-13 et seq.) Public Drinking Water Regulations	Relevant and Appropriate	Establishes provisions for the protection and management of potable drinking waters, including the development of ground water classifications and associated standards which specify maximum contaminant levels for each classification.	Ground water at Camp Fogarty is not a current source of drinking water, but is classified as GAA-NA at Site 10; therefore, these regulations are relevant and appropriate and contaminant concentrations will be compared to the established ground water quality standards.
Surface Water --	RI Water Pollution Control Law (RIGL 46-12 et seq.) RI Water Quality Standards	Applicable	Establishes water use classification and water quality criteria for all waters of the state. Also establishes acute and chronic water quality criteria for the protection of aquatic life.	Regulation will be applicable for remedial alternatives which involve discharges to surface water.

TABLE 4-14
FEDERAL LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - EXTRACTION/TREATMENT/DISCHARGE
INCLUDING OPTIONS GW-3A THROUGH GW-3D
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Wetlands/Water Resources--				
	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	Applicable	Requires action to avoid whenever possible the long- and short-term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	Will be applicable if wetland areas are present on-site. Remedial actions will be designed to minimize impacts to wetland areas.
Endangered Species--				
	Endangered Species (16 USC 1531) Protection of Endangered Species	Applicable	Restricts activities in areas inhabited by registered endangered species.	Will be applicable if endangered species are identified on-site.
Cultural Resources--				
	National Historic Preservation Act of 1966 (16 USC 470, et seq.) Protection of Historic Lands and Structures; Archaeological and Historic Preservation Act of 1974 (132 CFR 229 & 229.4, 43 CFR 7 & 7.4); Historic Sites, Building and Antiquities Act.	Applicable	Several statutes which govern the preservation at historic, scientific and archaeological sites and resources. Includes action to recover and preserve artifacts, preserve historic properties and minimize harm to National Historic Landmarks.	Will be applicable if significant scientific, prehistoric, historic or archaeological resources exist at the site.

TABLE 4-14(continued)
FEDERAL LOCATION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - EXTRACTION/TREATMENT/DISCHARGE
INCLUDING OPTIONS GW-3A THROUGH GW-3D
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
STATE				
Wetlands--				
	Rhode Island Wetlands Laws (RIGL 2-1-18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh-water Wetlands Act - As Amended, Dec. 21, 1986.	Applicable	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	Will be applicable if wetland areas are present on-site.
Wellhead Protection Areas--				
	RI Water Pollution Control Act; RI Rules and Regulations for Groundwater Quality	To be determined	Specific requirements for delineating and refining wellhead protection areas.	While the refined wellhead protection area for a proposed water supply well, if constructed, does not encompass Site 10, its proximity to the site may require continued monitoring of pumping rates and capture zones. Ground water remediation would be conducted in accordance with these regulations.

TABLE 4-15
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - EXTRACTION/TREATMENT/DISCHARGE
INCLUDING OPTIONS GW-3A THROUGH GW-3D
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
FEDERAL				
Discharge	Clean Water Act (40 CFR 122-125) National Pollutant Discharge Elimination System (NPDES) Permit Requirements	Applicable	Permits contain applicable effluent standards (i.e., technology-based and/or water quality-based), monitoring requirements, and standards and special conditions for discharge.	Discharges of treated water to surface waters will meet these requirements.
On-site/ Off-site Treatment/ Disposal	Resource Conservation and Recovery Act (RCRA) (40 CFR 262) Generator Requirements for Manifesting Waste for Off-Site Disposal	Applicable	Standards for manifesting, marking and recording off-site hazardous waste shipments for treatment/disposal.	If treatment system by-product requires off-site disposal/treatment as a hazardous waste, generator requirements will be followed.
	RCRA (40 CFR 264) Subpart I Use and Management of Containers	Applicable	Outlines use and management standards applicable to owners and operators of all hazardous waste facilities that store containers of hazardous waste.	Remedial actions which require storage of hazardous waste in containers will comply with these requirements.
	RCRA (40 CFR 263) Transporter Requirements for Off-Site Disposal	Applicable	Standards for transporters of hazardous waste materials.	If treatment system by-product requires off-site disposal/treatment as a hazardous waste, transporter requirements will be followed.
	RCRA (40 CFR 268) Land Disposal Restrictions	Applicable	Identifies hazardous wastes that are restricted from land disposal and sets treatment standards for restricted wastes.	If treatment system by-product requires off-site disposal as a hazardous waste, land disposal restrictions will be followed.
	Hazardous Materials Transportation Act (49 CFR 170, 171) Rules for Transportation of Hazardous Materials	Applicable	Procedures for packaging, labelling, manifesting, and off-site transport of hazardous materials.	If treatment system by-product is determined to be hazardous, transport procedures will be followed.

TABLE 4-15(continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE GW-3 - EXTRACTION/TREATMENT/DISCHARGE
INCLUDING OPTIONS GW-3A THROUGH GW-3D
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
STATE Discharge	RI Water Pollution Control Act			
	• RI Water Quality Regulations for Water Pollution Control (RIGL 46-12 et seq.) RI Water Quality Standards	Applicable	Establishes general requirements and effluent limits for discharge to area waters.	Discharges of treated water to area surface water will meet these requirements.
	• Regulations for the RI Pollutant Discharge Elimination Systems (RIGL 46-12 et seq.)	Applicable	Permits contain applicable effluent standards (i.e., technology-based and/or water quality-based), monitoring requirements, and standards and special conditions for discharge.	Discharges of treated water to area surface water will meet these requirements.
On-site/ Off-site Disposal/ Treatment	RI Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.) • Hazardous Waste Management Rules and Regulations	Applicable	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal.	If treatment system by-product is determined to be hazardous, these rules will be followed.
	• Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases (Site Remediation Regulations)	Applicable	Rules and regulations for the investigation and remediation of releases of hazardous materials.	Remedial systems will be designed and operated in accordance with these requirements.
	RI Hazardous Substance Community Right to Know Act (RIGL, Title 23, Chapter 24.4) Public Right-to-Know Requirements	Applicable	Establishes rules for the public's right-to-know concerning hazardous waste storage and transportation.	These rules will be followed if treatment system by-product requires management as a hazardous waste.
	RI Refuse Disposal Law Rules and Regulation for Solid Waste Management Facilities	Applicable	Rules and regulations for solid waste management facilities.	These rules will be followed if treatment system by-product requires management as a solid waste.

TABLE 4-16
COMPARISON AMONG GROUND WATER ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	COMPARISON OF OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
Alternative GW-1 - No Action	Least protective alternative; Does not limit future potable use of ground water and does not monitor ground water quality; Does not present any short-term impacts; Does not meet remedial response objectives
Alternative GW-2 - Limited Action	Provides protection of human health by limiting potential future exposures to inorganics in ground water through the institutional controls limiting potable ground water use and through the implementation of ground water monitoring to identify potential off-site ground water quality impacts; Does not provide compliance with drinking water standards through treatment; however, would prevent the development of a ground water ingestion exposure pathway; Uses institutional controls to meet remedial action objectives
Alternative GW-3 - Extraction/Treatment/ Discharge	Provides active treatment to reduce potential future risks to human health associated with ground water ingestion; Would comply with chemical-specific, location-specific, and action-specific ARARs; Some increased short-term risks would result during implementation; Would be effective in the long-term as long as the treatment system is operational but permanence is not ensured
Option GW-3A - Ground Water Extraction via Extraction Wells	Provides protection of the environment and human health by limiting potential ground water migration and by removing ground water for treatment; Would comply with applicable ARARs; Minimal short-term risks would result during implementation; Would be effective in the long-term
Option GW-3B - Precipitation Inorganic Treatment	Provides protection of the environment and human health through treatment of inorganic contaminants in ground water; Would comply with applicable ARARs; Some increased short-term risks would result during implementation due to residual handling; Would be effective in the long-term
Option GW-3C - Ion Exchange Inorganic Treatment	Provides protection of the environment and human health through treatment of inorganic contaminants in ground water; Would comply with applicable ARARs; Some increased short-term risks would result during implementation due to regenerant and residual handling; Would be effective in the long-term
Option GW-3D - Discharge to Surface Water	Provides protection of the environment and human health when combined with ground water extraction and treatment; Would comply with applicable ARARs; Minimal short-term risks would result during implementation; Would be effective in the long-term

TABLE 4–17
COMPARISON AMONG GROUND WATER ALTERNATIVES
COMPLIANCE WITH ARARS
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC – DAVISVILLE, RI

ACTION	CHEMICAL–SPECIFIC	LOCATION–SPECIFIC	ACTION–SPECIFIC
Alternative GW–1 – No Action	Does not meet criteria	Five–year reviews would require consideration of nearby production well pumping rates and capture zones	Not applicable
Alternative GW–2 – Limited Action	Does not meet criteria	Monitoring activities would comply with location–specific criteria	Monitoring would comply with RIDEM's Rules and Regulations for Ground Water Quality
Alternative GW–3 – Extraction/Treatment/ Discharge	Treatment would meet criteria	Extraction/Treatment/Discharge systems would comply with location–specific criteria	Extraction/Treatment/Discharge systems would comply with action–specific criteria
Option GW–3A – Ground Water Extraction via Extraction Wells	Meets criteria by capturing contaminants that exceed MCLs and PRGs	Installation would comply with location–specific criteria	Would be implemented in compliance with RIDEM Site Remediation Regulations
Option GW–3B – Precipitation Inorganic Treatment	Meets criteria by treating inorganic contaminants that exceed MCLs and PRGs	Construction would be conducted in accordance with location–specific criteria	Treatment system operation would comply with applicable criteria; Off–site disposal of sludge would require hazardous waste characterization and compliance with either hazardous or non–hazardous waste management regulations
Option GW–3C – Ion Exchange Inorganic Treatment	Meets criteria by treating inorganic contaminants that exceed MCLs and PRGs	Construction would be conducted in accordance with location–specific criteria	Treatment system operation would comply with applicable criteria; Off–site disposal of backwash from the treatment system would require hazardous waste characterization and compliance with either hazardous or non–hazardous waste management regulations
Option GW–3D – Discharge to Surface Water	Water quality of the treatment process effluent would be required to meet ambient water quality criteria	Construction would be conducted in accordance with location–specific criteria	Would comply with criteria applicable to surface water discharge

TABLE 4-18
COMPARISON AMONG GROUND WATER ALTERNATIVES
LONG-TERM EFFECTIVENESS AND PERMANENCE
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	COMPARISON OF LONG-TERM EFFECTIVENESS AND PERMANENCE
Alternative GW-1 - No Action	Effective in the long-term provided ground water is not used as a drinking water supply; Provides no long-term monitoring of ground water quality; Requires five-year reviews
Alternative GW-2 - Limited Action	Effective in minimizing the long-term risks associated with the potential construction and use of an on-site well as a source of drinking water; Monitoring program provides a means of monitoring potential changes in ground water quality or potential contaminant migration and off-site impacts; Requires five-year reviews
Alternative GW-3 - Extraction/Treatment/ Discharge	Treatment effective in treating lead and manganese and in preventing off-site migration of contaminants during operation; Permanent contaminant reduction would not necessarily result if ground water treatment is discontinued in the future; Requires long-term maintenance; Requires five-year reviews
Option GW-3A - Ground Water Extraction via Extraction Wells	Provides an effective and reliable means of extracting ground water; Well-proven in performance and can function with minimal maintenance
Option GW-3B - Precipitation Inorganic Treatment	Effective in the removal of inorganics from the wastestream; long-term risks associated with the residuals of ground water treatment would be relatively small; Sludge produced will require hazardous waste characterization and appropriate disposal; Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties
Option GW-3C - Ion Exchange Inorganic Treatment	Effective in the removal of most inorganics from the wastestream; long-term risks associated with the residuals of ground water treatment would be relatively small; Residual backwash produced will require hazardous waste characterization and appropriate disposal; Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties
Option GW-3D - Discharge to Surface Water	Long-term risks associated with discharge to surface water will be minimal, provided treatment system is operating properly; Long-term operation and maintenance of discharge piping is not expected to pose any major technical problems; Requires long-term monitoring of the quality of discharged water

TABLE 4-19
COMPARISON AMONG GROUND WATER ALTERNATIVES
REDUCTION OF TOXICITY, MOBILITY OR VOLUME THROUGH TREATMENT
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	COMPARISON OF REDUCTION IN TOXICITY, MOBILITY OR VOLUME THROUGH TREATMENT
Alternative GW-1 - No Action	Provides no reduction in toxicity, mobility or volume through treatment
Alternative GW-2 - Limited Action	Provides no reduction in toxicity, mobility or volume through treatment
Alternative GW-3 - Extraction/Treatment/ Discharge	Provides a reduction in toxicity, mobility and volume through treatment
Option GW-3A - Ground Water Extraction via Extraction Wells	Ground water extraction does not provide treatment but would be combined with a treatment option; Reduces the potential mobility of contaminated ground water
Option GW-3B - Precipitation Inorganic Treatment	Provides a reduction in the toxicity of identified inorganic contaminants through treatment; Volume of contaminated media is reduced through removal of contaminants from the ground water and subsequent production of a concentrated sludge residual
Option GW-3C - Ion Exchange Inorganic Treatment	Provides a reduction in the toxicity of identified inorganic contaminants through treatment; Volume of contaminated media is reduced through removal of contaminants from the ground water and subsequent production of a concentrated residual backwash
Option GW-3D - Discharge to Surface Water	Not expected to significantly affect the extraction or treatment system; therefore, it has little impact on the toxicity, mobility, or volume of contamination

TABLE 4-20
COMPARISON AMONG GROUND WATER ALTERNATIVES
SHORT-TERM EFFECTIVENESS
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	COMPARISON OF SHORT-TERM EFFECTIVENESS
Alternative GW-1 - No Action	No remedial activities conducted; Therefore, no short-term risks result; Five-year reviews would provide the only means of ensuring compliance with remedial action objectives
Alternative GW-2 - Limited Action	Implementation of deed restrictions would result in no short-term risks; Implementation of the monitoring program would have minimal short-term adverse impacts based on the use of existing wells for ground water monitoring purposes; Would meet remedial response objectives related to preventing ingestion of contaminated ground water by preventing on-site potable well installation and providing ground water monitoring to assess potential off-site migration
Alternative GW-3 - Extraction/Treatment/ Discharge	No significant risks to on-site workers or off-site risks are anticipated; Degree of short-term risk would be dependent upon the individual options employed; Remedial response objectives would be achieved during operation of the treatment system but may not be maintained if treatment is discontinued
Option GW-3A - Ground Water Extraction via Extraction Wells	Presents minimal short-term risks to on-site workers and would not be expected to result in any increased off-site risks to human health or the environment; Easily implemented within a minimal time frame
Option GW-3B - Precipitation Inorganic Treatment	No significant short-term risks to workers are expected; Major operation and maintenance activities associated with chemical precipitation include maintenance of chemical supplies and sludge handling; No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation
Option GW-3C - Ion Exchange Inorganic Treatment	No significant short-term risks to workers are expected; Major operation and maintenance activities associated with ion exchange include maintenance of chemical supplies and backwash handling; No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation
Option GW-3D - Discharge to Surface Water	Short-term risks to workers associated with the construction of discharge piping would not be significant; Maintenance of the system will require maintenance of the piping and discharge monitoring; No added risks to the adjacent community or the environment are anticipated

TABLE 4-21
COMPARISON AMONG GROUND WATER ALTERNATIVES
IMPLEMENTABILITY
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC - DAVISVILLE, RI

ACTION	COMPARISON OF IMPLEMENTABILITY
Alternative GW-1 - No Action	Requires no implementation other than five-year reviews; Would not limit the implementation of other remedial actions
Alternative GW-2 - Limited Action	A mechanism to ensure the implementation of deed restrictions would have to be established should the U.S. Army ever excess the site; The prohibition of future installation of on-site potable wells would not be expected to impact the present use of the site; Implementation of this alternative would not limit the implementation of future remedial actions
Alternative GW-3 - Extraction/Treatment/ Discharge	Relatively easy to implement; Technical implementability would be dependent upon the individual alternative options selected; Some treatment technologies are more easily implemented than others; Services and materials should be readily available for the implementation of all options
Option GW-3A - Ground Water Extraction via Extraction Wells	Implementation of a ground water extraction system is expected to be good; Materials and services are readily available; Minimal technical or administrative obstacles to implementation would be anticipated
Option GW-3B - Precipitation Inorganic Treatment	Easily implemented; Startup is not expected to result in unanticipated technical problems; Implementation is not expected to impact the implementation of any future remedial actions; Operational activities include maintenance of chemical suplies and sludge handling; Administrative feasibility is also expected to be good
Option GW-3C - Ion Exchange Inorganic Treatment	Implementation of an ion exchange treatment system is expected to be good; Treatment units are widely available and easily constructed; Implementation of an ion exchange system will not impact the implementation of future remedial actions; Operational activities include regeneration of the resin material and handling of residual backwash; Administrative feasibility is also expected to be good
Option GW-3D - Discharge to Surface Water	Technical implementation of a discharge to surface water system is good; Continued monitoring of the discharged water quality will be required; Administrative feasibility of discharging treated ground water to surface water depends on the treatment system's ability to meet surface water discharge criteria

TABLE 4-22
COMPARISON AMONG GROUND WATER ALTERNATIVES
COST
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC – DAVISVILLE, RI

ACTION	TOTAL CAPITAL COST	ANNUAL O&M COST	PRESENT WORTH O&M COST (1)	TOTAL PRESENT WORTH (2)
Alternative GW-1 – No Action	--	--	--	Nominal (3)
Alt rnative GW-2 – Limited Action	--	$8,300	$130,000	$150,000
Alt rnative GW-3 – Extraction/Treatment/ Discharge	--	--	--	--
Option GW-3A – Ground Water Extraction via Extraction Wells	$49,000	--	--	$58,000
Option GW-3B – Precipitation Inorganic Treatment	$150,000	$54,000	$830,000	$1,200,000
Option GW-3C – Ion Exchange Inorganic Treatment	$230,000	$13,000	$200,000	$520,000
Option GW-3D – Discharge to Surface Water	$6,600	$7,400	$110,000	$150,000

(1) – Based on 5% discount rate
(2) – Includes 20% contingency on all components
(3) – The only cost associated with the implementation of Alternative GW-1 would be that associated with conducting five-year reviews of the no action decision. Deed restrictions would be implemented under the base closure property transfer process.

TABLE 4-23
COST SENSITIVITY ANALYSIS
SITE 10 - CAMP FOGARTY DISPOSAL AREA

Item Varied (Minimum - Maximum)	Alternative	Minimum Cost	Maximum Cost
Discount Factor (3% - 10%)	Soil	**10%**	**3%**
	S-2	$18,000	$21,500
	Ground Water		
	GW-2	$94,000	$195,000
	GW-3A	$58,000	$58,000
	GW-3B	$795,000	$1,450,000
	GW-3C	$425,000	$590,000
	GW-3D	$92,000	$183,000
Remediation Period (15 yrs - 40 yrs)	Ground Water	**15 yrs**	**40 yrs**
	GW-3A	$58,000	$58,000
	GW-3B	$855,000	$1,295,000
	GW-3C	$440,000	$550,000
	GW-3D	$101,000	$161,000

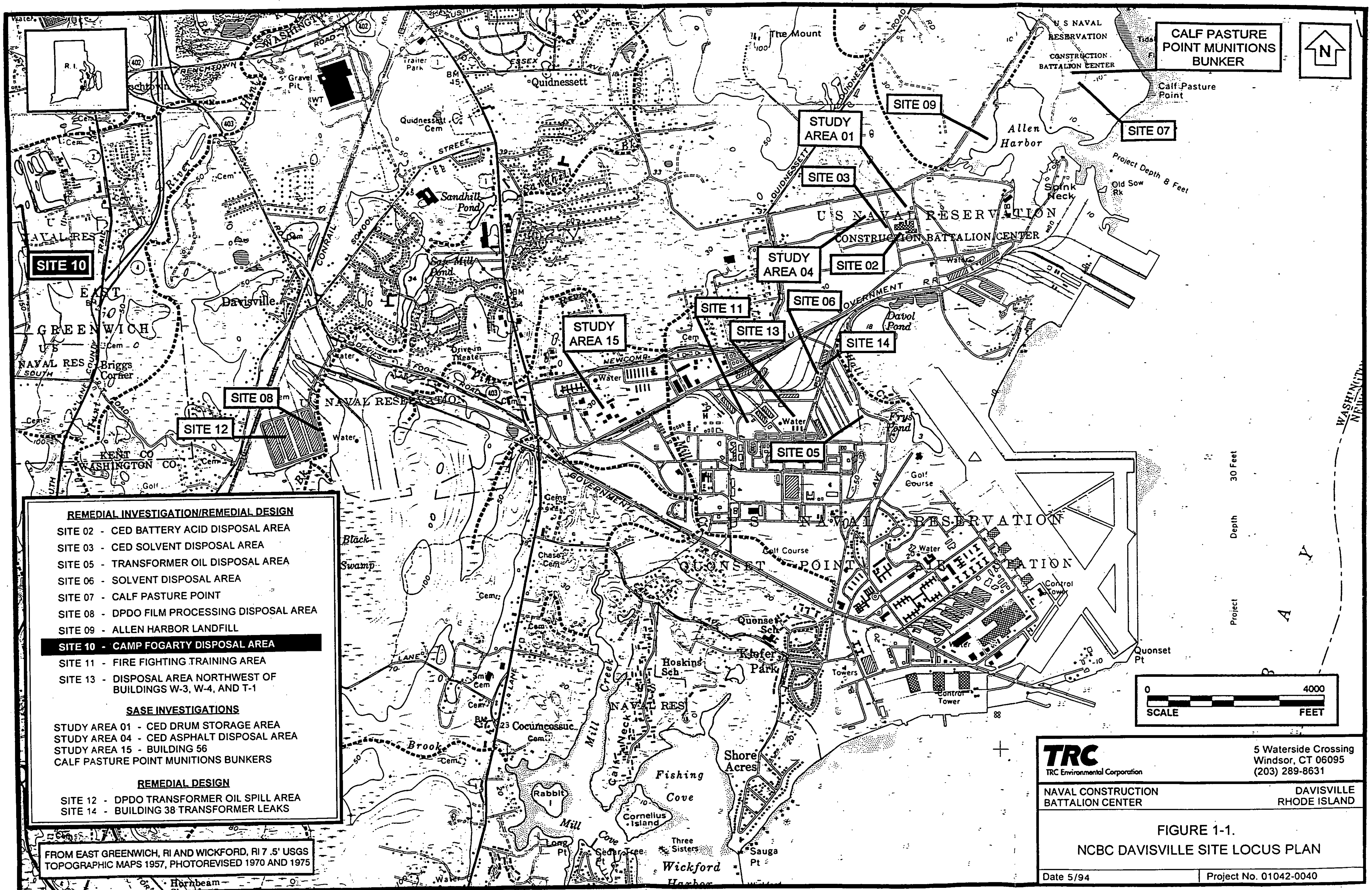

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FIGURE 1-1.
NCBC DAVISVILLE SITE LOCUS PLAN

Date 5/94 | Project No. 01042-0040

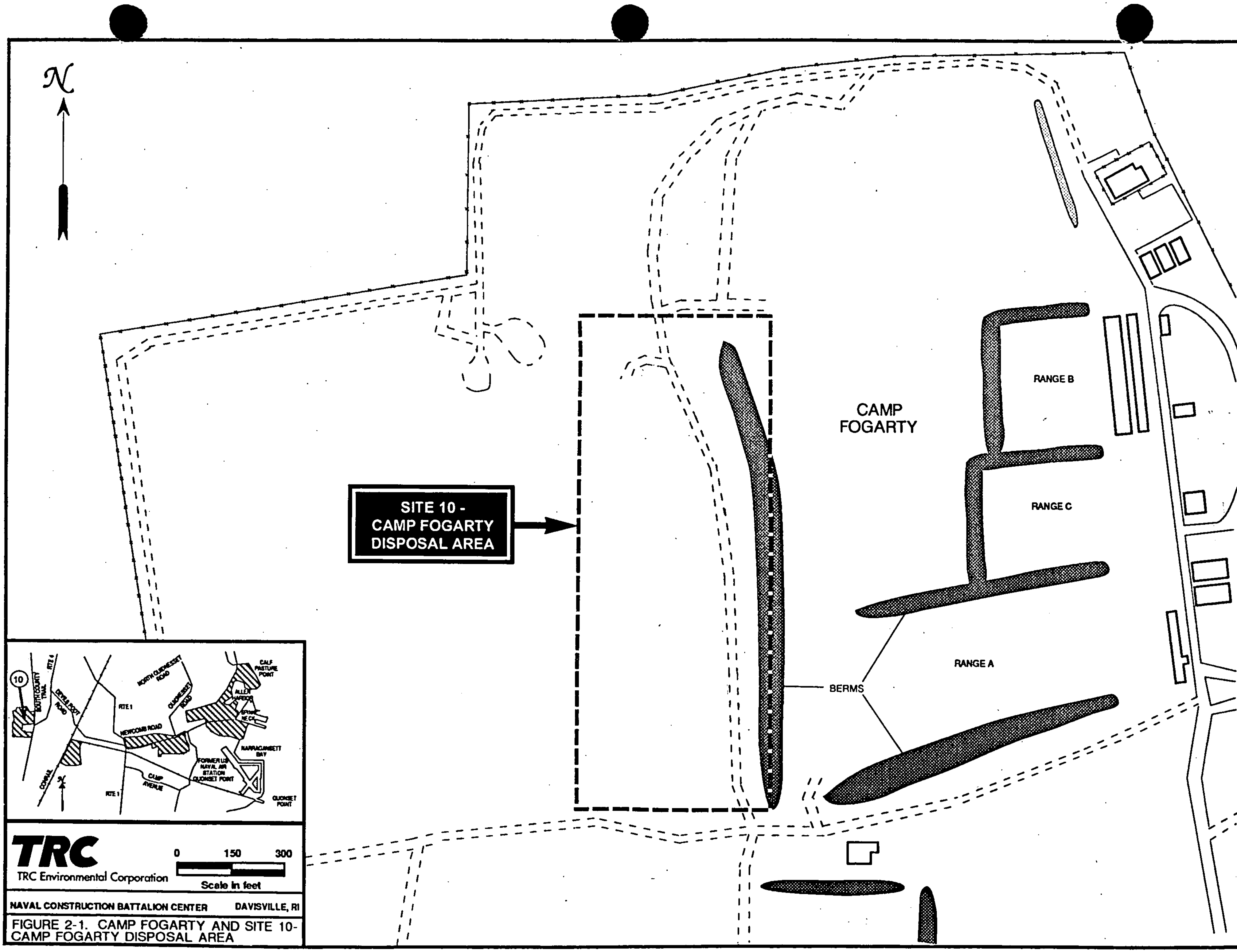
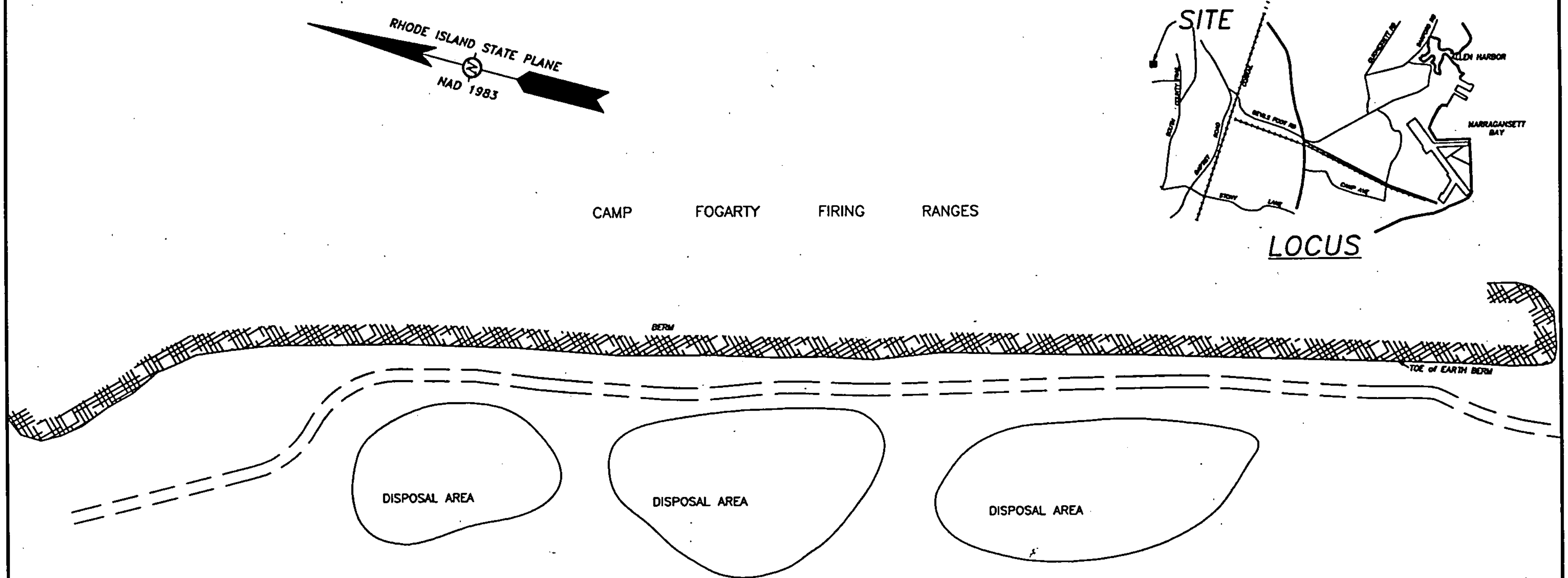


FIGURE 2-1. CAMP FOGARTY AND SITE 10-CAMP FOGARTY DISPOSAL AREA



NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

60 0 60 120 180 240 FEET

20 0 20 40 60 METERS

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FIGURE 2-2.
SITE 10-CAMP FOGARTY DISPOSAL AREA
SITE PLAN

Date: 5/94 | Project No. 01042-0040

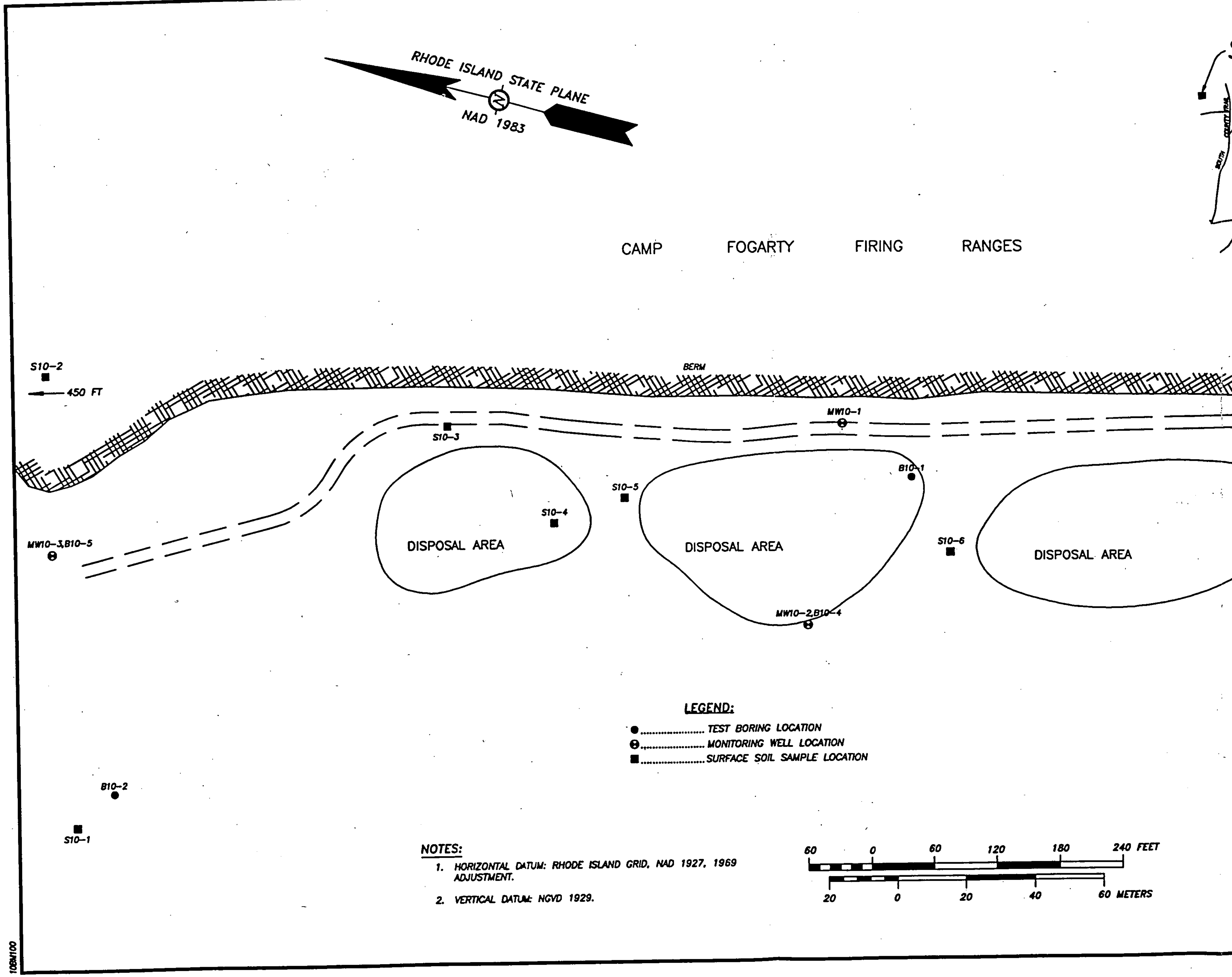

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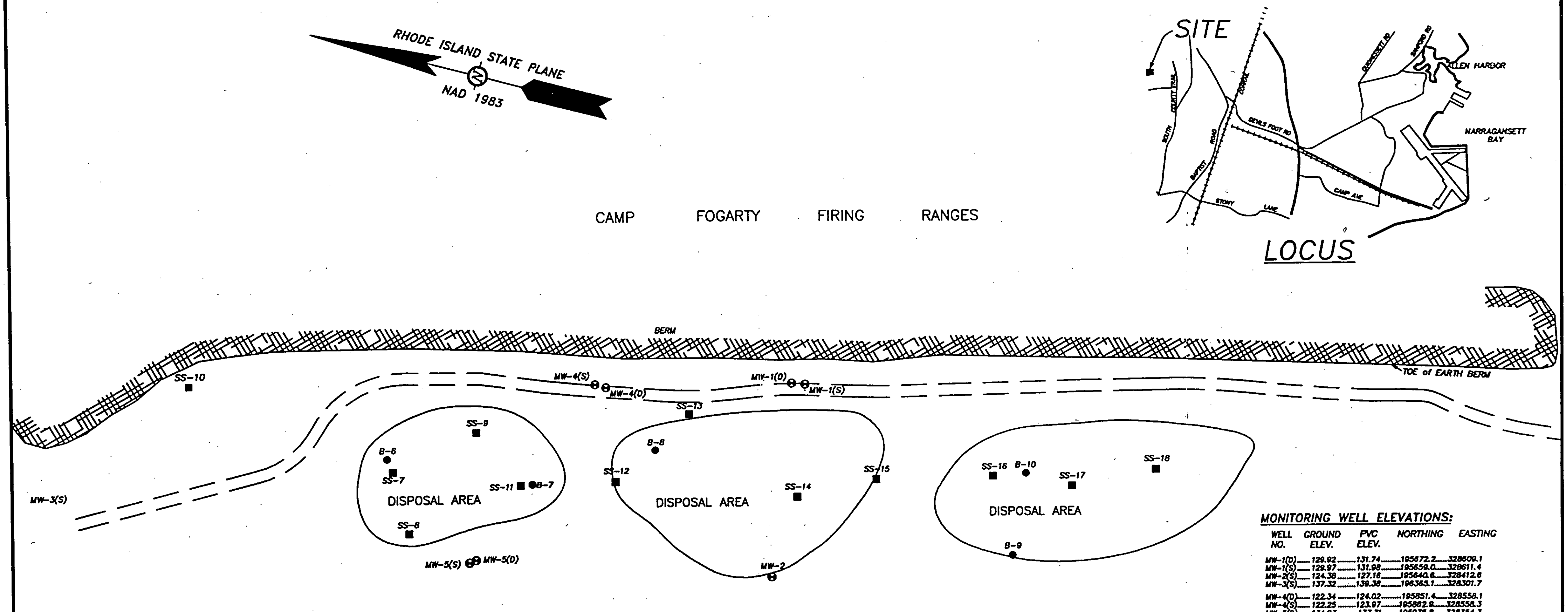
FIGURE 2-3.
SITE 10-CAMP FOGARTY DISPOSAL AREA
PHASE I SAMPLING LOCATIONS

Date: 5/94 | Project No. 01042-0040



MONITORING WELL ELEVATIONS:

WELL NO.	GROUND ELEV.	PVC ELEV.	NORTHING	EASTING
MW-1(D)	129.92	131.74	195672.2	328609.1
MW-1(S)	129.97	131.98	195659.0	328611.4
MW-2(S)	124.38	127.16	195640.6	328412.6
MW-3(S)	137.32	139.38	196365.1	328301.7
MW-4(D)	122.34	124.02	195851.4	328558.1
MW-4(S)	122.25	123.97	195862.9	328558.3
MW-5(D)	134.93	137.31	195935.8	328354.3
MW-5(S)	134.77	136.57	195941.5	328350.1

LEGEND:

- ● .... TEST BORING LOCATION
- ⊖ .... MONITORING WELL LOCATION
- ■ .... SURFACE SOIL SAMPLE LOCATION
- (S) .... SHALLOW WELL
- (D) .... DEEP WELL

NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

60 0 60 120 180 240 FEET

20 0 20 40 60 METERS

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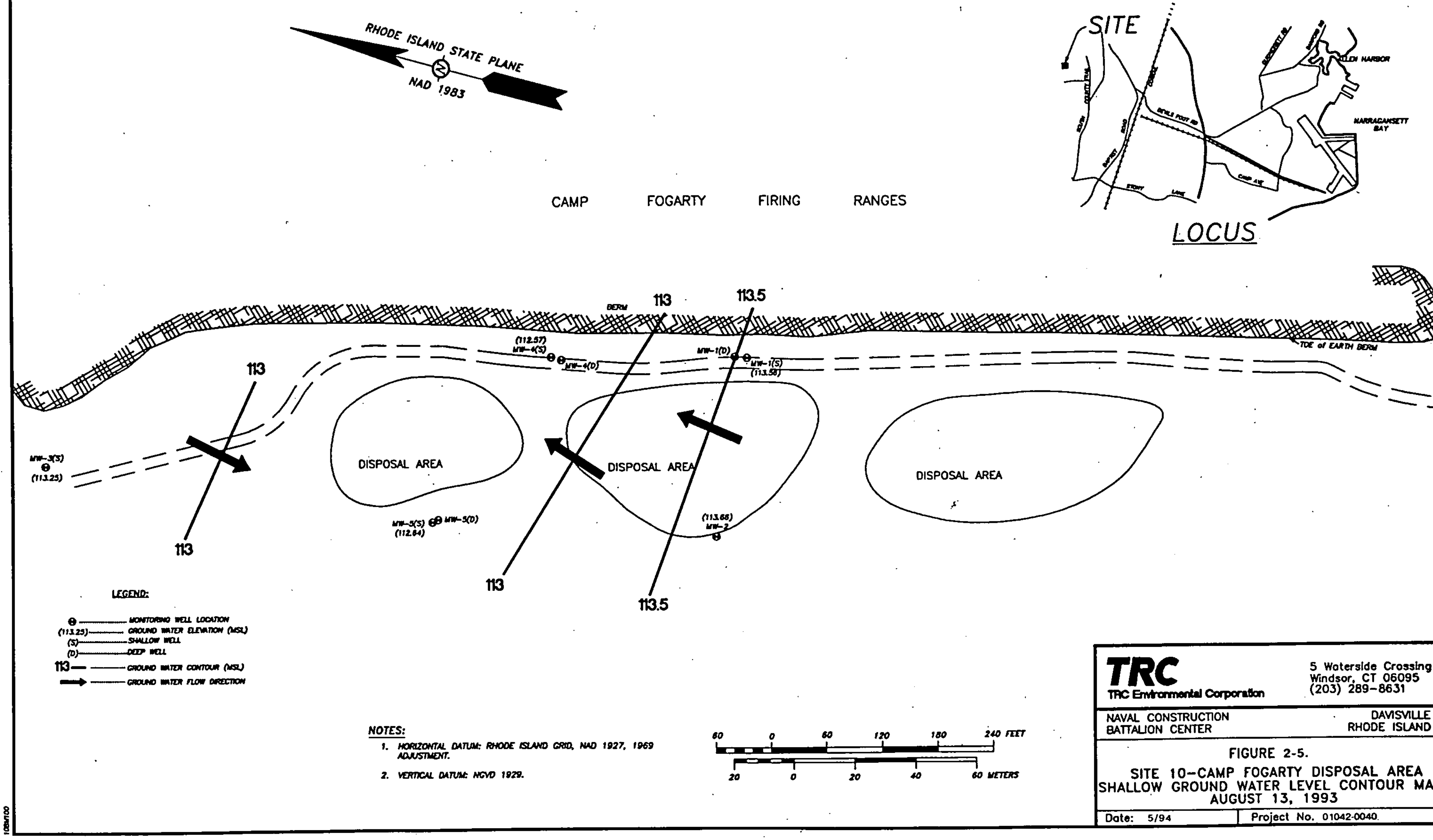
FIGURE 2-4.
SITE 10-CAMP FOGARTY DISPOSAL AREA
PHASE II SAMPLING LOCATIONS

Date: 5/94 | Project No. 01042-0040

10BN100



NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

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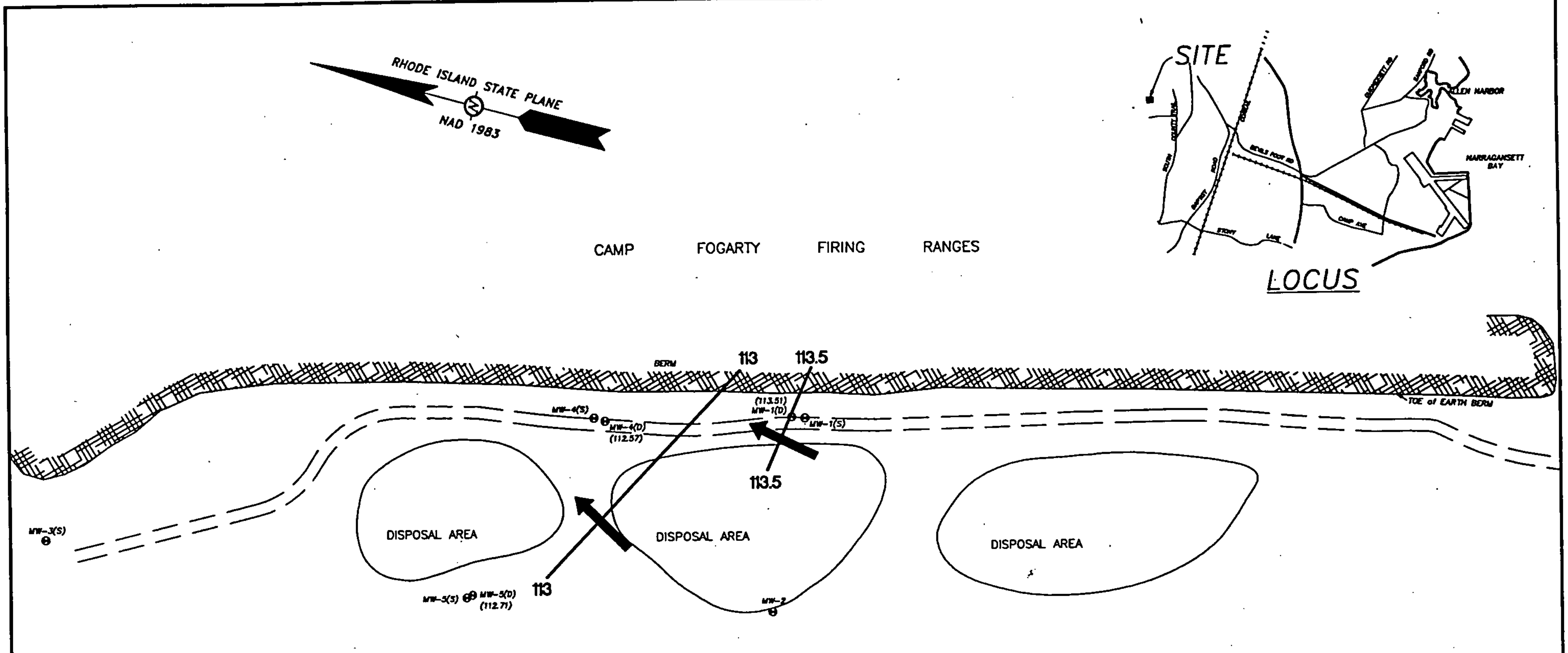
FIGURE 2-5.
SITE 10-CAMP FOGARTY DISPOSAL AREA
SHALLOW GROUND WATER LEVEL CONTOUR MAP
AUGUST 13, 1993

Date: 5/94 | Project No. 01042-0040

108M100



LEGEND:

- ⊖ — MONITORING WELL LOCATION
- (113.51) — GROUND WATER ELEVATION (MSL)
- (S) — SHALLOW WELL
- (D) — DEEP WELL
- 113 — GROUND WATER CONTOUR (MSL)
- ➡ — GROUND WATER FLOW DIRECTION

NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

60 0 60 120 180 240 FEET

20 0 20 40 60 METERS

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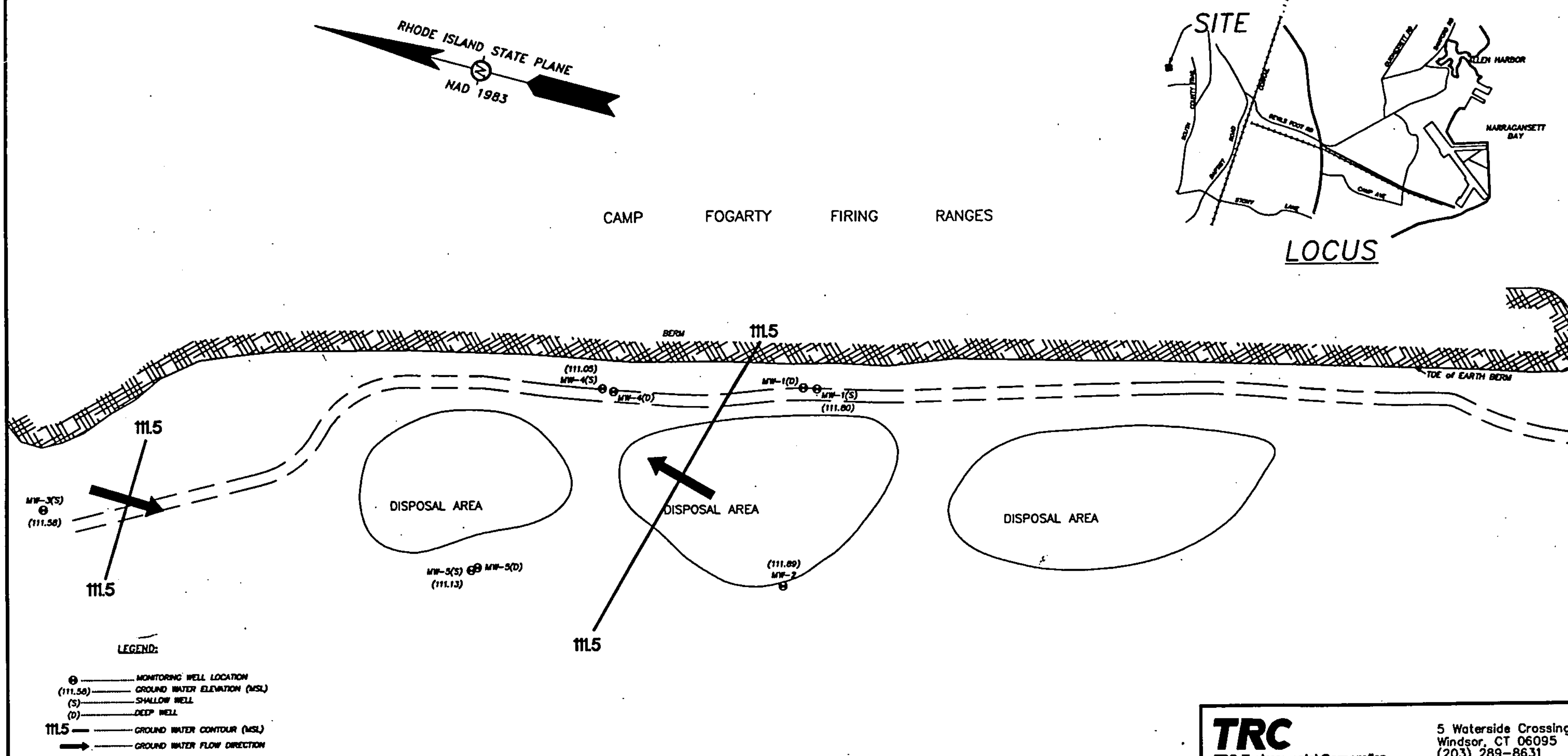
FIGURE 2-6.
SITE 10-CAMP FOGARTY DISPOSAL AREA
DEEP GROUND WATER LEVEL CONTOUR MAP
AUGUST 13, 1993

Date: 5/94 | Project No. 01042-0040

1069/100



NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

60 0 60 120 180 240 FEET

20 0 20 40 60 METERS

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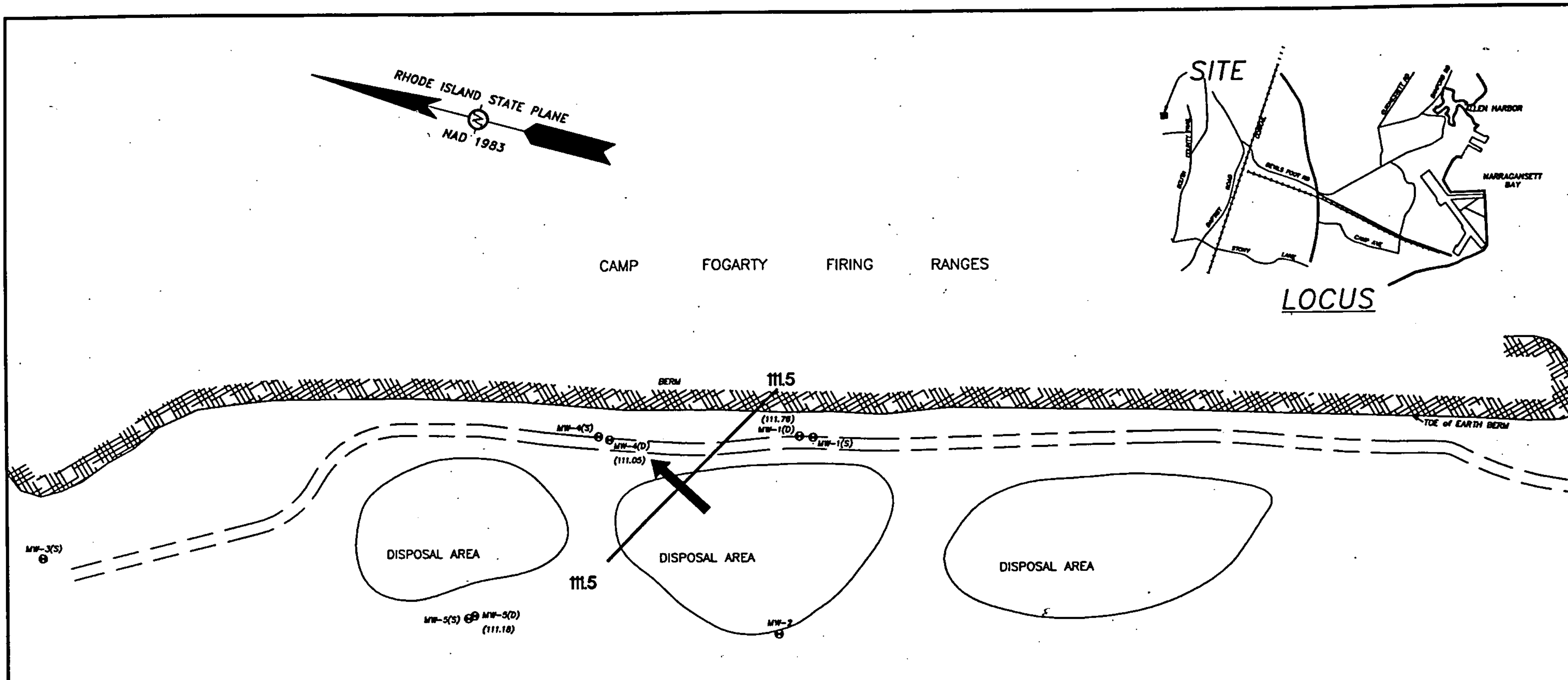
FIGURE 2-7.

SITE 10-CAMP FOGARTY DISPOSAL AREA
SHALLOW GROUND WATER LEVEL CONTOUR MAP
SEPTEMBER 17, 1993

Date: 5/94 | Project No. 01042-0040



LEGEND:

- ⊖ — MONITORING WELL LOCATION
- (111.05) — GROUND WATER ELEVATION (MSL)
- (S) — SHALLOW WELL
- (D) — DEEP WELL
- 111.5 — GROUND WATER CONTOUR (MSL)
- ➞ — GROUND WATER FLOW DIRECTION

NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

60 0 60 120 180 240 FEET

20 0 20 40 60 METERS

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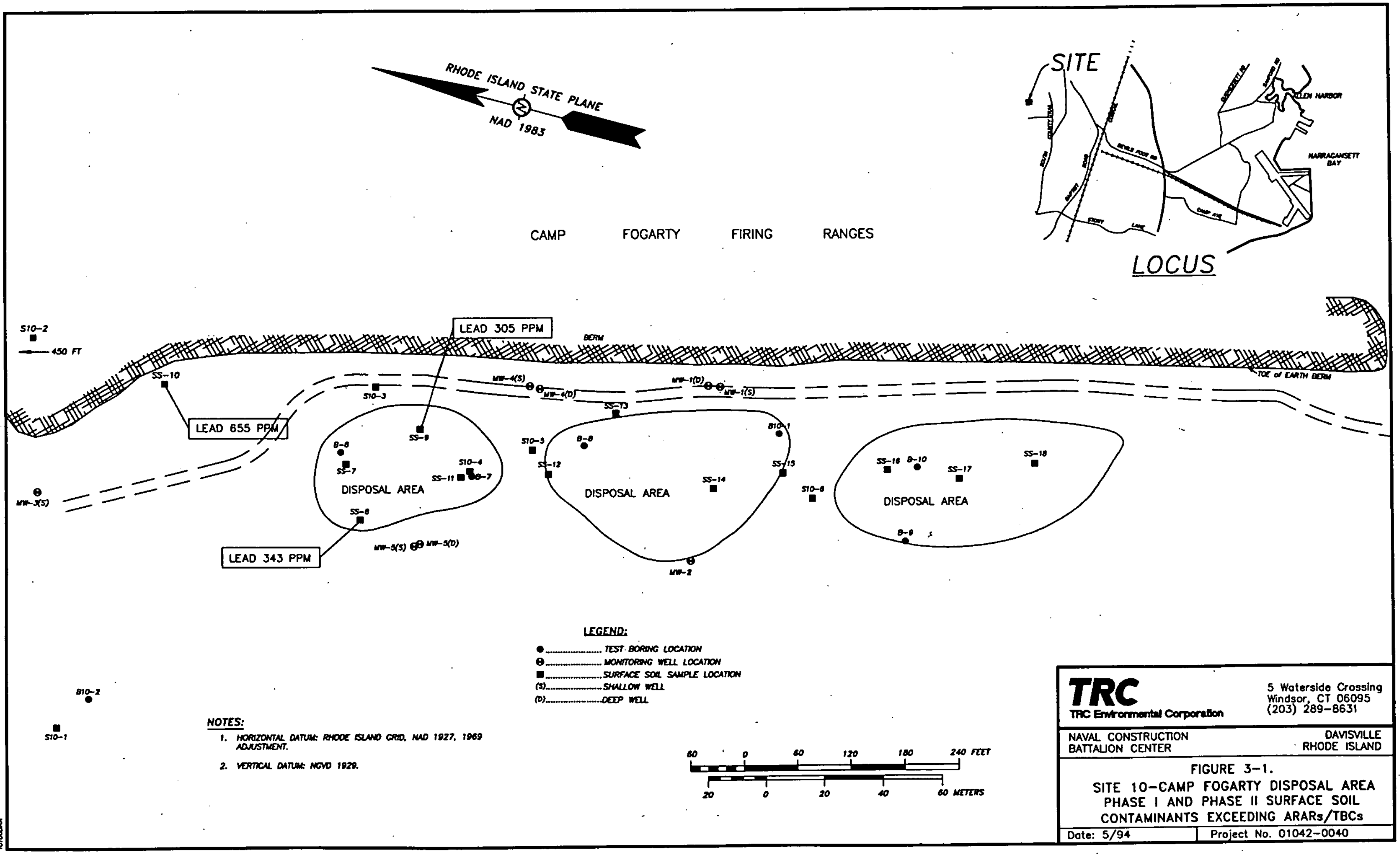
FIGURE 2-8.

SITE 10-CAMP FOGARTY DISPOSAL AREA
DEEP GROUND WATER LEVEL CONTOUR MAP
SEPTEMBER 17, 1993

Date: 5/94 | Project No. 01042-0040



NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

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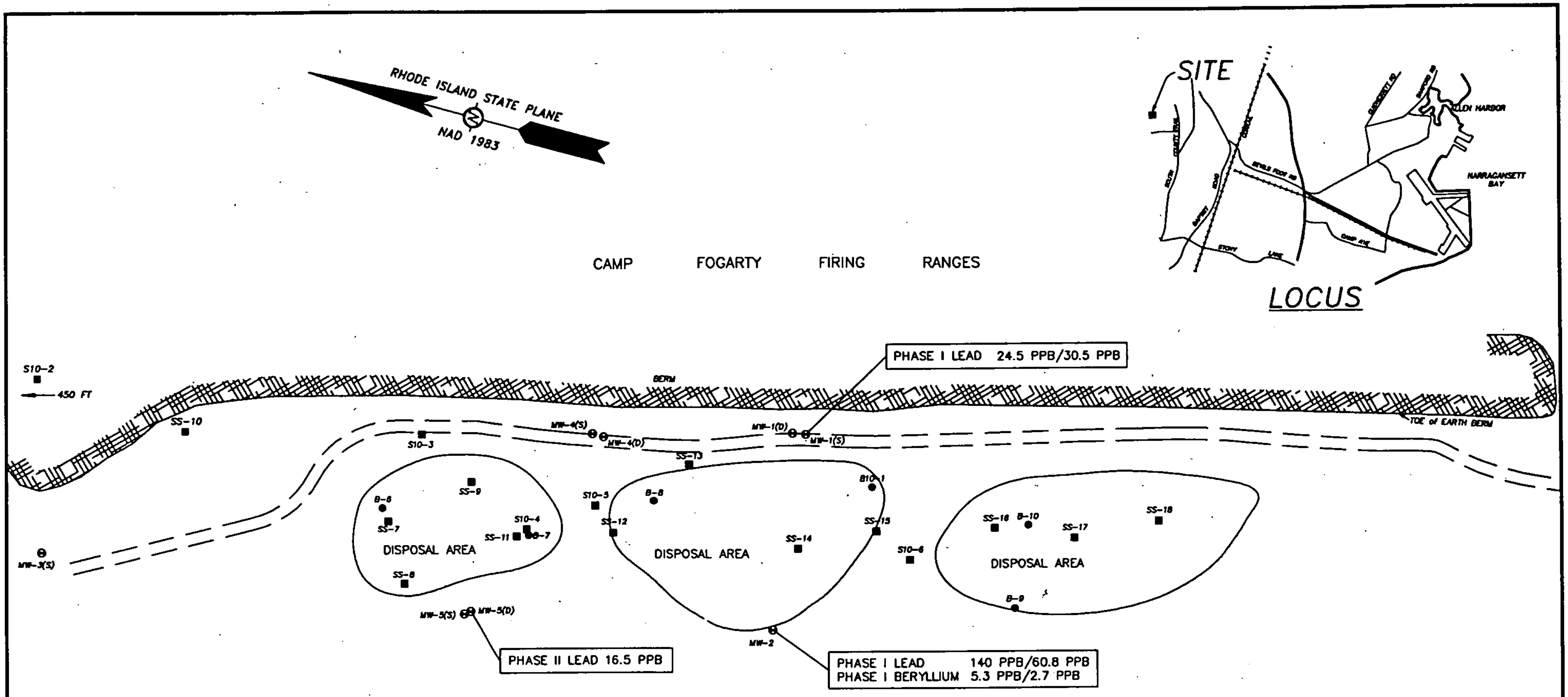
FIGURE 3-1.
SITE 10-CAMP FOGARTY DISPOSAL AREA
PHASE I AND PHASE II SURFACE SOIL
CONTAMINANTS EXCEEDING ARARs/TBCs

Date: 5/94 | Project No. 01042-0040

1010034A



LEGEND:

- ●........ TEST BORING LOCATION
- ʘ........ MONITORING WELL LOCATION
- ■........ SURFACE SOIL SAMPLE LOCATION
- (S)........ SHALLOW WELL
- (D)........ DEEP WELL

NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.
3. SEE TABLE 3-2 FOR MCL VALUES. TWO ROUNDS OF SAMPLING WERE CONDUCTED DURING THE PHASE I RI; ANALYTICAL RESULTS FOR BOTH ROUNDS ARE PROVIDED.

60 0 60 120 180 240 FEET
20 0 20 40 60 METERS

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FIGURE 3-2.
SITE 10-CAMP FOGARTY DISPOSAL AREA
PHASE I AND PHASE II GROUND WATER
CONTAMINANTS EXCEEDING MCLs

Date: 5/94 | Project No. 01042-0040

101000AA

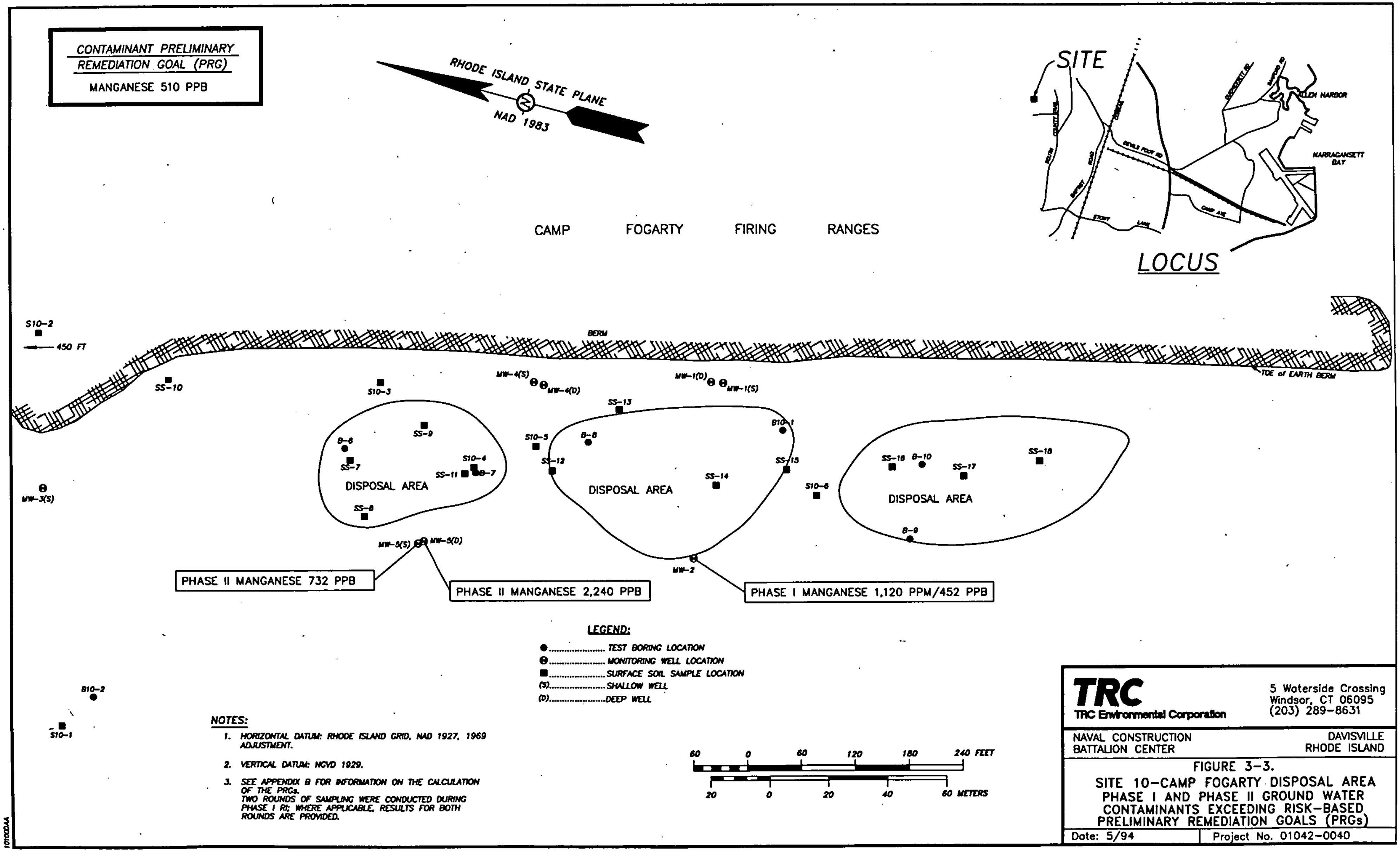

FIGURE 3-3.
SITE 10-CAMP FOGARTY DISPOSAL AREA PHASE I AND PHASE II GROUND WATER CONTAMINANTS EXCEEDING RISK-BASED PRELIMINARY REMEDIATION GOALS (PRGs)

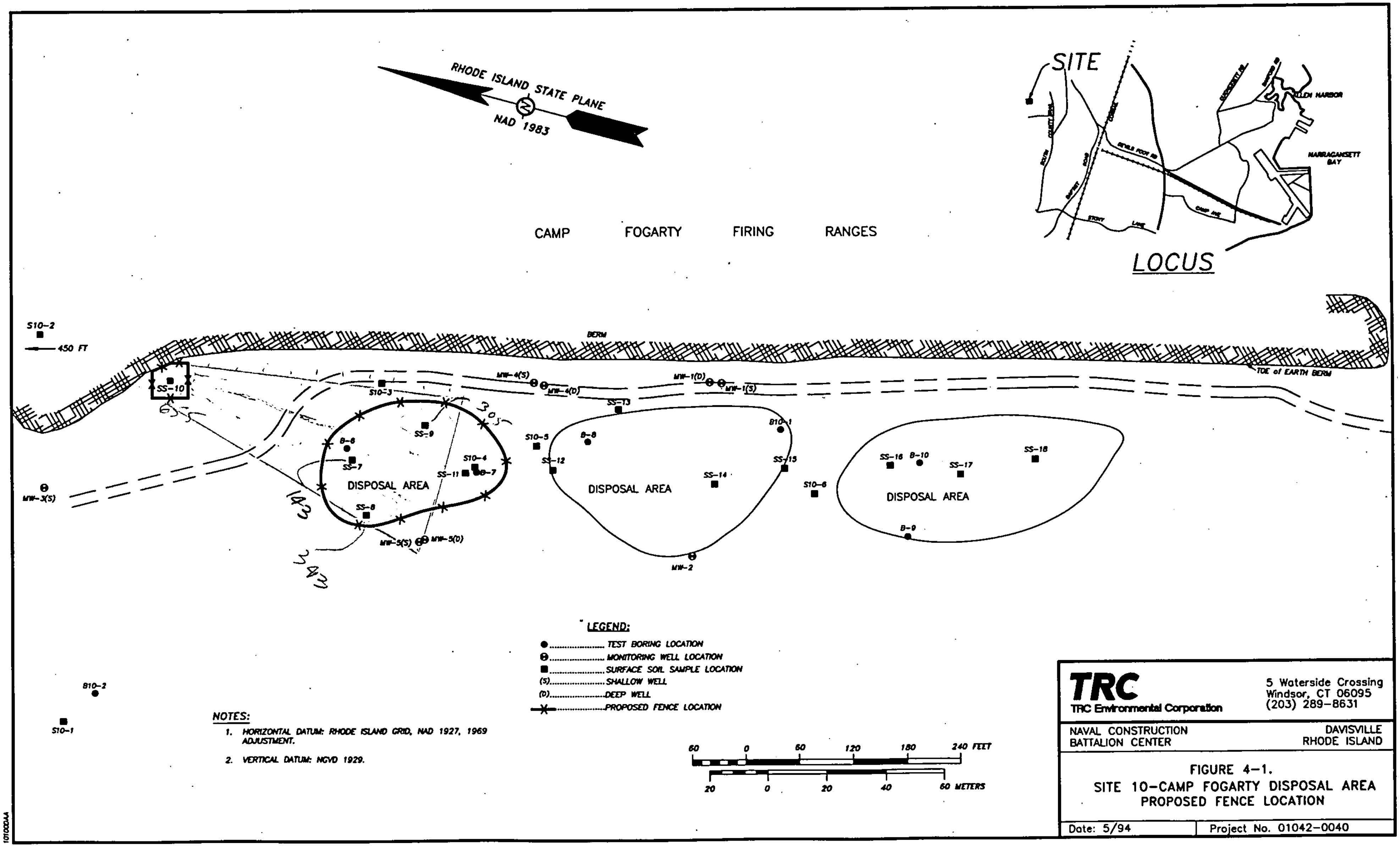

FIGURE 4-1.
SITE 10-CAMP FOGARTY DISPOSAL AREA
PROPOSED FENCE LOCATION

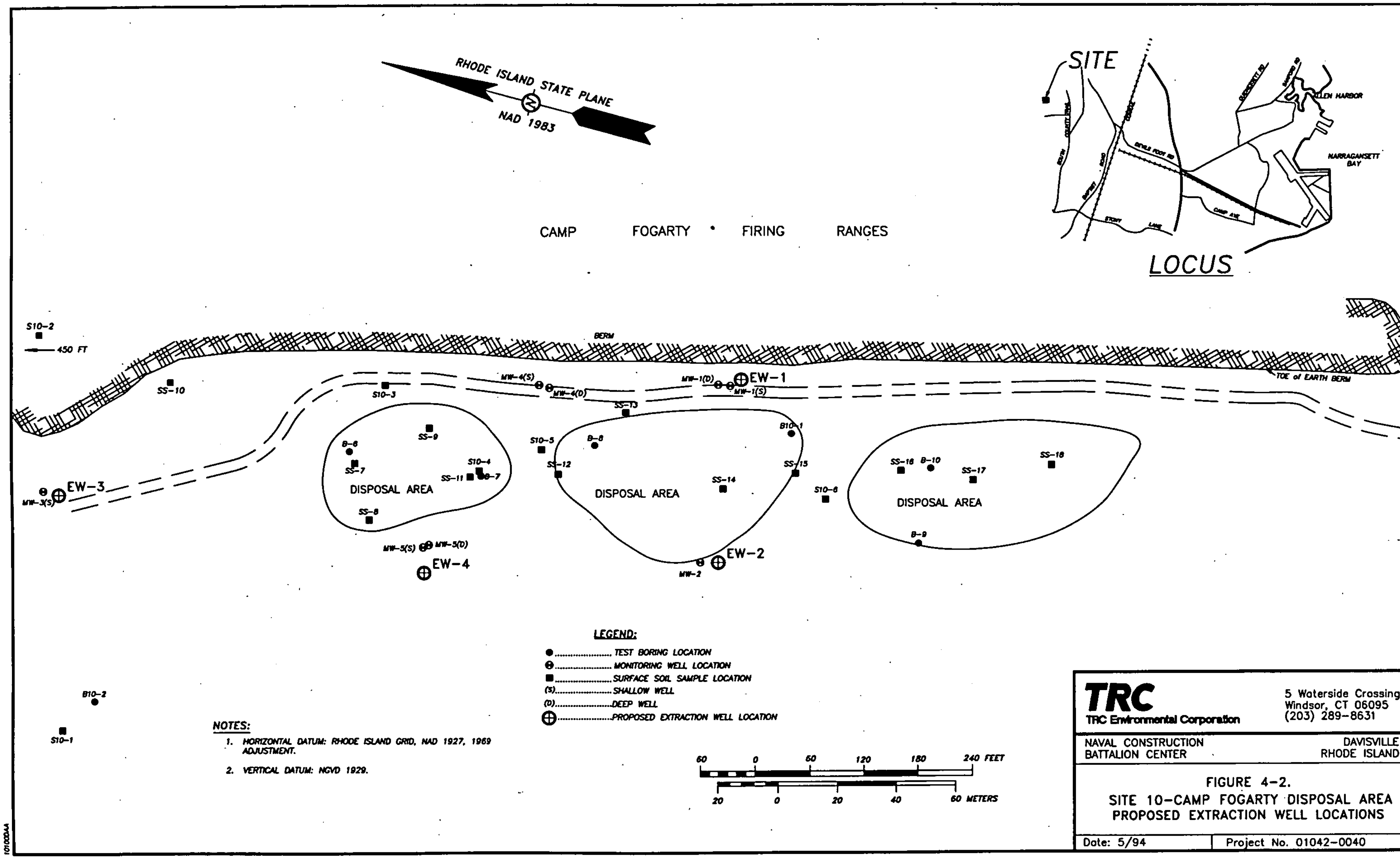
RHODE ISLAND STATE PLANE
NAD 1983
SITE
LOCUS
NARRAGANSETT BAY
CAMP FOGARTY FIRING RANGES
BERM
TOE of EARTH BERM
450 FT
S10-2
SS-10
S10-3
MW-4(S)
MW-4(D)
MW-1(D)
MW-1(S)
EW-1
SS-13
B10-1
S10-5
B-8
SS-9
B-6
SS-7
S10-4
SS-11
B-7
SS-12
SS-15
SS-14
S10-6
SS-16
B-10
SS-17
SS-18
DISPOSAL AREA
DISPOSAL AREA
DISPOSAL AREA
EW-3
MW-3(S)
SS-8
MW-5(S)
MW-5(D)
EW-4
MW-2
EW-2
B-9
B10-2
S10-1
LEGEND:
TEST BORING LOCATION
MONITORING WELL LOCATION
SURFACE SOIL SAMPLE LOCATION
(S) SHALLOW WELL
(D) DEEP WELL
PROPOSED EXTRACTION WELL LOCATION
NOTES:
1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.
60 0 60 120 180 240 FEET
20 0 20 40 60 METERS
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FIGURE 4-2.
SITE 10-CAMP FOGARTY DISPOSAL AREA
PROPOSED EXTRACTION WELL LOCATIONS
Date: 5/94
Project No. 01042-0040

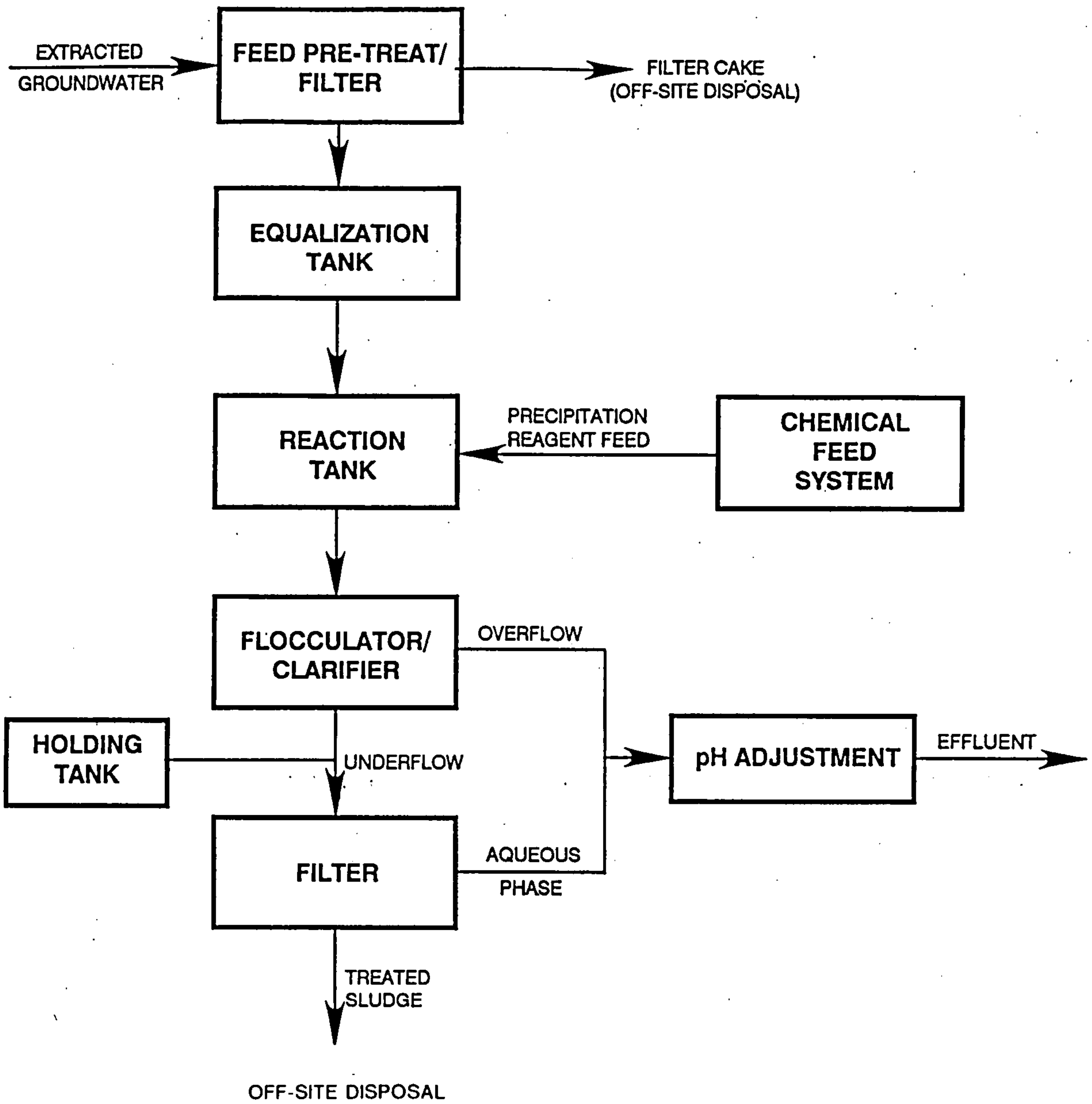

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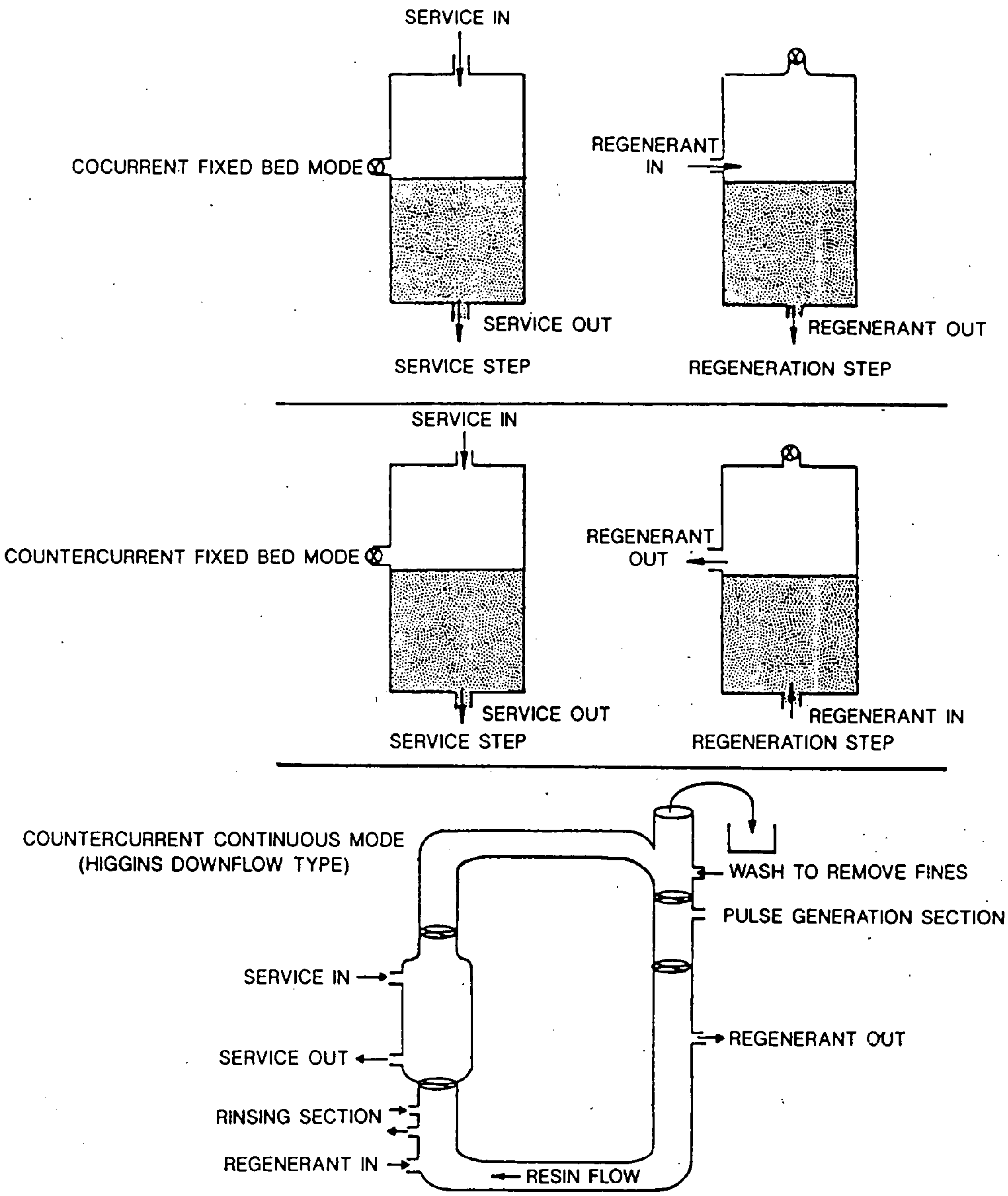
FIGURE 4-3.

SITE 10-CAMP FOGARTY DISPOSAL AREA
CHEMICAL PRECIPITATION SCHEMATIC

Date: 5/94 | Project No. 01042-0040



SOURCE: DeRENZO, D.J., 1978

TRC
TRC Environmental Corporation

5 Waterside Crossing
Windsor, CT 06095
(203) 289-8631

NAVAL CONSTRUCTION BATTALION CENTER — DAVISVILLE RHODE ISLAND

FIGURE 4-4.
SITE 10-CAMP FOGARTY DISPOSAL AREA
TYPICAL ION EXCHANGE SYSTEMS

Date: 5/94 | Project No. 01042-0040

APPENDIX A

APPENDIX A

IDENTIFICATION OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

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APPENDIX A

IDENTIFICATION OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

A.1 Introduction

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA, 1986), and the NCP (1990), requires that all remedial response actions attain or exceed applicable or relevant and appropriate requirements of Federal and more stringent promulgated requirements of State environmental statute(s). The NCP defines applicable requirements as "those cleanup standards, standards of control, other substantive environmental protection requirements or criteria, or limitations promulgated under federal environmental or state environmental facility siting law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances found at a CERCLA site." Relevant and appropriate requirements are defined in the NCP as "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at the CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site."

To-Be-Considered materials (TBCs) are non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status of potential ARARs. However, in many circumstances TBCs may be considered along with ARARs in determining the necessary level of cleanup for protection of health or the environment.

Current EPA CERCLA guidance calls for a preliminary identification of potential ARARs during the RI scoping phase to assist in the initial identification of remedial alternatives. Early identification also facilitates communications with support agencies to evaluate ARARs, and may help planning of field activities. Because of the iterative nature of the RI/FS process, ARAR identification continues throughout the RI/FS as better understanding is gained of the site conditions, site contaminants, and remedial action alternatives. Findings of the Phase I RI aided in the selection of ARARs as presented in Volume II of the Phase II RI/FS Work Plan (TRC, 1992). ARARs were further evaluated in the Initial Screening of Alternatives Report (TRC, 1993). This section revisits the information provided in that report, updating it on the basis of the specific information related to Site 10, as addressed herein, as well as on the basis of evolving regulatory requirements.

ARARs may be categorized as: 1) chemical-specific requirements, which may define acceptable exposure levels and, therefore, be used in establishing preliminary remediation goals; 2) location-specific requirements, which may set restrictions on activities within specific locations such as coastal areas or wetlands; and 3) performance, design or other action-specific requirements, which may set controls or restrictions for particular treatment and disposal activities related to the management of hazardous wastes. The documents "CERCLA Compliance With Other Laws Manual" (USEPA, 1988), and "CERCLA Compliance with Other Laws Manual: Part II. Clean Air Act and Other Environmental Statutes and State Requirements" (USEPA, 1989), contain detailed information on identifying and complying with ARARs. In addition, Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991) provides guidance on the use of ARARs for the development of preliminary remediation goals (PRGs).

A.2 Approach

This evaluation focuses on the identification of potential chemical-specific ARARs/TBCs which will guide the development of PRGs at Site 10. Preliminary location-specific and action-specific ARARs/TBCs are also evaluated herein, but are further evaluated with respect to the individual remedial alternatives in the detailed alternative analysis portion of this report.

To determine the chemical-specific requirements which may be applicable to remediation at Site 10 (i.e., to identify preliminary remediation goals (PRGs) and chemical-specific ARARs which may be applicable to certain remedial actions), an evaluation of federal and State of Rhode Island chemical-specific ARARs was conducted. Those federal and state chemical-specific ARARs considered to potentially be applicable or relevant and appropriate to the development of PRGs at Site 10 have been compiled, as presented in Tables A-1 and A-2.

A.3 Potential Federal Chemical-Specific ARARs/TBCs

Potential federal chemical-specific ARARS and TBC criteria are presented in Table A-1. Chemical-specific ARARs/TBCs which may be applicable to the development of preliminary remediation goals for the various media at the site are addressed by media below. Following this discussion is a presentation of potential chemical-specific ARARs/TBCs which may be considered in the evaluation of specific remedial actions at the site.

A.3.1 Ground Water

Ground water at Camp Fogarty is not a current source of drinking water although ground water at Site 10 is classified as GAA-NA, which indicates that the site is located in a non-attainment (NA) area where ground water resources are otherwise suitable for public drinking water without treatment. The goal for non-attainment areas is restoration to a quality consistent with the classification. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991) provides guidance on the development of PRGs for ground water. Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs), non-zero maximum contaminant level goals (MCLGs), and state drinking water standards are common ARARs and therefore PRGs for ground water that is a current or potential source of drinking water. Based on the site's ground water classification, MCLs, MCLGs and state drinking water standards are considered to be relevant and appropriate to Site 10. Where MCLs, MCLGs and state drinking water standards are unavailable for a particular ground water contaminant, USEPA Risk Reference Doses, Lifetime Health Advisories and Human Health Assessment Group Cancer Slope Factors will be used to develop risk-based PRGs.

A.3.2 Soils

The Toxic Substances Control Act provides PCB cleanup levels for solid surfaces and soils where spills occurred after May 4, 1987. These levels may be relevant and appropriate to the evaluation of any PCB contamination in Site 10 soils. USEPA Guidance on Remedial Actions for Superfund Sites with PCB Contamination (OSWER Directive 9355.4-02) will also be considered with respect to the evaluation of any PCB contamination in Site 10 soils. In addition, the Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02) will represent TBC criteria for lead in soils.

A.3.3 Chemical-Specific ARARs Potentially Applicable to Remedial Actions

Chemical-specific federal ARARs/TBCs which are applicable to the implementation of certain remedial actions include Ambient Water Quality Criteria (AWQC) and Effluent Discharge Limitations, both promulgated under the Clean Water Act, which represent potential chemical-specific ARARs for alternatives which involve discharges to surface waters.

The Toxicity Characteristic Leachate Parameter (TCLP) maximum concentrations (40 CFR 261.24) and the land disposal restrictions (40 CFR 268) present chemical-specific criteria which will be applicable to any action which requires a hazardous waste determination and disposal option evaluation.

Sections of the Clean Air Act which establish maximum concentrations for particulates and fugitive dust emissions, emissions limitations for new sources, and emissions limitations for hazardous air pollutants, will be considered potential chemical-specific ARARs for remedial alternatives which impact ambient air.

A.4 Potential Rhode Island Chemical-Specific ARARs/TBCs

A.4.1 Ground Water

Potential Rhode Island chemical-specific ARARs and TBC criteria are presented in Table A-2. As discussed in Section A.3.1, based on the site's GAA-NA ground water classification, Rhode Island Public Drinking Water Regulations are considered to be relevant and appropriate.

A.4.2 Soil

Rhode Island's Rules and Regulations for Solid Waste Management Facilities define solid wastes as including wastes which contain a concentration of 10 ppm or greater PCBs. The Rules and Regulations for Hazardous Waste Management define Type 6 - extremely hazardous waste as including wastes which contain a concentration of 50 ppm or greater PCBs. These regulations may be relevant and appropriate to the evaluation of soil PCB contaminant levels at Site 10.

RIDEM and the Rhode Island Department of Health-Risk Assessment consider a safe lead level in soil (total) as under 300 ppm, a TBC in the identification of PRGs at Site 10.

A.4.3 Chemical-Specific ARARs Potentially Applicable to Remedial Actions

Chemical-specific ARARs/TBCs which may be applicable to the implementation of certain remedial actions include the Rhode Island Water Quality Standards, established under the RI Water Pollution Control Law (RIGL, Title 46, Chapter 12), which will be applicable to remedial actions which involve discharges to surface water. The RI Clean Air Act (RI Title 23, Chapter 23) establishes maximum ambient levels for criteria pollutants under the Air Pollution Control Regulation Standards. These levels constitute potential chemical-specific ARARs for remedial alternatives which emit pollutants into the air.

A.5 Potential Location-Specific ARARs/TBCs

A site's location is a fundamental determinant of its impact on human health and the environment. Location-specific ARARs are restrictions placed on the concentrations of hazardous substances or the conduct of activities solely because they are in a specific location (USEPA, 1988).

A.5.1 Potential Federal Location-Specific ARARs/TBCs

Federal location-specific ARARs and TBCs identified as being potentially applicable to Site 10 are listed in Table A-3.

No formal wetlands delineation has been completed at Site 10, although depressions are present on site in which the collection of runoff during rain events has been observed. Therefore, wetlands/water resources regulations, including Executive Orders 11988 and 11990, Statement of Proceedings of Floodplain Management and Wetlands Protection, may potentially apply to remedial actions conducted on-site. The nearest wetlands identified on the USGS Compton and East Greenwich quadrangles are located approximately 2,000 feet east and southeast of Site 10.

The Endangered Species Act of 1973, which restricts activities in areas inhabited by registered endangered species, may also be a potential ARAR for Site 10 based on the conclusions of an endangered species survey conducted in 1989 by RIDEM (RIDEM, 1989). The survey of Camp Fogarty states that no occurrence records of rare species were identified for the Camp Fogarty property; however, two listed amphibians, the marbled salamander (*Ambystoma opacum*) and the four-toed salamander (*Hemidactylium scutatum*), have been found within a two-mile radius, and could potentially be found at Camp Fogarty. The report concludes that, if additional development of the facility is undertaken, impacts to wetland systems should be avoided and that, most importantly, small temporary pools of water potentially used as salamander breeding sites should not be disturbed.

No formal cultural resources survey has been conducted at Camp Fogarty. Therefore, the Archaeological and Historic Preservation Act of 1974 is considered to be a potential ARAR for remedial actions at Site 10.

The Clean Water Act Section 404 Requirements for Discharge of Dredge or Fill Material and the Rivers and Harbors Act Prohibition of Filling a Navigable Water will not apply to remedial actions conducted on-site since no streams or water bodies are present on-site.

Coastal area and harbor protection regulations are not applicable due to the site's distance from coastal areas.

The Fish and Wildlife Coordination Act of 1958 was enacted to protect fish and wildlife when federal actions result in the control or structural modification of a natural stream or water body. Since no permanent water bodies are located on or immediately adjacent to the site, the Fish and Wildlife Coordination Act is not expected to be applicable to remedial actions conducted on-site.

To determine the potential applicability of the Farmland Protection Policy Act, the U.S. Department of Agriculture Important Farmlands Map for Kent County was reviewed. This map, developed on the basis of soil survey information, indicates that limited areas designated as Prime Farmland and Additional Farmland of Statewide Importance are located in the general vicinity of Camp Fogarty but do not encompass or abut Site 10. Therefore, farmland protection regulations are not considered to be applicable to remedial actions at Site 10.

A.5.2 Potential State Location-Specific ARARs/TBCs

State location-specific ARARs/TBCs identified as being potentially applicable to Site 10 are indicated in Table A-4. As noted in Section A.5.1, a formal wetlands delineation has not been conducted at Site 10 but portions of the site may contain wetland areas. Therefore, the Rhode Island Wetlands Laws are considered to be potential ARARs for Site 10. Also worthy of consideration at Site 10 is the location of the site relative to public drinking water supply wells. Rhode Island Rules and Regulations for Groundwater Quality stipulate the delineation of refined wellhead protection areas around community water supply well locations. While Site 10 is not located within a wellhead protection area as currently delineated (RIGIS, 1993), the site is partially located within the capture zone of a proposed well location (see Figure 1-4 of Volume I for the proposed well location) (GZA, 1992). Since Site 10 is not located adjacent to the coast, Rhode Island Coastal Resources Management Law and Regulations are not applicable to the site.

A.6 Potential Action-Specific ARARs/TBCs

Based on the identification of contaminants in soil and ground water at Site 10, remediation activities may be required and numerous state and federal requirements could apply to the implementation of these activities. As discussed previously, potential action-specific ARARs/TBCs cannot be well-defined until remedial alternatives are developed and response actions defined. Action-specific ARARs will be defined in more detail in the detailed analysis of alternatives (Section 4 of this report).

A.6.1 Potential Federal Action-Specific ARARs/TBCs

Numerous federally promulgated action-specific ARARs and TBC criteria could potentially affect the implementation of remedial measures. A preliminary evaluation of federal regulatory requirements potentially applicable to remedial activities at Site 10 is presented in Table A-5.

A.6.2 Potential State Action-Specific ARARs/TBCs

The State of Rhode Island has promulgated regulations similar to those of the federal government. A preliminary evaluation of potential state action-specific ARARs which may be applicable to remedial activities at Site 10 is presented in Table A-6.

References

GZA, 1992. Phase I Report, Hunt River Aquifer Wellhead Recharge Area Study. Prepared for North Kingstown Water Department, Rhode Island Port Authority, Kent County Water Authority, North Kingstown Planning Department, and Warwick Planning Department by GZA GeoEnvironmental, Inc., December 1992.

RIDEM, 1989. Endangered Species Surveys at Camp Fogarty, West Davisville, and East Davisville.

TRC Environmental Corporation, 1992. Phase II RI/FS Work Plan, Naval Construction Battalion Center, Davisville, Rhode Island. Prepared for Northern Division Naval Facilities Engineering Command, Philadelphia, PA. August, 1992.

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USEPA, 1988. CERCLA Compliance with Other Laws Manual, Draft Guidance, Part I, OSWER Directive 9234.1-01, August 8, 1988.

USEPA, 1989. CERCLA Compliance with Other Law Manuals: Part II. Clean Air Act and Other Environmental Statues and State Requirements, Office of Solid Waste and Emergency Response, EPA/540/G-89/009, OSWER Directive 9234.1-02, August 1989.

USEPA, 1991. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), Interim. EPA/540/R-92/003, December 1991.

TABLE A–1
FEDERAL CHEMICAL–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Ground Water––				
	Safe Drinking Water Act (40 CFR 141.11–.16 and 141.60–.63) Maximum Contaminant Levels (MCL's)	Relevant and Appropriate	MCL's directly apply to "public water systems", defined as systems with at least 15 connections which service a minimum of 25 persons.	Ground water at Camp Fogarty is not a current source of drinking water, but is classified as GAA–NA at Site 10; therefore MCLs are relevant and appropriate. Contaminant concentrations are compared to MCLs to assess potential risks associated with ingestion of ground water.
	Safe Drinking Water Act (40 CFR 141.50–.52) Maximum Contaminant Level Goals (MCLGs)	Relevant and Appropriate	Non–enforceable health goals for public water supply systems, set at levels which result in no known or anticipated adverse health effects.	Ground water at Camp Fogarty is not a current source of drinking water, but is classified as GAA–NA at Site 10; therefore MCLGs are relevant and appropriate. Non–zero MCLGs are to be used as remedial goals for current or potential sources of drinking water, per the NCP (40 CFR 300). Contaminant concentrations are compared to MCLGs to assess potential risks associated with ingestion of ground water.
	USEPA Risk Reference Doses (RfDs)	To Be Considered	Toxicity values for evaluating noncarcinogenic effects resulting from exposures to contamination.	USEPA RfDs are used to characterize risks due to noncarcinogens in ground water.
	Lifetime Health Advisories	To Be Considered	Guidelines developed based on toxicity for noncarcinogenic compounds	TBC criteria due to the presence of contaminants in ground water.
	USEPA Human Health Assessment Group Cancer Slope Factors (CSFs)	To Be Considered	A slope factor is used to estimate an upper–bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.	USEPA CSFs are used to compute the individual incremental cancer risk resulting from exposure to certain compounds.

TABLE A-1 (continued)
FEDERAL CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Surface Water --				
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	To be determined	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms.	AWQC will be applicable to remedial alternatives which involve discharges to surface water.
	Clean Water Act (40 CFR 401.15) Effluent Discharge Limitations	To be determined	Regulates the discharge of contaminants from an industrial point source.	Regulations will be applicable to remedial alternatives which involve discharges to surface water.
Soils/Surfaces--				
	Toxic Substances Control Act (40 CFR 761.125)	Relevant and Appropriate	Establishes PCB cleanup levels for soils and solid surfaces.	Applicable to spills of materials containing PCBs at concentrations of 50 ppm or greater that occurred after May 4, 1987. These requirements may be relevant and appropriate to the evaluation of PCB levels in site soils.
	Guidance on Remedial Actions for Superfund Sites with PCB Contamination (OSWER Directive 9355.4-01)	To Be Considered	Provides guidance on identifying principal threat and low-threat areas of PCB contamination. At industrial sites, PCBs at concentrations of 500 ppm or greater generally pose a principal threat.	Will be considered at Site 10 with respect to soil PCB contamination.
	Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02)	To Be Considered	Sets forth an interim soil cleanup level for lead at 500 to 1000 ppm.	Will be considered at Site 10 with repect to soil lead contamination.
	Toxicity Characteristic (40 CFR 261.24)	To be determined	Establishes maximum concentrations of contaminants for the toxicity characteristic using the test method described in 40 CFR 261 Appendix II.	Applicable where wastes produced as a byproduct of a remedial action require handling as a hazardous waste on the basis of the Toxic Characteristic Leachate Parameter (TCLP) analysis.

TABLE A–1 (continued)
FEDERAL CHEMICAL–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Soils/Surfaces–– (cont.)	Land Disposal Restrictions (40 CFR 268)	To be determined	Establishes maximum concentrations of contaminants on the basis of which hazardous wastes are restricted from land disposal.	This regulation will be applicable to remedial alternatives which utilize land disposal of hazardous waste.
Air––				
	Clean Air Act (40 CFR 50) National Ambient Air Quality Standards (NAAQS)	To be determined	Establishes maximum levels for pollutants and particulates within air quality control districts.	Potential ARARS for alternatives involving remedial actions which impact ambient air (i.e. incinerators, soil venting, etc.).
	Clean Air Act (40 CFR 60) New Source Performance Standards (NSPS)	To be determined	Establishes emissions limitations for new sources.	Potential ARARS for alternatives involving treatment methods which emit pollutants.
	Clean Air Act (40 CFR 61) National Emissions Standard for Hazardous Air Pollutants	To be determined	Establishes emissions standards for hazardous air pollutants.	Potential ARARS for alternatives involving treatment methods which emit hazardous air pollutants.

TABLE A-2
STATE CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Ground Water--				
	RI Ground Water Protection Act (RIGL, 46-13 et seq.) Public Drinking Water Regulations	Relevant and Appropriate	Establishes provisions for the protection and management of potable drinking waters, including the development of ground water classifications and associated standards which specify maximum contaminant levels for each classification.	Ground water at Camp Fogarty is not a current sourceof drinking water, but is classified as GAA-NA at Site 10; therefore these regulations are relevant and appropriate and contaminant concentrations will be compared to the established ground water quality standards.
Surface Water --				
	RI Water Pollution Control Law (RIGL 46-12 et seq.) RI Water Quality Standards	To be determined	Establishes water use classification and water quality criteria for all waters of the state. Also establishes acute and chronic water quality criteria for the protection of aquatic life.	Regulation will be applicable for remedial alternatives which involve discharges to surface water.
Soils/Surfaces--				
	Lead Soil Cleanup Standards (Guidance)	To Be Considered	RIDEM and the Rhode Island Department of Health-Risk Assessment consider a safe lead level in soil (total) to be under 300 ppm.	To be considered with respect to lead soil contamination.
	RI Hazardous Waste Management Act of 1987 (RIGL 23-19.1 et seq.) Rules and Regulations for Hazardous Waste Management	Relevant and Appropriate	Defines Type 6 - extremely hazardous waste as including wastes which contain PCBs at a concentration of 50 ppm or greater or showing 10 micrograms/ 100 sq. cm. or greater as measured by a standard wipe test.	Relevant and appropriate to the evaluation of PCB levels in soil.
	Rules and Regulations for Solid Waste Management Facilities	Relevant and Appropriate	Defines solid waste as including any soil, debris or other material with a concentration of PCBs of 10 ppm or greater or containing 2 micrograms/100 sq. cm. or greater as measured by a standard wipe test.	Relevant and appropriate to the evaluation of PCB levels in soil.
Air--				
	RI Clean Air Act (RIGL Title 23, Chapter 23) Air Pollution Control Regulation Standards	To be determined	Establishes maximum ambient levels for criteria pollutants.	Potential ARARs for remedial alternatives involving treatment methods which emit criteria pollutants.

TABLE A–3
FEDERAL LOCATION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Wetlands/Water Resources––				
	Executive Order 11988 and 11990; Statement on Proceedings of Floodplain Management and Wetlands Protection (40 CFR 6, Appendix A)	To be determined	Requires action to avoid whenever possible the long– and short–term impacts associated with the destruction of wetlands and the occupancy and modifications of floodplains and wetlands whenever there is a practicable alternative which promotes the preservation and restoration of the natural and beneficial values of wetlands and floodplains.	May be applicable if wetland areas are present on–site.
Endangered Species––				
	Endangered Species (16 USC 1531) Protection of Endangered Species	To be determined	Restricts activities in areas inhabited by registered endangered species.	Information supplied by RIDEM indicates that no occurrence records of rare species were identified for Camp Fogarty; however two listed amphibians have been found within a two–mile radius and could be present at Site 10.
Cultural Resources––				
	National Historic Preservation Act of 1966 (16 USC 470, et seq.) Protection of Historic Lands and Structures; Archaeological and Historic Preservation Act of 1974 (132 CFR 229 & 229.4, 43 CFR 7 & 7.4); Historic Sites, Building and Antiquities Act.	To be determined	Several statutes which govern the preservation at historic, scientific and archaeological sites and resources. Includes action to recover and preserve artifacts, preserve historic properties and minimize harm to National Historic Landmarks.	May be applicable if significant scientific, prehistoric, historic or archaeological resources exist at the site.

TABLE A-4
STATE LOCATION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Wetlands--				
	Rhode Island Wetlands Laws (RIGL 2-1-18 et seq.); Rhode Island Department of Environmental Management Rules Governing the Enforcement of the Fresh-water Wetlands Act - As Amended, Dec. 21, 1986.	To be determined	Defines and establishes provisions for the protection of swamps, marshes and other freshwater wetlands in the state. Actions required to prevent the undesirable drainage, excavation, filling, alteration, encroachment or any other form of disturbance or destruction to a wetland.	May be applicable if wetland areas are present on-site.
Wellhead Protection Areas--				
	RI Water Pollution Control Act; RI Rules and Regulations for Groundwater Quality	To be determined	Specific requirements for delineating and refining wellhead protection areas.	While the refined wellhead protection area for a proposed water supply well, if constructed, does not encompass Site 10, its proximity to the site may require continued monitoring of pumping rates and capture zones.

TABLE A-5
FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
On-site/ Off-site Treatment/ Disposal	Resource Conservation and Recovery Act (RCRA) (40 CFR 262) Generator Requirements for Manifesting Waste for Off-Site Disposal	To be determined	Standards for manifesting, marking and recording off-site hazardous waste shipments for treatment/disposal.	This regulation will be applicable to alternatives which utilize an off-site disposal/treatment method for hazardous wastes.
	RCRA (40 CFR 263) Transporter Requirements for Off-Site Disposal	To be determined	Standards for transporters of hazardous waste materials.	This regulation will be applicable to alternatives which utilize an off-site disposal/treatment method for hazardous wastes.
	RCRA (40 CFR 264 and 265) Requirements for Hazardous Waste Treatment Facility Design and Operating Standards for Treatment and Disposal Systems	To be determined	Outlines specifications and standards for design, operation, closure and monitoring of performance for hazardous waste storage, treatment and disposal facilities.	Potential ARARs for alternatives which utilize a surface impoundment, waste pile, landfill, land treatment, incineration or miscellaneous treatment units for on-site storage/disposal/treatment of hazardous wastes.
	RCRA (40 CFR 264.10-264.18) Subpart B - General Facility Standards	To be determined	General requirements regarding waste analysis, security, training, inspections, and location applicable to a facility which stores, treats or disposes of hazardous wastes (a TSDF facility).	This regulation may be applicable to a remedial action conducted at Site 10, if it meets the definition of a TSDF.
	RCRA (40 CFR 264.30-264.37) Subpart C - Preparedness and Prevention	To be determined	Requirements applicable to the design and operation, equipment, and communications associated with a TSDF facility, and to arrangements with local response departments.	This regulation may be applicable to a remedial action conducted at Site 10, if it meets the definition of a TSDF.
	RCRA (40 CFR 264.50-264.56) Subpart D - Contingency Plan and Emergency Procedures	To be determined	Emergency planning procedures applicable to a TSDF facility.	This regulation may be applicable to a remedial action conducted at Site 10, if it meets the definition of a TSDF.

TABLE A–5(continued)
FEDERAL ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
On–site/ Off–site Treatment/ Disposal (cont.)	RCRA (40 CFR 264) Subpart F Ground Water Protection	To be determined	Ground water monitoring/corrective action requirements; dictates adherence to MCLs and establishes points of compliance.	Potential ARARs for alternatives which involve placement of hazardous wastes within solid waste management units, including surface impoundments, waste piles, and land treatment units.
	RCRA (40 CFR 264) Subpart G Closure/Post Closure Requirements	To be determined	Establishes requirements for the closure and long–term management of a hazardous disposal facility.	Applicable to the closure of any hazardous waste management facility.
	RCRA (40 CFR 264) Subpart I Use and Management of Containers	To be determined	Outlines use and management standards applicable to owners and operators of all hazardous waste facilities that store containers of hazardous waste.	Potential ARARs for remedial actions which require storage of hazardous waste in containers.
	RCRA (40 CFR 264) Subpart L Waste Piles	To be determined	Regulates owners and operators of facilities that store or treat hazardous waste in piles.	Potential ARARs for remedial alternatives which utilize a waste pile for on–site storage/treatment of hazardous waste.
	RCRA (40 CFR 264) Subpart O Incinerator Restrictions	To be determined	Outlines specifications and standards for incinerating hazardous waste.	Potential ARARs for alternatives which utilize incineration for on–site treatment of hazardous wastes.
	RCRA (40 CFR 265) Subpart Q – Chemical, Physical and Biological Treatment	To be determined	General operating, waste analysis and trial test, inspection and closure requirements for facilities which treat hazardous waste by chemical, physical or biological methods in other than tanks, surface impoundments and land treatment facilities.	Remedial alternatives which utilize chemical, physical and biological treatment methods as described to treat hazardous wastes will meet these requirements.

TABLE A–5(continued)
FEDERAL ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Off–site Treatment/ Disposal (cont.)	RCRA (40 CFR 264.600–264.999) Subpart X – Miscellaneous Units	To be determined	Environmental performance standards, monitoring requirements and post–closure care requirements applicable to miscellaneous units (not otherwise defined in the RCRA regulations) used to treat, store or dispose of hazardous waste.	Potential ARARs for remedial actions involving hazardous waste treatment, storage or disposal in units not otherwise covered under RCRA regulations.
	RCRA (40 CFR 268) Land Disposal Restrictions	To be determined	Identifies hazardous wastes that are restricted from land disposal and sets treatment standards for restricted wastes.	This regulation will be applicable to alternatives which utilize land disposal of hazardous wastes.
	Hazardous Materials Transportation Act (49 CFR 170, 171) Rules for Transportation of Hazardous Materials	To be determined	Procedures for packaging, labelling, manifesting, and off–site transport of hazardous materials.	This regulation will be applicable to alternatives which include off–site transport of hazardous materials.
	Toxic Substances Control Act (15 USC. Sect. 2601) Subpart D – Storage and Disposal Requirements for PCBs	To be determined	Establishes requirements for the storage, landfilling, and incineration of PCBs.	This regulation may be applicable or relevant and appropriate to alternatives which involve handling of PCB–contaminated materials.
	Guidance on Remedial Actions for Superfund Sites with PCB Contamination (OSWER Directive 9355.4–01)	To be determined	Describes the recommended approach for remediating Superfund sites with PCB contamination.	This guidance will be considered in the evaluation of treatment/disposal actions.
Discharge	Safe Drinking Water Act (40 CFR 144 and 146) Underground Injection Control Requirements	To be determined	Establishes the general requirements, technical criteria and standards for underground injection wells.	This regulation will be applicable to alternatives in which treated water is discharged back to the ground water.
	Clean Water Act (40 CFR 122–125) National Pollutant Discharge Elimination System (NPDES) Permit Requirements	To be determined	Permits contain applicable effluent standards (i.e., technology–based and/or water quality–based), monitoring requirements, and standards and special conditions for discharge.	This regulation will be applicable to alternatives in which treated water is discharged to surface waters or back to the ground water.

TABLE A-5(continued)
FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Discharge (cont.)	Clean Water Act (40 CFR 403) Discharge to Publicly- Owned Treatment Works (POTW)	To be determined	A national pretreatment program designed to protect municipal wastewater treatment plants and the environment from damage that may occur when hazardous, toxic or other non-domestic wastes are discharged into a sewer system.	This regulation is applicable to alternatives in which waters are discharged to a POTW.
Venting/ Discharges to Air	Clean Air Act (40 CFR 50) National Ambient Air Quality Standards (NAAQS)-Particulates	To be determined	Establishes maximum concentrations for particulates and fugitive dust emissions.	ARARs for alternatives involving treatment methods which impact ambient air (i.e. incineration, soil venting, etc.).
	Clean Air Act, Section 5 171 through 178, 42 USC §§ 7471-7478 (Requirements for Non-Attainment Areas)	To be determined	RI has adopted State Implementation Plan (SIP) requirements approved and enforcable by EPA which meet the New Source Review (NSR) requirement of the CAA. These provisions require that new or modified major sources of VOCs defined as a source which has the potential to emit 50 tpy install equipment to meet Lowest Available Emissions Rate (LAER), which is set on a case-by-case basis and is either the most stringent emissions limitation contained in any SIP for that category or source or the most stringent emissions limitation which is achieved for the source. NSR requirements apply to non-attainment pollutants, which are VOCs and NO_x in RI.	Monitoring will be conducted to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels and on the need to be protective of human health and the environment.
	Clean Air Act, Section 5 160 through 169A - Prevention of Significant Deterioration Provisions	To be determined	RI has adopted SIP requirements approved and enforceable by EPA which meet the Prevention of Significant Deterioration (PSD) requirements of the CAA. These provisions require that new or modified major sources of VOCs, defined as a source which has the potential to emit 25 tons/year, install equipment to meet Best Available Control Technology (BACT). PSD requirements apply to attainment pollutants, which are SO2, CO, lead and particulates in Rhode Island.	Monitoring will be conducted to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels.

TABLE A–5(continued)
FEDERAL ACTION–SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	Clean Air Act (40 CFR 61) National Emissions Standards for Hazardous Pollutants (NESHAPS)	To be determined	Establishes emissions limitations for hazardous air pollutants, and sets forth regulated sources of those pollutants.	Potential ARARs for alternatives using treatments (i.e., incineration, etc.) which result in emissions to the air.
	RCRA 40 CFR 265.375 Subpart P – Thermal Treatment	To be determined	Establishes requirements for air emissions from thermal treatment units.	Remedial actions which involve thermal treatment units, as defined in 40 CFR 265.370, will meet these standards.
	RCRA 40 CFR 264.1030 – 264.1036 Subpart AA – Air Emission Standards for Process Vents	To be determined	Establishes standards for air emissions from process vents associated with distillation, fractionation, thin film evaporation, column extraction or air steam stripping operations that treat RCRA substances and have total organic concentrations of 10 ppm or greater.	If these technologies are utilized and the threshold organic concentration is met, air emissions will comply with the standards.
	RCRA 40 CFR 264.1050 – 264.1065 Subpart BB – Air Emission Standards for Equipment Leaks	To be determined	Establishes standards for air emissions for equipment that contains or contacts RCRA wastes with organic concentrations of at least 10% by weight.	If such concentrated wastes are treated, the equipment used will meet these standards.
	EPA Technical Guidance Document: Control of Air Emissions from Superfund Air Strippers at Superfund Ground Water Sites (OSWER Directive 9355.0.28)	To Be Considered	Guidance regarding the control of air emissions from air strippers used at Superfund sites for ground water treatment. Distinguishes between attainment and non–attainment areas for ozone.	These guidelines will be considered if air stripping is used as a ground water treatment alternative.

TABLE A-6
STATE ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 – CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
On-site/ Off-site Disposal/ Treatment	RI Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.) • Hazardous Waste Management Rules and Regulations	To be determined	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal.	These rules will be applicable for alternatives which involve the on- or off-site management of hazardous wastes.
	• Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases (Site Remediation Regulations)	To be determined	Rules and regulations for the investigation and remediation of releases of hazardous materials.	These rules will be applicable to the design and operation of remedial systems.
	RI Hazardous Substance Community Right to Know Act (RIGL, Title 23, Chapter 24.4) Public Right-to-Know Requirements	To be determined	Establishes rules for the public's right-to-know concerning hazardous waste storage and transportation.	These rules will be applicable for alternatives which involve the on- or off-site management of hazardous wastes.
	RI Refuse Disposal Law Rules and Regulation for Solid Waste Management Facilities	To be determined	Rules and regulations for solid waste management facilities.	ARARs for alternatives involving the on-site storage and disposal of solid wastes.
Discharge	RI Water Pollution Control Act • RI Water Quality Regulations for Water Pollution Control (RIGL 46-12 et seq.) RI Water Quality Standards	To be determined	Establishes general requirements and effluent limits for discharge to area waters.	This regulation will be applicable to alternatives in which treated water is discharged to area surface water or ground water.
	• Regulations for the RI Pollutant Discharge Elimination Systems (RIGL 46-12 et seq.)	To be determined	Permits contain applicable effluent standards (i.e., technology-based and/or water quality-based), monitoring requirements, and standards and special conditions for discharge.	This regulation will be applicable to alternatives in which treated water is discharged to area surface water or ground water.

TABLE A-6(continued)
STATE ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Discharge (cont.)	RI Water Pollution Control Act			
	• RI Pretreatment Regulations (RIGL 46-12 et seq.)	To be determined	Covers pollutants in wastewaters which can have detrimental effects on POTW processes. Sets specified limitations, pretreatment and monitoring requirements for discharges to POTWs based on federal regulations.	Remedial actions which include discharge to a POTW will meet all required discharge limitations.
	• RI Underground Injection Control Regulations (RIGL 46-12 et seq.)	To be determined	Establishes the general requirements, technical criteria and standards for underground injection wells.	This regulation will be applicable to alternatives in which treated water is discharged back to the ground water via injection.
	• RI Ground Water Protection Act (RIGL, Title 46, Chapter 13.1) Protection of Ground Water	To be determined	Establishes ground water classifications and maximum contaminant levels for each classification.	Potential ARARs for alternatives involving the treatment of contaminated ground water.
Venting/ Discharge to Air	RI Clean Air Act (RIGL, Title 23, Chapter 23) General Air Quality and Air Emissions Requirements	To be determined	Sets emissions limitations for particulates and visible air contaminants.	ARARs for alternatives involving remedial actions which impact ambient air.
	RI Clean Air Act (RIGL, Title 23, Chapter 23) General Air Quality and Air Emissions Requirements • RI Air Pollution Control Regulations, RI Dept. of Health, Div. of Air Pollution Control, effective 8/2/67, most recently amended 5/20/91			
	– Regulation No. 1 – Visible Emissions	To be determined	No air contaminant emissions will be allowed for more than 3 minutes in any one hour which are greater than or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulation.

TABLE A-6(continued)
STATE ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 10 - CAMP FOGARTY DISPOSAL AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharge to Air (cont.)	RI Clean Air Act (cont.) • RI Air Pollution Control Regulations, (cont.)			
	- Regulation No. 5 - Fugitive Dust	To be determined	Requires that reasonable precaution be taken to prevent particulate matter from becoming airborne.	On-site remedial actions will use good industrial practices to prevent particulate matter from becoming airborne.
	- Regulation No. 7 - Emissions Detrimental to Person or Property	To be determined	Prohibits emissions of contaminants which may be injurious to human, plant or animal life or cause damage to property or which reasonably interferes with the enjoyment of life and property.	All emissions will meet this requirement or gas treatment will be required.
	- Regulation No. 9 - Approval to Construct, Install, Modify or Operate	To be determined	Establishes guidelines for the construction, installation, modification or operation of potential air emission units. Establishes permissible emission rates for some contaminants.	Technologies involving construction, installation, modification or operation of air emission units will meet these requirements.
	- Regulation No. 15 - Control of Organic Solvent Emissions	To be determined	Limits the amount of organic solvents emitted to the atmosphere.	If emissions exceed limits in this regulation, emission controls will be designed and implemented to meet these requirements.
	- Regulation No. 17 - Odors	To be determined	Prohibits the release of objectionable odors across property lines.	No remedial action or air emissions will emit objectionable odors beyond the facility boundary, as practicable.
	- Regulation No. 22 - Air Toxics	To be determined	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels or acceptable ambient levels with LAER, as set in the regulation.	If air emissions contain regulated substances, air emissions control equipment will be used as necessary to meet these standards.

APPENDIX B

APPENDIX B

CALCULATION OF PRELIMINARY RISK-BASED REMEDIATION GOALS

Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991a) provides additional guidance on the development of risk-based preliminary remediation goals (PRGs). One of the initial steps in the development of PRGs is the identification of the most appropriate future land use for the site so that the appropriate exposure pathways, parameters and equations can be used to calculate PRGs. Although Camp Fogarty is not included in the Comprehensive Base Reuse Plan, Camp Fogarty (including Site 10) has been excessed to the Army and continued use in its present form is expected. Therefore, exposures to surface soils and ground water under the future commercial/industrial use exposure scenario were used to guide the development of PRGs.

According to the OSWER directive "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (USEPA, 1991b), action is generally warranted at a site when the cumulative carcinogenic risk is greater than 10^{-4} or the cumulative non-carcinogenic Hazard Index (HI) exceeds 1 based on reasonable maximum exposure (RME) assumptions. Therefore, the cumulative risks associated with a given medium under future commercial/industrial use were evaluated to determine if any medium poses a cumulative cancer risk greater than 10^{-4} or HI greater than 1. At Site 10, the cumulative RME risk associated with exposure to soils was less than 10^{-4} and the total HI was less than 1. Evaluation of exposures to ground water resulted in a cumulative carcinogenic risk of less than 10^{-4} and a non-cancer RME HI of 5. Therefore, the development of PRGs was evaluated with respect to ground water exposures to non-carcinogens only.

As described in the National Contingency Plan [40 CFR 300.43(e)(2)(i)(A)(2)], "The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available...". As summarized in Table B-1, those ground water constituents which contributed an individual RME hazard quotient of greater than one to the total hazard index for noncarcinogenic risks were identified and then evaluated to determine if there were any for which an ARAR/TBC was not available. For those constituents without an associated ARAR/TBC, a risk-based preliminary remediation goal (PRG) was calculated, based on a future commercial/industrial use scenario. As shown in Table B-2, the calculations for ground water incorporate commercial/industrial worker exposures as an adult. Under this scenario, exposure is assumed to occur through ingestion of ground water. The exposure parameters for the ground water calculations are taken directly from the risk assessment portion of the Phase II RI. The only non-carcinogen determined to pose an unacceptable hazard qutient value was manganese. The risk-based PRG for manganese is 510 ppb. As noted in the footnote to Table B-2, the calculated PRG is within the concentration range detected in upgradient wells at the NCBC Davisville sites.

References

USEPA, 1991a. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), Interim. EPA/540/R-92/003, December 1991.

USEPA, 1991b. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. OSWER Directive 9355.0-30, April 1991.

Table B-1

Constituents Considered for the Development of Risk-Based Preliminary Remediation Goals [a]
Site 10 - Camp Fogarty Disposal Area

Constituent	Scenario	Medium	Cancer Risk or Hazard Quotient Elevated?	Soil ARAR or Ground Water MCL Available?	Selected for Development of Risk-Based PRGs?
Manganese	Commercial	Ground Water	HQ_{RME}	No	Yes

[a] i.e., Constituents associated with individual cancer risks above 1E-06 or hazard quotients above 1 as estimated under the key exposure scenario for each medium (i.e., commercial/industrial for ground water)

Table B-2

Non-Cancer-Risk-Based Preliminary Remediation Goals (PRGs)
for Constituents in Ground Water
Assuming Future Commercial/Industrial Use
Site 10 - Camp Fogarty Disposal Area

Constituent	Oral Reference Dose (RfD) $(mg/kd*d)^{-1}$	Oral Relative Absorption Factor (RAF) (--)	Ground Water PRG [a] (mg/l)
Manganese	5.0E-03	1	5.1E-01 [b]

[a] Based on USEPA (1991) guidance and Phase II Human Health Risk Assessment
[b] PRG is within or less than concentrations detected upgradient for all sites (i.e., 0.034 mg/l at 03-MW03 to 2.2 mg/l at 10-MW05).

$$PRG = [THI * AT * BW] / [(1/RfD) * IR_w * RAF_o * EF * ED]$$

Where:

THI = Target hazard index:	1 --
AT = Averaging time:	9125 d
BW = Body weight:	70 kg
RfD = Reference dose:	CS Chemical-specific
IR_w = Water ingestion rate:	1 l/d
RAF_o = Oral relative absorption factor:	CS Chemical-specific
EF = Exposure frequency:	250 d/yr
ED = Exposure duration:	25 yr

APPENDIX C

APPENDIX C

EVALUATION OF LEACHING POTENTIAL BASED ON APPLICATION OF LEACHING MODEL

To evaluate the potential for surface and subsurface soil contaminants to leach into the ground water, an infiltration/leaching model was used. USEPA's document entitled Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples (EPA/540/2-89/057, October 1989) presents various methods which have been used to derive soil cleanup levels based on potential threats to ground water quality.

The Summers model and the "unnamed" model, as described in this USEPA document, were evaluated in terms of applicability to site conditions at Site 10 - Camp Fogarty Disposal Area. Both of these three-dimensional models assume that a percentage of rainfall will infiltrate and desorb contaminants from the soil based on equilibrium soil:water partitioning. It is assumed that this contaminated infiltration will mix completely with ground water below the site, resulting in an equilibrium ground water concentration with all contaminants from the infiltration in the final mixture. The Summers model is applicable to a large spill area and is based on a mass balance approach which is applied to the entire area and affected soil volume of the spill. Therefore, it involves a mass balance of the total volume and contaminant concentration of infiltration over the entire area of the site, the total volume and contaminant concentration of ground water flowing into the site area, and the total volume and contaminant concentration of ground water exiting the site.

The unnamed model is a variation of the Summers model in which the mass balance approach is applied to a column of the site, of unit area and of depth equal to the saturated portion of the aquifer. Since subsurface contamination at Site 10 is heterogeneous, characterized by small areas of elevated contamination, rather than consistently contaminated throughout the areal extent of the site, application of the unnamed model was determined to be more appropriate. The unnamed model also provides for the separate estimation of critical saturated and unsaturated soil contaminant levels.

Data Requirements

- Volumetric flow rate of recharge flowing downward through a unit area (based on the infiltration rate of precipitation) (cf/day)
- Volumetric flow rate of ground water in saturated zone in water column through unit width (cf/day)
- Concentration of contaminant in ground water recharge (μg/l)
- Hydraulic conductivity (ft/day)
- Hydraulic gradient (ft/ft)
- Concentration of contaminant adsorbed to the soil in the unsaturated zone (μg/kg)
- Concentration of contaminant in ground water in the saturated zone (μg/l)
- Total organic carbon concentration (mg/mg)

Method Description

In the unnamed model, soil cleanup levels (or maximum allowable soil contaminant levels) are calculated for saturated and unsaturated soils assuming equilibrium between dissolved and adsorbed phases for each contaminant using the following relationship:

$$S_{sat} = (K_d)(C_{sat}) \tag{1}$$

where: S_{sat} = concentration of contaminant adsorbed to the soil in the saturated zone (μg/kg)
K_d = distribution coefficient
C_{sat} = concentration of contaminant in ground water in saturated zone (μg/l)

The K_d is calculated as follows:

$$K_d = (0.63)(F_{oc})(K_{ow}) \tag{2}$$

where: 0.63 = Adjustment factor
F_{oc} = total organic carbon concentration in soil (mg/mg)
K_{ow} = octanol-water partition coefficient

In calculating K_d, it is assumed that the maximum desired contaminant concentration for ground water is equal to an established health-based criteria (i.e., MCLs). Using equation (1), the maximum soil contaminant concentration in the saturated zone may then be calculated.

Subsequent calculations to derive unsaturated soil maximum contaminant concentrations include the assumption that dissolved contamination in ground water recharge reaches equilibrium with the adsorbed phase on unsaturated soils, and that such recharge is fully diluted into the entire water column upon reaching the water table. Thus the maximum unsaturated soil contaminant level is established using equation (1) and a dilution equation for calculating C_{sat}, the contaminant concentration in the ground water in the saturated zone which is based on the mass-balance approach, as indicated in Figure C-1.

$$C_{sat} = (C_{unsat})(e)/(e+Q) \quad (3)$$

where:

C_{unsat}	=	contaminant concentration of ground water in recharge (μg/l)
e	=	volumetric flow rate of recharge flowing downward through a unit area (cf/day)
Q	=	volumetric flow rate of ground water in the saturated zone throughout the unit (cf/day)

The equilibrium assumption:

$$S_{unsat} = (K_d)(C_{unsat}) \quad (4)$$

and equation (1) combined with equation (3) yields the following relationship. The resultant equation is used to calculate the maximum contaminant concentration for soils in the unsaturated zone.

$$(S_{sat})/(K_d) = (S_{unsat})/(K_d)(e)/(e+Q)$$

and

$$S_{unsat} = (S_{sat})(e + Q)/e \quad (5)$$

where:

S_{unsat}	=	concentration of contaminant adsorbed to the soil in the unsaturated zone (μg/kg)

and the ground water volumetric flow rate through the saturated zone (Q) is estimated from Darcy's Law:

$$Q = (K)\ (i)\ (A) \quad (6)$$

where:

K	=	hydraulic conductivity (ft/day)
i	=	hydraulic flow gradient (ft/ft)
A	=	area of flow (unit width x saturated thickness of aquifer) (ft^2)

Site-Specific Application

The unnamed model was applied to Site 10 to determine the potential migration of soil contaminants into ground water. The evaluation was focused upon the soil contaminants which were identified as the Constituents of Concern (COCs) within the Phase II RI. Because the model assumes the maximum allowable ground water contaminant level is equal to the MCL, application of the model is generally limited to those constituents for which MCLs have been identified. For those COCs without final MCLs, proposed or tentative MCLs were used in the evaluation.

At Site 10 - Camp Fogarty Disposal Area, two Phase II RI soil samples were analyzed for total organic carbon. Detected levels were 0.02% and 0.021%, with an average level of 0.0205%. Using this value and published octanol-water partition coefficient values, the maximum saturated soil contaminant level was calculated for the Contaminants of Concern identified in the Phase II RI for which an MCL was available. The contaminants, octanol-water partition coefficients (K_{ow}) values used, calculated K_d values, assumed maximum ground water concentrations in the saturated zone (C_{sat} = MCL) and maximum saturated soil contaminant levels (S_{sat}) are presented in the first 4 columns of Table C-1.

To calculate the maximum acceptable unsaturated soil contaminant levels, the volumetric flow rate of ground water in the saturated zone through the unit area (Q) was calculated. The average linear velocity for the site was estimated to be 0.18 ft/day by averaging the velocity values presented in Table 2-2 of this report. The average saturated thickness, estimated at 11.4 feet, was calculated by averaging the thickness of the interval from the water table surface to the top of the bedrock layer as measured at the on-site monitoring wells. Therefore, for a unit width of soil,

$$Q = (0.18 \text{ ft/day})\ (11.4 \text{ ft})\ (1 \text{ ft})$$
$$= 2.05 \text{ cf/d}$$

To estimate e, the volumetric flow rate of recharge flowing downward through a unit area, the information provided in Section 1.3.2 of the Phase II RI regarding precipitation and infiltration was used. Based on an average annual precipitation of 42.3 inches and 36% infiltration, the annual infiltration is 1.27 ft/yr or 0.0035 ft/day. Therefore, for a unit area of surface,

$$e = (0.0035 \text{ ft/day})\ (1 \text{ ft})\ (1 \text{ ft})$$
$$= 0.0035 \text{ cf/day}$$

Then S_{unsat} can be calculated using equation (5), where:

$$S_{unsat} = (S_{sat})\ (e + Q)/e$$
$$= (S_{sat})\ (0.0035 + 2.05)/0.0035$$
$$= (S_{sat})\ (586.7)$$

The calculated S_{unsat} values are presented in column 7 of Table C-1. The maximum detected soil contaminant levels in the unsaturated zone and the location of the maximum detected concentration for each contaminant are presented in columns 8 and 9, respectively. Only one unsaturated soil sample, surface soil sample 10-SS09, exhibited a contaminant at a level exceeding the calculated maximum allowable level. Benzo(a)anthracene was detected at a level of 3.4 ppm, which exceeds the modeled maximum allowable unsaturated concentration of 3.1 ppm. It should be noted, however, that the model calculations are based on subsurface TOC values. TOC values for surface soil samples could be expected to be higher than for subsurface soil samples (due to increased organic matter near the surface) and would therefore be expected to be more resistant to contaminant leaching. The average TOC value for subsurface soils at Site 10 is 0.0205% (0.000205 mg/mg). If this value were increased by as little as 0.0021% (to 0.000226 mg/mg) the maximum detected benzo(a)anthracene level would not be considered unacceptable (S_{unsat} = 3.46 ppm).

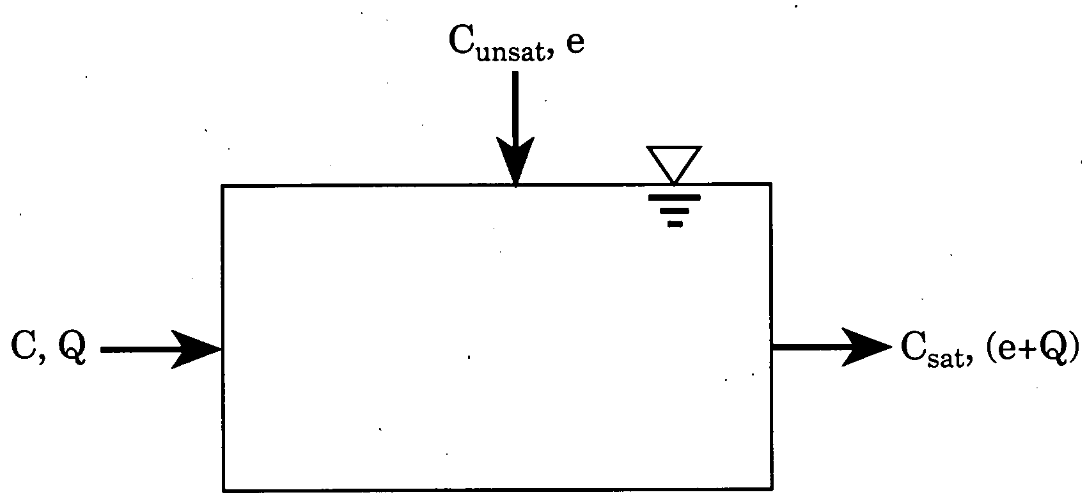
TABLE C-1

Site 10 – Camp Fogarty Disposal Area
Comparsion of Soil Contaminant Levels to Modeled Soil Response Action Levels
Using the Unnamed Model (USEPA, EPA/540/2-89/057)

Column:	1	2	3		4	5	6	7	8	9
Constituent	K_{ow}	K_d	C_{sat} (ppm)		S_{sat} (ppm)	Q (cf/d)	e (cf/d)	S_{unsat} (ppm)	Max. Unsaturated Soil Concentration Detected (ppm)	Sample Location
Chloroform	89.1	0.012	0.1	T	0.0012	2.05	0.0035	0.70	0.001	B-10-01-04-S
1,1,1-Trichloroethane	295	0.038	0.2	F	0.0076	2.05	0.0035	4.5	0.0080	10-SS-09
Toluene	490	0.063	1	F	0.063	2.05	0.0035	37.0	0.012	10-SS-13, 10-SS-15
Bis(2-ethylhexyl)phthalate	2.00E+05	25.83	0.006	F	0.155	2.05	0.0035	90.9	0.71	10-SS-10
Chrysene	4.07E+05	52.56	0.0002	P	0.011	2.05	0.0035	6.5	2.9	10-SS-09
Indeno(1,2,3-cd)pyrene	4.57E+07	5903.3	0.0004	P	2.4	2.05	0.0035	1408.1	0.94	10-B8-01
Dibenzo(a,h)anthracene	9.33E+05	120.53	0.0003	P	0.036	2.05	0.0035	21.1	0.43	10-SS-09
Benzo(a)anthracene	4.07E+05	52.61	0.0001	P	0.0053	2.05	0.0035	3.1	3.4	10-SS-09
Benzo(a)pyrene	9.55E+05	123.34	0.0002	F	0.025	2.05	0.0035	14.7	2.6	10-SS-09
Benzo(b)fluoranthene	3.72E+06	480.44	0.0002	P	0.10	2.05	0.0035	58.7	5.1	10-SS-09
Benzo(k)fluoranthene	6.92E+06	893.50	0.0002	P	0.18	2.05	0.0035	105.6	2.2	10-B8-01

K_d = 0.63 x 0.000205 x K_{ow} where 0.63=adjustment factor and 0.000205=average total organic carbon concentration
C_{sat} = Maximum Contaminant Level; F = Final MCL; P = Proposed MCL; T = Tenative MCL
S_{sat} = C_{sat} x K_d
Q = Avg linear velocity * unit area
Avg linear velocity = 0.18 ft/d (from Table 2-2 of Feasibility Study)
Unit Area = Avg saturated thickness to top of bedrock (11.4 ft) * unit width (1 ft) = 11.4 sq ft
Q = 0.18 x 11.4 = 2.05 cf/d
e = infiltration rate x unit area
Infiltration rate = 15.2 in/yr = 0.0035 ft/d (= recharge at 36% of average annual 42.3 in precipitation)
Unit area = 1 ft by 1 ft = 1 sq ft
e = 0.0035 x 1 = 0.0035 cf/d
S_{unsat} = S_{sat} x (e+Q)/e

FIGURE C-1
MASS BALANCE DERIVATION OF THE INFILTRATION EQUATION



$$(C_{unsat})(e) + (C)(Q) = (C_{sat})(e + Q)$$

$$C_{sat} = [(C_{unsat})(e) + (C)(Q)] / (e + Q)$$

Since C = 0, then:

$$C_{sat} = (C_{unsat})(e) / (e + Q)$$

C_{sat}	=	concentration of contaminant in ground water in saturated zone (µg/l)
C	=	initial concentration of contaminant in ground water (assumed zero)
C_{unsat}	=	contaminant concentration of ground water in recharge (µg/l)
e	=	volumetric flow rate of infiltration (cf/day)
Q	=	volumetric flow rate of ground water in the saturated zone throughout the unit (cf/day)

APPENDIX D

APPENDIX D

TECHNOLOGY AND PROCESS OPTION SCREENING

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APPENDIX D

TECHNOLOGY AND PROCESS OPTION SCREENING

Based on the general response actions developed for Site 10, remedial technologies which could potentially meet the remedial action objectives and cleanup criteria are identified and screened. This process is a two-step process in which technologies are initially screened on the basis of technical implementability. For the technologies which pass the initial screening, the process options associated with each technology are screened based on effectiveness, implementability and cost. Representative process options are then chosen based on this screening for inclusion in the comprehensive remedial alternatives developed for the site.

Technology Screening

The intent of the technology screening is to reduce the universe of potentially applicable technology types and process options based on technical implementability. Two factors which may be considered in the evaluation of the technical implementability of a technology are the type of contaminants present at a site and site-specific conditions which may limit the implementability of a technology. Examples of the application of these factors include the screening of a technology because it does not treat the contaminants of concern, or the screening of a technology which cannot be applied to a site due to site-specific subsurface conditions. The technologies or technology process options which do not pass the screening process on the basis of technical implementability are not retained for further consideration.

A combined technology screening was performed for all of the sites addressed within the Initial Screening of Alternatives Report. The technology screening presented herein revisits the technology screening, considering the results of the Phase II RI. The Site 10 technology screening is conducted for soil in Table 3-5 of the report and for ground water in Table 3-6.

The technology screening tables each include brief descriptions of the individual technologies or process options. More detailed descriptions of the technologies are provided in the text which follows this introduction. The technology screening tables also include comments on the general applicability of the technologies and limiting characteristics which may prevent their application at Site 10. The technology or process option title block is shaded gray only for those technologies which have been screened from further analysis.

For Site 10 soil, the potential remedial technologies presented in Table 3-5 were identified based on the remedial action objectives and consistent with the Superfund program, as outlined in the National Contingency Plan [NCP, 40 CFR 300.430(a)(1)]. The technologies which were identified include no action and site use restrictions. Active remediation of Site 10 surface soils was not considered because the surface soils do not pose a principal threat to human health or the environment, as described in Section 3.2.1 of the report. None of the identified technologies chosen were screened from further consideration based on technical implementability.

The potential remedial technologies identified for ground water at Site 10 include no action, ground water monitoring, ground water use restrictions, extraction, off-site treatment, inorganic treatment, and discharge. In ground water, only inorganic contaminants exceeded water quality standards. Therefore, when considering treatment technologies, only those process options which address inorganic contaminants were included in the screening process. One technology, off-site treatment, was screened from further consideration. Off-site treatment was screened based on difficulties associated with the technical implementability of off-site ground water treatment at a POTW or at a RCRA facility.

Ground water process options screened from further consideration based on technical implementability include provision of an alternate water supply, the interceptor trench extraction system, and discharge of treated ground water to a POTW. Due to the lack of potable ground water receptors, provision of an alternate water supply is not technically implementable. Due to the presence of a subsurface boulder layer at Site 10, an interceptor trench would be difficult to install. Discharge of treated ground water to a POTW was eliminated because of preliminary indications that the POTW would not be amenable to accepting such discharges.

Process Option Screening

Upon identification of those technologies which are technically implementable, the process options are further evaluated to allow the selection of representative process option(s) for each technology type. In the process option screening, the process options are evaluated on the basis of effectiveness, implementability, and cost. Factors considered in the effectiveness evaluation include the effectiveness of the process in handling the estimated areas or volumes of media, its ability to meet remediation goals, potential impacts to human health and the environment during construction and implementation, and how proven and reliable the process is. Both technical and administrative feasibility are considered in the implementability evaluation, while relative capital and O&M costs are broadly compared in the cost evaluations.

The process option evaluation for soil is presented in Table 3-7 of the report and the evaluation for ground water is presented in Table 3-8. The selected representative process options are indicated with a bullet in these tables.

Due to the limited number of process options evaluated for soil, all of the process options were retained for further consideration, as indicated in Table 3-7.

For ground water, one process option for extraction was selected for further consideration. The use of well points was considered, but the large distance between monitoring wells with inorganic concentrations exceeding ARARs/TBCs and the presence of inorganics at levels exceeding ARARs/TBCs and risk-based PRGs in deep well 10-MW5D limit the applicability of a well point system. Therefore, extraction wells were selected for further consideration.

For inorganic treatment, precipitation, and ion exchange treatment were selected as representative process options to be used for remedial alternative development. Filtration processes (both filtration and microfiltration) may not be successful in achieving inorganic PRGs alone since inorganic analyses conducted on filtered and unfiltered samples collected using the low-flow sampling methodology (which reduced the siltiness of the samples) indicated that the inorganics are probably dissolved rather than suspended (filtered and unfiltered results were comparable). However, filtration will be considered as a potential pretreatment process for either precipitation or ion exchange, since the silty nature of the ground water at Site 10 could interfere with the effectiveness of the precipitation or ion exchange processes. Filtering would remove the suspended solids from the ground water to increase the effectiveness of the precipitation and ion exchange treatment systems. Ion exchange is a commonly used inorganic treatment technology but the resin must be tailored to the contaminants requiring treatment. Precipitation is a commonly used treatment technology for which significant treatability data exists. Therefore, precipitation and ion exchange treatments were selected as representative inorganic treatment process options. For ground water discharge, discharge to surface water was selected as the representative discharge option. Due to the presence of inorganics in the upgradient deep well at levels exceeding MCLs and risk-based PRGs, and the nature of shallow ground water flow at the site, discharge to ground water was not selected based on the uncertainty associated with locating an appropriate upgradient discharge location.

SOIL/WASTE REMEDIAL TECHNOLOGIES

Site Use Restrictions

Site use restrictions are intended to prevent or reduce exposure to on-site contamination. They include actions such as fencing, signage, and restrictive covenants on the property deed to prevent development of the site or use of the ground water of the site. Site use restrictions may also be imposed to reduce required maintenance and to protect the integrity of a remedial alternative. Conditions in the area of the site should be evaluated in the five-year reviews to assess the continuing or future need for site use restrictions. Two types of access restrictions typically used at hazardous waste sites include deed restrictions and fencing.

Deed Restrictions

Deed restrictions are intended to prevent or limit site use and development. Restrictive covenants, written into the property deed, notify any potential purchaser of the site property that the land use must be restricted in order to ensure the integrity of any waste remediation systems, if they exist. The effectiveness of deed restrictions depends on state and local laws, continued enforcement, and maintenance. Since Site 10 has been excessed to the Army, deed restrictions would only be implemented if the site was transferred from federal ownership in the future.

Fencing

Fencing is used to physically limit access to the site. The most common type of fence used to limit access is a chain-link fence about eight feet high. Signs may be posted to make clear to potential trespassers that there may be a health threat associated with direct exposure to the site. Fencing may also help reduce the required maintenance and protect the integrity of a remediation system. Access to Camp Fogarty is presently restricted due to its use as an active firing range. Additional access restrictions could be implemented in the former Camp Fogarty Disposal Area.

GROUND WATER REMEDIAL TECHNOLOGIES

Institutional Control

Institutional controls are intended to minimize exposures to contaminated ground water. They include actions such as ground water monitoring, ground water use restrictions and provision of alternate water supplies. If a five-year review is required for a remedial action involving institutional controls, site conditions such as ground water monitoring results, if available, or changes in ground water usage should be reviewed to determine the need for continuing or future site use restrictions.

Ground Water Monitoring

Ground water monitoring provides a means to assess changes in ground water quality and contaminant migration patterns.

Ground Water Use Restrictions

Ground water use restrictions are intended to prevent or reduce exposure to ground water contamination. The use of ground water below or adjacent to the site is usually restricted. Ground water use restrictions may encompass potable use as well as non-potable use of the ground water. At Site 10, ground water is not currently used as a potable water supply. However, ground water at Site 10 is classified as Class GAA-NA, for which RIDEM has set a goal for the ground water quality to return to drinking water standards. Site 10 is also located within the ground water capture zone of a proposed public well site (GZA, 1992) and private potable wells may exist downgradient of the site. While ground water use restrictions would limit on-site ground water use, they would not impact surrounding ground water use.

Alternate Water Supply

Alternate water supply represents another type of institutional control in restricting ground water usage. Basically, ground water that is contaminated is no longer utilized as a potable water source, and an alternate source is provided. Since Camp Fogarty does not utilize ground water as a potable water supply, this process option is screened from further consideration.

Extraction

Extraction technology provides a means to collect contaminated ground water at a site. Various means of extraction include extraction wells, well points, or interceptor trenches.

Extraction Wells

Extraction wells represent a conventional technology which is frequently used in the removal of contaminated ground water. Stainless steel or PVC well casings and screens are installed within the contaminated ground water, and submersible pumps are typically used to extract water from the well. An array of wells with overlapping radii of influence can be designed to capture an entire plume or to halt contaminant migration.

Well Points

This ground water extraction technology involves the removal of ground water through a group of closely spaced wells connected by a header pipe. The wells are installed by driving a perforated pipe with a pointed cap into the area to be dewatered. Well point systems are best suited for shallow aquifers where extraction is not needed below twenty feet. The suction lifting pump technique commonly employed with well points is effective up to this depth. The depth to the water table (which ranges from 10 to 26 feet below the ground surface) and the large areal extent of the site limits the applicability of well points at Site 10.

Interceptor Trench

Interceptor trenches may be employed as a means of collecting ground water through the use of a perforated pipe placed below the natural ground water table. Ground water enters the perforated pipe and flows by gravity to the lowest point in the pipe, where it is pumped to the surface for treatment and/or discharge. This technology is typically limited to areas where the depth to ground water is not so deep that trench construction becomes prohibitively expensive or complicated (bracing, etc.). This technology offers the advantage of a horizontally oriented intake structure which allows collection of ground water within the area of interest. Additionally, trenches are relatively simple to construct and are passive structures with little maintenance required. The depth to the water table (which is as great as 26 feet at 10-MW3S) and the presence of a subsurface boulder layer at a depth of approximately 9 to 12 feet would make the implementation of an interceptor trench impracticable at Site 10.

Off-Site Treatment

Off-site treatment utilizes an off-site facility to treat extracted ground water. The contaminated ground water must be transported or conveyed to the treatment facility. Costs associated with conveyance or transportation can be extremely expensive if the distance from the site to the off-site treatment facility is far. Two types of off-site treatment facilities include publicly owned treatment works (POTW) and RCRA treatment facilities.

Off-Site Treatment at a POTW

This technology involves the discharge of aqueous wastes, which can constitute the majority of waste treated during a remedial cleanup effort, from a site to a Publicly Owned Treatment Works (POTW) for off-site treatment. These aqueous wastes can include ground water, leachate, surface water runoff, or other aqueous wastes. A number of criteria must be met when utilizing a POTW. These restrictions, as they apply to CERCLA sites, are detailed in the U.S. EPA's CERCLA Site Discharges to POTWs: Guidance Manual (U.S. EPA, 1990a). Typically, the proximity of a POTW to the site is such that the wastes can be piped to the POTW. An additional concern of POTWs in accepting a discharge from a CERCLA site is the issue of whether the POTW is then considered a hazardous waste treatment facility. Therefore, the administrative acceptability of discharging water to a POTW may be limited. Based on preliminary indications that the local POTW will not be amenable to accepting contaminated ground water, off-site treatment at a POTW will be screened from further consideration.

Off-Site Treatment at a RCRA Facility

Discharge to a RCRA facility also represents a potential off-site treatment technology for remediating contaminated ground water and other aqueous wastes. The extracted ground water is collected and transported off-site to a licensed RCRA facility for treatment. High extraction rates and the distance to the nearest RCRA treatment facility can greatly limit the cost-effectiveness of this alternative. This technology is screened from further consideration based on the lack of a locally available RCRA treatment facility.

Inorganic Treatment

Inorganic treatment typically involves physical or chemical treatment processes, as discussed below.

Ion Exchange

Ion exchange is a process whereby the toxic ions are removed from the aqueous phase by being exchanged with relatively harmless ions held by the ion exchange material. Ion exchange is a well-established technology for removal of heavy metals and hazardous anions from dilute solutions. Ion exchange can be expected to perform well for these applications when fed wastes of variable composition, provided the system's effluent is continually monitored to determine when the resin bed exhaustion has occurred. However, the reliability of ion exchange is markedly affected by the presence of suspended solids.

Ion exchange systems are commercially available from a number of vendors. The units are relatively compact and are not energy intensive. Although exchange columns can be operated manually or automatically, manual operation is better suited for hazardous waste site applications because of the diversity of wastes encountered. In addition, use of several exchange columns at a site can provide considerable flexibility. Ion exchange, with filtration pretreatment to remove suspended solids, will be retained for further consideration.

Precipitation

Precipitation is a physicochemical process whereby some or all of a substance in solution is transformed into a solid phase. It is based on alteration of the chemical equilibrium relationships affecting the solubility of inorganic species. Removal of metals as hydroxides or sulfides is the most common precipitation application in wastewater treatment. Generally, lime or sodium sulfide is added to the wastewater in a rapid mixing tank along with flocculating agents. The wastewater flows to a flocculating chamber in which adequate mixing and retention time is provided for agglomeration of precipitate particles. Agglomerated particles are separated from the liquid phase by settling in a sedimentation chamber, and/or by other physical processes such as filtration. Precipitation, with filtration pretreatment, will be retained for further evaluation.

Membrane Microfiltration

Membrane microfiltration involves the use of an automatic pressure filter in which the filter material has tiny openings (0.10 microns or 1 ten-millionth of a meter) which allow for the filtration of particles normally not separated from the wastestream using standard filtration processes. Membrane microfiltration is most applicable to hazardous waste suspensions, ground water contaminated with heavy metals, landfill leachate and process wastewaters containing uranium (U.S. EPA, 1991). Filtration processes (both filtration and microfiltration) may not be successful in meeting inorganic remediation goals since inorganic analyses conducted on filtered and unfiltered samples collected using the low flow sampling methodology (which reduced the siltiness of the samples) indicated that the inorganics are probably dissolved rather than suspended (filtered and unfiltered results were comparable). For this reason, membrane microfiltration is screened from further consideration.

Filtration

Filtration is a type of physical separation of a solid material based on particle size. As commonly employed in ground water treatment, filtration involves the separation of suspended solids, primarily silt, from the influent stream. As water passes through the bed of the granular filter medium, suspended particles become trapped on top of and within the bed. Backwashing is periodically required to clean the filter bed and retain treatment efficiency. Inorganic analyses conducted on filtered and unfiltered samples collected using the low-flow sampling methodology (which reduced the siltiness of the samples) indicated that the inorganics are probably dissolved rather than suspended (filtered and unfiltered results were comparable). Therefore, filtration would not be effective as a "stand-alone" treatment, but will be considered as a pretreatment process to improve the efficiency of the treatment technology.

Electrochemical

Electrochemical treatment provides treatment of inorganic contaminants. Contaminated water passes through an electrochemical cell where ferrous ions, hydroxide ions and hydrogen are produced. The ferrous ions act as reducing agents for oxidized heavy metals and also react with the hydroxide ions, forming iron hydroxides and metal hydroxides. The metal hydroxides are removed by adsorption onto the iron hydroxide precipitate that is formed (Hazardous Waste Consultant, 1991). Electrochemical treatment will be retained for further consideration since it is an innovative technology and has been proven effective for inorganic treatment during test operations.

Discharge

Following treatment, extracted ground water must be discharged back to the environment. Several options exist for the discharge of ground water, as described below.

Discharge to Ground Water

Treated ground water can be discharged to ground water using recharge basins, infiltration galleries or reinjection wells. The technology selected for recharge is dependent on site-specific considerations such as available space, extent of contamination, and hydrogeology. Ground water recharge systems can provide an added element of hydraulic control to ground water extraction systems. Typically recharge systems can be subject to clogging or other operational problems and must be closely monitored. Compliance with ground water discharge regulations must also be maintained. Ground water in the vicinity of Site 10 is classified GAA-NA, so ground water discharge would have to be in compliance with drinking water standards.

Discharge to Surface Water

Treated ground water can also be discharged to a surface water body. The nearest surface water body to Site 10 would be a tributary of Frenchtown Creek, located approximately 500 feet north of the site. Frenchtown Creek discharges into the Hunt River, which eventually discharges into Narragansett Bay. Implementation of this alternative would require compliance with NPDES discharge requirements. Discharge to surface water will be retained for further consideration.

Discharge to Sanitary Sewer/POTW

If available nearby, discharge of treated or untreated ground water to a sanitary sewer for subsequent treatment at a Publicly Owned Treatment Works (POTW) is a possible alternative. Many POTWs have regulations prohibiting discharges of ground water to the treatment system and special approval for such a discharge may be required. The POTW may also require pretreatment of the wastestream prior to acceptance. An additional concern of POTWs in accepting a discharge from a CERCLA site is the issue of whether the POTW is then considered a hazardous waste treatment facility. The administrative acceptability of discharging water to a POTW may therefore be limited. Based on preliminary indications that the local POTW will not be amenable to accepting aqueous discharges from the site, this option will be screened from further evaluation.

APPENDIX E

APPENDIX E

REMEDIAL COST ESTIMATES

Cost estimates are provided for the following alternatives:

SOIL ALTERNATIVES

Alternative S-2, Deed Restrictions and Fencing

GROUND WATER ALTERNATIVES

Alternative GW-2, Long-Term Monitoring

Alternative GW-3A, Extraction of Ground Water via Extraction Wells

Alternative GW-3B, Chemical Precipitation

Alternative GW-3C, Ion Exchange

Alternative GW-3D, Discharge to Surface Water

ALTERNATIVE S-2
FENCING AND DEED RESTRICTIONS
SITE 10 - CAMP FOGARTY DISPOSAL AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST - DIRECT										
Fencing										
- Chain Link, 9 gauge wire, aluminized steel, 6' high	700	l. ft.	$13.75	1994	2	1.000	$13.75	$9,625.00		
- Double Swing Gate 6' high, 4' opening	2	each	$252.00	1994	2	1.000	$252.00	$504.00		
- Warning Signs	8	each	$45.50	1994	2	1.000	$45.50	$364.00		
Total Fencing Cost										$10,493.00
Direct Capital Cost Subtotal										$10,493.00
CAPITAL COSTS - INDIRECT										
Engineering and Design (10%)					1			$1,049.30		
Legal and Administrative (4%)					1			$419.72		
Indirect Capital Cost Total										$1,469.02
TOTAL CAPITAL COSTS										$11,962.02
OPERATION AND MAINTENANCE COSTS										
Site Fence Maintenance	1	each	$300.00	1994	5	1.000	$300.00	$300.00	30	$4,611.60
ANNUAL O & M COST								$300.00		
TOTAL NET PRESENT VALUE OF O & M										$4,611.60
SUBTOTAL COST										$16,573.62
CONTINGENCY (20%)										$3,314.72
TOTAL PRESENT VALUE COST FOR ALTERNATIVE S-2										$19,888.34

(1) - Calculated based on 5% interest rate.

ALTERNATIVE GW-2
LONG-TERM GROUND WATER MONITORING
SITE 10 - CAMP FOGARTY DISPOSAL AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
TOTAL CAPITAL COSTS										$0.00
OPERATION AND MAINTENANCE COSTS										
Ground Water Monitoring (including trip blanks, field blanks and duplicate samples)										
- Annual Sampling	8	samples	$300.00	1994	5	1.000	$300.00	$2,400.00	30	$36,892.80
- Analysis:										
TAL + cyanide	9	samples	$320.00	1994	3	1.000	$320.00	$2,880.00	30	$44,271.36
- Report Preparation	1	each	$3,000.00	1994	5	1.000	$3,000.00	$3,000.00	30	$46,116.00
ANNUAL O&M (1994 $)								$8,280.00		
TOTAL NET PRESENT VALUE OF O & M										$127,280.16
SUBTOTAL COST										$127,280.16
CONTINGENCY (20%)										$25,456.03
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW-2										$152,736.19

(1) - Calculated based on 5% interest rate.

ALTERNATIVE GW-3, OPTION A
EXTRACTION OF GROUND WATER VIA EXTRACTION WELLS
SITE 10 - CAMP FOGARTY DISPOSAL AREA

Item	Quantity Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST - DIRECT									
Ground Water Extraction Wells									
- Well Construction and Materials (4 30-foot deep wells)	4 each	$4,250.00	1992	7	1.077	$4,577.25	$18,309.00		
- Health & Safety (17%)							$3,112.53		
Ground Water Extraction System									
- Pump with Appurtenances	4 each	$2,400.00	1994	8	1.000	$2,400.00	$9,600.00		
- Air Compressor with Appurtenances	1 each	$4,355.00	1994	8	1.000	$4,355.00	$4,355.00		
Pipe Trench from Manhole to Treatment Area									
- 1 1/4" O.D. Non-Slotted HDPE Pipe	1200 l. ft.	$4.60	1994	2	1.000	$4.60	$5,520.00		
-Excavation and Backfill	150 cu. yd.	$3.59	1994	2	1.000	$3.59	$538.50		
-Bedding Sand	75 cu. yd.	$16.20	1994	2	1.000	$16.20	$1,215.00		
Total Ground Water Extraction Wells									$42,650.03
Total Direct Capital Cost Subtotal									$42,650.03
CAPITAL COST - INDIRECT									
Engineering and Design (10 %)				1			$4,265.00		
Legal and Administrative (4%)				1			$1,706.00		
Total Indirect Capital Cost									$5,971.00
TOTAL CAPITAL COSTS									$48,621.03
SUBTOTAL									$48,621.03
CONTINGENCY (20%)									$9,724.21
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW-3, OPTION A									$58,345.24

(1) - Calculated based on 5% interest rate.

ALTERNATIVE GW-3, OPTION B
CHEMICAL PRECIPITATION
SITE 10 – CAMP FOGARTY DISPOSAL AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST – DIRECT										
Precipitation Treatment System										
– Neutralization/Precipitation/ Filtration/Filter Press Unit	1	each	$72,000.00	1987	4	1.219	$87,768.00	$87,768.00		
– Electrical Connections	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
– Equalization Tank	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
Total Ground Water Treatment System Cost										$127,768.00
Direct Capital Cost Subtotal										$127,768.00
CAPITAL COST – INDIRECT										
Engineering and Design (15%)					1			$19,165.20		
Legal and Administrative (5%)					1			$6,388.40		
Total Indirect Capital Cost										$25,553.60
TOTAL CAPITAL COSTS										$153,321.60
OPERATION AND MAINTENANCE COSTS										
– Precipitation O&M	5,256	1000 gal	$8.00	1985	6	1.281	$10.25	$53,863.49	30	$827,989.54
ANNUAL O&M (1994 $)								$53,863.49		
TOTAL NET PRESENT VALUE OF O&M										$827,989.54
SUBTOTAL										$981,311.14
CONTINGENCY (20%)										$196,262.23
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW-3, OPTION B										$1,177,573.37

(1) – Calculated based on 5% interest rate.

ALTERNATIVE GW-3, OPTION C
ION EXCHANGE
SITE 10 - CAMP FOGARTY DISPOSAL AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST - DIRECT										
Ground Water Treatment System										
-Ion Exchange Unit (with pre-filtration)	1	each	$122,300.00	1987	4	1.219	$149,083.70	$149,083.70		
-Electrical Connection	1	L.S.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
-Piping and Controls	1	L.S.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
-Transfer Pumps	2	each	$580.00	1992	2	1.000	$580.00	$1,160.00		
Total Direct Cost										$190,243.70
CAPITAL COST - INDIRECT										
Engineering and Design (15 %)								$28,536.56		
Legal and Administrative (5%)								$9,512.19		
Total Indirect Capital Cost										$38,048.74
Total Direct Capital Cost Subtotal										$228,292.44
OPERATION AND MAINTENANCE COSTS										
Ion Exchange O&M										
-Ion Exchange O&M	1	year	$10,940.00	1987	4	1.219	$13,335.86	$13,335.86	30	$204,998.84
ANNUAL O&M (1994 $)								$13,335.86		
TOTAL NET PRESENT VALUE OF O&M										$204,998.84
SUBTOTAL										$433,291.28
CONTINGENCY (20%)										$86,658.26
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW-3, OPTION C										$519,949.54

(1) - Calculated based on 5% interest rate.

ALTERNATIVE GW-3, OPTION D
DISCHARGE TO SURFACE WATER
SITE 10 - CAMP FOGARTY DISPOSAL AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST - DIRECT										
Piping From Treatment System To Surface Water										
- Trench Excavation & Backfill	500	l. ft.	$5.73	1994	2	1.000	$5.73	$2,865.00		
- 2" Diam. PVC in Trench	500	l. ft.	$4.60	1994	2	1.000	$4.60	$2,300.00		
- Pipe Bedding (sand)	500	l. ft.	$1.32	1994	2	1.000	$1.32	$660.00		
Total Piping Cost										$5,825.00
Direct Capital Cost Subtotal										$5,825.00
CAPITAL COST - INDIRECT										
Engineering and Design (10%)					1			$582.50		
Legal and Administrative (4%)					1			$233.00		
Total Indirect Capital Cost										$815.50
TOTAL CAPITAL COSTS										$6,640.50
OPERATION AND MAINTENANCE COSTS										
Discharge Sampling & Analysis										
- Monthly Sampling	12	samples	$300.00	1994	5	1.000	$300.00	$3,600.00	30	$55,339.20
- TAL + cyanide	12	samples	$320.00	1994	3	1.000	$320.00	$3,840.00	30	$59,028.48
ANNUAL O&M (1994 $)								$7,440.00		
TOTAL NET PRESENT VALUE OF O&M										$114,367.68
SUBTOTAL										$121,008.18
CONTINGENCY (20%)										$24,201.64
TOTAL PRESENT VALUE COST FOR ALTERNATIVE GW-3, OPTION D										$145,209.82

(1) - Calculated based on 5% interest rate.

COST REFERENCES

1) Remedial Action Costing Procedures Manual; JRB Associates; October 1987.

2) Means Site Work & Landscape Cost Data; 1994.

3) Complete Environmental Testing, Inc.; 1994.

4) Technical Resource Document; Treatment Technologies for Metals/Cyanide Containing Wastes, Alliance Technologies Corp.; December 1987.

5) TRC Environmental Corporation; 1994.

6) Remedial Action at Waste Disposal Sites; October 1985. EPA/625/6-85/006.

7) Empire Soils Investigation, Inc., Division of Huntingdon; January 1992.

8) QED Ground Water Specialists, April 1994.

APPENDIX F

APPENDIX F

GROUND WATER MODELING SUMMARY

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APPENDIX F

GROUND WATER MODELING SUMMARY

1.0 INTRODUCTION/OBJECTIVES

Under Alternative GW-3A - Ground Water Extraction via Extraction Wells, a system of ground water extraction wells was proposed for the capture and extraction of impacted Site 10 ground water from the unconsolidated overburden for treatment and disposal. The Phase I and Phase II RI field investigations revealed that at Site 10 the depth to bedrock ranges from 22 to 31 feet, the sandy overburden deposits contain very little silt, and the site shallow ground water flow converges toward the topographically low central portion of the site (the 10-MW04S/D and 10-MW05S/D area). Due to these circumstances, extraction wells were judged to be a more effective means than interceptor trenches in providing effective capture of the Site 10 ground water and preventing off-site migration of the ground water contaminants. In order to produce a preliminary extraction wellfield design for the purposes of option analysis, evaluation, and costing, a ground water flow model was used to: 1) simulate the ground water flow regime at Site 10, and 2) configure an extraction well system to provide control and capture of the estimated areal extent of site ground water with contaminant concentrations exceeding ARARs and/or risk-based PRGs. ARARs and/or risk-based PRGs were equaled or exceeded in the Phase I and/or Phase II samples from all of the Site 10 shallow and deep monitoring wells except shallow monitoring well 10-MW04S and deep monitoring wells 10-MW01D and 10-MW04D. Therefore, the area of Site 10 requiring ground water capture, extraction and treatment was assumed to include the entire site except the area immediately surrounding the 10-MW04S/D shallow/deep monitoring well cluster. In addition, within the estimated area of ground water impacts, it was assumed that the entire saturated interval between the shallow water table and the bedrock underlying Site 10 would require capture and extraction. A description of the modeling procedures, including the model assumptions and the input initial and boundary conditions, is presented in the following sections. Model data sheets are provided following this summary and the associated figures.

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2.0 INITIAL MODEL SETUP

FLOWPATH™ Version 3.0 (Waterloo Hydrogeologic Software, 1992), a two-dimensional numerical ground water flow and particle pathlines simulation model, was used to simulate the Site 10 ground water flow regime and to design the proposed ground water extraction well system. The area encompassed by the FLOWPATH™ model grid is shown in Figure F-1. The grid was configured with the principal axes oriented to parallel the primary directions of shallow ground water flow at Site 10. The Site 10 shallow ground water flow converges toward the topographically low central portion of the site (the 10-MW04S/D and 10-MW05S/D areas). In the southern portion of the site, the shallow and deep ground water flow generally north-northeastward toward 10-MW04S/D and 10-MW05S/D; in the northern portion of the site, the shallow ground water flows generally south-southwestward toward 10-MW04S/D and 10-MW05S/D. Due to the lack of a deep monitoring well in the northern portion of the site, the deep ground water flow direction in that area cannot be determined. However, based on the similarity between the shallow and deep ground water potentiometric elevations and flow directions and gradients in the southern portion of the site, the deep ground water flow regime in the northern portion of the site is presumed to closely mirror the shallow regime. The model grid is comprised of 29 rows and 32 columns; the variable nodal spacing ranges from 20 to 40 feet. The grid measures 1,240 feet by 1,000 feet, for a total simulation area of 1,240,000 square feet (28.5 acres). The nodal spacing was considered to be optimal to provide coverage of the large modeled area while also allowing flexibility in the development and optimization of the extraction wellfield configuration.

A one-layer simulation was used to simulate the Site 10 unconsolidated overburden aquifer. The aquifer was modeled as unconfined, where a portion of the water stored in the aquifer is released by dewatering of the aquifer, and the transmissivity is a product of the hydraulic conductivity (K-value) and the saturated thickness (the hydraulic head minus the elevation of the aquifer bottom at bedrock). The initial input nodal K-value was 6.0 ft/d; this value represents the median K-value determined from the slug tests conducted at the Phase II shallow and deep monitoring wells during the Phase II RI field investigation (Table 6-6, Phase II RI, TRC, 1993). The input aquifer porosity was 0.15 (15 percent); this value represents the average typical value for silty sands determined from 55 field sites (EPRI, 1985). The aquifer bottom was input as 101.56 feet above mean sea level (ft msl), the average bedrock elevation value determined from the logs for the three monitoring well borings where bedrock cores were collected, 10-MW01D, 10-MW04D and 10-MW05D.

A large area was modeled to account for the spatial distribution and potential influence area of the extraction well system; a substantial distance between the system components and the model boundaries must be maintained to limit the influence of boundary effects. The model boundaries were extended outward as far as considered practical when taking into account the areal range of Site 10 water level data points available. As the modeled area of the unconsolidated overburden aquifer is not bounded on any side by an impermeable boundary, constant-head boundaries were placed at the edges of the modeled area to establish flow through the model. The potential constant head boundary effects are considered to be minimal and conservative.

3.0 MODEL CALIBRATION

The ground water flow model was calibrated to steady-state (non-stressed) conditions existing at Site 10 on August 13, 1993. After each model run was conducted, the nodal K-value and/or constant head boundary head values were adjusted as necessary until the model was calibrated to the non-pumping conditions at Site 10 on August 13, 1993. Figure F-2 shows the results of the steady-state calibration for the unconsolidated overburden aquifer at the site. The resulting nodal K-values were kept at the initial input nodal K-value of 6.0 ft/d.

4.0 REMEDIAL SIMULATIONS

After completing the model calibration, remedial simulations were run to establish the optimal configuration of an extraction well system for capturing the unconsolidated overburden ground water flow from areas that were found in the Phase I and Phase II RI field investigations to exhibit contamination above ARARs and/or risk-based PRGs. A system of ground water extraction wells was simulated to assist in the determination of the optimum number, locations and extraction rates for the wells. The resulting ground water hydraulic head distributions and corresponding model-calculated ground water particle pathlines were inspected to ensure that adequate capture was accomplished across the estimated area of ground water to be extracted and treated. The capture zones were limited to those portions of the flow regime where the ground water particles were shown migrating toward and into the wells for extraction. The positions and extraction rates of the wells were adjusted until capture of the ground water requiring extraction and treatment was shown.

One concern with respect to ground water extraction is the topographic depression area in the central portion of the site. This area is subject to swampy conditions during periods of high ground water table, and as such may provide a wetlands habitat during those periods. During the modeling of the extraction well system, care was taken to minimize the depression of the shallow water table in the area between 10-MW04S/D and 10-MW05S/D. Based on the low yields (approximately 1.0 gallon per minute (gpm)) of the Site 10 monitoring wells during their development, a 1.0 gpm maximum extraction rate was assumed for each modeled extraction well.

5.0 RESULTS OF REMEDIAL SIMULATIONS

The evaluation of the extraction well simulations determined that a system of four extraction wells, each pumping at a rate of 0.75 gpm (for a total extraction rate of 3.0 gpm), would provide adequate control and capture of the impacted site ground water while minimizing the depression of the shallow water table in the central portion of the site. Figure F-3 shows the locations of the four proposed extraction wells, as well as the hydraulic head distribution resulting from the 3.0 gpm total extraction at the wells. Figure F-4 presents the model-calculated ground water particle pathlines, and shows the extent of capture that the extraction wells would establish as modeled. Figure 4-2 also shows the locations of the four proposed extraction wells. Extraction wells would be located at the locations of 10-MW01S/D, 10-MW02S and 10-MW03S, and approximately 40 feet north of 10-MW05S/D.

6.0 RECOMMENDED EXTRACTION WELL SYSTEM DESIGN

The proposed Site 10 ground water extraction wells should be designed to screen the entire saturated thickness at their locations. Based on the Phase II RI monitoring well logs for 10-MW01D, 10-MW04D and 10-MW05D, it is estimated that the maximum depth to bedrock in the proposed extraction well areas is 30 feet below grade. The Phase II water level measurements indicate an approximate maximum seasonal high ground water level depth of 10 feet below grade in the extraction well areas. Therefore, it is recommended that each extraction well be approximately 30 feet deep, with the bottom 20 feet (10 to 30 feet below grade) screened with 0.010-inch slotted screen. The screen and riser should consist of four-inch I.D. steel.

For the installation of each extraction well, a ten-inch diameter borehole should be advanced to bedrock using the mud rotary drilling method. After completion of the borehole, the screen and riser are lowered to bedrock, and a sand filter pack is placed in the annular space between the screen and the borehole wall. The filter pack should extend up to 7 feet below grade. A two-foot bentonite chip seal should then be placed above the sand, and the remainder of the open borehole should be grouted to the surface with a cement/bentonite grout.

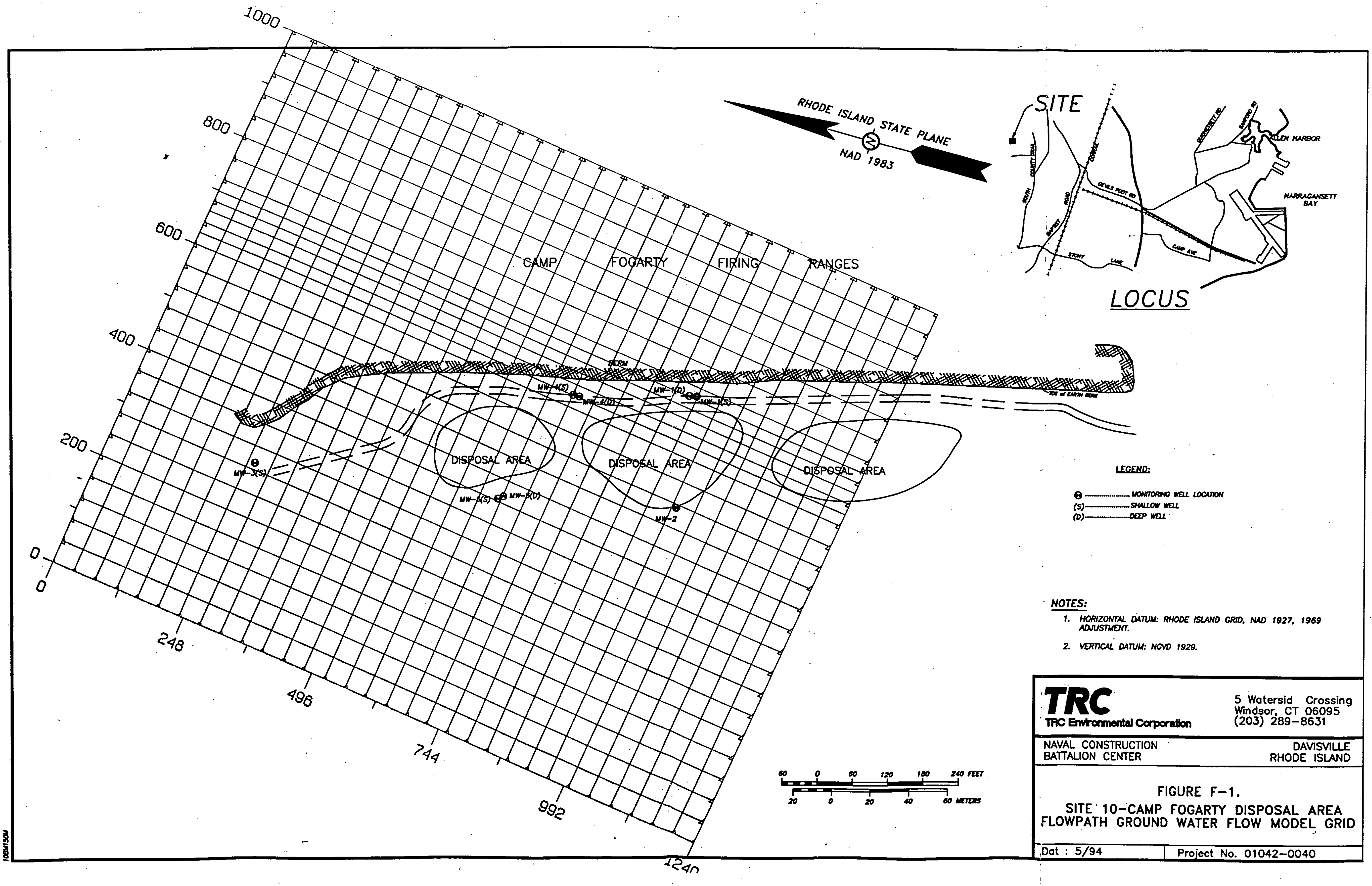
The recommended pump for this application is an automatic-control, low-flow positive air displacement remediation pump (e.g., the QED HammerHead™ H23SEB 1.75-inch cleanup pump). These pumps operate using compressed air, and cycle on and off in response to an internal float. Therefore, no external controls such as cycle timers, electrical equipment, downwell probes, or level controls are required at the wellhead. It is assumed that one air compressor would provide the compressed air supply via HDPE-type tubing to the four proposed extraction wells.

REFERENCES - APPENDIX F

Electric Power Research Institute (EPRI), 1985. A review of field-scale physical solute transport processes in saturated and unsaturated porous media. EPRI EA-4190, Electric Power Research Institute, Palo Alto, California.

TRC Environmental Corporation (TRC), 1993. Phase II Remedial Investigation Report, Naval Construction Battalion Center, Davisville, Rhode Island. Prepared for Northern Division, Naval Facilities Engineering Command, Philadelphia, Pennsylvania. Contract No. N62472-86-C-1282, November 1993.

Waterloo Hydrogeologic Software, 1992. FLOWPATH™ Version 3.0 Steady-State Two-Dimensional Horizontal Aquifer Simulation Model. Waterloo Hydrogeologic Software, Waterloo, Ontario, Canada.



NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.

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FIGURE F-1.
SITE 10-CAMP FOGARTY DISPOSAL AREA
FLOWPATH GROUND WATER FLOW MODEL GRID

Dat : 5/94 | Project No. 01042-0040

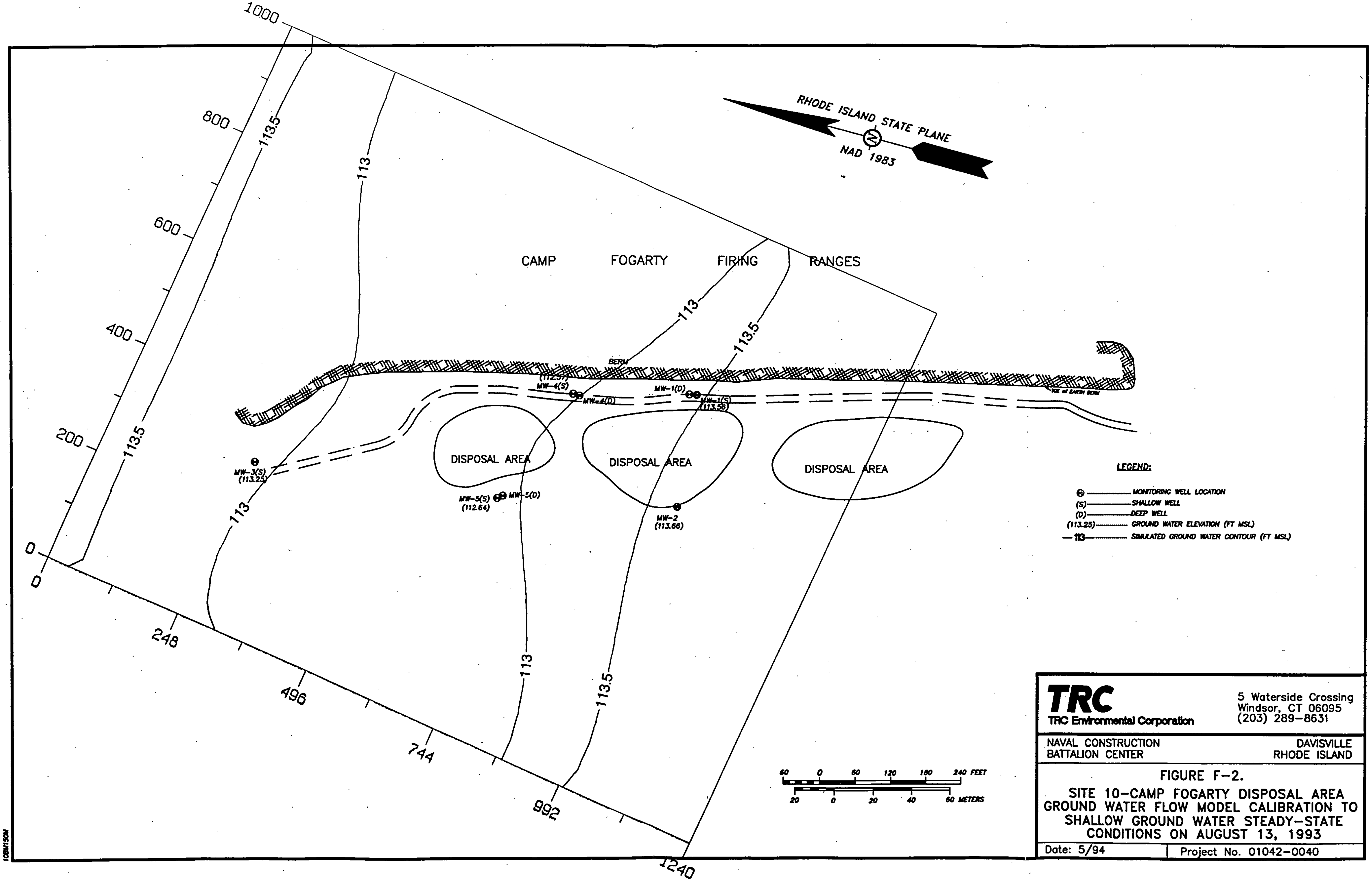

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FIGURE F-2.
SITE 10-CAMP FOGARTY DISPOSAL AREA GROUND WATER FLOW MODEL CALIBRATION TO SHALLOW GROUND WATER STEADY-STATE CONDITIONS ON AUGUST 13, 1993

Date: 5/94 | Project No. 01042-0040

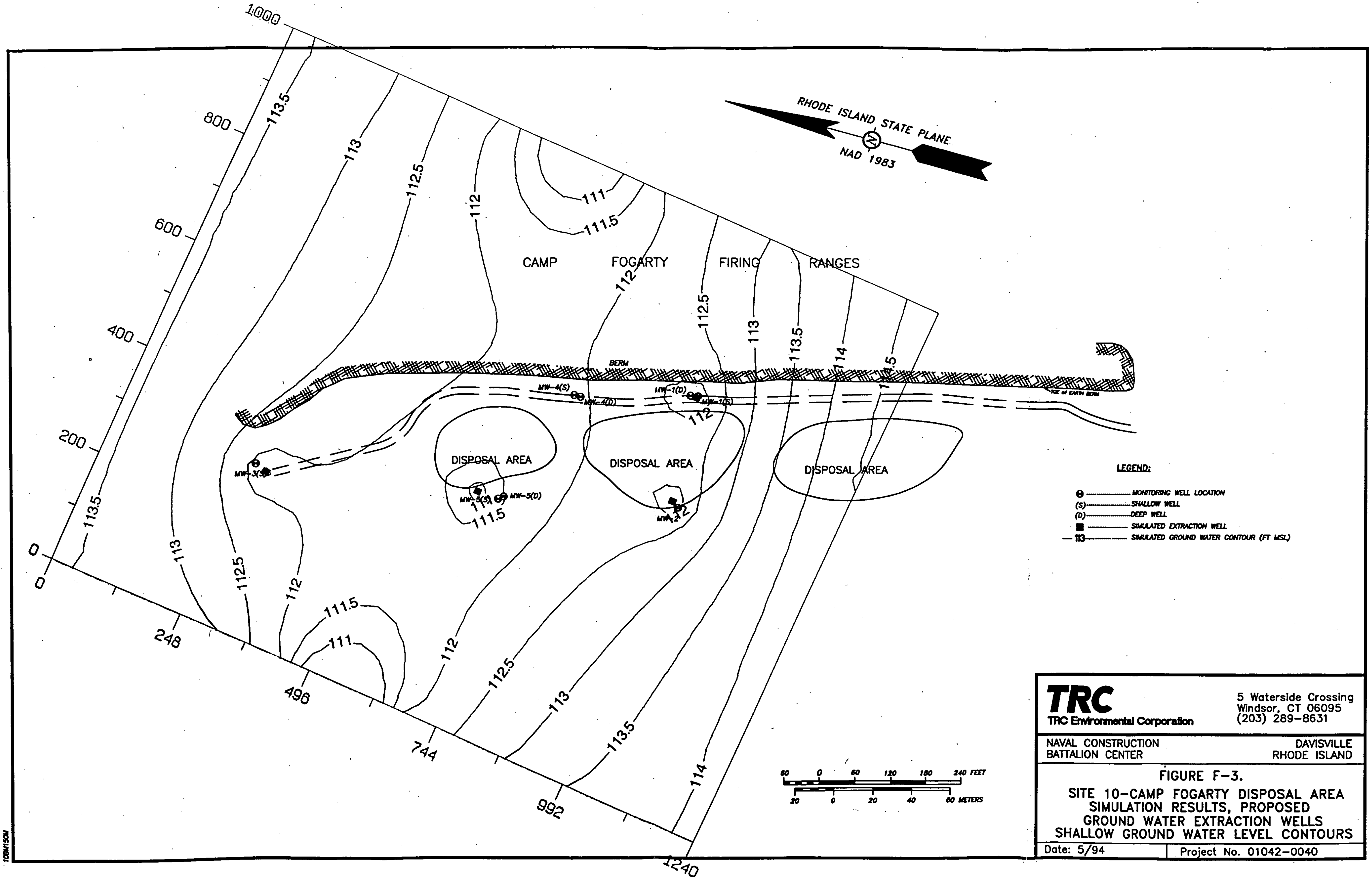

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FIGURE F-3.

SITE 10-CAMP FOGARTY DISPOSAL AREA
SIMULATION RESULTS, PROPOSED
GROUND WATER EXTRACTION WELLS
SHALLOW GROUND WATER LEVEL CONTOURS

Date: 5/94 | Project No. 01042-0040

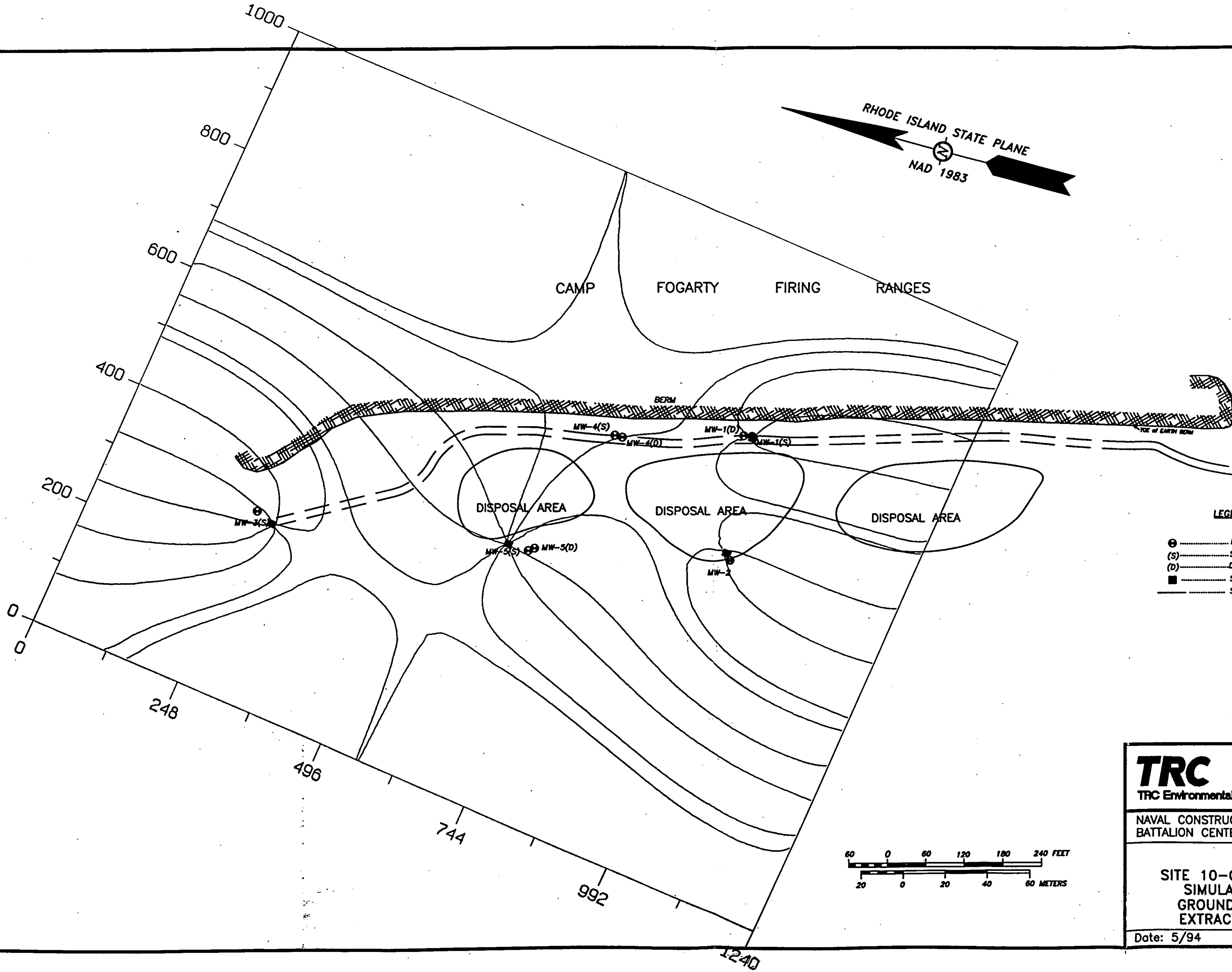

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FIGURE F-4.

SITE 10-CAMP FOGARTY DISPOSAL AREA
SIMULATION RESULTS, PROPOSED
GROUND WATER EXTRACTION WELLS
EXTRACTION WELL CAPTURE ZONES

Date: 5/94 | Project No. 01042-0040

1084150M

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*************************************************************
*                     E C H O P R I N T                     *
*                                                           *
*                      F L O W P A T H                      *
*                        version 3.0                        *
*                                                           *
*  FLOWPATH was written by Thomas Franz and Nilson Guiguer  *
*                                                           *
*************************************************************
*                                                           *
*                  Copyright 1989, 1990                     *
*                           by                              *
*              Waterloo Hydrogeologic Software              *
*                  113-106 Seagram Drive                    *
*                   Waterloo, Ontario                       *
*                    N2L 3B8, Canada                        *
*                                                           *
*                    ph (519) 746-1798                      *
*                                                           *
*************************************************************
```

FLOWPATH logbook for data set : SITE10CA

Unit System : English units [ft/gal/d]

***** GRID PARAMETERS *****

Number of x-grid lines : 32

Number of y-grid lines : 29

Grid coordinates (x-grid lines) [ft] :

1	0.00000E+00
2	4.00000E+01
3	8.00000E+01
4	1.20000E+02
5	1.60000E+02
6	2.00000E+02
7	2.40000E+02
8	2.80000E+02
9	3.20000E+02
10	3.60000E+02
11	4.00000E+02
12	4.40000E+02
13	4.80000E+02
14	5.20000E+02
15	5.60000E+02
16	6.00000E+02
17	6.40000E+02

18	6.80000E+02
19	7.20000E+02
20	7.60000E+02
21	8.00000E+02
22	8.40000E+02
23	8.80000E+02
24	9.20000E+02
25	9.60000E+02
26	1.00000E+03
27	1.04000E+03
28	1.08000E+03
29	1.12000E+03
30	1.16000E+03
31	1.20000E+03
32	1.24000E+03

Grid coordinates (y-grid lines) [ft] :

1	0.00000E+00
2	4.00000E+01
3	8.00000E+01
4	1.20000E+02
5	1.60000E+02
6	2.00000E+02
7	2.40000E+02
8	2.80000E+02
9	3.20000E+02
10	3.60000E+02
11	4.00000E+02
12	4.40000E+02
13	4.80000E+02
14	5.20000E+02
15	5.60000E+02
16	6.00000E+02
17	6.21118E+02
18	6.40000E+02
19	6.61491E+02
20	6.80000E+02
21	6.98758E+02
22	7.20000E+02
23	7.60000E+02
24	8.00000E+02
25	8.40000E+02
26	8.80000E+02
27	9.20000E+02
28	9.60000E+02
29	1.00000E+03

***** WELL PARAMETERS *****

Number of wells : 5

No.	i	j	X [ft]	Y [ft]	well discharge [gpd]
1	24	21	9.19410E+02	6.98758E+02	0.00000E+00

2	25	14	9.60326E+02	5.18634E+02	0.00000E+00
3	8	8	2.79193E+02	2.79503E+02	0.00000E+00
4	19	17	7.19643E+02	6.21118E+02	0.00000E+00
5	18	11	6.81134E+02	4.00621E+02	0.00000E+00

***** CONSTRAINED HEAD NODES *****

Number of constant head nodes : 112

No.	i	j	X [ft]	Y [ft]	const. head [ft]
1	1	29	0.00000E+00	1.00000E+03	1.13600E+02
2	1	28	0.00000E+00	9.59627E+02	1.13600E+02
3	1	27	0.00000E+00	9.19255E+02	1.13600E+02
4	1	26	0.00000E+00	8.78882E+02	1.13600E+02
5	1	25	0.00000E+00	8.38509E+02	1.13600E+02
6	1	24	0.00000E+00	8.01242E+02	1.13600E+02
7	1	23	0.00000E+00	7.60870E+02	1.13600E+02
8	1	22	0.00000E+00	7.20497E+02	1.13600E+02
9	2	29	4.09161E+01	1.00000E+03	1.13500E+02
10	1	20	0.00000E+00	6.80124E+02	1.13600E+02
11	3	29	7.94255E+01	1.00000E+03	1.13500E+02
12	1	18	0.00000E+00	6.39752E+02	1.13600E+02
13	4	29	1.20342E+02	1.00000E+03	1.13400E+02
14	1	16	0.00000E+00	5.99379E+02	1.13600E+02
15	1	15	0.00000E+00	5.59006E+02	1.13600E+02
16	1	14	0.00000E+00	5.18634E+02	1.13600E+02
17	1	13	0.00000E+00	4.81366E+02	1.13600E+02
18	1	12	0.00000E+00	4.40994E+02	1.13600E+02
19	1	11	0.00000E+00	4.00621E+02	1.13600E+02
20	1	10	0.00000E+00	3.60248E+02	1.13600E+02
21	1	9	0.00000E+00	3.19876E+02	1.13600E+02
22	1	8	0.00000E+00	2.79503E+02	1.13600E+02
23	1	7	0.00000E+00	2.39130E+02	1.13600E+02
24	1	6	0.00000E+00	1.98758E+02	1.13600E+02
25	1	5	0.00000E+00	1.61491E+02	1.13600E+02
26	1	4	0.00000E+00	1.21118E+02	1.13600E+02
27	1	3	0.00000E+00	8.07453E+01	1.13600E+02
28	1	2	0.00000E+00	4.03727E+01	1.13600E+02
29	1	1	0.00000E+00	0.00000E+00	1.13600E+02
30	2	1	4.09161E+01	0.00000E+00	1.13500E+02
31	3	1	7.94255E+01	0.00000E+00	1.13500E+02
32	4	1	1.20342E+02	0.00000E+00	1.13400E+02
33	5	1	1.58851E+02	0.00000E+00	1.13400E+02
34	6	1	1.99767E+02	0.00000E+00	1.13300E+02
35	7	1	2.40683E+02	0.00000E+00	1.13200E+02
36	8	1	2.79193E+02	0.00000E+00	1.13100E+02
37	9	1	3.20109E+02	0.00000E+00	1.13000E+02
38	10	1	3.61025E+02	0.00000E+00	1.12700E+02
39	11	1	3.99534E+02	0.00000E+00	1.12300E+02
40	12	1	4.40450E+02	0.00000E+00	1.12000E+02
41	13	1	4.78960E+02	0.00000E+00	1.11000E+02
42	14	1	5.19876E+02	0.00000E+00	1.10000E+02
43	15	1	5.60792E+02	0.00000E+00	1.09000E+02
44	16	1	5.99301E+02	0.00000E+00	1.10000E+02
45	17	1	6.40217E+02	0.00000E+00	1.11000E+02

46	18	1	6.81134E+02	0.00000E+00	1.12000E+02
47	19	1	7.19643E+02	0.00000E+00	1.12200E+02
48	20	1	7.60559E+02	0.00000E+00	1.12400E+02
49	21	1	7.99068E+02	0.00000E+00	1.12600E+02
50	22	1	8.39984E+02	0.00000E+00	1.12800E+02
51	23	1	8.80901E+02	0.00000E+00	1.13000E+02
52	24	1	9.19410E+02	0.00000E+00	1.13100E+02
53	25	1	9.60326E+02	0.00000E+00	1.13300E+02
54	26	1	9.98835E+02	0.00000E+00	1.13500E+02
55	27	1	1.03975E+03	0.00000E+00	1.13600E+02
56	28	1	1.08067E+03	0.00000E+00	1.13700E+02
57	29	1	1.11918E+03	0.00000E+00	1.13800E+02
58	30	1	1.16009E+03	0.00000E+00	1.13900E+02
59	31	1	1.20101E+03	0.00000E+00	1.14000E+02
60	32	1	1.23952E+03	0.00000E+00	1.14100E+02
61	32	2	1.23952E+03	4.03727E+01	1.14100E+02
62	32	3	1.23952E+03	8.07453E+01	1.14100E+02
63	32	4	1.23952E+03	1.21118E+02	1.14100E+02
64	32	5	1.23952E+03	1.61491E+02	1.14200E+02
65	32	6	1.23952E+03	1.98758E+02	1.14200E+02
66	32	7	1.23952E+03	2.39130E+02	1.14200E+02
67	32	8	1.23952E+03	2.79503E+02	1.14200E+02
68	32	9	1.23952E+03	3.19876E+02	1.14300E+02
69	32	10	1.23952E+03	3.60248E+02	1.14300E+02
70	32	11	1.23952E+03	4.00621E+02	1.14300E+02
71	32	12	1.23952E+03	4.40994E+02	1.14400E+02
72	32	13	1.23952E+03	4.81366E+02	1.14400E+02
73	32	14	1.23952E+03	5.18634E+02	1.14400E+02
74	32	15	1.23952E+03	5.59006E+02	1.14500E+02
75	32	16	1.23952E+03	5.99379E+02	1.14500E+02
76	32	18	1.23952E+03	6.39752E+02	1.14500E+02
77	32	20	1.23952E+03	6.80124E+02	1.14600E+02
78	32	22	1.23952E+03	7.20497E+02	1.14600E+02
79	32	23	1.23952E+03	7.60870E+02	1.14600E+02
80	32	24	1.23952E+03	8.01242E+02	1.14700E+02
81	32	25	1.23952E+03	8.38509E+02	1.14700E+02
82	32	26	1.23952E+03	8.78882E+02	1.14700E+02
83	32	27	1.23952E+03	9.19255E+02	1.14800E+02
84	32	28	1.23952E+03	9.59627E+02	1.14800E+02
85	32	29	1.23952E+03	1.00000E+03	1.14800E+02
86	31	29	1.20101E+03	1.00000E+03	1.14600E+02
87	30	29	1.16009E+03	1.00000E+03	1.14400E+02
88	29	29	1.11918E+03	1.00000E+03	1.14200E+02
89	28	29	1.08067E+03	1.00000E+03	1.14000E+02
90	27	29	1.03975E+03	1.00000E+03	1.13800E+02
91	26	29	9.98835E+02	1.00000E+03	1.13600E+02
92	25	29	9.60326E+02	1.00000E+03	1.13500E+02
93	24	29	9.19410E+02	1.00000E+03	1.13000E+02
94	23	29	8.80901E+02	1.00000E+03	1.12800E+02
95	22	29	8.39984E+02	1.00000E+03	1.12600E+02
96	21	29	7.99068E+02	1.00000E+03	1.12400E+02
97	20	29	7.60559E+02	1.00000E+03	1.12200E+02
98	19	29	7.19643E+02	1.00000E+03	1.12000E+02
99	18	29	6.81134E+02	1.00000E+03	1.11500E+02
100	17	29	6.40217E+02	1.00000E+03	1.11000E+02
101	16	29	5.99301E+02	1.00000E+03	1.10000E+02
102	15	29	5.60792E+02	1.00000E+03	1.09000E+02
103	14	29	5.19876E+02	1.00000E+03	1.10000E+02
104	13	29	4.78960E+02	1.00000E+03	1.11000E+02
105	12	29	4.40450E+02	1.00000E+03	1.11500E+02

106	11	29	3.99534E+02	1.00000E+03	1.12000E+02
107	10	29	3.61025E+02	1.00000E+03	1.12200E+02
108	9	29	3.20109E+02	1.00000E+03	1.12400E+02
109	8	29	2.79193E+02	1.00000E+03	1.12600E+02
110	7	29	2.40683E+02	1.00000E+03	1.12800E+02
111	6	29	1.99767E+02	1.00000E+03	1.13000E+02
112	5	29	1.58851E+02	1.00000E+03	1.13300E+02

***** SPECIFIED FLUX NODES *****

Number of flux nodes : 0

***** SURFACE WATER BODIES *****

Number of surface water body nodes : 0

***** AQUIFER PROPERTIES *****

Number of different material properties : 1

No.	Kxx [ft/d]	Kyy [ft/d]	Porosity [-]	
1	6.00000E+00	6.00000E+00	1.50000E-01	(default)

********** DISTRIBUTION OF AQUIFER MATERIAL PROPERTIES **********

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
[illegible]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

***** AQUIFER TYPE *****

Unconfined aquifer

***** AQUIFER BOTTOM ELEVATIONS *****

Number of different aquifer bottom elevations : 1

No.	aquifer bottom elevation [ft]
1	1.01560E+02 (default)

********** DISTRIBUTION OF AQUIFER BOTTOM ELEVATIONS **********

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
[illegible]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

***** AREAL RECHARGE *****

Number of different infiltration/evapotranspiration rates : 1

No.	infiltration [L/T]	evapotranspiration [L/T]	effective recharge [L/T]	
1	0.00000E+00	0.00000E+00	0.00000E+00	(default)

********** DISTRIBUTION OF AREAL IN/OUT-FLUXES **********

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
[illegible]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
[illegible]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

***** PATHLINE & PARTICLE TRACKING DATA *****

Number of forward particles : 0

Number of reverse particles : 0

Particles released at wells :

Well-No.	Particles released
1	0
2	0
3	0
4	0
5	0

************ HYDRAULIC HEAD DISTRIBUTION ************

	1	2	3	4	5	6
29	1.1360E+02	1.1350E+02	1.1350E+02	1.1340E+02	1.1330E+02	1.1300E+02
28	1.1360E+02	1.1351E+02	1.1344E+02	1.1334E+02	1.1321E+02	1.1302E+02
27	1.1360E+02	1.1351E+02	1.1342E+02	1.1331E+02	1.1318E+02	1.1303E+02
26	1.1360E+02	1.1351E+02	1.1341E+02	1.1330E+02	1.1318E+02	1.1304E+02
25	1.1360E+02	1.1350E+02	1.1340E+02	1.1330E+02	1.1318E+02	1.1306E+02
24	1.1360E+02	1.1350E+02	1.1341E+02	1.1331E+02	1.1320E+02	1.1309E+02
23	1.1360E+02	1.1351E+02	1.1341E+02	1.1332E+02	1.1322E+02	1.1311E+02
22	1.1360E+02	1.1351E+02	1.1342E+02	1.1333E+02	1.1324E+02	1.1314E+02
21	1.1358E+02	1.1351E+02	1.1342E+02	1.1334E+02	1.1325E+02	1.1316E+02
20	1.1360E+02	1.1351E+02	1.1343E+02	1.1334E+02	1.1326E+02	1.1317E+02
19	1.1358E+02	1.1351E+02	1.1343E+02	1.1335E+02	1.1326E+02	1.1318E+02
18	1.1360E+02	1.1351E+02	1.1343E+02	1.1335E+02	1.1327E+02	1.1319E+02
17	1.1358E+02	1.1351E+02	1.1344E+02	1.1336E+02	1.1328E+02	1.1320E+02
16	1.1360E+02	1.1352E+02	1.1344E+02	1.1336E+02	1.1329E+02	1.1321E+02
15	1.1360E+02	1.1352E+02	1.1345E+02	1.1337E+02	1.1330E+02	1.1322E+02
14	1.1360E+02	1.1352E+02	1.1345E+02	1.1338E+02	1.1330E+02	1.1323E+02
13	1.1360E+02	1.1353E+02	1.1345E+02	1.1338E+02	1.1331E+02	1.1324E+02
12	1.1360E+02	1.1353E+02	1.1345E+02	1.1338E+02	1.1331E+02	1.1324E+02
11	1.1360E+02	1.1353E+02	1.1345E+02	1.1338E+02	1.1330E+02	1.1323E+02
10	1.1360E+02	1.1353E+02	1.1345E+02	1.1338E+02	1.1330E+02	1.1322E+02
9	1.1360E+02	1.1352E+02	1.1345E+02	1.1337E+02	1.1329E+02	1.1322E+02
8	1.1360E+02	1.1352E+02	1.1345E+02	1.1337E+02	1.1329E+02	1.1321E+02
7	1.1360E+02	1.1352E+02	1.1345E+02	1.1337E+02	1.1328E+02	1.1320E+02
6	1.1360E+02	1.1352E+02	1.1345E+02	1.1337E+02	1.1328E+02	1.1319E+02
5	1.1360E+02	1.1352E+02	1.1345E+02	1.1337E+02	1.1328E+02	1.1319E+02
4	1.1360E+02	1.1353E+02	1.1345E+02	1.1337E+02	1.1329E+02	1.1320E+02
3	1.1360E+02	1.1353E+02	1.1346E+02	1.1339E+02	1.1331E+02	1.1322E+02
2	1.1360E+02	1.1352E+02	1.1347E+02	1.1340E+02	1.1334E+02	1.1325E+02
1	1.1360E+02	1.1350E+02	1.1350E+02	1.1340E+02	1.1340E+02	1.1330E+02
	1	2	3	4	5	6

	7	8	9	10	11	12
29	1.1280E+02	1.1260E+02	1.1240E+02	1.1220E+02	1.1200E+02	1.1150E+02
28	1.1283E+02	1.1264E+02	1.1245E+02	1.1225E+02	1.1201E+02	1.1166E+02
27	1.1286E+02	1.1269E+02	1.1251E+02	1.1232E+02	1.1211E+02	1.1186E+02
26	1.1289E+02	1.1274E+02	1.1258E+02	1.1242E+02	1.1224E+02	1.1205E+02
25	1.1293E+02	1.1280E+02	1.1266E+02	1.1251E+02	1.1237E+02	1.1223E+02
24	1.1297E+02	1.1285E+02	1.1273E+02	1.1261E+02	1.1249E+02	1.1239E+02
23	1.1301E+02	1.1290E+02	1.1280E+02	1.1270E+02	1.1260E+02	1.1252E+02
22	1.1305E+02	1.1295E+02	1.1286E+02	1.1278E+02	1.1270E+02	1.1263E+02
21	1.1307E+02	1.1298E+02	1.1289E+02	1.1281E+02	1.1274E+02	1.1268E+02
20	1.1308E+02	1.1300E+02	1.1292E+02	1.1284E+02	1.1278E+02	1.1272E+02

19	1.1310E+02	1.1302E+02	1.1294E+02	1.1287E+02	1.1281E+02	1.1276E+02
18	1.1311E+02	1.1304E+02	1.1296E+02	1.1290E+02	1.1284E+02	1.1279E+02
17	1.1312E+02	1.1305E+02	1.1298E+02	1.1292E+02	1.1286E+02	1.1282E+02
16	1.1313E+02	1.1306E+02	1.1300E+02	1.1294E+02	1.1289E+02	1.1285E+02
[illegible]	1.1315E+02	1.1308E+02	1.1302E+02	1.1296E+02	1.1292E+02	1.1288E+02
[illegible]	1.1316E+02	1.1310E+02	1.1303E+02	1.1298E+02	1.1293E+02	1.1290E+02
13	1.1317E+02	1.1310E+02	1.1304E+02	1.1299E+02	1.1294E+02	1.1290E+02
12	1.1317E+02	1.1310E+02	1.1304E+02	1.1298E+02	1.1293E+02	1.1289E+02
11	1.1316E+02	1.1309E+02	1.1303E+02	1.1297E+02	1.1291E+02	1.1287E+02
10	1.1315E+02	1.1308E+02	1.1301E+02	1.1294E+02	1.1288E+02	1.1283E+02
9	1.1314E+02	1.1306E+02	1.1298E+02	1.1290E+02	1.1284E+02	1.1278E+02
8	1.1312E+02	1.1303E+02	1.1295E+02	1.1286E+02	1.1278E+02	1.1271E+02
7	1.1310E+02	1.1301E+02	1.1291E+02	1.1281E+02	1.1271E+02	1.1262E+02
6	1.1309E+02	1.1299E+02	1.1287E+02	1.1275E+02	1.1263E+02	1.1251E+02
5	1.1309E+02	1.1297E+02	1.1284E+02	1.1269E+02	1.1254E+02	1.1238E+02
4	1.1309E+02	1.1297E+02	1.1282E+02	1.1264E+02	1.1245E+02	1.1223E+02
3	1.1311E+02	1.1298E+02	1.1282E+02	1.1262E+02	1.1236E+02	1.1208E+02
2	1.1315E+02	1.1302E+02	1.1287E+02	1.1263E+02	1.1231E+02	1.1195E+02
1	1.1320E+02	1.1310E+02	1.1300E+02	1.1270E+02	1.1230E+02	1.1200E+02
	7	8	9	10	11	12

	13	14	15	16	17	18
29	1.1100E+02	1.1000E+02	1.0900E+02	1.1000E+02	1.1100E+02	1.1150E+02
28	1.1127E+02	1.1080E+02	1.1050E+02	1.1080E+02	1.1128E+02	1.1168E+02
27	1.1159E+02	1.1134E+02	1.1123E+02	1.1135E+02	1.1161E+02	1.1189E+02
26	1.1187E+02	1.1173E+02	1.1168E+02	1.1175E+02	1.1190E+02	1.1209E+02
25	1.1211E+02	1.1202E+02	1.1200E+02	1.1204E+02	1.1214E+02	1.1228E+02
24	1.1230E+02	1.1224E+02	1.1223E+02	1.1226E+02	1.1234E+02	1.1245E+02
[illegible]	1.1246E+02	1.1242E+02	1.1241E+02	1.1244E+02	1.1250E+02	1.1259E+02
[illegible]	1.1258E+02	1.1256E+02	1.1255E+02	1.1258E+02	1.1263E+02	1.1270E+02
21	1.1264E+02	1.1262E+02	1.1262E+02	1.1264E+02	1.1269E+02	1.1276E+02
20	1.1268E+02	1.1266E+02	1.1267E+02	1.1269E+02	1.1273E+02	1.1280E+02
19	1.1272E+02	1.1271E+02	1.1271E+02	1.1273E+02	1.1277E+02	1.1283E+02
18	1.1276E+02	1.1275E+02	1.1275E+02	1.1277E+02	1.1281E+02	1.1287E+02
17	1.1279E+02	1.1278E+02	1.1278E+02	1.1280E+02	1.1284E+02	1.1289E+02
16	1.1282E+02	1.1280E+02	1.1281E+02	1.1283E+02	1.1287E+02	1.1292E+02
15	1.1285E+02	1.1284E+02	1.1285E+02	1.1287E+02	1.1290E+02	1.1295E+02
14	1.1287E+02	1.1286E+02	1.1287E+02	1.1289E+02	1.1292E+02	1.1297E+02
13	1.1288E+02	1.1287E+02	1.1287E+02	1.1289E+02	1.1292E+02	1.1297E+02
12	1.1287E+02	1.1286E+02	1.1286E+02	1.1287E+02	1.1291E+02	1.1295E+02
11	1.1284E+02	1.1282E+02	1.1283E+02	1.1284E+02	1.1288E+02	1.1292E+02
10	1.1280E+02	1.1278E+02	1.1277E+02	1.1279E+02	1.1283E+02	1.1288E+02
9	1.1273E+02	1.1271E+02	1.1270E+02	1.1272E+02	1.1276E+02	1.1281E+02
8	1.1265E+02	1.1261E+02	1.1261E+02	1.1262E+02	1.1267E+02	1.1273E+02
7	1.1254E+02	1.1249E+02	1.1248E+02	1.1250E+02	1.1255E+02	1.1263E+02
6	1.1241E+02	1.1234E+02	1.1231E+02	1.1234E+02	1.1241E+02	1.1251E+02
5	1.1223E+02	1.1213E+02	1.1209E+02	1.1212E+02	1.1222E+02	1.1236E+02
4	1.1202E+02	1.1185E+02	1.1178E+02	1.1184E+02	1.1200E+02	1.1220E+02
3	1.1174E+02	1.1145E+02	1.1132E+02	1.1144E+02	1.1172E+02	1.1203E+02
2	1.1140E+02	1.1087E+02	1.1056E+02	1.1087E+02	1.1138E+02	1.1191E+02
1	1.1100E+02	1.1000E+02	1.0900E+02	1.1000E+02	1.1100E+02	1.1200E+02
	13	14	15	16	17	18

	19	20	21	22	23	24
29	1.1200E+02	1.1220E+02	1.1240E+02	1.1260E+02	1.1280E+02	1.1300E+02
28	1.1203E+02	1.1228E+02	1.1249E+02	1.1270E+02	1.1291E+02	1.1314E+02

27	1.1215E+02	1.1238E+02	1.1259E+02	1.1279E+02	1.1299E+02	1.1321E+02
26	1.1230E+02	1.1250E+02	1.1269E+02	1.1288E+02	1.1307E+02	1.1326E+02
25	1.1244E+02	1.1261E+02	1.1278E+02	1.1295E+02	1.1313E+02	1.1331E+02
24	1.1258E+02	1.1272E+02	1.1287E+02	1.1303E+02	1.1319E+02	1.1335E+02
23	1.1270E+02	1.1282E+02	1.1295E+02	1.1309E+02	1.1324E+02	1.1339E+02
22	1.1280E+02	1.1290E+02	1.1302E+02	1.1315E+02	1.1328E+02	1.1342E+02
21	1.1284E+02	1.1294E+02	1.1305E+02	1.1318E+02	1.1330E+02	1.1344E+02
20	1.1288E+02	1.1297E+02	1.1308E+02	1.1320E+02	1.1332E+02	1.1345E+02
19	1.1291E+02	1.1300E+02	1.1310E+02	1.1321E+02	1.1333E+02	1.1346E+02
18	1.1294E+02	1.1303E+02	1.1313E+02	1.1323E+02	1.1335E+02	1.1347E+02
17	1.1296E+02	1.1305E+02	1.1314E+02	1.1325E+02	1.1336E+02	1.1348E+02
16	1.1299E+02	1.1307E+02	1.1316E+02	1.1326E+02	1.1337E+02	1.1348E+02
15	1.1301E+02	1.1309E+02	1.1318E+02	1.1327E+02	1.1338E+02	1.1349E+02
14	1.1303E+02	1.1310E+02	1.1319E+02	1.1328E+02	1.1338E+02	1.1349E+02
13	1.1303E+02	1.1310E+02	1.1318E+02	1.1328E+02	1.1337E+02	1.1348E+02
12	1.1302E+02	1.1309E+02	1.1317E+02	1.1326E+02	1.1336E+02	1.1346E+02
11	1.1299E+02	1.1306E+02	1.1315E+02	1.1324E+02	1.1334E+02	1.1344E+02
10	1.1295E+02	1.1302E+02	1.1311E+02	1.1321E+02	1.1331E+02	1.1342E+02
9	1.1289E+02	1.1297E+02	1.1307E+02	1.1317E+02	1.1328E+02	1.1339E+02
8	1.1282E+02	1.1291E+02	1.1302E+02	1.1313E+02	1.1324E+02	1.1335E+02
7	1.1273E+02	1.1284E+02	1.1296E+02	1.1308E+02	1.1320E+02	1.1332E+02
6	1.1263E+02	1.1276E+02	1.1289E+02	1.1302E+02	1.1315E+02	1.1328E+02
5	1.1252E+02	1.1267E+02	1.1282E+02	1.1297E+02	1.1311E+02	1.1324E+02
4	1.1240E+02	1.1258E+02	1.1275E+02	1.1291E+02	1.1307E+02	1.1321E+02
3	1.1229E+02	1.1250E+02	1.1269E+02	1.1287E+02	1.1303E+02	1.1318E+02
2	1.1221E+02	1.1244E+02	1.1264E+02	1.1283E+02	1.1300E+02	1.1315E+02
1	1.1220E+02	1.1240E+02	1.1260E+02	1.1280E+02	1.1300E+02	1.1310E+02
	19	20	21	22	23	24

	25	26	27	28	29	30
29	1.1350E+02	1.1360E+02	1.1380E+02	1.1400E+02	1.1420E+02	1.1440E+02
28	1.1342E+02	1.1362E+02	1.1381E+02	1.1401E+02	1.1420E+02	1.1440E+02
27	1.1343E+02	1.1363E+02	1.1382E+02	1.1401E+02	1.1420E+02	1.1439E+02
26	1.1346E+02	1.1365E+02	1.1383E+02	1.1401E+02	1.1419E+02	1.1437E+02
25	1.1349E+02	1.1366E+02	1.1384E+02	1.1401E+02	1.1419E+02	1.1436E+02
24	1.1352E+02	1.1368E+02	1.1385E+02	1.1401E+02	1.1418E+02	1.1434E+02
23	1.1354E+02	1.1370E+02	1.1385E+02	1.1401E+02	1.1417E+02	1.1432E+02
22	1.1357E+02	1.1371E+02	1.1386E+02	1.1401E+02	1.1415E+02	1.1430E+02
21	1.1358E+02	1.1372E+02	1.1386E+02	1.1400E+02	1.1415E+02	1.1429E+02
20	1.1358E+02	1.1372E+02	1.1386E+02	1.1400E+02	1.1414E+02	1.1428E+02
19	1.1359E+02	1.1372E+02	1.1386E+02	1.1400E+02	1.1413E+02	1.1427E+02
18	1.1360E+02	1.1372E+02	1.1386E+02	1.1399E+02	1.1412E+02	1.1426E+02
17	1.1360E+02	1.1373E+02	1.1385E+02	1.1399E+02	1.1412E+02	1.1425E+02
16	1.1360E+02	1.1372E+02	1.1385E+02	1.1398E+02	1.1411E+02	1.1424E+02
15	1.1360E+02	1.1372E+02	1.1384E+02	1.1397E+02	1.1409E+02	1.1422E+02
14	1.1360E+02	1.1371E+02	1.1383E+02	1.1395E+02	1.1407E+02	1.1419E+02
13	1.1359E+02	1.1370E+02	1.1381E+02	1.1393E+02	1.1405E+02	1.1417E+02
12	1.1357E+02	1.1368E+02	1.1379E+02	1.1391E+02	1.1402E+02	1.1414E+02
11	1.1355E+02	1.1366E+02	1.1377E+02	1.1389E+02	1.1400E+02	1.1411E+02
10	1.1353E+02	1.1364E+02	1.1375E+02	1.1386E+02	1.1397E+02	1.1408E+02
9	1.1350E+02	1.1361E+02	1.1372E+02	1.1384E+02	1.1395E+02	1.1406E+02
8	1.1347E+02	1.1358E+02	1.1370E+02	1.1381E+02	1.1392E+02	1.1403E+02
7	1.1344E+02	1.1356E+02	1.1367E+02	1.1378E+02	1.1389E+02	1.1400E+02
6	1.1341E+02	1.1353E+02	1.1365E+02	1.1376E+02	1.1387E+02	1.1398E+02
5	1.1338E+02	1.1350E+02	1.1362E+02	1.1374E+02	1.1385E+02	1.1396E+02
4	1.1335E+02	1.1348E+02	1.1361E+02	1.1372E+02	1.1383E+02	1.1393E+02
3	1.1333E+02	1.1347E+02	1.1359E+02	1.1371E+02	1.1382E+02	1.1392E+02
2	1.1331E+02	1.1347E+02	1.1359E+02	1.1370E+02	1.1381E+02	1.1391E+02

1	1.1330E+02	1.1350E+02	1.1360E+02	1.1370E+02	1.1380E+02	1.1390E+02
	25	26	27	28	29	30

	31	32
29	1.1460E+02	1.1480E+02
28	1.1460E+02	1.1480E+02
27	1.1458E+02	1.1480E+02
26	1.1455E+02	1.1470E+02
25	1.1453E+02	1.1470E+02
24	1.1451E+02	1.1470E+02
23	1.1447E+02	1.1460E+02
22	1.1445E+02	1.1460E+02
21	1.1443E+02	1.1457E+02
20	1.1442E+02	1.1460E+02
19	1.1440E+02	1.1452E+02
18	1.1439E+02	1.1450E+02
17	1.1437E+02	1.1447E+02
16	1.1437E+02	1.1450E+02
15	1.1435E+02	1.1450E+02
14	1.1431E+02	1.1440E+02
13	1.1428E+02	1.1440E+02
12	1.1426E+02	1.1440E+02
11	1.1422E+02	1.1430E+02
10	1.1419E+02	1.1430E+02
9	1.1417E+02	1.1430E+02
8	1.1412E+02	1.1420E+02
7	1.1410E+02	1.1420E+02
6	1.1409E+02	1.1420E+02
	1.1407E+02	1.1420E+02
	1.1403E+02	1.1410E+02
3	1.1401E+02	1.1410E+02
2	1.1401E+02	1.1410E+02
1	1.1400E+02	1.1410E+02
	31	32

************ End of logbook ************

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**************************************************************
*                      E C H O P R I N T                     *
*                                                            *
*                       F L O W P A T H                      *
*                         version 3.0                        *
*                                                            *
*  FLOWPATH was written by Thomas Franz and Nilson Guiguer   *
*                                                            *
**************************************************************
*                                                            *
*                  Copyright 1989, 1990                      *
*                            by                              *
*              Waterloo Hydrogeologic Software               *
*                  113-106 Seagram Drive                     *
*                    Waterloo, Ontario                       *
*                    N2L 3B8, Canada                         *
*                                                            *
*                    ph (519) 746-1798                       *
*                                                            *
**************************************************************
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FLOWPATH logbook for data set : SITE10EX

Unit System : English units [ft/gal/d]

***** GRID PARAMETERS *****

Number of x-grid lines : 32

Number of y-grid lines : 29

Grid coordinates (x-grid lines) [ft] :

1	0.00000E+00
2	4.00000E+01
3	8.00000E+01
4	1.20000E+02
5	1.60000E+02
6	2.00000E+02
7	2.40000E+02
8	2.80000E+02
9	3.20000E+02
10	3.60000E+02
11	4.00000E+02
12	4.40000E+02
13	4.80000E+02
14	5.20000E+02
15	5.60000E+02
16	6.00000E+02
17	6.40000E+02

18	6.80000E+02
19	7.20000E+02
20	7.60000E+02
21	8.00000E+02
22	8.40000E+02
23	8.80000E+02
24	9.20000E+02
25	9.60000E+02
26	1.00000E+03
27	1.04000E+03
28	1.08000E+03
29	1.12000E+03
30	1.16000E+03
31	1.20000E+03
32	1.24000E+03

Grid coordinates (y-grid lines) [ft] :

1	0.00000E+00
2	4.00000E+01
3	8.00000E+01
4	1.20000E+02
5	1.60000E+02
6	2.00000E+02
7	2.40000E+02
8	2.80000E+02
9	3.20000E+02
10	3.60000E+02
11	4.00000E+02
12	4.40000E+02
13	4.80000E+02
14	5.20000E+02
15	5.60000E+02
16	6.00000E+02
17	6.21118E+02
18	6.40000E+02
19	6.61491E+02
20	6.80000E+02
21	6.98758E+02
22	7.20000E+02
23	7.60000E+02
24	8.00000E+02
25	8.40000E+02
26	8.80000E+02
27	9.20000E+02
28	9.60000E+02
29	1.00000E+03

***** WELL PARAMETERS *****

Number of wells : 6

No.	i	j	X [ft]	Y [ft]	well discharge [gpd]
1	24	21	9.19410E+02	6.98758E+02	-1.08000E+03

2	25	14	9.60326E+02	5.18634E+02	-1.08000E+03
3	8	8	2.79193E+02	2.79503E+02	-1.08000E+03
4	17	11	6.40076E+02	3.99162E+02	-1.08000E+03
5	18	11	6.80229E+02	3.99162E+02	0.00000E+00
6	19	17	7.19643E+02	6.21118E+02	0.00000E+00

***** CONSTRAINED HEAD NODES *****

Number of constant head nodes : 112

No.	i	j	X [ft]	Y [ft]	const. head [ft]
1	1	29	0.00000E+00	1.00000E+03	1.13600E+02
2	1	28	0.00000E+00	9.59627E+02	1.13600E+02
3	1	27	0.00000E+00	9.19255E+02	1.13600E+02
4	1	26	0.00000E+00	8.78882E+02	1.13600E+02
5	1	25	0.00000E+00	8.38509E+02	1.13600E+02
6	1	24	0.00000E+00	8.01242E+02	1.13600E+02
7	1	23	0.00000E+00	7.60870E+02	1.13600E+02
8	1	22	0.00000E+00	7.20497E+02	1.13600E+02
9	2	29	4.09161E+01	1.00000E+03	1.13500E+02
10	1	20	0.00000E+00	6.80124E+02	1.13600E+02
11	3	29	7.94255E+01	1.00000E+03	1.13500E+02
12	1	18	0.00000E+00	6.39752E+02	1.13600E+02
13	4	29	1.20342E+02	1.00000E+03	1.13400E+02
14	1	16	0.00000E+00	5.99379E+02	1.13600E+02
15	1	15	0.00000E+00	5.59006E+02	1.13600E+02
16	1	14	0.00000E+00	5.18634E+02	1.13600E+02
17	1	13	0.00000E+00	4.81366E+02	1.13600E+02
18	1	12	0.00000E+00	4.40994E+02	1.13600E+02
19	1	11	0.00000E+00	4.00621E+02	1.13600E+02
20	1	10	0.00000E+00	3.60248E+02	1.13600E+02
21	1	9	0.00000E+00	3.19876E+02	1.13600E+02
22	1	8	0.00000E+00	2.79503E+02	1.13600E+02
23	1	7	0.00000E+00	2.39130E+02	1.13600E+02
24	1	6	0.00000E+00	1.98758E+02	1.13600E+02
25	1	5	0.00000E+00	1.61491E+02	1.13600E+02
26	1	4	0.00000E+00	1.21118E+02	1.13600E+02
27	1	3	0.00000E+00	8.07453E+01	1.13600E+02
28	1	2	0.00000E+00	4.03727E+01	1.13600E+02
29	1	1	0.00000E+00	0.00000E+00	1.13600E+02
30	2	1	4.09161E+01	0.00000E+00	1.13500E+02
31	3	1	7.94255E+01	0.00000E+00	1.13500E+02
32	4	1	1.20342E+02	0.00000E+00	1.13400E+02
33	5	1	1.58851E+02	0.00000E+00	1.13400E+02
34	6	1	1.99767E+02	0.00000E+00	1.13300E+02
35	7	1	2.40683E+02	0.00000E+00	1.13200E+02
36	8	1	2.79193E+02	0.00000E+00	1.13100E+02
37	9	1	3.20109E+02	0.00000E+00	1.13000E+02
38	10	1	3.61025E+02	0.00000E+00	1.12700E+02
39	11	1	3.99534E+02	0.00000E+00	1.12300E+02
40	12	1	4.40450E+02	0.00000E+00	1.12000E+02
41	13	1	4.78960E+02	0.00000E+00	1.11000E+02
42	14	1	5.19876E+02	0.00000E+00	1.10000E+02
43	15	1	5.60792E+02	0.00000E+00	1.09000E+02
44	16	1	5.99301E+02	0.00000E+00	1.10000E+02

45	17	1	6.40217E+02	0.00000E+00	1.11000E+02
46	18	1	6.81134E+02	0.00000E+00	1.12000E+02
47	19	1	7.19643E+02	0.00000E+00	1.12200E+02
48	20	1	7.60559E+02	0.00000E+00	1.12400E+02
49	21	1	7.99068E+02	0.00000E+00	1.12600E+02
50	22	1	8.39984E+02	0.00000E+00	1.12800E+02
51	23	1	8.80901E+02	0.00000E+00	1.13000E+02
52	24	1	9.19410E+02	0.00000E+00	1.13100E+02
53	25	1	9.60326E+02	0.00000E+00	1.13300E+02
54	26	1	9.98835E+02	0.00000E+00	1.13500E+02
55	27	1	1.03975E+03	0.00000E+00	1.13600E+02
56	28	1	1.08067E+03	0.00000E+00	1.13700E+02
57	29	1	1.11918E+03	0.00000E+00	1.13800E+02
58	30	1	1.16009E+03	0.00000E+00	1.13900E+02
59	31	1	1.20101E+03	0.00000E+00	1.14000E+02
60	32	1	1.23952E+03	0.00000E+00	1.14100E+02
61	32	2	1.23952E+03	4.03727E+01	1.14100E+02
62	32	3	1.23952E+03	8.07453E+01	1.14100E+02
63	32	4	1.23952E+03	1.21118E+02	1.14100E+02
64	32	5	1.23952E+03	1.61491E+02	1.14200E+02
65	32	6	1.23952E+03	1.98758E+02	1.14200E+02
66	32	7	1.23952E+03	2.39130E+02	1.14200E+02
67	32	8	1.23952E+03	2.79503E+02	1.14200E+02
68	32	9	1.23952E+03	3.19876E+02	1.14300E+02
69	32	10	1.23952E+03	3.60248E+02	1.14300E+02
70	32	11	1.23952E+03	4.00621E+02	1.14300E+02
71	32	12	1.23952E+03	4.40994E+02	1.14400E+02
72	32	13	1.23952E+03	4.81366E+02	1.14400E+02
73	32	14	1.23952E+03	5.18634E+02	1.14400E+02
74	32	15	1.23952E+03	5.59006E+02	1.14500E+02
75	32	16	1.23952E+03	5.99379E+02	1.14500E+02
76	32	18	1.23952E+03	6.39752E+02	1.14500E+02
77	32	20	1.23952E+03	6.80124E+02	1.14600E+02
78	32	22	1.23952E+03	7.20497E+02	1.14600E+02
79	32	23	1.23952E+03	7.60870E+02	1.14600E+02
80	32	24	1.23952E+03	8.01242E+02	1.14700E+02
81	32	25	1.23952E+03	8.38509E+02	1.14700E+02
82	32	26	1.23952E+03	8.78882E+02	1.14700E+02
83	32	27	1.23952E+03	9.19255E+02	1.14800E+02
84	32	28	1.23952E+03	9.59627E+02	1.14800E+02
85	32	29	1.23952E+03	1.00000E+03	1.14800E+02
86	31	29	1.20101E+03	1.00000E+03	1.14600E+02
87	30	29	1.16009E+03	1.00000E+03	1.14400E+02
88	29	29	1.11918E+03	1.00000E+03	1.14200E+02
89	28	29	1.08067E+03	1.00000E+03	1.14000E+02
90	27	29	1.03975E+03	1.00000E+03	1.13800E+02
91	26	29	9.98835E+02	1.00000E+03	1.13600E+02
92	25	29	9.60326E+02	1.00000E+03	1.13500E+02
93	24	29	9.19410E+02	1.00000E+03	1.13000E+02
94	23	29	8.80901E+02	1.00000E+03	1.12800E+02
95	22	29	8.39984E+02	1.00000E+03	1.12600E+02
96	21	29	7.99068E+02	1.00000E+03	1.12400E+02
97	20	29	7.60559E+02	1.00000E+03	1.12200E+02
98	19	29	7.19643E+02	1.00000E+03	1.12000E+02
99	18	29	6.81134E+02	1.00000E+03	1.11500E+02
100	17	29	6.40217E+02	1.00000E+03	1.11000E+02
101	16	29	5.99301E+02	1.00000E+03	1.10000E+02
102	15	29	5.60792E+02	1.00000E+03	1.09000E+02
103	14	29	5.19876E+02	1.00000E+03	1.10000E+02
104	13	29	4.78960E+02	1.00000E+03	1.11000E+02

105	12	29	4.40450E+02	1.00000E+03	1.11500E+02
106	11	29	3.99534E+02	1.00000E+03	1.12000E+02
107	10	29	3.61025E+02	1.00000E+03	1.12200E+02
108	9	29	3.20109E+02	1.00000E+03	1.12400E+02
109	8	29	2.79193E+02	1.00000E+03	1.12600E+02
110	7	29	2.40683E+02	1.00000E+03	1.12800E+02
111	6	29	1.99767E+02	1.00000E+03	1.13000E+02
112	5	29	1.58851E+02	1.00000E+03	1.13300E+02

***** SPECIFIED FLUX NODES *****

Number of flux nodes : 0

***** SURFACE WATER BODIES *****

Number of surface water body nodes : 0

***** AQUIFER PROPERTIES *****

Number of different material properties : 1

No.	Kxx [ft/d]	Kyy [ft/d]	Porosity [-]	
1	6.00000E+00	6.00000E+00	1.50000E-01	(default)

********** DISTRIBUTION OF AQUIFER MATERIAL PROPERTIES **********

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

***** AQUIFER TYPE *****

nconfined aquifer

***** AQUIFER BOTTOM ELEVATIONS *****

Number of different aquifer bottom elevations : 1

No.	aquifer bottom elevation [ft]
1	1.01560E+02 (default)

********** DISTRIBUTION OF AQUIFER BOTTOM ELEVATIONS **********

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

***** AREAL RECHARGE *****

Number of different infiltration/evapotranspiration rates : 1

No.	infiltration [L/T]	evapotranspiration [L/T]	effective recharge [L/T]	
1	0.00000E+00	0.00000E+00	0.00000E+00	(default)

********** DISTRIBUTION OF AREAL IN/OUT-FLUXES **********

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
[illegible]	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
29	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
28	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
27	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
26	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
25	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
24	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
23	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
22	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
21	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
20	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
19	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
18	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
17	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
15	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
14	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
13	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
12	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
10	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
9	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
8	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
7	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
6	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32

***** PATHLINE & PARTICLE TRACKING DATA *****

Number of forward particles : 28

No.	x-release	y-release
1	2.40683E+00	5.52795E+02
2	2.36190E+00	5.00724E+02
3	1.23711E+03	9.19255E+02

4	2.40683E+00	6.61491E+02
5	1.23711E+03	9.40994E+02
6	2.40683E+00	6.05590E+02
7	1.23711E+03	6.61491E+02
8	1.23711E+03	3.60248E+02
9	1.23711E+03	1.61491E+02
10	2.40683E+00	4.00621E+02
11	2.40683E+00	1.61491E+02
12	2.40683E+00	2.39130E+02
13	1.58851E+02	3.10559E+00
14	1.23711E+03	1.39752E+02
15	1.23711E+03	6.39752E+02
16	2.40683E+00	6.80124E+02
17	2.40683E+00	3.19876E+02
18	2.40683E+00	4.81366E+02
19	1.20457E+02	2.36190E+00
20	1.23711E+03	9.59627E+02
21	1.23711E+03	3.38509E+02
22	1.23711E+03	7.48447E+02
23	1.23711E+03	8.32298E+02
24	1.23711E+03	2.20497E+02
25	1.23711E+03	2.79503E+02
26	2.40683E+00	8.07453E+01
27	1.23711E+03	4.53416E+02
28	1.23711E+03	5.46584E+02

Number of reverse particles : 0

Particles released at wells :

Well-No.	Particles released
1	0
2	0
3	0
4	0
5	0
6	0

************ HYDRAULIC HEAD DISTRIBUTION ************

	1	2	3	4	5	6
29	1.1360E+02	1.1350E+02	1.1350E+02	1.1340E+02	1.1330E+02	1.1300E+02
28	1.1360E+02	1.1351E+02	1.1343E+02	1.1332E+02	1.1319E+02	1.1299E+02
27	1.1360E+02	1.1350E+02	1.1339E+02	1.1327E+02	1.1313E+02	1.1296E+02
26	1.1360E+02	1.1349E+02	1.1337E+02	1.1324E+02	1.1310E+02	1.1295E+02
25	1.1360E+02	1.1348E+02	1.1336E+02	1.1323E+02	1.1309E+02	1.1294E+02
24	1.1360E+02	1.1347E+02	1.1335E+02	1.1321E+02	1.1308E+02	1.1293E+02
23	1.1360E+02	1.1347E+02	1.1334E+02	1.1321E+02	1.1307E+02	1.1293E+02
[illegible]	1.1360E+02	1.1346E+02	1.1333E+02	1.1320E+02	1.1306E+02	1.1293E+02
21	1.1357E+02	1.1346E+02	1.1333E+02	1.1320E+02	1.1306E+02	1.1292E+02
20	1.1360E+02	1.1346E+02	1.1333E+02	1.1319E+02	1.1306E+02	1.1292E+02
19	1.1357E+02	1.1346E+02	1.1332E+02	1.1319E+02	1.1305E+02	1.1292E+02

	1	2	3	4	5	6
18	1.1360E+02	1.1346E+02	1.1332E+02	1.1318E+02	1.1305E+02	1.1291E+02
17	1.1357E+02	1.1345E+02	1.1332E+02	1.1318E+02	1.1304E+02	1.1291E+02
16	1.1360E+02	1.1345E+02	1.1331E+02	1.1317E+02	1.1303E+02	1.1290E+02
15	1.1360E+02	1.1345E+02	1.1331E+02	1.1316E+02	1.1302E+02	1.1287E+02
14	1.1360E+02	1.1345E+02	1.1330E+02	1.1314E+02	1.1299E+02	1.1285E+02
13	1.1360E+02	1.1344E+02	1.1328E+02	1.1312E+02	1.1296E+02	1.1281E+02
12	1.1360E+02	1.1344E+02	1.1327E+02	1.1310E+02	1.1293E+02	1.1276E+02
11	1.1360E+02	1.1343E+02	1.1325E+02	1.1307E+02	1.1289E+02	1.1270E+02
10	1.1360E+02	1.1342E+02	1.1324E+02	1.1305E+02	1.1285E+02	1.1263E+02
9	1.1360E+02	1.1342E+02	1.1323E+02	1.1304E+02	1.1282E+02	1.1256E+02
8	1.1360E+02	1.1342E+02	1.1324E+02	1.1304E+02	1.1281E+02	1.1253E+02
7	1.1360E+02	1.1343E+02	1.1325E+02	1.1306E+02	1.1284E+02	1.1260E+02
6	1.1360E+02	1.1344E+02	1.1328E+02	1.1310E+02	1.1291E+02	1.1270E+02
5	1.1360E+02	1.1346E+02	1.1331E+02	1.1315E+02	1.1299E+02	1.1281E+02
4	1.1360E+02	1.1347E+02	1.1335E+02	1.1321E+02	1.1307E+02	1.1292E+02
3	1.1360E+02	1.1349E+02	1.1339E+02	1.1328E+02	1.1317E+02	1.1304E+02
2	1.1360E+02	1.1351E+02	1.1344E+02	1.1335E+02	1.1327E+02	1.1316E+02
1	1.1360E+02	1.1350E+02	1.1350E+02	1.1340E+02	1.1340E+02	1.1330E+02

	7	8	9	10	11	12
29	1.1280E+02	1.1260E+02	1.1240E+02	1.1220E+02	1.1200E+02	1.1150E+02
28	1.1279E+02	1.1260E+02	1.1240E+02	1.1219E+02	1.1194E+02	1.1159E+02
27	1.1279E+02	1.1260E+02	1.1241E+02	1.1221E+02	1.1198E+02	1.1171E+02
26	1.1278E+02	1.1261E+02	1.1243E+02	1.1224E+02	1.1204E+02	1.1184E+02
25	1.1278E+02	1.1262E+02	1.1246E+02	1.1229E+02	1.1212E+02	1.1195E+02
24	1.1279E+02	1.1263E+02	1.1248E+02	1.1233E+02	1.1218E+02	1.1204E+02
23	1.1279E+02	1.1265E+02	1.1250E+02	1.1236E+02	1.1223E+02	1.1211E+02
22	1.1279E+02	1.1265E+02	1.1252E+02	1.1239E+02	1.1227E+02	1.1216E+02
21	1.1279E+02	1.1265E+02	1.1252E+02	1.1240E+02	1.1228E+02	1.1218E+02
20	1.1279E+02	1.1265E+02	1.1253E+02	1.1240E+02	1.1229E+02	1.1219E+02
19	1.1278E+02	1.1265E+02	1.1253E+02	1.1241E+02	1.1229E+02	1.1219E+02
18	1.1278E+02	1.1265E+02	1.1252E+02	1.1240E+02	1.1229E+02	1.1220E+02
17	1.1277E+02	1.1264E+02	1.1252E+02	1.1240E+02	1.1229E+02	1.1219E+02
16	1.1276E+02	1.1263E+02	1.1251E+02	1.1239E+02	1.1228E+02	1.1219E+02
15	1.1274E+02	1.1261E+02	1.1248E+02	1.1237E+02	1.1226E+02	1.1216E+02
14	1.1270E+02	1.1257E+02	1.1245E+02	1.1233E+02	1.1223E+02	1.1213E+02
13	1.1266E+02	1.1252E+02	1.1240E+02	1.1228E+02	1.1218E+02	1.1208E+02
12	1.1260E+02	1.1245E+02	1.1233E+02	1.1222E+02	1.1213E+02	1.1203E+02
11	1.1252E+02	1.1236E+02	1.1224E+02	1.1215E+02	1.1207E+02	1.1198E+02
10	1.1241E+02	1.1222E+02	1.1213E+02	1.1207E+02	1.1201E+02	1.1194E+02
9	1.1227E+02	1.1197E+02	1.1198E+02	1.1198E+02	1.1196E+02	1.1190E+02
8	1.1213E+02	1.1139E+02	1.1183E+02	1.1193E+02	1.1193E+02	1.1188E+02
7	1.1230E+02	1.1200E+02	1.1199E+02	1.1198E+02	1.1194E+02	1.1187E+02
6	1.1248E+02	1.1227E+02	1.1216E+02	1.1207E+02	1.1197E+02	1.1187E+02
5	1.1263E+02	1.1245E+02	1.1230E+02	1.1216E+02	1.1201E+02	1.1186E+02
4	1.1276E+02	1.1260E+02	1.1243E+02	1.1225E+02	1.1205E+02	1.1184E+02
3	1.1290E+02	1.1275E+02	1.1257E+02	1.1236E+02	1.1210E+02	1.1181E+02
2	1.1304E+02	1.1291E+02	1.1275E+02	1.1250E+02	1.1218E+02	1.1182E+02
1	1.1320E+02	1.1310E+02	1.1300E+02	1.1270E+02	1.1230E+02	1.1200E+02

	13	14	15	16	17	18
29	1.1100E+02	1.1000E+02	1.0900E+02	1.1000E+02	1.1100E+02	1.1150E+02
28	1.1118E+02	1.1070E+02	1.1039E+02	1.1069E+02	1.1117E+02	1.1156E+02
27	1.1143E+02	1.1116E+02	1.1103E+02	1.1114E+02	1.1139E+02	1.1165E+02

26	1.1163E+02	1.1147E+02	1.1140E+02	1.1144E+02	1.1158E+02	1.1175E+02
25	1.1180E+02	1.1168E+02	1.1163E+02	1.1164E+02	1.1172E+02	1.1184E+02
24	1.1192E+02	1.1183E+02	1.1178E+02	1.1178E+02	1.1182E+02	1.1190E+02
23	1.1201E+02	1.1193E+02	1.1188E+02	1.1187E+02	1.1189E+02	1.1194E+02
	1.1207E+02	1.1199E+02	1.1195E+02	1.1193E+02	1.1194E+02	1.1196E+02
	1.1209E+02	1.1202E+02	1.1197E+02	1.1195E+02	1.1195E+02	1.1197E+02
20	1.1210E+02	1.1203E+02	1.1198E+02	1.1196E+02	1.1196E+02	1.1197E+02
19	1.1211E+02	1.1204E+02	1.1199E+02	1.1196E+02	1.1196E+02	1.1197E+02
18	1.1211E+02	1.1204E+02	1.1199E+02	1.1196E+02	1.1195E+02	1.1196E+02
17	1.1211E+02	1.1204E+02	1.1199E+02	1.1195E+02	1.1194E+02	1.1195E+02
16	1.1210E+02	1.1203E+02	1.1197E+02	1.1194E+02	1.1193E+02	1.1194E+02
15	1.1208E+02	1.1200E+02	1.1193E+02	1.1189E+02	1.1188E+02	1.1189E+02
14	1.1203E+02	1.1195E+02	1.1187E+02	1.1181E+02	1.1179E+02	1.1182E+02
13	1.1198E+02	1.1189E+02	1.1179E+02	1.1170E+02	1.1165E+02	1.1172E+02
12	1.1193E+02	1.1182E+02	1.1169E+02	1.1153E+02	1.1138E+02	1.1157E+02
11	1.1188E+02	1.1177E+02	1.1161E+02	1.1135E+02	1.1074E+02	1.1141E+02
10	1.1185E+02	1.1175E+02	1.1164E+02	1.1149E+02	1.1136E+02	1.1157E+02
9	1.1183E+02	1.1176E+02	1.1168E+02	1.1162E+02	1.1161E+02	1.1172E+02
8	1.1182E+02	1.1176E+02	1.1171E+02	1.1169E+02	1.1172E+02	1.1182E+02
7	1.1180E+02	1.1174E+02	1.1171E+02	1.1171E+02	1.1177E+02	1.1187E+02
6	1.1177E+02	1.1170E+02	1.1166E+02	1.1169E+02	1.1176E+02	1.1188E+02
5	1.1171E+02	1.1160E+02	1.1156E+02	1.1160E+02	1.1171E+02	1.1187E+02
4	1.1162E+02	1.1144E+02	1.1137E+02	1.1144E+02	1.1161E+02	1.1183E+02
3	1.1147E+02	1.1118E+02	1.1104E+02	1.1117E+02	1.1146E+02	1.1178E+02
2	1.1126E+02	1.1073E+02	1.1041E+02	1.1072E+02	1.1125E+02	1.1179E+02
1	1.1100E+02	1.1000E+02	1.0900E+02	1.1000E+02	1.1100E+02	1.1200E+02
	13	14	15	16	17	18

	19	20	21	22	23	24
	1.1200E+02	1.1220E+02	1.1240E+02	1.1260E+02	1.1280E+02	1.1300E+02
28	1.1191E+02	1.1215E+02	1.1236E+02	1.1257E+02	1.1278E+02	1.1301E+02
27	1.1191E+02	1.1213E+02	1.1233E+02	1.1253E+02	1.1273E+02	1.1295E+02
26	1.1194E+02	1.1212E+02	1.1229E+02	1.1247E+02	1.1266E+02	1.1287E+02
25	1.1197E+02	1.1211E+02	1.1225E+02	1.1240E+02	1.1256E+02	1.1275E+02
24	1.1199E+02	1.1209E+02	1.1220E+02	1.1231E+02	1.1244E+02	1.1260E+02
23	1.1200E+02	1.1207E+02	1.1214E+02	1.1220E+02	1.1227E+02	1.1237E+02
22	1.1200E+02	1.1205E+02	1.1208E+02	1.1210E+02	1.1206E+02	1.1195E+02
21	1.1200E+02	1.1204E+02	1.1206E+02	1.1206E+02	1.1197E+02	1.1146E+02
20	1.1200E+02	1.1203E+02	1.1205E+02	1.1205E+02	1.1198E+02	1.1181E+02
19	1.1199E+02	1.1202E+02	1.1204E+02	1.1204E+02	1.1202E+02	1.1200E+02
18	1.1198E+02	1.1201E+02	1.1204E+02	1.1205E+02	1.1206E+02	1.1211E+02
17	1.1198E+02	1.1200E+02	1.1203E+02	1.1206E+02	1.1208E+02	1.1216E+02
16	1.1196E+02	1.1199E+02	1.1203E+02	1.1206E+02	1.1210E+02	1.1217E+02
15	1.1193E+02	1.1198E+02	1.1202E+02	1.1206E+02	1.1209E+02	1.1211E+02
14	1.1188E+02	1.1195E+02	1.1202E+02	1.1207E+02	1.1209E+02	1.1202E+02
13	1.1183E+02	1.1193E+02	1.1203E+02	1.1211E+02	1.1217E+02	1.1221E+02
12	1.1176E+02	1.1192E+02	1.1206E+02	1.1217E+02	1.1228E+02	1.1239E+02
11	1.1173E+02	1.1193E+02	1.1210E+02	1.1224E+02	1.1238E+02	1.1252E+02
10	1.1179E+02	1.1198E+02	1.1215E+02	1.1231E+02	1.1246E+02	1.1262E+02
9	1.1188E+02	1.1205E+02	1.1221E+02	1.1237E+02	1.1253E+02	1.1270E+02
8	1.1195E+02	1.1211E+02	1.1227E+02	1.1243E+02	1.1260E+02	1.1277E+02
7	1.1200E+02	1.1216E+02	1.1232E+02	1.1249E+02	1.1266E+02	1.1283E+02
6	1.1203E+02	1.1220E+02	1.1237E+02	1.1254E+02	1.1271E+02	1.1288E+02
5	1.1204E+02	1.1222E+02	1.1241E+02	1.1258E+02	1.1276E+02	1.1293E+02
	1.1204E+02	1.1225E+02	1.1244E+02	1.1263E+02	1.1280E+02	1.1297E+02
	1.1205E+02	1.1228E+02	1.1249E+02	1.1268E+02	1.1286E+02	1.1302E+02
2	1.1209E+02	1.1233E+02	1.1254E+02	1.1273E+02	1.1292E+02	1.1307E+02
1	1.1220E+02	1.1240E+02	1.1260E+02	1.1280E+02	1.1300E+02	1.1310E+02

	19	20	21	22	23	24
	25	26	27	28	29	30
29	1.1350E+02	1.1360E+02	1.1380E+02	1.1400E+02	1.1420E+02	1.1440E+02
28	1.1331E+02	1.1352E+02	1.1373E+02	1.1394E+02	1.1415E+02	1.1436E+02
27	1.1320E+02	1.1342E+02	1.1365E+02	1.1387E+02	1.1410E+02	1.1432E+02
26	1.1309E+02	1.1333E+02	1.1356E+02	1.1380E+02	1.1404E+02	1.1427E+02
25	1.1298E+02	1.1322E+02	1.1347E+02	1.1372E+02	1.1397E+02	1.1422E+02
24	1.1284E+02	1.1310E+02	1.1338E+02	1.1365E+02	1.1391E+02	1.1417E+02
23	1.1266E+02	1.1297E+02	1.1328E+02	1.1357E+02	1.1384E+02	1.1411E+02
22	1.1243E+02	1.1283E+02	1.1318E+02	1.1349E+02	1.1378E+02	1.1406E+02
21	1.1233E+02	1.1278E+02	1.1314E+02	1.1346E+02	1.1375E+02	1.1403E+02
20	1.1234E+02	1.1275E+02	1.1311E+02	1.1343E+02	1.1373E+02	1.1401E+02
19	1.1236E+02	1.1273E+02	1.1308E+02	1.1340E+02	1.1371E+02	1.1399E+02
18	1.1238E+02	1.1271E+02	1.1305E+02	1.1337E+02	1.1368E+02	1.1397E+02
17	1.1237E+02	1.1269E+02	1.1303E+02	1.1335E+02	1.1366E+02	1.1395E+02
16	1.1234E+02	1.1266E+02	1.1300E+02	1.1333E+02	1.1364E+02	1.1394E+02
15	1.1217E+02	1.1256E+02	1.1295E+02	1.1330E+02	1.1361E+02	1.1391E+02
14	1.1164E+02	1.1245E+02	1.1292E+02	1.1328E+02	1.1360E+02	1.1389E+02
13	1.1226E+02	1.1262E+02	1.1298E+02	1.1331E+02	1.1360E+02	1.1388E+02
12	1.1253E+02	1.1278E+02	1.1307E+02	1.1335E+02	1.1362E+02	1.1388E+02
11	1.1269E+02	1.1291E+02	1.1315E+02	1.1339E+02	1.1364E+02	1.1387E+02
10	1.1280E+02	1.1300E+02	1.1321E+02	1.1343E+02	1.1365E+02	1.1387E+02
9	1.1288E+02	1.1307E+02	1.1327E+02	1.1347E+02	1.1367E+02	1.1387E+02
8	1.1294E+02	1.1313E+02	1.1331E+02	1.1350E+02	1.1369E+02	1.1387E+02
7	1.1300E+02	1.1317E+02	1.1335E+02	1.1353E+02	1.1370E+02	1.1387E+02
6	1.1305E+02	1.1322E+02	1.1338E+02	1.1355E+02	1.1371E+02	1.1388E+02
5	1.1309E+02	1.1326E+02	1.1342E+02	1.1357E+02	1.1373E+02	1.1388E+02
4	1.1314E+02	1.1330E+02	1.1345E+02	1.1360E+02	1.1374E+02	1.1387E+02
3	1.1319E+02	1.1335E+02	1.1349E+02	1.1363E+02	1.1376E+02	1.1388E+02
2	1.1324E+02	1.1341E+02	1.1354E+02	1.1366E+02	1.1378E+02	1.1389E+02
1	1.1330E+02	1.1350E+02	1.1360E+02	1.1370E+02	1.1380E+02	1.1390E+02

	25	26	27	28	29	30
	31	32				
29	1.1460E+02	1.1480E+02				
28	1.1458E+02	1.1480E+02				
27	1.1455E+02	1.1480E+02				
26	1.1450E+02	1.1470E+02				
25	1.1446E+02	1.1470E+02				
24	1.1443E+02	1.1470E+02				
23	1.1437E+02	1.1460E+02				
22	1.1433E+02	1.1460E+02				
21	1.1430E+02	1.1454E+02				
20	1.1429E+02	1.1460E+02				
19	1.1426E+02	1.1450E+02				
18	1.1424E+02	1.1450E+02				
17	1.1422E+02	1.1445E+02				
16	1.1422E+02	1.1450E+02				
15	1.1420E+02	1.1450E+02				
14	1.1416E+02	1.1440E+02				
13	1.1414E+02	1.1440E+02				
12	1.1413E+02	1.1440E+02				
11	1.1410E+02	1.1430E+02				
10	1.1409E+02	1.1430E+02				
9	1.1408E+02	1.1430E+02				

8	1.1405E+02	1.1420E+02
7	1.1404E+02	1.1420E+02
6	1.1404E+02	1.1420E+02
5	1.1403E+02	1.1420E+02
	1.1400E+02	1.1410E+02
	1.1399E+02	1.1410E+02
2	1.1400E+02	1.1410E+02
1	1.1400E+02	1.1410E+02
	31	32

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Detailed Analysis of Alternatives Naval Construction Battalion Center

Volume III Site 11 - Fire Fighting Training Area

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1.0 INTRODUCTION

This volume addresses the Detailed Analysis of Alternatives for Site 11 - Fire Fighting Training Area. The location of Site 11 relative to the Davisville facility is presented in Figure 1-1. The following sections provide background information and a description of the site, followed by a summary of remedial response objectives and cleanup criteria, general response actions, identification and screening of technologies and process options, a refinement of remedial alternatives previously developed in the ISA, and a detailed analysis of the remedial alternatives. It builds upon the evaluation conducted in the ISA (TRC, 1993a) and incorporates the results of the Phase II RI in the evaluation of potential remedial technologies for Site 11.

2.0 SITE CHARACTERIZATION

2.1 Site Location and Description

Site 11, the Fire Fighting Training Area, consists of an open, grassy, roughly egg-shaped area, measuring approximately 200 feet by 300 feet. A general site location map is provided in Figure 2-1. Site 11 is bounded by Moscrip Avenue, Building 390 and Warehouses W-1, W-2 and W-3 to the south, and is located approximately one mile west of Narragansett Bay. Middletown Street borders the site to the west. There are no trees on the site, although a few border the northeast edge of the site. Several large, devegetated areas exist and may be attributable to historic fire training exercises. The ground surface slopes gradually to the southwest, and small, shallow, eroded drainage swales are evident in the central portion of the study area. The swales drain to a catch basin on the western side of the study area, which is part of a storm sewer system which runs through the site. The sewer system begins on the eastern side of the site, and exits the site to the south, eventually discharging into a tributary of Mill Creek. The assumed destination of ground water flowing from Site 11 is also Mill Creek, located approximately one-quarter mile to the southwest.

The Comprehensive Reuse Plan for NCBC Davisville specifies the area in which Site 11 is located is to be used for economic/industrial development.

2.2 Site History Overview

Between the mid-1940s and 1955, fire fighting training exercises were held in a field at the intersection of Moscrip Avenue and Middletown Street at the NCBC Davisville Main Center. Waste oils contaminated with solvent and paint thinners were poured on the ground, ignited and subsequently extinguished. The total amount of wastes destroyed in this manner is not known (Hart, 1984).

2.3 Site Geology, Hydrogeology and Hydrology

The site-specific geologic and hydrogeologic characteristics were determined in the Verification Step, the Phase I RI and the Phase II RI with the excavation of a test pit, drilling of soil borings, and the installation of monitoring wells. Phase I and Phase II RI sampling locations are presented in Figures 2-2 and 2-3, respectively.

2.3.1 Site Geology

In the "Interim Soil Survey Report for North Kingstown, Rhode Island" (USDA, 1973), the Site 11 surface soils are mapped as Quonset gravelly sandy loam. The Phase II surface soil sample descriptions indicate that the surface soils on this site consist predominantly of native fine to medium sand with variable silt, coarse sand and gravel content. The descriptions of the Phase II surface soil samples were consistent with the mapped surface soils at Site 11.

According to the USGS surficial geologic map of the Wickford, Rhode Island quadrangle (Schafer, 1961), overlying the bedrock at Site 11 are surficial overburden deposits of Pleistocene glacial water-laid ice-contact sediments, consisting of sand, gravel and silt. The Phase II soil boring results indicate that the overburden deposits on this site consist of native fine to medium sand with variable silt, coarse sand and gravel content, sand and silt layers, peat, and weathered shale. Fill was encountered at two locations (11-B07 and 11-B08) in the southern portion of the site. The descriptions of the Phase II soil boring samples were consistent with the mapped surficial overburden materials at Site 11. Overburden thicknesses ranged from 30.5 feet (11-MW9D) to 46.0 feet (11-MW2D and 11-MW6D).

Competent bedrock was encountered at the four Site 11 deep monitoring well locations at elevations ranging from 24.9 feet below msl (11-MW6D) to 3.8 feet below msl (11-MW9D). Based on these elevations alone, the bedrock surface at Site 11 appears to slope downward to the southwest. A two-foot layer of weathered bedrock was encountered above competent bedrock at monitoring well 11-MW3D.

Two seismic refraction survey lines were also completed at Site 11, one running north to south through the center of the site and the other running east-northeast to west-southwest, also through the center of the site. These investigations indicated that the competent bedrock at Site 11 is located from approximately 26 to 41 feet below ground surface, and appears to dip to the west. The survey indicated the presence of a large competent bedrock depression in the vicinity of 11-MW2S/D. Apparent competent bedrock elevations from the seismic refraction survey at Site 11 ranged from 24.2 feet below msl to 9.7 feet above msl.

According to the USGS bedrock geologic map of the Wickford, Rhode Island quadrangle (Williams, 1964), Site 11 is underlain at depth by bedrock belonging to the Pennsylvanian Rhode Island Formation. Nx rock cores were collected of competent bedrock at three deep monitoring well borings. The rock cores indicate that the bedrock at 11-MW6D and 11-MW9D in the west-central and central portions of the site consists of massive and competent, light to medium grey, fine- to medium-grained meta-sandstone gneiss, interbedded with brittle to competent, medium to dark grey argillaceous shale. The 11-MW6D core contained several quartz veins and vein-healed natural fractures. The 11-MW9D core contained scattered thin quartz veins and iron oxide-stained natural fractures. The core from 11-MW3D, located in the southwestern portion of the site, consisted of massive and competent, light grey, medium-grained meta-sandstone gneiss, containing scattered thin quartz veins and numerous iron oxide-stained natural fractures.

2.3.2 Site Hydrogeology

Ground water levels were measured in the twelve Phase I and Phase II monitoring wells on August 13 and September 17, 1993. Contour maps of the shallow and deep ground water elevations are presented as Figures 2-4 through 2-7. The ground water contour maps indicate that the site shallow ground water is flowing generally to the southwest and west, and the deep ground water is flowing generally to the southwest, toward Mill Creek.

Vertical hydraulic gradients were calculated at the three sets of paired monitoring wells, as presented in Table 2-1. A positive hydraulic gradient indicates a potential for upward flow and a negative gradient indicates a potential for downward flow of ground water.

For the two measuring events, the calculated vertical gradients ranged from -4.69×10^{-3} ft/ft to -4.26×10^{-2} ft/ft. Negative vertical gradients (downward) were measured at all well pairs during both events. The negative vertical hydraulic gradients at Site 11 are moderate in magnitude; this indicates that downward vertical transport may have an impact on contaminant migration at the site. Other factors such as ground water contaminant specific density and aquifer heterogeneity may be expected to play a greater role in contaminant transport.

Horizontal hydraulic gradients were calculated from the water level measurements at the site. Representative average horizontal gradients for both the shallow and deep ground water were determined for several areas on the site, and are provided in Table 2-2. Average horizontal gradients for shallow ground water ranged from 3.42×10^{-3} ft/ft to the northwest to 1.65×10^{-2} ft/ft to the southwest. Average deep ground water horizontal gradients ranged from 6.40×10^{-3} ft/ft to the west to 9.57×10^{-3} ft/ft to the southwest.

The calculated average horizontal hydraulic gradients, hydraulic conductivity, horizontal hydraulic gradient, and estimated effective porosity values were used to calculate average linear ground water flow velocity values at the site. Shallow and deep hydraulic conductivities of 19 and 1.3 ft/d, respectively, were the median values derived from the Phase II RI slug tests at the site. An effective porosity of 20% was assumed for the silty sands at the site (EPRI, 1985). The average linear velocity values are presented in Table 2-2. Average linear velocities of the shallow ground water ranged from 0.33 ft/d to 1.58 ft/d. Average deep linear velocities ranged from 0.04 ft/d to 0.06 ft/d.

Rhode Island Department of Environmental Management (RIDEM) has classified ground water under the majority of NCBC Davisville, including the area in which Site 11 is located, as Class GB. Ground water classified as GB encompasses those resources designated as not suitable for public or private drinking water use without treatment due to known or presumed degradation. GB-classified ground water is primarily located at highly urbanized areas or in the vicinity of disposal sites for solid waste, hazardous wastes or sewage sludge.

2.3.3 Site Hydrology

The topography of Site 11 slopes slightly to the southwest. Surface soils consist of medium-grained sand with varying amounts of gravel and silt, thus suggesting the soils are well drained. Very little vegetation covers the area. Several small gullies, approximately six inches deep and eighteen to twenty-four inches wide, were noted on the site. A storm sewer runs from east to west through the site, then turns south to exit the site. Catch basins are present periodically along the storm sewer, as indicated in Figure 2-1. The storm sewer drains into a tributary of Mill Creek, south of Site 11, approximately 2,200 feet away from the site.

Pine River and a smaller stream west of Site 11 flow into Mill Creek, as well as the small tributary to the south of Site 11 which receives the storm sewer discharge. Mill Creek flows south and is culverted between the Government Railroad and Camp Avenue. The location of Mill Creek is noted on Figure 1-1.

2.4 Ecological Setting

No surface water bodies exist within or adjacent to Site 11. However, Site 11 is located within the Mill Creek Watershed. The ecological assessment activities conducted as part of the Phase II RI for NCBC Davisville included an assessment of terrestrial risks, which considered Site 11 surface soil data, and an assessment of the Mill Creek Watershed, including surface water and sediment sampling and analysis.

Mill Creek Watershed appears to support a diverse avian fauna, exhibits signs of small mammals and supports fish species. Twelve bird species were observed along the main stem of Mill Creek and associated tributaries. A cottontail rabbit and raccoon tracks were observed along the stream bank. A juvenile pickerel, adult eel and small green frogs were also noted.

The benthic populations were relatively high along the length of the creek. In general, benthic populations were similar at locations upgradient of NCBC and along Mill Creek and its tributaries within NCBC.

The State of Rhode Island (RIDEM, 1989) conducted an endangered species survey of East Davisville, also referred to as the Main Center. It describes the area as having fringing saline and brackish marsh which do not provide suitable habitat for rare species, and upland areas which are slowly reverting to natural communities of shrubs.

2.5 Site Investigation Overview

2.5.1 Confirmation Study

Field investigations conducted during the Confirmation Study in 1985 included a geophysical survey, a site walk-over with an organic vapor analyzer (OVA), and two rounds of surface soil sampling. One composite surface soil sample, collected from four locations, was analyzed for petroleum-based hydrocarbons and scanned for purgeable organics during the first round of sampling. The second round of sampling included the collection of four grab surface soil samples. Two of the samples were analyzed for Priority Pollutants, and the other two samples were analyzed for volatile organics only.

2.5.2 Phase I RI

The Phase I RI included a soil gas survey, surface soil sampling, catch basin sampling, six soil borings, and the installation and sampling of five ground water monitoring wells. Phase I RI sample locations are presented in Figure 2-2.

A total of seventeen surface soil samples were collected from ten surface soil sample locations, six test boring locations (0- to 2- feet), and one catch basin. The eleven surface soil/catch basin samples were analyzed for TCL pesticides/PCBs and petroleum hydrocarbons, and the six surface soil samples collected during the test boring investigation were analyzed for full TCL/TAL parameters. Six subsurface soil samples were collected and analyzed for TCL/TAL parameters, as well. Ten ground water samples were also collected from five monitoring wells in two rounds of sampling. All ground water samples were analyzed for TCL/TAL parameters. Two subsurface soil samples were also submitted for TCLP analysis.

2.5.3 Phase II RI

The purpose of the Phase II RI at Site 11 was to further delineate the horizontal and vertical extent of contamination associated with the fire fighting training activities historically conducted at the site. The investigations also provided a basis for the evaluation of contaminant fate and transport mechanisms and data for use in quantitatively evaluating human health risks and ecological risks.

The Phase II field investigation activities conducted at Site 11 included a seismic refraction survey; sampling of surface soil at fifteen surface soil locations and ten test boring/monitoring well locations; excavation and sampling of a test pit to determine whether the backfill material around the storm sewer may be acting as a contaminant transport pathway; the drilling and sampling of twelve test boring/monitoring well locations; collection of three catch basin sediment samples; installation and sampling of two shallow wells, one shallow/deep cluster, and three deep wells; and the performance of hydraulic conductivity tests. Phase II RI sampling locations are indicated in Figure 2-3. A total of twenty-five surface soil samples, thirteen subsurface soil samples (including one test pit soil sample) and twelve ground water samples were collected at the site in addition to the three sediment samples. The surface soil, subsurface soil, catch basin sediment, and ground water samples were all analyzed for full

TCL/TAL parameters. In addition, one surface soil sample and one subsurface soil sample were collected for TCLP analysis, the three catch basin sediment samples were analyzed for total organic carbon, and three of the ground water samples were analyzed for filtered metals, BOD, COD and TSS.

Also included within the scope of the Phase II RI was an investigation of background soil quality at the NCBC Davisville facility. Eighteen background surface soil samples were collected across NCBC Davisville during the Phase II RI and analyzed for full TCL/TAL parameters. Background soil quality results for semivolatiles, pesticides and inorganics are summarized in Table 2-3 and are considered in the evaluation of contaminant levels at Site 11, as presented below.

2.6 Summary of Contamination

2.6.1 Volatile Organic Compounds (VOCs)

Surface Soils

During the Confirmation Study, the analysis of a composite soil sample indicated a total volatile organic response of up to 12 ppm. The second round grab samples exhibited no detectable levels of volatile organics.

During the Phase I RI, acetone was detected in one of the surface soil samples (B-11-03-00) at a concentration of 12 ppb. No other VOCs were detected in Site 11 surface soils during the Phase I RI.

No volatile organic compounds were detected in Site 11 surface soils during the Phase II RI.

Subsurface Soils

No subsurface soil sampling was conducted during the Confirmation Study.

During the Phase I RI, VOCs detected in the subsurface soils at Site 11 included chloroform, acetone, and 2-butanone at concentrations ranging from 2 ppb to 30 ppb.

The Phase II subsurface soil analyses indicated that acetone and 2-butanone were present in subsurface soils. Acetone was detected in five of the subsurface soil samples at estimated concentrations ranging from 20 ppb to 100 ppb. 2-Butanone was detected in one of the subsurface soil samples (11-B07-02) at an estimated concentration of 8 ppb.

Ground Water

No ground water sampling was conducted during the Confirmation Study.

Methylene chloride, acetone and 2-butanone were detected in Site 11 ground water during the Phase I ground water sampling rounds. Methylene chloride was detected in monitoring well 11-MW5S at an estimated concentration of 2 ppb during the first round of sampling. Acetone was detected in monitoring wells 11-MW2S and 11-MW3S at concentrations of 12 ppb and 42 ppb, respectively, and 2-butanone was detected in monitoring well 11-MW3S at an estimated concentration of 3 ppb during the second round of sampling.

One VOC, 1,1,1-trichloroethane, was detected in Phase II RI ground water samples at estimated concentrations of 2 ppb and 1 ppb in monitoring wells 11-MW2D and 11-MW5S, respectively.

Catch Basin Sediments

Sediment samples were not collected during the Confirmation Study.

The one sediment sample collected during the Phase I RI was not analyzed for VOCs. VOCs were not detected in the sediment samples collected during the Phase II RI.

2.6.2 Semivolatile Organic Compounds (SVOCs)

Surface Soils

No SVOCs were detected in the two surface soil samples collected during the Confirmation Study which were subject to a full GC scan. Total petroleum hydrocarbons were present at a level of 7,800 ppm in sample SS11C-1, which was a composite sample collected from four separate locations of the site.

Based on the Phase I analyses, PAH compounds were present in surface soil samples B-11-01-00 and B-11-04-00 at total PAH concentrations of 971 ppb and 190 ppb, respectively. Bis(2-ethylhexyl)phthalate was also detected in surface soil samples B-11-05-00 and B-11-06-00 at estimated concentrations of 85 ppb and 180 ppb, respectively.

PAH compounds were detected in thirteen Phase II RI surface soil samples and one duplicate sample at total PAH concentrations ranging from 82 ppb to 28,433 ppb. PAHs were detected in samples located throughout the site. The highest concentrations of PAHs were detected in surface soil sample 11-B10-01, located in the central portion of the site within the devegetated area. Carcinogenic PAHs totalled 15,660 ppb of the 28,433 ppb total PAHs detected in the sample. Of the remaining twelve samples which contained PAHs, only one (11-B14-01) contained a total PAH concentration of greater than 5,000 ppb.

Other semivolatile organic compounds detected in the Site 11 surface soils include bis(2-ethylhexyl)phthalate, butyl benzyl phthalate, di-n-butyl phthalate, dibenzofuran, and carbazole. These compounds were detected infrequently across the site and at low concentrations.

As indicated in Table 2-3, surface soil SVOC levels generally exceeded facility background levels.

Subsurface Soils

No subsurface soil sampling was conducted during the Confirmation Study.

During the Phase I RI, SVOCs detected in the subsurface soils included bis(2-ethylhexyl)phthalate, benzoic acid, and PAH compounds. Bis(2-ethylhexyl)phthalate was detected in two samples at concentrations of 200 ppb and 450 ppb. Benzoic acid was detected in three subsurface soil samples at a maximum concentration of 310 ppb. PAH compounds were detected in three of the subsurface soil samples at total concentrations ranging from 230 ppb to 256 ppb.

PAHs, phthalate esters, and dibenzofurans were among the SVOC compounds detected in the Phase II RI subsurface soil samples. PAH compounds were detected in six of the subsurface soil samples at total PAH concentrations ranging from 189 ppb to 10,800 ppb. PAHs were detected in subsurface soil samples collected from soil borings 11-B08, 11-B10, 11-B12, 11-MW2, and 11-MW6. The highest PAH concentrations were detected in subsurface soil samples 11-B10-02 (10,800 ppb) collected from the 2- to 4- foot interval, 11-B2-02 (6,624 ppb) collected from the 2- to 4-foot interval, and sample 11-B08-03 (4,017 ppb) collected from the 4- to 6- foot interval. At 11-B08 and 11-B10, PAHs were detected in both surface soils and subsurface soils.

Dibenzofuran was detected in subsurface soil samples 11-B08-03 and 11-B12-02 at estimated concentrations of 82 ppb and 65 ppb, respectively. Bis(2-ethylhexyl)phthalate was detected in five of the subsurface soil samples at estimated concentrations ranging from 48 ppb to 150 ppb.

Ground Water

No ground water sampling was conducted during the Confirmation Study.

Bis(2-ethylhexyl)phthalate was detected at an estimated concentration of 6 ppb in one monitoring well (11-MW2S) during the first round of the Phase I RI sampling.

Three SVOCs were detected in the Phase II RI ground water samples. Bis(2-ethylhexyl)phthalate was detected in monitoring well 11-MW1S at an estimated concentration of 14 ppb. Diethyl phthalate was detected in monitoring wells 11-MW2D and 11-MW9D at estimated concentrations of 1 ppb and 2 ppb, respectively. Phenol was detected in monitoring well 11-MW9D at an estimated concentration of 1 ppb. None of the PAH compounds detected in the site surface and subsurface soils were present in the Site 11 ground water.

Catch Basin Sediments

Sediment samples were not collected during the Confirmation Study.

The single catch basin sediment sample collected during the Phase I RI was not analyzed for SVOCs. PAH compounds were present, however, in each of the three Phase II RI catch basin sediment samples. The highest total concentration of PAH compounds(4,370 ppb) was detected in catch basin sample 11-SD03, located downgradient of the site. Samples 11-SD01 and 11-SD02 contained total PAH concentrations of 994 ppb and 827 ppb, respectively. Asphalt fragments were contained within each of the sediment samples collected. While an attempt was made to remove the asphalt, the detection of PAHs in each of the samples may be attributable to the presence of asphalt in the sample.

2.6.3 Pesticides/PCBs

Surface Soil

The two grab samples analyzed for pesticides during the Confirmation Study were contaminated with 4,4'-DDT, 4,4'-DDD, and 4,4'-DDE. 4,4'-DDT was detected at the highest concentrations, present in samples SS-11:1 and SS-11:2 at 690 ppm and 64 ppm, respectively.

Pesticides were detected in five of the Phase I RI surface soil samples at concentrations ranging from 22 ppb to 310 ppb. The pesticides detected in the Phase I RI surface soil samples were identical to those detected during the Confirmation Study (4,4'-DDT, 4,4'-DDD, and 4,4'-DDE). No PCB compounds were detected in the surface soils during the Phase I RI.

Both pesticides and PCBs were detected in the Phase II RI surface soil samples at low concentrations. Pesticides were detected in twenty-three of the twenty-five surface soil samples collected at the site. Pesticides were also detected in several of the background soil samples collected throughout the NCBC facility, as shown in Table 2-3, indicative of potential general use of pesticides at the facility. Alpha-BHC, Delta-BHC, aldrin, endosulfan I, dieldrin, endrin, endosulfan II, endosulfan sulfate, p,p'-methoxychlor, and endrin ketone were detected in site surface soils at levels exceeding facility background levels.

PCB Aroclor-1254 and Aroclor-1260 were detected at two separate surface soil sample locations at concentrations of 96 ppb (11-SS23) and 13 ppb (11-B11-01), respectively. The two samples were collected in the northern portion of the site.

<u>Subsurface Soils</u>

A subsurface investigation was not conducted during the Confirmation Study at Site 11.

No pesticide or PCB compounds were detected in the Phase I RI subsurface soil samples.

The Phase II RI subsurface soil sampling results indicated that pesticides are present in the subsurface soils at low concentrations. Pesticides were detected in eight of the twelve subsurface soil samples collected across the site. Of the twenty-one pesticide analytes, sixteen of the compounds were detected in at least one of the samples. Of the eight subsurface soil samples which contained detectable levels of pesticides, only one contained a total pesticide concentration greater than 10 ppb (11-B08-03 at 56.79 ppb). p,p'-Methoxychlor accounted for the majority (53 ppb) of the total concentration at this south-central sample location.

The PCB Aroclor-1254 was detected in one Phase II RI subsurface soil sample, 11-B12-02, (2- to 4-foot interval), at an estimated concentration of 5.7 ppb.

<u>Ground Water</u>

A ground water investigation was not conducted during the Confirmation Study.

No pesticide/PCB compounds were detected during either of the Phase I RI ground water sampling rounds.

Results of the Phase II RI ground water sampling indicated that three pesticide compounds are present in one of the shallow monitoring wells. Alpha-BHC and aldrin were detected in monitoring well 11-MW7S, located in the northern part of the site, at estimated concentrations of 0.0011 ppb and 0.0015 ppb, respectively. Gamma-BHC (lindane) was detected at an estimated concentration of 0.0017 ppb in a duplicate sample (11-MW11S) collected at monitoring well 11-MW7S, although alpha-BHC and aldrin were not detected. No PCB compounds were detected in the Site 11 ground water.

Catch Basin Sediments

Sediment samples were not collected during the Confirmation Study.

Two pesticide compounds and one PCB Aroclor were present in the single Phase I RI catch basin sediment sample, collected at the point where the storm sewer turns to the south, 4,4'-DDT and 4,4'-DDE were detected at estimated concentrations of 220 ppb and 39 ppb, respectively. The PCB Aroclor-1260 was detected at an estimated concentration of 870 ppb.

Nine pesticide compounds were each detected in at least one of the sediment samples collected during the Phase II RI. The highest concentrations of pesticides were detected in catch basin sediment sample 11-SD03, located downgradient of the site. The pesticide detected at the highest concentration (1,100 ppb) at this location was 4,4'-DDD. The PCB Aroclor-1260 was detected in each of the three catch basin sediment samples, at estimated concentrations of 28 ppb (11-SD01), 16 ppb (11-SD02) and 300 ppb (11-SD03).

Based on these results, it would appear that both pesticides and PCBs may have migrated from the site surface soils to the stormwater drainage system, although PCBs were detected in surface soils only in the northern portion of the site, not in the immediate vicinity of the catch basin locations.

2.6.4 Inorganics

Surface Soil

Surface soil samples collected during the Confirmation Study were not analyzed for inorganic analytes.

The inorganic compounds common to each of the surface soil samples collected during the Phase I RI were lead, barium, iron, manganese, aluminum, magnesium and calcium. Arsenic, beryllium, chromium, copper, zinc, vanadium and potassium were also detected in Phase I RI surface soil samples.

The inorganics detected in Phase II RI surface soil samples were compared with background sample results from surface soil samples collected throughout the NCBC Davisville facility. A comparison of the observed surface soil concentration ranges at Site 11 to the NCBC background samples is presented in Table 2-3.

Fourteen inorganic analytes were detected in Site 11 surface soils at concentrations outside of the NCBC background concentration ranges. These inorganics include aluminum, antimony, barium, beryllium, calcium, cobalt, iron, magnesium, manganese, mercury, nickel, potassium, sodium and cyanide. The highest levels of inorganics were detected in surface soil sample 11-B08-01, which was collected in the southern portion of the site.

Subsurface Soils

No subsurface soil sampling was conducted during the Confirmation Study.

The same inorganic analytes which were present in every Phase I RI surface soil sample were also present in each Phase I RI subsurface soil sample. Other inorganics detected in the subsurface soil samples also mirrored the surface soil samples with the exception of nickel and cobalt, which were detected only in subsurface soil samples.

As described in the surface soil sample discussion, soil sample results from the Phase II RI were compared to the background samples collected through the NCBC facility. Thirteen inorganic analytes were detected in Site 11 subsurface soils at concentrations above the NCBC background ranges. The analytes include aluminum, barium, beryllium, calcium, cobalt, copper, iron, magnesium, manganese, mercury, nickel, potassium and thallium. The highest levels of inorganics were detected in soil boring samples 11-B11-02, collected from the 2- to 4- foot interval, and 11-MW2-03, collected from the 4- to 6- foot interval. Well boring 11-MW2 is located in the southern portion of the site while soil boring 11-B11 is located in the northern portion of the site. The inorganic concentrations detected in the subsurface soils were generally comparable to the concentrations detected in the surface soil samples.

Ground Water

No ground water sampling was conducted during the Confirmation Study.

Each of the inorganic analytes detected in Phase I RI surface and/or subsurface soil samples was also detected in Phase I RI ground water samples, along with cadmium, silver, and sodium.

Results of the Phase II RI ground water sampling indicate that low levels of inorganic analytes are present in the Site 11 ground water. The inorganic analytes detected in the Phase II RI ground water samples included aluminum, antimony, arsenic, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, potassium, silver, selenium, sodium, and vanadium. Comparison of the Phase I and Phase II analytical data reveals a significant reduction in analyte concentrations, which may be attributed to the low-flow sampling methodology employed during the Phase II ground water sampling program.

Inorganic analyses were also conducted on three filtered ground water samples collected during the Phase II RI from monitoring wells 11-MW3D, 11-MW4S, and 11-MW7S. A comparison of the Phase II filtered vs. non-filtered sample results indicates that the inorganic concentrations in the filtered samples are primarily equivalent to or slightly less than the concentration of the non-filtered samples.

Catch Basin Sediments

Sediment samples were not collected during the Confirmation Study.

The single sediment sample collected during the Phase I RI was not analyzed for inorganic analytes.

The only TAL inorganic analytes not detected in the Phase II RI catch basin sediment samples were antimony, mercury, selenium, thallium, and cyanide. When comparing those inorganics detected in the catch basin sediment samples to background sample results from surface soil samples collected throughout the NCBC Davisville facility, only nine inorganic analytes were detected above the background range. These inorganics include barium, beryllium, cadmium, chromium, copper, lead, nickel, sodium and zinc. Inorganics were only detected at concentrations above the background levels in sediment samples 11-SD01 and 11-SD03. Of these two samples, sediment sample 11-SD01, located upgradient of the site, typically contained the highest inorganic concentrations. This would indicate that inorganics present in the catch basin sediments are not due to the previous activities conducted at the Fire Fighting Training Area.

2.6.5 TCLP Analyses

No samples collected during the Confirmation Study were analyzed using the Toxicity Characteristic Leachate Procedure (TCLP).

Two soil samples were collected and analyzed for TCLP during the Phase I RI. The VOCs detected in sample B-11-06-04-S included toluene at 33 ppb, styrene at 11 ppb, acetone at 12 ppb, and 2-butanone at 24 ppb. Chromium, copper, lead, zinc, barium, iron, manganese, aluminum, cobalt, magnesium, and calcium are the inorganic analytes detected in the samples. No analytes were detected at levels exceeding the maximum Toxicity Characteristic concentrations (40 CFR 261.24).

Two soil samples were also collected and analyzed for TCLP during the Phase II RI. These samples included 11-MW14-01 and 11-B07-02. No analytes were detected at concentrations exceeding the maximum Toxicity Characteristic concentrations (40 CFR 261.24).

2.7 Summary of Contaminant Fate and Transport

A contaminant fate and transport analysis was initially conducted as a part of the Phase I RI and incorporated in the Initial Screening of Alternatives (TRC, 1993a). Subsequently, information obtained during the Phase II RI was incorporated into the contaminant fate and transport analysis and a revised discussion was presented in the Draft Phase II RI Technical Report (TRC, 1993b).

Potential routes of migration, contaminant persistence and observed contaminant migration were considered in evaluating the fate and transport of the site contaminants identified during the RI investigation.

In general, of the environmental media at Site 11, surface soils, ground water and catch basin sediments have the greatest potential for off-site migration. Typically, contaminants in surface soils can migrate or be carried off-site by surface runoff (resulting from precipitation), by being sorbed to windblown dust, and by site visitors via adherence to vehicle tires, shoes, etc. Based on current site use, dust generation and surface runoff at Site 13 are expected to be moderate, given the relatively flat, sparsely vegetated area. Contaminants can also migrate from the surface soils through leaching (by infiltration of precipitation) and subsequent transport by ground water, by volatilization to ambient air, or by uptake by plants or animals. Subsurface contaminants can migrate through leaching and ground water transport. Ground water transport at Site 11 would be to the west-southwest. No significant differences were observed between shallow ground water quality and deep ground water quality at the site. Migration of contaminants off-site would also be affected by the storm drainage system on-site. The catch basins collect the runoff from the site and eventually discharge to a tributary of Mill Creek. Sediments in the catch basins could be carried by storm waters toward the discharge point. The backfill material surrounding the storm drainage system could be more permeable than surrounding soil and act as a potential subsurface migration pathway.

The following sections examine the presence of Constituents of Concern (COCs), as identified during the Human Health Risk Assessment process (TRC, 1993b), across the site in combination with the potential migration pathways to provide an understanding of contaminant persistence and potential for migration at the site. The discussions below are presented with respect to individual contaminants or contaminant groups based on environmental fate data such as water solubility, vapor pressure, Henry's Law constants, organic carbon-water partition coefficients (K_{oc}), octanol-water partition coefficients (K_{ow}) and half-life in water.

Volatile Organic Compounds

In general, VOCs were detected infrequently and at low concentrations in soils at Site 11.

No VOC COCs were identified for surface soils at Site 11. In subsurface soil, three VOCs (acetone, 2-butanone, and chloroform) were identified as COCs. The principal mechanism for the natural removal of VOCs is through volatilization, based on vapor pressures (@ approximately 25°C) ranging from 100 mmHg (2-butanone) to 270 mmHg (acetone), and Henry's Law Constants for these VOCs range from 4.3×10^{-5} atm-m^3/mol (acetone) to 3.4×10^{-3} atm-m^3/mol (chloroform).

The role of biodegradation in the natural attenuation of these compounds is compound-specific. Similarly the role of adsorption is compound-specific (i.e., a greater log K_{oc} indicates a tendency to be retained by soils). The volatile COCs are fairly soluble in water with solubilities of 9,300 mg/l (chloroform) to being miscible (acetone). The tendency of these constituents to partition from organic media into water varies, with log K_{ow}s ranging from 1.95 (for chloroform) to -0.24 (for acetone, which is highly water soluble). The volatile COCs in subsurface soil are not expected to persist. The primary migration pathway from soil for these constituents is expected to be leaching through soil into ground water; volatilization would play a lesser role for contaminant migration from the subsurface soils.

Of the three volatile COCs in subsurface soil, one was identified as a COC in ground water (acetone). Although not detected in soil, 1,1,1-trichloroethane was also selected as a COC in ground water. The solubility of 1,1,1-trichloroethane (4,400 mg/l) is similar to the solubility of chloroform in soils.

Semi-Volatile Organic Compounds

Fourteen SVOCs were identified as COCs in surface soil at Site 11, including eleven PAHs, two phthalates, and benzoic acid. In subsurface soil, twenty SVOCs were selected as COCs, including sixteen PAHs, one phthalate, benzoic acid, carbazole, and dibenzofuran. Five PAHs, one phthalate, carbazole, and dibenzofuran were identified as COCs in subsurface soils but not in surface soils. Butylbenzyl phthalate was identified as a COC in surface soil but not in subsurface soil. In general, the PAHs and phthalates were associated with the highest detection frequencies and concentrations. It should be noted that phthalates are common laboratory contaminants and are widespread in the environment (ATSDR, 1987; ATSDR, 1989).

SVOCs, particularly PAHs, are persistent in the environment due to their complex chemical nature. While some of the lighter PAHs (with fewer aromatic rings) are subject to biodegradation or volatilization, chemical persistence generally increases with increasing number of aromatic rings. SVOCs are generally characterized by high boiling point, low vapor pressure, and low solubility (except for lower molecular weight PAHs, phenols).

PAHs generally exhibit a very low solubility (i.e., as low as 1×10^{-4} mg/l), with higher solubilities for the smaller PAHs (e.g., 26 mg/l for 2-methylnaphthalene). The solubility of the phthalate COCs ranges from 0.4 mg/l for bis(2-ethylhexyl)phthalate to 2.9 mg/l for butyl benzyl phthalate.

SVOCs, in general, have moderate to high log K_{oc} and log K_{ow} values indicating a relative affinity for organic materials in solid (e.g., soil) and liquid (e.g., octanol) phases. The log K_{oc}s and log K_{ow}s of PAHs and phthalates are generally greater than 3 with many greater than 5.

Of the 20 semivolatile COCs in soil, one (bis(2-ethylhexyl)phthalate) was identified in ground water. One additional semivolatile COC was identified in ground water (diethylphthalate). Diethylphthalate is more soluble (and therefore more likely to migrate into ground water) than most of the SVOCs identified as COCs in soil only.

With the exception of the more soluble SVOCs identified as COCs in ground water, migration of SVOCs from soil to ground water is not likely to be a primary route of concern. Off-site transport of these less soluble SVOCs may be possible through dust generation at the soil surface and through soil transport in surface water runoff. SVOCs in soil are more likely to persist than VOCs, but are less likely to persist than pesticides/PCBs or inorganics.

Contaminants transported by surface water runoff could migrate off-site via the storm sewer system. PAHs were detected in each of the catch basin sediment samples, with the highest level of SVOCs detected in the downgradient sample, 11-SD03. While the presence of SVOCs in the catch basin sediments may be attributable to Site 11, their detection may also be due to the presence of asphalt fragments in the sediment samples.

Pesticides and PCBs

Eighteen pesticides and one PCB (PCB-1254) were identified as COCs in surface and/or subsurface soil at Site 11. Pesticides and PCBs have a strong affinity for organic materials in soils which tends to reduce their mobility in this medium. In addition, many pesticides and PCBs are persistent in the environment (i.e., have large half-lives). No pesticide/PCB compounds were identified as COCs in ground water. The relative absence of pesticides/PCBs in ground water indicates that the migration of these constituents from soil into ground water is not significant. The primary migration pathways for pesticides and PCBs in surface soil include transport of soil particulates in surface water runoff and via wind erosion.

Pesticides and PCBs were detected in the catch basin sediment samples, indicating that pesticides and PCBs may have migrated from surface soil into the catch basins. The highest detected pesticide (4,4'-DDD) and PCB (Arclor 1260) levels were detected in the downgradient catch basin, indicating that pesticides and/or PCBs may be migrating off-site through the storm sewer system.

Inorganic Analytes

Many metals have a strong affinity for soils (particularly clay particles and organic matter in soils) which reduces their mobility. Under extremes of pH, some metals can be rendered mobile. The presence of the inorganic analytes at Site 11, particularly the naturally occurring elements, were examined in the context of facility background concentrations and background concentrations in eastern U.S. soils, as presented in Table 2-3. Site background samples were collected as composite samples from background locations at Sites 02, 07, 09, 10 and wooded areas east of Sites 06, 11 and 13 during the Phase II RI. The inorganic COCs in surface soil include arsenic, antimony, barium, beryllium, cadmium, chromium, cobalt, cyanide, lead, manganese, mercury, and nickel. The inorganic COCs in subsurface soils include arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, thallium and vanadium.

The inorganic COCs in ground water include aluminum, arsenic, barium, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, nickel, silver, vanadium, and zinc. The presence of a number of these inorganics in surface and subsurface soils indicates migration from soil to ground water may have occurred. However, it is important to note that a comparison of Phase I and Phase II RI results indicates a considerable decrease in the concentration of inorganics in ground water during the Phase II RI. This decrease is believed to be due to the sampling methodology utilized in the Phase II RI which incorporated a low-flow sampling rate to decrease the turbidity of the ground water samples. Thus, the Phase II ground water data are thought to be more reflective of the actual concentrations of inorganics than the Phase I data.

Surface soil COCs detected in the catch basin samples include arsenic, barium, beryllium, cadmium, chromium, cobalt, lead, manganese, and nickel. The highest concentrations of beryllium, manganese and nickel were detected in the upgradient catch basin, indicating that these inorganics may not be associated with fire training activities. The highest concentrations of the remaining elements were detected in the downgradient catch basin. The presence and elevated levels of these elements in 11-SD03 indicates migration from surface soil to catch basin sediment may have occurred.

TCLP Analyses

The results of the TCLP analyses indicate that there were no soil samples which exhibited contaminants above the regulatory action levels as identified on the TCLP list (40 CFR 261.24).

2.8 Summary of Human Health Risk Assessment

The Human Health Risk Assessment conducted for Site 11 (TRC, 1993b) evaluated the contaminants of potential concern, assessed potential exposure pathways and chemical toxicity, and characterized potential risks to human health posed by the site. Both Phase I RI and Phase II RI data were used to characterize the human health risks. Exposure doses were developed based on the geometric mean of chemical concentrations (mean) as well as on the basis of the maximum detected chemical concentration (Reasonable Maximum Exposure or RME). Potential human health exposure scenarios evaluated include the following:

- Scenario 1 (Future Construction Worker) - Exposure of adult workers to subsurface soils (via dermal contact, ingestion, and inhalation) for a one-year period, assuming construction of commercial buildings; and

- Scenario 2 (Future Commercial/Industrial Worker) - Exposure of adult employees to surface soils (via dermal contact and ingestion) and to ground water (through ingestion) under future commercial/industrial use of the site.

Human health risks were presented with regard to potential cancerous or non-cancerous (systemic) effects from the contaminants of concern. Cancer risks are presented in scientific notation where a lifetime cancer risk of 1×10^{-4} represents a lifetime cancer risk of one in ten thousand. The calculated cancer risk is compared to the acceptable cancer risk range (1×10^{-4} to 1×10^{-6}) for evaluating the need for remediation, as stated in 40 CFR Part 300. A cancer risk of 1×10^{-6} is considered as the point of departure for determining risk-based remediation goals. For non-carcinogens, a summation of hazard quotients (referred to as the hazard index or HI), which exceeds unity (1) indicates there may be a concern for potential non-cancer health effects. Therefore, the cancer risk and HI ratios that constitute a potential concern are those greater than 1×10^{-6} and 1, respectively.

Cancer and non-cancer risk estimates for Site 11 are summarized in Table 2-4. Subsurface soil exposures under Scenario 1 (construction scenario) indicated a cumulative potential cancer risk range of 1×10^{-6} (mean) to 4×10^{-6} (RME) and non-cancer HIs below 1. Exposure to arsenic, beryllium, and carcinogenic PAHs accounts for the majority of the estimated cancer risks. Surface soil exposures under Scenario 2 (commercial/industrial) indicated a cumulative potential cancer risk range of 2×10^{-6} (mean) to 2×10^{-5} (RME) and non-cancer HIs below 1. Exposure to arsenic, beryllium, and carcinogenic PAHs accounts for the majority of the estimated cancer risks.

Ground water exposures under Scenario 2 (commercial/industrial scenario) indicated a potential cancer risk range of 5 x 10^{-5} (mean) to 2 x 10^{-4} (RME) and non-cancer HIs ranging from 1 (mean) to 6 (RME). Exposure to arsenic and beryllium accounts for the majority of estimated cancer risks, while manganese accounts for the majority of the estimated non-cancer risks.

2.9 Summary of Ecological Risk Assessment

Ecological risks were assessed based on an evaluation of potential receptors identified through the ecological characterization of the Mill Creek Watershed, and the detected levels and bioavailability of contaminants in environmental media. Terrestrial risks were characterized based on site-specific biological observations and surface soil data. Aquatic risk was assessed for the watershed and considered the results of surface water and sediment samples collected at various stations within the watershed. A "weight of evidence" approach was used in which information generated from exposure and ecological effects assessments, field observations, and a toxicity quotient (TQ) evaluation are used to provide an overall weight of evidence concerning the nature of risks. As with the human health HI ratios, when the calculated TQ value exceeds unity (one), a potential for environmental risks exists.

Risks to benthic invertebrates were assessed based on sediment quality criteria derived from equilibrium partitioning on a station by station basis; an estimate of metal bioavailability based on a ratio of Simultaneously Extracted Metal (SEM) to Acid Volatile Sulfide (AVS); a comparison to NOAA ER-L (Effects Range-Low) and ER-M (Effects Range-High) values; and direct observations on the freshwater benthos in the watershed. Risks to water column organisms were estimated based on a comparison to ambient water quality criteria. An exposure model was used to estimate risks to mink from exposure to PCBs in the sediments. Risks to small mammals and birds were estimated on the basis of calculated TQ values.

The ecological assessment concluded that Site 11 and the developed areas of NCBC in the Mill Creek Watershed do not pose an ecological risk to aquatic or terrestrial communities in the Mill Creek Watershed because:

- benthic communities within the watershed exhibit similar, relatively high abundance and taxonomic diversity at upstream and downstream areas;

- the local watershed exhibits a diverse avian fauna, although the habitat is fragmented by developed areas;

- sediment metals are generally within naturally occurring ranges;

- SEM and AVS data generally indicate that metals in the sediment of the brook have low bioavailability - the only station where the ratio exceeded 1 was upgradient of the site;

- toxicity quotients based on comparison to derived sediment quality criteria are less than 1 at all stations in the watershed, except for station 17 which exhibited several exceedances (note that station 17 is at the far western end of NCBC and at the crossroads of several public transportation corridors);

- the sediment contaminant concentrations for pesticides, PAHs, and PCBs are generally between the NOAA ER-L and ER-M;

- sediment metals are generally below the NOAA ER-L, except for lead;

- the wildlife observations in this system indicate a taxonomically and functionally diverse ecosystem;

- modeled doses of contaminants to birds and shrew near Site 11 do not indicate toxicity quotients greater than 1; and,

- estimated dietary exposures of PCBs to mink foraging in the watershed are less than the toxicity benchmark.

3.0 SCREENING OF TECHNOLOGIES AND DEVELOPMENT OF ALTERNATIVES

Based on the available site information, potential remedial actions can be identified. Remedial action objectives are developed in order to set goals for protecting human health and the environment early in the alternative development process. General response actions are then developed to address the objectives. Remedial technologies and process options associated with the general response actions are identified and screened to eliminate those that are not technically implementable and to identify those that offer the optimum combination of effectiveness, implementability and cost. Remedial alternatives are then developed for detailed analysis.

3.1 Development of Preliminary Remediation Goals (PRGs)

Prior to the development of remedial action objectives, preliminary remediation goals (PRGs) are developed and evaluated with respect to site contaminant levels. Existing contaminant levels are compared to Applicable or Relevant and Appropriate Requirements (ARARs), To-Be-Considered guidance (TBCs), and risked-based PRGs to identify the extent of contamination requiring remediation. Also included in the evaluation is the role of environmental risk and the application of models to predict the potential for migration of soil contaminants to the ground water.

3.1.1 Comparison of Contaminants to ARARs/TBCs

Soil, ground water and catch basin sediment quality are considered in the identification of potential remedial actions at Site 11. The soil and ground water contaminants are evaluated separately against appropriate chemical-specific ARARs/TBCs below. No chemical-specific ARARs/TBCs were identified as being applicable to catch basin sediments. A more detailed identification and evaluation of potential chemical-specific ARARs/TBCs is presented in Appendix A.

Soil Contamination

In evaluating soil contaminant levels, available state and federal standards and guidance levels were used as ARARs/TBCs. Only a limited number of standards are applicable to soil contamination. The only identified standards and guidance levels applicable to soils were those associated with PCB and lead contamination. Therefore, these levels were used as the basis for this evaluation.

As presented in Table 3-1, TSCA includes a PCB Spill Cleanup Policy (Subpart G, 40 CFR 761.120 through 761.135) which establishes a PCB cleanup level of 10 ppm for soils to a minimum depth of 10 inches in nonrestricted access areas. This level is applicable to spills of materials containing PCBs at concentrations of 50 ppm or greater which occurred after May 4, 1987. While not applicable to Site 11, this cleanup level is to be considered in the remedial evaluation of surface soils at the site. The State of Rhode Island Department of Environmental Management (RIDEM) Rules and Regulations for Solid Waste Management Facilities define solid waste as including any soil, debris, or other material with a concentration of 10 ppm or greater PCBs, while the Rules and Regulations for Hazardous Waste Management define Type 6 - extremely hazardous waste as including waste which contains 50 ppm or greater PCBs. These definitions are also considered with respect to soil contamination at Site 11.

With respect to lead contamination, the USEPA has developed an Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02) which sets forth an interim lead soil cleanup level of 500 to 1,000 ppm, based on residential exposures. RIDEM considers a safe lead level in soil to be under 300 ppm. These guidance values will be considered in the evaluation of surface soil contamination at the site.

Table 3-1 provides a comparison of maximum detected surface soil contaminant levels to associated guidance levels. No surface soil samples collected from the Phase I RI or the Phase II RI exhibited lead or PCB concentrations which exceeded the state or federal guidance levels.

While the action levels listed in Table 3-1 may not be applicable to catch basin sediments, they do allow for a relative evaluation of sediment containment levels. No catch basin sediment samples exhibited lead or PCB concentrations at levels which exceed state or federal guidance levels. Catch basin sediment sample S-11-11-00-S, collected during the Phase I RI contained PCBs at a level of 0.87 ppm, but this level is below all applicable action levels. The maximum level of lead detected in catch basin sediments was 187 ppm, also below applicable action levels.

Ground Water Contamination

For ground water which is a potential source of drinking water, MCLs, MCLGs, state drinking water requirements or other health-based levels generally are appropriate for consideration as PRGs. Also considered in the evaluation are the Rhode Island Ground Water Quality Standards as amended by RIDEM in July 1993 for Class GAA and Class GA ground waters. For those detected contaminants for which RIDEM Maximum Contaminant Levels and Ground Water Quality Standards have been established, the standards mirror the federal MCLs.

The maximum concentrations of ground water contaminants that exceed state and federal MCLs for the Phase I and Phase II RIs are presented by well location on Figure 3-1. Table 3-2 presents a comparison of maximum detected ground water contaminant levels to associated federal and state standards and guidelines.

Of the contaminants detected in the Phase I RI ground water samples, three inorganics, lead, cadmium, and beryllium, were detected at concentrations that exceed federal and state standards. During the Phase II RI, one semi-volatile organic, bis(2-ethylhexyl)phthalate, and one inorganic, antimony, were the only ground water contaminants detected at levels which exceed the federal MCL. The disparity between the Phase I and Phase II RI inorganic results may be attributable to the low-flow sampling methodology which was used during the Phase II RI to minimize the presence of suspended solids in the sample. Therefore, the Phase I RI results may not be indicative of actual ground water quality at Site 11. The presence of bis(2-ethylhexyl)phthalate in Phase II RI ground water samples is thought to be attributable to tubing used during the low-flow sampling. The source of antimony detected during the Phase II RI in well 11-MW6D is unknown.

3.1.2 Human Health Risk-Based Considerations

As described in the National Contingency Plan [40 CFR 300.43(e)(2)(i)(A)(2)], "The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available...". The 10^{-6} starting point indicates U.S. EPA's preference for setting cleanup levels at the more protective end of the acceptable 10^{-4} to 10^{-6} risk range for Superfund remedial actions. Site-specific and remedy-specific factors are then taken into consideration in the determination of where within the 10^{-4} to 10^{-6} risk range the cleanup standard for a given contaminant will be established. For the purposes of this evaluation, preliminary remediation goals (PRGs) which correspond to a 10^{-6} risk are calculated. Site-specific and remedy-specific factors which may affect the determination of the final cleanup level will be addressed in subsequent portions of this document.

Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991a) provides additional guidance on the development of preliminary remediation goals (PRGs). One of the initial steps in development of PRGs is the identification of the most appropriate future land use for the site so that the appropriate exposure pathways, parameters and equations can be used to calculate PRGs. At Site 11, based on the Comprehensive Base Reuse Plan, the most appropriate future land use is as an economic/industrial development area. Therefore, the risk assessment scenario (Scenario 2) which evaluated risks to commercial/industrial workers based on exposures to surface soils and ground water will be used in the development of PRGs.

As a further guide to determining the media and chemicals of potential concern at a site, the OSWER directive "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (USEPA, 1991b) states that "where the cumulative site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10^{-4}, and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted unless there are adverse environmental impacts."

At Site 11, the cumulative carcinogenic risk to an individual based on reasonable maximum exposure to surface soils under the future economic/industrial development scenario does not exceed 10^{-4}, and the cumulative hazard index (HI) value does not exceed unity. Therefore, risk-based preliminary remediation goals will not be calculated for Site 11 surface soils.

For ground water, the cumulative carcinogenic risk to an individual based on reasonable maximum exposure to ground water under the future commercial/industrial site use scenario is 2×10^{-4} and the non-cancer HI value is 6. Therefore, risked-based PRGs were calculated for ground water contaminants which contribute an individual cancer risk of greater than 1×10^{-6} to the overall cancer risk estimate or which result in a non-cancer hazard quotient greater than 1 under the reasonable maximum exposure scenario for future commercial/industrial use, as presented in the human health risk assessment portion of the Phase II RI Report (TRC, 1993b), and for which an ARAR/TBC has not been identified. Arsenic and beryllium are the greatest contributors to the overall cancer risk. Since MCLs exist for these analytes, risk-based PRGs were not calculated. However, no MCL exists for manganese, the main contributor to the elevated HI value. A noncarcinogenic risked-based PRG of 510 ppb was calculated for manganese based on an HI of 1, as presented in Table 3-3. As indicated in Figure 3-2, manganese was detected in each of the five Phase I RI shallow monitoring wells and in six of the twelve Phase II RI shallow and deep monitoring wells at levels which exceed the developed risk-based PRG of 510 ppb, with a maximum concentration of 2,710 ppb detected at 11-MW3D. A more detailed discussion of the development of risk-based PRGs for Site 11 and the associated calculations are presented in Appendix B. Worthy of note in the consideration of the manganese PRG is the fact that the calculated PRG is within the concentration range detected in upgradient wells at the NCBC Davisville sites.

3.1.3 Environmental Risk-Based Considerations

As discussed in the ecological risk assessment (TRC, 1993b), Site 11 does not pose an ecological risk to aquatic or terrestrial communities in the Mill Creek Watershed based on a weight of evidence approach to risk evaluation. This conclusion is based on an evaluation of site surface soil quality, watershed sediment and surface water quality, and direct observations of the site and watershed.

Of consideration with respect to potential future impacts to the watershed is the characterization of catch basin sediments, since these sediments provide an indication of the potential impacts of surface soil runoff on sediment quality within the storm sewer system as well as an indication of potential impacts to the watershed, should the storm sewer sediments migrate from the catch basins to the watershed. To provide a preliminary evaluation of storm sewer sediment quality, catch basin sediment contaminant levels were compared to NOAA ER-L (Effects Range-Low) and ER-M (Effects Range-High) values (Long and Morgan, 1990), as presented in Table 3-4. ER-L and ER-M values represent the lower 10th percentile (ER-L) and median (ER-M) concentrations at which effects have been observed or predicted, based on Long and Morgan's evaluation. While not intended to be used as criteria by which to judge whether sediments are contaminated, ER-L and ER-M values provide initial screening criteria and may be used to assess contaminant levels in a qualitative way. Comparison of contaminant levels to ER-L and ER-M values was assessed as just one consideration in the overall evaluation of ecological risk to the Mill Creek Watershed. For instance, lead was detected in Mill Creek sediments at levels exceeding ER-M values but, in the overall weight of evidence approach to evaluating environmental risks, lead was not considered to pose a significant ecological risk. Therefore, the comparison provided in Table 3-4 is useful in providing an indication of the relative contamination of catch basin sediments at Site 11, but must be considered with respect to other available evidence of potential risk. As indicated in Table 3-4, the contaminants detected at levels exceeding ER-M values in catch basin sediment samples include total PCBs (in the one Phase I RI sediment sample), 4,4'-DDT (in one Phase I sediment sample and two Phase II sediment samples), lead (in two of three Phase II sediment samples), and zinc (in one of three Phase II sediment samples).

In general, the catch basin organic and inorganic sediment contaminant levels generally exceeded the ER-M values by no more than approximately a factor of two, with the exception of 4,4'-DDT which was detected in the Phase I RI catch basin sediment sample (S-11-11-00-S) at a level of 220 ppb (the ER-M value for 4,4--DDT is 7 ppb). It should be noted, however, that the higher end of the background range for 4,4'-DDT in surface soils at the NCBC facility, 610 ppb, exceeds the maximum detected catch basin sediment level. Therefore, although the detected 4,4'-DDT level in the catch basin sediment sample significantly exceeds the ER-M value, it is within the surface soil background range for the NCBC facility. The 4,4'-DDT level in downgradient catch basin sediment sample 11-SD03 was approximately an order of magnitude less than the level detected in sample S-11-11-00-S, and 4,4'-DDT was not detected in Mill Creek sediment samples located downgradient of Site 11. PCBs, also detected in catch basin sediment sample S-11-11-00-S, were detected at a lower concentration in the downgradient catch basin sediment sample and were not detected in downgradient Mill Creek sediment samples. Lead was the only inorganic detected at levels exceeding ER-M levels in the downgradient catch basin sediment sample. However, it was also present in the upgradient catch basin sediment sample at a level exceeding the ER-M. Surface soils at Site 11 exhibit significantly lower lead levels (maximum concentration detected was 39.3 ppm) than those detected in the catch basin sediment, further indicating that its presence may not be site-related.

3.1.4 Contaminant Migration Considerations

Another consideration in the development of remedial response objectives is the potential for contaminant migration, especially as it applies to subsurface soil contamination. Since exposures to subsurface soils are not included in the expected future use exposure scenario (future economic/industrial development use) for the site, potential leaching of subsurface contaminants to the ground water is the greatest concern with respect to subsurface soil contamination. To evaluate the potential for contaminant leaching to be a major factor in contaminant migration, the "Unnamed Model" described in Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples (USEPA, 1989a) was applied to existing site data. The unnamed model is a variation of the Summers Model, also described in the above-referenced document. Both models utilize a mass balance approach in estimating the maximum allowable soil contaminant levels, assuming that the maximum allowable ground water contaminant concentration is equal to the Maximum Contaminant Level. A detailed description of both models is provided in Appendix C. Data used in the model include the volumetric flow rate of infiltration, estimated based on known precipitation and infiltration values, and the volumetric flow rate of ground water entering the site, estimated based on information obtained during the Phase I and II RIs. Using published octanol-water partition coefficients (K_{OW}) and organic carbon soil concentrations measured during the RI, the maximum allowable concentration of a contaminant in the ground water (equal to the MCL) can be related to the maximum allowable contaminant concentration in the soil in the saturated zone. The maximum concentration of a contaminant adsorbed to the soil in the unsaturated zone can then be back-calculated using a mass-balance approach.

The calculations conducted for Site 11 are described in detail in Appendix C. When final MCLs were unavailable for COCs, proposed or tentative MCLs were utilized to allow for a broader evaluation of soil contaminants. The results of the unnamed model calculations for Site 11, as presented in Appendix C and summarized in Table 3-5, indicate that constituents detected in unsaturated surface and subsurface soil samples do not exceed the estimated maximum allowable contaminant concentration in unsaturated soils which is protective of ground water quality (based on use of the MCL as the maximum allowable ground water concentration). Only one soil sample was collected from the saturated zone during either the Phase I RI or Phase II RI for TCL/TAL analysis. Sample B-11-01-09, collected at a depth interval of 9 to 11 feet, exhibited chloroform at a level less than the maximum allowable saturated soil concentration, as indicated in Table 3-5.

Another consideration in the potential migration of contaminants from site soils is the information provided by the Toxicity Characteristic Leaching Procedure (TCLP) analyses conducted during both the Phase I and Phase II RIs on one surface and three subsurface soil samples. Of the four samples collected and analyzed for TCLP (Phase I RI samples B-11-06-02-S and B-11-06-04-S and Phase II RI samples 11-B07-02, and 11-MW14-01), no detected constituent exceeded maximum allowable TCLP levels. Therefore, the TCLP analyses support the unnamed model results in indicating that minimal leaching of contaminants from unsaturated subsurface soils could be expected, especially considering that the leaching conditions at Site 11 would be expected to be less severe than those employed in the TCLP analysis.

3.2 Remedial Action Objectives

The remedial action objectives developed to guide the implementation of a remedial response at Site 11 are presented by environmental medium below.

3.2.1 Soils

Based on the absence of soil contaminants at levels exceeding federal or state action levels, the lack of significant human health risks associated with exposures to surface soil contaminants under future commercial/industrial site use, the lack of environmental risks associated with Site 11 soil contaminants, and the lack of potential impact to ground water as indicated by the results of the leaching model evaluation, no remedial action objectives were developed for Site 11 soils.

3.2.2 Ground Water

While ground water is classified GB and would not provide a suitable potable water source, no regulatory means of preventing installation of a potable well and subsequent exposures exist. Based on the detection of contaminants at levels exceeding ARARs/TBCs and PRGs, the remedial action objective for ground water is as follows:

- Prevent exposure, due to ground water ingestion, to contaminants which are present at levels exceeding acceptable ARARs/TBCs as indicated in Table 3-2, or which exceed risk-based preliminary remediation goals as indicated in Table 3-3.

3.2.3 Catch Basin Sediment

The ecological assessment for NCBC Davisville (TRC, 1993b) concluded that Site 11 and the developed areas of NCBC Davisville in the Mill Creek Watershed do not pose an ecological risk to aquatic or terrestrial communities in the watershed. Considering that the suspected source of environmental contamination at Site 11, fire fighting training exercises, was discontinued in the mid-1950's, potential migration of catch basin sediments impacted by the historic site use would be expected to have occurred by now. While catch basin sediment samples did contain pesticides, PCBs and inorganic contaminants at levels exceeding ER-M values, no current unacceptable impacts to the receiving watershed have been identified. Considering the presence of pesticides in facility background samples at levels exceeding the catch basin sediment levels, the lack of PCBs at levels exceeding the ER-M value in the most downgradient catch basin sediment sample, the distance of the site from the point of discharge to the watershed (approximately 2,200 feet), and the lack of identification of significant existing ecological risks to the watershed, the catch basin sediments and their potential off-site migration are not expected to pose a significant risk to the watershed. Therefore, no remedial action objectives were developed for catch basin sediment at Site 11.

3.2.4 Other Considerations

A test pit was excavated during the Phase II RI and a subsurface soil sample collected to investigate whether backfill material around the storm drainage piping which passes through the site may be acting as a conduit for the migration of site-related contamination. The material surrounding the pipe was described as a black/brown fine to medium sand, with little silt. The soil sample collected at a depth of 7 feet from beneath the corrugated drainage pipe exhibited no VOCs. Detected semivolatile contaminant levels were generally less than the maximum subsurface contaminant levels detected at Site 11 and were generally within NCBC facility background ranges. 4,4'-DDD, which was not detected in other Site 11 subsurface soil samples, was detected in the test pit sample at an estimated concentration of 1.6 ppb, which also is within the NCBC facility background range. Various inorganics were also detected in the sample at levels less than the maximum levels detected in other Site 11 subsurface soil samples, with the exception of silver (0.08 ppm) and thallium (0.96 ppm). Thallium was the only inorganic detected at levels exceeded NCBC facility background ranges. Based on the detected contaminant levels and the relative lack of significant soil contamination at the site, as evidenced by the previous evaluations, the storm drainage pipe backfill material does not seem to be acting as a significant conduit for potential contaminant migration and will not be considered further with respect to remedial action objective development.

3.3 General Response Actions

General response actions are those remedial actions which will satisfy the remedial action objectives. The first step in determining appropriate general response actions for Site 11 is an initial determination of the areas or volumes to which the general response actions may be applied. In determining these volumes/areas of media, consideration has been given to site conditions, the nature and extent of contamination, acceptable exposure levels and potential exposure routes.

In order to provide a preliminary estimate of the volume of ground water requiring remediation, the extent of ground water contamination at levels exceeding ground water ARARs/TBCs and risk-based cleanup standards must be evaluated. As discussed in Section 3.1.1 and 3.1.2, inorganic constituents present in ground water samples at Site 11 exceed MCLs or risk-based PRGs. The area of ground water containing inorganics at levels exceeding MCLs and risk-based PRGs was estimated to encompass approximately 204,600 square feet. Using an estimated saturated thickness of 34.3 feet, and assuming a conservative effective porosity of 20%, the volume of ground water containing inorganics at levels exceeding MCLs or risk-based

PRGs at Site 11 is on the order of 10,500,000 gallons. The uncertainty associated with this estimate is high, based on the relative lack of detection of elevated inorganic levels during the Phase II RI, the presence of antimony at a level exceeding the MCL in a single monitoring well sample during the Phase II RI and the apparent facility-wide presence of manganese in ground water at levels exceeding the risk-based PRG.

A listing of general response actions developed for ground water at Site 11 is provided below.

- No Action
- Institutional Control
- Extraction/Treatment/Discharge

While containment was considered as a general response action within the ISA, it has not been included herein due to the lack of potential contaminant migration indicted by the leaching model and due to the variability in the depth to bedrock across the site.

3.4 Identification and Screening of Technologies and Process Options

The general response actions are developed further through the identification and screening of remedial technologies which could potentially meet the remedial action objectives and PRGs. Following a screening of the remedial technologies on the basis of technical implementability, the process options associated with each technology are screened based on effectiveness, implementability and cost. Representative process options are chosen for inclusion in the remedial alternatives developed for the sites.

While technology and process option screenings were conducted in the Initial Screening of Alternatives Report (TRC, 1993a), the screening process is re-evaluated herein based on the results of the Phase II RI and the impact of those results on the remedial action objectives for the site.

3.4.1 Technology Screening

The technology screening performed for Site 11 is presented for ground water in Table 3-6. The table includes brief descriptions of the individual technologies or process options, and comments on their technical implementability. Technologies which are screened from further consideration are shaded in the technology screening tables. More detailed descriptions of the screening process and the technologies considered are provided in Appendix D.

3.4.2 Process Option Screening

Upon identification of those technologies which are technically implementable, the process options are further evaluated to allow the selection of representative process options to be used in the development of remedial alternatives. The process options are evaluated on the basis of effectiveness, implementability, and cost. The process option screening is presented for ground water in Table 3-7. The selected representative process options are indicated with a bullet in the process option screening table. Table 3-8 summarizes the technologies and process options which passed the technology screening, with selected representative process options indicated with an asterisk. More details on the representative process option selection process are provided in Appendix D.

3.5 Remedial Alternative Development

The selected technologies and process options identified in Section 3.4.2 are combined as appropriate in this section to form remedial alternatives. The developed range of alternatives is intended to provide a streamlined evaluation of possible remedial actions. The alternatives presented herein have been developed in accordance with the expectations of the Superfund program, as outlined within the NCP. The remedial alternatives developed for ground water at Site 11 are presented in Table 3-9.

Within the Initial Screening of Alternatives Report (TRC, 1993a), no soil remedial alternatives were developed due to the lack of soil contamination indicated by Phase I RI data for Site 11. The Phase II RI data have supported this approach. Ground water remedial alternatives were developed within the ISA based on the presence of inorganics at levels which exceeded ARARs/TBCs and which presented unacceptable risks. Therefore, the ground water remedial alternatives presented within this report have been developed on the basis of the initial evaluation presented within the ISA Report with the incorporation of Phase II RI data. All developed alternatives undergo a detailed analysis herein.

4.0 DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

Each of the remedial alternatives developed for the site, as presented in Section 3.5, is further defined and then undergoes a detailed analysis. Following the detailed analysis of individual alternatives, a comparative analysis is conducted between alternatives.

4.1 Evaluation Criteria

The NCP defines nine evaluation criteria to be considered in the detailed analysis of alternatives. The evaluation criteria are divided into three groups; threshold criteria, which relate to statutory requirements that each alternative must satisfy; balancing criteria, which are the technical criteria that are considered during the detailed analysis; and modifying criteria, which are formally assessed after the public comment period. The nine criteria include the following:

Threshold Criteria

- Overall protection of human health and the environment;
- Compliance with applicable or relevant and appropriate requirements (ARARs);

Balancing Criteria

- Long-term effectiveness and permanence;
- Reduction of toxicity, mobility, or volume through treatment;
- Short-term effectiveness;
- Implementability;
- Cost;

Modifying Criteria

- Community acceptance; and
- State acceptance.

When evaluating alternatives in terms of overall protection of human health and the environment, consideration is given to the manner in which site-related risks are eliminated, reduced, or controlled through treatment, engineering controls, or institutional controls. Long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs are given major consideration in determining the overall protection offered by each alternative.

The alternatives are assessed to determine whether they attain applicable or relevant and appropriate requirements (ARARs) under federal environmental laws and state environmental laws and state environmental or facility siting laws. The identification of ARARs in a site-specific process which is dependent on the specific hazardous substances, pollutants, and contaminants at a site, the physical characteristics of a site, and the remedial actions under consideration at a site. Therefore, it is an iterative process which requires re-examination throughout the RI/FS process, until a Record of Decision (ROD) is issued. A preliminary ARARs analysis is presented in Appendix A of this document. In the following alternative analysis, the individual remedial alternatives will be evaluated in detail to determine their compliance with ARARs/TBCs which are applicable to the specific media being addressed by the remedial action, and the potential impacts of ARARs/TBCs on the alternative's implementation.

An alternative that does not meet an ARAR may be selected as a remedial action under several circumstances, including the following:

- If the alternative is an interim measure and will become part of a total remedial action that will attain the applicable or relevant and appropriate federal or state requirement;
- If compliance with the requirement will result in greater risk to human health and the environment than other alternatives;
- If compliance with the requirement is technically impracticable from an engineering perspective;
- If the alternative will attain an equivalent standard of performance through the use of another method or approach; or
- If the ARAR is a state requirement that the state has not consistently applied in similar circumstances.

Each alternative is also evaluated for long-term effectiveness and permanence, in which the magnitude of residual risk remaining from untreated waste or treatment residuals and the adequacy and reliability of containment systems and institutional controls is evaluated. The degree to which alternatives employ recycling or treatment to reduce toxicity, mobility, or volume is assessed, including how treatment is used to address the principal threats at the site.

The short-term effectiveness evaluation takes into consideration the short-term risks that might be posed to on-site workers, the surrounding community, or the environment during implementation, as well as the time until protection is achieved. The analysis of implementability considers the technical feasibility and administrative feasibility of implementation, as well as the availability of required materials and services. The cost analysis evaluates capital (direct and indirect) costs and annual operation and maintenance (O&M). The net present value of capital and O&M costs is presented for each alternative.

In selecting a remedial action, the following criteria must be considered. Each selected remedial action shall meet the threshold criteria, and thereby be protective of human health and the environment. Provided the remedy meets the threshold criteria, it shall also be cost effective. The overall effectiveness of an alternative is determined by evaluating long-term effectiveness and permanence, reduction of toxicity, mobility, or volume through treatment, and short-term effectiveness. The alternative is then evaluated with regard to cost to ensure that it is cost-effective. Each remedial action shall also utilize permanent solutions and alternative treatment technologies to the maximum extent practicable. This requirement is fulfilled by selecting the alternative that satisfies the threshold criteria and provides the best balance of trade-offs among alternatives in terms of the five balancing criteria, with an emphasis on long-term effectiveness and reduction of toxicity, mobility, and toxicity through treatment.

4.2 Ground Water Alternative Individual Descriptions and Evaluations

Three ground water remedial alternatives were developed, as described below.

4.2.1 Alternative 1 - No Action Alternative Description

The NCP requires consideration of the no-action alternative; at a minimum, it provides a baseline for comparison with other alternatives. This alternative would involve no remedial response activities with respect to ground water. No removal or treatment of ground water which contains lead at levels exceeding the drinking water action level or manganese at levels exceeding the risk-based PRG would be conducted. Because remaining contamination would not allow for unlimited future use of the site (i.e., potable ground water use), five-year reviews of the no action decision would be required.

An evaluation of the no action alternative with respect to federal and state chemical-specific ARARs/TBCs is presented in Table 4-1. No location-specific ARARs were identified for Site 11. Since the alternative involves no actions, no action-specific ARARs/TBCs were identified for this alternative.

4.2.2 Alternative 1 - No Action Alternative Evaluation

Overall Protection of Human Health and the Environment - The no action alternative does not address antimony and manganese, which would remain in the ground water on-site at levels exceeding ARARs and PRGs. However, based on the site's GB ground water classification, the exceedance of the antimony action level in one deep well during the Phase II RI, the presence of manganese in upgradient wells at all of the Phase II RI sites, and the lack of unacceptable environmental risks within the downgradient Mill Creek Watershed, the lack of ground water treatment would not be expected to result in significant risks to human health and the environment unless a potable water supply well was installed at the site. This alternative does not limit future use of the site, and therefore does not limit the potential for future exposures due to changes in site use (e.g., installation of a potable well on-site). Should ground water in the site area ever be considered for potable use, protection of human health may not be provided under the no action alternative. This alternative is not expected to result in adverse impacts to the environment, based on the current lack of significant environmental risks associated with metals in the Mill Creek Watershed. Implementation of this alternative results in no short-term impacts to the site, but does not meet remedial action objectives.

Compliance with ARARs - Based on the presence of antimony at a level exceeding the antimony MCL in a deep well during the Phase II RI, this alternative would not meet chemical-specific ARARs, as listed in Table 4-1. No action-specific or location-specific ARARs/TBCs were identified for this alternative.

Long-Term Effectiveness and Permanence - The no action alternative would be effective in the long-term provided ground water is not used as a drinking water supply. Potential impacts to the environment are not expected based on the current lack of significant environmental risks attributable to metals within the Mill Creek Watershed. Due to the presence of antimony and manganese at levels which do not allow for unrestricted ground water use, five-year reviews of the no action decision would be required under the NCP.

Reduction of Toxicity, Mobility, or Volume through Treatment - The no action alternative does not include any treatment methods other than naturally occurring degradation or attenuation processes. Therefore, the alternative offers no significant reductions in the toxicity, mobility, or volume of inorganic ground water contaminants through treatment.

Short-Term Effectiveness - The no action alternative does not present any increased short-term risks due to the lack of activities associated with its implementation. The five-year reviews would provide the only means of ensuring continued compliance with remedial action objectives.

Implementability - The no action alternative would require no implementation other than the five-year reviews of the no action decision. Its implementation would not limit the future implementation of additional remedial actions.

Cost - The cost associated with the no action alternative would be the nominal cost associated with the five-year reviews.

4.2.3 Alternative 2 - Limited Action Alternative Description

Alternative 2 consists of the institution of ground water use restrictions and/or ground water monitoring. Ground water use restrictions would provide no active ground water remediation but would limit potential risks to human health through the implementation of institutional controls, such as deed restrictions, to limit future potable ground water use on site. While ground water at Site 11 is classified as GB and is expected to have no value as a potable water source, there is no regulatory mechanism which limits the potential installation of a drinking water supply well at the site. Therefore, deed restrictions may be appropriate.

Long-term (30-year) ground water monitoring, consisting of annual monitoring of the existing monitoring wells, is included in the limited action alternative. The long-term monitoring would provide a means of further defining ground water quality at the site and of identifying any ground water quality changes over time. The proposed monitoring time frame (30 years) could be reduced if subsequent monitoring indicates that ground water quality is acceptable, given regional conditions.

An evaluation of Alternative 2 with respect to federal and state chemical-specific ARARs/TBCs is presented in Table 4-1. No location-specific ARARs were identified for Site 11. Action-specific ARARs/TBCs are presented in Table 4-2.

4.2.4 Alternative 2 - Limited Action Alternative Evaluation

Overall Protection to Human Health and the Environment - Implementation of the limited action option would protect human health by limiting potential future exposures to inorganics in the ground water which could occur should a drinking water supply well be installed on site. This alternative is not expected to result in adverse impacts to the environment, based on the current lack of significant environmental risks associated with metals in the Mill Creek Watershed. Ground water monitoring would provide a means of identifying changes in ground water quality and potential resultant impacts to the environment. While this alternative would not provide compliance with drinking water standards through treatment, it would prevent the development of a ground water ingestion exposure pathway.

Compliance with ARARs - Based on the presence of antimony at a level exceeding the MCL in a single deep well during the Phase II RI, this alternative would not achieve chemical-specific ARARs, as listed in Table 4-1. However, continued ground water monitoring would confirm the presence of antimony on-site at levels exceeding the MCL. No location-specific ARARs/TBCs were identified for Site 11. Ground water monitoring would be conducted in accordance with RIDEM's Rules and Regulations for Ground Water Quality, as indicated in Table 4-2.

Long-Term Effectiveness and Permanence - Provided deed restrictions are enforced, they can be effective in minimizing the long-term risks associated with the potential construction and use of an on-site well as a source of drinking water. Since contaminants will remain on site at levels which do not allow for unlimited use and unrestricted exposure, five-year reviews of Alternative 2 would be required. The monitoring program would provide a means of monitoring potential changes in ground water quality. If monitoring indicated that ground water quality was deteriorating, additional remedial measures could be implemented.

Reduction of Toxicity, Mobility or Volume through Treatment - Alternative 2 provides no treatment nor associated reduction of contaminant toxicity, mobility or volume.

Short-Term Effectiveness - Since implementation of deed restrictions is an administrative effort, no short-term risks would result from implementation of this option. This option would meet remedial response objectives related to minimizing potential human exposure to contaminated ground water due to on-site potable water supply well installation. Implementation of the monitoring program would have minimal short-term adverse impacts based on the use of existing wells for ground water monitoring purposes.

Implementability - Deed restrictions would have to be implemented as part of the base closure property transfer process. Deed restrictions limiting future installation of on-site potable wells would not be expected to prevent future commercial/industrial use of the site. Similarly, implementation of deed restrictions or ground water monitoring would not limit the implementation of future remedial actions.

Cost - The costs associated with the implementation of deed restrictions would primarily be limited to legal costs and could be incorporated into the base closure property transfer process. The costs associated with ground water monitoring include the long-term sampling, analysis and reporting costs. The overall cost includes $12,000 in annual operation and maintenance costs ($190,000 net present value). The present worth value of this alternative, including contingency, is estimated at $220,000. A detailed cost estimate is provided in Appendix E.

4.2.5 Alternative 3 - Extraction/Treatment/Discharge Alternative Description

Alternative 3 consists of active remediation of the ground water to meet chemical-specific ARARs and risk-based PRGs. The alternative would provide hydraulic control of the ground water at the site, thereby reducing potential off-site migration, but would not address the source of the antimony detected in the deep well or the presence of manganese in ground water throughout the facility.

The extraction/treatment/discharge alternative would consist of separate options which would be combined to form a complete alternative. These options are described in detail in Sections 4.2.7 through 4.2.14. This discussion and the evaluation presented in Section 4.2.6 focus on the extraction/treatment/discharge alternative in general terms, and will provide a basis for alternative comparisons.

The main contaminants of concern are manganese and antimony. The results of the Phase I RI ground water sampling also indicate the presence of beryllium, cadmium, and lead at levels exceeding the MCLs or drinking water action levels. However, during the Phase II RI, in which the low flow sampling methodology was used to minimize the presence of suspended sediments in the samples, beryllium, cadmium, and lead were not detected above the MCL/action level in any of the Phase II monitoring wells. Therefore, the evaluation of the extraction/treatment/discharge options will focus on the treatment of manganese and antimony.

Antimony was detected at a level exceeding the MCL of 6 ppb in one deep well sampled during the Phase II RI. Although antimony contamination was detected in only one well, it will still be considered in the evaluation of the extraction/treatment/discharge options.

Manganese, the other inorganic contaminant of concern, was present in each of the five wells sampled during the Phase I RI at levels exceeding the risk-based PRG, and was present in six of the wells (including the upgradient well) sampled during the Phase II RI at levels exceeding the PRG. Treatment of manganese will be considered in the evaluation of extraction/treatment/discharge options. However, as previously discussed in Section 3.1.2, the manganese PRG is within the range of manganese concentrations detected in upgradient wells at all of the Davisville sites and, therefore, manganese is not considered to be a site-related contaminant.

An evaluation of Alternative 3 and its associated options with respect to federal and state chemical-specific and action-specific ARARs/TBCs is presented in Tables 4-3 and 4-4, respectively. No location-specific ARARs were identified for Section 11.

4.2.6 Alternative 3 - Extraction/Treatment/Discharge Alternative Evaluation

Overall Protection of Human Health and the Environment - Alternative 3 would provide active treatment of ground water at Site 11 and therefore, would provide a reduction in potential future risks to human health and the environment which could be associated with ground water ingestion or contaminant migration. Its long-term effectiveness would be good as long as the treatment system was operational. If treatment was discontinued, however, manganese could return to the site based on the presence of manganese in the upgradient well. The extraction/treatment/discharge options would be designed to comply with action-specific ARARs/TBCs.

Compliance with ARARs - Alternative 3 would be designed to treat ground water contaminants present at levels exceeding chemical-specific ARARs, as indicated in Table 4-3. The treatment system would also be required to comply with chemical-specific discharge criteria, also listed in Table 4-3. The extraction, treatment and discharge systems would be operated in accordance with action-specific ARARs as indicated in Table 4-4. A more detailed identification of the action-specific ARARs applicable to this alterative is provided in the individual option evaluations which follow.

Long-Term Effectiveness and Permanence - Ground water treatment would be effective in treating inorganic contaminants which exceed ARARs or risk-based PRGs and in preventing off-site migration of these contaminants during operation but would not necessarily result in a permanent contaminant reduction if ground water treatment is discontinued at some point in the future. Long-term ground water monitoring would be required to evaluate the effectiveness of the alternative after operations cease. Since contaminants would be present on-site during the operating period at levels which do not allow for unlimited use and unrestricted exposure, five-year reviews of Alternative 3 would be required.

Reduction of Toxicity, Mobility or Volume through Treatment - Alternative 3 would utilize treatment to reduce the toxicity and mobility of existing ground water contaminants.

Short-Term Effectiveness - No significant risks to on-site workers or off-site risks are anticipated as a result of implementation of this alternative. The degree of short-term risk would be dependent upon the individual options employed. Remedial response objectives would be achieved during operation of the treatment system but may not be maintained if treatment is discontinued.

Implementability - Implementation of a ground water extraction, treatment, and discharge system would be relatively easy, with the possible exception of the discharge component. The technical implementability would be dependent upon the individual alternative options selected, with some treatment technologies more easily implemented than others. Services and materials should be readily available for the implementation of all options.

<u>Cost</u> - The cost of this alternative is dependent on the operational period as well as the individual options utilized in the final alternative. Based on the individual option evaluations presented in the following sections, the total cost of Alternative 3 is estimated to range from $1,000,000 for electrochemical reduction to $1,500,000 for precipitation.

4.2.7 Alternative 3A - Ground Water Extraction via Interceptor Trench and Extraction Wells Option Description

A combined extraction system consisting of an interceptor trench and ground water extraction wells would be an effective means of extracting shallow and deep ground water at Site 11. Ground water modeling was conducted to determine optimum trench and well locations and designs. Modeling efforts are presented in Appendix F. The computer ground water flow model MODFLOW was used to simulate the shallow and deep ground water flow regimes and to design the proposed shallow and deep ground water extraction systems. Based on the modeling results, one trench would be installed for shallow ground water extraction in the southwest portion of the site, stretching from the northwest to the southeast. The proposed trench location would be placed along the downgradient portion of the site, as shown on Figure 4-1. The trench would be approximately 280 feet long, 3 to 4 feet wide, and 14 feet deep. The drain itself would consist of a perforated pipe placed at an incline within a trench. The trench would be filled with a highly-permeable gravel up to a depth of 4 feet below grade. Prior to backfilling with the gravel, the trench would be lined with a geotextile fabric filter to prevent silt from clogging the drain. Excavated soil would be backfilled above the gravel layer. The ground water would flow by gravity into and through the pipe to pre-cast manhole sumps where it would be lifted by means of a submersible pump to the surface for treatment. Ground water would be extracted at a rate of approximately 3.5 gpm from the trench.

The interceptor trench would be supplemented by two deep extraction wells, located in the southwestern portion of the site, to provide capture of the antimony detected in well 11-MW6D and the manganese detected in wells 11-MW3D and 11-MW9D. The extraction wells would each be approximately 43 feet deep, screened over the lower 30 feet. Ground water would be extracted from the two wells at a total combined rate of approximately 1 gpm.

The combined extraction rate would be 4.5 gpm, although for ground water treatment alternative evaluations, a maximum treatment rate of 10 gpm has been assumed. It has also been assumed that the ground water extraction system would operate for a period of thirty years, which would allow for the removal of a minimum of seven pore volumes.

Also incorporated into this alternative is the installation and monitoring of piezometers, to evaluate the effectiveness of the interceptor trench. The installation of six piezometers, three upgradient and three downgradient of the interceptor trench, has been assumed for this evaluation.

4.2.8 Alternative 3A - Ground Water Extraction via Interceptor Trench and Extraction Wells Option Evaluation

Overall Protection of Human Health and the Environment - Use of a combined extraction system consisting of an interceptor trench and extraction wells to remove ground water for treatment would be protective of both human health and the environment. Ground water would be pumped from the interceptor trench and extraction wells and piped directly to an on-site treatment system. The extraction system would be effective and reliable in the long-term and would have minimal short-term risks associated with its installation and operation.

Compliance with ARARs - The proposed ground water extraction system has been developed to capture ground water containing antimony at levels exceeding drinking water action levels and manganese at levels exceeding PRGs. Therefore, it has been developed to provide compliance with chemical-specific ARARs, as presented in Table 4-3. Extraction would be implemented in accordance with RIDEM Site Remediation Regulations, as indicated in Table 4-4.

Long-Term Effectiveness and Permanence - The combined extraction system would be an effective and reliable means of extracting ground water at Site 11. Both interceptor trenches and extraction wells are well-proven in their performance and can function with minimal maintenance.

Reduction of Toxicity, Mobility or Volume through Treatment - The ground water extraction option does not provide treatment although it would be combined with a treatment option in a final alternative. By extracting contaminated ground water, the potential mobility of ground water contaminants is reduced.

Short-Term Effectiveness - Installation of an interceptor trench and extraction wells would present minimal short-term risks to on-site workers and would not be expected to result in any increased off-site risks to human health or the environment. The installation could be implemented within a minimal time frame.

Implementability - The implementability of a ground water extraction system is expected to be good. Materials and services are readily available and minimal technical or administrative obstacles to implementation would be anticipated.

Cost - The major cost component associated with implementation of Alternative 3A is the cost of installation of the interceptor trench and extraction wells. The estimated cost of Alternative 3A consists of $55,000 in direct capital costs, $7,800 in indirect capital costs, and $4,800 in annual operation and maintenance costs ($74,000 net present value). The present worth value of this alternative, including contingency, is estimated at $160,000. A detailed cost estimate is presented in Appendix E.

4.2.9 Alternative 3B - Precipitation Inorganic Treatment Option Description

Alternative 3B involves the treatment of inorganic ground water contaminants using chemical reduction and precipitation. Chemical precipitation is an inorganic removal method often used in industrial as well as ground water remediation applications.

For this evaluation, it is assumed that the chemical precipitation treatment system will include a filtration unit to remove gross solids prior to treatment and a flow equalization tank. The provision of an initial filtration system could result in reduced reagent costs and smaller equipment sizing for the remainder of the treatment system. A typical precipitation system includes the following:

- Reaction tank including mixers and pH control instrumentation;
- Chemical feed system, including a storage tank, mixers, level instrumentation, and metering equipment;
- Clarifier;
- pH adjustment tank;

Filter; and
Solidification/stabilization system.

A schematic of a typical system is provided on Figure 4-2.

The extracted ground water flows from the filtration system, through the equalization tank, and into the reaction tank. In the reaction tank, a reagent is added to adjust the pH of the wastestream to the level required for optimum precipitation. The selection of an applicable precipitation reagent is dependent upon the flow rate, pH, pollution loading, and waste/reagent compatibility.

Following the reaction tank, a flocculent such as anionic or cationic polymer is added and the solution flocculated to aid in the settling of the metal precipitate. In the clarifier, flow is decreased to the point where solids with a specific gravity greater than that of the liquid settle to the bottom. The supernatant is drawn off and discharged to a pH adjustment tank for neutralization. The solids are discharged to a holding tank for subsequent dewatering. Dewatering is accomplished using mechanical dewatering equipment such as a filter press. Once dewatered, the sludge is stabilized prior to off-site landfill disposal in accordance with federal and state disposal requirements.

Little data is available on the removal of antimony from water (Sittig, 1976), although removal using lime precipitation has been reported (Palmer, et.al., 1988). Manganese can also be removed at a pH above 9.4 using lime soda type treatment. Removal of manganese generally results in the simultaneous removal of iron, since the conditions under which high soluble iron levels occur are essentially the same as those for soluble manganese.

4.2.10 Alternative 3B - Precipitation Inorganic Treatment Option Evaluation

Overall Protection of Human Health and the Environment - Option 3B is expected to provide overall protection of human health and the environment through treatment of inorganic ground water contaminants. The long-term effectiveness and permanence and short-term effectiveness are expected to be good, and the system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs - The ability of a chemical precipitation treatment system to treat inorganics such as antimony and manganese is expected to be good. Treatment system operation would be conducted in compliance with action-specific ARARs, as listed in Table 4-4. Chemical precipitation generates a sludge which requires subsequent disposal off-site. If the sludge is characterized as a hazardous waste, federal RCRA hazardous waste generator and transporter requirements as well as state hazardous waste management regulations will be followed in the handling of the sludge. If not hazardous, the residuals would be handled in accordance with state solid waste management regulations. The treatment system would be required to treat the inorganic contaminants sufficiently to meet the applicable discharge requirements, also listed in Table 4-4.

Long-Term Effectiveness and Permanence - The long-term risks associated with chemical precipitation will be minimal based on the system's ability to treat antimony and manganese contamination. However, the treatment system does produce a sludge that will require hazardous waste characterization and appropriate disposal. Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties.

Reduction of Toxicity, Mobility or Volume Through Treatment - This alternative will provide a reduction in the toxicity of identified inorganic ground water contaminants through treatment. The volume of contaminated media is reduced through removal of contaminants from the ground water and subsequent production of a concentrated sludge residual.

Short-Term Effectiveness - Short-term risks to workers under Alternative 3B are not expected to be significant. Maintenance of chemical supplies and sludge handling are the major operation and maintenance activities associated with the chemical precipitation system. No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation.

Implementability - A chemical precipitation system should be easily implemented. Start-up is not expected to result in unanticipated technical problems. Its implementation is not expected to impact the implementation of any future remedial actions. Operational activities include maintenance of the chemical supplies and sludge handling. Administrative feasibility is also expected to be good.

Cost - The major costs associated with the precipitation treatment system are the capital costs associated with the construction of a chemical precipitation unit and associated operation and maintenance costs, including chemical supply costs. The overall estimated cost includes

$130,000 in direct costs, $26,000 in indirect capital costs, and $54,000 in annual operation and maintenance costs ($830,000 net present value). The present worth value of this alternative, including contingency, is estimated at $1,200,000. A detailed cost estimate is provided in Appendix E.

4.2.11 Alternative 3C - Electrochemical Inorganic Treatment Option Description

Alternative 3C consists of on-site treatment of inorganic ground water contaminants using an electrochemical treatment system. Electrochemical treatment is an inorganic removal method which is often used in industry although it has not been widely applied to ground water treatment. Treatability studies conducted at other sites have shown electrochemical treatment to be effective in the removal of many inorganics, including arsenic, beryllium, cadmium, chromium, cyanide, mercury, nickel, lead, antimony, selenium, vanadium, and silver (Andco, 1992). Effluent levels ranging from non-detectable to less than 50 ppb were commonly achieved in these studies.

In the electrochemical treatment process, an electric current passing through a sacrificial electrode generates ferrous ions (Fe^{+2}) within the wastewater stream. The ferrous ions then act as a reducing agents for oxidized heavy metals species. The electric current also causes water to break down at the cathode, forming hydrogen gas and hydroxyl ions. The reaction results in the formation of ferric hydroxide and insoluble metal hydroxides which are then removed by adsorption onto the iron hydroxide precipitate that is formed.

A process flow diagram of an electrochemical reduction process offered by Andco Environmental Processes, Inc. is provided in Figure 4-3. Influent enters an equalization tank where, if necessary, the pH is adjusted to a neutral level. The water then passes through an electrochemical cell, where ferrous ions, hydroxide ions and hydrogen are produced. After exiting the electrochemical cell, the treated water containing the iron/metal hydroxide matrix enters a degassing tank, where the hydrogen gas is allowed to effervesce from the liquid. Next the liquid enters a pH adjustment tank where the pH is adjusted and hydrogen peroxide is added to facilitate the oxidation of residual ferrous ions (Fe^{+2}) to ferric ions (Fe^{+3}) which precipitate as ferric hydroxide. The solution then enters a clarifier where a polyelectrolyte is added to promote flocculation/coagulation of the insoluble hydroxides. After settling out, the solids are dewatered within a filter press.

To remove small amounts of the floc that exit the clarifier, the effluent may be further treated within a multi-media filtering system. In such a system, the effluent passes through a mix of media, where remaining particles down to 10 microns in size are removed.

4.2.12 Alternative 3C - Electrochemical Inorganic Treatment Option Evaluation

Overall Protection of Human Health and the Environment - Alternative 3C would provide overall protection of human health and the environment when combined with ground water extraction and discharge. The long-term effectiveness and permanence of this option are expected to be good and the treatment system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs - An electrochemical removal system is expected to be able to treat the inorganics of concern. Treatment system operation would be conducted in compliance with action-specific ARARs, as listed in Table 4-4. An iron hydroxide precipitate would be formed by the treatment process which would require off-site disposal/treatment. If the precipitate was characterized as a hazardous waste, it would be handled in accordance with the applicable federal and state hazardous waste management regulations. If not hazardous, it would be handled in accordance with state solid waste management regulations. The treatment system would be required to treat the inorganics contaminants sufficiently to meet the applicable discharge requirements, also listed in Table 4-4.

Long-Term Effectiveness and Permanence - Electrochemical treatment has been widely proven in industrial wastewater treatment, with fewer applications in contaminated ground water treatment. Treatability studies would be required to verify the effectiveness of the process in meeting discharge criteria. The long-term effectiveness of this alternative is expected to be good. Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties.

Reduction of Toxicity, Mobility or Volume through Treatment - This alternative will provide a reduction in the toxicity of inorganic ground water contaminants through treatment. The volume of contaminated media is reduced through the removal of the inorganics from the ground water and subsequent production of a concentrated iron hydroxide precipitate that would require disposal.

Short-Term Effectiveness - Short-term risks to workers under this alternative are not expected to be significant. Maintenance of electrodes and precipitate handling are the main operation and maintenance activities associated with the electrochemical treatment system. No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation.

Implementability - The implementability of this alternative good, although it requires construction of an additional on-site treatment facility and is limited by the number of available vendors which provide the treatment system. Start-up is not expected to result in any unanticipated technical problems. Its implementation is not expected to impact the implementation of any future remedial actions. Operational activities include maintenance of the electrodes and precipitate handling. Administrative feasibility is also expected to be good.

Cost - The major costs associated with the electrochemical treatment system are the capital costs associated with the construction of an electrochemical unit. The overall estimated cost includes $150,000 in direct costs, $30,000 in indirect capital costs, and $24,000 in annual operation and maintenance costs ($380,000 net present value). The present worth value of this alternative, including contingency, is estimated at $670,000. A detailed cost estimate is provided in Appendix E.

4.2.13 Alternative 3D - Discharge to Surface Water Option Description

Alternative 3D involves the discharge of treated ground water to surface water, which in this case would be a tributary of Mill Creek. The discharge would be piped from the site to the discharge location, an approximate distance of 2,200 feet south-southwest of the site. The discharge rate would be equal to the extraction rate, estimated at 4.5 gpm. Implementation of discharge to the surface water is expected to have little, if any, effect on the ground water extraction and treatment system.

4.2.14 Alternative 3D - Discharge to Surface Water Option Evaluation

Overall Protection of Human Health and the Environment - Alternative 3D would provide overall protection of human health and the environment when combined with ground water extraction and treatment. The long-term effectiveness and permanence of this option are expected to be good, due to its simplicity, and the treatment system would be operated in compliance with ARARs/TBCs.

Compliance with ARARs/TBCs - The water quality of the treatment process effluent would be required to comply with state and federal surface water discharge criteria, including ambient water quality criteria as listed in Table 4-3 and surface water discharge regulations listed in Table 4-4.

Long-Term Effectiveness and Permanence - The long-term risks associated with the discharge to surface water will be minimal, provided the treatment system is operating properly. Long-term operation and maintenance of the discharge piping is not expected to pose any major technical problems. Long-term monitoring of the discharge water quality will be required.

Reduction in Toxicity, Mobility or Volume through Treatment - This alternative is not expected to significantly impact the extraction or treatment system; therefore, it has little impact on the toxicity, mobility or volume of contamination.

Short-Term Effectiveness - Short-term risks to workers under this alternative are not expected to be significant, involving only the construction of the discharge piping. Maintenance of the system will require maintenance of the piping and discharge monitoring. No significant added risks to the adjacent community or the environment are anticipated.

Implementability - The technical implementation of a discharge to surface water system is affected by the distance to a discharge point. The estimated distance to a tributary of Mill Creek from Site 11 is approximately 2,200 feet to the south-southwest. Maintenance of the system will be limited. Continued monitoring of the discharged water quality will be required. The administrative feasibility of discharging treated ground water to surface water depends on the treatment system's ability to meet surface water discharge criteria.

Cost - The major costs associated with Alternative 3D are the on-going maintenance and discharge monitoring costs associated with its implementation. The overall estimated cost includes $26,000 in direct capital costs, $3,600 in indirect capital costs, and $7,400 in annual operation and maintenance costs ($110,000 net present value). The present worth value of this alternative, including contingency, is estimated at $170,000. A detailed cost estimate is provided in Appendix E.

4.3 Ground Water Alternative Comparative Evaluation

A comparative analysis of the ground water alternatives is conducted to evaluate the significant differences between the alternatives based on the threshold and balancing criteria. Tables 4-5 through 4-12 comparatively summarize the alternative evaluations conducted strictly on the basis of ground water considerations for each of the evaluation criteria.

4.3.1 Overall Protection of Human Health and the Environment

A comparative analysis of the remedial alternatives with respect to their overall protection of human health and the environment is presented in Table 4-5.

The no action alternative would be considered protective of human health under the proposed future commercial/industrial site use scenario provided ground water is not utilized for potable use. However, Alternative 1 would not provide a means of limiting future use of the site, and therefore does not limit the potential for future installation of a potable well on-site. Therefore, remedial action objectives are not met.

Alternative 2 also provides protection of human health and the environment under the proposed commercial/industrial site use. In addition, Alternative 2 would also provide future protection of human health and the environment by applying deed restrictions which would not allow the future installation of a potable well on-site.

Alternative 3, ground water extraction/treatment/discharge, would provide the greatest degree of overall protection of human health and the environment through its active remediation of ground water contamination; however its permanence once treatment is discontinued is not ensured. For the treatment options evaluated under this alternative, both options provided relatively comparable protection of human health and the environment. The extraction and discharge options would also be protective of human health and the environment.

4.3.2 Compliance with ARARs

A comparative analysis of the remedial alternatives with respect to their compliance with ARARs is presented in Table 4-6.

Alternatives 1 and 2 would not comply with chemical-specific ARARs since neither alternative provides for the treatment of contaminated ground water. By providing direct remediation of contaminated ground water, Alternative 3 would achieve chemical-specific ARARs. The precipitation and electrochemical reduction options would be effective in meeting chemical-specific ARARs. However, long-term maintenance of reduced levels for these contaminants is not guaranteed once operation of the treatment system is discontinued.

Alternative 2 and Alternative 3 would be implemented in accordance with action-specific criteria. No location-specific ARARs/TBCs were identified which apply to Site 11.

4.3.3 Long-Term Effectiveness and Permanence

A comparative analysis of the remedial alternatives with respect to long-term effectiveness and permanence is presented in Table 4-7.

Alternative 2 would be expected to be effective in the long-term. The limited action alternative would provide a means of monitoring the site over the long-term to identify any changes in ground water quality and would limit the potential for future use of the ground water as a potable water supply. The extraction, treatment, and discharge options are all expected to be effective in the long-term. Both the precipitation (Alternative 3B) and electrochemical reduction (Alternative 3C) options are effective and easily operated and maintained. However, after treatment operations cease, ground water monitoring would be required to evaluate the permanence of Alternative 3. The no action alternative offers the least long-term effectiveness and permanence.

4.3.4 Reduction of Toxicity, Mobility and Volume through Treatment

A comparative analysis of the remedial alternatives with respect to reduction of toxicity, mobility and volume through treatment is presented in Table 4-8.

Alternative 3 is the only alternative which provides for a reduction in contaminant toxicity, mobility, and volume through treatment. Alternatives 1 and 2 provide no reduction in toxicity, mobility, or volume through treatment.

4.3.5 Short-Term Effectiveness

A comparative analysis of the remedial alternatives with respect to short-term effectiveness is presented in Table 4-9.

Alternative 2 is the most effective alternative in the short-term, providing a means of monitoring compliance with remedial action objectives but resulting in no increase in short-term risks. The limited action alternative allows for the long-term monitoring of ground water and meets remedial action objectives with respect to minimizing future human exposures to contaminated ground water. Alternative 1 also poses no increased short-term risks, but does not ensure compliance with remedial action objectives.

Alternative 3 also provides a means of complying with remedial action objectives within a short time frame with minimal risk incurred. The precipitation (Alternative 3B) option could be more effective in the short-term since the treatment process may be more readily available than electrochemical treatment (Alternative 3C). Both options would require the handling of residual waste materials. Both ground water extraction (Alternative 3A) and discharge to surface water (Alternative 3D) could be quickly implemented and effective in the short-term.

4.3.6 Implementability

A comparative analysis of the remedial alternatives with respect to implementability is presented in Table 4-10.

Alternative 1 would be the most implementable since it requires no action other than five-year reviews. Alternative 2 would be next in terms of implementability, requiring initiation of long-term monitoring and deed restrictions but no on-site construction activities. Neither Alternative 1 nor 2 would limit the implementation of other remedial actions at the site.

Alternative 3 would require the disruption of the site for implementation. However, none of the options of Alternative 3 would pose difficulty in implementation. For Alternative 3, precipitation (Alternative 3B) would be easily implemented due to its commercial availability.

Electrochemical reduction (Alternative 3C) may be more difficult to implement due to its somewhat limited commercial availability. Ground water extraction (Alternative 3A) and discharge to surface water (Alternative 3D) would both be easily implemented.

4.3.7 Cost

A comparative analysis of the remedial alternatives with respect to cost is presented in Table 4-11.

The no action alternative is the least costly alternative, with the only cost being the nominal cost associated with five-year reviews. Alternative 2 follows, with a total estimated present worth cost of $220,000. Alternative 3 would be the most costly. The total estimated present worth cost for combined ground water extraction/treatment/discharge ranges from $1,000,000 (electrochemical reduction) to $1,500,000 (chemical precipitation). The present worth costs for individual options include: $160,000 for extraction (Alternative 3A); $1,200,000 for chemical precipitation (Alternative 3B); $670,000 for electrochemical reduction (Alternative 3C); and $170,000 for discharge to surface water (Alternative 3D).

4.4 Sensitivity Analysis

A sensitivity analysis was conducted to assess the effect that variations in specific assumptions made during alternative development and assessment could have on the total estimated remedial cost. The main uncertainty factors which are applicable to the remedial alternatives and associated options are the uncertainties associated with the discount factor over the life of the remedy and over the remediation period for the ground water treatment alternatives. The resultant impacts to remedial costs are summarized in Table 4-12.

The discount rate can vary from the 5% rate used in the cost evaluation. Alternatives with large O&M cost components and extended remedial periods can be significantly impacted by a variation in the discount rate. The sensitivity analysis has been conducted assuming a variation in the annual discount rate, with total present worth costs estimated for each alternative at annual discount rates of 3% and 10%. The long-term ground water monitoring option (Alternative 2) and long-term treatment options with high operation and maintenance costs (Alternatives 3B and 3C) are impacted the greatest by variations in the discount rate.

Variations in the estimated remediation period also impacted the ground water remedial alternatives. Alternative 3B was the most affected due to its high operation and maintenance costs.

5.0 RECOMMENDATIONS AND CONCLUSIONS

Based on the evaluation of ground water remedial alternatives presented in Section 4, the recommended remedial alternative for Site 11 is a limited action, consisting of the following:

- Deed restrictions to prevent ground water from being used as a potable water source.

- Long-term monitoring of ground water to identify any future changes in ground water quality or potential migration of ground water contaminants.

This alternative would be protective of human health and the environment under the proposed future commercial/industrial site use based on the lack of unacceptable human health risks associated with such a future site use and the lack of unacceptable environmental risks associated with the site.

The limited action alternative uses institutional controls to limit exposures to ground water contaminants at levels exceeding drinking water action levels, which would be consistent with EPA's expectations for Superfund that allow the use of institutional controls when active remediation measures are determined not to be practicable, based on the balancing of trade-offs among alternatives. Considering the site's GB ground water classification which indicates that the ground water is not suitable for consumption without treatment, the presence of antimony within only one well at a level exceeding the MCL, the presence of manganese in an upgradient well at a level exceeding the risk-based preliminary remediation goal, and the apparent presence of manganese in ground water throughout the facility, the balancing of trade-offs conducted among the ground water remedial alternatives indicates that active ground water treatment would not be practicable to implement and would not offer any guarantee of permanence with respect to maintaining remedial goals upon discontinuation of treatment. The lack of ground water treatment at Site 11 is not expected to adversely effect the environment. The long-term monitoring would provide a means of identifying any changes in ground water quality in the future.

Implementation of deed restrictions is an administrative effort which would be incorporated into the base closure property transfer process; therefore, no short-term effects would result from implementation. The ground water monitoring program would have minimal short-term risks associated with its implementation and, provided deed restrictions are enforced, the limited action alternative would be effective in the long-term. Due to the continued presence of contaminants at the site at levels which do not allow for unrestricted use, five-year reviews of the limited action decision would be required. The alternative would complement future use of the site for commercial/industrial purposes, as specified in the Base Reuse Plan.

Rhode Island Rules and Regulations for Ground Water Quality include methods of establishing for a facility a point of compliance, which is used to determine compliance with ground water quality standards. They also define appropriate responses to a violation of a ground water quality standard at the point of compliance. The establishment of a ground water monitoring program is included in the list of potential responses to a ground water quality standard violation. Seeing as antimony was present in only one well at a level exceeding its ground water quality standard, the definition of a facility-specific point of compliance and the establishment of a ground water monitoring program could be a potential means of further defining the presence of antimony in ground water at the site. The proposed monitoring time frame (30 years) could be reduced if subsequent monitoring indicates that ground water quality at the point of compliance is acceptable. If the results of the ground water monitoring program indicate that ground water quality is deteriorating, additional remedial measures could be implemented, as necessary.

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TABLE 2-1

SITE 11 – FIRE FIGHTING TRAINING AREA
VERTICAL HYDRAULIC GRADIENTS

WELL CLUSTER NUMBER	VERTICAL DISTANCE (ft) (1)		HEAD DIFFERENCE (ft) (2)		GRADIENT (ft/ft)	
	8/13/93	9/17/93	8/13/93	9/17/93	8/13/93	9/17/93
11–MW02	34.53	33.59	–1.42	–1.16	–4.11E–2	–3.45E–2
11–MW03	19.60	19.24	–0.67	–0.82	–3.42E–2	–4.26E–2
11–MW06	36.26	35.97	–0.17	–0.29	–4.69E–3	–8.06E–3

NOTES: (1) The vertical distance is the difference in elevation between the water table in the shallow well and the middle of the screened interval in the deep well.
(2) The head difference is the elevation of the deep well piezometric level minus the water table elevation. Thus, negative signs represent downward gradients.

TABLE 2-2

SITE 11 – FIRE FIGHTING TRAINING AREA
AVERAGE HORIZONTAL HYDRAULIC GRADIENTS AND LINEAR VELOCITIES

LOCATION	AVERAGE HORIZONTAL GRADIENT (ft/ft) 8/13/93	AVERAGE HORIZONTAL GRADIENT (ft/ft) 9/17/93	AVERAGE LINEAR VELOCITY (ft/d) 8/13/93	AVERAGE LINEAR VELOCITY (ft/d) 9/17/93
SHALLOW WELLS:				
11-MW02S to 11-MW01S	1.65E-2	1.34E-2	1.58	1.29
11-MW04S to 11-MW06S	9.10E-3	5.98E-3	0.87	0.57
11-MW05S to 11-MW06S	1.01E-2	8.01E-3	0.97	0.77
11-MW07S to 11-MW04S	8.55E-3	7.15E-3	0.82	0.69
11-MW08S to 11-MW02S	4.55E-3	4.29E-3	0.44	0.41
11-MW08S to 11-MW05S	3.78E-3	3.42E-3	0.36	0.33
DEEP WELLS:				
11-MW02D to 11-MW03D	8.04E-3	6.40E-3	0.05	0.04
11-MW09D to 11-MW03D	9.57E-3	7.84E-3	0.06	0.05

NOTES: The shallow and deep hydraulic conductivities for the site (19.2 ft/d and 1.3 ft/d, respectively) are the median values derived from the Phase II RI slug tests.
An effective porosity of 0.20 for silty sands (EPRI, 1985) was assumed.

TABLE 2-3

SITE 11 – FIRE FIGHTING TRAINING AREA
Comparison of Background Soils to Surface and Subsurface Soil Samples
Range of Semivolatile Organic Compounds Detected

COMPOUND (ug/Kg)	SURFACE SOIL RANGE	SUBSURFACE SOIL RANGE	BACKGROUND RANGE
Phenol	ND	ND	ND
bis(2-Chloroethyl)ether	ND	ND	ND
2-Chlorophenol	ND	ND	ND
1,3-Dichlorobenzene	ND	ND	ND
1,4-Dichlorobenzene	ND	ND	ND
1,2-Dichlorobenzene	ND	ND	ND
2-Methylphenol	ND	ND	ND
2,2'-Oxybis(1-chloropropane)	ND	ND	ND
4-Methylphenol	ND	ND	ND
N-Nitroso-di-n-propylamine	ND	ND	ND
Hexachloroethane	ND	ND	ND
Nitrobenzene	ND	ND	ND
Isophorone	ND	ND	ND
2-Nitrophenol	ND	ND	ND
2,4-Dimethylphenol	ND	ND	ND
bis(2-Chloroethoxy)methane	ND	ND	ND
2,4-Dichlorophenol	ND	ND	ND
1,2,4-Trichlorobenzene	ND	ND	ND
Naphthalene	ND	ND-1,200	ND
4-Chloroaniline	ND	ND	ND
Hexachlorobutadiene	ND	ND	ND
4-Chloro-3-methylphenol	ND	ND	ND
2-Methylnaphthalene	ND	ND-130	ND
Hexachlorocyclopentadiene	ND	ND	ND
2,4,6-Trichlorophenol	ND	ND	ND
2,4,5-Trichlorophenol	ND	ND	ND
2-Chloronaphthalene	ND	ND	ND
2-Nitroaniline	ND	ND	ND
Dimethyl phthalate	ND	ND	ND
Acenaphthylene	ND-48	ND	ND
2,6-Dinitrotoluene	ND	ND	ND
3-Nitroaniline	ND	ND	ND
Acenaphthene	ND-38	ND-160	ND
2,4-Dinitrophenol	ND	ND	ND
4-Nitrophenol	ND	ND	ND
Dibenzofuran	ND-85	ND-82	ND
2,4-Dinitrotoluene	ND	ND	ND
Diethyl phthalate	ND	ND	ND
4-Chlorophenyl phenyl ether	ND	ND	ND
Fluorene	ND-190	ND-150	ND
4-Nitroaniline	ND	ND	ND
4,6-Dinitro-2-methylphenol	ND	ND	ND
N-Nitrosodiphenylamine(1)	ND	ND	ND
4-Bromophenyl phenyl ether	ND	ND	ND
Hexachlorobenzene	ND	ND	ND
Pentachlorophenol	ND	ND	ND
Phenanthrene	ND-1,000	ND-990	ND
Anthracene	ND-730	ND	ND
Carbazole	ND-130	ND	ND
Di-n-butyl phthalate	ND	ND	ND - 41
Fluoranthene	ND-7,000	ND-2,100	ND - 250
Pyrene	ND-4,400	ND-1,300	ND - 260
Butyl benzyl phthalate	ND-60	ND	ND - 51
3,3'-Dichlorobenzidine	ND	ND	ND
Benzo(a)anthracene	ND-3,200	ND-1,200	ND
Chrysene	ND-2,800	ND-930	ND - 190
bis(2-Ethylhexyl)phthalate	ND-340	ND-370	ND
Di-n-octyl phthalate	ND	ND	ND
Benzo(b)fluoranthene	ND-3,500	ND-1,300	ND - 270
Benzo(k)fluoranthene	ND-3,500	ND-1,300	ND - 73
Benzo(a)pyrene	ND-1,500	ND-680	ND
Indeno(1,2,3-cd)pyrene	ND-560	ND-390	ND
Dibenzo(a,h)anthracene	ND-180	ND-120	ND
Benzo(g,h,i)perylene	ND-420	ND-290	ND

ND = NON-DETECT
Subsurface soil range includes test pit results
Background surface soil samples which exhibited 1,1,1-trichloroethane or PCBs have not been excluded within background range.

TABLE 2–3, continued

SITE 11 – FIRE FIGHTING TRAINING AREA
Comparison of Background Soils to Surface and Subsurface Soil Samples
Range of Pesticides/PCBs Detected

COMPOUND (ug/Kg)	SURFACE SOIL RANGE	SUBSURFACE SOIL RANGE	BACKGROUND RANGE
Alpha–BHC	ND–0.18	ND–0.14	ND
Beta–BHC	ND	ND	ND
Delta–BHC	ND–0.29	ND–0.22	ND
Gamma–BHC (Lindane)	ND	ND	ND
Heptachlor	ND	ND–0.28	ND – 1.7
Aldrin	ND–0.59	ND–0.2	ND – 0.16
Heptachlor epoxide	ND–0.92	ND–0.12	ND – 3
Endosulfan I	ND–0.093	ND–0.22	ND
Dieldrin	ND–1.1	ND–0.53	ND
4,4'–DDE	ND–11	ND–0.91	ND – 590
Endrin	ND–1.5	ND–1.1	ND – 0.31
Endosulfan II	ND–1.1	ND	ND
4,4'–DDD	ND–1.2	ND–1.6	ND – 62
Endosulfan sulfate	ND–2.8	ND–0.87	ND – 1.2
4,4'–DDT	ND–34	ND–7	ND – 610
p,p'–Methoxychlor	ND–5.7	ND–53	ND – 1.4
Endrin ketone	ND–1.8	ND–0.57	ND
Endrin aldehyde	ND–1.3	ND–1.3	ND – 4.2
Alpha chlordane	ND–2.5	ND–0.13	ND – 54
Gamma chlordane	ND–1.7	ND	ND – 44
Toxaphene	ND	ND	ND
PCB–1016	ND	ND	ND
PCB–1221	ND	ND	ND
PCB–1232	ND	ND	ND
PCB–1242	ND	ND	ND
PCB–1248	ND	ND	ND
PCB–1254	ND–96	ND–5.7	ND
PCB–1260	ND–13	ND	ND

ND = NON–DETECT
Subsurface soil range includes test pit results
Background surface soil samples which exhibited 1,1,1–trichloroethane or PCBs have not been included within background range.

TABLE 2–3, continued

SITE 11 – FIRE FIGHTING TRAINING AREA
Comparison of Background, Surface and Subsurface Soil Samples
Range of Inorganics Detected

ELEMENT	SURFACE SOIL RANGES	SUBSURFACE SOIL RANGES	OBSERVED BACKGROUND SURFACE SOIL CONCENTRATION RANGES (mg/kg)
Aluminum	1,450–10,200	2,300–10,600	1,170 – 8,560
Antimony	ND–7.9	ND	ND
Arsenic	ND–2.4	ND–3.8	0.59 – 8.1
Barium	5.5–34.2	6.3–32.9	5.6 – 15.5
Beryllium	0.23–0.84	0.34–0.82	0.12 – 0.66
Cadmium	ND–0.41	ND–0.12	ND – 0.46
Calcium	140–1,030	265–6,750	62.7 – 628
Chromium	ND–15	ND–9.6	ND – 96
Cobalt	ND–7.5	ND–6.9	ND – 4.6
Copper	ND–14.4	ND–15.8	ND – 15
Iron	2,590–17,100	5,180–16,000	3,810 – 10,700
Lead	1.8–39.3	2.9–12.4	3.4 – 53.8
Magnesium	133–2,080	332–2,640	325 – 1,220
Manganese	27.8–189	51.6–275	21.8 – 150
Mercury	ND–0.11	ND–0.12	ND
Nickel	ND–12.3	ND–11.3	ND – 6.2
Potassium	ND–1,510	ND–1,230	ND – 728
Selenium	ND–0.72	ND	ND – 0.77
Silver	ND–0.06	ND–0.08	ND – 0.16
Sodium	ND–165	ND–114	ND – 119
Thallium	ND	ND–0.96	ND – 0.19
Vanadium	ND–14	2.8–15.1	3.3 – 24.6
Zinc	15.7–81.6	14.5–54	10.3–172
Cyanide	ND–0.54	ND	ND

NOTES:

ND Indicates that the element was not detected in the soil sample.
Subsurface soil range includes test pit results
Background surface soil samples which exhibited 1,1,1–trichloroethane or PCBs have not been included within background range.

TABLE 2-4
SITE 11 - FIRE FIGHTING TRAINING AREA
SUMMARY OF CANCER AND NON-CANCER RISK ESTIMATES
FOR ALL SCENARIOS
NCBC DAVISVILLE - SITE 11

Pathway	CANCER RISKS			
	Scenario 1 (Construction Worker)		Scenario 2 (Commercial/Industrial Worker)	
	Geometric Mean	RME	Geometric Mean	RME
Incidental ingestion of soil	1E-06	4E-06	2E-06	2E-05
Dermal contact with soil	4E-09	4E-10	NA	NA
Inhalation of particulates	8E-10	2E-09	--	--
Ingestion of ground water	--	--	5E-05	2E-04

[shaded] = Cancer risk > 1E-6

Pathway	NON-CANCER HAZARD INDICES			
	Scenario 1 (Construction Worker)		Scenario 2 (Commercial/Industrial Worker)	
	Geometric Mean	RME	Geometric Mean	RME
Incidental ingestion of soil	4E-02	1E-01	1E-02	2E-02
Dermal contact with soil	1E-05	1E-05	8E-06	2E-05
Inhalation of particulates	6E-04	1E-03	--	--
Ingestion of ground water	--	--	1E+00	6E+00

[shaded] = Hazard index > 1E+0

TABLE 3-1

Site 11 – Fire Fighting Training Area
Comparison of Soil Contaminant Levels to Action Levels

Parameter	Maximum Concentration Detected (ppm) — Surface Soils (0–2') Phase I RI	Maximum Concentration Detected (ppm) — Surface Soils (0–2') Phase II RI	Federal Action Level (ppm)	State Action Level (ppm)
LEAD	39.2	39.3	500–1,000[1]	300[2]
PCBs	ND	0.096	10[3]	10/50[4]

(1) USEPA, OSWER Directive 9355.4–02, Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites.
(2) RIDEM and RI Dept. of Health–Risk Assessment Guidance Level.
(3) TSCA (40 CFR 761); Requirements for decontaminating spills in nonrestricted areas.
(4) RIDEM Rules and Regulations for Solid Waste Management Facilities define solid waste as including any soil debris or other material with a concentration of 10 ppm or greater PCBs.
RIDEM Rules and Regulations for Hazardous Waste Management define Type 6 – extremely hazardous waste as including waste which contains 50 ppm or greater PCBs.
ND – No Pesticides/PCBs were detected in Phase I soil samples.

TABLE 3-2
Site 11 – Fire Fighting Training Area
Comparison of Detected Ground Water Contaminants to
Applicable or Relevant and Appropriate Requirements (ARARs) or To-be-Considered Requirements (TBCs)

	Maximum Concentration Detected in Ground Water		-- FEDERAL ARARs/TBCs--		RHODE ISLAND -- ARARs/TBCs --	
Parameter	Phase I (ppb)	Phase II (ppb)	MCL(1) (ppb)	MCLG(2) (ppb)	MCL(3) (PPB)	Ground Water(3) Quality Standards (ppb)
Volatiles						
Acetone	42	16				
2-Butanone	3	ND				
Methylene Chloride	2	ND				
1,1,1-Trichloroethane	ND	2	200	200	200	200
Semivolatiles						
Bis(2-ethylhexyl)phthalate	6	14	6	0		
Phenol	ND	1				
Diethyl phthalate	ND	2				
Pesticides/PCBs						
Alpha-BHC	ND	0.0011				
Aldrin	ND	0.0015				
Gamma-BHC(Lindane)	ND	0.0017	0.2	0.2	0.2	0.2
Inorganics						
Arsenic	9.8	6.2	50	–	50	50
Beryllium	9.8	ND	4	4		
Cadmium	10.7	0.44	5	5	5	5
Chromium	64	9.9	100	100	100	100
Copper	187	11.5	1,300*		1,300	
Lead	111	2.2	15*	0	15	15
Nickel	96	ND	100	100		
Silver	3.4	1				
Zinc	265	ND				
Barium	170	71.7	2,000	2,000	2,000	2,000
Iron	163,000	55,800				
Manganese	2,300	2,710				
Vanadium	96.7	7.6				
Aluminum	63,700	4,760				
Cobalt	86.5	13.6				
Magnesium	14,400	8,240				
Calcium	64,800	29,300				
Sodium	19,100	33,100				
Potassium	24,800	9,320				
Antimony	NA	44.8	6	6		

1. MCL – Maximum Contaminant Level. National Primary Drinking Water Regulations.
2. MCLG – Maximum Contaminant Level Goal, based on health considerations only.
3. Rhode Island Maximum Contaminant Level. Rules and Regulations Pertaining to Public Drinking Water (R46-13-DWQ) Sections 6.80(c), 16.1, 16.2(a) and 16.2(b).
3. Water Quality Standards, Class GAA and Class GA ground waters, Rhode Island Regulation DEM-GW-01-92, July 1993. Site 11 is located in a Class GB area.

*–Action levels representative of drinking water quality at the tap, U.S. EPA, May 7, 1991.

ND – Not detected

TABLE 3-3
SUMMARY OF RISK-BASED CLEANUP LEVELS - GROUND WATER
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RHODE ISLAND

Parameter	Ground Water Maximum Detected Concentration (ppm) Phase I (ppm)	Phase II (ppm)	Estimated [1] Non-Cancer Based Hazard Index Commercial/Industrial Use	Hazard Index Based [2] Cleanup Level (ppm)
Site 11 - Fire Fighting Training Area				
Manganese	2.3	2.71	5.3	0.51

(1) - Risk estimate represents total non-cancer hazard index ratio due to ingestion of manganese in ground water under future commercial/industrial use as presented in the Draft Remedial Investigation Report (TRC, May 1993b).

(2) - See Appendix B for discussion of risk-based cleanup level calculations.

TABLE 3–4

SITE 11 – FIRE FIGHTING TRAINING AREA
COMPARISON OF CATCH BASIN SEDIMENT COC CONCENTRATIONS TO NOAA ER–L AND ER–M VALUES

			Phase I	Phase II		
Parameter	NOAA ER–L (µg/kg)	NOAA ER–M (µg/kg)	CATCH BASIN SEDIMENT S–11–11–00–S	CATCH BASIN SEDIMENT 11–SD01	CATCH BASIN SEDIMENT 11–SD02	CATCH BASIN SEDIMENT 11–SD03
Volatile Organic Compounds (µg/kg)						
Semivolatile Organic Compounds (µg/kg)						
Phenanthrene	225	1380	NA	98	90	ND
Fluoranthene	600	3600	NA	170	180	2000
Pyrene	350	2200	NA	110	110	970
Benzo(a)anthracene	230	1600	NA	55	62	570
Chrysene	400	2800	NA	130	85	830
Benzo(b)fluoranthene	NA	NA	NA	180	150	ND
Benzo(k)fluoranthene	NA	NA	NA	180	150	ND
Benzo(a)pyrene	400	2500	NA	71	ND	ND
Total SVOCs	2205	14080	NA	994	827	4370
Total PAHs	2205	14080	NA	994	827	4370
Total CaPAHs	1030	6900	NA	616	447	1400
Pesticides/PCB Organic Compounds (µg/kg)						
Alpha–BHC	NA	NA	ND	0.15	ND	ND
Aldrin	NA	NA	ND	0.36	0.17	2.5
Heptachlor epoxide	NA	NA	ND	0.4	0.16	1.1
Dieldrin	0.02	8	ND	1	0.68	2.9
4,4'–DDE	NA	NA	39	1.4	0.97	82
4,4'–DDD	NA	NA	ND	ND	0.53	1100
4,4'–DDT	1	7	220	5.8	8.8	27
Alpha chlordane	0.5	6	ND	1.3	0.81	ND
Gamma chlordane	0.5	6	ND	2.3	1.5	4
PCB–1260	NA	NA	870	28	16	300
Total PCBs (µg/kg)	50	400	870	28	16	300
Inorganic Compounds (mg/kg)						
Aluminum	NA	NA	NA	2190	1730	1890
Arsenic	33	85	NA	ND	ND	1.5
Barium	NA	NA	NA	30.2	4	52.2
Beryllium	NA	NA	NA	0.85	ND	ND
Cadmium	5	9	NA	ND	0.07	0.66
Calcium	NA	NA	NA	512	142	275
Chromium	NA	NA	NA	12.9	2.2	15.8
Cobalt	NA	NA	NA	3.6	1.5	4.6
Copper	NA	NA	NA	54.5	8.8	18.3
Iron	NA	NA	NA	5710	3600	4870
Lead	35	110	NA	151	21.1	176
Magnesium	NA	NA	NA	779	655	441
Manganese	NA	NA	NA	61.5	44.4	32.2
Nickel	NA	NA	NA	16.7	3.8	6.8
Potassium	NA	NA	NA	669	ND	ND
Silver	NA	NA	NA	0.09	ND	0.046
Sodium	NA	NA	NA	125	52.4	75.7
Vanadium	NA	NA	NA	9.9	3.8	9.2
Zinc	120	270	NA	366	72.2	75.4

Shaded values exceed the ER–M.

ND = Not Detected

NA = Not Available or Not Analyzed

TABLE 3–5

Site 11 – Fire Fighting Training Area
Comparsion of Soil Contaminant Levels to Calculated Leaching Model Levels

Constituent	Maximum Modeled(1) Unsaturated Concentration (ppm)	Maximum Concentration Detected in Unsaturated Soils (ppm)	Maximum Modeled(1) Saturated Concentration (ppm)	Maximum Concentration Detected in Saturated Soils (ppm)
Volatile Organics				
Chloroform	420	ND	0.06	0.002
Semivolatile Organics				
Bis(2–ethylhexyl)phthalate	58,200	0.45	ND	--
Butylbenzylphthalate	292,600	0.34	ND	--
Chrysene	3,949	2.8	ND	--
Benzo(a)anthracene	1,976	3.2	ND	--
Benzo(a)pyrene	9,240	1.5	ND	--
Benzo(k)fluoranthene	67,200	3.5	ND	--
Benzo(b)fluoranthene	36,400	3.5	ND	
Dibenzo (a,h) anthracene	13,300	0.18	ND	--
Indeno(1,2,3–cd)pyrene	887,000	0.56	ND	--
Pesticides/PCBs				
Endrin	38,650	0.0015	ND	--
Heptachlor	490	0.00028	ND	--
Heptachlor epoxide	420	0.00092	ND	--
PCB – 1254	71,400	0.096	ND	--

Notes:
(1) See Appendix C for model description and associated calculations.
ND – Not Detected

TABLE 3-6

GROUND WATER REMEDIAL TECHNOLOGY SCREENING
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

Screened On Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
No Action	None	Not Applicable	No action.	Fulfills NCP requirement for consideration of no action alternative.
Institutional Control	Ground Water Monitoring	Not Applicable	Continued ground water monitoring.	Would provide monitoring of water quality and potential contaminant migration.
	Ground Water Use Restrictions	Deed Restrictions	Legal restrictions on ground water use in the contaminated area.	Would prevent future exposures to existing ground water contamination by restricting future installation of on-site potable wells.
		Alternate Water Supply	Provision of alternate water supply to receptors impacted by ground water contamination.	No potable water receptors have been impacted.
Extraction/ Treatment/ Discharge	Extraction	Extraction Wells	Wells and pumping system used for extraction of contaminated ground water.	Potentially viable, proven technology; silty soils could limit effectiveness.
		Well Points	Manifold system of extraction points connected to common collection source.	Potentially viable, proven technology; silty soils could limit effectiveness.
		Interceptor Trench	Placement of trench with high permeability materials, used to divert ground water flow.	Potentially viable, proven technology, suitable for shallow ground water extraction only.
	Off-Site Treatment	Off-site POTW	Extracted ground water discharged to local POTW for treatment.	Regulations often prohibit discharge of subsurface water to sewer systems; preliminary evaluation indicates POTW will not be amenable to accepting extracted ground water.
		Off-site RCRA Facility	Extracted ground water discharged to licensed RCRA facility for treatment and/or disposal.	High ground water extraction rates can prohibit feasibility of this treatment option.

TABLE 3-6

GROUND WATER REMEDIAL TECHNOLOGY SCREENING
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

(Shaded) Screened On Basis of Technical Implementability

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	DESCRIPTION	COMMENTS
Extraction/ Treatment/ Discharge (Cont.)	Inorganic Treatment	Ion Exchange	Contaminants removed from aqueous phase by exchanging places with ions held by ion exchange material.	Effective for inorganics; ineffective for organics.
		Precipitation	Contaminants removed by decreasing solubility.	Effective for inorganics; ineffective for organics, which generally have solubilities less affected by pH adjustments.
		Membrane Microfiltration (shaded)	Solid particles removed from liquids using pressure filter.	SITE program technology; applicable to ground water contaminated with suspended heavy metals; would not remove dissolved organics.
		Filtration (shaded)	Suspended particles are removed from the ground water stream using conventional filtration methods.	Effective for removal of suspended solids contaminated with heavy metals; would not remove dissolved inorganics.
		Electrochemical	Utilizes the oxidation/reduction properties of ferrous ions for removing heavy metals from aqueous solutions.	Proven for treatment of heavy metals; ineffective for organics.
	Discharge	Ground Water	Treated water is recharged to the ground water via wells and/or infiltration galleries.	Potentially viable.
		Surface Water	Treated water is discharged directly or indirectly (via storm sewer) into surface water.	Potentially viable.
		Sanitary Sewer/ POTW (shaded)	Treated water is discharged indirectly to surface water body via sanitary sewer and POTW.	Regulations may prohibit discharge of ground water to sewer system; preliminary evaluation indicates POTW will not be amenable to accepting treated ground water.

TABLE 3-7

GROUND WATER PROCESS OPTION SCREENING
SITE 11 – FIRE FIGHTING TRAINING AREA
NCBC-DAVISVILLE

● Representative Process Option

GENERAL RESPONSE ACTION	TECHNOLOGY	PROCESS OPTION	EFFECTIVENESS	IMPLEMENTABILITY	COST
No Action	None	Not Applicable	● Not effective in prohibiting or monitoring contaminant migration.	No implementation required.	No cost.
Institutional Control	Ground Water Monitoring	Not Applicable	● Would provide means of monitoring contaminant migration but provides no treatment.	Easily implemented.	Low capital; moderate O&M.
Institutional Control	Ground Water Use Restrictions	Deed Restrictions	● Effective in limiting public ingestion of ground water contaminants by eliminating installation of potable wells in contaminated areas.	Requires legal authority.	Moderate capital.
Extraction/ Treatment/ Discharge	Extraction	Extraction Wells	● Effective; best suited for steep hydraulic gradients and miscible contaminants.	Easily implemented.	Moderate capital; moderate O&M.
Extraction/ Treatment/ Discharge	Extraction	Interceptor Trench	● Effective; best suited to shallow aquifers or floating contaminants.	Easily implemented; mechanically simple.	Moderate capital; moderate O&M.
Extraction/ Treatment/ Discharge	Inorganic Treatment	Ion Exchange	Effective for inorganic removal; requires selection of resin suitable for contaminants of concern; has not been well-demonstrated in treatment of antimony.	Fairly easily implemented; operation is relatively simple.	Moderate capital; moderate O&M.
Extraction/ Treatment/ Discharge	Inorganic Treatment	Precipitation	● Effective for removal of dissolved inorganics; precipitate must be disposed of.	Readily implemented.	Low to moderate capital; moderate O&M.
Extraction/ Treatment/ Discharge	Inorganic Treatment	Electrochemical	● Effective in producing metal hydroxide precipitates of such inorganic species as arsenic, cadmium, zinc and copper; treatability studies have indicated potential effectiveness in the treatment of antimony.	Newly developing technology; may not be widely available; more complicated than other inorganic treatment systems.	Moderate capital, moderate O&M.
Extraction/ Treatment/ Discharge	Discharge	Ground Water	Effective with permeable soils and relatively low flow rates; presence of manganese in upgradient wells complicates selection of injection location.	Requires construction of a recharge system; requires compliance with discharge criteria.	Moderate capital; low to moderate O&M.
Extraction/ Treatment/ Discharge	Discharge	Surface Water	● Effective for discharge of treated ground water.	Requires installation of a discharge pipe; requires compliance with discharge criteria.	Moderate capital; low O&M.

TABLE 3–8

GROUND WATER REMEDIAL TECHNOLOGIES WHICH PASSED SCREENING
SITE 11 – FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

<u>No Action</u>

- ● No Action

<u>Institutional Control</u>

- ● Ground Water Monitoring
- ● Deed Restrictions

<u>Extraction/Treatment/Discharge</u>

- ● Extraction Wells
- ● Interceptor Trench
- Ion Exchange
- ● Precipitation
- ● Electrochemical
- Discharge to Ground Water
- ● Discharge to Surface Water

● – Process Technology Used to Formulate Remedial Alternatives

TABLE 3–9

GROUND WATER REMEDIAL ALTERNATIVES UNDERGOING DETAILED ANALYSIS
SITE 11 – FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

Alternative 1

No Action

Alternative 2

Limited Action (Institutional Controls)

A. Deed Restrictions/Ground Water Monitoring

Alternative 3

Extraction/Treatment/Discharge

A. Interceptor Trench/Extraction Wells
B. Precipitation
C. Electrochemical Treatment
D. Discharge to Surface Water

TABLE 4-1
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE 1 - NO ACTION
ALTERNATIVE 2 - LIMITED ACTION
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL Ground Water--				
	Safe Drinking Water Act (40 CFR 141.11-.16 and 141.60-.63) Maximum Contaminant Levels (MCL's)	Relevant and Appropriate	MCL's directly apply to "public water systems", defined as systems with at least 15 connections which service a minimum of 25 persons.	Ground water at NCBC is not a current source of drinking water, but is classified as GB at Site 11. Since there is no regulatory mechanism to prohibit potable use of the ground water, MCLs are relevant and appropriate. Contaminant concentrations are compared to MCLs to assess potential risks associated with ingestion of ground water.
	Safe Drinking Water Act (40 CFR 141.50-.52) Maximum Contaminant Level Goals (MCLGs)	Relevant and Appropriate	Non-enforceable health goals for public water supply systems, set at levels which result in no known or anticipated adverse health effects.	Ground water at NCBC is not a current source of drinking water, but is classified as GB at Site 11. Since there is no regulatory mechanism to prohibit potable use of the ground water, MCLGs are relevant and appropriate. Non-zero MCLGs are to be used as remedial goals for current or potential sources of drinking water, per the NCP (40 CFR 300). Contaminant concentrations are compared to MCLGs to assess potential risks associated with ingestion of ground water.
	USEPA Risk Reference Doses (RfDs)	To Be Considered	Toxicity values for evaluating noncarcinogenic effects resulting from exposures to contamination.	USEPA RfDs are used to characterize risks due to noncarcinogens in ground water.
	Lifetime Health Advisories	To Be Considered	Guidelines developed based on toxicity for noncarcinogenic compounds.	TBC criteria due to the presence of contaminants in ground water.
STATE Ground Water--				
	RI Ground Water Protection Act (RIGL, 46-13 et seq.) Public Drinking Water Regulations	Relevant and Appropriate	Establishes provisions for the protection and management of potable drinking waters, including the development of ground water classifications and associated standards which specify maximum contaminant levels for each classification.	Ground water at NCBC is not a current source of drinking water, but is classified as GB at Site 11. Since there is no regulatory mechanism to prohibit potable use of the ground water, these regulations are relevant and appropriate and contaminant concentrations will be compared to the established ground water quality standards.

TABLE 4-2
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE 2 - LIMITED ACTION
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
STATE Monitoring				
	Rules and Regulations for Ground Water Quality	Applicable	Rules and regulations intended to protect and restore the quality of the State's ground water. Includes ground water program monitoring requirements and monitoring well construction and abandonment.	Ground water monitoring programs and well construction/abandonment methodologies will comply with these regulations.

TABLE 4-3
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE 3 - EXTRACTION/TREATMENT/DISCHARGE
INCLUDING OPTIONS 3A THROUGH 3D
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
FEDERAL				
Ground Water--				
	Safe Drinking Water Act (40 CFR 141.11-.16 and 141.60-.63) Maximum Contaminant Levels (MCL's)	Relevant and Appropriate	MCL's directly apply to "public water systems", defined as systems with at least 15 connections which service a minimum of 25 persons.	Ground water at NCBC is not a current source of drinking water, but is classified as GB at Site 11. Since there is no regulatory mechanism to prohibit potable use of the ground water, MCLs are relevant and appropriate. Contaminant concentrations are compared to MCLs to assess potential risks associated with ingestion of ground water.
	Safe Drinking Water Act (40 CFR 141.50-.52) Maximum Contaminant Level Goals (MCLGs)	Relevant and Appropriate	Non-enforceable health goals for public water supply systems, set at levels which result in no known or anticipated adverse health effects.	Ground water at NCBC is not a current source of drinking water, but is classified as GB at Site 11. Since there is no regulatory mechanism to prohibit potable use of the ground water, MCLGs are relevant and appropriate. Non-zero MCLGs are to be used as remedial goals for current or potential sources of drinking water, per the NCP (40 CFR 300). Contaminant concentrations are compared to MCLGs to assess potential risks associated with ingestion of ground water.
	USEPA Risk Reference Doses (RfDs)	To Be Considered	Toxicity values for evaluating noncarcinogenic effects resulting from exposures to contamination.	USEPA RfDs are used to characterize risks due to noncarcinogens in ground water.
	Lifetime Health Advisories	To Be Considered	Guidelines developed based on toxicity for noncarcinogenic compounds	TBC criteria due to the presence of contaminants in ground water.
Surface Water --				
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	Applicable	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms.	AWQC will be applicable to remedial alternatives which involve discharges to surface water.
	Clean Water Act (40 CFR 401.15) Effluent Discharge Limitations	Applicable	Regulates the discharge of contaminants from an industrial point source.	Regulations will be applicable to remedial alternatives which involve discharges to surface water.

TABLE 4-3(continued)
FEDERAL AND STATE CHEMICAL-SPECIFIC ARARs AND TBCs
ALTERNATIVE 3 - EXTRACTION/TREATMENT/DISCHARGE
INCLUDING OPTIONS 3A THROUGH 3D
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
STATE				
Ground Water--	RI Ground Water Protection Act (RIGL, 46-13 et seq.) Public Drinking Water Regulations	Relevant and Appropriate	Establishes provisions for the protection and management of potable drinking waters, including the development of ground water classifications and associated standards which specify maximum contaminant levels for each classification.	Ground water at NCBC is not a current source of drinking water, but is classified as GB at Site 11. Since there is no regulatory mechanism to prohibit potable use of the ground water, these regulations are relevant and appropriate and contaminant concentrations will be compared to the established ground water quality standards.
Surface Water --	RI Water Pollution Control Law (RIGL 46-12 et seq.) RI Water Quality Standards	Applicable	Establishes water use classification and water quality criteria for all waters of the state. Also establishes acute and chronic water quality criteria for the protection of aquatic life.	Regulation will be applicable for remedial alternatives which involve discharges to surface water.

TABLE 4-4
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE 3 - EXTRACTION/TREATMENT/DISCHARGE
INCLUDING OPTIONS 3A THROUGH 3D
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
FEDERAL				
Discharge	Clean Water Act (40 CFR 122-125) National Pollutant Discharge Elimination System (NPDES) Permit Requirements	Applicable	Permits contain applicable effluent standards (i.e., technology-based and/or water quality-based), monitoring requirements, and standards and special conditions for discharge.	Discharges of treated water to surface waters will meet these requirements.
On-site/ Off-site Treatment/ Disposal	Resource Conservation and Recovery Act (RCRA) (40 CFR 262) Generator Requirements for Manifesting Waste for Off-Site Disposal	Applicable	Standards for manifesting, marking and recording off-site hazardous waste shipments for treatment/disposal.	If treatment system by-product requires off-site disposal/treatment as a hazardous waste, generator requirements will be followed.
	RCRA (40 CFR 264) Subpart I Use and Management of Containers	Applicable	Outlines use and management standards applicable to owners and operators of all hazardous waste facilities that store containers of hazardous waste.	Remedial actions which require storage of hazardous waste in containers will comply with these requirements.
	RCRA (40 CFR 263) Transporter Requirements for Off-Site Disposal	Applicable	Standards for transporters of hazardous waste materials.	If treatment system by-product requires off-site disposal/treatment as a hazardous waste, transporter requirements will be followed.
	RCRA (40 CFR 268) Land Disposal Restrictions	Applicable	Identifies hazardous wastes that are restricted from land disposal and sets treatment standards for restricted wastes.	If treatment system by-product requires off-site disposal as a hazardous waste, land disposal restrictions will be followed.
	Hazardous Materials Transportation Act (49 CFR 170, 171) Rules for Transportation of Hazardous Materials	Applicable	Procedures for packaging, labelling, manifesting, and off-site transport of hazardous materials.	If treatment system by-product is determined to be hazardous, transport procedures will be followed.

TABLE 4-4(continued)
FEDERAL AND STATE ACTION-SPECIFIC ARARs AND TBCs
ALTERNATIVE 3 - EXTRACTION/TREATMENT/DISCHARGE
INCLUDING OPTIONS 3A THROUGH 3D
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
STATE Discharge	RI Water Pollution Control Act			
	• RI Water Quality Regulations for Water Pollution Control (RIGL 46-12 et seq.) RI Water Quality Standards	Applicable	Establishes general requirements and effluent limits for discharge to area waters.	Discharges of treated water to area surface water will meet these requirements.
	• Regulations for the RI Pollutant Discharge Elimination Systems (RIGL 46-12 et seq.)	Applicable	Permits contain applicable effluent standards (i.e., technology-based and/or water quality-based), monitoring requirements, and standards and special conditions for discharge.	Discharges of treated water to area surface water will meet these requirements.
On-site/ Off-site Disposal/ Treatment	RI Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.) • Hazardous Waste Management Rules and Regulations	Applicable	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal.	If treatment system by-product is determined to be hazardous, these rules will be followed.
	• Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases (Site Remediation Regulations)	Applicable	Rules and regulations for the investigation and remediation of releases of hazardous materials.	Remedial systems will be designed and operated in accordance with these requirements.
	RI Hazardous Substance Community Right to Know Act (RIGL, Title 23, Chapter 24.4) Public Right-to-Know Requirements	Applicable	Establishes rules for the public's right-to-know concerning hazardous waste storage and transportation.	These rules will be followed if treatment system by-product requires management as a hazardous waste.
	RI Refuse Disposal Law Rules and Regulation for Solid Waste Management Facilities	Applicable	Rules and regulations for solid waste management facilities.	These rules will be followed if treatment system by-product requires management as a solid waste.

TABLE 4-5
COMPARISON AMONG GROUND WATER ALTERNATIVES
OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	COMPARISON OF OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT
Alternative 1 - No Action	Least protective alternative; Does not limit future potable use of ground water and does not monitor ground water quality; Does not present any short-term impacts; Does not meet remedial response objectives
Alternative 2 - Limited Action	Provides protection of human health by limiting potential future exposures to inorganics in ground water through the institution of deed restrictions limiting potable ground water use; Does not provide compliance with drinking water standards through treatment; however, would prevent the development of a ground water ingestion exposure pathway; Uses institutional controls to meet remedial action objectives
Alternative 3 - Extraction/Treatment/ Discharge	Provides a reduction in potential future risks to human health associated with ground water ingestion through active treatment; Would comply with chemical-specific and action-specific ARARs; Some increased short-term risks would result during implementation; Would be effective in the long-term as long as the treatment system is operational although permanence is not ensured
Option 3A - Ground Water Extraction via Interceptor Trench and Extraction Wells	Provides protection of the environment and human health by limiting potential ground water migration and by removing ground water for treatment; Would comply with applicable ARARs; Minimal short-term risks would result during implementation; Would be effective in the long-term
Option 3B - Precipitation Inorganic Treatment	Provides protection of the environment and human health through treatment of inorganic contaminants in ground water; Would comply with applicable ARARs; Some increased short-term risks would result during implementation due to residual handling; Would be effective in the long-term
Option 3C - Electrochemical Inorganic Treatment	Provides protection of the environment and human health through treatment of inorganic contaminants in ground water; Would comply with applicable ARARs; Some increased short-term risks would result during implementation due to residual handling; Would be effective in the long-term
Option 3D - Discharge to Surface Water	Provides protection of the environment and human health when combined with ground water extraction and treatment; Would comply with applicable ARARs; Minimal short-term risks would result during implementation; Would be effective in the long-term

TABLE 4-6
COMPARISON AMONG GROUND WATER ALTERNATIVES
COMPLIANCE WITH ARARS
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	CHEMICAL-SPECIFIC	LOCATION-SPECIFIC	ACTION-SPECIFIC
Alternative 1 - No Action	Does not meet criteria	Not applicable	Not applicable
Alternative 2 - Limited Action	Does not meet criteria	Not applicable	Monitoring would comply with RIDEM's Rules and Regulations for Ground Water Quality
Alternative 3 - Extraction/Treatment/ Discharge	Treatment would meet criteria	Not applicable	Extraction/Treatment/Discharge systems would comply with action-specific criteria
Option 3A - Ground Water Extraction via Interceptor Trench and Extraction Wells	Meets criteria by capturing contaminants that exceed MCLs and PRGs	Not applicable	Would be implemented in compliance with RIDEM Site Remediation Regulations
Option 3B - Precipitation Inorganic Treatment	Meets criteria by treating inorganic contaminants that exceed MCLs and PRGs	Not applicable	Treatment system operation would comply with applicable criteria; Off-site disposal of sludge would require hazardous waste characterization and compliance with either hazardous or non-hazardous waste management regulations
Option 3C - Electrochemical Inorganic Treatment	Meets criteria by treating inorganic contaminants that exceed MCLs and PRGs	Not applicable	Treatment system operation would comply with applicable criteria; Off-site disposal of precipitate from the treatment system would require hazardous waste characterization and compliance with either hazardous or non-hazardous waste management regulations
Option 3D - Discharge to Surface Water	Water quality of the treatment process effluent would be required to meet ambient water quality criteria	Not applicable	Would comply with criteria applicable to surface water discharge

TABLE 4-7
COMPARISON AMONG GROUND WATER ALTERNATIVES
LONG-TERM EFFECTIVENESS AND PERMANENCE
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	COMPARISON OF LONG-TERM EFFECTIVENESS AND PERMANENCE
Alternative 1 – No Action	Effective in the long-term provided ground water is not used as a drinking water supply; Provides no long-term monitoring of ground water quality; Requires five-year reviews
Alternative 2 – Limited Action	Effective in minimizing the long-term risks associated with the potential construction and use of an on-site well as a source of drinking water; Monitoring program provides a means of monitoring potential changes in ground water quality; Requires 5-year reviews
Alternative 3 – Extraction/Treatment/ Discharge	Treatment effective in treating contaminants which exceed ARARs or risk-based PRGs and in preventing off-site migration of contaminants during operation; Permanent contaminant reduction would not necessarily result if ground water treatment is discontinued in the future; Requires long-term maintenance
Option 3A – Ground Water Extraction via Interceptor Trench and Extraction Wells	Provides an effective and reliable means of extracting ground water; Well-proven in performance and can function with minimal maintenance
Option 3B – Precipitation Inorganic Treatment	Effective in the removal of inorganics from the wastestream; Long-term risks associated with the residuals of ground water treatment would be relatively small; Sludge produced will require hazardous waste characterization and appropriate disposal; Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties
Option 3C – Electrochemical Inorganic Treatment	Effective in the removal of most inorganics from the wastestream; Long-term risks associated with the residuals of ground water treatment would be relatively small; Precipitate produced will require hazardous waste characterization and appropriate disposal; Long-term operation and maintenance of the treatment system is expected to pose no significant difficulties
Option 3D – Discharge to Surface Water	Long-term risks associated with discharge to surface water will be minimal, provided treatment system is operating properly; Long-term operation and maintenance of discharge piping is not expected to pose any major technical problems; Requires long-term monitoring of the quality of discharged water

TABLE 4-8
COMPARISON AMONG GROUND WATER ALTERNATIVES
REDUCTION OF TOXICITY, MOBILITY OR VOLUME THROUGH TREATMENT
SITE 11 – FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	COMPARISON OF REDUCTION IN TOXICITY, MOBILITY OR VOLUME
Alternative 1 – No Action	Provides no reduction in toxicity, mobility or volume through treatment
Alt rnative 2 – Limited Action	Provides no reduction in toxicity, mobility or volume through treatment
Alt rnative 3 – Extraction/Treatment/ Discharge	Provides a reduction in toxicity, mobility and volume through treatment
Option 3A – Ground Water Extraction via Interceptor Trench and Extraction Wells	Ground water extraction does not provide treatment but would be combined with a treatment option; Reduces the potential mobility of contaminated ground water
Option 3B – Precipitation Inorganic Treatment	Provides a reduction in the toxicity of identified inorganic contaminants through treatment; Volume of contaminated media is reduced through removal of contaminants from the ground water and subsequent production of a concentrated sludge residual
Option 3C – Electrochemical Inorganic Treatment	Provides a reduction in the toxicity of identified inorganic contaminants through treatment; Volume of contaminated media is reduced through removal of contaminants from the ground water and subsequent production of a precipitate residual
Option 3D – Discharge to Surface Water	Not expected to significantly affect the extraction or treatment system; therefore, it has little impact on the toxicity, mobility, or volume of contamination

TABLE 4-9
COMPARISON AMONG GROUND WATER ALTERNATIVES
SHORT-TERM EFFECTIVENESS
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	COMPARISON OF SHORT-TERM EFFECTIVENESS
Alternative 1 - No Action	No remedial activities conducted; Therefore, no short-term risks result; Five-year reviews would provide the only means of ensuring compliance with remedial action objectives
Alternative 2 - Limited Action	Implementation of deed restrictions would result in no short-term risks; Implementation of the monitoring program would have minimal short-term adverse impacts based on the use of existing wells for ground water monitoring purposes; Would meet remedial response objectives related to minimizing potential human exposures to contaminated ground water by preventing on-site potable well installation
Alternative 3 - Extraction/Treatment/ Discharge	No significant risks to on-site workers or off-site risks are anticipated; Degree of short-term risk would be dependent upon the individual options employed; Remedial response objectives would be achieved during operation of the treatment system but may not be maintained if treatment is discontinued
Option 3A - Ground Water Extraction via Interceptor Trench and Extraction Wells	Presents minimal short-term risks to on-site workers and would not be expected to result in any increased off-site risks to human health or the environment; Easily implemented within a minimal time frame
Option 3B - Precipitation Inorganic Treatment	No significant short-term risks to workers are expected; Major operation and maintenance activities associated with chemical precipitation include maintenance of chemical supplies and sludge handling; No significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation
Option 3C - Electrochemical Inorganic Treatment	No significant short-term risks to workers are expected; Major operation and maintenance activities associated with electrochemical treatment include maintenance of electrodes and precipitate disposal; significant added risks to the adjacent community or the environment are anticipated as a result of treatment system installation or operation
Option 3D - Discharge to Surface Water	Short-term risks to workers associated with the construction of discharge piping would not be significant; Maintenance of the system will require maintenance of the piping and discharge monitoring; No added risks to the adjacent community or the environment are anticipated

TABLE 4-10
COMPARISON AMONG GROUND WATER ALTERNATIVES
IMPLEMENTABILITY
SITE 11 – FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

ACTION	COMPARISON OF IMPLEMENTABILITY
Alternative 1 – No Action	Requires no implementation other than five-year reviews; Would not limit the implementation of other remedial actions
Alternative 2 – Limited Action	Deed restrictions would have to be implemented as part of the base closure property transfer process; Deed restrictions limiting future installation of on-site potable wells would not be expected to prevent future commercial/industrial use of the site; Implementation of deed restrictions or ground water monitoring would not limit the implementation of future remedial actions
Alt mative 3 – Extraction/Treatment/ Discharge	Relatively easy to implement; Technical implementability would be dependent upon the individual alternative options selected; Some treatment technologies are more easily implemented than others; Services and materials should be readily available for the implementation of all options
Option 3A – Ground Water Extraction via Interceptor Trench and Extraction Wells	Implementation of a ground water extraction system is expected to be good; Materials and services are readily available; Minimal technical or administrative obstacles to implementation would be anticipated
Option 3B – Precipitation Inorganic Treatment	Easily implemented; Startup is not expected to result in unanticipated technical problems; Implementation is not expected to impact the implementation of any future remedial actions; Operational activities include maintenance of chemical suplies and sludge handling; Administrative feasibility is also expected to be good
Option 3C – Electrochemical Inorganic Treatment	Implementation is expected to be good; Availability of treatment units is somewhat limited; Implementation will not impact the implementation of future remedial actions; Operational activities include maintenance of the electrodes and handling of the precipitate; Administrative feasibility is also expected to be good
Option 3D – Discharge to Surface Water	Technical implementation of a discharge to surface water system is good; Continued monitoring of the discharged water quality will be required; Administrative feasibility of discharging treated ground water to surface water depends on the treatment system's ability to meet surface water discharge criteria

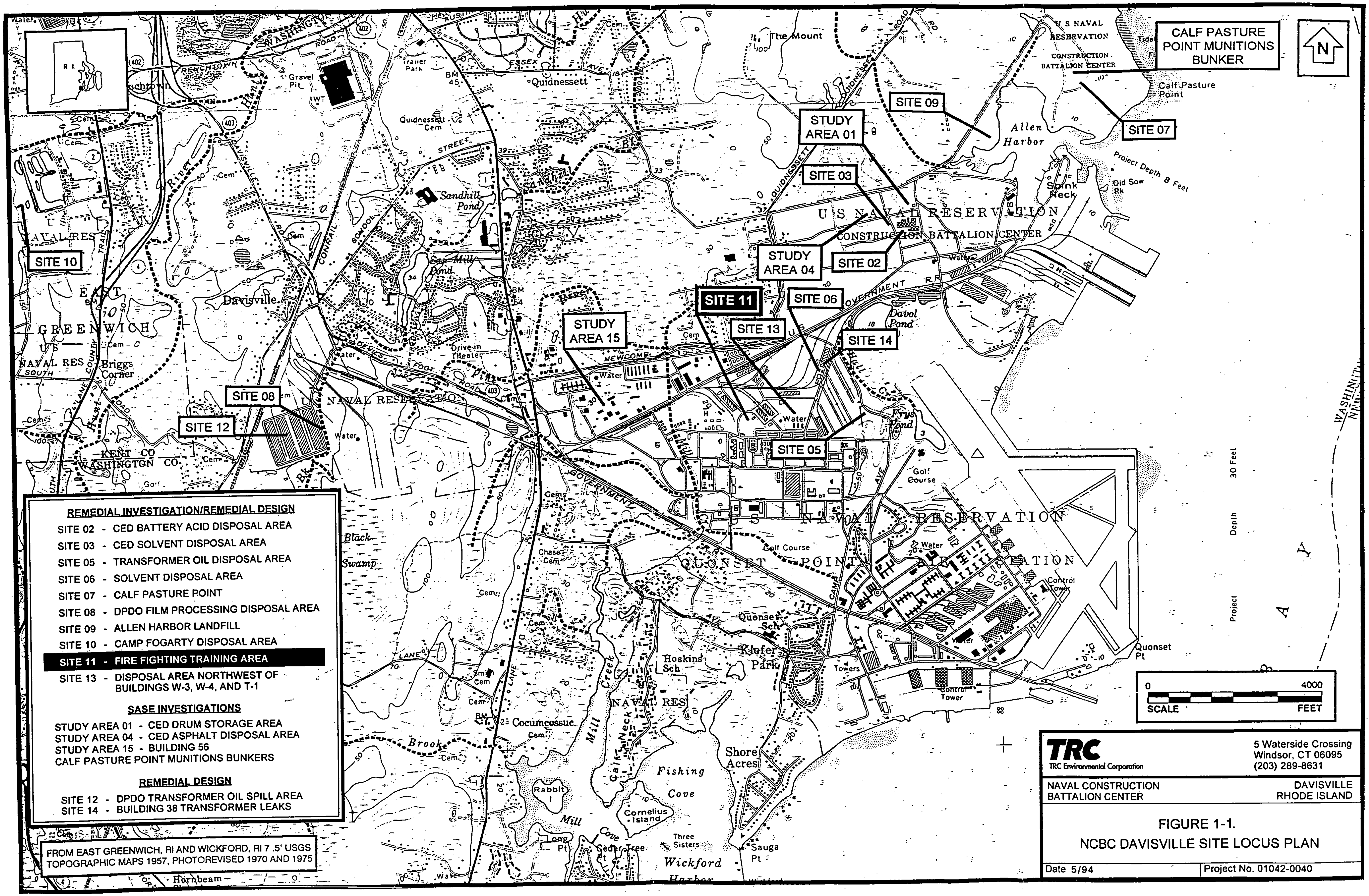
TABLE 4-11
COMPARISON AMONG GROUND WATER ALTERNATIVES
COST
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE, RI

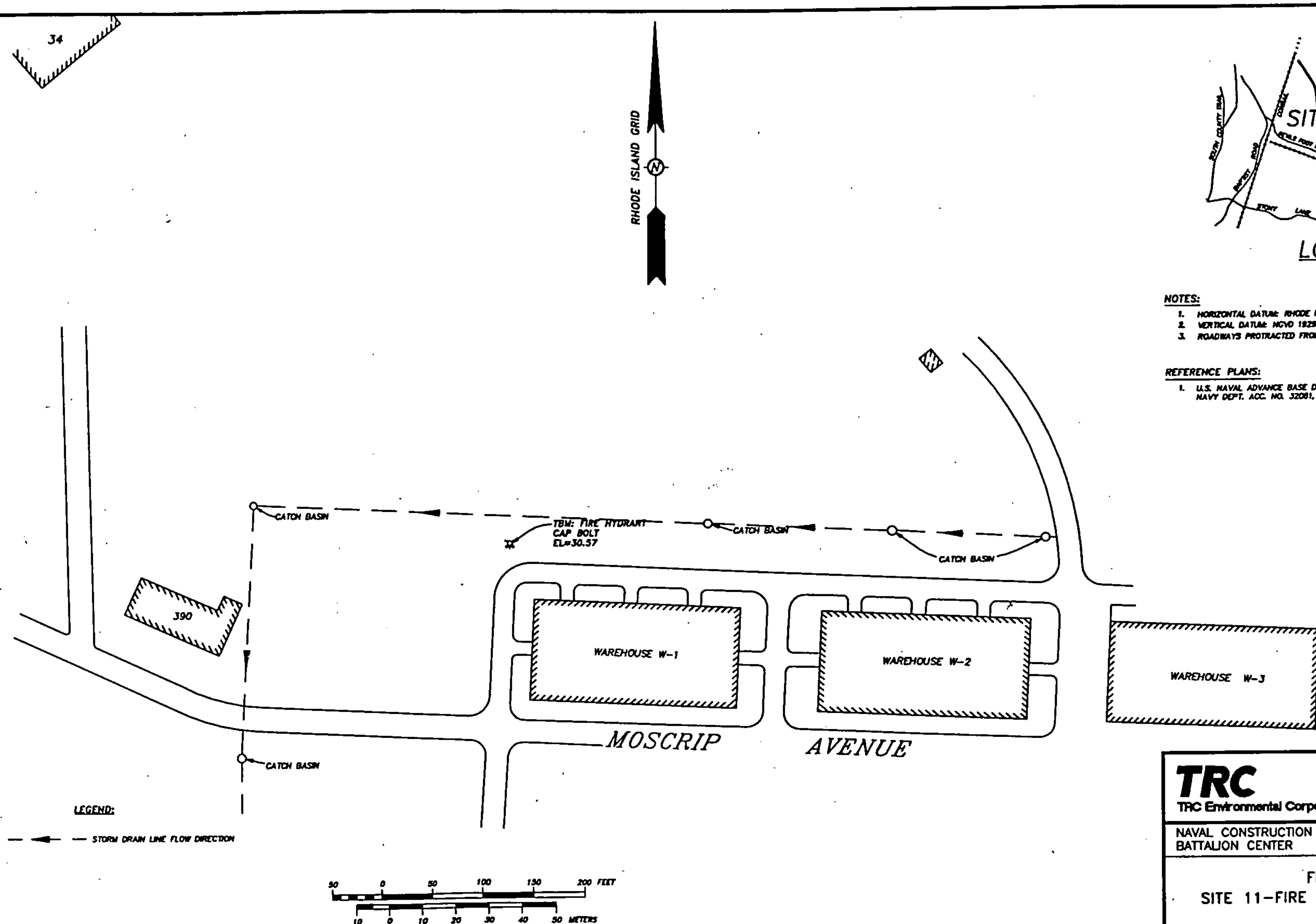
ACTION	TOTAL CAPITAL COST	ANNUAL O&M COST	PRESENT WORTH O&M COST (1)	TOTAL PRESENT WORTH (2)
Alternative 1 - No Action	--	--	--	Nominal (3)
Alternative 2 - Limited Action	--	$12,000	$190,000	$220,000
Alternative 3 - Extraction/Treatment/ Discharge	--	--	--	--
Option 3A - Ground Water Extraction via Interceptor Trench and Extraction Wells	$63,000	$4,800	$74,000	$160,000
Option 3B - Precipitation Inorganic Treatment	$150,000	$54,000	$830,000	$1,200,000
Option 3C - Electrochemical Inorganic Treatment	$180,000	$24,000	$380,000	$670,000
Option 3D - Discharge to Surface Water	$29,000	$7,400	$110,000	$170,000

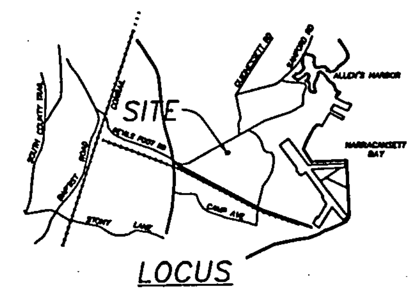
(1) - Based on 5% discount rate
(2) - Includes 20% contingency on all components
(3) - The only cost associated with the implementation of Alternative 1 would be that associated with conducting five-year reviews of the no action decision. Deed restrictions would be implemented under the base closure property transfer process.

TABLE 4-12
COST SENSITIVITY ANALYSIS
SITE 11 - FIRE FIGHTING TRAINING AREA

Item Varied (Minimum - Maximum)	Alternative	Minimum Cost	Maximum Cost
Discount Factor (3% - 10%)		**10%**	**3%**
	Ground Water		
	Alt. 2	$137,000	$284,000
	Alt. 3A	$130,000	$189,000
	Alt. 3B	$793,000	$1,451,000
	Alt. 3C	$495,000	$794,000
	Alt. 3D	$119,000	$210,000
Remediation Period (15 yrs - 40 yrs)	Ground Water	**15 yrs**	**40 yrs**
	Alt. 3A	$136,000	$175,000
	Alt. 3B	$855,000	$1,293,000
	Alt. 3C	$523,000	$722,000
	Alt. 3D	$128,000	$188,000


CALF PASTURE POINT MUNITIONS BUNKER
N
SITE 07
SITE 09
STUDY AREA 01
SITE 03
STUDY AREA 04
SITE 02
SITE 11
SITE 06
SITE 13
SITE 14
STUDY AREA 15
SITE 08
SITE 12
SITE 10
SITE 05
REMEDIAL INVESTIGATION/REMEDIAL DESIGN
SITE 02 - CED BATTERY ACID DISPOSAL AREA
SITE 03 - CED SOLVENT DISPOSAL AREA
SITE 05 - TRANSFORMER OIL DISPOSAL AREA
SITE 06 - SOLVENT DISPOSAL AREA
SITE 07 - CALF PASTURE POINT
SITE 08 - DPDO FILM PROCESSING DISPOSAL AREA
SITE 09 - ALLEN HARBOR LANDFILL
SITE 10 - CAMP FOGARTY DISPOSAL AREA
SITE 11 - FIRE FIGHTING TRAINING AREA
SITE 13 - DISPOSAL AREA NORTHWEST OF BUILDINGS W-3, W-4, AND T-1
SASE INVESTIGATIONS
STUDY AREA 01 - CED DRUM STORAGE AREA
STUDY AREA 04 - CED ASPHALT DISPOSAL AREA
STUDY AREA 15 - BUILDING 56
CALF PASTURE POINT MUNITIONS BUNKERS
REMEDIAL DESIGN
SITE 12 - DPDO TRANSFORMER OIL SPILL AREA
SITE 14 - BUILDING 38 TRANSFORMER LEAKS
FROM EAST GREENWICH, RI AND WICKFORD, RI 7.5' USGS TOPOGRAPHIC MAPS 1957, PHOTOREVISED 1970 AND 1975
0
4000
SCALE
FEET
TRC
TRC Environmental Corporation
5 Waterside Crossing
Windsor, CT 06095
(203) 289-8631
NAVAL CONSTRUCTION BATTALION CENTER
DAVISVILLE RHODE ISLAND
FIGURE 1-1.
NCBC DAVISVILLE SITE LOCUS PLAN
Date 5/94
Project No. 01042-0040





NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.
3. ROADWAYS PROTRACTED FROM REFERENCE PLAN NO. 1.

REFERENCE PLANS:

1. U.S. NAVAL ADVANCE BASE DEPOT, DAVISVILL, R.I., SUB-SURFACE, A.B.D., NAVY DEPT. ACC. NO. 32061, SHEET NO. 1273.

TRC
TRC Environmental Corporation
5 Waterside Crossing
Windsor, CT 06095
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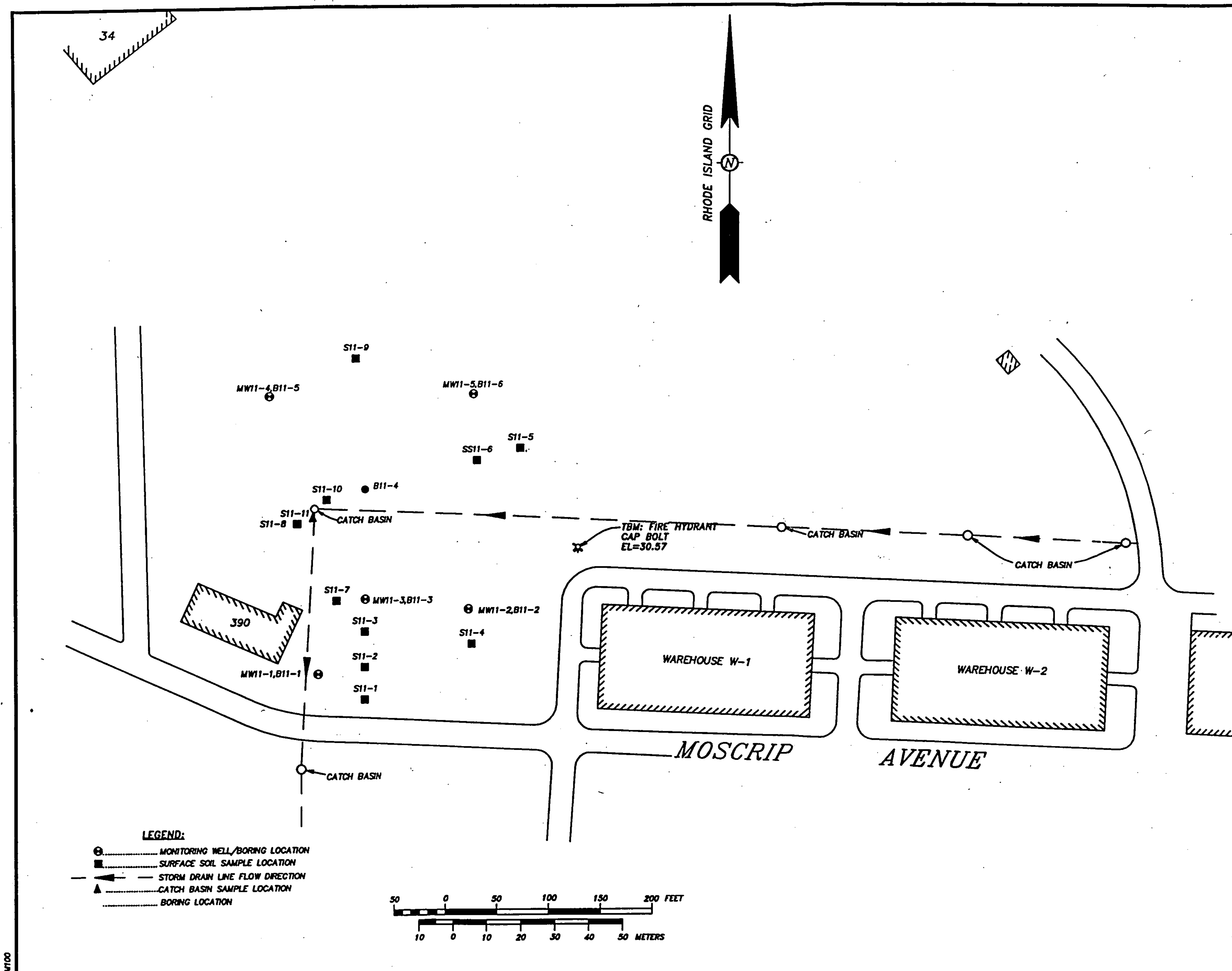
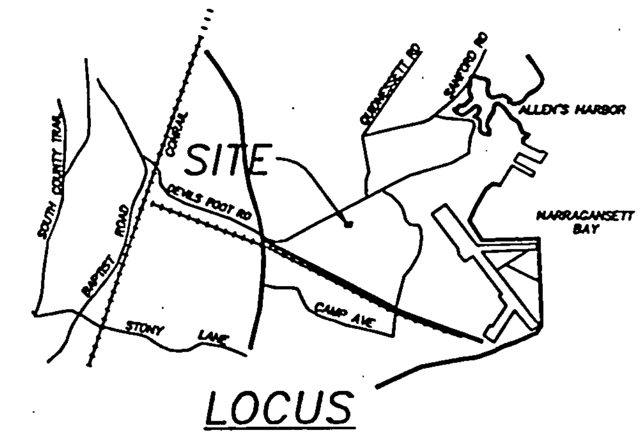
NAVAL CONSTRUCTION BATTALION CENTER — DAVISVILLE RHODE ISLAND

FIGURE 2-1.
SITE 11-FIRE FIGHTING TRAINING AREA
SITE PLAN

Date: 5/94 | Project No. 01042-0040





NOTES:

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2. VERTICAL DATUM: NGVD 1929.
3. ROADWAYS PROTRACTED FROM REFERENCE PLAN NO. 1.

REFERENCE PLANS:

1. U.S. NAVAL ADVANCE BASE DEPOT, DAVISVILL, R.I., SUB-SURFACE, A.B.D., NAVY DEPT. ACC. NO. 32061, SHEET NO. 1275.

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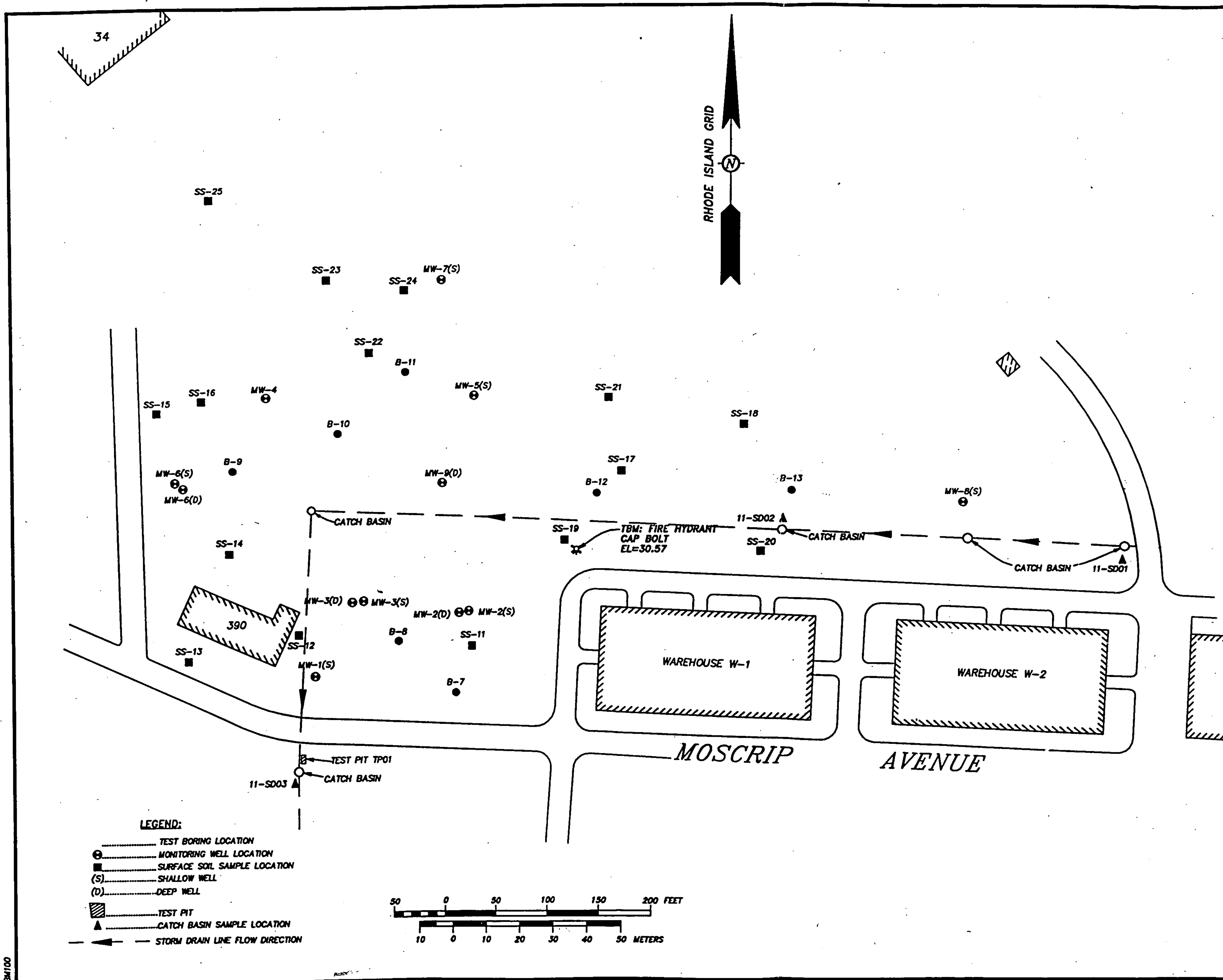
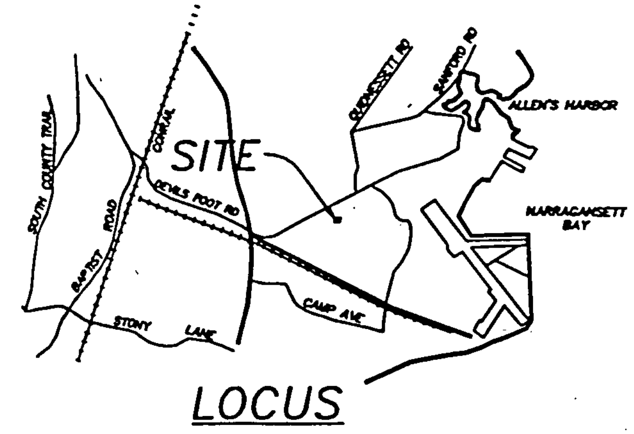
NAVAL CONSTRUCTION BATTALION CENTER — DAVISVILLE, RHODE ISLAND

FIGURE 2-2.
SITE 11-FIRE FIGHTING TRAINING AREA
PHASE I SAMPLING LOCATIONS

Date: 5/94 | Project No. 01042-0040

11BM100





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1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.
3. ROADWAYS PROTRACTED FROM REFERENCE PLAN NO. 1.

REFERENCE PLANS:

1. U.S. NAVAL ADVANCE BASE DEPOT, DAVISVILL, R.I., SUB-SURFACE, A.B.D., NAVY DEPT. ACC. NO. 32061, SHEET NO. 1275.

MONITORING WELL ELEVATIONS:

WELL NO.	GROUND ELEV.	PVC ELEV.	NORTHING	EASTING
MW-1(S)	21.88	24.22	189541.6	516943.4
MW-2(D)	25.89	27.74	189601.8	517061.4
MW-2(S)	25.89	29.53	189603.1	517069.9
MW-3(D)	23.54	25.48	189612.4	516978.8
MW-3(S)	23.54	26.76	189613.5	516989.4
MW-4	22.93	25.34	189611.6	516898.9
MW-5	27.50	29.41	189812.1	517095.8
MW-6(D)	20.59	23.18	189724.2	516820.3
MW-6(S)	20.59	23.01	189729.8	516812.7
MW-7(S)	27.24	29.34	189923.7	517064.5
MW-8	31.03	32.93	189708.2	517563.7
MW-9(D)	26.73	28.77	189727.8	517065.1

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FIGURE 2-3.
SITE 11-FIRE FIGHTING TRAINING AREA
PHASE II SAMPLING LOCATIONS

Date: 5/94 | Project No. 01042-0040

11BM100

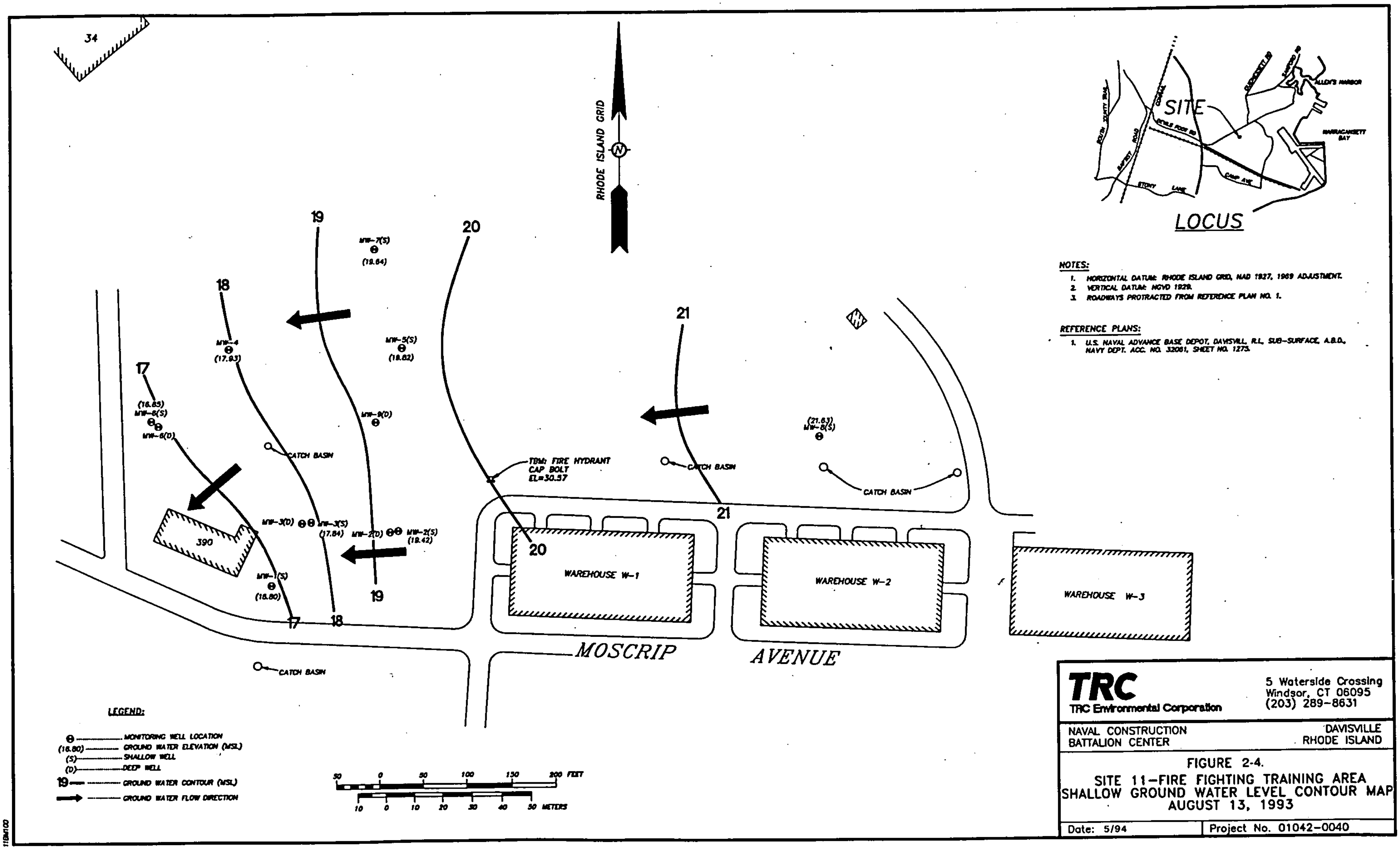

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FIGURE 2-4.
SITE 11-FIRE FIGHTING TRAINING AREA
SHALLOW GROUND WATER LEVEL CONTOUR MAP
AUGUST 13, 1993

Date: 5/94 | Project No. 01042-0040

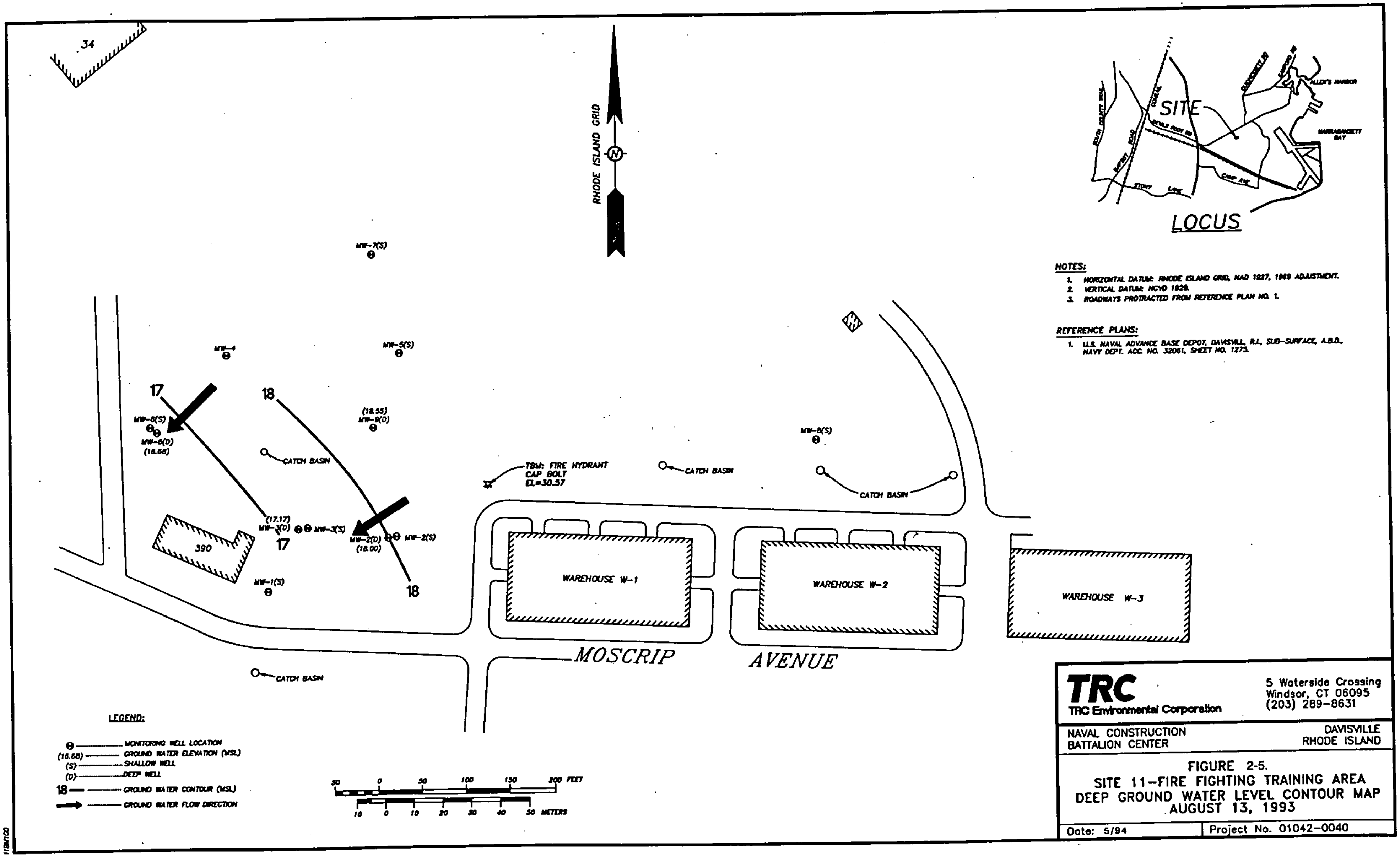

FIGURE 2-5.
SITE 11-FIRE FIGHTING TRAINING AREA
DEEP GROUND WATER LEVEL CONTOUR MAP
AUGUST 13, 1993

Date: 5/94 | Project No. 01042-0040

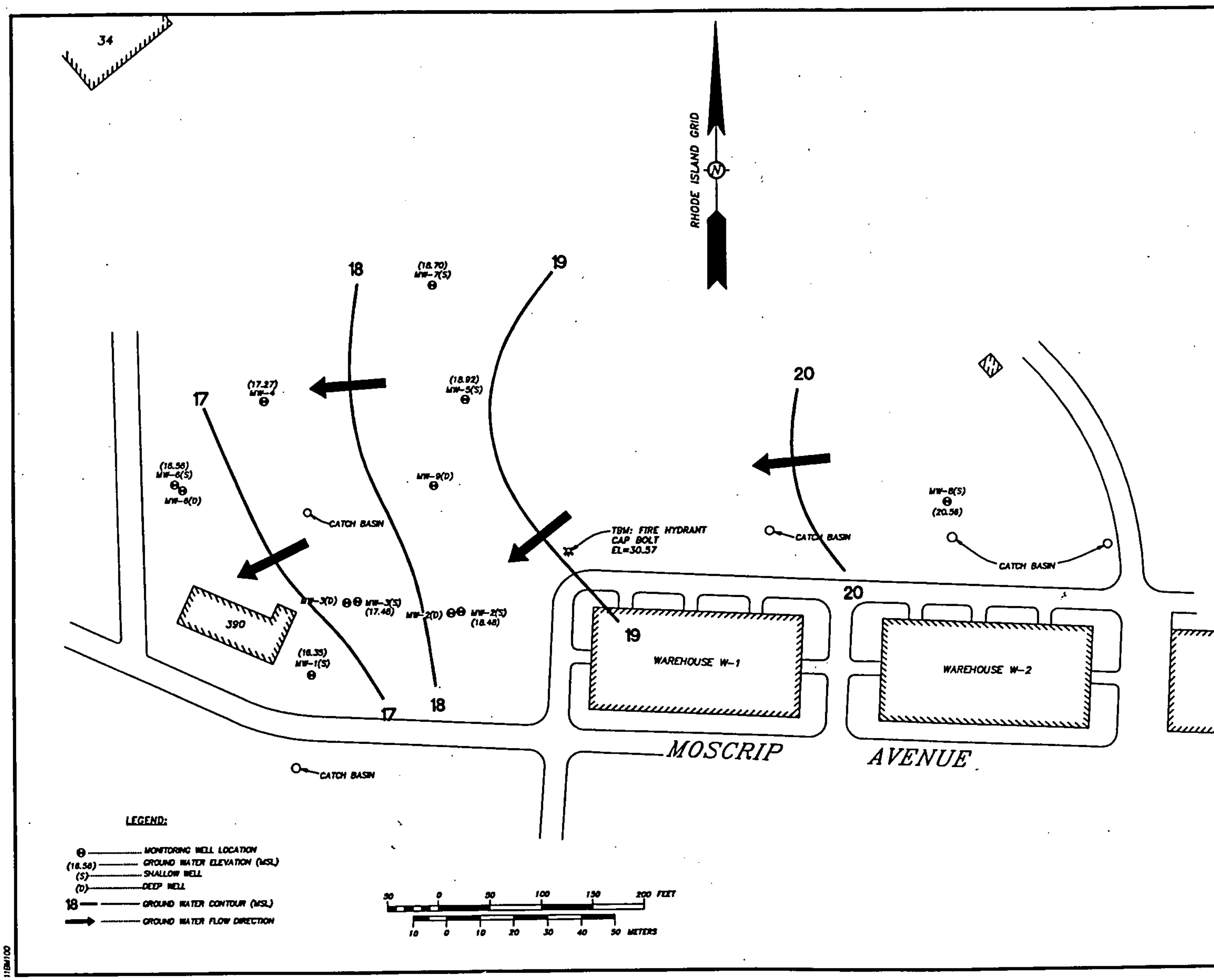

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FIGURE 2-6.
SITE 11–FIRE FIGHTING TRAINING AREA
SHALLOW GROUND WATER LEVEL CONTOUR MAP
SEPTEMBER 17, 1993

Date: 5/94 | Project No. 01042-0040

11BM100

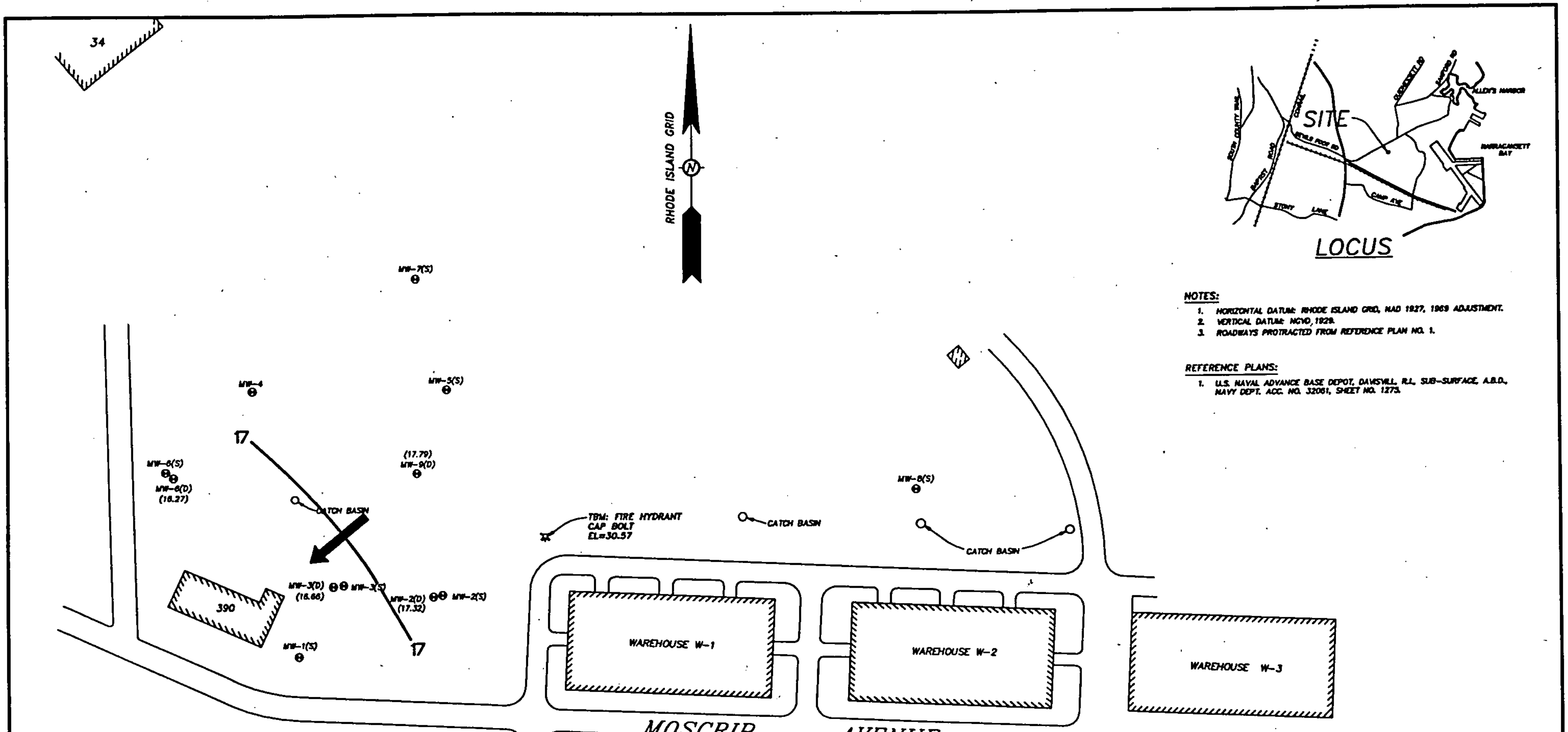

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FIGURE 2-7.
SITE 11-FIRE FIGHTING TRAINING AREA
DEEP GROUND WATER LEVEL CONTOUR MAP
SEPTEMBER 17, 1993

Date: 5/94 | Project No. 01042-0040

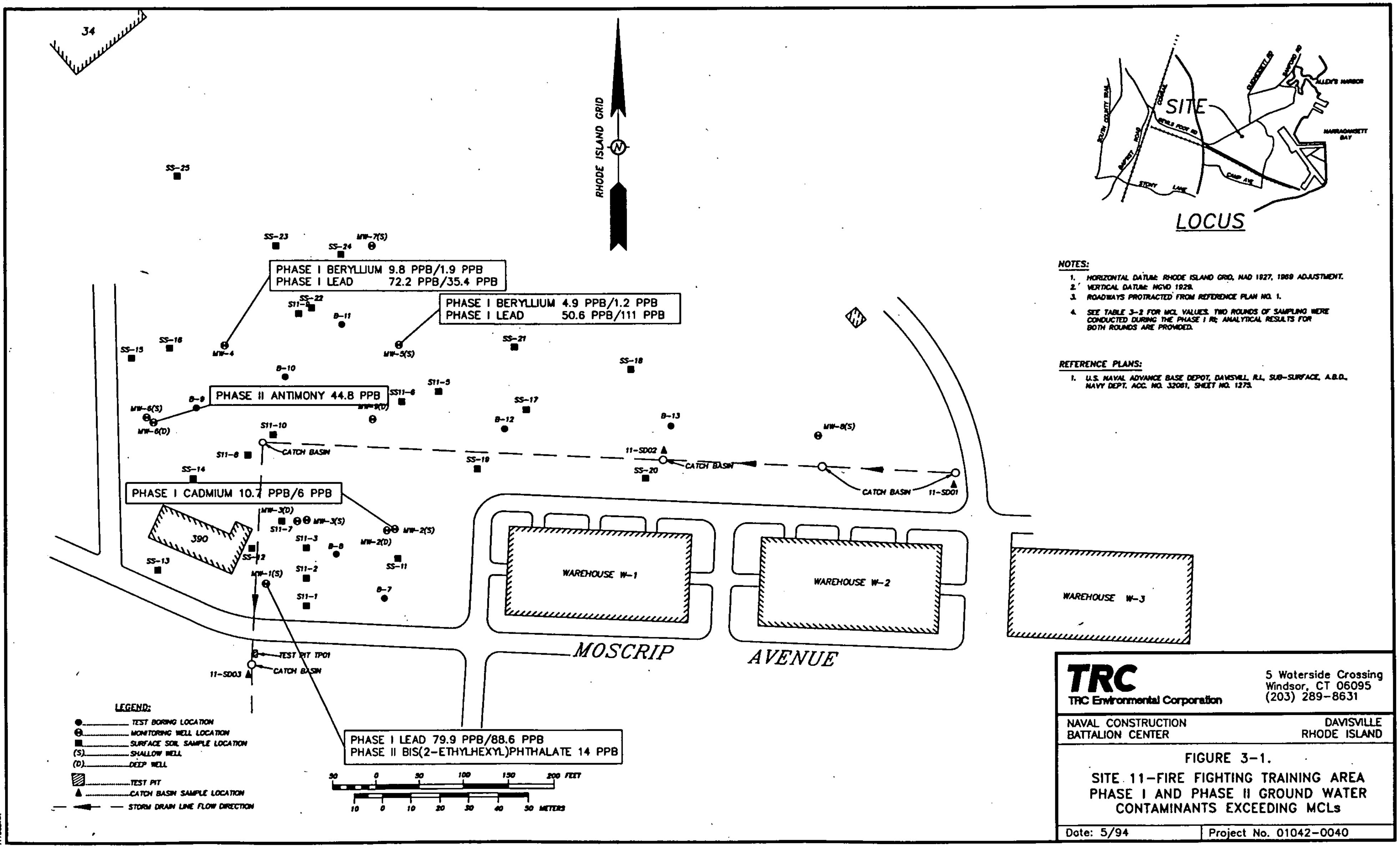
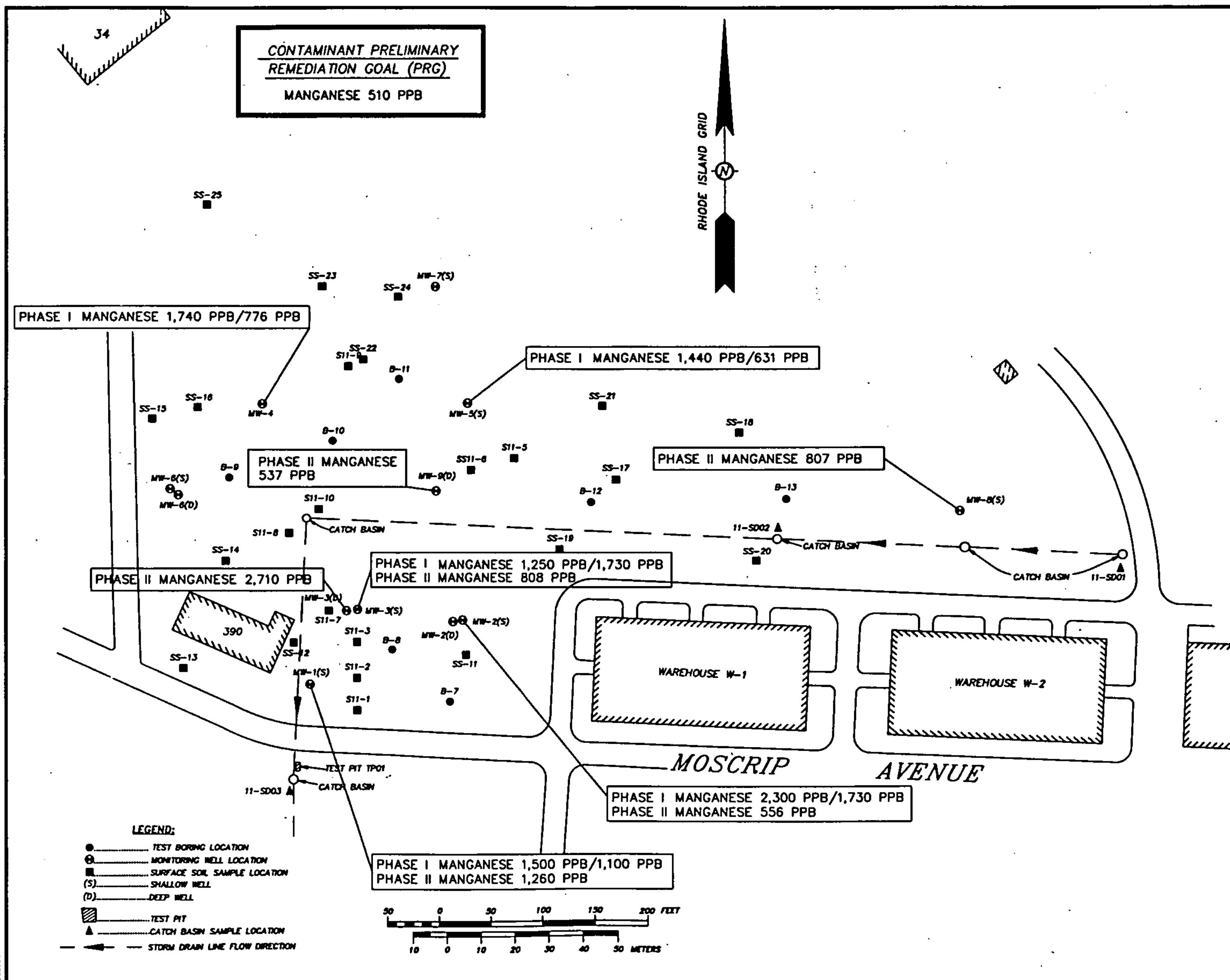
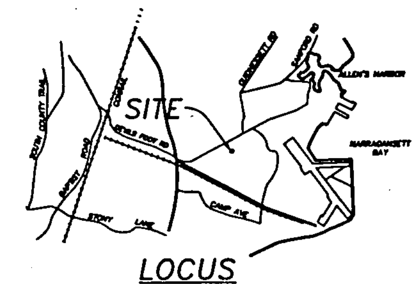


FIGURE 3-1.
SITE 11-FIRE FIGHTING TRAINING AREA PHASE I AND PHASE II GROUND WATER CONTAMINANTS EXCEEDING MCLs





NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.
3. ROADWAYS PROTRACTED FROM REFERENCE PLAN NO. 1.
4. SEE APPENDIX B FOR INFORMATION ON THE CALCULATION FOR THE PRGs. TWO ROUNDS OF SAMPLING WERE CONDUCTED DURING THE PHASE I RI. RESULTS FOR BOTH ROUNDS ARE PROVIDED.

REFERENCE PLANS:

1. U.S. NAVAL ADVANCE BASE DEPOT, DAVISVILL, R.I., SUB-SURFACE, A.B.D., NAVY DEPT. ACC. NO. 32081, SHEET NO. 1275.

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FIGURE 3-2.
SITE 11-FIRE FIGHTING TRAINING AREA
PHASE I AND PHASE II GROUND WATER CONTAMINANTS EXCEEDING RISK-BASED PRELIMINARY REMEDIATION GOALS (PRGs)

Date: 5/94 | Project No. 01042-0040

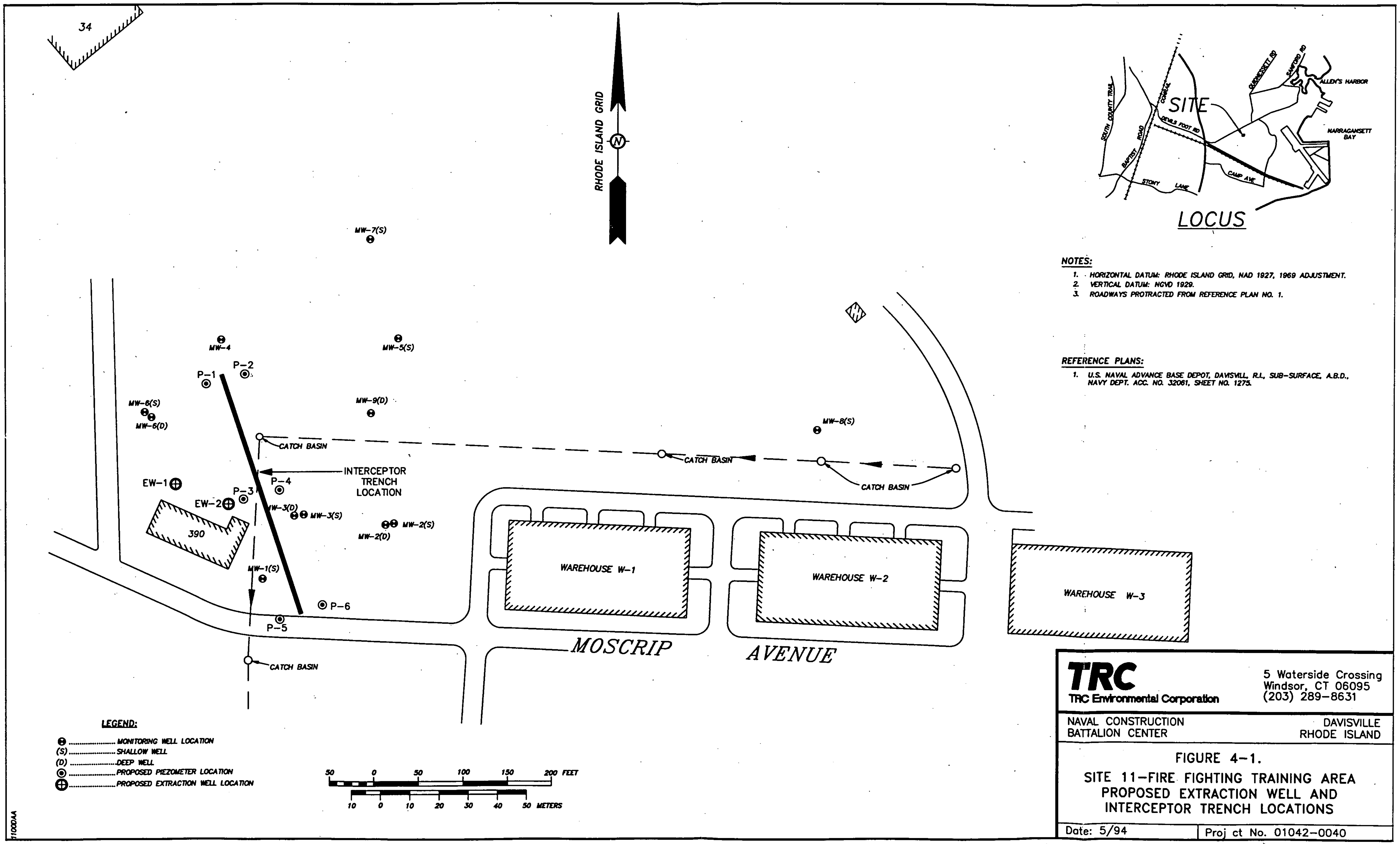

FIGURE 4-1.
SITE 11-FIRE FIGHTING TRAINING AREA PROPOSED EXTRACTION WELL AND INTERCEPTOR TRENCH LOCATIONS

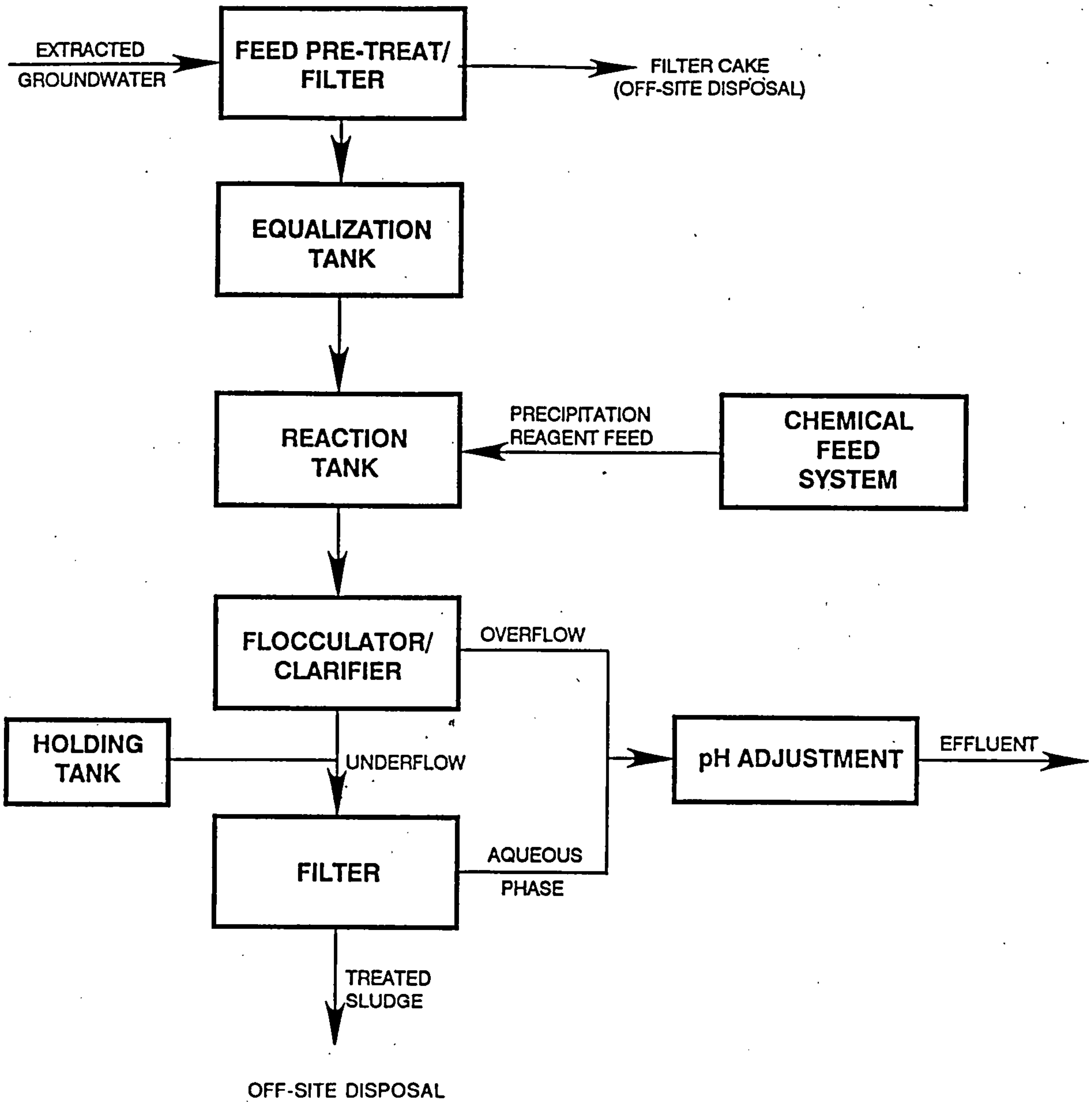

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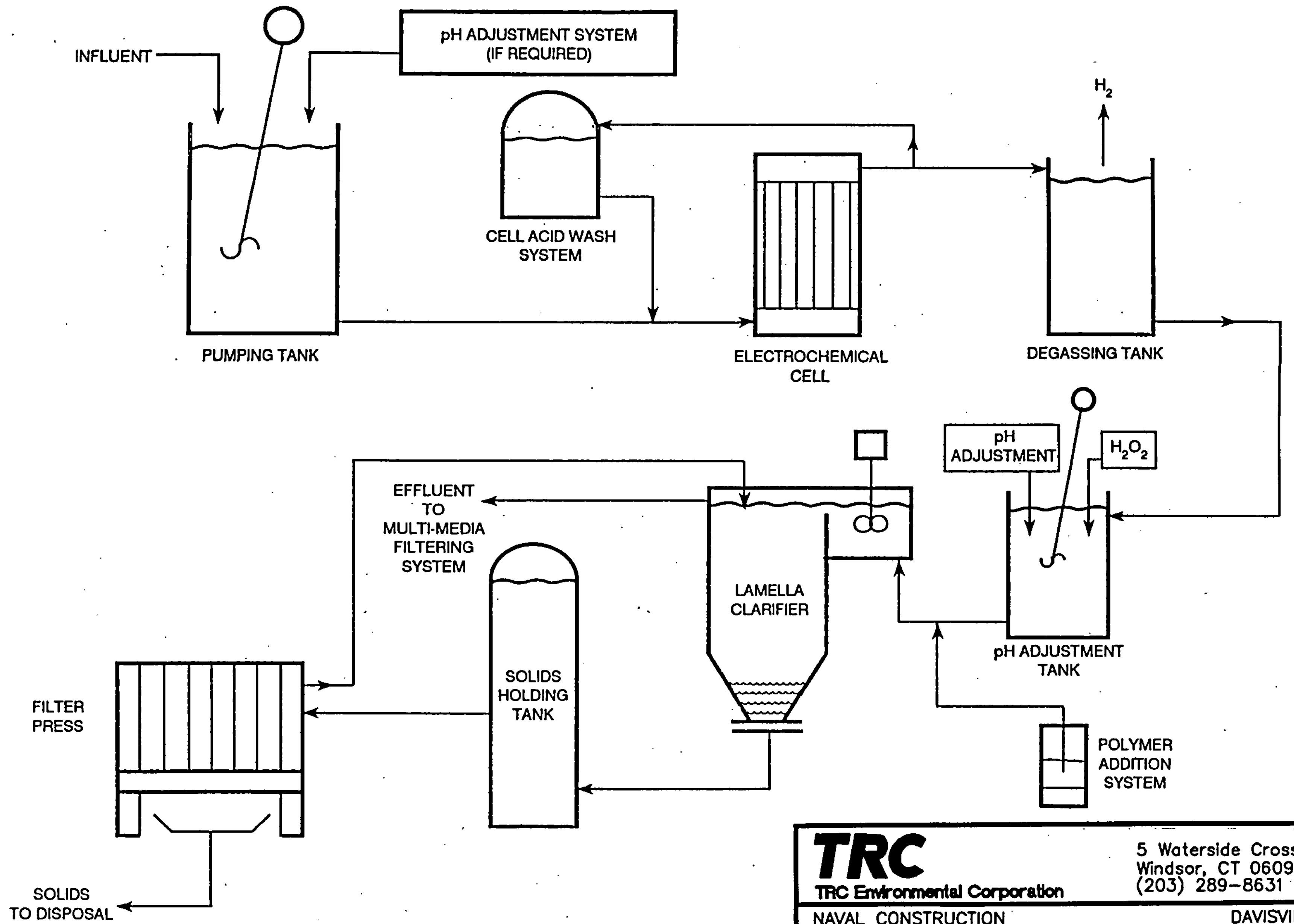
FIGURE 4-2.
SITE 11-FIRE FIGHTING TRAINING AREA
CHEMICAL PRECIPITATION SCHEMATIC

Date: 5/94 | Project No. 01042-0040



SOURCE: ANDCO ENVIRONMENTAL PROCESSES, INC.

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FIGURE 4-3.

SITE 11–FIRE FIGHTING TRAINING AREA
ELECTROCHEMICAL REDUCTION SYSTEM

Dat : 5/94 | Project No. 01042-0040

APPENDIX A

APPENDIX A

IDENTIFICATION OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

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TABLES

APPENDIX A

IDENTIFICATION OF POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARS)

A.1 Introduction

The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA, 1986), and the NCP (1990), requires that all remedial response actions attain or exceed applicable or relevant and appropriate requirements of Federal and more stringent promulgated requirements of State environmental statute(s). The NCP defines applicable requirements as "those cleanup standards, standards of control, other substantive environmental protection requirements or criteria, or limitations promulgated under federal environmental or state environmental facility siting law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstances found at a CERCLA site." Relevant and appropriate requirements are defined in the NCP as "those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at the CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site."

To-Be-Considered materials (TBCs) are non-promulgated advisories or guidance issued by federal or state government that are not legally binding and do not have the status of potential ARARs. However, in many circumstances TBCs may be considered along with ARARs in determining the necessary level of cleanup for protection of health or the environment.

Current EPA CERCLA guidance calls for a preliminary identification of potential ARARs during the RI scoping phase to assist in the initial identification of remedial alternatives. Early identification also facilitates communications with support agencies to evaluate ARARs, and may help planning of field activities. Because of the iterative nature of the RI/FS process, ARAR identification continues throughout the RI/FS as better understanding is gained of the site conditions, site contaminants, and remedial action alternatives. Findings of the Phase I RI aided in the selection of ARARs as presented in Volume II of the Phase II RI/FS Work Plan (TRC, 1992). ARARs were further evaluated in the Initial Screening of Alternatives Report (TRC, 1993). This section revisits the information provided in that report, updating it on the basis of the specific information related to Site 11, as addressed herein, as well as on the basis of evolving regulatory requirements.

ARARs may be categorized as: 1) chemical-specific requirements, which may define acceptable exposure levels and, therefore, be used in establishing preliminary remediation goals; 2) location-specific requirements, which may set restrictions on activities within specific locations such as coastal areas or wetlands; and 3) performance, design or other action-specific requirements, which may set controls or restrictions for particular treatment and disposal activities related to the management of hazardous wastes. The documents "CERCLA Compliance With Other Laws Manual" (USEPA, 1988), and "CERCLA Compliance with Other Laws Manual: Part II. Clean Air Act and Other Environmental Statutes and State Requirements" (USEPA, 1989), contain detailed information on identifying and complying with ARARs. In addition, Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991) provides guidance on the use of ARARs for the development of preliminary remediation goals (PRGs).

A.2 Approach

This evaluation focuses on the identification of potential chemical-specific ARARs/TBCs which will guide the development of PRGs at Site 11. Preliminary location-specific and action-specific ARARs/TBCs are also evaluated herein, but are further evaluated with respect to the individual remedial alternatives in the detailed alternative analysis portion of this report.

To determine the chemical-specific requirements which may be applicable to remediation at Site 11 (i.e., to identify preliminary remediation goals (PRGs) and chemical-specific ARARs which may be applicable to certain remedial actions), an evaluation of federal and State of Rhode Island chemical-specific ARARs was conducted. Those federal and state chemical-specific ARARs considered to potentially be applicable or relevant and appropriate to the development of PRGs at Site 11 have been compiled, as presented in Tables A-1 and A-2.

A.3 Potential Federal Chemical-Specific ARARs/TBCs

Potential federal chemical-specific ARARS and TBC criteria are presented in Table A-1. Chemical-specific ARARs/TBCs which may be applicable to the development of preliminary remediation goals for the various media at the site are addressed by media below. Following this discussion is a presentation of potential chemical-specific ARARs/TBCs which may be considered in the evaluation of specific remedial actions at the site.

A.3.1 Ground Water

Ground water at NCBC Davisville is not a current source of drinking water, and ground water at Site 11 is classified as GB. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991) provides guidance on the development of PRGs for ground water. Safe Drinking Water Act (SDWA) maximum contaminant levels (MCLs), non-zero maximum contaminant level goals (MCLGs), and state drinking water standards are common ARARs and therefore PRGs for ground water that is a current or potential source of drinking water. Although the ground water at Site 11 is classified as GB, indicating that it would not be suitable for use as a drinking water supply without treatment, there currently is no regulatory mechanism which would prevent the installation of a potable well on-site. Therefore, MCLs, MCLGs and state drinking water standards are considered to be relevant and appropriate to Site 11. Where MCLs, MCLGs and state drinking water standards are unavailable for a particular ground water contaminant, USEPA Risk Reference Doses, Lifetime Health Advisories and Human Health Assessment Group Cancer Slope Factors will be used to develop risk-based PRGs.

A.3.2 Soils

The Toxic Substances Control Act provides PCB cleanup levels for solid surfaces and soils where spills occurred after May 4, 1987. These levels may be relevant and appropriate to the evaluation of any PCB contamination in Site 11 soils. USEPA Guidance on Remedial Actions for Superfund Sites with PCB Contamination (Oswer Directive 9355.4-02) will also be considered with respect to the evaluation of any PCB contamination in Site 11 soils. In addition, the Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02) will represent TBC criteria for lead in soils.

A.3.3 Chemical-Specific ARARs Potentially Applicable to Remedial Actions

Chemical-specific federal ARARs/TBCs which are applicable to the implementation of certain remedial actions include Ambient Water Quality Criteria (AWQC) and Effluent Discharge Limitations, both promulgated under the Clean Water Act, which represent potential chemical-specific ARARs for alternatives which involve discharges to surface waters.

The Toxicity Characteristic Leachate Parameter (TCLP) maximum concentrations (40 CFR 261.24) and the land disposal restrictions (40 CFR 268) present chemical-specific criteria which will be applicable to any action which requires a hazardous waste determination and disposal option evaluation.

Sections of the Clean Air Act which establish maximum concentrations for particulates and fugitive dust emissions, emissions limitations for new sources, and emissions limitations for hazardous air pollutants, will be considered potential chemical-specific ARARs for remedial alternatives which impact ambient air.

A.4 Potential Rhode Island Chemical-Specific ARARs/TBCs

A.4.1 Ground Water

Potential Rhode Island chemical-specific ARARs and TBC criteria are presented in Table A-2. As discussed in Section A.3.1, Rhode Island Public Drinking Water Regulations are not applicable to Site 11, based on its GB ground water classification, but are considered to be relevant and appropriate based on the lack of a regulatory mechanism to prohibit installation of a potable well on-site.

A.4.2 Soil

Rhode Island's Rules and Regulations for Solid Waste Management Facilities define solid wastes as including wastes which contain a concentration of 10 ppm or greater PCBs. The Rules and Regulations for Hazardous Waste Management define Type 6 - extremely hazardous waste as including wastes which contain a concentration of 50 ppm or greater PCBs. These regulations may be relevant and appropriate to the evaluation of soil PCB contaminant levels at Site 11. RIDEM and the Rhode Island Department of Health-Risk Assessment consider a safe lead level in soil (total) as under 300 ppm, a TBC in the identification of PRGs at Site 11.

A.4.3 Chemical-Specific ARARs Potentially Applicable to Remedial Actions

Chemical-specific ARARs/TBCs which may be applicable to the implementation of certain remedial actions include the Rhode Island Water Quality Standards, established under the RI Water Pollution Control Law (RIGL, Title 46, Chapter 12), which will be applicable to remedial actions which involve discharges to surface water. The RI Clean Air Act (RI Title 23, Chapter 23) establishes maximum ambient levels for criteria pollutants under the Air Pollution Control Regulation Standards. These levels constitute potential chemical-specific ARARs for remedial alternatives which emit pollutants into the air.

A.5 Potential Location-Specific ARARs/TBCs

A site's location is a fundamental determinant of its impact on human health and the environment. Location-specific ARARs are restrictions placed on the concentrations of hazardous substances or the conduct of activities solely because they are in a specific location (USEPA, 1988).

A.5.1 Potential Federal Location-Specific ARARs/TBCs

No federal location-specific ARARs and TBCs were identified as being potentially applicable to Site 11. The nearest wetlands are located approximately 2,400 feet northeast of Site 11. Therefore, wetlands/water resources regulations, including Executive Orders 11988 and 11990, Statement of Proceedings of Floodplain Management and Wetlands Protection, the Clean Water Act Section 404 Requirements for Discharge of Dredge or Fill Material and the Rivers and Harbors Act Prohibition of Filling a Navigable Water will not apply to remedial actions conducted on-site. Coastal area and harbor protection regulations are not applicable due to the site's distance from coastal areas.

The Fish and Wildlife Coordination Act of 1958 was enacted to protect fish and wildlife when federal actions result in the control or structural modification of a natural stream or water body. Since no water bodies are located on or immediately adjacent to the site, the Fish and Wildlife Coordination Act is not expected to be applicable to remedial actions conducted on-site. The Endangered Species Act of 1973, which restricts activities in areas inhabited by registered endangered species, is not considered to be a potential ARAR for Site 11 based on the conclusion of an endangered species survey conducted in 1989 by RIDEM (RIDEM, 1989).

Based on the results of a cultural resources survey conducted at the NCBC facility, as described in Cultural Resource Assessment for Base Closure and Realignment, Redevelopment and Reuse at the Naval Construction Battalion Center, Davisville, Rhode Island, prepared by Ecology and Environment, Inc. and dated November 1993, the Archaeological and Historic Preservation Act of 1974 is not considered to be a potential ARAR for remedial actions at Site 11. The cultural resource survey report concluded that the majority of surficial deposits at the facility have been severely impacted by extensive land moving activities conducted by the Navy, and the report did not recommend archaeological surveys or identify historic properties in the immediate vicinity of Site 11. Site 13, located to the east of Site 11, has the potential to be an archaeologically sensitive area, as described in the Site 13 DAA Report (TRC, 1994).

To determine the potential applicability of the Farmland Protection Policy Act, the U.S. Department of Agriculture Important Farmlands Map for Kent County was reviewed. This map, developed on the basis of soil survey information, indicates that limited areas designated as Prime Farmland and Additional Farmland of Statewide Importance are located in the general vicinity of the NCBC Davisville facility but do not encompass or abut Site 11. Therefore, farmland protection regulations are not considered to be applicable to remedial actions at Site 11.

A.5.2 Potential State Location-Specific ARARs/TBCs

No state location-specific ARARs/TBCs were identified as being potentially applicable to Site 11. As noted in Section A.5.1, Site 11 does not encompass or abut any wetland areas. Therefore, the Rhode Island Wetlands Laws are not considered to be potential ARARs for Site 11. Also, since Site 11 is not located adjacent to the coast, Rhode Island Coastal Resources Management Law and Regulations are not applicable to the site.

A.6 Potential Action-Specific ARARs/TBCs

Based on the identification of contaminants in soil, ground water and catch basin sediment at Site 11, remediation activities may be required and numerous state and federal requirements could apply to the implementation of these activities. As discussed previously, potential action-specific ARARs/TBCs cannot be well-defined until remedial alternatives are developed and response actions defined. Action-specific ARARs are defined in more detail in the detailed analysis of remedial alternatives (Section 4 of this report).

A.6.1 Potential Federal Action-Specific ARARs/TBCs

Numerous federally promulgated action-specific ARARs and TBC criteria could potentially affect the implementation of remedial measures. A preliminary evaluation of federal regulatory requirements potentially applicable to remedial activities at Site 11 is presented in Table A-3.

A.6.2 Potential State Action-Specific ARARs/TBCs

The State of Rhode Island has promulgated regulations similar to those of the federal government. A preliminary evaluation of potential state action-specific ARARs which may be applicable to remedial activities at Site 11 is presented in Table A-4.

References

RIDEM, 1989. Endangered Species Surveys at Camp Fogarty, West Davisville, and East Davisville.

TRC Environmental Corporation, 1992. Phase II RI/FS Work Plan, Naval Construction Battalion Center, Davisville, Rhode Island. Prepared for Northern Division Naval Facilities Engineering Command, Philadelphia, PA. August, 1992.

TRC Environmental Corporation, 1993. Initial Screening of Alternatives, Naval Construction Battalion Center, Davisville, Rhode Island. Prepared for Northern Division, Naval Facilities Engineering Command, Philadelphia, PA. Contract No. N62472-85-C-1026, April 1993.

TRC Environmental Corporation, 1994. Detailed Analysis of Alternatives, Site 06 - Solvent Disposal Area, Site 13 - Disposal Area Northwest of Buildings W-3, W-4 and T-1. Prepared for Northern Division, Naval Facilities Engineering Command, Philadelphia, PA. Contract No. N62472-86-C-1282, April 1994.

USEPA, 1988. CERCLA Compliance with Other Laws Manual, Draft Guidance, Part I, OSWER Directive 9234.1-01, August 8, 1988.

USEPA, 1989. CERCLA Compliance with Other Law Manuals: Part II. Clean Air Act and Other Environmental Statues and State Requirements, Office of Solid Waste and Emergency Response, EPA/540/G-89/009, OSWER Directive 9234.1-02, August 1989.

USEPA, 1991. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), Interim. EPA/540/R-92/003, December 1991.

TABLE A-1
FEDERAL CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Ground Water--				
	Safe Drinking Water Act (40 CFR 141.11-.16 and 141.60-.63) Maximum Contaminant Levels (MCL's)	Relevant and Appropriate	MCL's directly apply to "public water systems", defined as systems with at least 15 connections which service a minimum of 25 persons.	Ground water at NCBC is not a current source of drinking water, but is classified as GB at Site 11. Since there is no regulatory mechanism to prohibit potable use of the ground water, MCLs are relevant and appropriate. Contaminant concentrations are compared to MCLs to assess potential risks associated with ingestion of ground water.
	Safe Drinking Water Act (40 CFR 141.50-.52) Maximum Contaminant Level Goals (MCLGs)	Relevant and Appropriate	Non-enforceable health goals for public water supply systems, set at levels which result in no known or anticipated adverse health effects.	Ground water at NCBC is not a current source of drinking water, but is classified as GB at Site 11. Since there is no regulatory mechanism to prohibit potable use of the ground water, MCLGs are relevant and appropriate. Non-zero MCLGs are to be used as remedial goals for current or potential sources of drinking water, per the NCP (40 CFR 300). Contaminant concentrations are compared to MCLGs to assess potential risks associated with ingestion of ground water.
	USEPA Risk Reference Doses (RfDs)	To Be Considered	Toxicity values for evaluating noncarcinogenic effects resulting from exposures to contamination.	USEPA RfDs are used to characterize risks due to noncarcinogens in ground water.
	Lifetime Health Advisories	To Be Considered	Guidelines developed based on toxicity for noncarcinogenic compounds	TBC criteria due to the presence of contaminants in ground water.
	USEPA Human Health Assessment Group Cancer Slope Factors (CSFs)	To Be Considered	A slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen.	USEPA CSFs are used to compute the individual incremental cancer risk resulting from exposure to certain compounds.

TABLE A-1(continued)
FEDERAL CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Surface Water --				
	Clean Water Act (40 CFR 121) Ambient Water Quality Criteria (AWQC)	To be determined	Non-enforceable guidelines established for the protection of human health and/or aquatic organisms.	AWQC will be applicable to remedial alternatives which involve discharges to surface water.
	Clean Water Act (40 CFR 401.15) Effluent Discharge Limitations	To be determined	Regulates the discharge of contaminants from an industrial point source.	Regulations will be applicable to remedial alternatives which involve discharges to surface water.
Soils/Surfaces--				
	Toxic Substances Control Act (40 CFR 761.125)	Relevant and Appropriate	Establishes PCB cleanup levels for soils and solid surfaces.	Applicable to spills of materials containing PCBs at concentrations of 50 ppm or greater that occurred after May 4, 1987. These requirements may be relevant and appropriate to the evaluation of PCB levels in site soils.
	Guidance on Remedial Actions for Superfund Sites with PCB Contamination (OSWER Directive 9355.4-01)	To Be Considered	Provides guidance on identifying principal threat and low-threat areas of PCB contamination. At industrial sites, PCBs at concentrations of 500 ppm or greater generally pose a principal threat.	Will be considered at Site 11 with respect to soil PCB contamination.
	Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites (OSWER Directive 9355.4-02)	To Be Considered	Sets forth an interim soil cleanup level for lead at 500 to 1000 ppm.	Will be considered at Site 11 with repect to soil lead contamination.
	Toxicity Characteristic (40 CFR 261.24)	To be determined	Establishes maximum concentrations of contaminants for the toxicity characteristic using the test method described in 40 CFR 261 Appendix II.	Applicable where wastes produced as a byproduct of a remedial action require handling as a hazardous waste on the basis of the Toxic Characteristic Leachate Parameter (TCLP) analysis.

TABLE A-1(continued)
FEDERAL CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Soils/Surfaces--(cont.)	Land Disposal Restrictions (40 CFR 268)	To be determined	Establishes maximum concentrations of contaminants on the basis of which hazardous wastes are restricted from land disposal.	This regulation will be applicable to remedial alternatives which utilize land disposal of hazardous waste.
Air--	Clean Air Act (40 CFR 50) National Ambient Air Quality Standards (NAAQS)	To be determined	Establishes maximum levels for pollutants and particulates within air quality control districts.	Potential ARARS for alternatives involving remedial actions which impact ambient air (i.e. incinerators, soil venting, etc.).
	Clean Air Act (40 CFR 60) New Source Performance Standards (NSPS)	To be determined	Establishes emissions limitations for new sources.	Potential ARARS for alternatives involving treatment methods which emit pollutants.
	Clean Air Act (40 CFR 61) National Emissions Standard for Hazardous Air Pollutants	To be determined	Establishes emissions standards for hazardous air pollutants.	Potential ARARS for alternatives involving treatment methods which emit hazardous air pollutants.

TABLE A-2
STATE CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 – FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

MEDIA	REQUIREMENT	STATUS	SYNOPSIS	APPLICABILITY TO SITE CONDITIONS
Ground Water--				
	RI Ground Water Protection Act (RIGL, 46-13 et seq.) Public Drinking Water Regulations	Relevant and Appropriate	Establishes provisions for the protection and management of potable drinking waters, including the development of ground water classifications and associated standards which specify maximum contaminant levels for each classification.	Ground water at NCBC is not a current source of drinking water, but is classified as GB at Site 11. Since there is no regulatory mechanism to prohibit potable use of the ground water, these regulations are relevant and appropriate and contaminant concentrations will be compared to the established ground water quality standards.
Surface Water --				
	RI Water Pollution Control Law (RIGL 46-12 et seq.) RI Water Quality Standards	To be determined	Establishes water use classification and water quality criteria for all waters of the state. Also establishes acute and chronic water quality criteria for the protection of aquatic life.	Regulation will be applicable for remedial alternatives which involve discharges to surface water.
Soils/Surfaces--				
	Lead Soil Cleanup Standards (Guidance)	To Be Considered	RIDEM and the Rhode Island Department of Health-Risk Assessment consider a safe lead level in soil (total) to be under 300 ppm.	To be considered with respect to lead soil contamination.
	RI Hazardous Waste Management Act of 1987 (RIGL 23-19.1 et seq.) Rules and Regulations for Hazardous Waste Management	Relevant and Appropriate	Defines Type 6 – extremely hazardous waste as including wastes which contain PCBs at a concentration of 50 ppm or greater or showing 10 micrograms/ 100 sq. cm. or greater as measured by a standard wipe test.	Relevant and appropriate to the evaluation of PCB levels in soil.
	Rules and Regulations for Solid Waste Management Facilities	Relevant and Appropriate	Defines solid waste as including any soil, debris or other material with a concentration of PCBs of 10 ppm or greater or containing 2 micrograms/100 sq. cm. or greater as measured by a standard wipe test.	Relevant and appropriate to the evaluation of PCB levels in soil.
Air--				
	RI Clean Air Act (RIGL Title 23, Chapter 23) Air Pollution Control Regulation Standards	To be determined	Establishes maximum ambient levels for criteria pollutants.	Potential ARARs for remedial alternatives involving treatment methods which emit criteria pollutants.

TABLE A-3
FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
On-site/ Off-site Treatment/ Disposal	Resource Conservation and Recovery Act (RCRA) (40 CFR 262) Generator Requirements for Manifesting Waste for Off-Site Disposal	To be determined	Standards for manifesting, marking and recording off-site hazardous waste shipments for treatment/disposal.	This regulation will be applicable to alternatives which utilize an off-site disposal/treatment method for hazardous wastes.
	RCRA (40 CFR 263) Transporter Requirements for Off-Site Disposal	To be determined	Standards for transporters of hazardous waste materials.	This regulation will be applicable to alternatives which utilize an off-site disposal/treatment method for hazardous wastes.
	RCRA (40 CFR 264 and 265) Requirements for Hazardous Waste Treatment Facility Design and Operating Standards for Treatment and Disposal Systems	To be determined	Outlines specifications and standards for design, operation, closure and monitoring of performance for hazardous waste storage, treatment and disposal facilities.	Potential ARARs for alternatives which utilize a surface impoundment, waste pile, landfill, land treatment, incineration or miscellaneous treatment units for on-site storage/disposal/treatment of hazardous wastes.
	RCRA (40 CFR 264.10-264.18) Subpart B - General Facility Standards	To be determined	General requirements regarding waste analysis, security, training, inspections, and location applicable to a facility which stores, treats or disposes of hazardous wastes (a TSDF facility).	This regulation may be applicable to a remedial action conducted at Site 11, if it meets the definition of a TSDF.
	RCRA (40 CFR 264.30-264.37) Subpart C - Preparedness and Prevention	To be determined	Requirements applicable to the design and operation, equipment, and communications associated with a TSDF facility, and to arrangements with local response departments.	This regulation may be applicable to a remedial action conducted at Site 11, if it meets the definition of a TSDF.
	RCRA (40 CFR 264.50-264.56) Subpart D - Contingency Plan and Emergency Procedures	To be determined	Emergency planning procedures applicable to a TSDF facility.	This regulation may be applicable to a remedial action conducted at Site 11, if it meets the definition of a TSDF.
	RCRA (40 CFR 264) Subpart F Ground Water Protection	To be determined	Ground water monitoring/corrective action requirements; dictates adherence to MCLs and establishes points of compliance.	Potential ARARs for alternatives which involve placement of hazardous wastes within solid waste management units, including surface impoundments, waste piles, and land treatment units.

TABLE A-3(continued)
FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
On-site/ Off-site Treatment/ Disposal (cont.)	RCRA (40 CFR 264) Subpart G Closure/Post Closure Requirements	To be determined	Establishes requirements for the closure and long-term management of a hazardous disposal facility.	Applicable to the closure of any hazardous waste management facility.
	RCRA (40 CFR 264) Subpart I Use and Management of Containers	To be determined	Outlines use and management standards applicable to owners and operators of all hazardous waste facilities that store containers of hazardous waste.	Potential ARARs for remedial actions which require storage of hazardous waste in containers.
	RCRA (40 CFR 264) Subpart L Waste Piles	To be determined	Regulates owners and operators of facilities that store or treat hazardous waste in piles.	Potential ARARs for remedial alternatives which utilize a waste pile for on-site storage/treatment of hazardous waste.
	RCRA (40 CFR 264) Subpart O Incinerator Restrictions	To be determined	Outlines specifications and standards for incinerating hazardous waste.	Potential ARARs for alternatives which utilize incineration for on-site treatment of hazardous wastes.
	RCRA (40 CFR 265) Subpart Q - Chemical, Physical and Biological Treatment	To be determined	General operating, waste analysis and trial test, inspection and closure requirements for facilities which treat hazardous waste by chemical, physical or biological methods in other than tanks, surface impoundments and land treatment facilities.	Remedial alternatives which utilize chemical, physical and biological treatment methods as described to treat hazardous wastes will meet these requirements.
	RCRA (40 CFR 264.600-264.999) Subpart X - Miscellaneous Units	To be determined	Environmental performance standards, monitoring requirements and post-closure care requirements applicable to miscellaneous units (not otherwise defined in the RCRA regulations) used to treat, store or dispose of hazardous waste.	Potential ARARs for remedial actions involving hazardous waste treatment, storage or disposal in units not otherwise covered under RCRA regulations.

TABLE A-3(continued)
FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Off-site Treatment/ Disposal (cont.)	RCRA (40 CFR 268) Land Disposal Restrictions	To be determined	Identifies hazardous wastes that are restricted from land disposal and sets treatment standards for restricted wastes.	This regulation will be applicable to alternatives which utilize land disposal of hazardous wastes.
	Hazardous Materials Transportation Act (49 CFR 170, 171) Rules for Transportation of Hazardous Materials	To be determined	Procedures for packaging, labelling, manifesting, and off-site transport of hazardous materials.	This regulation will be applicable to alternatives which include off-site transport of hazardous materials.
	Toxic Substances Control Act (15 USC. Sect. 2601) Subpart D - Storage and Disposal Requirements for PCBs	To be determined	Establishes requirements for the storage, landfilling, and incineration of PCBs.	This regulation may be applicable or relevant and appropriate to alternatives which involve handling of PCB-contaminated materials.
	Guidance on Remedial Actions for Superfund Sites with PCB Contamination (OSWER Directive 9355.4-01)	To be determined	Describes the recommended approach for remediating Superfund sites with PCB contamination.	This guidance will be considered in the evaluation of treatment/disposal actions.
Discharge	Safe Drinking Water Act (40 CFR 144 and 146) Underground Injection Control Requirements	To be determined	Establishes the general requirements, technical criteria and standards for underground injection wells.	This regulation will be applicable to alternatives in which treated water is discharged back to the ground water.
	Clean Water Act (40 CFR 122-125) National Pollutant Discharge Elimination System (NPDES) Permit Requirements	To be determined	Permits contain applicable effluent standards (i.e., technology-based and/or water quality-based), monitoring requirements, and standards and special conditions for discharge.	This regulation will be applicable to alternatives in which treated water is discharged to surface waters or back to the ground water.
	Clean Water Act (40 CFR 403) Discharge to Publicly-Owned Treatment Works (POTW)	To be determined	A national pretreatment program designed to protect municipal wastewater treatment plants and the environment from damage that may occur when hazardous, toxic or other non-domestic wastes are discharged into a sewer system.	This regulation is applicable to alternatives in which waters are discharged to a POTW.

TABLE A-3(continued)
FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air	Clean Air Act (40 CFR 50) National Ambient Air Quality Standards (NAAQS)-Particulates	To be determined	Establishes maximum concentrations for particulates and fugitive dust emissions.	ARARs for alternatives involving treatment methods which impact ambient air (i.e. incineration, soil venting, etc.).
	Clean Air Act, Section 5 171 through 178, 42 USC §§ 7471-7478 (Requirements for Non-Attainment Areas)	To be determined	RI has adopted State Implementation Plan (SIP) requirements approved and enforcable by EPA which meet the New Source Review (NSR) requirement of the CAA. These provisions require that new or modified major sources of VOCs defined as a source which has the potential to emit 50 tpy install equipment to meet Lowest Available Emissions Rate (LAER), which is set on a case-by-case basis and is either the most stringent emissions limitation contained in any SIP for that category or source or the most stringent emissions limitation which is achieved for the source. NSR requirements apply to non-attainment pollutants, which are VOCs and NO_x in RI.	Monitoring will be conducted to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels and on the need to be protective of human health and the environment.
	Clean Air Act, Section 5 160 through 169A - Prevention of Significant Deterioration Provisions	To be determined	RI has adopted SIP requirements approved and enforceable by EPA which meet the Prevention of Significant Deterioration (PSD) requirements of the CAA. These provisions require that new or modified major sources of VOCs, defined as a source which has the potential to emit 25 tons/year, install equipment to meet Best Available Control Technology (BACT). PSD requirements apply to attainment pollutants, which are SO2, CO, lead and particulates in Rhode Island.	Monitoring will be conducted to determine if the requirements of this standard are applicable or relevant and appropriate based on the emissions levels.
	Clean Air Act (40 CFR 61) National Emissions Standards for Hazardous Pollutants (NESHAPS)	To be determined	Establishes emissions limitations for hazardous air pollutants, and sets forth regulated sources of those pollutants.	Potential ARARs for alternatives using treatments (i.e., incineration, etc.) which result in emissions to the air.

TABLE A-3(continued)
FEDERAL ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 – FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharges to Air (cont.)	RCRA 40 CFR 265.375 Subpart P – Thermal Treatment	To be determined	Establishes requirements for air emissions from thermal treatment units.	Remedial actions which involve thermal treatment units, as defined in 40 CFR 265.370, will meet these standards.
	RCRA 40 CFR 264.1030 – 264.1036 Subpart AA – Air Emission Standards for Process Vents	To be determined	Establishes standards for air emissions from process vents associated with distillation, fractionation, thin film evaporation, column extraction or air steam stripping operations that treat RCRA substances and have total organic concentrations of 10 ppm or greater.	If these technologies are utilized and the threshold organic concentration is met, air emissions will comply with the standards.
	RCRA 40 CFR 264.1050 – 264.1065 Subpart BB – Air Emission Standards for Equipment Leaks	To be determined	Establishes standards for air emissions for equipment that contains or contacts RCRA wastes with organic concentrations of at least 10% by weight.	If such concentrated wastes are treated, the equipment used will meet these standards.
	EPA Technical Guidance Document: Control of Air Emissions from Superfund Air Strippers at Superfund Ground Water Sites (OSWER Directive 9355.0.28)	To Be Considered	Guidance regarding the control of air emissions from air strippers used at Superfund sites for ground water treatment. Distinguishes between attainment and non-attainment areas for ozone.	These guidelines will be considered if air stripping is used as a ground water treatment alternative.

TABLE A-4
STATE ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
On-site/ Off-site Disposal/ Treatment	RI Hazardous Waste Management Act of 1978 (RIGL 23-19.1 et seq.) • Hazardous Waste Management Rules and Regulations	To be determined	Rules and regulations for hazardous waste generation, transportation, treatment, storage, and disposal.	These rules will be applicable for alternatives which involve the on- or off-site management of hazardous wastes.
	• Rules and Regulations for the Investigation and Remediation of Hazardous Material Releases (Site Remediation Regulations)	To be determined	Rules and regulations for the investigation and remediation of releases of hazardous materials.	These rules will be applicable to the design and operation of remedial systems.
	RI Hazardous Substance Community Right to Know Act (RIGL, Title 23, Chapter 24.4) Public Right-to-Know Requirements	To be determined	Establishes rules for the public's right-to-know concerning hazardous waste storage and transportation.	These rules will be applicable for alternatives which involve the on- or off-site management of hazardous wastes.
	RI Refuse Disposal Law Rules and Regulation for Solid Waste Management Facilities	To be determined	Rules and regulations for solid waste management facilities.	ARARs for alternatives involving the on-site storage and disposal of solid wastes.
Discharge	RI Water Pollution Control Act • RI Water Quality Regulations for Water Pollution Control (RIGL 46-12 et seq.) RI Water Quality Standards	To be determined	Establishes general requirements and effluent limits for discharge to area waters.	This regulation will be applicable to alternatives in which treated water is discharged to area surface water or ground water.
	• Regulations for the RI Pollutant Discharge Elimination Systems (RIGL 46-12 et seq.)	To be determined	Permits contain applicable effluent standards (i.e., technology-based and/or water quality-based), monitoring requirements, and standards and special conditions for discharge.	This regulation will be applicable to alternatives in which treated water is discharged to area surface water or ground water.

TABLE A-4(continued)
STATE ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Discharge (cont.)	RI Water Pollution Control Act			
	• RI Pretreatment Regulations (RIGL 46-12 et seq.)	To be determined	Covers pollutants in wastewaters which can have detrimental effects on POTW processes. Sets specified limitations, pretreatment and monitoring requirements for discharges to POTWs based on federal regulations.	Remedial actions which include discharge to a POTW will meet all required discharge limitations.
	• RI Underground Injection Control Regulations (RIGL 46-12 et seq.)	To be determined	Establishes the general requirements, technical criteria and standards for underground injection wells.	This regulation will be applicable to alternatives in which treated water is discharged back to the ground water via injection.
	• RI Ground Water Protection Act (RIGL, Title 46, Chapter 13.1) Protection of Ground Water	To be determined	Establishes ground water classifications and maximum contaminant levels for each classification.	Potential ARARs for alternatives involving the treatment of contaminated ground water.
Venting/ Discharge to Air	RI Clean Air Act (RIGL, Title 23, Chapter 23) General Air Quality and Air Emissions Requirements	To be determined	Sets emissions limitations for particulates and visible air contaminants.	ARARs for alternatives involving remedial actions which impact ambient air.
	RI Clean Air Act (RIGL, Title 23, Chapter 23) General Air Quality and Air Emissions Requirements • RI Air Pollution Control Regulations, RI Dept. of Health, Div. of Air Pollution Control, effective 8/2/67, most recently amended 5/20/91			
	- Regulation No. 1 - Visible Emissions	To be determined	No air contaminant emissions will be allowed for more than 3 minutes in any one hour which are greater than or equal to 20% opacity.	Air emissions from remedial actions will meet emission levels in regulation.

TABLE A-4 (continued)
STATE ACTION-SPECIFIC ARARs AND TBCs
FEASIBILITY STUDY
SITE 11 - FIRE FIGHTING TRAINING AREA
NCBC DAVISVILLE

AUTHORITY/ ACTION	REQUIREMENT	STATUS	SYNOPSIS	ACTION TAKEN TO MEET ARAR
Venting/ Discharge to Air (cont.)	RI Clean Air Act (cont.) • RI Air Pollution Control Regulations, (cont.)			
	- Regulation No. 5 - Fugitive Dust	To be determined	Requires that reasonable precaution be taken to prevent particulate matter from becoming airborne.	On-site remedial actions will use good industrial practices to prevent particulate matter from becoming airborne.
	- Regulation No. 7 - Emissions Detrimental to Person or Property	To be determined	Prohibits emissions of contaminants which may be injurious to human, plant or animal life or cause damage to property or which reasonably interferes with the enjoyment of life and property.	All emissions will meet this requirement or gas treatment will be required.
	- Regulation No. 9 - Approval to Construct, Install, Modify or Operate	To be determined	Establishes guidelines for the construction, installation, modification or operation of potential air emission units. Establishes permissible emission rates for some contaminants.	Technologies involving construction, installation, modification or operation of air emission units will meet these requirements.
	- Regulation No. 15 - Control of Organic Solvent Emissions	To be determined	Limits the amount of organic solvents emitted to the atmosphere.	If emissions exceed limits in this regulation, emission controls will be designed and implemented to meet these requirements.
	- Regulation No. 17 - Odors	To be determined	Prohibits the release of objectionable odors across property lines.	No remedial action or air emissions will emit objectionable odors beyond the facility boundary, as practicable.
	- Regulation No. 22 - Air Toxics	To be determined	Prohibits the emission of specified contaminants at rates which would result in ground level concentrations greater than acceptable ambient levels or acceptable ambient levels with LAER, as set in the regulation.	If air emissions contain regulated substances, air emissions control equipment will be used as necessary to meet these standards.

APPENDIX B

APPENDIX B

CALCULATION OF PRELIMINARY RISK-BASED REMEDIATION GOALS

Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-based Preliminary Remediation Goals), Interim (USEPA, 1991a) provides guidance on the development of risk-based preliminary remediation goals (PRGs). One of the initial steps in the development of PRGs is the identification of the most appropriate future land use for the site so that the appropriate exposure pathways, parameters and equations can be used to calculate PRGs. At Site 11, based on the Comprehensive Base Reuse Plan, the most appropriate future land use is for economic/industrial development. Therefore, exposures to surface soils and ground water, evaluated under the Human Health Risk Assessment for the future commercial/industrial use exposure scenario, will guide the development of PRGs.

According to the OSWER directive "Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions" (USEPA, 1991b), action is generally warranted at a site when the cumulative carcinogenic risk is greater than 10^{-4} or the cumulative non-carcinogenic Hazard Index (HI) exceeds 1 based on reasonable maximum exposure (RME) assumptions. Therefore, the cumulative risks associated with a given medium under future commercial/industrial use were evaluated to determine if any medium poses a cumulative cancer risk greater than 10^{-4} or HI greater than 1. At Site 11, cumulative risks associated with exposure to surface soils were less than 10^{-4} (cancer risks) or less than 1 (non-cancer risks). However, exposure to ground water results in a cumulative carcinogenic risk of 2×10^{-4} and a non-cancer RME HI of 6. Therefore, the development of PRGs was evaluated with respect to ground water exposures only.

As described in the National Contingency Plan [40 CFR 300.430(e)(2)(i)(A)(2)], "The 10^{-6} risk level shall be used as the point of departure for determining remediation goals for alternatives when ARARs are not available...". As summarized in Table B-1, those ground water constituents which contributed an individual RME cancer risk of greater than 1×10^{-6} to the overall cancer risk estimate, or an individual RME hazard quotient of greater than one to the total hazard index for noncarcinogenic risks, were identified and then evaluated to determine if there were any for which an ARAR/TBC was not available. For those constituents without an associated ARAR/TBC, a risk-based preliminary remediation goal (PRG) was calculated, based on a future commercial/industrial use scenario. Arsenic and beryllium, which are the main contributors to the estimated cancer risk, have established MCLs. Therefore, PRGs were not calculated for these analytes. However, manganese, the main contributor to the elevated non-cancer HI value, has not been assigned an MCL. Therefore, a risk-based PRG was calculated for manganese. As shown in Table B-2, the calculations for ground water incorporate commercial/industrial worker exposures as an adult. Under this scenario, exposure is assumed to occur through ingestion of ground water. The exposure parameters for the ground water calculations are taken directly from the risk assessment portion of the Phase II RI. The risk-based PRG for manganese is 510 ppb. As noted in the footnote to Table B-2, the calculated PRG is within the concentration range detected in upgradient wells at the NCBC Davisville sites.

References

USEPA, 1991a. Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals), Interim. EPA/540/R-92/003, December 1991.

USEPA, 1991b. Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions. OSWER Directive 9355.0-30, April 1991.

Table B-1
Constituents Considered for the Development of Risk-Based Preliminary Remediation Goals [a]
NCBC Davisville - Site 11 FIRE FIGHTING TRAINING AREA

Constituent	Scenario	Medium	Cancer Risk or Hazard Quotient Elevated?	Ground Water MCL Available?	Selected for Development of Risk-Based PRGs?
Arsenic	Commercial	Ground Water	CR	Yes	No
Beryllium	Commercial	Ground Water	CR	Yes	No
Manganese	Commercial	Ground Water	HQ	No	**Yes**

[a] i.e., Constituents associated with individual cancer risks above 1E-06 or hazard quotients above 1 as estimated under the key exposure scenario for each medium (i.e., commercial/industrial for ground water)

Table B-2
Non-Cancer-Risk-Based Preliminary Remediation Goals (PRGs) for Constituents in Ground Water Assuming Future Commercial/Industrial Use
NCBC Davisville - Site 11 FIRE FIGHTING TRAINING AREA

Constituent	Oral Reference Dose (RfD) (mg/kd*d)$^{-1}$	Oral Relative Absorption Factor (RAF) (--)	Ground Water PRG [a] (mg/l)
Manganese	5.0E-03	1	5.1E-01 [b]

[a] Based on USEPA (1991) guidance and Phase II Human Health Risk Assessment
[b] PRG is within or less than concentrations detected upgradient for all sites (i.e., 0.034 mg/l at 03-MW03 to 2.2 mg/l at 10-MW05).

PRG = [THI * AT * BW] / [(1/RfD) * IR_w * RAF_o * EF * ED]

Where:

THI = Target hazard index:	1 --
AT = Averaging time:	9125 d
BW = Body weight:	70 kg
RfD = Reference dose:	CS Chemical-specific
IR_w = Water ingestion rate:	1 l/d
RAF_o = Oral relative absorption factor:	CS Chemical-specific
EF = Exposure frequency:	250 d/yr
ED = Exposure duration:	25 yr

APPENDIX C

APPENDIX C

EVALUATION OF LEACHING POTENTIAL BASED ON APPLICATION OF LEACHING MODEL

To evaluate the potential for surface and subsurface soil contaminants to leach into the ground water, an infiltration/leaching model was used. USEPA's document entitled Determining Soil Response Action Levels Based on Potential Contaminant Migration to Ground Water: A Compendium of Examples (EPA/540/2-89/057, October 1989) presents various methods which have been used to derive soil cleanup levels based on potential threats to ground water quality.

The Summers model and the "unnamed" model, as described in this USEPA document, were evaluated in terms of applicability to site conditions at Site 11 - Fire Fighting Training Area. Both of these three-dimensional models assume that a percentage of rainfall will infiltrate and desorb contaminants from the soil based on equilibrium soil:water partitioning. It is assumed that this contaminated infiltration will mix completely with ground water below the site, resulting in an equilibrium ground water concentration with all contaminants from the infiltration in the final mixture. The Summers model is applicable to a large spill area and is based on a mass balance approach which is applied to the entire area and affected soil volume of the spill. Therefore, it involves a mass balance of the total volume and contaminant concentration of infiltration over the entire area of the site, the total volume and contaminant concentration of ground water flowing into the site area, and the total volume and contaminant concentration of ground water exiting the site.

The unnamed model is a variation of the Summers model in which the mass balance approach is applied to a column of the site, of unit area and of depth equal to the saturated portion of the aquifer. Since subsurface contamination at Site 11 is heterogeneous, characterized by small areas of elevated contamination, rather than consistently contaminated throughout the areal extent of the site, application of the unnamed model was determined to be more appropriate. The unnamed model also provides for the separate estimation of critical saturated and unsaturated soil contaminant levels.

Data Requirements

- Volumetric flow rate of recharge flowing downward through a unit area (based on the infiltration rate of precipitation) (cf/day)
- Volumetric flow rate of ground water in saturated zone in water column through unit width (cf/day)
- Concentration of contaminant in ground water recharge (μg/l)
- Hydraulic conductivity (ft/day)
- Hydraulic gradient (ft/ft)
- Concentration of contaminant adsorbed to the soil in the unsaturated zone (μg/kg)
- Concentration of contaminant in ground water in the saturated zone (μg/l)
- Total organic carbon concentration (mg/mg)

Method Description

In the unnamed model, soil cleanup levels (or maximum allowable soil contaminant levels) are calculated for saturated and unsaturated soils assuming equilibrium between dissolved and adsorbed phases for each contaminant using the following relationship:

$$S_{sat} = (K_d)(C_{sat}) \qquad (1)$$

where: S_{sat} = concentration of contaminant adsorbed to the soil in the saturated zone (μg/kg)
K_d = distribution coefficient
C_{sat} = concentration of contaminant in ground water in saturated zone (μg/l)

The K_d is calculated as follows:

$$K_d = (0.63)(F_{oc})(K_{ow}) \qquad (2)$$

where: 0.63 = Adjustment factor
F_{oc} = total organic carbon concentration in soil (mg/mg)
K_{ow} = octanol-water partition coefficient

In calculating K_d, it is assumed that the maximum desired contaminant concentration for ground water is equal to an established health-based criteria (i.e., MCLs). Using equation (1), the maximum soil contaminant concentration in the saturated zone may then be calculated.

Subsequent calculations to derive unsaturated soil maximum contaminant concentrations include the assumption that dissolved contamination in ground water recharge reaches equilibrium with the adsorbed phase on unsaturated soils, and that such recharge is fully diluted into the entire water column upon reaching the water table. Thus the maximum unsaturated soil contaminant level is established using equation (1) and a dilution equation for calculating C_{sat}, the contaminant concentration in the ground water in the saturated zone which is based on the mass-balance approach, as indicated in Figure C-1.

$$C_{sat} = (C_{unsat})(e)/(e+Q) \quad (3)$$

where:
- C_{unsat} = contaminant concentration of ground water in recharge (μg/l)
- e = volumetric flow rate of recharge flowing downward through a unit area (cf/day)
- Q = volumetric flow rate of ground water in the saturated zone throughout the unit (cf/day)

The equilibrium assumption:

$$S_{unsat} = (K_d)(C_{unsat}) \quad (4)$$

and equation (1) combined with equation (3) yields the following relationship. The resultant equation is used to calculate the maximum contaminant concentration for soils in the unsaturated zone.

$$(S_{sat})/(K_d) = (S_{unsat})/(K_d)(e)/(e+Q)$$

and

$$S_{unsat} = (S_{sat})(e + Q)/e \quad (5)$$

where:
- S_{unsat} = concentration of contaminant adsorbed to the soil in the unsaturated zone (μg/kg)

and the ground water volumetric flow rate through the saturated zone (Q) is estimated from Darcy's Law:

$$Q = (K)\ (i)\ (A) \quad (6)$$

where:
- K = hydraulic conductivity (ft/day)
- i = hydraulic flow gradient (ft/ft)
- A = area of flow (unit width x saturated thickness of aquifer) (ft^2)

Site-Specific Application

The unnamed model was applied to Site 11 to determine the potential migration of soil contaminants into ground water. The evaluation was focused upon the soil contaminants which were identified as the Constituents of Concern (COCs) within the Phase II RI. Because the model assumes the maximum allowable ground water contaminant level is equal to the MCL, application of the model is generally limited to those constituents for which MCLs have been identified. For those COCs without final MCLs, proposed or tentative MCLs were used in the evaluation.

At Site 11 - Fire Fighting Training Area, two Phase II RI soil samples were analyzed for total organic carbon. Detected levels were 10,200 mg/kg and 11,800 mg/kg, with an average level of 11,000 mg/kg or 0.011 mg/mg. Using this value and published octanol-water partition coefficient values, the maximum saturated soil contaminant level was calculated for the Contaminants of Concern identified in the Phase II RI for which an MCL was available. The contaminants, octanol-water partition coefficients (K_{ow}) values used, calculated K_d values, assumed maximum ground water concentrations in the saturated zone (C_{sat} = MCL) and maximum saturated soil contaminant levels (S_{sat}) are presented in the first 4 columns of Table C-1. No soil samples were collected from the saturated zone during the Phase II RI. One soil sample collected in the saturated zone during the Phase I RI exhibited chloroform at a level of 2 ppb. A comparison of this level to the maximum allowable saturated soil contaminant level (S_{sat}) of 60 ppb is presented in columns 4 and 5 of Table C-1.

To calculate the maximum acceptable unsaturated soil contaminant levels, the volumetric flow rate of ground water in the saturated zone through the unit area (Q) was calculated. The average linear velocity for the site was estimated to be 0.76 ft/day by averaging the velocity values presented in Table 2-2 of the Detailed Analysis of Alternatives for Site 11. The average saturated thickness varies across the site, due to significant variations in the depth to bedrock. To determine the most applicable saturated thickness value, soil contaminant levels were evaluated to determine the location where the greatest contaminant levels were detected. At Site 11, the surface soil sample collected at boring location 11-B10 during the Phase II RI exhibited the highest levels of SVOC COCs. Two pesticides were also detected at their highest concentrations at boring location 11-B10. Therefore, the estimated saturated thickness at boring location 11-B10 was used in the model. Since soil boring 11-B10 did not extend to competent bedrock, a saturated thickness level of 32.2 feet was calculated by averaging the thickness of the interval from the water table surface to the top of the bedrock layer as measured at on-site monitoring wells 11-MW6D and 11-MW9D. Therefore, for a unit width of soil,

$$
\begin{aligned}
Q &= (0.76 \text{ ft/day})\ (32.2 \text{ ft})\ (1 \text{ ft}) \\
&= 24.5 \text{ cf/d}
\end{aligned}
$$

To estimate e, the volumetric flow rate of recharge flowing downward through a unit area, the information provided in Section 1.3.2 of the Phase II RI regarding precipitation and infiltration was used. Based on an average annual precipitation of 42.3 inches and 36% infiltration, the annual infiltration is 1.27 ft/yr or 0.0035 ft/day. Therefore, for a unit area of surface,

$$
\begin{aligned}
e &= (0.0035 \text{ ft/day})\ (1 \text{ ft})\ (1 \text{ ft}) \\
&= 0.0035 \text{ cf/day}
\end{aligned}
$$

Then S_{unsat} can be calculated using equation (5), where:

$$
\begin{aligned}
S_{unsat} &= (S_{sat})\ (e + Q)/e \\
&= (S_{sat})\ (0.0035 + 24.5)/0.0035 \\
&= (S_{sat})\ (7001)
\end{aligned}
$$

The calculated S_{unsat} values are presented in column 9 of Table C-1. The maximum detected soil contaminant levels in the unsaturated zone and the location of the maximum detected concentration for each contaminant are presented in columns 10 and 11, respectively. No unsaturated soil samples exhibited contaminants at levels exceeding the calculated maximum allowable level.

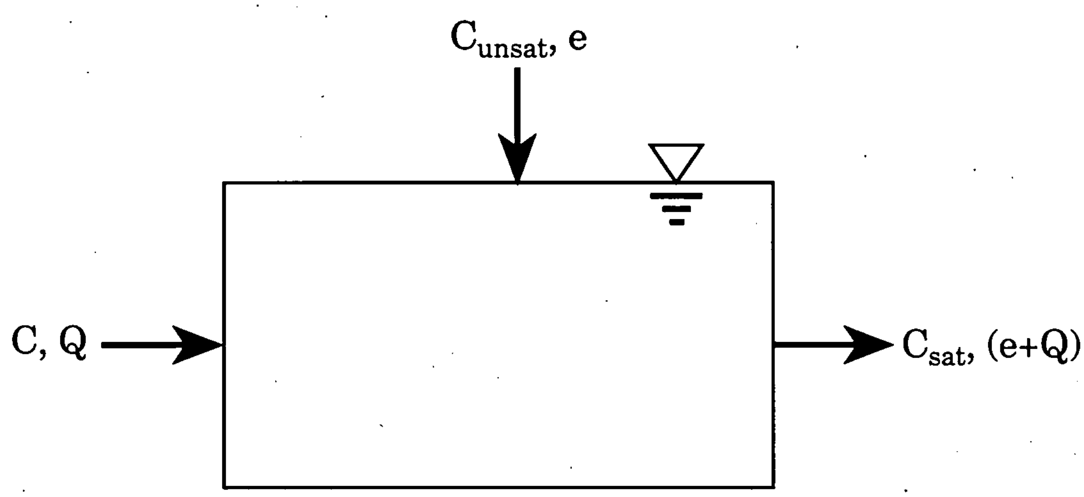
TABLE C-1

Site 11 – Fire Fighting Training Area
Comparsion of Soil Contaminant Levels to Modeled Soil Response Action Levels
Using the Unnamed Model (USEPA, EPA/540/2-89/057)

Column:	1	2	3	4	5	6	7	8	9	10	11
Constituent	K_{ow}	K_d	C_{sat} (ppm)	S_{sat} (ppm)	Max. Saturated Subsurface Soil Concentration Detected (ppm)	Location of Maximum Detected Level	Q (cf/d)	e (cf/d)	S_{unsat} (ppm)	Max. Unsaturated Soil Concentration Detected (ppm)	Sample Location
Chloroform	89.1	0.62	0.1 T	0.06	0.002	B-11-01-09-S	24.5	0.004	420.0	ND	--
Bis(2-ethylhexyl)phthalate	2.00E+05	1386	0.006 F	8.32	ND	--	24.5	0.004	58200	0.45	B-11-02-04-S
Butylbenzylphthalate	6.03E+04	418	0.1 P	41.8	ND	--	24.5	0.004	292600	0.34	11-MW7-01
Chrysene	4.07E+05	2821	0.0002 P	0.56	ND	--	24.5	0.004	3949	2.8	11-B10-01
Benzo(a)anthracene	4.07E+05	2823	0.0001 P	0.28	ND	--	24.5	0.004	1976	3.2	11-B10-01
Benzo(a)pyrene	9.55E+05	6618	0.0002 F	1.32	ND	--	24.5	0.004	9240	1.5	11-B10-01
Benzo(k)fluoranthene	6.92E+06	47944	0.0002 P	9.60	ND	--	24.5	0.004	67200	3.5	11-B10-01
Benzo(b)fluoranthene	3.72E+06	25780	0.0002 P	5.20	ND	--	24.5	0.004	36400	3.5	11-B10-01
Dibenzo (a,h) anthracene	9.33E+05	6466	0.0003 P	1.90	ND	--	24.5	0.004	13300	0.18	11-B10-01
Indeno(1,2,3-cd)pyrene	4.57E+07	316701	0.0004 P	126.70	ND	--	24.5	0.004	887000	0.56	11-B10-01
Endrin	3.98E+05	2758	0.002 F	5.52	ND	--	24.5	0.004	38650	0.0015	11-SS14
Heptachlor	2.51E+04	174	0.0004 F	0.07	ND	--	24.5	0.004	490	0.00028	11-B10-02
Heptachlor epoxide	4.47E+03	31	0.002 F	0.06	ND	--	24.5	0.004	420	0.00092	11-B10-01
PCB-1254	2.95E+06	20444	0.0005 F	10.2	ND	--	24.5	0.004	71400	0.096	11-SS23

K_d = 0.63 x 0.011 x K_{ow} where 0.63=adjustment factor and 0.011=average total organic carbon concentration
C_{sat} = Maximum Contaminant Level; F = Final MCL; P = Proposed MCL; T = Tentative.
S_{sat} = C_{sat} x K_d
Q = Avg linear velocity * unit area
Avg linear velocity = 0.76 ft/d (from Table 8-8 of Phase II RI)
Unit Area = Avg saturated thickness to top of bedrock (32.2 ft) * unit width (1 ft) = 32.2 sq ft
Q = 0.76 x 32.2 = 24.5 cf/d
e = infiltration rate x unit area
Infiltration rate = 15.2 in/yr = 0.0035 ft/d (= recharge at 36% of average annual 42.3 in precipitation)
Unit area = 1 ft by 1 ft = 1 sq ft
e = 0.0035 x 1 = 0.0035 cf/d
S_{unsat} = S_{sat} x (e+Q)/e
ND – Not Detected

FIGURE C-1
MASS BALANCE DERIVATION OF THE INFILTRATION EQUATION



$$(C_{unsat})\,(e) + (C)\,(Q) = (C_{sat})\,(e + Q)$$

$$C_{sat} = [(C_{unsat})\,(e) + (C)\,(Q)] \,/\, (e + Q)$$

Since C = 0, then:

$$C_{sat} = (C_{unsat})\,(e) \,/\, (e + Q)$$

C_{sat}	=	concentration of contaminant in ground water in saturated zone (µg/l)
C	=	initial concentration of contaminant in ground water (assumed zero)
C_{unsat}	=	contaminant concentration of ground water in recharge (µg/l)
e	=	volumetric flow rate of infiltration (cf/day)
Q	=	volumetric flow rate of ground water in the saturated zone throughout the unit (cf/day)

APPENDIX D

APPENDIX D

TECHNOLOGY AND PROCESS OPTION SCREENING

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APPENDIX D

TECHNOLOGY AND PROCESS OPTION SCREENING

Based on the general response actions developed for Site 11, remedial technologies which could potentially meet the remedial action objectives and cleanup criteria are identified and screened. This process is a two-step process in which technologies are initially screened on the basis of technical implementability. For the technologies which pass the initial screening, the process options associated with each technology are screened based on effectiveness, implementability and cost. Representative process options are then chosen based on this screening for inclusion in the comprehensive remedial alternatives developed for the site.

Technology Screening

The intent of the technology screening is to reduce the universe of potentially applicable technology types and process options based on technical implementability. Two factors which may be considered in the evaluation of the technical implementability of a technology are the type of contaminants present at a site and site-specific conditions which may limit the implementability of a technology. Examples of the application of these factors include the screening of a technology because it does not treat the contaminants of concern, or the screening of a technology which cannot be applied to a site due to site-specific subsurface conditions. The technologies or technology process options which do not pass the screening process on the basis of technical implementability are not retained for further consideration.

A combined technology screening was performed for all of the sites addressed within the Initial Screening of Alternatives Report. For the ISA report, Site 11 ground water was included in the remedial action development process. The technology screening presented herein revisits the technology screening, considering the results of the Phase II RI. The Site 11 technology screening is conducted for ground water in Table 3-6.

The technology screening tables each include brief descriptions of the individual technologies or process options. More detailed descriptions of the technologies are provided in the text which follows this introduction.

The technology screening tables also include comments on the general applicability of the technologies and limiting characteristics which may prevent their application at Site 11. The technology or process option title block is shaded gray only for those technologies which have been screened from further analysis.

The potential remedial technologies identified for ground water at Site 11 include no action, ground water monitoring, ground water use restrictions, and extraction, treatment, and discharge. In ground water, only inorganic contaminants exceeded water quality standards (while bis(2-ethylhexyl)phthalate exceeding the MCL in one Phase II RI sample, its presence is thought to be attributable to the sampling methodology). Therefore, when considering treatment technologies, only those process options which address inorganic contaminants were included in the screening process. One technology, off-site treatment, was screened from further consideration. Off-site treatment was screened based on difficulties associated with the technical implementability of off-site ground water treatment at a POTW or at a RCRA facility. Ground water process options screened from further consideration based on technical implementability include provision of an alternate water supply, well point extraction system, interceptor trenches, ion exchange, precipitation, membrane microfiltration, filtration, electrochemical, discharge to ground and discharge to surface water. Due to the lack of potable ground water receptors, provision of an alternate water supply is not technically implementable. Due to the silty formation at Site 11, well points would not be effective means of extracting ground water. Membrane microfiltration and filtration were eliminated because analytical results for filtered and unfiltered Phase II RI ground water samples indicated that detected inorganics are likely to be dissolved and would not be removed by filtration mechanisms. Discharge of treated ground water to a POTW was eliminated because of preliminary indications that the POTW would not be amenable to accepting such discharges.

Process Option Screening

Upon identification of those technologies which are technically implementable, the process options are further evaluated to allow the selection of representative process option(s) for each technology type. In the process option screening, the process options are evaluated on the basis of effectiveness, implementability, and cost. Factors considered in the effectiveness evaluation include the effectiveness of the process in handling the estimated areas or volumes of media, its ability in meeting remediation goals, potential impacts to human health and the environment during construction and implementation, and how proven and reliable the process is. Both technical and administrative feasibility are considered in the implementability evaluation, while relative capital and O&M costs are broadly compared in the cost evaluations.

The process option evaluation for ground water is presented in Table 3-7. The selected representative process options are indicated with a bullet in this table. Two process options for extraction were selected for further consideration. The use of extraction wells was considered to be suitable for deep ground water extraction, based on the limited area in which ARARs and PRGs were exceeded and the extraction rates achievable during well development. For the shallow ground water, however, based on the low monitoring well extraction rates observed during the RI, sustainable extraction rates would be minimal. Therefore, an interceptor trench was selected for further consideration for shallow ground water extraction.

For inorganic treatment, precipitation, and electrochemical treatment were selected as representative process options to be used for remedial alternative development. Filtration processes (both filtration and microfiltration) were screened in the technology screening because they may not be successful in achieving inorganic PRGs alone, since inorganic analyses conducted on filtered and unfiltered samples collected using the low-flow sampling methodology (which reduced the siltiness of the samples) indicated that the inorganics are probably dissolved rather than suspended (filtered and unfiltered results were comparable). However, filtration will be considered as a potential pretreatment process for precipitation, since the silty nature of the ground water at Site 11 could interfere with the effectiveness of the precipitation processes. Electrochemical treatment is an inorganic treatment technology just recently applied to ground water treatment. Available treatability data indicate it is effective for the treatment of both antimony and manganese in ground water. Precipitation is a commonly used treatment technology for which significant treatability data exists. Therefore, precipitation and electrochemical treatment were selected as representative inorganic treatment process options.

For ground water discharge, discharge to surface water was selected as a representative discharge option. Due to the presence of inorganics in the upgradient well at levels exceeding MCLs and risk-based PRGs, discharge to ground water was not selected based on the uncertainty associated with locating an appropriate discharge location. Discharge to surface water was also considered to be more administratively implementable and more economically feasible than discharging to a POTW.

GROUND WATER REMEDIAL TECHNOLOGIES

Institutional Control

Institutional controls are intended to minimize exposures to contaminated ground water. They include actions such as ground water monitoring, ground water use restrictions and provision of alternate water supplies. If a five-year review is required for a remedial action involving institutional controls, site conditions such as ground water monitoring results, if available, or changes in ground water usage should be reviewed to determine the need for continuing or future site use restrictions.

Ground Water Monitoring

Ground water monitoring provides a means to assess changes in ground water quality and contaminant migration patterns.

Ground Water Use Restrictions

Ground water use restrictions are intended to prevent or reduce exposure to ground water contamination. The use of ground water below or adjacent to the site is usually restricted. Ground water use restrictions may encompass potable use as well as non-potable use of the ground water. At Site 11, potable use would not be anticipated due to the industrial nature of the area, the GB ground water classification, and the easy access to municipal water supplies. However, non-potable use could be conceivable in association with potential future industrial site use.

Alternate Water Supply

Alternate water supply represents another type of institutional control in restricting ground water usage. Basically, ground water that is contaminated is no longer utilized as a potable water source, and an alternate source is provided. Since ground water is not used for potable water supply in the vicinity of Site 11, this process option is screened from further consideration.

Extraction

Extraction technology provides a means to collect contaminated ground water at a site. Various means of extraction include extraction wells, well points, or interceptor trenches.

Extraction Wells

Extraction wells represent a conventional technology which is frequently used in the removal of contaminated ground water. Stainless steel or PVC well casings and screens are installed within the contaminated ground water, and submersible pumps are typically used to extract water from the well. An array of wells with overlapping radii of influence can be designed to capture an entire plume or to halt contaminant migration. At Site 11, limited extraction rates were sustainable within on-site shallow monitoring wells during the RI, although higher rates were achieved within the deep monitoring wells.

Well Points

This ground water extraction technology involves the removal of ground water through a group of closely spaced wells connected by a header pipe. The wells are installed by driving a perforated pipe with a pointed cap into the area to be dewatered. Well point systems are best suited for shallow aquifers where extraction is not needed below twenty feet. The suction lifting pump technique commonly employed with well points is effective up to this depth. However, well points are ineffective when high percentages of silt or clay are present in site soils. Due to the silty nature of soils at Site 11, this technology has been screened from further evaluation.

Interceptor Trench

Interceptor trenches may be employed as a means of collecting ground water through the use of a perforated pipe placed below the natural ground water table. Ground water enters the perforated pipe and flows by gravity to the lowest point in the pipe, where it is pumped to the surface for treatment and/or discharge. This technology is typically limited to areas where the depth to ground water is not so deep that trench construction becomes prohibitively expensive or complicated (bracing, etc.). This technology offers the advantage of a horizontally oriented intake structure which allows collection of ground water within the area of interest. Additionally, trenches are relatively simple to construct and are passive structures with little maintenance required. This technology is retained for further consideration for shallow ground water extraction at Site 11.

Off-Site Treatment

Off-site treatment utilizes an off-site facility to treat extracted ground water. The contaminated ground water must be transported or conveyed to the treatment facility. Costs associated with conveyance or transportation can be extremely expensive if the distance from the site to the off-site treatment facility is far. Two types of off-site treatment facilities include publicly owned treatment works (POTW) and RCRA treatment facilities.

Off-Site Treatment at a POTW

This technology involves the discharge of aqueous wastes, which can constitute the majority of waste treated during a remedial cleanup effort, from a site to a Publicly Owned Treatment Works (POTW) for off-site treatment. These aqueous wastes can include ground water, leachate, surface water runoff, or other aqueous wastes. A number of criteria must be met when utilizing a POTW. These restrictions, as they apply to CERCLA sites, are detailed in the U.S. EPA's CERCLA Site Discharges to POTWs: Guidance Manual (U.S. EPA, 1990a). Typically, the wastes are piped to the POTW via an existing sanitary sewer or by constructing a dedicated sewer line. An additional concern of POTWs in accepting a discharge from a CERCLA site is the issue of whether the POTW is then considered a hazardous waste treatment facility. Therefore, the administrative acceptability of discharging water to a POTW may be limited. Based on preliminary indications that the local POTW will not be amenable to accepting contaminated ground water, off-site treatment at a POTW will be screened from further consideration.

Off-Site Treatment at a RCRA Facility

Discharge to a RCRA facility also represents a potential off-site treatment technology for remediating contaminated ground water and other aqueous wastes. The extracted ground water is collected and transported off-site to a licensed RCRA facility for treatment. High extraction rates and the distance to the nearest RCRA treatment facility can greatly limit the cost-effectiveness of this alternative. This technology is screened from further consideration based on the lack of a locally available RCRA treatment facility.

Inorganic Treatment

Inorganic treatment typically involves physical or chemical treatment processes, as discussed below.

Ion Exchange

Ion exchange is a process whereby the toxic ions are removed from the aqueous phase by being exchanged with relatively harmless ions held by the ion exchange material. Ion exchange is a well-established technology for removal of heavy metals and hazardous anions from dilute solutions. Ion exchange can be expected to perform well for these applications when fed wastes of variable composition, provided the system's effluent is continually monitored to determine when the resin bed exhaustion has occurred. However, the reliability of ion exchange is markedly affected by the presence of suspended solids.

Ion exchange systems are commercially available from a number of vendors. The units are relatively compact and are not energy intensive. Although exchange columns can be operated manually or automatically, manual operation is better suited for hazardous waste site applications because of the diversity of wastes encountered. In addition, use of several exchange columns at a site can provide considerable flexibility. Ion exchange has had little application in the treatment of antimony (Sybron Chemicals, Inc., 1994).

Precipitation

Precipitation is a physicochemical process whereby some or all of a substance in solution is transformed into a solid phase. It is based on alteration of the chemical equilibrium relationships affecting the solubility of inorganic species. Removal of metals as hydroxides or sulfides is the most common precipitation application in wastewater treatment. Generally, lime or sodium sulfide is added to the wastewater in a rapid mixing tank along with flocculating agents. The wastewater flows to a flocculating chamber in which adequate mixing and retention time is provided for agglomeration of precipitate particles. Agglomerated particles are separated from the liquid phase by settling in a sedimentation chamber, and/or by other physical processes such as filtration. Precipitation, with filtration pretreatment, will be retained for further evaluation.

Membrane Microfiltration

Membrane microfiltration involves the use of an automatic pressure filter in which the filter material has tiny openings (0.10 microns or 1 ten-millionth of a meter) which allow for the filtration of particles normally not separated from the wastestream using standard filtration processes. Membrane microfiltration is most applicable to hazardous waste suspensions, ground water contaminated with heavy metals, landfill leachate and process wastewaters containing uranium (U.S. EPA, 1991). Filtration processes (both filtration and microfiltration) may not be successful in meeting inorganic remediation goals since inorganic analyses conducted on filtered and unfiltered samples collected using the low-flow sampling methodology (which reduced the siltiness of the samples) indicated that the inorganics are probably dissolved rather than suspended (filtered and unfiltered results were comparable). For this reason, membrane microfiltration is screened from further consideration.

Filtration

Filtration is a type of physical separation of a solid material based on particle size. As commonly employed in ground water treatment, filtration involves the separation of suspended solids, primarily silt, from the influent stream. As water passes through the bed of the granular filter medium, suspended particles become trapped on top of and within the bed. Backwashing is periodically required to clean the filter bed and retain treatment efficiency. Inorganic analyses conducted on filtered and unfiltered samples collected using the low-flow sampling methodology (which reduced the siltiness of the samples) indicated that the inorganics are probably dissolved rather than suspended (filtered and unfiltered results were comparable). Therefore, filtration would not be effective as a "stand-alone" treatment, but will be considered as a pretreatment process to improve the efficiency of the treatment technology.

Electrochemical

Electrochemical treatment provides treatment of inorganic contaminants. Contaminated water passes through an electrochemical cell where ferrous ions, hydroxide ions and hydrogen are produced. The ferrous ions act as reducing agents for oxidized heavy metals and also react with the hydroxide ions, forming iron hydroxides and metal hydroxides. The metal hydroxides are removed by adsorption onto the iron hydroxide precipitate that is formed (Hazardous Waste Consultant, 1991). Electrochemical treatment will be retained for further consideration since it is an innovative technology and has been proven effective for inorganic treatment of analytes such as antimony and manganese during treatability studies (Andco, 1992).

Discharge

Following treatment, extracted ground water must be discharged back to the environment. Several options exist for the discharge of ground water, as described below.

Discharge to Ground Water

Treated ground water can be discharged to ground water using recharge basins, infiltration galleries or reinjection wells. The technology selected for recharge is dependent on site-specific considerations such as available space, extent of contamination, and hydrogeology. Ground water recharge systems can provide an added element of hydraulic control to ground water extraction systems. Typically recharge systems can be subject to clogging or other operational problems and must be closely monitored. Compliance with ground water discharge regulations must also be maintained. Since ground water in the vicinity is classified GB, discharge to ground water will be retained for further consideration. However, the presence of manganese in the Site 11 upgradient well at levels exceeding risk-based PRGs may complicate the placement of a ground water recharge system.

Discharge to Surface Water

Treated ground water can also be discharged to a surface water body. The nearest surface water body to Site 11 would be a tributary of Mill Creek, located approximately 2,200 feet south of the site. Implementation of this alternative would require compliance with NPDES discharge requirements. Discharge to surface water will be retained for further consideration.

Discharge to Sanitary Sewer/POTW

If available nearby, discharge of treated or untreated ground water to a sanitary sewer for subsequent treatment at a Publicly Owned Treatment Works (POTW) is a possible alternative. Many POTWs have regulations prohibiting discharges of ground water to the treatment system and special approval for such a discharge may be required. The POTW may also require pretreatment of the wastestream prior to acceptance. An additional concern of POTWs in accepting a discharge from a CERCLA site is the issue of whether the POTW is then considered a hazardous waste treatment facility. The administrative acceptability of discharging water to a POTW may therefore be limited. Based on preliminary indications that the POTW will not be amenable to accepting aqueous discharges from the site, this option will be screened from further evaluation.

APPENDIX E

APPENDIX E

REMEDIAL COST ESTIMATES

Cost estimates are provided for the following alternatives:

GROUND WATER ALTERNATIVES

Alternative 2, Long-Term Ground Water Monitoring

Alternative 3A, Extraction of Ground Water via Extraction Wells/Interceptor Trench

Alternative 3B, Chemical Precipitation

Alternative 3C, Electrochemical Treatment

Alternative 3D, Discharge to Surface Water

ALTERNATIVE 2
LONG-TERM GROUND WATER MONITORING
SITE 11 - FIRE FIGHTING TRAINING AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
TOTAL CAPITAL COSTS										$0.00
OPERATION AND MAINTENANCE COSTS										
Ground Water Monitoring (including trip blanks, field blanks and duplicate samples)										
- Annual Sampling	12	samples	$300.00	1994	5	1.000	$300.00	$3,600.00	30	$55,339.20
- Analysis:										
TAL + cyanide	14	samples	$320.00	1994	3	1.000	$320.00	$4,480.00	30	$68,866.56
- Report Preparation	1	each	$4,000.00	1994	5	1.000	$4,000.00	$4,000.00	30	$61,488.00
ANNUAL O&M (1994 $)								$12,080.00		
TOTAL NET PRESENT VALUE OF O & M										$185,693.76
SUBTOTAL COST										$185,693.76
CONTINGENCY (20%)										$37,138.75
TOTAL PRESENT VALUE COST FOR ALTERNATIVE 2										$222,832.51

(1) - Calculated based on 5% interest rate.

ALTERNATIVE 3, OPTION A
EXTRACTION OF GROUND WATER VIA INTERCEPTOR TRENCH AND EXTRACTION WELLS
SITE 11 - FIRE FIGHTING TRAINING AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST - DIRECT										
Ground Water Extraction Trench										
- Excavation and Backfill	580	cu. yd.	$3.59	1994	2	1.000	$3.59	$2,082.20		
- 1/2" Crushed Stone	415	cu. yd.	$30.00	1994	2	1.000	$30.00	$12,450.00		
- Geotextile Filter Fabric	870	sq. yd.	$1.41	1994	2	1.000	$1.41	$1,226.70		
- 4" O.D. Slotted HDPE	280	l. ft.	$6.95	1994	2	1.000	$6.95	$1,946.00		
- Submersible Pumps	1	each	$196.00	1994	2	1.000	$196.00	$196.00		
- Pre-Cast Concrete Manhole	1	each	$2,584.00	1994	2	1.000	$2,584.00	$2,584.00		
Pipe Trench from Manhole to Treatment Area										
- 1 1/4" O.D. Non-Slotted HDPE Pipe	200	l. ft.	$4.60	1994	2	1.000	$4.60	$920.00		
- Excavation and Backfill	50	cu. yd.	$3.59	1994	2	1.000	$3.59	$179.50		
- Bedding Sand	25	cu. yd.	$16.20	1994	2	1.000	$16.20	$405.00		
Total Ground Water Extraction Trench										$21,989.40
Pizeometer Installation										
- 6 14-ft Piezometers - 2"	6	each	$1,315.00	1992	7	1.077	$1,416.26	$8,497.53		
Total Piezometer Installation										$8,497.53
Ground Water Extraction Wells										
- Well Construction and Materials (2 43-foot deep wells)	2	each	$5,680.00	1992	7	1.077	$6,117.36	$12,234.72		
- Health & Safety (17%)								$3,112.53		
Ground Water Extraction System										
- Pump with Appurtenances	2	each	$2,400.00	1994	8	1.000	$2,400.00	$4,800.00		
- Air Compressor with Appurtenances	1	each	$4,355.00	1994	8	1.000	$4,355.00	$4,355.00		
Pipe Trench from Manhole to Treatment Area										
- 1 1/4" O.D. Non-Slotted HDPE Pipe	50	l. ft.	$4.60	1994	2	1.000	$4.60	$230.00		
- Excavation and Backfill	20	cu. yd.	$3.59	1994	2	1.000	$3.59	$71.80		
- Bedding Sand	10	cu. yd.	$16.20	1994	2	1.000	$16.20	$162.00		
Total Ground Water Extraction Wells										$24,966.05
Total Direct Capital Cost Subtotal										$55,452.98
CAPITAL COST - INDIRECT										
Engineering and Design (10 %)					1			$5,545.30		
Legal and Administrative (4%)					1			$2,218.12		
Total Indirect Capital Cost										$7,763.42
TOTAL CAPITAL COSTS										$63,216.40

ALTERNATIVE 3, OPTION A (continued)
EXTRACTION OF GROUND WATER VIA INTERCEPTOR TRENCH AND EXTRACTION WELLS
SITE 11 - FIRE FIGHTING TRAINING AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
OPERATION AND MAINTENANCE COSTS										
Piezometer Monitoring	48	hours	$100.00	1994	5	1.000	$100.00	$4,800.00	30	$73,785.60
ANNUAL O&M (1994)								$4,800.00		
TOTAL NET PRESENT VALUE OF O&M										$73,785.60
SUBTOTAL										$137,002.00
CONTINGENCY (20%)										$27,400.40
TOTAL PRESENT VALUE COST FOR ALTERNATIVE 3, OPTION A										$164,402.40

(1) - Calculated based on 5% interest rate.

ALTERNATIVE 3, OPTION B
CHEMICAL PRECIPITATION
SITE 11 - FIRE FIGHTING TRAINING AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST - DIRECT										
Precipitation Treatment System										
- Neutralization/Precipitation/ Filtration/Filter Press Unit	1	each	$72,000.00	1987	4	1.219	$87,768.00	$87,768.00		
- Electrical Connections	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
- Equalization Tank	1	LS.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
Total Ground Water Treatment System Cost										$127,768.00
Direct Capital Cost Subtotal										$127,768.00
CAPITAL COST - INDIRECT										
Engineering and Design (15%)					1			$19,165.20		
Legal and Administrative (5%)					1			$6,388.40		
Total Indirect Capital Cost										$25,553.60
TOTAL CAPITAL COSTS										$153,321.60
OPERATION AND MAINTENANCE COSTS										
- Precipitation O&M	5,256	1000 gal	$8.00	1985	6	1.281	$10.25	$53,863.49	30	$827,989.54
ANNUAL O&M (1994 $)								$53,863.49		
TOTAL NET PRESENT VALUE OF O&M										$827,989.54
SUBTOTAL										$981,311.14
CONTINGENCY (20%)										$196,262.23
TOTAL PRESENT VALUE COST FOR ALTERNATIVE 3, OPTION B										$1,177,573.37

(1) - Calculated based on 5% interest rate.

ALTERNATIVE 3, OPTION C
ELECTROCHEMICAL TREATMENT
SITE 11 - FIRE FIGHTING TRAINING AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST - DIRECT										
Electrochemical Treatment System										
-Electrochemical Treatment System	1	L.S.	$110,000.00	1994	9	1.000	$110,000.00	$110,000.00		
-Electrical Connection	1	L.S.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
-Piping and Controls	1	L.S.	$20,000.00	1994	5	1.000	$20,000.00	$20,000.00		
-Transfer Pumps	2	each	$580.00	1992	2	1.000	$580.00	$1,160.00		
Total Electrochemical Treatment System										$151,160.00
Direct Capital Cost Subtotal										$151,160.00
CAPITAL COST - INDIRECT										
Engineering and Design (15 %)								$22,674.00		
Legal and Administrative (5%)								$7,558.00		
Total Indirect Capital Cost										$30,232.00
TOTAL CAPITAL COSTS										$181,392.00
OPERATION AND MAINTENANCE COSTS										
Electrochemical Treatment O&M	5,256	1,000 gal	$4.66	1994	9	1.000	$4.66	$24,492.96	30	$376,505.78
ANNUAL O&M (1994 $)								$24,492.96		
TOTAL NET PRESENT VALUE OF O&M										$376,505.78
SUBTOTAL										$557,897.78
CONTINGENCY (20%)										$111,579.56
TOTAL PRESENT VALUE COST FOR ALTERNATIVE 3, OPTION C										$669,477.34

(1) - Calculated based on 5% interest rate.

ALTERNATIVE 3, OPTION D
DISCHARGE TO SURFACE WATER
SITE 11 - FIRE FIGHTING TRAINING AREA

Item	Quantity	Units	Unit Price	Basis Year	Reference	Escalation	1994 Unit Costs	1994 Costs	Years (O&M)	(1) Present Value (O&M)
CAPITAL COST - DIRECT										
Piping From Treatment System To Surface Water										
- Trench Excavation & Backfill	2,200	l. ft.	$5.73	1994	2	1.000	$5.73	$12,606.00		
- 2" Diam. PVC in Trench	2,200	l. ft.	$4.60	1994	2	1.000	$4.60	$10,120.00		
- Pipe Bedding (sand)	2,200	l. ft.	$1.32	1994	2	1.000	$1.32	$2,904.00		
Total Piping Cost										$25,630.00
Direct Capital Cost Subtotal										$25,630.00
CAPITAL COST - INDIRECT										
Engineering and Design (10%)					1			$2,563.00		
Legal and Administrative (4%)					1			$1,025.20		
Total Indirect Capital Cost										$3,588.20
TOTAL CAPITAL COSTS										$29,218.20
OPERATION AND MAINTENANCE COSTS										
Discharge Sampling & Analysis										
- Monthly Sampling	12	samples	$300.00	1994	5	1.000	$300.00	$3,600.00	30	$55,339.20
- TAL + cyanide	12	samples	$320.00	1994	3	1.000	$320.00	$3,840.00	30	$59,028.48
ANNUAL O&M (1994 $)								$7,440.00		
TOTAL NET PRESENT VALUE OF O&M										$114,367.68
SUBTOTAL										$143,585.88
CONTINGENCY (20%)										$28,717.18
TOTAL PRESENT VALUE COST FOR ALTERNATIVE 3, OPTION D										$172,303.06

(1) - Calculated based on 5% interest rate.

COST REFERENCES

1) Remedial Action Costing Procedures Manual; JRB Associates; October 1987.

2) Means Site Work & Landscape Cost Data; 1994.

3) USEPA, 1993. Resources Conservation Company B.E.S.T.™ Solvent Extraction Technology Applications Analysis Report; June 1993.

4) Compendium of Costs of Remedial Technologies at Hazardous Waste Sites; Environmental Law Institute; October 1987. EPA/600/2-87/08.

5) TRC Environmental Corporation; 1994.

6) Empire Soils Investigations, Inc., Division of Huntingdon; January 1992.

7) Waste Alternatives; December 1988.

8) Gundle Lining Systems; 1994.

9) ANDCO, May 1994.

APPENDIX F

APPENDIX F

GROUND WATER MODELING SUMMARY

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APPENDIX F
GROUND WATER MODELING SUMMARY

1.0 INTRODUCTION/OBJECTIVES

Under Alternative GW-3A - Ground Water Extraction via Interceptor Trench and Extraction Wells, a system consisting of a shallow ground water interceptor trench and deep ground water extraction wells was proposed for the capture and extraction of impacted Site 11 ground water from the unconsolidated overburden for treatment and disposal. The Phase I and Phase II RI field investigations revealed that at Site 11 the depth to bedrock averages approximately 40.5 feet below grade and the Phase II shallow monitoring wells were low-yielding during their development. Due to these circumstances, a system including a shallow ground water interceptor trench and deep ground water extraction wells was judged to be an effective means of providing effective capture of the Site 11 ground water and preventing off-site migration of the ground water contaminants. In order to produce a preliminary shallow interceptor trench/deep extraction wellfield design for the purposes of option analysis, evaluation, and costing, a ground water flow model was used to: 1) simulate the shallow and deep ground water flow regimes at Site 11, and 2) configure a shallow interceptor trench/deep extraction well system to provide control and capture of the estimated areal extent of site shallow and deep ground water with contaminant concentrations exceeding ARARs and/or risk-based PRGs. ARARs and/or risk-based PRGs were exceeded in the Phase I and/or Phase II samples from all of the Site 11 shallow and deep monitoring wells except shallow monitoring wells 11-MW06S and 11-MW07S and deep monitoring wells 11-MW02D and 11-MW09D. Therefore, the Site 11 ground water requiring capture, extraction and treatment was assumed to include the entire site except the northernmost and westernmost portions of the shallow ground water. Within the estimated area of ground water impacts, it was assumed that the entire saturated interval between the shallow water table and the bedrock underlying Site 11 would require capture and extraction. A description of the modeling procedures, including the model assumptions and the input initial and boundary conditions, is presented in the following sections.

2.0 INITIAL MODEL SETUP

MODFLOW Version 3.2 (McDonald and Harbaugh, 1988), a three-dimensional numerical ground water flow model, was used to simulate the Site 11 shallow and deep ground water flow regimes and to design the proposed shallow and deep ground water extraction systems. The area encompassed by the MODFLOW model grid is shown in Figure F-1. The grid was configured with the principal axes oriented to parallel the primary direction of shallow ground water flow at Site 11. The Site 11 shallow ground water flows generally west-southwestward, and the deep ground water flows southwestward. The model grid is comprised of 24 rows and 28 columns, with a 40-foot uniform nodal spacing; the grid thus measures 960 feet by 1,120 feet, for a total simulation area of 1,075,200 square feet (24.7 acres). The nodal spacing was considered to be optimal to provide coverage of the large modeled area while also allowing flexibility in the development and optimization of the various extraction scenarios for the purpose of the Detailed Analysis of Alternatives.

Two-layer simulations were used to simulate the Site 11 shallow (Layer 1) and deep (Layer 2) ground water within the unconsolidated overburden aquifer. Layer 1 was simulated as unconfined and Layer 2 was modeled as semi-confined, with the interlayer vertical leakance estimated at 1E-4 1/d. The deep ground water was designated as semi-confined for modeling purposes because the transmissivity of the deep portion will remain constant with time, unlike the shallow portion, where water level fluctuations will increase or decrease the saturated thickness, and hence the transmissivity. The deep ground water at Site 11 is not known to be actually confined or semi-confined. Hydraulic communication between the layers was slightly restricted in the model, in order to simulate the negative (downward) vertical gradients observed at the shallow/deep well clusters (Table 7-7, Phase II RI (TRC, 1993)). For the shallow ground water, where a portion of the water stored in the aquifer is released by dewatering of the aquifer, the transmissivity is input as the product of the hydraulic conductivity (K-value) and the saturated thickness (the hydraulic head minus the elevation of the aquifer bottom). For the deep ground water, where the transmissivity remains constant with time as long as the aquifer is not dewatered, the transmissivity is entered as a single value. The initial input shallow aquifer nodal K-value was 19.0 ft/d; the initial input deep aquifer nodal transmissivity was 34.6 ft^2/d, or 1.3 ft/d (K) x 26.6 ft (b). These K-values are the median shallow and deep monitoring well K-values determined from the slug tests conducted at the Phase II monitoring wells during the Phase II RI field investigation (Table 7-6, Phase II RI (TRC, 1993)). The Layer 1 bottom was input as 10.3 feet above mean sea level (ft msl), the average bottom elevation of the Site 11 shallow monitoring wells.

A large area was modeled to account for the spatial distribution and potential influence area of the interceptor trench and extraction well systems; a substantial distance between the system components and the model boundaries must be maintained to limit the influence of boundary effects. The model boundaries were extended outward as far as considered practical when taking into account the areal range of Site 11 water level data points available. As the modeled area of the unconsolidated overburden aquifer is not bounded on any side by an impermeable boundary, constant-head boundaries were placed at the edges of the modeled area to establish flow through the model. The potential constant head boundary effects are considered to be minimal and conservative.

Model data sheets are provided following this summary and the associated figures. The MODFLOW output item "drawdown" is included in the model output regardless of whether or not a hydraulic source or sink is simulated in the model. In the case of the steady-state calibration, the term quantifies only the change in hydraulic head between the initial input head value and the final equilibrium head calculated during the calibration. The head change closure criterion used for all simulations was 0.001 foot.

3.0 MODEL CALIBRATION

The ground water flow model was calibrated to the shallow and deep ground water steady-state (non-stressed) conditions existing at Site 11 on August 13, 1993. After each model run was conducted, the Layer 1 and 2 nodal K-value and/or constant head boundary head values were adjusted as necessary until the model was calibrated to the non-pumping conditions at Site 11 on August 13, 1993. Figures F-2 and F-3 show the results of the steady-state calibration for the shallow and deep unconsolidated overburden aquifer at the site. The Layer 2 transmissivity and the interlayer vertical leakance were not adjusted from their initial input values.

4.0 REMEDIAL SIMULATIONS

After completing the model calibration, remedial simulations were run to establish the optimal configuration of a shallow interceptor trench/deep extraction well system for capturing the unconsolidated overburden ground water flow from areas that were found in the Phase I and Phase II RI field investigations to exhibit contamination above ARARs and/or risk-based PRGs.

Shallow Ground Water Interceptor Trench

Prior to simulating the shallow ground water interceptor trench system, a preliminary evaluation was made whereby a system of shallow ground water extraction wells was simulated to assist in the determination of the optimum location and total extraction rate for the trench. The resulting ground water hydraulic head distributions were inspected to ensure that adequate capture was accomplished across the estimated area of shallow ground water to be extracted and treated. Based on the low yields (approximately 0.5 gallon per minute) of the Site 11 shallow monitoring wells during their development, it was determined that a system of seven shallow extraction wells, located in an northwest-southeast line just northeast of Building 390, each extracting at a rate of 0.5 gpm, would provide adequate control and capture of the impacted site ground water.

After completing the preliminary extraction well simulations, numerous interceptor trench remedial simulations were run to determine the optimum trench location, length and total extraction rate to provide shallow ground water hydraulic control and capture equivalent to that produced by the simulated shallow extraction wells. The resulting ground water hydraulic head distributions were inspected to ensure that adequate capture was accomplished across the estimated area of shallow ground water to be extracted and treated. The capture zone was limited to that portion of the shallow ground water flow regime where the ground water was shown migrating perpendicular to the simulated potentiometric contours toward and into the trench for extraction. Based on the results of the preliminary extraction well simulations, it was assumed that one interceptor trench would be capable of capturing and extracting the site shallow ground water at a total rate of 3.5 gpm. The position and length of the trench were adjusted until capture of the shallow ground water requiring extraction and treatment was shown. In addition, the trench was located so that it would not cross under streets nor lie too close to existing buildings.

Deep Ground Water Extraction Wells

A system of deep ground water extraction wells was simulated to assist in the determination of the optimum number, locations and extraction rates for the wells. The resulting deep ground water hydraulic head distributions were inspected to ensure that adequate capture was accomplished across the estimated area of deep ground water to be extracted and treated. The capture zones were limited to those portions of the flow regime where the deep ground water was shown migrating perpendicular to the simulated potentiometric contours toward and into the wells for extraction. The positions and extraction rates of the wells were adjusted until capture of the ground water requiring extraction and treatment was shown. Based on the low yields of some of the Site 11 monitoring wells during their development, a 0.5 gpm maximum extraction rate was assumed for each modeled deep extraction well.

5.0 RESULTS OF REMEDIAL SIMULATIONS

Shallow Interceptor Trench

The evaluation of the interceptor trench simulations determined that a 280-foot-long interceptor trench, extracting ground water at a total rate of 3.5 gpm, would be required in order to capture the ground water from the entire estimated areal extent of Site 11 shallow ground water with contaminant levels in excess of ARARs and/or risk-based PRGs. Figure F-4 shows the location of the trench, as well as the shallow ground water hydraulic head distribution resulting from the 3.5 gpm total extraction at the trench, and shows the extent of shallow ground water capture that the trench would establish as modeled. Figure 4-1 also shows the location of the trench. The trench would be located along the western margin of the site and would be elongated northwest-southeast, perpendicular to the principal direction of ground water flow in that area.

Deep Extraction Wells

The evaluation of the extraction well simulations determined that a system of two deep ground water extraction wells, each pumping at a rate of 0.5 gpm (for a total extraction rate of 1.0 gpm), would provide adequate control and capture of the impacted site deep ground water. Figure F-5 shows the locations of the two proposed deep extraction wells, as well as the hydraulic head distribution resulting from the 1.0 gpm total extraction at the wells, and shows the extent of capture that the extraction wells would establish as modeled. Figure 4-1 also shows the locations of the two proposed extraction wells. The extraction wells would be located between the locations of the 11-MW03S/D and 11-MW06S/D monitoring well clusters, and would be spaced approximately 57 feet from each other.

6.0 RECOMMENDED SYSTEM DESIGN

Interceptor Trench

The trench would be approximately 280 feet long, 14 feet deep and 3 to 4 feet wide, and would be equipped on one end with a precast manhole sump into which the intercepted ground water would flow to be lifted by means of a submersible pump to the surface for treatment. Within the trench, the drain itself would consist of a 280-foot length of 4-inch O.D. perforated HDPE pipe placed at a slight incline toward the sump end of the trench, to direct drainage flow toward the sump. The placement depth of the drain pipe would be approximately 13 feet below grade.

After trench excavation, a nonwoven geotextile fabric filter should be installed around the trench perimeter to surround the gravel envelope for the pipe drain and inhibit the entrance of fines into the trench. The gravel envelope, consisting of one-half- to three-quarter-inch diameter crushed stone, would then be installed to surround the drainage pipe. At least one foot of compacted gravel should underlie the drainage pipe to establish a gravel bed for the pipe. After installing the drain pipe, additional gravel should be installed and compacted up to a depth of four feet below grade (the approximate maximum seasonal high ground water level); the fabric filter should then be wrapped over the top of the gravel envelope. The remainder of the trench should then be backfilled with excavated soil, compacted and brought to original grade. The trench sump should be fitted with a one-quarter-horsepower sump pump to lift the intercepted ground water to the surface for treatment.

In order to monitor the effectiveness of the interceptor trench in providing capture of the site shallow ground water, a system of ground water piezometers should be installed surrounding the trench. It is proposed that a total of six piezometers, three hydraulically upgradient and three downgradient, be installed after the trench installation. Figure 4-1 shows the locations of the piezometers relative to the trench location. The piezometers would be located approximately 10 feet from the sides of the trench, and would be spaced every 140 feet along the trench length. Each piezometer would be installed to screen the shallow ground water from the water table to a total depth of approximately 14 feet below grade. Each piezometer would be constructed of two-inch I.D. Schedule 40 PVC, with the bottom 10 feet screened with 0.010-inch slotted screen.

Deep Ground Water Extraction Wells

Based on the Phase II RI monitoring well logs for 11-MW02D, 11-MW03D, 11-MW06D and 11-MW09D, it is estimated that the maximum depth to bedrock in the area of the proposed extraction wells is approximately 43 feet below grade. It is recommended that each extraction well be approximately 43 feet deep, with the bottom 30 feet (13 to 43 feet below grade) screened with 0.010-inch slotted screen. The screen and riser should consist of four-inch I.D. steel.

For the installation of each extraction well, a ten-inch diameter borehole should be advanced to bedrock using the mud rotary drilling method. After completion of the borehole, the screen and riser are lowered to bedrock, and a sand filter pack is placed in the annular space between the screen and the borehole wall. The filter pack should extend up to 10 feet below grade. A two-foot bentonite chip seal should then be placed above the sand, and the remainder of the open borehole should be grouted to the surface with a cement/bentonite grout.

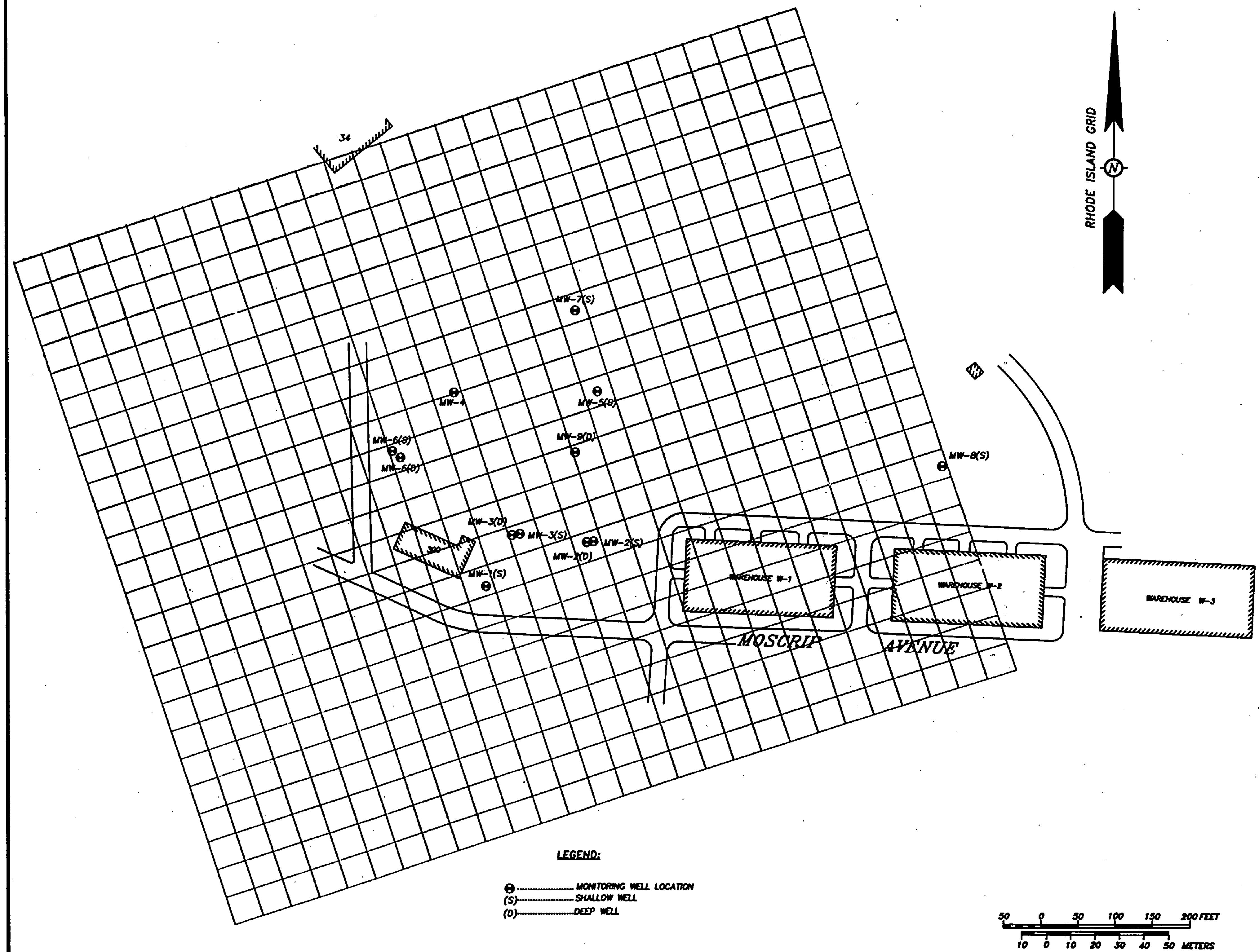
The recommended pump for this application is an automatic-control, low-flow positive air displacement remediation pump (e.g., the QED HammerHead™ H23SEB 1.75-inch cleanup pump). These pumps operate using compressed air, and cycle on and off in response to an internal float. Therefore, no external controls such as cycle timers, electrical equipment, downwell probes, or level controls are required at the wellhead. It is assumed that one air compressor would provide the compressed air supply via HDPE-type tubing to the two proposed extraction wells.

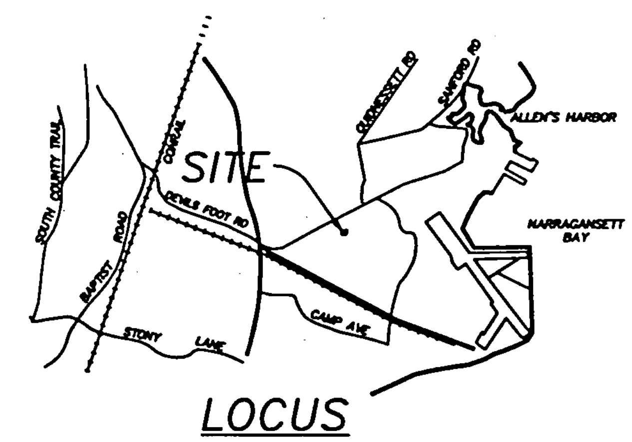
REFERENCES - APPENDIX F

Electric Power Research Institute (EPRI), 1985. A review of field-scale physical solute transport processes in saturated and unsaturated porous media. EPRI EA-4190, Electric Power Research Institute, Palo Alto, California.

McDonald, M.G. and Harbaugh, A.W., 1988. A modular three-dimensional finite-difference ground-water flow model: U.S. Geological Survey Open-File Report 83-875 update, Chapter A1.

TRC Environmental Corporation (TRC), 1993. Phase II Remedial Investigation Report, Naval Construction Battalion Center, Davisville, Rhode Island. Prepared for Northern Division, Naval Facilities Engineering Command, Philadelphia, Pennsylvania. Contract No. N62472-86-C-1282, November 1993.





LOCUS

NOTES:

1. HORIZONTAL DATUM: RHODE ISLAND GRID, NAD 1927, 1969 ADJUSTMENT.
2. VERTICAL DATUM: NGVD 1929.
3. ROADWAYS PROTRACTED FROM REFERENCE PLAN NO. 1.

REFERENCE PLANS:

1. U.S. NAVAL ADVANCE BASE DEPOT, DAVISVILL, R.I., SUB-SURFACE, A.B.D., NAVY DEPT. ACC. NO. 32061, SHEET NO. 1275.

LEGEND:

⊖ .... MONITORING WELL LOCATION
(S)............ SHALLOW WELL
(D)............ DEEP WELL

TRC
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5 Waterside Crossing
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(203) 289-8631

NAVAL CONSTRUCTION BATTALION CENTER — DAVISVILLE RHODE ISLAND

FIGURE F-1.
SITE 11-FIRE FIGHTING TRAINING AREA
MODFLOW GROUND WATER FLOW MODEL GRID

Date: 5/94 | Project No. 01042-0040

11BM150M

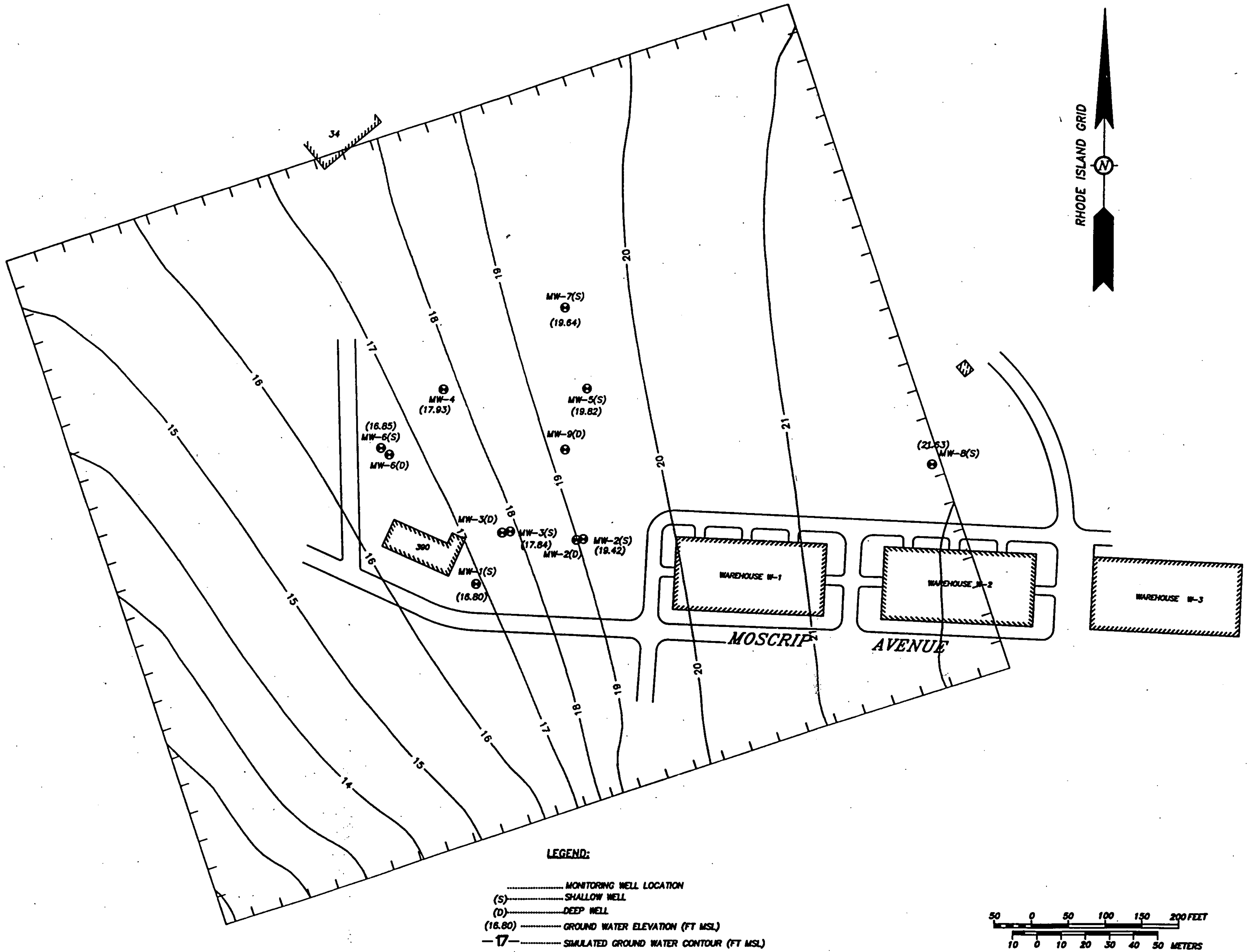

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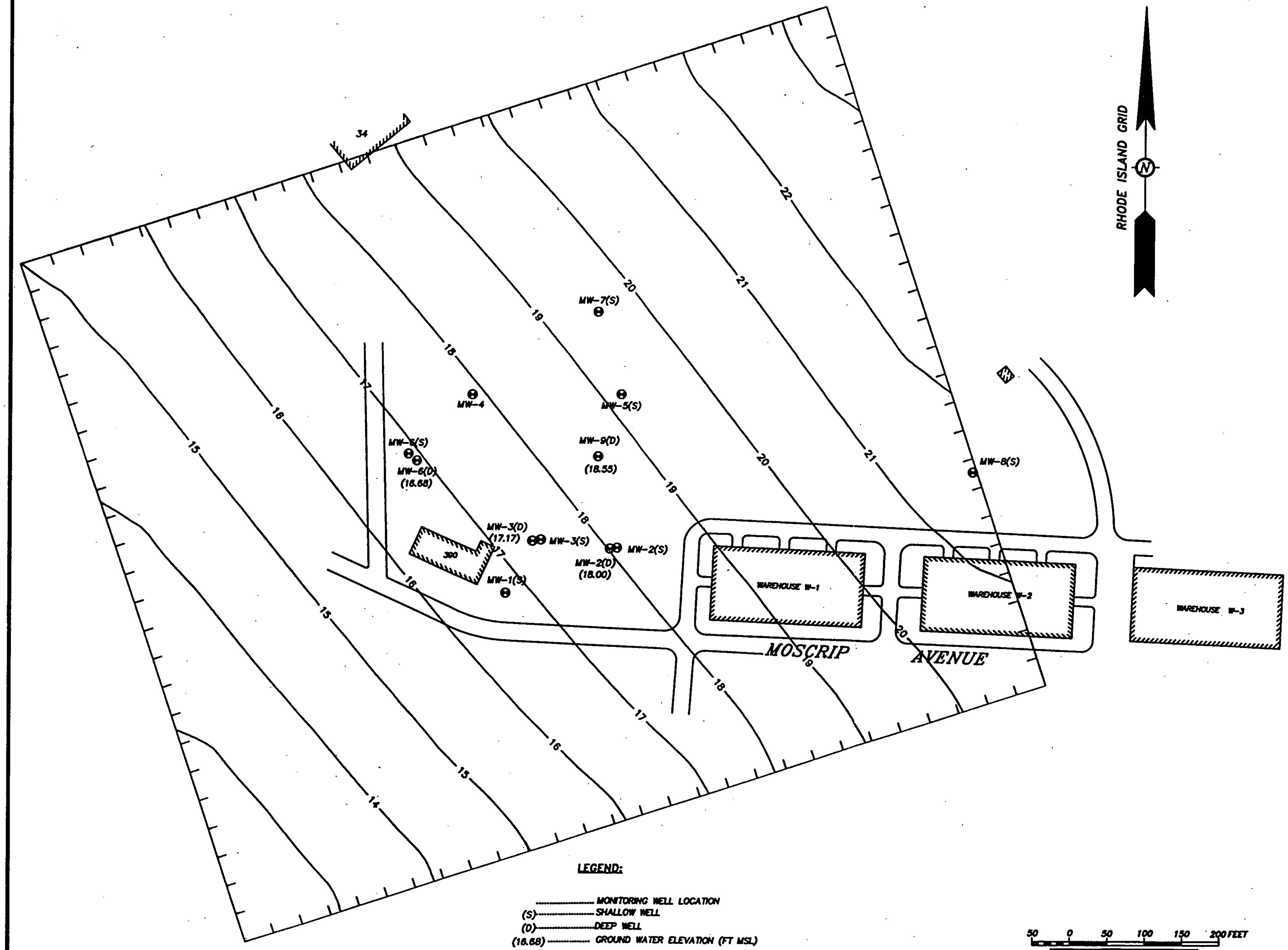
FIGURE F-2.
SITE 11-FIRE FIGHTING TRAINING AREA
GROUND WATER FLOW MODEL CALIBRATION TO SHALLOW GROUND WATER STEADY-STATE CONDITIONS ON AUGUST 13, 1993

Date: 5/94 | Project No. 01042-0040



LEGEND:

	MONITORING WELL LOCATION
(S)	SHALLOW WELL
(D)	DEEP WELL
(16.68)	GROUND WATER ELEVATION (FT MSL)
—17—	SIMULATED GROUND WATER CONTOUR (FT MSL)

50 0 50 100 150 200 FEET

10 0 10 20 30 40 50 METERS

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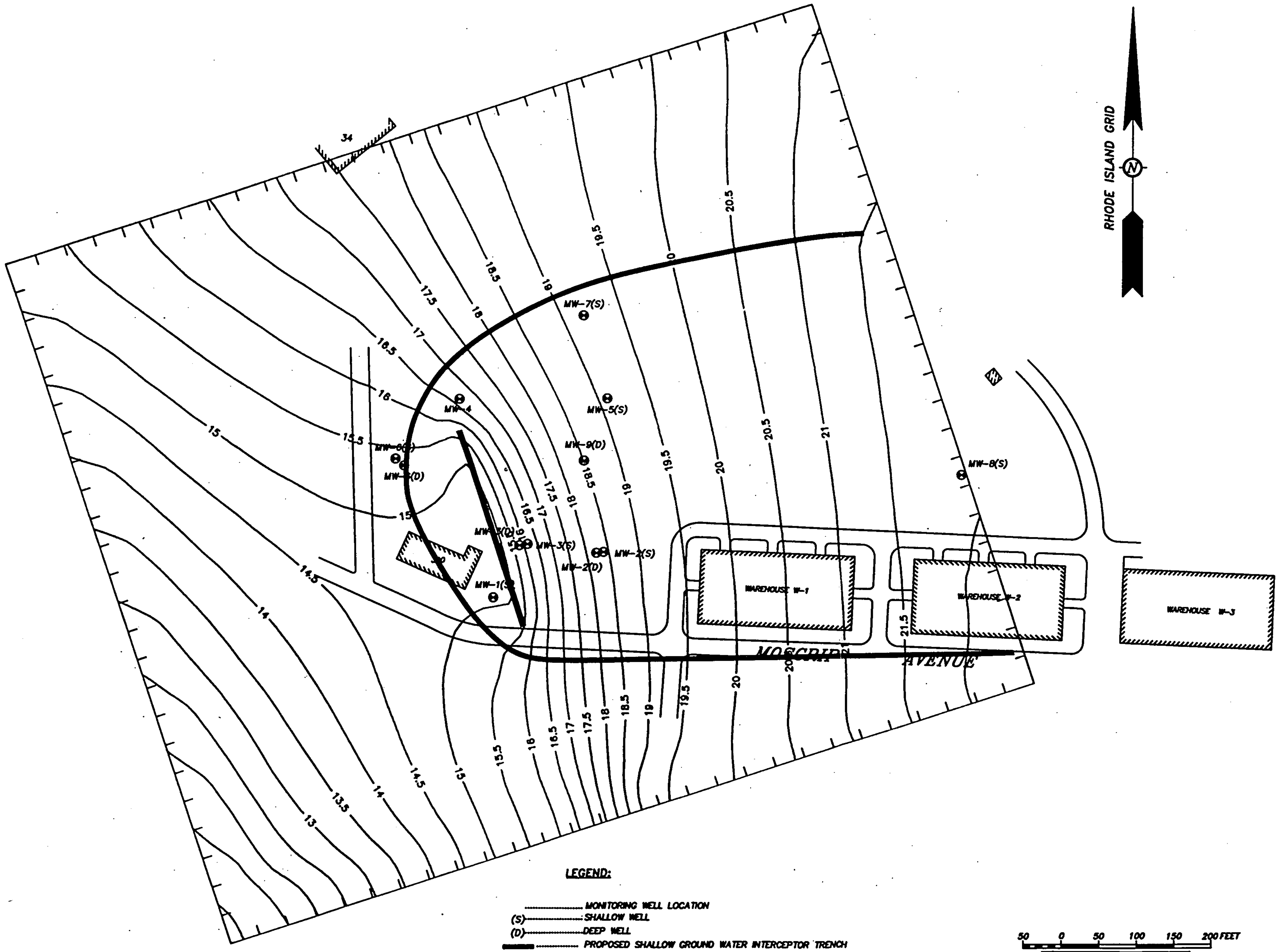
FIGURE F-3.
SITE 11-FIRE FIGHTING TRAINING AREA
GROUND WATER FLOW MODEL CALIBRATION TO
DEEP GROUND WATER STEADY-STATE
CONDITIONS ON AUGUST 13, 1993

Date: 5/94 | Project No. 01042-0040

11B4/150M



LEGEND:

MONITORING WELL LOCATION
(S) SHALLOW WELL
(D) DEEP WELL
PROPOSED SHALLOW GROUND WATER INTERCEPTOR TRENCH
—17— SIMULATED GROUND WATER CONTOUR (FT MSL)
SIMULATED SHALLOW GROUND WATER CAPTURE ZONE

50 0 50 100 150 200 FEET
10 0 10 20 30 40 50 METERS

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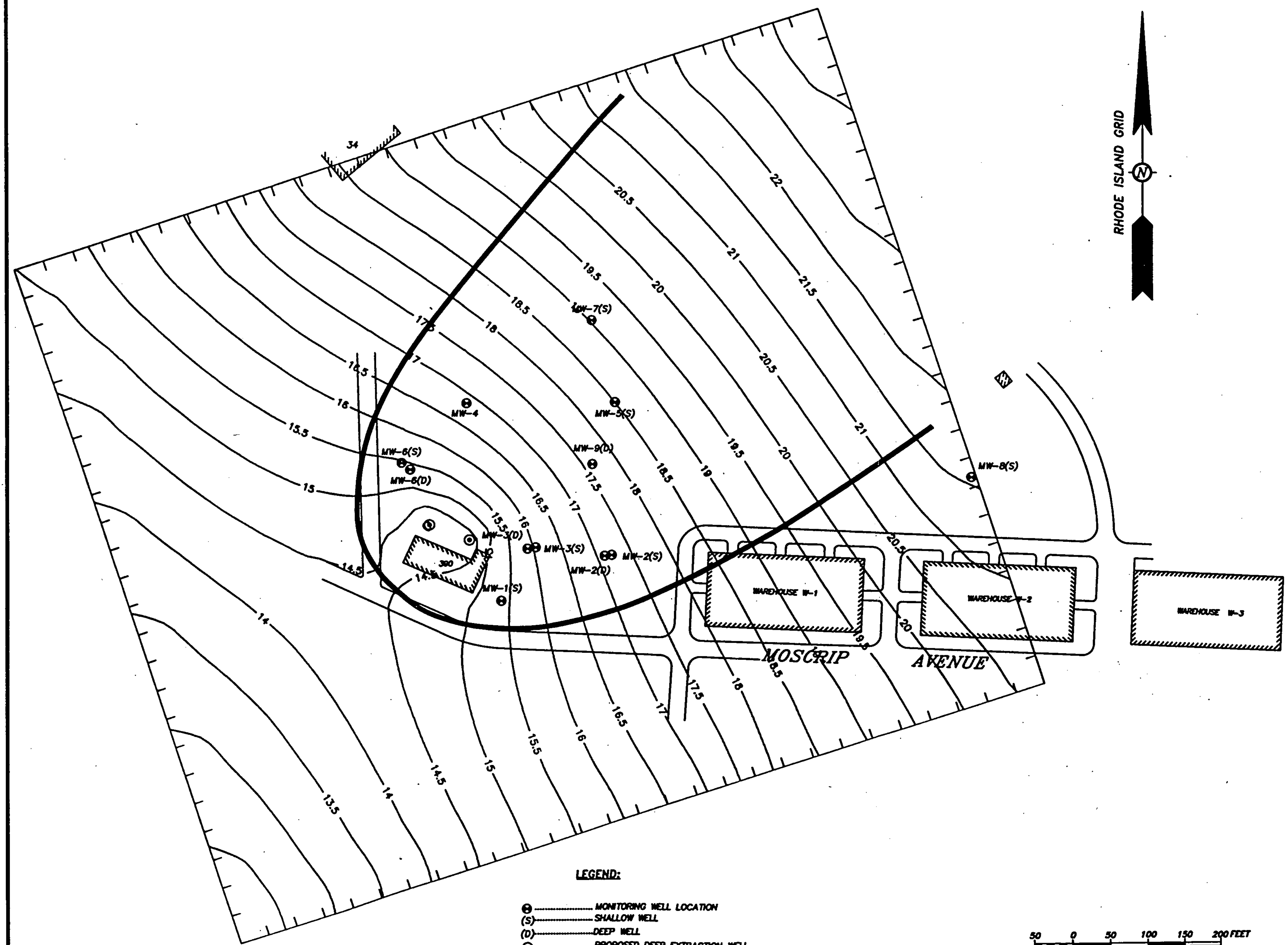
FIGURE F-4.
SITE 11-FIRE FIGHTING TRAINING AREA
SIMULATION RESULTS, PROPOSED SHALLOW GROUND WATER INTERCEPTOR TRENCH
SHALLOW GROUND WATER LEVEL CONTOURS AND CAPTURE ZONE

Date: 5/94 | Project No. 01042-0040

11B4150M



LEGEND:

- ⊖ .... MONITORING WELL LOCATION
- (S) .... SHALLOW WELL
- (D) .... DEEP WELL
- ⊙ .... PROPOSED DEEP EXTRACTION WELL
- —17— .... SIMULATED GROUND WATER CONTOUR (FT MSL)
- ━━ .... SIMULATED DEEP GROUND WATER CAPTURE ZONE

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FIGURE F-5.
SITE 11-FIRE FIGHTING TRAINING AREA SIMULATION RESULTS, PROPOSED DEEP GROUND WATER EXTRACTION WELLS DEEP GROUND WATER LEVEL CONTOURS AND CAPTURE ZONE

Date: 5/94 | Project No. 01042-0040

```
1                     U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
0NCBC DAVISVILLE SITE 11, FIRE FIGHTING TRAINING AREA - FEASIBILITY STUDY        STEADY-STATE CALIBRATION TO CONDITIONS 08/13/93
    2 LAYERS         24 ROWS         28 COLUMNS
   1 STRESS PERIOD(S) IN SIMULATION
 MODEL TIME UNIT IS DAYS
0I/O UNITS:
 ELEMENT OF IUNIT:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
        I/O UNIT: 11  0  0  0  0  0  0  0 19  0  0 22  0  0  0  0  0  0  0  0  0  0  0  0
0BAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT  1
 ARRAYS RHS AND BUFF WILL SHARE MEMORY.
 START HEAD WILL BE SAVED
    12828 ELEMENTS IN X ARRAY ARE USED BY BAS
    12828 ELEMENTS OF X ARRAY USED OUT OF  100000
0BCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 11
 STEADY-STATE SIMULATION
      LAYER  AQUIFER TYPE
      -------------------
         1         1
         2         0
     1346 ELEMENTS IN X ARRAY ARE USED BY BCF
    14174 ELEMENTS OF X ARRAY USED OUT OF  100000
0SIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 19
 MAXIMUM OF  50 ITERATIONS ALLOWED FOR CLOSURE
  5 ITERATION PARAMETERS
     5581 ELEMENTS IN X ARRAY ARE USED BY SIP
    19755 ELEMENTS OF X ARRAY USED OUT OF  100000
1NCBC DAVISVILLE SITE 11, FIRE FIGHTING TRAINING AREA - FEASIBILITY STUDY        STEADY-STATE CALIBRATION TO CONDITIONS 08/13/93
0
```

BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (26I3)

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0 2	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 3	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
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0 16	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 17	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 18	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 19	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 20	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 21	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 22	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 23	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 24	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

0

BOUNDARY ARRAY FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (26I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
0 1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
0 2	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 3	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 4	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 5	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 6	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2

```
0  7  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0  8  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0  9  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 10  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 11  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 12  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 13  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 14  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 15  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 16  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 17  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 18  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 19  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 20  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 21  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 22  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 23  -2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2  2 -2
0 24  -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2 -2
0AQUIFER HEAD WILL BE SET TO -99.990     AT ALL NO-FLOW NODES (IBOUND=0).
0
```

```
                                 INITIAL HEAD FOR LAYER  1 WILL BE READ ON UNIT  1 USING FORMAT: (16F5.1)
                              ------------------------------------------------------------------------------

              1         2         3         4         5         6         7         8         9        10
             11        12        13        14        15        16        17        18        19        20
             21        22        23        24        25        26        27        28
 ...........................................................................................................
0  1      15.20     15.40     15.60     15.80     16.00     16.20     16.40     16.60     16.80     17.00
          17.40     17.60     17.80     18.00     18.50     19.00     19.00     19.20     19.30     19.50
          19.70     19.80     20.00     20.20     20.40     20.60     20.80     21.00
0  2      15.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.10
0  3      14.80     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.20
0  4      14.60     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.20
0  5      14.40     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.30
0  6      14.20     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.40
0  7      14.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.50
0  8      13.80     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.60
0  9      13.60     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.70
0 10      13.40     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.70
0 11      13.20     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.80
0 12      13.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.80
0 13      12.80     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.80
0 14      12.60     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     21.90
0 15      12.40     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
          18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00     18.00
```

	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.90		
0 16	12.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.90		
0 17	12.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.00		
0 18	11.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.00		
0 19	11.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.10		
0 20	11.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.10		
0 21	11.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.20		
0 22	11.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.20		
0 23	10.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.30		
0 24	10.60	11.10	11.60	12.10	12.60	13.10	13.60	14.10	14.60	15.10
	15.50	15.80	16.50	18.00	19.50	19.70	19.80	20.00	20.20	20.50
	20.70	21.00	21.20	21.50	21.70	22.00	22.20	22.30		
0										

INITIAL HEAD FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.1)

	1	2	3	4	5	6	7	8	9	10
	11	12	13	14	15	16	17	18	19	20
	21	22	23	24	25	26	27	28		
0 1	14.90	15.20	15.50	15.80	16.10	16.40	16.70	17.00	17.50	18.00
	18.30	18.60	18.90	19.20	19.50	19.80	20.10	20.40	20.70	21.00
	21.30	21.60	21.90	22.20	22.50	22.80	23.10	23.40		
0 2	14.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	23.30		
0 3	14.70	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	23.20		
0 4	14.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	23.10		
0 5	14.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	23.00		
0 6	14.30	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.90		
0 7	14.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.80		
0 8	14.10	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.70		
0 9	13.90	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.60		
0 10	13.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.50		
0 11	13.70	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.40		
0 12	13.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00

	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.30		
0 13	13.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.20		
0 14	13.30	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.10		
0 15	13.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.00		
0 16	13.10	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.80		
0 17	12.90	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.70		
0 18	12.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.50		
0 19	12.70	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.30		
0 20	12.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.20		
0 21	12.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.00		
0 22	12.30	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	20.90		
0 23	12.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	20.80		
0 24	12.10	12.40	12.70	13.00	13.30	13.60	13.90	14.20	14.50	14.80
	15.10	15.40	15.70	16.00	16.30	16.60	17.00	17.50	18.00	18.30
	18.60	18.90	19.20	19.50	19.80	20.10	20.40	20.70		

0HEAD PRINT FORMAT IS FORMAT NUMBER 4 DRAWDOWN PRINT FORMAT IS FORMAT NUMBER 9
0HEADS WILL BE SAVED ON UNIT 30 DRAWDOWNS WILL BE SAVED ON UNIT 40
0OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
0 COLUMN TO ROW ANISOTROPY = 1.000000
0 DELR = 40.00000
0 DELC = 40.00000
0

HYD. COND. ALONG ROWS FOR LAYER 1 WILL BE READ ON UNIT 11 USING FORMAT: (16F5.1)

	1 11 21	2 12 22	3 13 23	4 14 24	5 15 25	6 16 26	7 17 27	8 18 28	9 19	10 20
0 1	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 2	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 3	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 4	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 5	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 6	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 7	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00

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        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0  8   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     10.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0  9   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     10.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 10   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     10.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 11   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     10.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 12   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     10.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 13   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 14   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 15   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 16   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 17   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 18   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 19   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
   20   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 21   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 22   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 23   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
 0 24   25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00     25.00
        25.00     25.00     10.00     10.00     10.00     10.00     19.00     19.00     19.00     19.00
        19.00     19.00     19.00     19.00     19.00     19.00     19.00     19.00
0                                                        BOTTOM =    10.30000      FOR LAYER  1
0                                    VERT HYD COND /THICKNESS =    .1000000E-03  FOR LAYER  1
0                                       TRANSMIS. ALONG ROWS =    34.60000      FOR LAYER  2
0


                                              SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE
                                              -------------------------------------------
0                                 MAXIMUM ITERATIONS ALLOWED FOR CLOSURE =        50
                                                  ACCELERATION PARAMETER =      1.0000
                                     HEAD CHANGE CRITERION FOR CLOSURE =      .10000E-02
                                     SIP HEAD CHANGE PRINTOUT INTERVAL =         1
0                                    CALCULATE ITERATION PARAMETERS FROM MODEL CALCULATED WSEED
1                                   STRESS PERIOD NO.    1, LENGTH =    1825.000
                                    ----------------------------------------------

                                    NUMBER OF TIME STEPS =      1

                                     MULTIPLIER FOR DELT =     1.000

                                  INITIAL TIME STEP SIZE =   1825.000
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0AVERAGE SEED =  .00177001
 MINIMUM SEED =  .00051249
0
    5 ITERATION PARAMETERS CALCULATED FROM AVERAGE SEED:

           .0000000E+00   .7948866E+00   .9579285E+00   .9913706E+00   .9982300E+00
0
    16 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD  1
0MAXIMUM HEAD CHANGE FOR EACH ITERATION:
0 HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL
 ------------------------------------------------------------------------------------------------------------------------------------
    -4.614     (  2, 23,  2)  -2.006     (  1, 22,  3)  -1.694     (  2, 19,  6)  -1.453     (  1, 16,  6)   .6484      (  1,  8, 15)
    .6397E-01 (  1, 15, 14)  -.8502E-01 (  1, 14, 19)   .1124      (  1, 14,  9)  -.1063     (  1, 13, 18)  -.4715E-01 (  1, 17, 13)
    .7996E-02 (  1, 11, 15)  -.7350E-02 (  1, 11,  7)   .1028E-01 (  1, 14, 18)  -.7096E-02 (  1, 10,  8)   .3533E-02 (  1, 11, 10)
    .6832E-03 (  1,  7, 13)
0
0HEAD/DRAWDOWN PRINTOUT FLAG = 1     TOTAL BUDGET PRINTOUT FLAG = 1     CELL-BY-CELL FLOW TERM FLAG = 0
0OUTPUT FLAGS FOR EACH LAYER:
          HEAD    DRAWDOWN  HEAD   DRAWDOWN
 LAYER  PRINTOUT  PRINTOUT  SAVE    SAVE
 ----------------------------------------
    1       1         1       1       1
    2       1         1       1       1
1                   HEAD IN LAYER  1 AT END OF TIME STEP  1 IN STRESS PERIOD  1
```

Row	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
0 1	15.20	15.40	15.60	15.80	16.00	16.20	16.40	16.60	16.80	17.00	17.40	17.60	17.80	18.00	18.50	19.00	19.00	19.20	19.30	19.50	19.70	19.80	20.00	20.20	20.40	20.60	20.80	21.00
0 2	15.00	15.24	15.47	15.69	15.91	16.12	16.33	16.54	16.75	16.97	17.21	17.48	17.80	18.12	18.51	18.89	19.08	19.25	19.40	19.58	19.76	19.92	20.11	20.30	20.50	20.70	20.90	21.10
0 3	14.80	15.07	15.33	15.57	15.81	16.03	16.26	16.47	16.69	16.90	17.11	17.40	17.78	18.15	18.52	18.88	19.13	19.30	19.47	19.65	19.83	20.01	20.20	20.39	20.59	20.78	20.98	21.20
0 4	14.60	14.91	15.19	15.45	15.70	15.94	16.17	16.40	16.62	16.83	17.03	17.34	17.76	18.15	18.54	18.90	19.17	19.35	19.53	19.72	19.90	20.09	20.28	20.47	20.67	20.86	21.04	21.20
0 5	14.40	14.74	15.04	15.33	15.59	15.85	16.09	16.32	16.55	16.76	16.96	17.29	17.73	18.15	18.54	18.92	19.21	19.40	19.59	19.78	19.97	20.16	20.36	20.55	20.75	20.94	21.12	21.30
0 6	14.20	14.57	14.90	15.20	15.48	15.75	16.00	16.24	16.47	16.69	16.90	17.24	17.70	18.14	18.55	18.95	19.24	19.44	19.63	19.83	20.03	20.23	20.43	20.62	20.82	21.02	21.21	21.40
0 7	14.00	14.40	14.75	15.08	15.37	15.65	15.92	16.17	16.40	16.63	16.85	17.20	17.68	18.13	18.56	18.96	19.27	19.47	19.68	19.88	20.08	20.29	20.49	20.69	20.89	21.10	21.30	21.50
0 8	13.80	14.23	14.61	14.95	15.26	15.56	15.83	16.09	16.33	16.57	16.79	17.16	17.65	18.11	18.56	18.98	19.29	19.50	19.72	19.92	20.13	20.34	20.55	20.75	20.96	21.17	21.38	21.60
0 9	13.60	14.06	14.47	14.83	15.16	15.46	15.75	16.01	16.27	16.51	16.74	17.11	17.62	18.10	18.55	18.99	19.31	19.53	19.75	19.96	20.18	20.39	20.60	20.81	21.02	21.24	21.46	21.70
0 10	13.40	13.90	14.33	14.70	15.05	15.37	15.66	15.94	16.20	16.45	16.68	17.07	17.58	18.08	18.55	19.00	19.33	19.56	19.78	20.00	20.22	20.43	20.65	20.86	21.08	21.29	21.50	21.70
0 11	13.20	13.73	14.19	14.58	14.94	15.27	15.58	15.87	16.14	16.39	16.63	17.01	17.54	18.05	18.54	19.00	19.35	19.58	19.81	20.03	20.26	20.48	20.69	20.91	21.12	21.34	21.56	21.80
0 12	13.00	13.57	14.05	14.46	14.84	15.18	15.50	15.80	16.08	16.34	16.59	16.95	17.48	18.01	18.52	19.01	19.36	19.60	19.84	20.07	20.29	20.51	20.73	20.95	21.17	21.38	21.59	21.80
0 13	12.80	13.41	13.91	14.35	14.73	15.08	15.41	15.72	16.02	16.30	16.58	16.88	17.36	17.96	18.50	19.01	19.38	19.62	19.86	20.09	20.32	20.55	20.77	20.99	21.20	21.42	21.62	21.80
0 14	12.60	13.26	13.78	14.23	14.63	14.99	15.33	15.65	15.96	16.25	16.54	16.83	17.30	17.92	18.48	19.01	19.39	19.64	19.89	20.12	20.36	20.59	20.81	21.03	21.24	21.46	21.67	21.90
0 15	12.40	13.10	13.65	14.11	14.52	14.89	15.24	15.57	15.89	16.19	16.49	16.78	17.26	17.89	18.47	19.01	19.40	19.66	19.91	20.15	20.39	20.62	20.85	21.07	21.28	21.49	21.70	21.90
0 16	12.20	12.95	13.51	13.99	14.40	14.79	15.14	15.48	15.81	16.12	16.43	16.73	17.21	17.87	18.47	19.02	19.42	19.68	19.94	20.18	20.42	20.66	20.88	21.10	21.32	21.53	21.73	21.90
0 17	12.00	12.80	13.38	13.86	14.28	14.67	15.04	15.39	15.72	16.05	16.36	16.67	17.17	17.85	18.46	19.03	19.44	19.71	19.97	20.22	20.46	20.69	20.92	21.14	21.36	21.57	21.78	22.00
0 18	11.80	12.65	13.24	13.72	14.15	14.55	14.92	15.28	15.63	15.96	16.29	16.61	17.13	17.83	18.47	19.05	19.47	19.74	20.00	20.25	20.49	20.73	20.96	21.18	21.40	21.62	21.82	22.00
0 19	11.60	12.50	13.09	13.57	14.01	14.41	14.79	15.16	15.52	15.86	16.20	16.54	17.09	17.82	18.48	19.07	19.50	19.77	20.03	20.29	20.53	20.77	21.00	21.23	21.45	21.66	21.88	22.10
0 20	11.40	12.34	12.92	13.41	13.84	14.25	14.64	15.02	15.39	15.75	16.11	16.46	17.04	17.81	18.50	19.11	19.54	19.81	20.07	20.33	20.57	20.81	21.04	21.27	21.50	21.71	21.92	22.10
0 21	11.20	12.16	12.73	13.20	13.64	14.06	14.46	14.85	15.24	15.62	15.99	16.36	16.99	17.82	18.55	19.17	19.59	19.86	20.12	20.37	20.61	20.85	21.09	21.32	21.55	21.77	21.98	22.20
0 22	11.00	11.96	12.49	12.95	13.39	13.82	14.24	14.65	15.06	15.46	15.85	16.24	16.92	17.86	18.68	19.27	19.66	19.91	20.16	20.41	20.65	20.90	21.13	21.37	21.60	21.82	22.03	22.20

```
0 23    10.80   11.67   12.15   12.61   13.06   13.51   13.96   14.41   14.85   15.29   15.69   16.07   16.81   17.93   18.90
        19.43   19.74   19.96   20.19   20.45   20.69   20.94   21.18   21.43   21.66   21.90   22.11   22.30
  24    10.60   11.10   11.60   12.10   12.60   13.10   13.60   14.10   14.60   15.10   15.50   15.80   16.50   18.00   19.50
        19.70   19.80   20.00   20.20   20.50   20.70   21.00   21.20   21.50   21.70   22.00   22.20   22.30
1                    HEAD IN LAYER  2 AT END OF TIME STEP  1 IN STRESS PERIOD  1
            ---------------------------------------------------------------------------------------

           1       2       3       4       5       6       7       8       9      10      11      12      13      14      15
          16      17      18      19      20      21      22      23      24      25      26      27      28
..........................................................................................................................
0  1    14.90   15.20   15.50   15.80   16.10   16.40   16.70   17.00   17.50   18.00   18.30   18.60   18.90   19.20   19.50
        19.80   20.10   20.40   20.70   21.00   21.30   21.60   21.90   22.20   22.50   22.80   23.10   23.40
0  2    14.80   15.10   15.40   15.70   16.00   16.31   16.63   16.97   17.37   17.77   18.11   18.43   18.74   19.05   19.35
        19.66   19.96   20.26   20.56   20.86   21.17   21.47   21.77   22.07   22.38   22.68   22.99   23.30
0  3    14.70   14.99   15.29   15.59   15.90   16.21   16.54   16.88   17.24   17.60   17.94   18.26   18.58   18.90   19.21
        19.52   19.82   20.13   20.43   20.73   21.04   21.34   21.65   21.95   22.26   22.57   22.88   23.20
0  4    14.60   14.88   15.17   15.48   15.79   16.11   16.43   16.77   17.11   17.45   17.79   18.11   18.44   18.75   19.07
        19.38   19.69   20.00   20.30   20.61   20.91   21.22   21.53   21.83   22.14   22.46   22.78   23.10
0  5    14.40   14.74   15.05   15.37   15.68   16.00   16.32   16.65   16.98   17.32   17.65   17.97   18.30   18.62   18.94
        19.25   19.56   19.87   20.18   20.49   20.80   21.10   21.41   21.72   22.04   22.35   22.67   23.00
0  6    14.30   14.62   14.93   15.25   15.56   15.88   16.21   16.53   16.86   17.19   17.52   17.84   18.17   18.49   18.81
        19.12   19.44   19.75   20.06   20.37   20.68   20.99   21.30   21.61   21.93   22.25   22.57   22.90
0  7    14.20   14.50   14.82   15.13   15.45   15.77   16.09   16.41   16.74   17.06   17.39   17.71   18.04   18.36   18.68
        19.00   19.32   19.63   19.94   20.26   20.57   20.88   21.19   21.51   21.83   22.15   22.47   22.80
0  8    14.10   14.39   14.69   15.01   15.33   15.65   15.97   16.29   16.61   16.94   17.26   17.59   17.91   18.24   18.56
        18.88   19.20   19.52   19.83   20.14   20.46   20.77   21.09   21.40   21.72   22.04   22.37   22.70
0  9    13.90   14.24   14.57   14.89   15.21   15.53   15.85   16.17   16.49   16.81   17.14   17.46   17.79   18.11   18.44
        18.76   19.08   19.40   19.72   20.03   20.35   20.66   20.98   21.30   21.62   21.94   22.27   22.60
0 10    13.80   14.12   14.44   14.76   15.08   15.40   15.72   16.05   16.37   16.69   17.02   17.34   17.67   17.99   18.32
        18.64   18.97   19.29   19.60   19.92   20.24   20.56   20.87   21.19   21.52   21.84   22.17   22.50
0 11    13.70   14.01   14.32   14.64   14.96   15.28   15.60   15.92   16.25   16.57   16.90   17.22   17.55   17.88   18.20
        18.53   18.85   19.17   19.49   19.81   20.13   20.45   20.77   21.09   21.41   21.74   22.07   22.40
0 12    13.60   13.89   14.20   14.52   14.84   15.16   15.48   15.80   16.12   16.45   16.77   17.10   17.43   17.76   18.08
        18.41   18.74   19.06   19.38   19.70   20.02   20.34   20.66   20.98   21.31   21.63   21.97   22.30
0 13    13.40   13.75   14.07   14.39   14.71   15.03   15.35   15.68   16.00   16.32   16.65   16.98   17.31   17.64   17.96
        18.29   18.62   18.94   19.27   19.59   19.91   20.23   20.55   20.87   21.20   21.53   21.86   22.20
  14    13.30   13.62   13.95   14.27   14.59   14.91   15.23   15.55   15.88   16.20   16.53   16.85   17.18   17.51   17.84
        18.17   18.50   18.83   19.15   19.47   19.80   20.12   20.44   20.76   21.09   21.42   21.75   22.10
0 15    13.20   13.51   13.82   14.14   14.46   14.78   15.10   15.43   15.75   16.07   16.40   16.73   17.06   17.39   17.72
        18.05   18.38   18.71   19.04   19.36   19.68   20.00   20.32   20.64   20.97   21.30   21.63   22.00
0 16    13.10   13.39   13.70   14.01   14.33   14.65   14.98   15.30   15.62   15.95   16.27   16.60   16.93   17.26   17.60
        17.93   18.26   18.59   18.92   19.24   19.56   19.88   20.20   20.52   20.84   21.17   21.49   21.80
0 17    12.90   13.24   13.57   13.89   14.21   14.53   14.85   15.17   15.49   15.81   16.14   16.47   16.80   17.13   17.47
        17.80   18.14   18.47   18.80   19.12   19.45   19.77   20.08   20.40   20.72   21.03   21.36   21.70
0 18    12.80   13.12   13.44   13.76   14.08   14.40   14.72   15.04   15.36   15.68   16.00   16.33   16.66   17.00   17.33
        17.67   18.01   18.34   18.67   19.00   19.32   19.64   19.96   20.27   20.58   20.89   21.20   21.50
0 19    12.70   13.00   13.32   13.63   13.95   14.26   14.58   14.90   15.22   15.54   15.87   16.19   16.52   16.86   17.19
        17.53   17.87   18.21   18.55   18.88   19.20   19.52   19.84   20.15   20.45   20.75   21.04   21.30
0 20    12.60   12.88   13.19   13.50   13.82   14.13   14.45   14.76   15.08   15.40   15.72   16.05   16.37   16.71   17.05
        17.39   17.73   18.08   18.42   18.75   19.08   19.40   19.71   20.02   20.32   20.61   20.90   21.20
0 21    12.40   12.74   13.06   13.37   13.69   14.00   14.31   14.63   14.94   15.26   15.57   15.89   16.22   16.55   16.89
        17.23   17.58   17.94   18.29   18.63   18.96   19.28   19.59   19.89   20.19   20.48   20.76   21.00
0 22    12.30   12.62   12.93   13.25   13.56   13.87   14.18   14.48   14.80   15.11   15.42   15.74   16.06   16.38   16.71
        17.06   17.42   17.80   18.17   18.51   18.84   19.15   19.46   19.76   20.06   20.35   20.63   20.90
0 23    12.20   12.51   12.82   13.12   13.43   13.73   14.04   14.34   14.65   14.95   15.26   15.57   15.88   16.20   16.52
        16.86   17.23   17.65   18.06   18.40   18.72   19.03   19.33   19.63   19.93   20.23   20.52   20.80
0 24    12.10   12.40   12.70   13.00   13.30   13.60   13.90   14.20   14.50   14.80   15.10   15.40   15.70   16.00   16.30
        16.60   17.00   17.50   18.00   18.30   18.60   18.90   19.20   19.50   19.80   20.10   20.40   20.70
OHEAD WILL BE SAVED ON UNIT 30 AT END OF TIME STEP  1, STRESS PERIOD  1
1               DRAWDOWN IN LAYER  1 AT END OF TIME STEP  1 IN STRESS PERIOD  1
            ---------------------------------------------------------------------------------------

         1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20
        21    22    23    24    25    26    27    28
..........................................................................................................................
0  1   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
       .00   .00   .00   .00   .00   .00   .00   .00
0  2   .00  2.76  2.53  2.31  2.09  1.88  1.67  1.46  1.25  1.03   .79   .52   .20  -.12  -.51  -.89 -1.08 -1.25 -1.40 -1.58
     -1.76 -1.92 -2.11 -2.30 -2.50 -2.70 -2.90   .00
0  3   .00  2.93  2.67  2.43  2.19  1.97  1.74  1.53  1.31  1.10   .89   .60   .22  -.15  -.52  -.88 -1.13 -1.30 -1.47 -1.65
     -1.83 -2.01 -2.20 -2.39 -2.59 -2.78 -2.98   .00
   4   .00  3.09  2.81  2.55  2.30  2.06  1.83  1.60  1.38  1.17   .97   .66   .24  -.15  -.54  -.90 -1.17 -1.35 -1.53 -1.72
     -1.90 -2.09 -2.28 -2.47 -2.67 -2.86 -3.04   .00
```

```
0  5    .00  3.26  2.96  2.67  2.41  2.15  1.91  1.68  1.45  1.24  1.04   .71   .27  -.15  -.54  -.92 -1.21 -1.40 -1.59 -1.78
     -1.97 -2.16 -2.36 -2.55 -2.75 -2.94 -3.12   .00
0  6    .00  3.43  3.10  2.80  2.52  2.25  2.00  1.76  1.53  1.31  1.10   .76   .30  -.14  -.55  -.95 -1.24 -1.44 -1.63 -1.
     -2.03 -2.23 -2.43 -2.62 -2.82 -3.02 -3.21   .00
0  7    .00  3.60  3.25  2.92  2.63  2.35  2.08  1.83  1.60  1.37  1.15   .80   .32  -.13  -.56  -.96 -1.27 -1.47 -1.68 -1.88
     -2.08 -2.29 -2.49 -2.69 -2.89 -3.10 -3.30   .00
0  8    .00  3.77  3.39  3.05  2.74  2.44  2.17  1.91  1.67  1.43  1.21   .84   .35  -.11  -.56  -.98 -1.29 -1.50 -1.72 -1.92
     -2.13 -2.34 -2.55 -2.75 -2.96 -3.17 -3.38   .00
0  9    .00  3.94  3.53  3.17  2.84  2.54  2.25  1.99  1.73  1.49  1.26   .89   .38  -.10  -.55  -.99 -1.31 -1.53 -1.75 -1.96
     -2.18 -2.39 -2.60 -2.81 -3.02 -3.24 -3.46   .00
0 10    .00  4.10  3.67  3.30  2.95  2.63  2.34  2.06  1.80  1.55  1.32   .93   .42  -.08  -.55 -1.00 -1.33 -1.56 -1.78 -2.00
     -2.22 -2.43 -2.65 -2.86 -3.08 -3.29 -3.50   .00
0 11    .00  4.27  3.81  3.42  3.06  2.73  2.42  2.13  1.86  1.61  1.37   .99   .46  -.05  -.54 -1.00 -1.35 -1.58 -1.81 -2.03
     -2.26 -2.48 -2.69 -2.91 -3.12 -3.34 -3.56   .00
0 12    .00  4.43  3.95  3.54  3.16  2.82  2.50  2.20  1.92  1.66  1.41  1.05   .52  -.01  -.52 -1.01 -1.36 -1.60 -1.84 -2.07
     -2.29 -2.51 -2.73 -2.95 -3.17 -3.38 -3.59   .00
0 13    .00  4.59  4.09  3.65  3.27  2.92  2.59  2.28  1.98  1.70  1.42  1.12   .64   .04  -.50 -1.01 -1.38 -1.62 -1.86 -2.09
     -2.32 -2.55 -2.77 -2.99 -3.20 -3.42 -3.62   .00
0 14    .00  4.74  4.22  3.77  3.37  3.01  2.67  2.35  2.04  1.75  1.46  1.17   .70   .08  -.48 -1.01 -1.39 -1.64 -1.89 -2.12
     -2.36 -2.59 -2.81 -3.03 -3.24 -3.46 -3.67   .00
0 15    .00  4.90  4.35  3.89  3.48  3.11  2.76  2.43  2.11  1.81  1.51  1.22   .74   .11  -.47 -1.01 -1.40 -1.66 -1.91 -2.15
     -2.39 -2.62 -2.85 -3.07 -3.28 -3.49 -3.70   .00
0 16    .00  5.05  4.49  4.01  3.60  3.21  2.86  2.52  2.19  1.88  1.57  1.27   .79   .13  -.47 -1.02 -1.42 -1.68 -1.94 -2.18
     -2.42 -2.66 -2.88 -3.10 -3.32 -3.53 -3.73   .00
0 17    .00  5.20  4.62  4.14  3.72  3.33  2.96  2.61  2.28  1.95  1.64  1.33   .83   .15  -.46 -1.03 -1.44 -1.71 -1.97 -2.22
     -2.46 -2.69 -2.92 -3.14 -3.36 -3.57 -3.78   .00
0 18    .00  5.35  4.76  4.28  3.85  3.45  3.08  2.72  2.37  2.04  1.71  1.39   .87   .17  -.47 -1.05 -1.47 -1.74 -2.00 -2.25
     -2.49 -2.73 -2.96 -3.18 -3.40 -3.62 -3.82   .00
0 19    .00  5.50  4.91  4.43  3.99  3.59  3.21  2.84  2.48  2.14  1.80  1.46   .91   .18  -.48 -1.07 -1.50 -1.77 -2.03 -2.29
     -2.53 -2.77 -3.00 -3.23 -3.45 -3.66 -3.88   .00
0 20    .00  5.66  5.08  4.59  4.16  3.75  3.36  2.98  2.61  2.25  1.89  1.54   .96   .19  -.50 -1.11 -1.54 -1.81 -2.07 -2.33
     -2.57 -2.81 -3.04 -3.27 -3.50 -3.71 -3.92   .00
0 21    .00  5.84  5.27  4.80  4.36  3.94  3.54  3.15  2.76  2.38  2.01  1.64  1.01   .18  -.55 -1.17 -1.59 -1.86 -2.12 -2.37
     -2.61 -2.85 -3.09 -3.32 -3.55 -3.77 -3.98   .00
0 22    .00  6.04  5.51  5.05  4.61  4.18  3.76  3.35  2.94  2.54  2.15  1.76  1.08   .14  -.66 -1.27 -1.66 -1.91 -2.16 -2.41
     -2.65 -2.90 -3.13 -3.37 -3.60 -3.82 -4.03   .00
0 23    .00  6.33  5.85  5.39  4.94  4.49  4.04  3.59  3.15  2.71  2.31  1.93  1.19   .07  -.90 -1.43 -1.74 -1.96 -2.19 -2.4
     -2.69 -2.94 -3.18 -3.43 -3.66 -3.90 -4.11   .00
0 24    .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
        .00   .00   .00   .00   .00   .00   .00   .00
1                    DRAWDOWN IN LAYER  2 AT END OF TIME STEP  1 IN STRESS PERIOD  1
               ----------------------------------------------------------------------

          1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20
         21    22    23    24    25    26    27    28
.....................................................................................................................................
0  1    .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
        .00   .00   .00   .00   .00   .00   .00   .00
0  2    .00  2.90  2.60  2.30  2.00  1.69  1.37  1.03   .63   .23  -.11  -.43  -.74 -1.05 -1.35 -1.66 -1.96 -2.26 -2.56 -2.86
     -3.17 -3.47 -3.77 -4.07 -4.38 -4.68 -4.99   .00
0  3    .00  3.01  2.71  2.41  2.10  1.79  1.46  1.12   .76   .40   .06  -.26  -.58  -.90 -1.21 -1.52 -1.82 -2.13 -2.43 -2.73
     -3.04 -3.34 -3.65 -3.95 -4.26 -4.57 -4.88   .00
0  4    .00  3.12  2.83  2.52  2.21  1.89  1.57  1.23   .89   .55   .21  -.11  -.44  -.75 -1.07 -1.38 -1.69 -2.00 -2.30 -2.61
     -2.91 -3.22 -3.53 -3.83 -4.14 -4.46 -4.78   .00
0  5    .00  3.26  2.95  2.63  2.32  2.00  1.68  1.35  1.02   .68   .35   .03  -.30  -.62  -.94 -1.25 -1.56 -1.87 -2.18 -2.49
     -2.80 -3.10 -3.41 -3.72 -4.04 -4.35 -4.67   .00
0  6    .00  3.38  3.07  2.75  2.44  2.12  1.79  1.47  1.14   .81   .48   .16  -.17  -.49  -.81 -1.12 -1.44 -1.75 -2.06 -2.37
     -2.68 -2.99 -3.30 -3.61 -3.93 -4.25 -4.57   .00
0  7    .00  3.50  3.18  2.87  2.55  2.23  1.91  1.59  1.26   .94   .61   .29  -.04  -.36  -.68 -1.00 -1.32 -1.63 -1.94 -2.26
     -2.57 -2.88 -3.19 -3.51 -3.83 -4.15 -4.47   .00
0  8    .00  3.61  3.31  2.99  2.67  2.35  2.03  1.71  1.39  1.06   .74   .41   .09  -.24  -.56  -.88 -1.20 -1.52 -1.83 -2.14
     -2.46 -2.77 -3.09 -3.40 -3.72 -4.04 -4.37   .00
0  9    .00  3.76  3.43  3.11  2.79  2.47  2.15  1.83  1.51  1.19   .86   .54   .21  -.11  -.44  -.76 -1.08 -1.40 -1.72 -2.03
     -2.35 -2.66 -2.98 -3.30 -3.62 -3.94 -4.27   .00
0 10    .00  3.88  3.56  3.24  2.92  2.60  2.28  1.95  1.63  1.31   .98   .66   .33   .01  -.32  -.64  -.97 -1.29 -1.60 -1.92
     -2.24 -2.56 -2.87 -3.19 -3.52 -3.84 -4.17   .00
0 11    .00  3.99  3.68  3.36  3.04  2.72  2.40  2.08  1.75  1.43  1.10   .78   .45   .12  -.20  -.53  -.85 -1.17 -1.49 -1.81
     -2.13 -2.45 -2.77 -3.09 -3.41 -3.74 -4.07   .00
0 12    .00  4.11  3.80  3.48  3.16  2.84  2.52  2.20  1.88  1.55  1.23   .90   .57   .24  -.08  -.41  -.74 -1.06 -1.38 -1.70
     -2.02 -2.34 -2.66 -2.98 -3.31 -3.63 -3.97   .00
0 13    .00  4.25  3.93  3.61  3.29  2.97  2.65  2.32  2.00  1.68  1.35  1.02   .69   .36   .04  -.29  -.62  -.94 -1.27 -1.5
     -1.91 -2.23 -2.55 -2.87 -3.20 -3.53 -3.86   .00
0 14    .00  4.38  4.05  3.73  3.41  3.09  2.77  2.45  2.12  1.80  1.47  1.15   .82   .49   .16  -.17  -.50  -.83 -1.15 -1.47
```

```
     -1.80 -2.12 -2.44 -2.76 -3.09 -3.42 -3.75   .00
0 15   .00  4.49  4.18  3.86  3.54  3.22  2.90  2.57  2.25  1.93  1.60  1.27   .94   .61   .28  -.05  -.38  -.71 -1.04 -1.36
     -1.68 -2.00 -2.32 -2.64 -2.97 -3.30 -3.63   .00
  16   .00  4.61  4.30  3.99  3.67  3.35  3.02  2.70  2.38  2.05  1.73  1.40  1.07   .74   .40   .07  -.26  -.59  -.92 -1.24
     -1.56 -1.88 -2.20 -2.52 -2.84 -3.17 -3.49   .00
0 17   .00  4.76  4.43  4.11  3.79  3.47  3.15  2.83  2.51  2.19  1.86  1.53  1.20   .87   .53   .20  -.14  -.47  -.80 -1.12
     -1.45 -1.77 -2.08 -2.40 -2.72 -3.03 -3.36   .00
0 18   .00  4.88  4.56  4.24  3.92  3.60  3.28  2.96  2.64  2.32  2.00  1.67  1.34  1.00   .67   .33  -.01  -.34  -.67 -1.00
     -1.32 -1.64 -1.96 -2.27 -2.58 -2.89 -3.20   .00
0 19   .00  5.00  4.68  4.37  4.05  3.74  3.42  3.10  2.78  2.46  2.13  1.81  1.48  1.14   .81   .47   .13  -.21  -.55  -.88
     -1.20 -1.52 -1.84 -2.15 -2.45 -2.75 -3.04   .00
0 20   .00  5.12  4.81  4.50  4.18  3.87  3.55  3.24  2.92  2.60  2.28  1.95  1.63  1.29   .95   .61   .27  -.08  -.42  -.75
     -1.08 -1.40 -1.71 -2.02 -2.32 -2.61 -2.90   .00
0 21   .00  5.26  4.94  4.63  4.31  4.00  3.69  3.37  3.06  2.74  2.43  2.11  1.78  1.45  1.11   .77   .42   .06  -.29  -.63
      -.96 -1.28 -1.59 -1.89 -2.19 -2.48 -2.76   .00
0 22   .00  5.38  5.07  4.75  4.44  4.13  3.82  3.52  3.20  2.89  2.58  2.26  1.94  1.62  1.29   .94   .58   .20  -.17  -.51
      -.84 -1.15 -1.46 -1.76 -2.06 -2.35 -2.63   .00
0 23   .00  5.49  5.18  4.88  4.57  4.27  3.96  3.66  3.35  3.05  2.74  2.43  2.12  1.80  1.48  1.14   .77   .35  -.06  -.40
      -.72 -1.03 -1.33 -1.63 -1.93 -2.23 -2.52   .00
0 24   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
       .00   .00   .00   .00   .00   .00   .00   .00
0DRAWDOWN WILL BE SAVED ON UNIT 40 AT END OF TIME STEP  1, STRESS PERIOD  1
0


                     VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1 IN STRESS PERIOD  1
                     ----------------------------------------------------------------------------

0            CUMULATIVE VOLUMES      L**3                             RATES FOR THIS TIME STEP      L**3/T
             ------------------                                       ------------------------

                  IN:                                                          IN:
                  ---                                                          ---
                    STORAGE =     .00000                                          STORAGE =     .00000
              CONSTANT HEAD =     .30582E+07                                CONSTANT HEAD =     1675.7
0                  TOTAL IN =     .30582E+07                                     TOTAL IN =     1675.7
0                OUT:                                                        OUT:
                 ----                                                        ----
                    STORAGE =     .00000                                          STORAGE =     .00000
              CONSTANT HEAD =     .30587E+07                                CONSTANT HEAD =     1676.0
0                 TOTAL OUT =     .30587E+07                                    TOTAL OUT =     1676.0
0                  IN - OUT =    -559.75                                         IN - OUT =    -.30676
0      PERCENT DISCREPANCY =                 -.02             PERCENT DISCREPANCY =                 -.02


0


         TIME SUMMARY AT END OF TIME STEP  1 IN STRESS PERIOD  1
                                 SECONDS        MINUTES        HOURS         DAYS          YEARS
                             ------------------------------------------------------------------------
     TIME STEP LENGTH         .157680E+09    .262800E+07    43800.0       1825.00        4.99658
   STRESS PERIOD TIME         .157680E+09    .262800E+07    43800.0       1825.00        4.99658
 TOTAL SIMULATION TIME        .157680E+09    .262800E+07    43800.0       1825.00        4.99658
1
```

```
1                    U.S. GEOLOGICAL SURVEY MODULAR FINITE-DIFFERENCE GROUND-WATER MODEL
ONCBC DAVISVILLE SITE 11, FIRE FIGHTING TRAINING AREA - FEASIBILITY STUDY       REMED SIMULATION - SHALLOW DRAIN, DEEP EXTRA
    2 LAYERS        24 ROWS        28 COLUMNS
   1 STRESS PERIOD(S) IN SIMULATION
 MODEL TIME UNIT IS DAYS
OI/O UNITS:
 ELEMENT OF IUNIT:  1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
         I/O UNIT: 11 12 13  0  0  0  0  0 19  0  0 22  0  0  0  0  0  0  0  0  0  0  0  0
OBAS1 -- BASIC MODEL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT  1
 ARRAYS RHS AND BUFF WILL SHARE MEMORY.
 START HEAD WILL BE SAVED
    12828 ELEMENTS IN X ARRAY ARE USED BY BAS
    12828 ELEMENTS OF X ARRAY USED OUT OF  100000
OBCF1 -- BLOCK-CENTERED FLOW PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 11
 STEADY-STATE SIMULATION
      LAYER  AQUIFER TYPE
      -------------------
         1        1
         2        0
     1346 ELEMENTS IN X ARRAY ARE USED BY BCF
    14174 ELEMENTS OF X ARRAY USED OUT OF  100000
OWEL1 -- WELL PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM 12
 MAXIMUM OF    2 WELLS
        8 ELEMENTS IN X ARRAY ARE USED FOR WELLS
    14182 ELEMENTS OF X ARRAY USED OUT OF  100000
ODRN1 -- DRAIN PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 13
 MAXIMUM OF    7 DRAINS
       35 ELEMENTS IN X ARRAY ARE USED FOR DRAINS
    14217 ELEMENTS OF X ARRAY USED OUT OF  100000
OSIP1 -- STRONGLY IMPLICIT PROCEDURE SOLUTION PACKAGE, VERSION 1, 9/1/87 INPUT READ FROM UNIT 19
 MAXIMUM OF  50 ITERATIONS ALLOWED FOR CLOSURE
  5 ITERATION PARAMETERS
     5581 ELEMENTS IN X ARRAY ARE USED BY SIP
    19798 ELEMENTS OF X ARRAY USED OUT OF  100000
1NCBC DAVISVILLE SITE 11, FIRE FIGHTING TRAINING AREA - FEASIBILITY STUDY       REMED SIMULATION - SHALLOW DRAIN, DEEP EXTRACT
0
```

BOUNDARY ARRAY FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (26I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
0 1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
0 2	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 3	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 4	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 5	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 6	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 7	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 8	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 9	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 10	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 11	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 12	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 13	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 14	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 15	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 16	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 17	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 18	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 19	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 20	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 21	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 22	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 23	-1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	-1
0 24	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1

0

BOUNDARY ARRAY FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (26I3)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
0 1	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
0 2	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 3	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 4	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 5	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 6	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 7	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 8	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 9	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 10	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 11	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 12	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 13	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 14	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 15	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 16	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 17	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 18	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 19	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 20	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 21	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 22	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 23	-2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	-2
0 24	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2

0AQUIFER HEAD WILL BE SET TO -99.990 AT ALL NO-FLOW NODES (IBOUND=0).
0

INITIAL HEAD FOR LAYER 1 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.1)

	1 11 21	2 12 22	3 13 23	4 14 24	5 15 25	6 16 26	7 17 27	8 18 28	9 19	10 20
0 1	15.20	15.40	15.60	15.80	16.00	16.20	16.40	16.60	16.80	17.00
	17.40	17.60	17.80	18.00	18.50	19.00	19.00	19.20	19.30	19.50
	19.70	19.80	20.00	20.20	20.40	20.60	20.80	21.00		
0 2	15.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.10		
0 3	14.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.20		
0 4	14.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.20		
0 5	14.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.30		
0 6	14.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.40		
0 7	14.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.50		
0 8	13.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.60		
0 9	13.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.70		
0 10	13.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.70		
0 11	13.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.80		
0 12	13.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.80		

0 13	12.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.80		
0 14	12.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.90		
0 15	12.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.90		
0 16	12.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.90		
0 17	12.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.00		
0 18	11.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.00		
0 19	11.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.10		
0 20	11.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.10		
0 21	11.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.20		
0 22	11.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.20		
0 23	10.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.30		
0 24	10.60	11.10	11.60	12.10	12.60	13.10	13.60	14.10	14.60	15.10
	15.50	15.80	16.50	18.00	19.50	19.70	19.80	20.00	20.20	20.50
	20.70	21.00	21.20	21.50	21.70	22.00	22.20	22.30		

0

INITIAL HEAD FOR LAYER 2 WILL BE READ ON UNIT 1 USING FORMAT: (16F5.1)

	1	2	3	4	5	6	7	8	9	10
	11	12	13	14	15	16	17	18	19	20
	21	22	23	24	25	26	27	28		
0 1	14.90	15.20	15.50	15.80	16.10	16.40	16.70	17.00	17.50	18.00
	18.30	18.60	18.90	19.20	19.50	19.80	20.10	20.40	20.70	21.00
	21.30	21.60	21.90	22.20	22.50	22.80	23.10	23.40		
0 2	14.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	23.30		
0 3	14.70	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	23.20		
0 4	14.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	23.10		
0 5	14.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	23.00		
0 6	14.30	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.90		
0 7	14.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.80		
0 8	14.10	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.70		
0 9	13.90	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.60		

0 10	13.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.50		
0 11	13.70	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.40		
0 12	13.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.30		
0 13	13.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.20		
0 14	13.30	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.10		
0 15	13.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	22.00		
0 16	13.10	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.80		
0 17	12.90	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.70		
0 18	12.80	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.50		
0 19	12.70	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.30		
0 20	12.60	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.20		
0 21	12.40	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	21.00		
0 22	12.30	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	20.90		
0 23	12.20	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00	18.00
	18.00	18.00	18.00	18.00	18.00	18.00	18.00	20.80		
0 24	12.10	12.40	12.70	13.00	13.30	13.60	13.90	14.20	14.50	14.80
	15.10	15.40	15.70	16.00	16.30	16.60	17.00	17.50	18.00	18.30
	18.60	18.90	19.20	19.50	19.80	20.10	20.40	20.70		

0HEAD PRINT FORMAT IS FORMAT NUMBER 4 DRAWDOWN PRINT FORMAT IS FORMAT NUMBER 9
0HEADS WILL BE SAVED ON UNIT 30 DRAWDOWNS WILL BE SAVED ON UNIT 40
0OUTPUT CONTROL IS SPECIFIED EVERY TIME STEP
0 COLUMN TO ROW ANISOTROPY = 1.000000
0 DELR = 40.00000
0 DELC = 40.00000
0

HYD. COND. ALONG ROWS FOR LAYER 1 WILL BE READ ON UNIT 11 USING FORMAT: (16F5.1)

	1	2	3	4	5	6	7	8	9	10
	11	12	13	14	15	16	17	18	19	20
	21	22	23	24	25	26	27	28		
0 1	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 2	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 3	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 4	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		

0 5	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 6	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 7	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 8	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 9	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 10	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 11	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 12	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	10.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 13	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 14	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 15	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 16	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 17	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 18	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 19	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 20	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 21	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 22	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 23	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		
0 24	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00	25.00
	25.00	25.00	10.00	10.00	10.00	10.00	19.00	19.00	19.00	19.00
	19.00	19.00	19.00	19.00	19.00	19.00	19.00	19.00		

0 BOTTOM = 10.30000 FOR LAYER 1

0 VERT HYD COND /THICKNESS = .1000000E-03 FOR LAYER 1

0 TRANSMIS. ALONG ROWS = 34.60000 FOR LAYER 2

0

SOLUTION BY THE STRONGLY IMPLICIT PROCEDURE

0 MAXIMUM ITERATIONS ALLOWED FOR CLOSURE = 50

ACCELERATION PARAMETER = 1.0000

HEAD CHANGE CRITERION FOR CLOSURE = .10000E-02

SIP HEAD CHANGE PRINTOUT INTERVAL = 1

0 CALCULATE ITERATION PARAMETERS FROM MODEL CALCULATED WSEED

```
1                                                         STRESS PERIOD NO.   1, LENGTH =   1825.000
                                                          ----------------------------------------------

                                                          NUMBER OF TIME STEPS =      1

                                                           MULTIPLIER FOR DELT =     1.000

                                                        INITIAL TIME STEP SIZE =   1825.000
0            2 WELLS
                                                      LAYER    ROW    COL   STRESS RATE   WELL NO.
                                                      --------------------------------------------
                                                        2       13     11    -96.300          1
                                                        2       14     12    -96.300          2
0

    7 DRAINS
0              LAYER     ROW     COL   ELEVATION   CONDUCTANCE   DRAIN NO.
               ---------------------------------------------------------
                 1        11      13    10.80         23.70          1
                 1        12      13    10.80         23.70          2
                 1        13      13    10.80         23.70          3
                 1        14      13    10.80         23.70          4
                 1        15      13    10.80         23.70          5
                 1        16      13    10.80         23.70          6
                 1        17      13    10.80         23.70          7
0AVERAGE SEED =  .00177001
 MINIMUM SEED =  .00051249
0
    5 ITERATION PARAMETERS CALCULATED FROM AVERAGE SEED:

          .0000000E+00   .7948866E+00   .9579285E+00   .9913706E+00   .9982300E+00
0
    16 ITERATIONS FOR TIME STEP   1 IN STRESS PERIOD  1
0MAXIMUM HEAD CHANGE FOR EACH ITERATION:
0 HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL HEAD CHANGE LAYER,ROW,COL
 ------------------------------------------------------------------------------------------------------------------------------------
   -4.614     (  2, 23,  2)  -2.013     (  1, 22,  3)  -1.740     (  2, 19,  6)  -1.914     (  1, 15,  7)   .6603     (  1,  8, 14)
    .9223E-01 (  1, 11, 12)   .9498E-01 (  1, 12, 11)   .1149     (  1, 13,  9)  -.1122     (  1, 14, 18)  -.4380E-01 (  1, 19, 14)
    .8205E-02 (  1, 10, 14)  -.5698E-02 (  1, 10,  6)   .9551E-02 (  1, 14, 17)   .5342E-02 (  1, 11, 19)   .2864E-02 (  1,  6, 15)
    .5881E-03 (  1,  9, 13)
0
0HEAD/DRAWDOWN PRINTOUT FLAG = 1     TOTAL BUDGET PRINTOUT FLAG = 1     CELL-BY-CELL FLOW TERM FLAG = 0
0OUTPUT FLAGS FOR EACH LAYER:
          HEAD    DRAWDOWN  HEAD  DRAWDOWN
 LAYER  PRINTOUT  PRINTOUT  SAVE    SAVE
 -----------------------------------------
    1       1         1       1       1
    2       1         1       1       1
1                            HEAD IN LAYER  1 AT END OF TIME STEP  1 IN STRESS PERIOD  1
                  ----------------------------------------------------------------------

               1        2        3        4        5        6        7        8        9       10       11       12       13       14       15
              16       17       18       19       20       21       22       23       24       25       26       27       28
 ...........................................................................................................................................
0  1       15.20    15.40    15.60    15.80    16.00    16.20    16.40    16.60    16.80    17.00    17.40    17.60    17.80    18.00    18.50
           19.00    19.00    19.20    19.30    19.50    19.70    19.80    20.00    20.20    20.40    20.60    20.80    21.00
0  2       15.00    15.23    15.45    15.66    15.87    16.07    16.27    16.48    16.68    16.90    17.14    17.41    17.73    18.05    18.45
           18.83    19.03    19.20    19.36    19.55    19.73    19.90    20.09    20.28    20.49    20.69    20.89    21.10
0  3       14.80    15.05    15.28    15.51    15.72    15.93    16.14    16.34    16.55    16.75    16.96    17.25    17.64    18.01    18.40
           18.77    19.03    19.21    19.39    19.58    19.78    19.96    20.16    20.36    20.56    20.77    20.97    21.20
0  4       14.60    14.87    15.11    15.35    15.57    15.79    15.99    16.20    16.40    16.60    16.80    17.11    17.53    17.94    18.35
           18.73    19.02    19.22    19.42    19.62    19.82    20.02    20.22    20.43    20.63    20.84    21.03    21.20
0  5       14.40    14.68    14.94    15.18    15.41    15.63    15.84    16.05    16.25    16.45    16.64    16.97    17.42    17.86    18.28
           18.70    19.00    19.22    19.43    19.64    19.85    20.07    20.28    20.49    20.70    20.91    21.11    21.30
0  6       14.20    14.50    14.77    15.02    15.25    15.47    15.68    15.89    16.09    16.28    16.48    16.82    17.29    17.75    18.21
           18.65    18.98    19.21    19.43    19.66    19.89    20.11    20.33    20.55    20.77    20.98    21.19    21.40
0  7       14.00    14.31    14.59    14.85    15.09    15.31    15.52    15.72    15.91    16.11    16.30    16.64    17.13    17.62    18.11
           18.59    18.95    19.19    19.44    19.68    19.91    20.15    20.38    20.60    20.83    21.06    21.28    21.50
0  8       13.80    14.12    14.41    14.68    14.92    15.14    15.35    15.55    15.73    15.92    16.10    16.44    16.94    17.46    18.00
           18.52    18.91    19.18    19.43    19.69    19.94    20.18    20.42    20.66    20.89    21.12    21.36    21.60
   9       13.60    13.94    14.24    14.51    14.75    14.97    15.18    15.37    15.54    15.71    15.88    16.18    16.67    17.25    17.86
           18.44    18.87    19.16    19.43    19.70    19.96    20.21    20.46    20.70    20.94    21.19    21.43    21.70
0 10       13.40    13.76    14.06    14.34    14.59    14.81    15.01    15.19    15.35    15.49    15.62    15.84    16.23    16.96    17.68
```

	18.35	18.83	19.13	19.43	19.71	19.98	20.24	20.49	20.74	20.99	21.23	21.48	21.70		
0 11	13.20	13.57	13.89	14.18	14.43	14.65	14.85	15.02	15.16	15.27	15.35	15.39	15.29	16.57	17.4[illegible]
	18.26	18.79	19.12	19.43	19.72	20.00	20.27	20.53	20.78	21.03	21.28	21.53	21.80		
0 12	13.00	13.39	13.73	14.02	14.28	14.50	14.70	14.86	14.99	15.08	15.12	15.06	14.87	16.32	17.35
	18.19	18.76	19.11	19.43	19.74	20.02	20.30	20.57	20.82	21.07	21.32	21.56	21.80		
0 13	12.80	13.22	13.57	13.87	14.14	14.37	14.56	14.73	14.85	14.93	14.95	14.89	14.70	16.18	17.27
	18.16	18.75	19.11	19.45	19.76	20.05	20.33	20.60	20.86	21.11	21.36	21.59	21.80		
0 14	12.60	13.05	13.42	13.74	14.01	14.25	14.45	14.62	14.76	14.84	14.87	14.83	14.64	16.14	17.25
	18.16	18.76	19.13	19.47	19.79	20.09	20.37	20.64	20.90	21.15	21.40	21.64	21.90		
0 15	12.40	12.89	13.28	13.61	13.90	14.15	14.37	14.55	14.70	14.81	14.86	14.84	14.67	16.17	17.29
	18.19	18.80	19.17	19.51	19.83	20.13	20.41	20.68	20.94	21.19	21.44	21.67	21.90		
0 16	12.20	12.73	13.15	13.50	13.80	14.07	14.30	14.51	14.69	14.82	14.91	14.94	14.80	16.29	17.37
	18.26	18.86	19.23	19.56	19.88	20.18	20.46	20.73	20.99	21.24	21.48	21.70	21.90		
0 17	12.00	12.58	13.02	13.39	13.71	14.00	14.26	14.49	14.70	14.88	15.03	15.13	15.11	16.50	17.52
	18.36	18.94	19.30	19.63	19.94	20.23	20.51	20.78	21.04	21.28	21.52	21.76	22.00		
0 18	11.80	12.44	12.90	13.29	13.63	13.94	14.22	14.49	14.73	14.97	15.19	15.42	15.88	16.83	17.70
	18.49	19.03	19.38	19.70	20.01	20.29	20.57	20.83	21.09	21.34	21.57	21.80	22.00		
0 19	11.60	12.30	12.78	13.18	13.54	13.87	14.18	14.48	14.77	15.05	15.34	15.64	16.21	17.08	17.89
	18.62	19.14	19.47	19.78	20.08	20.36	20.63	20.89	21.15	21.39	21.63	21.86	22.10		
0 20	11.40	12.16	12.65	13.07	13.44	13.80	14.13	14.46	14.79	15.11	15.44	15.79	16.41	17.27	18.06
	18.76	19.26	19.57	19.87	20.16	20.43	20.70	20.96	21.21	21.45	21.68	21.90	22.10		
0 21	11.20	12.01	12.51	12.93	13.32	13.70	14.06	14.43	14.79	15.15	15.51	15.88	16.55	17.45	18.24
	18.92	19.39	19.68	19.96	20.24	20.51	20.77	21.02	21.27	21.51	21.74	21.97	22.20		
0 22	11.00	11.83	12.32	12.75	13.16	13.56	13.96	14.36	14.76	15.15	15.54	15.93	16.64	17.62	18.46
	19.11	19.53	19.79	20.06	20.32	20.58	20.84	21.09	21.34	21.58	21.81	22.02	22.20		
0 23	10.80	11.58	12.05	12.50	12.93	13.37	13.81	14.26	14.70	15.13	15.53	15.91	16.67	17.81	18.81
	19.35	19.67	19.90	20.14	20.41	20.65	20.91	21.15	21.41	21.65	21.89	22.10	22.30		
0 24	10.60	11.10	11.60	12.10	12.60	13.10	13.60	14.10	14.60	15.10	15.50	15.80	16.50	18.00	19.50
	19.70	19.80	20.00	20.20	20.50	20.70	21.00	21.20	21.50	21.70	22.00	22.20	22.30		

1 HEAD IN LAYER 2 AT END OF TIME STEP 1 IN STRESS PERIOD 1

	1 16	2 17	3 18	4 19	5 20	6 21	7 22	8 23	9 24	10 25	11 26	12 27	13 28	14	15
0 1	14.90	15.20	15.50	15.80	16.10	16.40	16.70	17.00	17.50	18.00	18.30	18.60	18.90	19.20	19.5[illegible]
	19.80	20.10	20.40	20.70	21.00	21.30	21.60	21.90	22.20	22.50	22.80	23.10	23.40		
0 2	14.80	15.09	15.37	15.66	15.96	16.26	16.56	16.90	17.29	17.68	18.02	18.34	18.65	18.96	19.2[illegible]
	19.58	19.89	20.20	20.51	20.81	21.12	21.43	21.74	22.05	22.36	22.67	22.98	23.30		
0 3	14.70	14.97	15.24	15.52	15.81	16.10	16.41	16.73	17.08	17.43	17.76	18.08	18.40	18.72	19.04
	19.36	19.68	20.00	20.32	20.64	20.95	21.27	21.59	21.90	22.22	22.54	22.87	23.20		
0 4	14.60	14.84	15.10	15.38	15.66	15.94	16.24	16.54	16.86	17.19	17.51	17.84	18.16	18.49	18.82
	19.15	19.48	19.81	20.13	20.46	20.79	21.11	21.44	21.77	22.09	22.42	22.76	23.10		
0 5	14.40	14.69	14.96	15.23	15.50	15.77	16.05	16.34	16.65	16.96	17.27	17.59	17.92	18.26	18.60
	18.94	19.28	19.62	19.95	20.29	20.63	20.96	21.30	21.63	21.97	22.31	22.65	23.00		
0 6	14.30	14.56	14.82	15.07	15.33	15.59	15.86	16.14	16.42	16.72	17.03	17.35	17.68	18.02	18.37
	18.72	19.08	19.43	19.78	20.13	20.47	20.82	21.16	21.50	21.85	22.19	22.54	22.90		
0 7	14.20	14.43	14.67	14.92	15.16	15.41	15.66	15.92	16.19	16.47	16.77	17.09	17.43	17.78	18.14
	18.51	18.88	19.24	19.61	19.96	20.32	20.67	21.03	21.38	21.73	22.08	22.44	22.80		
0 8	14.10	14.30	14.53	14.76	14.99	15.22	15.46	15.70	15.95	16.21	16.50	16.82	17.17	17.54	17.91
	18.30	18.68	19.06	19.44	19.81	20.17	20.54	20.90	21.25	21.61	21.97	22.33	22.70		
0 9	13.90	14.15	14.38	14.60	14.82	15.03	15.25	15.46	15.69	15.93	16.20	16.52	16.89	17.28	17.68
	18.08	18.49	18.88	19.27	19.65	20.03	20.40	20.77	21.13	21.50	21.86	22.23	22.60		
0 10	13.80	14.02	14.23	14.44	14.65	14.84	15.03	15.22	15.41	15.61	15.86	16.19	16.58	17.00	17.44
	17.87	18.30	18.71	19.11	19.51	19.89	20.27	20.64	21.02	21.38	21.75	22.13	22.50		
0 11	13.70	13.89	14.09	14.29	14.48	14.66	14.83	14.98	15.12	15.25	15.44	15.79	16.24	16.72	17.20
	17.67	18.12	18.55	18.96	19.37	19.76	20.15	20.52	20.90	21.27	21.65	22.02	22.40		
0 12	13.60	13.77	13.96	14.15	14.33	14.49	14.64	14.75	14.82	14.84	14.86	15.30	15.87	16.44	16.98
	17.48	17.95	18.40	18.83	19.24	19.64	20.03	20.41	20.79	21.16	21.54	21.92	22.30		
0 13	13.40	13.62	13.82	14.01	14.19	14.35	14.48	14.57	14.58	14.43	13.86	14.67	15.49	16.19	16.79
	17.32	17.81	18.27	18.70	19.12	19.52	19.91	20.30	20.68	21.05	21.43	21.81	22.20		
0 14	13.30	13.50	13.70	13.89	14.07	14.23	14.36	14.46	14.49	14.43	14.24	14.05	15.25	16.04	16.66
	17.20	17.69	18.15	18.59	19.01	19.41	19.80	20.19	20.57	20.94	21.32	21.71	22.10		
0 15	13.20	13.39	13.59	13.78	13.96	14.13	14.28	14.41	14.50	14.56	14.62	14.81	15.43	16.04	16.61
	17.13	17.61	18.06	18.49	18.91	19.31	19.70	20.08	20.46	20.83	21.21	21.59	22.00		
0 16	13.10	13.28	13.48	13.68	13.87	14.06	14.23	14.39	14.54	14.69	14.88	15.16	15.60	16.10	16.60
	17.08	17.54	17.98	18.41	18.82	19.21	19.60	19.97	20.35	20.71	21.08	21.45	21.80		
0 17	12.90	13.14	13.37	13.58	13.79	14.00	14.19	14.39	14.58	14.79	15.03	15.34	15.72	16.16	16.61
	17.06	17.50	17.92	18.33	18.73	19.12	19.50	19.87	20.24	20.60	20.95	21.32	21.70		
0 18	12.80	13.03	13.26	13.49	13.72	13.94	14.16	14.38	14.61	14.85	15.12	15.44	15.80	16.20	16.6[illegible]
	17.03	17.45	17.86	18.27	18.66	19.04	19.41	19.77	20.13	20.48	20.82	21.16	21.50		
0 19	12.70	12.93	13.17	13.41	13.65	13.89	14.13	14.37	14.62	14.88	15.17	15.49	15.84	16.21	16.6[illegible]
	17.01	17.41	17.81	18.20	18.58	18.96	19.32	19.67	20.02	20.36	20.69	21.01	21.30		

```
0 20    12.60   12.82   13.07   13.32   13.58   13.83   14.09   14.35   14.62   14.89   15.19   15.51   15.85   16.21   16.59
        16.97   17.36   17.75   18.14   18.51   18.88   19.23   19.58   19.91   20.24   20.56   20.88   21.20
  21    12.40   12.69   12.97   13.24   13.51   13.77   14.04   14.32   14.60   14.89   15.19   15.50   15.84   16.19   16.55
        16.92   17.31   17.70   18.08   18.45   18.80   19.15   19.48   19.81   20.13   20.44   20.74   21.00
0 22    12.30   12.59   12.87   13.16   13.44   13.72   14.00   14.28   14.57   14.87   15.17   15.48   15.81   16.14   16.49
        16.85   17.24   17.63   18.02   18.39   18.73   19.07   19.39   19.71   20.02   20.33   20.62   20.90
0 23    12.20   12.49   12.78   13.08   13.37   13.66   13.95   14.24   14.54   14.84   15.14   15.44   15.76   16.08   16.41
        16.75   17.14   17.57   17.98   18.34   18.67   18.99   19.30   19.61   19.91   20.21   20.51   20.80
0 24    12.10   12.40   12.70   13.00   13.30   13.60   13.90   14.20   14.50   14.80   15.10   15.40   15.70   16.00   16.30
        16.60   17.00   17.50   18.00   18.30   18.60   18.90   19.20   19.50   19.80   20.10   20.40   20.70
OHEAD WILL BE SAVED ON UNIT 30 AT END OF TIME STEP  1, STRESS PERIOD  1
1                 DRAWDOWN IN LAYER  1 AT END OF TIME STEP  1 IN STRESS PERIOD  1
          ---------------------------------------------------------------------------

          1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20
         21    22    23    24    25    26    27    28
..............................................................................................................................
0  1    .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
        .00   .00   .00   .00   .00   .00   .00   .00
0  2    .00  2.77  2.55  2.34  2.13  1.93  1.73  1.52  1.32  1.10   .86   .59   .27  -.05  -.45  -.83 -1.03 -1.20 -1.36 -1.55
      -1.73 -1.90 -2.09 -2.28 -2.49 -2.69 -2.89   .00
0  3    .00  2.95  2.72  2.49  2.28  2.07  1.86  1.66  1.45  1.25  1.04   .75   .36  -.01  -.40  -.77 -1.03 -1.21 -1.39 -1.58
      -1.78 -1.96 -2.16 -2.36 -2.56 -2.77 -2.97   .00
0  4    .00  3.13  2.89  2.65  2.43  2.21  2.01  1.80  1.60  1.40  1.20   .89   .47   .06  -.35  -.73 -1.02 -1.22 -1.42 -1.62
      -1.82 -2.02 -2.22 -2.43 -2.63 -2.84 -3.03   .00
0  5    .00  3.32  3.06  2.82  2.59  2.37  2.16  1.95  1.75  1.55  1.36  1.03   .58   .14  -.28  -.70 -1.00 -1.22 -1.43 -1.64
      -1.85 -2.07 -2.28 -2.49 -2.70 -2.91 -3.11   .00
0  6    .00  3.50  3.23  2.98  2.75  2.53  2.32  2.11  1.91  1.72  1.52  1.18   .71   .25  -.21  -.65  -.98 -1.21 -1.43 -1.66
      -1.89 -2.11 -2.33 -2.55 -2.77 -2.98 -3.19   .00
0  7    .00  3.69  3.41  3.15  2.91  2.69  2.48  2.28  2.09  1.89  1.70  1.36   .87   .38  -.11  -.59  -.95 -1.19 -1.44 -1.68
      -1.91 -2.15 -2.38 -2.60 -2.83 -3.06 -3.28   .00
0  8    .00  3.88  3.59  3.32  3.08  2.86  2.65  2.45  2.27  2.08  1.90  1.56  1.06   .54   .00  -.52  -.91 -1.18 -1.43 -1.69
      -1.94 -2.18 -2.42 -2.66 -2.89 -3.12 -3.36   .00
0  9    .00  4.06  3.76  3.49  3.25  3.03  2.82  2.63  2.46  2.29  2.12  1.82  1.33   .75   .14  -.44  -.87 -1.16 -1.43 -1.70
      -1.96 -2.21 -2.46 -2.70 -2.94 -3.19 -3.43   .00
0 10    .00  4.24  3.94  3.66  3.41  3.19  2.99  2.81  2.65  2.51  2.38  2.16  1.77  1.04   .32  -.35  -.83 -1.13 -1.43 -1.71
      -1.98 -2.24 -2.49 -2.74 -2.99 -3.23 -3.48   .00
  11    .00  4.43  4.11  3.82  3.57  3.35  3.15  2.98  2.84  2.73  2.65  2.61  2.71  1.43   .51  -.26  -.79 -1.12 -1.43 -1.72
      -2.00 -2.27 -2.53 -2.78 -3.03 -3.28 -3.53   .00
0 12    .00  4.61  4.27  3.98  3.72  3.50  3.30  3.14  3.01  2.92  2.88  2.94  3.13  1.68   .65  -.19  -.76 -1.11 -1.43 -1.74
      -2.02 -2.30 -2.57 -2.82 -3.07 -3.32 -3.56   .00
0 13    .00  4.78  4.43  4.13  3.86  3.63  3.44  3.27  3.15  3.07  3.05  3.11  3.30  1.82   .73  -.16  -.75 -1.11 -1.45 -1.76
      -2.05 -2.33 -2.60 -2.86 -3.11 -3.36 -3.59   .00
0 14    .00  4.95  4.58  4.26  3.99  3.75  3.55  3.38  3.24  3.16  3.13  3.17  3.36  1.86   .75  -.16  -.76 -1.13 -1.47 -1.79
      -2.09 -2.37 -2.64 -2.90 -3.15 -3.40 -3.64   .00
0 15    .00  5.11  4.72  4.39  4.10  3.85  3.63  3.45  3.30  3.19  3.14  3.16  3.33  1.83   .71  -.19  -.80 -1.17 -1.51 -1.83
      -2.13 -2.41 -2.68 -2.94 -3.19 -3.44 -3.67   .00
0 16    .00  5.27  4.85  4.50  4.20  3.93  3.70  3.49  3.31  3.18  3.09  3.06  3.20  1.71   .63  -.26  -.86 -1.23 -1.56 -1.88
      -2.18 -2.46 -2.73 -2.99 -3.24 -3.48 -3.70   .00
0 17    .00  5.42  4.98  4.61  4.29  4.00  3.74  3.51  3.30  3.12  2.97  2.87  2.89  1.50   .48  -.36  -.94 -1.30 -1.63 -1.94
      -2.23 -2.51 -2.78 -3.04 -3.28 -3.52 -3.76   .00
0 18    .00  5.56  5.10  4.71  4.37  4.06  3.78  3.51  3.27  3.03  2.81  2.58  2.12  1.17   .30  -.49 -1.03 -1.38 -1.70 -2.01
      -2.29 -2.57 -2.83 -3.09 -3.34 -3.57 -3.80   .00
0 19    .00  5.70  5.22  4.82  4.46  4.13  3.82  3.52  3.23  2.95  2.66  2.36  1.79   .92   .11  -.62 -1.14 -1.47 -1.78 -2.08
      -2.36 -2.63 -2.89 -3.15 -3.39 -3.63 -3.86   .00
0 20    .00  5.84  5.35  4.93  4.56  4.20  3.87  3.54  3.21  2.89  2.56  2.21  1.59   .73  -.06  -.76 -1.26 -1.57 -1.87 -2.16
      -2.43 -2.70 -2.96 -3.21 -3.45 -3.68 -3.90   .00
0 21    .00  5.99  5.49  5.07  4.68  4.30  3.94  3.57  3.21  2.85  2.49  2.12  1.45   .55  -.24  -.92 -1.39 -1.68 -1.96 -2.24
      -2.51 -2.77 -3.02 -3.27 -3.51 -3.74 -3.97   .00
0 22    .00  6.17  5.68  5.25  4.84  4.44  4.04  3.64  3.24  2.85  2.46  2.07  1.36   .38  -.46 -1.11 -1.53 -1.79 -2.06 -2.32
      -2.58 -2.84 -3.09 -3.34 -3.58 -3.81 -4.02   .00
0 23    .00  6.42  5.95  5.50  5.07  4.63  4.19  3.74  3.30  2.87  2.47  2.09  1.33   .19  -.81 -1.35 -1.67 -1.90 -2.14 -2.41
      -2.65 -2.91 -3.15 -3.41 -3.65 -3.89 -4.10   .00
0 24    .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
        .00   .00   .00   .00   .00   .00   .00   .00
1                 DRAWDOWN IN LAYER  2 AT END OF TIME STEP  1 IN STRESS PERIOD  1
          ---------------------------------------------------------------------------

          1     2     3     4     5     6     7     8     9    10    11    12    13    14    15    16    17    18    19    20
         21    22    23    24    25    26    27    28
..............................................................................................................................
   1    .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
        .00   .00   .00   .00   .00   .00   .00   .00
```

```
0  2    .00  2.91  2.63  2.34  2.04  1.74  1.44  1.10   .71   .32  -.02  -.34  -.65  -.96 -1.27 -1.58 -1.89 -2.20 -2.51 -2.81
      -3.12 -3.43 -3.74 -4.05 -4.36 -4.67 -4.98   .00
0  3    .00  3.03  2.76  2.48  2.19  1.90  1.59  1.27   .92   .57   .24  -.08  -.40  -.72 -1.04 -1.36 -1.68 -2.00 -2.32 -2.
      -2.95 -3.27 -3.59 -3.90 -4.22 -4.54 -4.87   .00
0  4    .00  3.16  2.90  2.62  2.34  2.06  1.76  1.46  1.14   .81   .49   .16  -.16  -.49  -.82 -1.15 -1.48 -1.81 -2.13 -2.46
      -2.79 -3.11 -3.44 -3.77 -4.09 -4.42 -4.76   .00
0  5    .00  3.31  3.04  2.77  2.50  2.23  1.95  1.66  1.35  1.04   .73   .41   .08  -.26  -.60  -.94 -1.28 -1.62 -1.95 -2.29
      -2.63 -2.96 -3.30 -3.63 -3.97 -4.31 -4.65   .00
0  6    .00  3.44  3.18  2.93  2.67  2.41  2.14  1.86  1.58  1.28   .97   .65   .32  -.02  -.37  -.72 -1.08 -1.43 -1.78 -2.13
      -2.47 -2.82 -3.16 -3.50 -3.85 -4.19 -4.54   .00
0  7    .00  3.57  3.33  3.08  2.84  2.59  2.34  2.08  1.81  1.53  1.23   .91   .57   .22  -.14  -.51  -.88 -1.24 -1.61 -1.96
      -2.32 -2.67 -3.03 -3.38 -3.73 -4.08 -4.44   .00
0  8    .00  3.70  3.47  3.24  3.01  2.78  2.54  2.30  2.05  1.79  1.50  1.18   .83   .46   .09  -.30  -.68 -1.06 -1.44 -1.81
      -2.17 -2.54 -2.90 -3.25 -3.61 -3.97 -4.33   .00
0  9    .00  3.85  3.62  3.40  3.18  2.97  2.75  2.54  2.31  2.07  1.80  1.48  1.11   .72   .32  -.08  -.49  -.88 -1.27 -1.65
      -2.03 -2.40 -2.77 -3.13 -3.50 -3.86 -4.23   .00
0 10    .00  3.98  3.77  3.56  3.35  3.16  2.97  2.78  2.59  2.39  2.14  1.81  1.42  1.00   .56   .13  -.30  -.71 -1.11 -1.51
      -1.89 -2.27 -2.64 -3.02 -3.38 -3.75 -4.13   .00
0 11    .00  4.11  3.91  3.71  3.52  3.34  3.17  3.02  2.88  2.75  2.56  2.21  1.76  1.28   .80   .33  -.12  -.55  -.96 -1.37
      -1.76 -2.15 -2.52 -2.90 -3.27 -3.65 -4.02   .00
0 12    .00  4.23  4.04  3.85  3.67  3.51  3.36  3.25  3.18  3.16  3.14  2.70  2.13  1.56  1.02   .52   .05  -.40  -.83 -1.24
      -1.64 -2.03 -2.41 -2.79 -3.16 -3.54 -3.92   .00
0 13    .00  4.38  4.18  3.99  3.81  3.65  3.52  3.43  3.42  3.57  4.14  3.33  2.51  1.81  1.21   .68   .19  -.27  -.70 -1.12
      -1.52 -1.91 -2.30 -2.68 -3.05 -3.43 -3.81   .00
0 14    .00  4.50  4.30  4.11  3.93  3.77  3.64  3.54  3.51  3.57  3.76  3.95  2.75  1.96  1.34   .80   .31  -.15  -.59 -1.01
      -1.41 -1.80 -2.19 -2.57 -2.94 -3.32 -3.71   .00
0 15    .00  4.61  4.41  4.22  4.04  3.87  3.72  3.59  3.50  3.44  3.38  3.19  2.57  1.96  1.39   .87   .39  -.06  -.49  -.91
      -1.31 -1.70 -2.08 -2.46 -2.83 -3.21 -3.59   .00
0 16    .00  4.72  4.52  4.32  4.13  3.94  3.77  3.61  3.46  3.31  3.12  2.84  2.40  1.90  1.40   .92   .46   .02  -.41  -.82
      -1.21 -1.60 -1.97 -2.35 -2.71 -3.08 -3.45   .00
0 17    .00  4.86  4.63  4.42  4.21  4.00  3.81  3.61  3.42  3.21  2.97  2.66  2.28  1.84  1.39   .94   .50   .08  -.33  -.73
      -1.12 -1.50 -1.87 -2.24 -2.60 -2.95 -3.32   .00
0 18    .00  4.97  4.74  4.51  4.28  4.06  3.84  3.62  3.39  3.15  2.88  2.56  2.20  1.80  1.39   .97   .55   .14  -.27  -.66
      -1.04 -1.41 -1.77 -2.13 -2.48 -2.82 -3.16   .00
0 19    .00  5.07  4.83  4.59  4.35  4.11  3.87  3.63  3.38  3.12  2.83  2.51  2.16  1.79  1.39   .99   .59   .19  -.20  -.58
       -.96 -1.32 -1.67 -2.02 -2.36 -2.69 -3.01   .00
0 20    .00  5.18  4.93  4.68  4.42  4.17  3.91  3.65  3.38  3.11  2.81  2.49  2.15  1.79  1.41  1.03   .64   .25  -.14  -.
       -.88 -1.23 -1.58 -1.91 -2.24 -2.56 -2.88   .00
0 21    .00  5.31  5.03  4.76  4.49  4.23  3.96  3.68  3.40  3.11  2.81  2.50  2.16  1.81  1.45  1.08   .69   .30  -.08  -.45
       -.80 -1.15 -1.48 -1.81 -2.13 -2.44 -2.74   .00
0 22    .00  5.41  5.13  4.84  4.56  4.28  4.00  3.72  3.43  3.13  2.83  2.52  2.19  1.86  1.51  1.15   .76   .37  -.02  -.39
       -.73 -1.07 -1.39 -1.71 -2.02 -2.33 -2.62   .00
0 23    .00  5.51  5.22  4.92  4.63  4.34  4.05  3.76  3.46  3.16  2.86  2.56  2.24  1.92  1.59  1.25   .86   .43   .02  -.34
       -.67  -.99 -1.30 -1.61 -1.91 -2.21 -2.51   .00
0 24    .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00   .00
        .00   .00   .00   .00   .00   .00   .00   .00
0DRAWDOWN WILL BE SAVED ON UNIT 40 AT END OF TIME STEP  1, STRESS PERIOD  1
0


                   VOLUMETRIC BUDGET FOR ENTIRE MODEL AT END OF TIME STEP  1 IN STRESS PERIOD  1
                   ------------------------------------------------------------------------------
0            CUMULATIVE VOLUMES      L**3                           RATES FOR THIS TIME STEP      L**3/T
             ------------------                                     ------------------------

                IN:                                                       IN:
                ---                                                       ---
                   STORAGE =     .00000                                      STORAGE =     .00000
             CONSTANT HEAD =     .36856E+07                            CONSTANT HEAD =     2019.5
                     WELLS =     .00000                                        WELLS =     .00000
                    DRAINS =     .00000                                       DRAINS =     .00000
0                 TOTAL IN =     .36856E+07                                 TOTAL IN =     2019.5
0               OUT:                                                      OUT:
                ----                                                      ----
                   STORAGE =     .00000                                      STORAGE =     .00000
             CONSTANT HEAD =     .21031E+07                            CONSTANT HEAD =     1152.4
                     WELLS =     .35150E+06                                    WELLS =     192.60
                    DRAINS =     .12315E+07                                   DRAINS =     674.79
0                TOTAL OUT =     .36861E+07                                TOTAL OUT =     2019.8
0                 IN - OUT =    -557.50                                     IN - OUT =    -.30542
0     PERCENT DISCREPANCY =                   -.02          PERCENT DISCREPANCY =
```

0

TIME SUMMARY AT END OF TIME STEP 1 IN STRESS PERIOD 1

	SECONDS	MINUTES	HOURS	DAYS	YEARS
TIME STEP LENGTH	.157680E+09	.262800E+07	43800.0	1825.00	4.99658
STRESS PERIOD TIME	.157680E+09	.262800E+07	43800.0	1825.00	4.99658
TOTAL SIMULATION TIME	.157680E+09	.262800E+07	43800.0	1825.00	4.99658

1