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INSTALLATION RESTORATION PROGRAM PHASE II--CONFIRMATION/QUANTIFICATION

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Final Report

for

AIR FORCE PLANT 6, COBB COUNTY, GA.

U.S. AIR FORCE OCCUPATIONAL AND ENVIRONMENTAL HEALTH LABORATORY Brooks Air Force Base, Tex.

August 1986

Prepared by:

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC. P.O. Box ESE Gainesville, Fla. 32602-3052

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> MAJOR GEORGE R. NEW OEHL TECHNICAL MONITOR TECHNICAL SERVICES (TS) DIVISION

USAF Occupational and Health Laboratory (USAFOEHL) Technical Services Division (TS) Brooks Air Force Base, Texas 78235-5501

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INSTALLATION RESTORATION PROGRAM

PHASE II--CONFIRMATION/QUANTIFICATION

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AIR FORCE PLANT 6 COBB COUNTY, GA

ENVIRONMENTAL SCIENCE AND ENGINEERING, INC. P.O. Box ESE Gainesville, Florida 32602-3052

August 1986

Final (May 1984 - August 1985)

UNCLASSIFIED/UNLIMITED

Prepared for:

Major George R. New OEHL Technical Monitor Technical Services (TS) Division

UNITED STATES AIR FORCE Occupational and Environmental Health Laboratory (USAFOEHL) Technical Services Division (TS) Brooks Air Force Base, Texas 78235-5501

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APPENDIX A GLOSSARY OF TERMINOLOGY, ABBREVIATIONS, AND ACRONYMS È

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APPENDIX A

GLOSSARY OF TERMINOLOGY, ABBREVIATIONS, AND ACRONYMS

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	<u>८</u> र		GLOSSARY OF TERMINOLOGY, ABBREVIATIONS, AND ACRONYMS
		% РВ	Air Force Base
	Ś.	AFESC	Air Force Engineering and Service Center
	-	AFRES	Air Force Reserve
		Ag	Chemical symbol for silver, a metal used in photographic emulsions and other industrial expertional terms to burgers and expertise life at low
	Ň		concentrations
Â		As	Chemical symbol for arsenic
		AVGAS	Aviation gasoline
		Ва	Chemical symbol for barium
5		° C	Degrees Celsius
3.2.4.2.2.T	20	Cd	Chemical symbol for cadmium, a metal used in batteries and other industrial applications; nighly toxic to humans and aquatic life
		CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
	2	e n	Centimeter(s)
	• •	cm/sec	Centimeters per second
		CN	Chemical symbol for cyanide
5.2.2		Contamination	Degradation of natural water quality to the extent that its usefulness is impaired; degree of permissible contamination depends on intended use of water
		Cr	Chemical symbol for chromium, a metal used in plating, cleaning, and other industrial applications highly toxic to aquatic life at low concentrations,

toxic to humans at higher levels

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Cu	Chemical symbol for copper
DAFB	Dobbins Air Force Base
DC	Direct current
DEQPPM	Defense Environmental Quality Program Policy Memorandum
Disposal of hazardous waste	Discharge, deposit, injection, dumping, spilling, or placing of any hazardous waste into or on land or water so that such waste, or any constituent thereof, may enter the environment, be emitted into the air, or be discharged into any waters, including ground water
DNR	Department of Natural Resources
DOD	Department of Defense
Downgradient	In the direction of decreasing hydraulic static head; the direction in which ground water flows
EM	Electromagnetic
EP	Extraction procedure
EPA	U.S. Environmental Protection Agency
ESE	Environmental Science and Engineering, Inc.
F	Chemical symbol for fluoride
°F	Degrees Fahrenheit
Fe	Chemical symbol for iron, a metal commonly found in water as a consequence of dissolution of geologic materials; relatively nontoxic
ft	Foot (feet)
gal	Gallon(s)
Georgia EPD	State of Georgia Environmental Protection Division
g pm	Gallon(s) per minute
GOCO	Government-owned Contractor-operated
HARM	Hazard Assessment Rating Methodology

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Hazardous waste As defined in RCRA, a solid waste or combination of solid wastes which because of its quantity, concentration, or physical, chemical, or infectious characteristics may cause or significantly contribute to an increase in mortality or an increase in serious, irreversible, or incapacitating reversible Hazardous waste illness; or pose a substantial present or potential (Continued) hazard to human health or the environment when improperly treated, stored, transported, disposed of, or otherwise managed Chemical symbol for mercury Initial Installation Assessment Installation Restoration Program JP-5 aviation fuel Hydraulic conductivity Law Engineering Co. Pound(s) Pound(s) per cubic foot Leaking Underground Storage Tank Maximum contaminant level Million gallons Milligram(s) per liter Mean sea level Monitoring well Naval Air Station National Geodetic Vertical Datum Chemical symbol for nickel, a metal used in batteries, plating, and other industrial applications; highly toxic to humans and aquatic life National Interim Primary Drinking Water Regulations

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NO ₃	Chemical formula for nitrate, a common anion in natural water
NPDES	National Pollutant Discharge Elimination System
NSDWR	National Secondary Drinking Water Regulations
OEHL	Occupational and Environmental Health Laboratory
OVA	Organic vapor analyzer
РЬ	Chemical symbol for lead, à metal additive to gasoline and used in other industrial applications; toxic to humans and aquatic life; bioaccumulates
PCB	Polychlorinated biphenyls
рH	Negative logarithm of hydrogen ion concentration; an expression of acidity or alkalinity
POL	Petroleum, oils, and lubricants
ррЬ	Parts per billion
p pm	Parts per million
psi	Pounds per square inch
PVC	Polyvinyl chloride
QA/QC	Quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study
Se	Chemical symbol for selenium, a metal with numerous applications as a catalyst; toxic to humans and aquatic life
so ₄	Chemical formula for sulfate, a common anion in sea water
SWL	Static water level
TCA	l,l,l-Trichloroethane
TCE	Trichloroethylene
TDS	Total dissolved solids

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TOC	Total organic carbon
тох	Total organic halogens
2,4-D	2,4-Dichlorophenoxyacetic acid
2,4,5-TP	2,4,5-Trichlorophenoxyacetic acid
ug/g	Microgram(s) per gram
ug/l	Microgram(s) per liter
umhos/cm	Micromhos per centimeter
USAF	U.S. Air Force
USCGS	U.S. Coast and Geodetic Survey
USGS	U.S. Geological Survey
Zn	Chemical symbol of zinc, a metal with a wide variety of industrial applications, particularly corrosion- resistant; highly toxic to aquatic life, slightly toxic to humans at high dose levels

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APPENDIX B

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RESUMES OF KEY PROJECT PERSONNEL

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PROFESSIONAL

RESUME

C. RICHARD NEFF, M.S. Staff Engineer/Project Manager

SPECIALIZATION Water Quality, Hydrology, Environmental Engineering

RECENT EXPERIENCE

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Environmental Audits and Records Search of U.S. Air Force Facilities, <u>Project Team Leader</u>-Onsite environmental surveys to assess current and past waste management practice activities at Air Force installations.

Environmental Audits and Records Search of U.S. Army Facilities, <u>Project Team Engineer</u>--Onsite environmental surveys to assess current and past waste management activities at military installations. Team engineer inspects industrial operations, POL storage and transfer facilities, wastewater treatment facilities, RCRA status, and central records.

Environmental Licensing Study for Peat-Harvesting Project, Project Manager--Georgia-Pacific Corporation's 5,600-acre proposed peatharvesting project in north central Florida.

Environmental Assessment for Proposed Peat Synthetic Fuels, Project Engineer--Peat Methanol Associates proposed peat-to-methanol conversion facilities in North Carolina.

Environmental Assessments, Project Manager--Environmental assessment of a 50,000-acre development in central Florida and for a water quality baseline study for a 15,000-acre east central Florida development. Responsibilities included operation of the Soil Conservation Service's TR-20 and WSP-2 hydrological models; permit preparation for several FDER and Corps of Engineers wetlands permits and SFWMD surface water management permit.

<u>NPDES Studies, Project Manager--NPDES permit compliance studies for</u> Tampa Electric Company's three generating stations.

Water Quality Studies, Project Manager--Escambia River mixing zone and water quality analyses study for Monsanto Textiles Company. Water quality and nonpoint source pollution studies on Kiawah Island, S.C.

EDUCATION

M.S.	1978	Civil Engineering	University	of	Virginia
B.S.	1976	Environmental Engineering	University	of	Florida

PUBLICATIONS

Neff, C.R. 1978. Characterizing Urban Sediments, Presented at the Virginia Section of the Water Pollution Control Federation Conference; Roanoke, Virginia.

THOMAS L. CROSS Senior Engineer/Manager

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4

EDUCATION: B.S., Civil Engineering, West Virginia University M.S., Civil Engineering, West Virginia University Graduate Study in Business Administration, Georgia State University

 PROFESSIONAL

 MEMBERSHIP:
 American Society of Civil Engineers

 PROFESSIONAL

 REGISTRATION:
 Professional Engineer in Alabama, Georgia, South Carolina, Tennessee, and West Virginia

CAREER SUMMARY

Mr. Cross joined Law Engineering in 1973. He has served as a Soils Engineer, Hydrologist, and Project Manager in the Marietta, Georgia branch office. He is currently a Senior Engineer/Manager in the Waste Management Services Program. Mr. Cross provides a variety of geotechnical engineering and hydrologic services on projects throughout the southeastern United States. He has also managed many special multi-disciplined projects involving waste management and permitting.

WASTE MANAGEMENT EXPERIENCE

Mr. Cross has engineered several ground water quality assessments of existing waste management facilities owned and operated by chemical and manufacturing industries. Representative projects include the evaluation of ground water conditions beneath a hazardous waste landfill and lagoon in West Virginia, a series of lagoons in eastern Tennessee, and an area of sludge ponds and landfilled wastes in western Tennessee. Mr. Cross has also provided testing and evaluation services for a proposed hazardous waste landfill in eastern Georgia. A remedial action plan was developed for an Atlanta client to clean up an underground leak of diesel fuel. Recent projects have included engineering consultation and preparation of a Part B Application for a waste treatment and storage facility in Jacksonville, Florida. Recent geotechnical work has included investigations to develop hazardous and non-hazardous landfills for a chemical company. A lagoon closure evaluation has recently been performed for a metal fabricating facility in South Carolina.



DAVID E. BRUDERLY, M.S., P.E. National Program Manager

SPECIALIZATION

Hazardous Waste Management, Spill Assessment and Control, Solid Waste, Water and Wastewater Management, Environmental Permitting, Hydrology, Hydrography

RECENT EXPERIENCE

<u>Project Management</u>-Directed or managed seven major projects with fees exceeding \$3 million. Served as project manager or engineer for more than 40 waste management and water resources investigations.

National Program Manager for Hazardous Waste--Responsible for development and coordination of corporate hazardous waste program, including health and safety, personnel training, and emergency response programs. Senior investigator for feasibility, study, and remedial design projects.

Remedial Investigations/Feasibility Studies at 22 State Hazardous Waste Sites, Project Manager—Responsibilites include coordinating simultaneous activities of eight project teams while conducting site investigations, field sampling, analysis, and evaluation of remedial action alternatives for 22 sites. Project conducted for Florida Department of Environmental Regulation.

Feasibility Study of the Sapp Battery Salvage Site for Florida Department of Environmental Regulation, Project Manager--While conducting an assessment of site investigation results, ESE performed risk analysis, determined required remedial action, and evaluated restoration alternatives. In addition, ESE monitored cleanup activities.

Ground Water Contamination Assessment and Remedial Action, Project Manager--Conducted field investigations, geophysical investigations, ground water monitoring, and evaluated remedial action alternatives for abandoned hazardous waste site.

Immediate Emergency Response, Tyson's Dump, Norristown, Pennsylvania, <u>Project Director</u>--ESE designed, installed, and monitored a 40-gallonper-minute packed tower air stripper and supplied it to EPA subcontractors for removal of hazardous organic contaminants. Contaminants removed included toluene, xylene, and 1,1,1trichloropropane. System was online within 10 days after authorization to proceed.

<u>Remote Sensing, Drum Location and Analysis for Uncontrolled Disposal</u> <u>Site, Project Director--Responsible for location of burned drums using</u> remote sensing techniques; sampling and analyses of well samples during preliminary assessment, drum removal, aquifer pump tests, and post drum removal.

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D.E. BRUDERLY, M.S., P.E. Page 2

Hazardous Materials Assessment-Republic of Egypt--Directed USAID program to evaluate hazardous materials and wastes at free trade zones in Cairo, Alexandria, and Port Said. Recommended policies and procedures for management of hazardous wastes.

<u>Utility Waste Landfill</u>--Directed detailed site investigation (geophysics, borings, water quality). Conducted leachate simulation and EP toxicity tests and evaluated liner/capping performance using Prickett-Lonquist simulations to help assess leachate plume behavior. Developed capping and closure system design criteria in cooperation with State personnel to protect ground water resources.

Basinwide/Areawide Water Quality Management--Managed areawide water quality assessments for Tallahassee, Florida and Macon, Georgia and supported projects in Calcasieu River, Louisiana, Tampa Bay, Florida, and southwest Florida. Developed baseline water quality data and estimated point and nonpoint source loadings using simulation models calibrated with site data.

<u>Waste Treatment and Disposal</u>--Served as project engineer on industrial waste treatment and disposal projects in Illinois, Texas, Louisiana, New Jersey, Delaware, Alabama, and Florida. Worked with state and federal officials to obtain construction and operation permits for wastewater discharges and landfills.

<u>Commercial Waste Treatment Firm, Project Engineer</u>-Conducted site investigation and provided input to design modifications to hazardous waste treatment system.

Langollen County Landfill, Project Engineer--Designed outfall for leachate recovery and treatment system for uncontrolled site in sand borrow pits.

<u>Galveston Landfill, Project Engineer</u>--Conducted site investigations for expansion of the City of Galveston municipal landfill on Pelican Island, Tx.

Lockheed Development Systems, Project Engineer--Assessed technical and economic feasibility of ship and barge mounted waste treatment systems for the Houston region.

EDUCATION

M.S.	1971	Ocean Engineering	Columbia University
B.S.	1969	Marine Engineering	U.S. Merchant Marine Adademy

REGISTRATIONS

Professional Engineer, Florida

PUBLICATIONS

Ten technical publications and presentations in area of environmental management, liquid and solid wastes, site selection, water quality management.

THOMAS A. BRISLIN, B.S.C.E./B.S. ERM Senior Associate Engineer

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PROFESSIONAL RESUME

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Environmental/Civil Engineering: Municipal and Industrial Wastewater Treatment Processes; Environmental Surveys, Audits, and Wastewater Treatment Plant System Analyses; PAC, Polyelectrolyte and Flocculant Applications; Solids Concentration and Sludge Dewatering, PCB/Transformer Decommissioning, Decontamination, and Disposal; Hazardous/Toxic Waste Management, Remediation, and Disposal Strategies including thermal destruction technologies

RECENT EXPERIENCE

Conceived and Designed an Advanced Wastewater Treatment System for Toxic/Hazardous Waste, Design Engineer--Researched alternative technologies and conducted treatability studies to ascertain the best demonstrated technology for treatment/removal/disposal of toxic organics, heavy metals, and high brine concentrations for a 70 MG lagoon and ground water insurgent wells.

Assessment of Fugitive Air Emissions from Hazardous Waste Facilities, Project Engineer--Developed worst-case scenarios for toxic air emissions from treatment/storage/disposal facilities to be used for modeling predictions.

<u>Plant Closures/Environmental Audits, Project Coordinator</u>-Surveyed and evaluated several industrial facilities for compliances with RCRA and state solid waste regulations and instituted any appropriate sampling/monitor programs or site remediation to achieve closure certification.

Upgrading Biological Treatment Processes, Field Engineer--Assisted more than 30 clients in conducting system analyses to optimize performance on biological activated sludge or biooxidation processes, and compiling an operations manual.

Evaluation of PACT[®] Systems, Project Engineer--Conducted several extensive surveys and troubleshooting missions to optimize performance of biological/carbon reactors to optimize performance of improving removal of toxic organics and heavy metal chelants.

Optimization of Physical/Chemical Unit Processes for Wastewater <u>Treatment Systems, Field Engineer</u>--Performed more than 100 surveys for various industrial clients to ascertain the best cost/performing treatment schemes and operations for a multitude of waste streams and unit processes, in the petrochemical, refinery, paper processes, primary metals, and mineral processing industries throughout various locations in the United States and the world.

Participated in Several Superfund Emergency Response Cleanup Actions with the U.S. Environmental Protection Agency, Field Engineer--Assisted as a subcontractor in several cleanups involving waste characterization, extent of contamination surveys, excavation, and disposal of contaminated soil in a secure landfill. T.A. Brislin Page 2

> Environmental Audits/Electrical Contact Installments Resulting in Hazardous Waste Disposal Options, Project Manager--Conducted environmental audits and evaluated alternative treatment technologies to develop best management and disposal programs or plant closures. Sites included Eastern Plating, Martins Ferry, Ohio; GTE, Gibson Electrical Contacts, Delmont, Pennsylvania; BFG Electroplating, Punxatancy, Pennsylvania; and Westinghouse Corporation, East Pittsburgh and Beaver, Pennsylvania.

Assisted in Many Hazardous/Toxic Waste Remediation Projects, Project Engineer--Assisted in many cleanup projects ranging from emergency spills, PCB transformer decommissioning, to extensive lagoon remediation or drum excavation programs for industrial clients.

Research and Development of Innovative Chemical Treatments for Both Industrial and Toxic Wastewater, Project Manager--Participated in several projects to investigate and develop new treatment schemes and chemical aids for detoxification and clarification of wastewater. One such project resulted in a patented polyelectrolyte amphoteric emulsion effective for removal of emulsified oils and heavy metal, particularly in the steel industry.

Technology Training and Transfer Seminars, Instructor-Lectured in more than 30 seminars for operators, consultants, and industrial clients on various physical/chemical/biological unit processes in wastewater and hazardous waste management strategies for disposal/ remediation/treatment and thermal destruction.

EDUCATION

B.S.	1979	Environmental Resource Management/Engineering	Pennsylvania State Univ.
B.S.	1981	Civil Engineering (credit towards M.S.C.E.)	Bucknell University
Graduate Studies	1982- 1983	Mineral Processing	Pennsylvania State Univ. (Continuing Education Dept.)
Graduate Studies	1984- present	MBA Program (6 courses)	Duquesne University

AFFILIATIONS

Water Pollution Control Federation American Society of Civil Engineers American Institute of Mining, Metalurgical, and Petroleum Engineers Toastmasters International Hazardous Waste Management Association

PATENTS

New amphoteric flocculant emulsion pending permit (CAL-82/027)

SECURITY CLEARANCE

Class L security clearance from Dept. of Energy/Navy

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MEREDITH T. PARK, M.S. Trace Metals Group Leader

PROFESSIONAL RESUME

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Hazardous Waste Characterization, Water Chemistry, Trace Metals Analysis, Wastewater Treatment, Hazardous Waste Treatment

RECENT EXPERIENCE

Department of Defense (DOD) Installation Restoration Program (IRP), Project Manager--Responsible for project/task management as well as task technical support within the program structure. IRP is the DOD identification and control program for past hazardous materials released at military facilities under CERCLA.

Rocky Mountain Arsenal, Environmental Program, Task Manager-- Managing ongoing task involving analtyical methods development and subsequent analysis of environmental soil and sediment samples.

West Virginia Ordnance Works Environmental Survey, Task

Manager--Managing ongoing 10,000-manhour comprehensive environmental contamination survey for the above CERCLA (Superfund) site, ranked 86th on the National Priorities List (NPL).

Sharpe Army Depot, Task Manager--Managing ongoing chemical analysis task for ground water contamination assessment.

Maxwell Air Force Base, Environmental Survey, Task Manager--Managing ongoing 1,000 manhour environmental survey involving analysis of surface water, sediments, and hazardous wastes.

Aberdeen Proving Ground Environmental Survey, Project Manager--Managed 1,500-manhour exploratory ground water and surface water contamination survey at Edgewood Arsenal, Maryland.

Volunteer Army Ammunition Plant, Task Manager--Managed chemical analysis task involving testing of ground waters and soil samples.

Hazardous Waste Characterization for RCRA Compliance, Project Manager--On-going project providing analytical services for clients filing applications or fulfilling monitoring program requirements for RCRA compliance.

EDUCATION

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1976 Chemical Oceanography 1968 Chemistry Old Dominion University Duke University

AFFILIATIONS

American Chemical Society American Society of Limnology and Oceanography

PUBLICATIONS

Co-authored water quality monitoring technical report.

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MICHAEL J. GEDEN, B.S. Water Resources

PROFESSIONAL RESUME

SPECIALIZATION

Geophysical Investigation, Geologic Structure and Process, Geomorphology, Field Sampling and Techniques

RECENT EXPERIENCE

<u>Ohio Superfund Site, Task Manager</u>--Conducted a multitechnique geophysical survey at an abandoned hazardous waste site in northeastern Ohio. Also supervised installation of monitoring wells.

Solite Corporation, Project Geologist--Conducted a geophysical survey at a hazardous waste site in northeast Florida. Sampled surface and ground water and installed monitoring wells.

<u>Pinellas County, Subproject Manager</u>—Geophysical survey of refuse-toenergy plant and active landfills. Design and installation of ground water monitoring wells. Aquifer testing and analysis through use of single well slug tests.

Geophysical Investigations for Uncontrolled Disposal Site, Scientist--Conducted investigations to locate buried drums using remote sensing techniques. More than 1,000 drums were located and excavated.

<u>Midwest Manufacturer, Project Scientist</u>—Installation and sampling of ground water monitor wells to determine extent of ground water contamination. Aquifer testing and analysis through use of single well slug tests.

Florida Manufacturer, Associate Scientist--Conducted multitechnique geophysical survey. Design, construction, aquifer analysis, and sampling of ground water monitoring system to determine extent of subsurface contamination.

<u>Aero Corportion, Associate Scientist</u>--Construction, aquifer analysis, and sampling of ground water monitor wells to determine effectiveness of wastewater treatment process.

Ida-Con Corporation, Associate Scientist--Design, siting, construction, and sampling of ground water monitor wells to test effectiveness of surface water retention ponds.

<u>Seminole Electric Cooperative, Project Scientist</u>--Installation and aquifer testing of ground water monitor wells as part of siting study for new electric-generating station.

Alabama Army Ammunitions Plant Ground Water Monitoring, Associate Scientist—Installation, development, and sampling of ground water monitor wells and piezometric clusters.

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M.J. GEDEN, B.S. Page 2

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Georgia Pacific, Associate Scientist--Installation and development of ground water monitor wells and piezometric transects in Santa Fe Swamp.

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USATHAMA-Ft. Navajo, Ft. Wingate, Bluegrass, Phoenix, AAAP, Lima, and Savannah Army Depots, Associate Scientist--Compilation and preparation of field drilling data for entry into U.S. Army computer system.

<u>General Electric Company, Project Scientist</u>--Monthly sampling of ground water monitor wells to monitor integrity of surface chemical retention ponds.

EDUCATION

B.S. 1979 Earth Science

Northeastern Illinois University

CHARLES A. SPIERS Project Hydrogeologist

EDUCATION:

63.53

B.S., Geology, University of South Carolina, 1965

PROFESSIONAL MEMBERSHIP:

American Institute of Professional Geologists (A.I.P.G.) President, Georgia Section, 1983 Member of Subcommittee on State Affairs National Water Well Association (NWWA)

PROFESSIONAL REGISTRATION:

Registered Professional Geologist, State of Georgia

CAREER SUMMARY

Mr. Spiers joined Law Engineering in 1981. He has served as a Project Hydrogeologist in Law's salt dome investigations for the Department of Energy. He has also evaluated contaminant movement in the ground water system at landfills, on industrial firms, and at hazardous waste sites. Before joining Law, he was with the Water Resources Division of the U.S. Geological Survey for 14 years where he was a Project Chief on various water-resources-related projects.

NUCLEAR WASTE SITE INVESTIGATIONS

Mr. Spiers has been a Project Hydrogeologist with Law Engineering for the Department of Energy's Gulf Coast Salt Domes Project. He characterized major aquifer systems with respect to geochemical facies and determined hydraulic characteristics of both fresh and saline aquifers near the domes. He wrote reports culminating major findings of these studies. While with USGS, he served as Project Chief on salt dome studies in Mississippi. In South Carolina he served as a Staff Hydrogeologist on the Bedrock Waste Storage Project at the Savannah River Plant.

REPRESENTATIVE HAZARDOUS WASTE PROJECTS

Staff Hydrogeologist for a study of the Old Inger hazardous waste site near Baton Rouge, Louisiana. The project involved supervision of monitor well construction, soil sampling, and an evaluation of the hydrogeology of the site with respect to the contaminant movement.

Project Hydrogeologist in a study of the hydrogeology of the Union Carbide plant at Columbia, Tennessee. The scope of the project was to determine the direction and rate of ground water flow and the occurrence CHARLES A. SPIERS (Page 2)

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of a contaminant in the ground water system at two seepage points along the Duck River. Data from a surface resistivity survey, river profiling, and 25 wells were used to recommend an interceptor well system to prevent the contaminant from reaching the river.

Project Hydrogeologist for a study of the Tuscaloosa aquifer system at Olin Chemicals near Augusta, Georgia. The project was to define the degree of hydraulic interconnection between the shallow aquifers and deeper Tuscaloosa aquifers near a proposed new hazardous waste landfill.

Project Hydrogeologist in a study which involved preparation of UIC and hazardous waste permits for storage of waste in Vinton Salt Dome, Louisiana. The scope of the project was to characterize the hydrogeology of the dome and surrounding sediments so that both an Underground Injection Control (UIC) permit and a Part "B" hazardous waste permit could be prepared.

Site Investigations Manager for a hydrogeologic characterization of CECOS International's hazardous waste site in Puerto Rico. The scope of the project was to characterize the hydrogeology of the site and provide the necessary data to design the hazardous waste facility. Field activities consisted of surface and borehole geophysics, geologic mapping, test drilling, piezometer installation, monitoring well installation and aquifer testing.

REPRESENTATIVE NUCLEAR WASTE ISOLATION PROJECT

Project Hydrogeologist assigned to the Gulf Coast Salt Dome Project. Responsible for analyzing and reporting the results from aquifer tests in deep test wells near salt domes; designing, drilling, and testing procedures for hydrologic investigations in the Mississippi Salt Dome Basin; and participating in location characterization planning for the next phase of the salt dome investigations in Mississippi. KENNETH J. SEEFRIED, JR. Senior Engineer

EDUCATION: B.S.C.E., The Citadel, 1965 M.S.C.E., University of Kentucky, 1966

PROFESSIONAL MEMBERSHIP: National Society of Professional Engineers American Society of Civil Engineers (Member)

PROFESSIONAL REGISTRATION: Registered Professional Engineer in Georgia, Florida, and Mississippi

CAREER SUMMARY

Mr. Seefried joined Law Engineering in 1966. He has had extensive experience in the planning and execution of investigations for ground water studies, geologic and technical investigations and hazardous waste evaluations. Mr. Seefried has managed large interdisciplinary projects requiring the coordination of engineers, scientists, geologists, technicians, geophysicists, and laboratory personnel. Such projects have included the Metropolitan Atlanta Rapid Transit System. In addition to his management of these investigations, he has been the principal engineer in the evaluation and reporting phases of various projects.

REPRESENTATIVE HAZARDOUS WASTE PROJECTS

Project Engineer for closure of waste lagoons at a site near Morristown, Tennessee. Responsible for water quality assessment, water quality monitoring, Closure Plan, and implementation.

Principal Investigator for large plant near Atlanta, Georgia, following leakage of solvent to ground water. Responsible for establishing monitoring program, characterizing hydrogeology of site, performing pump test, and recommending cleanup alternatives.

Principal Investigator of landfill site (Superfund) in central Georgia for one of the possible responsible parties (PRPs). Evaluated all field data, determined hydrogeologic characteristics, analyzed chemical data, reviewed U.S. EPA RI/FS Draft Work Plan. Provided recommendations for rewrite of plan.

PROFESSIONAL STEPHEN A. DENAHAN, P.G. Department Head, Geology and Geophysics Department

SPECIALIZATION

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Engineering Geology, Hazardous Waste Site Evaluation, Geophysical Techniques, Mineral Resource Evaluation

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RESUME

RECENT EXPERIENCE

Geologic Environmental Assessment of Army Facilities, USATHAMA, Field Geologist--Conducted records search and environmental survey of existing and past waste disposal sites at more than 30 installations, to identify potential contamination. Assessed geohydrology of potential contamination sites and identified pollutant migration pathways. Corrective measures to mitigate pollutant transport were developed.

Feasibility Study of the Sapp Battery Salvage Site for FDER, Project Geohydrologist -- While conducting an assessment of site investigation results, ESE will perform risk analysis, determine required remedial action, and evaluate restoration alternatives. Critical concentrations will be set for air, soil, sediments, surface water, and ground water as a basis for determination of significant contamination.

Geophysical Investigations for Uncontrolled Disposal Site, Project Manager--Responsible for location of buried drums using remote sensing techniques. Sampling and analyses of well samples, drum removal, aquifer pump tests, and past drum removal.

Initial Installation Assessment, Naval Facilities, Team Geologist--Interdisciplinary team evaluated the potential for environmental contamination from past and present activities at U.S. Naval Bases. Sites include Charleston Navy Base, South Carolina; Sewell's Point Naval Complex, Norfolk, Virginia. Responsibilities included identification of contaminated areas and recommendation of specific monitoring programs.

Evaluation of Risk, Project Manager--An assessment of risk to structures from geologic hazards specifically sinkholes was conducted at a hazardous waste facility. Geophysical and aerial photographic methods were employed.

Assessment of Ground Water Contamination, Project Manager --Responsibilities included design and execution of a multi-technique geophysical survey and design of a ground water monitoring system at an industrial site.

Design and Installation of Ground Water Monitoring System at an Industrial Site, Subproject Manager -- A monitoring system was designed and installed to bring site into compliance with local and state regulations at a site in North Carolina.

Evaluation of Geophysical Techniques for Detection of Subsurface Cavities, Subproject Manager--Conducted field evaluation of several surface-remote geophysical methods for cavity detection at several sites representing different geologic settings.

Well Field Siting Using Geophysical Techniques in a Karst Area--The study involved locating a test well field for 17 MGD withdrawal and to minimize the effect of ground water withdrawal on rivers and springs. These systems are hydraulically connected to the aquifer through the sinkhole system in the area.

EDUCATION

B.S. 1968 Geology

University of Florida

REGISTRATION

Registered Professional Geologist in Indiana

APPENDIX C

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I.

SCOPE OF WORK AS OUTLINED BY OEHL

24 JUN 1985

INSTALLATION RESTORATION PROGRAM PHASE II - CONFIRMATION/QUANTIFICATION (STAGE 1) AIR FORCE PLANT 6 GEORGIA

I. DESCRIPTION OF WORK

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The purpose of this task is to undertake a field investigation at Air Force Plant 6 GA (1) to determine the presence or absence of contamination within the specified areas of investigation; (2) if contamination exists, determine the potential for migration of those contaminants in the various environmental media; (3) identify additional investigations necessary to determine the magnitude, extent, direction and rate of migration of discovered contaminants; and (4) identify potential environmental consequences and health risks of migrating pollutants.

The Phase I IRP Report (mailed under separate cover) incorporates the background and description of the sites for this task. To accomplish this survey effort, the contractor shall take the following actions:

A. General

1. The contractor shall monitor all exploratory well drilling and borehole operations with a photo-ionization meter or equivalent organic vapor detection device to identify potential generation of hazardous and/or toxic materials. In addition, the contractor shall monitor drill cuttings for discoloration and odor. During drilling operations, if soil cuttings are suspected to be hazardous, the contractor will place them in proper containers and test them for EP Toxicity and Ignitibility. Results of monitoring shall be included in boring logs. A maximum of five samples shall be collected for EP Toxicity and Ignitibility testing.

2. All water samples collected shall be analyzed on site by the contractor for pH, temperature, and specific conductance. Sampling, maximum holding time, and preservation of samples shall strictly comply with the following references: Standard Methods for The Examination of Water and Wastewater, 15th Ed. (1980), pp. 35-42; ASTM, Section II, Water and Environmental Technology; Methods for organic Chemical Analysis of Municipal and Industrial Wastewater, EPA-600/4-82-057; and Methods for Chemical Analysis of Waters and Wastes, EPA Manual 600/4-79-020, pp. xiii ro xix (1979). All chemical analyses (water and soil) shall meet the required limits of detection for the applicable EPA method identified in Attachment 1.

3. Locations where sediment samples are taken, or where soil exploratory borings are drilled shall be marked with a permanent marker. and the location marked on a project map of the site.

4. Field data collected for each site shall be plotted and mapped. The nature, magnitude, and potential for contaminant flow within each zone to receiving streams and ground waters shall be estimated. Upon completion of the sampling and analysis, the data shall be tabulated in the next R42 Status report as specified in Item VI below.

5. Determine the areal extent of the sites by reviewing available aerial photos, both historical and the most recent panchromatic and infrared.

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6. Split all water and soil samples as part of the contractor's specific Quality Assurance/Quality Control (QA/QC) protocols and procedures. One set of samples shall be analyzed by the contractor and the other set of samples shall be forwarded for analysis through overnight delivery to:

USAF OEHL/SA Bldg 140 Brooks AFB TX 78235-5501

The samples sent to the USAF OEHL/SA shall be accompanied by the following information:

- (a) Purpose of sample (analyte)
- (b) Installation name (base)
- (c) Sample number (on containers)
- (d) Source/location of sample
- (e) Contract Task Numbers and Title of Project
- (f) Method of collection (bailer, suction pump, air-lift pump etc.)
- (g) Volumes revomed before sample taken
- (h) Special Conditions (use of surrogate standard, etc.)
- (i) Preservatives used (indicate if non-standard)

This infromation shall be forwarded with each sample by properly completing an AF Form 2752 (copy of form and instruction on proper completion mailed under separate cover). In addition, copies of field logs documenting sample collection should accompany the samples.

Chain-of-custody records for all samples, field blanks, and quality control duplicates shall be maintained.

7. An additional 10% of all samples, for each parameter, shall be analyzed for quality control purposes, as indicated in Attachment 1.

8. For ground water monitoring wells, comply with the U.S. EPA Publication 330/9-S1-0002, NEIC Manual for Ground Water/Subsurface Investigators at Hazardous Waste Sites for monitoring well installation. Only screw type joints shall be used. Additionally, monitoring wells shall be constructed in accordance with guidelines in the Georgia Department of Natural Resorces Circular No. 5, "Monitoring Well Construction for "Hazardous Waste Sites in Georgia."

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9. Wells shall be of sufficient depth to collect samples representative of aquifer quality and to intercept contaminants if they are present. Well development shall proceed until the discharge water is clear and free of sediment to the fullest extent possible.

10. Elevations of all newly installed monitoring wells shall be surveyed with respect to bench mark on base to an accuracy of 0.05 feet. Horizontally locate the new wells to an accuracy of 10 feet and record on site maps.

11. Water levels shall be measured at all contractor installed wells to the nearest 0.01 feet, and locations recorded on a project map and specific site maps. Three ground-water elevation measurements shall be made at each new monitoring well; one when the well is developed, the second during ground water sampling, and the third approximately 1 month after sampling.

12. All monitor wells shall be drilled using the following specifications:

a. Each well shall be drilled with a 8-inch outside diameter drill bit using hollow-stem auger equipment. Samples shall be taken for stratigraphic control purposes at approximately 5-foot intervals. Each pilot boring log and well completion summaries shall be included in the Final Report (as specified in Item VI below).

b. The average depth of each of these wells shall be 50 feet. A total of <u>6</u> wells shall be drilled; therefore, total footage of wells shall not exceed 310 linear feet. Each well shall be constructed of Schedule 40 PVC casing using threaded, non-glued fittings. Each well shall be screened to a maximum of 30 feet. resulting in a total screening of 180 feet. The screen shall consist of two-inch diameter, PVC with up to 0.010 inch slots. The screen shall be capped at the bottom. All connections shall be flush-joint threaded. Each well shall be gravel-packed with washed and bagged rounded sand or gravel with a grain size distribution compatible with the screen and the formation. The pack will be emplaced from the bottom of the borehole to 5 feet above the top of the screen. Granulated or pelletized bentonite shall be tremied above the sand/gravel pack to a minimum thickness of three feet. Gelcement grout shall be emplaced from above the top of the bentonite seal to the land surface. Each well shall be completed with installation of a cap and locking hasp and shall be clearly numbered with an exterior paint.

13. Each well shall be developed using either a gasoline driven surface pump and hose or a 1-inch PVC pipe and foot valve until clean of suspended solids.

14. Wells shall be purged prior to sampling. Purging will be complete when three well volumes of water have been displaced or until the pH, temperature, specific conductance, color, and odor of the discharge is noted to stabilize. Purging operations shall be conducted using a stainless steel or PVC bottom-discharge bailer or bladder pump. All sampling shall be conducted using a PVC bailer or bladder pump. As the first step of ground-water sampling operation at each well, water level measurements shall be taken to the nearest 0.01 foot with respect to an established surveyed markpoint on top of the well casing.

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15. Shallow soil augering will be performed using a hand auger.

16. Attachment 3 summarizes sampling activities at all sites.

B. In addition to items delineated in A above, conduct the following specific actions at the following sites on AF Plant **9**:

1. There are numerous sites under active study by Lockheed. These sites include the Surface Impoundment, B-10 Aeration Basin, Position 65 (C-5 Wash Rack), TCE Spill, JP-5 Fuel Spill No. 2, Past Landfill, Bldg. B-96, and <u>Sanitary WWTP Sludge Disposal Area</u>. The results of the studies on these sites shall be reviewed as follows:

a. Obtain, review, and analyze the reports of ongoing studies currently being conducted through Lockheed. Geologic and ground-water elevation data shall be analyzed to define the hydrogeologic conditions at the site. Groundwater quality data shall be analyzed to determine any statistical relationship between the various wells and public health, and regulatory implications of the data.

b. Hydrogeologic models (in the form of subsurface profiles) shall be prepared to aid in the characterization of the site.

2. Site 5, Stormwater Retention Basin No. 2

a. Perform 1 soil test boring to a depth not exceed 50 feet.

b. Collect <u>12</u> split spoon samples. <u>Two</u> of the samples shall be selected for classification testing according to ASTM procedures.

c. Collect <u>1</u> undisturbed soil sample and test for permeability and classification.

d. Complete the boring as a ground-water-quality monitoring well.

e. The well shall be sampled and analyzed for the parameters listed in Attachment 2.

f. Prepare hydorgeologic models (in the form of subsurface profiles) to aid in the characterization of the site.

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a. Collect 3 sediment samples in the drainage ditch at 100 foot intervals begining at the spill site and continuing downstream. Samples will be a composite of the upper 6 inches of sediment. Samples shall be analyzed for leachable chromium, using the EP Toxicity Test Method.

b. Conduct EM-31 profiling with shallow resistivity soundings to locate the horizontal extent of the contaminated soil, if present.

c. Perform <u>4</u> soil test borings. Total footage of borings shall not exceed <u>200</u> feet.

d. Collect <u>40</u> split spoon samples. <u>Eight</u> of the samples shall be selected for classification testing according to ASTM procedures.

e. Collect <u>4</u> undisturbed soil samples. One of the samples shall be tested for permeability and classification.

f. Complete each boring as a ground-water-quality monitoring

g. Each well shall be sampled once, for a total of 4 samples. Analyze the samples for the parameters listed in Attachment 2; additionally, analyze each sample for chromium.

h. Prepare hydorgeologic models (in the form of subsurface profiles) to aid in the characterization of the site.

4. <u>Site 10</u>, JP-5 Fuel Spill No. 2: An OVA soil survey shall be performed to locate any contaminated soil.

5. Site 2, Existing Landfill

a. Conduct EM-31 profiling with shallow resistivity soundings to locate the leachate plume, if present.

b. Perform <u>l test boring</u>. Total footage of borings shall not exceed <u>50</u> feet.

c. Collect <u>10</u> split spoon samples. A maximum of <u>2</u> of the samples shall be selected for classification testing according to ASTM procedures.

d. Collect <u>1</u> undisturbed soil sample and test for permeability and classification.

e. Complete the boring as a ground-water-quality monitoring well.

f. The well shall be sampled once and analyzed for the parameters listed in Attachment 2.

g. Prepare hydrogeologic models (in the form of subsurface

profiles) to aid in the characterization of the site.

6. <u>Site 11</u>, JP-5 Spill Site No. 1: Take 1 soil sample from the spill site area and analyze it for petroleum halocarbons.

7. Perform a screening parameter validity test to test the validity of the water-quality parameters used in Phase II, Stage 1 as screening parameters. This testing shall be conducted as follows :

a. Ground-water-quality data from the on-going studies at Air Force Plant 6 will be reviewed.

b. Five monitor wells <u>installed under this contract shall</u> be selected which range from high to low levels of chlorinated hydrocarbon solvent contamination for the testing.

c. Contractor shall coordinate with AF Plant 6 contractor's current well sampling/analysis to split water-quality samples with the contractor during one of his regularly scheduled sampling episodes.

d. Contractor shall analyze the samples for the parameters listed in Attachment 2 and compare these results with historical data from the well and specific parameters analyzed by the contractor.

e. Results of these analyses shall be reduced and sent to OEHL in the current R&D Status report.

8. Distributed Computing Model Application

a. <u>Translate the Prickett-Lonnquist Aquifer Simulation Model</u> (PLASM) ground-water flow model and the Prickett-Naymik-Lonnquist (1981) Random Walk Solute Transport Model for operation on USAF compatible microcomputers.

b. <u>Provide all necessary software and documentation of the above</u> models and data base (Item VI).

c. <u>Provide a microcomputer based Data Management System (DMS) to be</u> <u>used for data reduction/analysis and data archival for all on-going</u> <u>studies. The following data shall be included in the system: Soil boring</u> <u>logs, well construction details, and chemical analysis data for each site</u>. <u>Outputs from the system shall include: well logs, lithologic cross-sections</u>, <u>contour maps, and tabulated analytical data in camera ready format</u>.

d. Conduct ground-water modeling for the various contaminated sites using the above models to estimate ground-water flow directions, contaminant transport pathways and plume configurations/concentrations.

e. Provide a separate report addressing this modeling effort (Item VI, Sequence 4).

C. Well and Borehole Cleanup

All well and boring area drill cuttings shall be removed and the general area cleaned following the completion of each well and boring. Only those drill cuttings suspected as being a hazardous waste (based on discoloration, odor, or organic vapor detection instrument) shall be properly containerized by the contractor for disposal. The suspected hazardous waste shall be tested by the contractor for EP Toxicity and Ignitibility. The contractor is not responsibile for ultimate disposal of the drill cuttings. Disposal will be conducted by Lockheed personnel.

D. Data Review

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Results of sampling and analysis shall be tabulated and incorporated in the Informal Technical Information Report (as specified in Item VI below) and forwarded to the USAF OEHL for review. Results shall also be forwarded as available in the next monthly R&D status report.

E. Reporting

1. A draft delineating all findings of this field investigation shall be prepared and forwarded to the USAF OEHL (as specified in item VI below) for Air Force review and comment. This report shall include a discussion of the regional/site specific hydrogeology, well and boring logs, data from water level surveys, ground-water surface and gradient maps, water quality and soil analysis results, available geohydrologic cross sections, and laboratory quality assurance information. The report shall follow the USAF OEHL supplied format (mailed under separate cover).

2. The recommendation section will address each site and list them by categories. Category I will consist of sites where no further action (including remedial action) is required. Data for these sites is considered sufficient to rule out unacceptable health or environmental risks. Category II sites are those requiring additional monitoring or work to quantify for further assess the extent of current or future contamination. Category III sites are sites that will require remedial actions (ready for IRP Phase IV actions). In each case, the contractor will summarize or present the results of field data, environmental or regulatory criteria, or other pertinent information supporting these conclusions.

F. Meetings

The contractor's project leader shall attend two meetings with Air Force headquarters and regulatory agency personnel to take place at a time to be specified by the USAF OEHL. The meeting shall take place at Air Force Plant 6 GA for a duration of two days (16 hours).

II. Site Location and Dates:

Air Force plant 6 GA Date to be established

TABLE 1

Analytical Methods, Detection Limits and Number of Samples (For Water Unless Otherwise Shown)

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Parameter	Method	Detection Limit	Number Samples	QA	Total Sample
^a Total Organic Carbon (TOC)	epa 415.1	1000 ug/L	11	2	13
Total Organic Halogens (TOX)	EPA 9020	5 ug/L	11	2	13
Oil and Grease (using IR)	EPA 413.2	100 ug/L	11	2	13
Petroleum Halocarbons	EPA 418.1	100 ug/g soil	1 Soil	0 soi'	1 soil
Chromium	EPA 218.1	50 ug/L	4	0	4
Leachable Chromium	EPA 1310	50 ug/L	3 soil	0 soil	3 soil
pH	EPA 150.1	-	11	-	11
Specific Conductance	EPA 120.1	1 umho/cm	_ 1	-	11
EP Toxicity	EPA 1310	b	3 soil	2 soil	⁵ scil
Ignitibility	EPA-1010	c	<u>5 3011</u>	<u>1-soit</u>	6-30 ===
Purgeable Hydrocan	rbons EPA 601	<u>d</u>	5 grndwtr	2 grndwt	r 7 grndwt:

a Detection limit for TOC must be 3 times the noise level of the instrument. Laboratory distilled water must show no response; if it shows a response, corrections for positive results must be made.

ug/L of solution
10
200
10
50
20
1
10
10

c Find if sample is ignitible at 140 degrees Farenheit or below. If so, it is a hazardous waste.

d Detection limits for Volatile Organic Compounds shall be as specified for the compounds by EPA Method 601. Method 601 for volatile organic compounds requires positive confirmation by second chrimatografic columns. This must be done before reporting the positive values. Method not specified the two columns to use. Second column confirmation is required where values avoided 10 mg/c. C-8
Attachment 2

LIST OF ANALYTICAL PARAMETERS AT AIR FORCE PLANT 6

Oil and Grease (O & G) Total Organic Carbon (TOC) Total Organic Halogens (TOX) pH Specific Conductance

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Attachment 3

Site Sampling and EM-31 Profiling Summary

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SITE	OVA SOIL Survey	WELLS (#, total ft.)	EM-31 PROF.	SPLIT SPOONS	UNDIST. SAMPLES	WATER * Samples	SOIL + SAMPLES	
Site 5, Stormwater Retention Basin No. 2		1,60		12	1	1		
Site 12, Sodium Dichromate Spill		4,200	x	40	4	4	3	
Site 10, JP-5 Fuel Spill No. 2	x							
Site 2, Existing Landfill		1,50	x	10	1	1		
Site 11, JP-5 Spill Site No. 1							1	
Screening Parameter Validity Test						5		1
Drill Cuttings							5	1
Excluding quality	control sa	mples.						•

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III. BASE SUPPORT: None

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IV. GOVERNMENT FURNISHED PROPERTY: None

V. GOVERNMENT POINTS OF CONTACT:

1. Maj George New USAF OEHL/TSS Brooks AFB TX 78235-<u>5501</u> (512) 536-2158 AV 240-2158 2. Mr Joe Caldwell AFPRO/PD Chief, Manufacturing Assy Br Lockheed-Georgia Co Marietta, GA 30063 (404) 424-5480

3. Col Paul Fallon HQ AFSC/SGPB Andrews AFB DC 20334-5000 (301) 981-5235 AV 858-5235

VI. In addition to sequence numbers 1, 5, and 11 in Attachment 1 to the contract, which are applicable to all orders, the sequence numbers listed below are applicable to this order. Also shown are data applicable to this order.

Sequence No.	Block 10	Block 11	Block 12	Block 13	Block 14
3 (Atch 1)	0/Time	•	•		
4 (Atch 1)	One/R	85 Aug 09	85 Aug 09	85 Nov 12	**
<u>1 (Atch 2)</u>	0/Time	NA	<u>85 Oct 31</u>	85 Nov 12	1
2 (Atch 2)	One/R	<u>NA</u>	85 Oct 31	85 Nov 29	3

*Upon completion of analytical effort before submission of 1st draft report.

**Two draft reports will be required. After incorporating Air Force comments first draft report, the contractor shall supply the USAF OEHL with one copy of the second draft report. Upon acceptance of the second draft, the USAF OEHL will furnish a distribution list for the remaining 24 copies of the second draft. The contractor shall supply 50 copies plus the original camera ready copy of the final report.

APPENDIX D

QUALITY ASSURANCE PLAN

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APPENDIX D QUALITY ASSURANCE PLAN

The purpose of the Quality Assurance (QA) Plan is to provide processes tor controlling the validity of the data generated in all phases of the sampling and analysis efforts proposed under the scope of work. The procedures detailed as follows describe the general methodologies during the study and when implemented will provide documentation of the individual work elements and mechanism by which "data gaps" can be controlled. It should be noted that procedures outlined below may not apply to all circumstances which may arise during the course and scope of the study. Deviation from these procedures will be noted in the field logbooks and discussed with USAFOEHL personnel to determine corrective actions.

Two types of audit procedures will be used by QA to assess and document performance of project staff--system audits and performance audits. These are performed at frequent intervals under the direction of the Project QA Supervisor. These audits form one of the bases for corrective action requirements and constitute a permanent record of the conformance of measurement systems to QA requirements.

System audits are inspections of training status, records, Quality Control (QC) data, calibrations, and conformance to Standard Operating Procedures (SOPs) without the analysis of check samples. System audits will be performed periodically on laboratory and office operations or on field operations. The development and approval of the project Work Plan constitutes the initial system audit for this study.

The systems audit protocol is summarized as follows:

1. Field Operations--The Project QA Supervisor will periodically check:

 Field notebooks, logsheets, bench sheets, tracking forms, and report any inconsistencies and/or omissions;

b. Field sampling plans; and

- c. Sample site briefing package.
- 2. Laboratory Operations--The Project QA Supervisor will periodically check:
 - a. Parameter and/or laboratory notebooks;
 - b. Instrument logbooks;
 - c. Sample log-in, dispensing, and labeling for analysis;
 - d. Updating of QC criteria for spike recoveries; and
 - e. Final approval of data from each sample lot.

In addition, the Project QA Supervisor will monitor all analyses to assure complete adherence to approved analytical methods.

3. Final Reports--The Project QA Supervisor will review all final reports and deliverables to USAFOEHL.

Performance audits will include evaluation and analysis of check samples. A performance evaluation sample from EPA will be analyzed periodically along with the regular samples.

ESE's laboratory is certified for drinking water analysis by the Florida Department of Health and Rehabilitative Services according to the regulations set forth under the Florida Safe Drinking Water Act (Chapter 403.863, F.S.). ESE is also certified by the National Institute for Occupational Safety and Health (NIOSH) through their NIOSH Proficiency Analytical Testing (PAT) Program.

ESE routinely participates in performance test sample programs administered by:

- 1. EPA, EMSL-CI;
- 2. EPA, EMSL-RTP;
- 3. EPA, Region IV;
- 4. Florida Department of Environmental Regulation;

- 5. Florida Department of Health and Rehabilitative Services;
- 6. Alabama Department of Health;
- 7. U.S. Army Corps of Engineers, South Atlantic Division; and
- American Industrial Hygiene Association (ESE is an AIHAaccredited laboratory).

The results of these interlaboratory studies will be periodically evaluated by the Project QA Supervisor during the project as part of the performance audits.

D.1 WELL DRILLING

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Prior to drilling any test borings and installing any monitoring wells, each proposed drilling location will be cleared with facility engineering departments to avoid drilling into buried cables, pipes, etc. Facility engineering will approve all locations. If required, appropriate drilling permits will be acquired.

Each well will be fully described on a well log as it is being drilled. Transcription of the log from a field notebook to log form will not be permitted. Upon completion of each well, information from the well logs will be transferred to OEHL. Data included in the logs are listed below:

- 1. Depths will be recorded in feet and fractions thereof.
- Soil descriptions, in accordance with the Unified Soil Classification System, will be prepared in the field by the Site Geologist.
- 3. Soil samples will be fully described on the log. For splitspoon samples, the description will include:
 - a. Classification,
 - b. Unified Soil Classification System symbol,
 - c. Secondary components and estimated percentage,
 - d. Color,
 - e. Plasticity,
 - f. Consistency (cohesive soil) or density (noncohesive soil),

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g. Moisture content, and

h. Texture/fabric/bedding.

Cutting descriptions will include basic classification, secondary components, and other parameters that are apparent.

- 4. Numerical, visual estimates will be made of secondary soil constituents. If terms such as "trace," "some," or "several" are used, their quantitative meanings will be defined in a general legend.
- 5. The length of sample recovered for each sampled interval for drive (split-spoon) samples will be recorded.
- 6. Blow counts, hammer weight, and length of fall for split-spoon samples will be recorded.
- Rock core, if obtained, will be fully described on the log.
 Core description will include:
 - a. Classification by rock type,
 - b. Lithologic characteristics,
 - c. Bedding characteristics,
 - d. Color,

- e. Hardness,
- f. Degree of cementation,
- g. Texture,
- h. Structure,
- i. Degree of weathering,
- j. Solution or void conditions,
- k. Primary and secondary permeability estimates and rationale, and
- Length of core recovered and rock quality designation (RQD).
- 8. The estimated interval for each sample will be specified.
- 9. Depth to water will be indicated along with the method of determination, as first encountered during drilling. Any distinct water-bearing zones below the first zone also will be noted.

- 10. When drilling fluid is used, fluid losses, quantities lost, and the intervals over which they occur will be recorded.
- 11. The drilling equipment used will be described generally on each log, including such information as rod size, bit type, pump type, rig manufacturer, and model.
- 12. The drilling sequence will be recorded on each log.
- 13. All special problems will be recorded.

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- 14. The dates for the start and completion of all borings will be recorded on the log.
- 15. Lithologic boundaries will be noted on the boring log.
- 16. The boring logs will be submitted to the OEHL within 10 working days after each individual boring is completed. In cases where a monitoring well is inserted into the boring hole, both the log for that boring and the installation sketch will be submitted within 10 working days.

Evaluation of the existing geologic and geohydrologic data at Air Force Plant 6 indicates that the six ground-water-sampling wells to be installed may be screened totally within a saturated-soil column, within a saturated-soil column and the uppermost fractured bedrock, or totally within the fractured bedrock. The screened interval will be determined by evaluation of the geologic data obtained during the drilling operations.

Fig. D-1 shows typical well configurations for overburden (i.e., soil) monitoring wells. The placement of the well screen in the saturated soil and/or uppermost bedrock will be determined in the field by the Site Geologist and will depend on the depth where ground water was encountered during the drilling process. The wells finished in the bedrock will be screened at a discrete depth interval within the bedrock. This interval will be determined by the water levels measured in the boreholes, the presence of fractures in the core samples, and/or permeable zones.

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When a boring is completed, the Site Geologist will visually inspect the hole to ensure plumbness and cleanliness. Plumbness will be obtained by careful leveling of the drill rig prior to commencement of the drilling. Additionally, the drilling will proceed in an efficient and controlled manner to eliminate wobble/chatter in the drill stem.

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All well installations will begin within 48 hours of boring completion, and, once begun, will continue until completion. The well screen and casing will be carefully cleaned with base-supplied potable water from an approved source prior to installation in the hole. All well screens will have a solid bottom. Solid casing will extend from the screen to approximately 2 feet (ft) above land surface.

Centralizers and filter material will be installed around the well screen to approximately 5 ft above the well screen. As the 3-ft bentonite seal is placed on top of the filter material, water from the approved source will be added when necessary to assure that the pellets expand to form a tight seal.

The gel-cement grout seal will extend from the top of the bentonite seal to the land surface. Grouting will be completed as a continuous operation in the presence of the Site Geologist. The grout will be pumped into the annular space under pressure using a tremie pipe or hose placed above the top of the bentonite seal to ensure a continuous grout seal. The protective casing will be sealed in the grout. A coarse gravel pad, 0.5-ft thick, extending 4 ft radially from the protective casing, will be placed at each monitoring well.

The following materials will be used in well construction:

Casing used in the well will be threaded PVC Schedule 40,
 2-in nominal inside diameter (I.D.). No PVC solvent will be used. The well screen will be factory slotted, with a slot width of 0.010 in.

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- 2. Grout will be composed by weight of about 10 parts portland cement to one-half part bentonite, with a maximum of about 10 gallons (gal) of approved water per 94-pound (1b) bag of cement. Bentonite will be added after mixing of the cement and water.
- 3. Bentonite pellets used in the seal will be a commercially available product designed for well-sealing purposes.
- 4. Sand material used in the filter envelope around the well screen will be selected to be compatible with both the screen slot size and aquifer materials.
 - 5. A 6-in protective steel casing will be installed around each well. This casing will extend approximately 2.5 ft above land surface and will be seated 2.5 ft into the well seal grout. This casing will be vented to the atmosphere via a lockable, hinged cap. This cap will prevent entry of water but will not be airtight. This way the well will be in open connection to the atmosphere to allow for water level stabilization. A 1/4-in diameter drainage port will be drilled about 1/2 in above the level of the internal monitor collar. The same key will be used for all padlocks at the site.
 - 6. A sketch of the well installation will be included on the boring log and show, by depth, the bottom of the boring, screen location, granular backfill, seals, grout, cave-in, and height of riser above ground surface. The actual composition of the grout, seals, and granular backfill will be recorded on each sketch.
 - 7. Well sketches will include the protective casing detail.
 - 8. After the grout seal has set (approximately 24 hours), it will be checked for settlement, and additional grout (of approved composition) will be added to fill any depressions.

D.2 WELL DEVELOPMENT

The initial development or the purging of drilling fluid from monitoring wells will be recorded and submitted to the OEHL within 10 working days

after development. The development will be performed, as soon as practical, after well installation. The following data will be recorded for development:

1. Well designation;

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- 2. Date of well installation;
- 3. Date of development;
- 4. Static water level before and 24 hours after development;
- Quantity of water loss during drilling and fluid purging, if water is used;
- 6. Quantity of standing water in well and annulus (30 percent porosity assumed for calculation) prior to development;
- 7. Specific conductivity, temperature, and pH measurements taken and recorded at the start, twice during, and at the conclusion of development. Calibration standards were run prior to and after each dag's operation in the field;
- 8. Depth from top of well casing to bottom of well;
- 9. Screen length;
- Depth from top of well casing to top of sediment inside well, before and after development;
- Physical character of removed water, including changes during development in clarity, color, particulates, and odor;
- Type and size/capacity of pump and/or well development equipment used;
- 13. Description of surge technique, if used;
- 14. Height of well casing above ground surface; and
- 15. Quantity of water removed and time for removal.

Development of wells will be accomplished using either a gasoline driven surface pump and hose or a 1-in PVC pipe and foot valve. The hose from the pump or PVC pumping equipment will be cleaned and rinsed with the approved drilling water prior to use in the next well. Well development will begin no sooner than 48 hours after completion of the mortar collar placement. Development will proceed until the following conditions are met:

- 1. The well water is reasonably clear to the unaided eye,
- The sediment thickness remaining in the well is less than
 5 percent of the screen length,
- At least 5 well volumes (including the saturated filter material in the annulus) have been removed from the well.

A 1-pt sample of the ground water obtained from the development process for each well will be obtained and stored so as not to freeze. The cap and all internal components of the well casing above the water table will be rinsed with well water to remove all traces of soil/sediment/ cuttings. This washing will be conducted before and/or during development.

D.3 WATER-LEVEL MEASUREMENTS

All water-level measurements at the various wells at Air Force Plant 6 will be obtained using the USGS wetted-tape method. This procedure is accurate to 0.01 ft. The tape will be rinsed with water from the approved source, wiped with a fresh cloth, and allowed to air dry between consecutive water-level measurements.

At least one complete set of static water level measurements for all wells considered in this study will be made over a single, consecutive 10-hour period.

D.4 SAMPLING AND ANALYSES

D.4.1 GROUND WATER SAMPLING

Ground water sampling at Air Force Plant 6 will begin after the new monitor wells have been allowed to reach equilibrium (no less than 7 days after well development). The following procedures will be followed on the day of sampling: 1. The depth to water will be measured from the top of casing.

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- 2. The well depth will be sounded and recorded. The depth of the water in the well will be calculated.
- 3. Samples will be taken after the fluid in the screen, well casing, and saturated annulus has been exchanged at least three times. In the event of low well yields (e.g., in the presence of fine-grained sediments and/or limited bedrock fracturing), some wells may have slow recovery rates. A decision to reduce the well purging to less than three volumes will be recommended by the Sampling Team Leader, only if excessive time would elapse attempting to collect one or two samples from low-yielding wells. This decision will be subject to approval by OEHL. The amount of fluid purge will be measured and recorded. Conductivity, pH, and temperature will be measured at the start, once during, and at the end of the fluid purging procedure. This data will be forwarded to the Contracting Officer at the end of sampling. Sampling will be accomplished by a bailer constructed of inert materials (PVC). No glue will be used in the construction of these bailers.

4. To protect the wells from contamination during sampling procedures, the following guidelines will be followed:

- A separate bailer will be supplied for each. If the wells are resampled, new bailers will be supplied for each well to preclude contamination of the original bailer during storage.
- b. If a pump is used to purge the standing water from the well, the pump and the hoses will be thoroughly cleaned between the samples, using the approved drilling water source. All sampling, however, will be performed by the dedicated bailer.
- c. All sampling equipment will be protected from ground water contact by polyethylene plastic sheeting to prevent soil contamination from tainting the ground water samples.

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- 5. Onsite measurements of water quality obtained during the sampling trip will consist of conductivity, temperature, and pH. These data will be presented in the final report for the phase in which they were measured. Calibration standards will be run and recorded prior to, during, and after each sampling day.

Inert threaded PVC well casings will be used in this program. Adsorption of certain compounds on the plastic surface may affect the apparent ground water concentration. However, the following precaution will be taken to minimize adsorption of analytes by PVC. Each well will be purged and then sampled as soon as sufficient water returns. In this manner, the contact time between the water sample and the PVC will be kept to the shortest possible period.

During the sampling of each monitor well, information regarding the sampling will be kept in a notebook. The following data will be collected:

- 1. Well number;
- 2. Date;

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- 3. Time;
- 4. Static water level;
- 5. Depth of well;
- 6. Number of bailer volumes removed, if applicable;
- 7. Pumping rate, if applicable;
- 8. Time of pumping, if applicable;
- 9. Drawn down water level;
- In situ water quality measurements such as pH, specific conductance, and temperature;
- 11. Fractions sampled and preservatives;
- 12. Weather conditions and/or miscellaneous observations; and
- 13. Signature of sampler and date.

Samples will be collected in a manner which will minimize its aeration and prevent oxidation of reduced compounds. The containers for metals, phenols, cyanide, and extractibles (as appropriate) will be filled until they overflow and then tightly capped. For volatiles, the bottles will be checked to verify that no air has been entrained. Volatile samples will be collected in duplicate directly from the bailer at each well and placed in the canisters containing activated carbon provided to prevent contamination. If a volatile bottle is contaminated by dropping the septum or touching the septum or lips of the bottle, it will be discarded and a clean bottle issued and labeled. <u>Under no circumstances</u> will volatile fractions be transferred from other sampling containers.

Nitric acid and/or sulfuric acid preservation performed in the field will be carried out under conditions of adequate ventilation to prevent potential release of hydrogen cyanide. Care will be taken to ensure excess acid is not added. The pH will be tested using colorpHast[®] indicator sticks on the waste portions of each fraction.

Each sample will be carefully labeled so it can be identified by laboratory personnel. The sample label will include the project number, sample number, time and date, and sampler's initials. All samples will be identified with non-water-soluble ink on a standard preprinted and prenumbered label immediately after collection. Information concerning preservation methods, matrix, and sample location will be included on the label. Samples will be shipped in styrofoam ice chests and will be kept below 4°C from time of sample collection until analysis.

D.4.2 SURFACE WATER SAMPLING

Prior to surface water sampling, the following data will be noted and recorded in the field notebook:

- 1. Site number or location;
- 2. Date;

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- Time (24-hour system);
- 4. Antecedent weather conditions, if known;

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- In situ parameter measurements (temperature, conductivity, and pH);
- 6. Fractions and preservatives;

- 7. Any other pertinent observations (odor, fish, etc.); and
- 8. Signature of sampler and date.

At the conclusion of each day in the field, the Sampling Team Leader will review each page of the notebook for errors and omissions. He/she will then date and sign each reviewed page.

All field instrument calibrations will be recorded in a designated portion of the notebook at the time of the calibration. Adverse trends in instrument calibration behavior will be corrected.

The sample will be collected in a manner which will minimize its aeration and prevent oxidation of reduced compounds in the sample. The container will be filled until it overflows without air bubbles and then tightly capped. Special attention will be given to minimize air contact with the water sample. Sampling procedures and precautions for the volatile fraction collection are identical to the ground water procedures.

Each sample will be carefully labeled so it can be identified by laboratory personnel. The sample label will include the project number, sample number, time and date, and sampler's initials. All samples will be identified with non-water-soluble ink on a standard preprinted and prenumbered label immediately after collection. Information concerning preservation methods, matrix, and sample location will be included on the label. Samples will be preserved as described in the Ground Water Section. Samples will be shipped in styrofoam ice chests and will be kept below 4°C from time of sample collection until analysis.

D.4.3 SOIL AND SEDIMENT SAMPLING

Prior to soil and/or sediment sampling, the following data will be noted and recorded in the field notebook:

- 1. Site number, location, or designation;
- 2. Date;

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- 3. Time (24-hours system);
- 4. Antecedent weather conditions, if known;
- 5. Any other pertinent observations (e.g., vegetation, substrate characteristics, etc.); and
- 6. Signature of sampler and date.

At the conclusion of each day in the field, the Sampling Team Leader will review each page of the notebook for errors and omissions. He/she will then date and sign each reviewed page.

D.4.4 SOIL SAMPLING

- Prior to sampling, surface vegetation, rocks, leaves, and debris will be removed.
- Appropriate point sampling or compositing techniques, as defined in the project sampling plan, will be used to ensure that the sample is representative of the area sampled and the type of information (e.g., depth of contamination) desired.
- 3. Soil samples will be placed in a glass wide-mouth jar with Teflon[®]-lined lid. Sample containers will be labeled with a preprinted label, chilled to 4°C, and shipped to the laboratory for analysis. Sampling equipment will be thoroughly cleaned between sampling locations with water from an approved source.
- 4. Sampling equipment will be rinsed and scrubbed with acetone and hexane after the water rinse and allowed to air dry. The acetone and hexane rinses will not be allowed to contaminate the ground or samples.
- 5. If a composite sample is required, a suitable compositing technique, such as that shown in Fig. D-2, will be used. Each composite soil sample will consist of a homogenized composite

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of five subsamples taken within a 10- to 30-ft radius at the selected sampling point. Each point sample taken from the surface to a specified depth should be quartered to approximately 1.0 1b and placed in the sample container.

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6. Mixing of subsamples in the field to form a composite sample should be performed by placing the subsamples in a steel or aluminum tray lined with aluminum foil (dull side up). No plastic should be allowed to contact soil samples requiring organic analysis to avoid phthalate contamination.

D.4.5 SEDIMENT SAMPLING

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- All sediment samples will be collected with a hand piston sampler or other appropriate device.
- After sampling, depth of water at each sampling point will be measured and recorded.
- 3. Sampling equipment will be thoroughly cleaned with water from an approved source and solvent rinsed with acetone and hexane and allowed to air dry.
- Sediment samples will be placed in glass containers with Teflon[®]-lined lids, shipped under ice, and stored at 4°C.

D.4.6 LABORATORY

The Laboratory Task Manager is responsible for implementing the laboratory Quality Control (QC) procedures. The QA Supervisor will monitor the performance of the analysts and the Chemical Analysis Supervisor for implementation of proper QC checks and to final approve all data.

For analyses conducted in this project, the following QC checks will apply:

 At least five standards for standard curve (three standards for organic analyses) [for_GC/MS analyses and metals analyses by inductively coupled argon plasma (ICAP) one calibration

D-17

standard is run and a daily response factor is established after initial calibration],

- 2. Correlation coefficient for curve is greater than 0.995,
- 3. Percent recovery for spikes is within acceptance criteria as described below,
- 4. Samples are within range of standards,
- At least 10 percent of the samples are replicates (except GC/MS).
- 6. At least 5 percent of the samples are spiked, and
- For GC/MS analysis no replicates are analyzed but every sample is spiked with surrogate analytes.

For data generated using standard methods, the acceptance criteria for precision and accuracy is determined as follows:

$$\overline{\mathbf{R}} = \overline{\mathbf{R}'} + 3\mathbf{p}$$

where:

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- R = Average percent recovery from spiked sample data during the run;
- $\overline{\mathbf{R}}'$ = Average percent recovery for the particular analyte as obtained from Tables A, B, and C; and
 - p = Standard deviation (expressed as percent) for the particular analyte.

D.5 DATA ANALYSES AND REPORT REVIEW

Peer review of all deliverable reports and data supporting this project will be performed by technically qualified individuals from each major discipline represented in the particular deliverable. Fig. D-3 is a sample Deliverable Review Form to be used in this project. USAF PLANT 6 08/09/85

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ESE ENVIRONMENTAL SCIENCE

DELIVERABLE REVIEW SHEET

SHORT TITLE: _____

DATE/TIME TO LEAVE ESE:

CLIENT: _

PROPOSAL/PROJECT NUMBER: ______

AUTHOR(S):_____

CLIENT DUE DATE:

DOCUMENT COORDINATOR:

REVIEW CHECKLIST		RE	EQUIRE	D REVII	EW	BY AUTH	W NDIVIDUAL		
REVIEW CHECK U REV	VER SHOULD PLACE INDER APPROPRIATE NEW CATEGORY	I STRUILD FEALE BR APPROPRIATE IN CATEGORY F-FINAL Technical Cai				Tables		Computer	
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APPENDIX E SAFETY PLAN

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APPENDIX E SAFETY PLAN

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This element consists of the activities necessary to ensure the safety of all ESE and subcontractor personnel and the general public during onsite and laboratory activities. This will be done by indoctrination of all personnel in the requirements of the Air Force Plant 6 safety plan prior to site activities and by ensuring that all personnel are adequately trained; provision of adequate safety equipment; medical surveillance for personnel exposed to potentially toxic chemicals; provision for safe, legal sample transport and handling; provision for the safe conduct of field inspections, construction, and well drilling operations; and provision, as necessary, of exclusion areas and decontamination activities to prevent contamination migration impact to onsite personnel, the general public, or the environment.

Principal physical hazards at Air Force Plant 6 during sampling and analysis involve the operation of the drilling rigs, operation of soil boring equipment, and operation of field testing equipment.

Chemical hazards at the site involve the potential inhalation of or skin contact by potentially high levels of chlorinated solvents during the drilling operations and the sampling of ground water. Also, the potential for injection of or skin contact with sediments potentially contaminated with chlorinated solvents and other nonspecific toxic materials is a concern at Air Force Plant 6.

It is anticipated that all sampling will be conducted using Level D protection. Level C protection (full-face canister masks equipped with organic vapor cartridges worn by samplers and drilling crew) will be required in these areas if organic vapors are detected in the atmosphere at breathing level during operations.

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The decontamination assumptions for equipment such as drilling rigs which are costed into the proposed scope include the decontamination between borings or well installations using approved drilling water in an area provided by the Base Civil Engineer. It must be recognized, however, that although the above decontamination activities are considered to be sufficient to prevent hazard to the public health or onsite personnel, regulatory review of the work plan may result in additional requirements. These would impact the time requirement for decontamination of equipment, as well as introducing construction costs for building a separate decontamination wash rack, storage of drill cuttings, and providing for storage, treatment, and testing of the decontamination water. Additional costs would be required for such an upgraded decontamination program.

APPENDIX F MONITORING WELL TEST BORING RECORDS

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		F-2		JOB NUMBER 1124352 Page 2 of 2	





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TEST BORING RECORD 6-INCH CASING STICKUP IS 3 FEET 2-INCH RISER STICKUP IS 2.5 FEET PENETRATION-BLOWS PER FOOT 5 10 15 20 30 40 60 80 100 DEPTH PEET ELEV. DESCRIPTION 1006.4 SOFT TO FIRM RED-BROWN AND BROWN FINE TO COARSE SANDY CLAYEY SILT WITH OCCASIONAL GRAVEL - FILL 1001.4 9.5 996.4 HARD RED FINE TO COARSE SANDY CLAYEY SILT AND FINE TO COARSE <u>GRAVEL - FILL</u> 12.0 FIRM GRAY SLIGHTLY SANDY VERY CLAYEY SILT WITH SOME FINE GRAVEL-991.4 FILL _ 986.4 24.0 981.4 STIFF TO VERY STIFF BROWN AND GRAY MICACEOUS SILTY FINE TO MEDIUM SAND (SM) 976.4 971.4 35.5 BORING TERMINATED 966.4 **REMARKS:** RB 312-2 DRILLED BY BORING NUMBER LOCATION COORDINATES: WGG 2 6 55 LOGGED BY DATE STARTED N 1,422,017 2 0 55 XJB CHECKED BY _ DATE COMPLETED E 393,789 :124352 JOB NUMBER

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86.0											
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		CLAYEY SILTY MICACEOUS FINE TO MEDIUM SAND (SM)									
76.0	14.0	LOOSE TO FINE GRAY, BLACK AND WHITE				 		! _ • • •			
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983.0						•			GS
978.0	14.0	LOOSE TO FIRM GRAY, WHITE, AND BLACK SLIGHTLY SILTY MICACEOUS FINE TO MEDIUM SAND (SM)							
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. APPENDIX G GRAIN SIZE DISTRIBUTION

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ت نس **GRAIN SIZE DISTRIBUTION** CLAY SIZES LAW ENGINEERING TESTING COMPANY 0.001 国 **JOB NO.** MA4352 FINES SILT SIZES 0.01 Silty micaceous fine to medium SAND (SM) 200 0 DESCRIPTION OR CLASSIFICATION **GRAIN SIZE IN MILLIMETERS** FINE U.S. STANDARD SIEVE SIZES 60 100 9 SAND MEDIUM 202 o 2 COARSE **H** FINE 3/8.. ٦ 0 PL GRAVEL 1..3/4.. . BORING NO ELEV. OR DEPTHINAT WC LL COARSE 2: :.... 14.01-10.41 8 COBBLES JEL S BOUE 1001 ò 20 60 20 ġ 50 10 30 ~~ PERCENT FINER BY WEIGHT G-10

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APPENDIX H WELL DEVELOPMENT DATA

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BY DATE 2- 14 - 33	_ ck	AS DAT	TE <u>2 - 28-35</u> SHEET	0F
1. WELL NO G12-1	NELL P	EVELOPMENT	DATA	
2. DATE OF INSTALLATION :	2-4-8	5		
3. DATE OF DEVELOPMENT:	2-14-85			
4. STATIC WATER LEVEL : BI	EFORE DE	ev. <u>6.29</u>	ET ; 24 HOURS AF	TER
5. QUANTITY OF WATER LOSS D	DRING DRI	LING, IF USED	GAL.	
6. QUANTITY OF STANDING WAT	er in wel	L AND ANNU	45 BEFORE DEV.	SAL.
		START	Dyring	END
7. SPECIFIC CONDUCTANCE (UI	nhos/cm)	220		_`
TEMPERATURE (C)		13.0	<u> </u>	
рн (s.u)		56.7	<u> </u>	
9 SCREEN LENGTH 20		22.1		
10. DEPTH TO TOP OF SEDUMENT:	ATER :	In Hally	<u>Driwit /</u> Sucieraid	· · · · · · · · · · · · · · · · · · ·
12. TYPE AND SIZE OF WELL	DEVELOP	ENT EQUIPM	ENT: 100 1 FM	<u> </u>
13 DESCRIPTION OF SURGE TEC	HAIQUE ,	IF USED:	<u>1911 - Tr. L </u>	
14. HEIGHT OF WELL CASING A	BOVE GRO	UND SARFACE	:	<u>F</u> T.
15. QUANTITY OF WATER RE	MOVED:	120	_GAL.	
TIME FOR REMOVAL: _	<u></u>	HR./NU	N.	
16 1 - PINT WATER SAMPLE	E COLLEO	TED:	5;00 (TINE)	
* DEVELOPMENT CONDITIONS:	i) WELL U 2) SEDIMEN 3) REMOVAL	NATTR 13 REAS IT THICKNESS LOF 5 WELL VOL	ONABLY CLEAR 4 590 OF SCREEN LUMES INCLUDING SAT	LENGTH TURATED FILTER ANNUL

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	<u>25 </u> ck <u> </u>	<u>AS 1</u>	DATE 2-28	<u>- 85</u> Sheet	OF	
1. WELL NOG12-2	WELL D	EVELOPMEN	IT DATA			
2. DATE OF INSTALLATION :	2-6-8	5				
3. DATE OF DEVELOPMENT: _	2/13-1	5/85				
4. STATIC WATER LEVEL :	BEFORE DE	ev. 18.32	FT ; 24	Hours AFT	ER	<u> </u>
5. QUANTITY OF WATER LOSS	DURING DRI	LING, IF US	ED	GAL		
6. QUANTITY OF STANDING WA	TER IN WEL	L AND ANN	ulus BEFOR	E DEV		
		START	DURI	140 90L	END ->	r
7. SPECIFIC CONDUCTANCE (umhos/cm)	_600_	<u>4<u></u><u></u><u>4</u><u></u><u></u><u></u><u></u><u>4</u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u><u></u></u>	350	270	-
TEMPERATURE (C)		12.5	1.5	<u> </u>	<u> </u>	
рн (s.u)		8.00	2.20	8.28	1.21	
O DEPTH TO TOP OF SEPIMEN	T: BEFORE	DEV. <u>30</u> .	4 FT,	AFTER DEV	l. <u> </u>	<u>،</u>
IL PHYSICAL CHARACTER OF	WATER : _	Instally	<u></u>	u_/	<u> </u>	
L'ILL FIT FILL	1-1-1-1-2	<u>lear</u>	<u> </u>	· · · · · · ·		
12. TYPE AND SIZE OF WELL 1" TI 12 - 10 p 20	. DEVELOPA <u>- 3/e'' p</u> i	AENT EQU P	menst: _15		<u> </u>	
13 DESCRIPTION OF SURGET	ECHAJIQUE	F USED:	<u></u>	· · · · · · · · · · · · · · · · · · ·		
4 HEIGHT OF WELL CASING	ABOVE GRO	UND SURFAC	# :	31	<u>=</u> T	
	E MOVED :	130	<u></u> A.			
15 QUANTITY OF WATER P	6	:- н г. /1	, MIN.			
IS QUANTITY OF WATER R TIME FOR REMOVAL:	ľ L n					
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	DATE _2.19-	- <u>35</u> ck <u></u>	<u>ts</u> D.	ATE 2-28-85 SHEE	T OF
I. WELL N	0. <u>G12-3</u>	WELL DI	EVELOPMEN	T DATA	
2. DATE OF	INSTALLATION :	2-13-8	5		
3. DATE OF	F DEVELOPMENT:	2-19-85	5		
4. STATIC	WATER LEVEL :	BEFORE DE	v. <u>5.94</u>	ET ; 24 HOURS AF	TER
5. QUANT	ITY OF WATER LOS	S DURING DRIL	LING, IF USE	D GAL	
6. QUANTI	TY OF STANDING V	NATER IN WEL	L AND ANN	LUS BEFORE DEV	G
			START	DURING	END
7. SPECI	FK CONDUCTANCE	E (umhos/cm)	20	125, 130	
TEMPE	ERATURE (C)		11.5	13.0 , 13.3	<u> </u>
рн	(s.u)		7.21	7.7: 7.7%	7.;4
8. DEPTH 9. SCREEN	FROM TOP OF WELL	. САБІЛИЄ ТО ВО	ftom of wel	L 22.92 FT	
8. DEPTH 9. SCREEN 10. DEPTH 11. PHYSIC	FROM TOP OF WELL N LENGTH TO TOP OF SEDIME CAL CITARACTER OF	ET. ENT: BEFORE WATER :	DEV. 18.0 	L 22.92 FT. L FT., AFTER DI L DOWN	en. <u>22.77</u>
8. DEPTH 9. SCREEN 10. DEPTH 11. PHYSIC	FROM TOP OF WELL N LENGTH TO TOP OF SEDIME CAL CITARACTER OF <u>FROMITIES</u> . FIG.	ET. ET. ENT: BEFORE F WATER : ally_clear	DEV. 18.0 	L 22.92 FT. L FT., AFTER DI Brown Brown	ev. <u>22.77</u>
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8. DEPTH 9. SCREEN 10. DEPTH 11. PHYSIC 12. Type 13. Desc. 14. Heigh	FROM TOP OF WELL N LENGTH TO TOP OF SEDIME CAL CITARACTER OF SCALIFICAL OF SEDIME TO TOP OF SURGE TO TOP OF SURGE ODM- PRESSOF HT OF WELL CASING	ET. ENT: BEFORE F WATER : ally <u>alear</u> CL DEVELDPM CE TECHANIQUE, G ABOVE GROUP	DEV. <u>18.0</u> <u>Initally</u> <u>Initally</u> <u>ENT Equip</u> <u>Stastic tu</u> IF USED: <u></u>	$L = \frac{22.94}{\text{FT}}$ $\frac{1}{22.94} \text{FT}$ $\frac{1}{2.94} \text{FT}$ $\frac{1}{2.94} \text{FT}$ $\frac{1}{2.94} \text{FT}$ $\frac{1}{2.94} \text{FT}$	EV. <u>22.77</u>
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2. DATE OF INSTA	ALLATION :	2-15-85	-		
3. DATE OF DEVI	ELOPMENT:	2-18-85/	2-19-85	-	
4. STATIC WAT	TER LEVEL: BE	FORE DEV	7.45	I; 24 Hours 1	FTER
5. QUANTITY OF	WATER LOSS DUP	RING DRILLING	, IF USED	GI	
6. QUANTITY OF	STANDING WATE	e in well Ai	ND ANNUL	us before dev	GAG
		-	START	(30)~ (90 to	END
7. SPECIFIC C	ONDUCTANCE (UM	hos/cm) _1	15	3), 105	12.0
TEMPERATH	RE (C)	16	6.0	,,	13.5
рн (s.u)		6	.97	7.01, 7.01	0.5
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8. DEPTH FROM 9. SCREEN LEN 10. DEPTH TO TH 11. PH ISICAL CH 	N TOP OF WELL CASH IGTHFT OP OF SEDIMENT: HARACTER OF WA ICT SIZE OF WELL D DIC T N OF SURGE TECH PETERC	NG TO BOTTOM BEFORE DEV. TER: TER: TER: TEVELOPMENT TEVELOPMENT HUIQUE, IF US	of WELL <u>22.5</u> <u>Initalio</u> <u>Initalio</u> <u>Initalio</u> <u>Equipmin</u> <u>Fuicing</u>	28.86 FT ET., AFTER U CUCCET DEL ENT: 100 2FT CCASIONALLY 1	DEVF
 B. DEPTH FROM 9. SCREEN LEN 10. DEPTH TO TO 11. PL ISICAL CONSTRUCT 12. TYPE AND S 13. DESCRIPTION 13. DESCRIPTION 14. HEIGHT OF 	N TOP OF WELL CASH IGTHFT OP OF SEDIMENT: HARACTER OF WA ICTFT SIZE OF WELL D DIC F DC N OF SURGE TECH DELL CASING AB	NG TO BOTTOM BEFORE DEV. MER:I <u>MER:I</u> MEVELOPMENT <u>POTTO</u> HAJIQUE, IF US OVE GROUND	of WELL <u>22.5</u> <u>nitali</u> <u>little</u> Equipmi <u>fuci</u> <u>surface</u>	<u>28.86</u> FT <u>FT.</u> , AFTER <u>U. 17</u> <u>CUCD-7021</u> ENT: <u>100</u> <u>2F7</u> <u>CUCCT111</u> <u>2.86</u>	DEVF
8. DEPTH FROM 9. SCREEN LEN 10. DEPTH TO TH 11. PH ISICAL CH 12. TYPE AND S 14. HEIGHT OF 15. QUANTITY	TOP OF WELL CASH IGTH OP OF SEDIMENT: HARACTER OF WAR ICT SIZE OF WELL D DIC T N OF SURGE TECH FIELD CASING ABI OF WATER REA	NG TO BOTTOM BEFORE DEV. TER:	of WELL <u>22.5</u> <u>Initali</u> <u>Initali</u> <u>Equipmin</u> <u>Fugin</u> <u>SED:</u> <u>Initali</u> <u>Surface</u> <u>120</u>	<u>28.86</u> FT <u>FT</u> , AFTER 1 <u>U</u> , 17, A <u>CUCCTOPIC</u> ENT: <u>100 CF</u> <u>U</u> <u>CUCCTOPIC</u> <u>2.86</u> <u>GAL</u> .	DEVF
8. DEPTH FROM 9. SCREEN LEN 10. DEPTH TO TH 11. PH ISICAL CH 12. TYPE AND S 13. DESCRIPTION 13. DESCRIPTION 14. HEIGHT OF 15. QUANTITY TIME FOR	IGTHFT IGTHFT OP OF SEDIMENT: HARACTER OF WA SIZE OF WELL D DIC F CON BLL D DIC F CON BLL D DIC F CON BLL WELL CASING ABING OF WATER REA : REMOVAL :	NG TO BOTTOM BEFORE DEV. MER: MER: MER: MEVELOPMENT GEVELOPMENT GEVELOPMENT GEVELOPMENT GEOUND MOVED: 5 His.	of WELL <u>22.5</u> <u>nitalio</u> <u>little</u> Equipmin <u>fuicing</u> Surface <u>120</u> <u>HR./Nuc</u>	<u>28.86</u> FT FT:, AFTER 1 <u>U 17 A</u> <u>CUCCTTAR</u> ENT: <u>100 CF</u> <u>CUCCTTAR</u> <u>2.86</u> GAL.	DEVF
8. DEPTH FROM 9. SCREEN LEN 10. DEPTH TO TH 11. PHYSICAL CH 12. TYPE AND S 13. DESCRIPTION 13. DESCRIPTION 14. HEIGHT OF 15. QUANTITY TIME FOR 16. I - PINT	N TOP OF WELL CASH IGTHFT OP OF SEDIMENT: HARACTER OF WAR IGT SIZE OF WELL D DIC T CC N OF SURGE TECH DIC CASING AB OF WATER REN : REMOVAL : WATER SAMPLE	NG TO BOTTOM BEFORE DEV. MER: MER: MEVELOPMENT DEVELOPMENT MOVED: COLLECTED	of WELL <u>22.5</u> <u>11112</u> EQUIPMI <u>11112</u> EQUIPMI <u>11112</u> SURFACE <u>120</u> <u>HR./Nue</u>	<u>28.86</u> FT FT., AFTER <u>U</u> <u>CUCCTANE</u> ENT: <u>100</u> <u>2F</u> <u>CUCCTANE</u> <u>2.86</u> <u>GAL</u> <u>100</u> <u>CIME</u>	DEVF
8. DEPTH FROM 9. SCREEN LEN 10. DEPTH TO TO 11. PH ISICAL CH 12. TYPE AND S 11" TRIDO. 13. DESCRIPTION 13. DESCRIPTION 14. HEIGHT OF 15. QUANTITY TIME FOR 16. I - PINT * DEVELOPME	N TOP OF WELL CASH IGTH OP OF SEDIMENT: HARACTER OF WAR ICT SIZE OF WELL D DIC F CONSTITUTES: I WELL CASING AB OF WATER REM CF WATER REM INTER SAMPLE INTER SAMPLE	NG TO BOTTOM BEFORE DEV. MER: MER: MELLOPMENT MOVED: COLLECTED WELL WATTR 2) SEDIMENT TH 3) REMOVAL OF 5	OF WELL 22.5 <u>11the</u> EQUIPMIN <u>FUCI</u> SURFACE <u>120</u> <u>HR./NUE</u> 	<u>28.86</u> FT <u>FT</u> , AFTER I <u>U</u> <u>II</u> <u>II</u> <u>N</u> <u>CUCCTINE</u> <u>CUCCTINE</u> <u>2.86</u> <u>GAL</u> . <u>1.</u> <u>2.86</u> <u>CAL</u> <u>CITINE</u> <u>CAL</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CUCCTINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u> <u>CITINE</u>	DEVF

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SALADAAN SIDINAA SALADAAN SALA

W ENGINEERING	C TESTING COMPANY JOB	NAME	Goco	JOB	NO. 17 -352
KN	DATE 2-15-85	_ CK	<u>45</u> D/	ATE 2-23-35 SHE	ET OF
). WELL 1	NO. <u>65-5</u> W	ELL DI	VELOPMEN	T DATA	
2. DATE O	F INSTALLATION :	2-7-8	5		
3. DATE C	OF DEVELOPMENT:2	-15-85	/2-18-65	-, 2-19-85	
4. STATI	C WATER LEVEL : BE	FORE DE	v34.75	FT ; 24 HOURS A	FTER
5. QUAN	TITY OF WATER LOSS DUP	LING DRIL	LING, IF USE	D GAL	
6. QUANT	ITY OF STANDING WATER	2 IN WEL	L AND ANNU	LUS BEFORE DEV	6
			START	Dyring	END
7. SPEC	IFIC CONDUCTANCE (UM	nos/cm)	30	(<u>@_32)</u> (12)~, 35 (30)	25
TEMP	PERATURE (C)	.,,	15.0	·7.0 17.5	3.5
04			6.83	6.53 6 1	·
9. SCREE 10. DEPTH	N LENGTH <u>20</u> FT	BEFORE	DEN. 50.7	5 ET , AFTER D	ev. <u>- 56.1</u>
и. Рнусі <u>1</u> 2	ICAL CITARACTER OF WA	TER :	<u>clear, cl</u>	ji <u>r dre st</u>	
12. TYPE	AND SIZE OF WELL D HILDL PIC FILE	E VELOPM 3/ 2 11	ENT EQUIPA	NENT :	<u>) () () () () () () () () () () () () ()</u>
13 Dese	ERIPTION OF SURGE TECH	NIQUE , I	F USED:		
14. HEIG	HT OF WELL CASING ABO	VE GROU	NO SURFACE		FT.
15. QUA	NTITY OF WATER REM	INED: _	120	GAL.	
TIM	E FOR REMOVAL:	8	HR./N	1 	
16 1 - Pi	INT UNTER SAMPLE	COLLEC	TED:	1::-) (TIME)	
+ Dev	ELOPMENT CONDITIONS: 1 2 3	س WELL) SEPIMENT DREMOVAL H-5	ATTR 13 READ THICKNESS OF 5 WELL VO	SONABLY CLEAR < 5% OF SCREEN DLUMES (NCLUDING SA	LENGTH THEATED FUTERAN

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VELOPMENT	<u>[[] CATA</u>	· • ·
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v. <u>13.57</u>	FT ; 24 HOURS AF	TER
LING, IF USE	D GAL	
L AND ANNU	LUS BEFORE DEV.	ź
START	DURING	END
<u>240</u>	575,	<u>_675</u>
16.2	17.5 , 7.7	
6.92	- 7.0%, - 7. 5	<u> </u>
DEV. <u>36.15</u> Initall	<u>y brown</u>	v. <u> </u>
<u> </u>	T AdAR.	
ENT EQUIPA		
f used:		
ND SURFACE		<u>FT</u> ,
140	<u>sal</u> .	
	N.	
TED :		
	V. 13.57 LING, IF USE LAND ANNU <u>START</u> <u>240</u> <u>16.7</u> <u>6.92</u> TOM OF WELL DEV. <u>36.1</u> <u>17.7</u> <u>6.92</u> TOM OF WELL DEV. <u>36.1</u> <u>6.1</u> <u>17.7</u> <u>6.92</u> TOM OF WELL <u>17.7</u> <u>6.92</u> TOM OF WELL <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u> <u>17.7</u>	V. <u>13.57</u> FT; 24 HOURS AF LING, IF USED <u>GAL</u> LAND ANNULUS BEFORE DEV. <u>5TART</u> <u>DURING</u> <u>5TART</u> <u>DURING</u> <u>10.0</u> <u>17.5</u> , <u>17.7</u> <u>10.0</u> <u>17.5</u> <u>10.0</u> <u>17.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u> <u>11.5</u>

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APPENDIX I IN SITU PERMEABILITY (SLUG TESTS AND LABORATORY PERMEABILITY RESULTS)

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WELL 2/2	NO. GIZ		3-40an	r r
	WELL C	ONSTAN	TS	-
STATIC	WATER L	EVEL	6.37	FT
R	OR rc=	. 98 29 99	3 FT 0 FT	
POINT	TIME	WATER	& WATER	
NO.	- <u>5</u> 360	LEVEL	LEVEL	
234	0333	4,33 4 46 4 64	1 99* 1.91* 1 73*	
56	2500 3333	4.76	1.61* 1.50*	
9 9	7500	5.16	1.21*	
10 11 12	1.0933 1.2500 1.4167	5.38	99* 94*	
13 14 15	1 5333 1.7500 1.9167	5,49 5,54 5,59	.88× .83× .73×	
16 17 18	2.0000 2.5 3.0	5.61 5.72 5.81	.76* 65* .56*	
19 20	3.5	5.39 5.95 6.88	. 48# . 42* . 37*	
22	5 8	6.04	.33× .29× .24×	
25	7.5	6.17 6.20	20	
23	14.0	6.29	.03	
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		_	FFF B	
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HYD	RAULIC	CONDUC	TIVITY	
	NAV	-D0CK		
×	 (=3 17E-	 004 FT	-MIN	

STATIC WA R OI	ATER LE R rc= L=	VEL .083 20.000	6.37 FT FT	۶Ť
POINT NO.	TIME	WATER LEVEL	A WATER	
1 2 3 4 5 6 7 8 9 9 10 11 12 13 14 15 16 7 18 20 22 23 26 27	$\begin{array}{c} 0.267\\ 0.2633\\ 0.500\\ 2.167\\ 3.0067\\ 1.5330\\ 0.567\\ 3.0067\\ 1.5330\\ 0.56330\\ 1.65330\\ 1.556330\\ 2.5\\ 3.0067\\ 1.25067\\ 3.0067\\ 1.25067\\ 3.000\\ 5.5\\ 0.00\\ 5.5\\ 0.00\\ 0.00\\ 1.4\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\ 0\\$			
. 91		ү/ү0 © 1		1. Ø
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5 10 15 Time(min)		+ 0000000 + +		
20				

WELL NO. G12-1 SLUG OUT

WELL CONSTANTS

9:10am

2/22/85

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12222255

HYDRAULIC CONDUCTIVITY ------NAV-DOCK -----

K=3.48E-004 FT/MIN K=1 77E-004 CM/SEC

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2/4	22/8	5		10-00am
•	WE	LL CON	STANT	3
STATIC R	WAT OR	ER LEV	EL .083	5.24 FT FT
		L= 1	5.000	FT
r -	NO.	- 10E	LEVEL	2 78#
	234	0567 1000 1500	2.68 3.01 3.07	2 56# 2 23# 2 17#
	5673	2009 2509 3167 4167	3.13 3.19 3.24 3.38	2.118 2 068 2 098 1 948
	9 10 11	5933 7500 9167	3.38 3.45 3.50	1 36# 1 79# 1 74#
	12	1 9833 1 3333 1 5833 1 8333	3.56 3.63 3.69 3.75	1 68# 1.61# 1 55# 1 49#
	16 17 19	2 8880 2 5 3 8	3 79 3 89 3 98	1 46¥ 1.35× 1.26×
	19 20 21 22	3.5 4.0 4.5 5.0	4 86 4 14 4 21 4 27	1 18# 1 10# 1 03# 97#
	23 24 25	55	4 33 4 39 4 45	318 858 798
	27 29 29	75 80 8.5	4 55 4 59 4 63	698 638 618
	30 31 32	9 8 9 5 12 8	4 67 4 71 4 86	57* 53* 38*
	34 35 36	16 0 20 0 24 0	5.03 5.14 5.21	21% 10* 03
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WELL NO. 65-6 SLUG OUT

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## 2/22/85 4-30pm

## WELL CONSTRNTS

## STATIC WATER LEVEL 13 08 FT R OR rc= .083 FT L= 20.000 FT

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## APPENDIX J CHAIN-OF-CUSTODY DOCUMENTATI N

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 APPENDIX K ANALYTICAL RESULTS FOR GROUND WATER AND SOILS Ê

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PROJECT NAME GOCO PLANT 6 Project Manager: Rick Neff Field Group Leader: D. Victor

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APPENDIX L ANALYTICAL METHODS, DETECTION LIMITS, AND QUALITY CONTROL DATA SUMMARY

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Standard Methods for the Examination of Water and Wastewater, 16th ed. 1985, Sample has been extracted for EP Toxicity according to method No. 1310 Water and Wastes, EPA 600/4-79-020, Wastewater, EPA 600/4-82-057, July 1982, modified for use with soil. Test methods for Evaluating Solid Waste, SW-846, 2nd ed., July 1982, Test Methods for evaluating Solid Waste, SW-846, 2nd ed. July 1982. Methods for Organic Chemical Analysis of Municipal and Industrial modified for use on 0.1. Comp. Model 610 TOX Analysis with soil. The low recovery was checked by reanalysis and confirmed. revised in March 1983, modified for use with soil published in E.P.A. Publication No. SW-846. Results not corrected for recent moisture. modified for use with soil samples. Methods for Chemical Analysis of A matrix effect is suspected.

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The analytical technique between the Methods published in EPA-SW-R46. 600/4-79-020, and Standard Methods 16th ed. are the same. EPA

Denotes Value less than the limit of detection.

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Denotes the sample was not ignitable.



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MONITORING, MISCELLANEOUS Total and Ammable Cyanide

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*Sample preservation should be performed immediately upon sample collection. For composite chemical samples each aliquot should be preserved at the time of collection. When use of an automated sampler and samples optimes to be preserved at the time of collection. When use of an automated sampler and samples optimes to be preserved at the time of collection. When use of an automated sampler period by component care or sert through the United States Mail, it must compositive and "Transportation Hizzhous Maternation (49 CFR Pert 172). The person othering such material for transportation is responsible for ensuing such complexiton. For the preservation requerements of Table II, the Office of Hazardus Maternation and composition and comparised on the following maternatic Hydrochort scate (HCQ) in wester solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater). Nitic acid (HMQ) in wester solutions at concentrations of 0.04% by weight or less (pH about 1.96 or greater). Nitic acid (HMQ) in wester solutions at concentrations of 0.05% by weight or less (pH about 1.20 or isse). "Samples should be analyzed as soon as possible effort about 1.20 or isses). "Samples should be analyzed as soon as possible effort about 1.20 or isses). "Samples should be onelyzed as soon as possible effort collection. The times letted are the maximum times that samples may be held before analyzed as soon as possible effort collection. The times letted are the maximum times that samples under study are stable for the longer time, and has recovered a venerice for a horder time if throwing exists to show that this is necessary to maximum times bearing and great at the maximum held of longer periods only if the periods of longer. "Singled only be used in the present, collection." "Interview of the maximum times beating the stable, so are stable for the inservate or maxima and periods the interview stable is the ensure as soon as porter time. An ensure those thold the analyse of reacting and theme the tended of thome that

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sorres,... 14 12-dephanylhydrazane is likely to be present, adjust the pH of the sample to  $4.0\pm0.2$  to pn "Extends may be stored up to 7 days before analysis if storage is conducted under an mart ( "For the analysis of dephanylmbroasmes, add 0.008% Na,S,C), and adjust pH to 7-10 with N "The pH adjustment may be performed upon receipt at the laboratory and may be omitted if it 72 hours of collection. For the analysis of aldrin, add 0.008%

8. Appendices A, B, and C are added to Part 136 to read as follows:

APPENDIX A TO PART 136-METHODS FOR ORGANIC CHEMICAL ANALYSIS OF MUNICIPAL AND INDUSTRIAL WASTEWATER.

### Method 601-Purgeable Halocarbone

1. Scope and Application

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1.1 This method covers the determination of 29 purgeable halocarbons.

The following parameters may be

determined by this method:

Peramotar	No.	CAS No.
Bramadichiaramethene	32101	75-27-4
Bromotorm	32104	75-25-2
Bromomethene	34412	74-63-0
Carbon tetrachioride	32102	56-23-6
Chiorobeneene	34301	108-00-7
Chicrosthere	34311	75-00-3
2-Chloroethylvinyl ether	34676	100-75-8
Chierolom	32106	67-66-3
Chioromethane	34418	74-87-3
Obromochioromethene	32106	124-48-1
1,2-Olchioroberzene	34536	96-50-1
1,3-Dichlorobenzene	34666	541-73-1
1,4-Dichlorobenzene	34571	106-46-7
Dichlorodifuoromethene	34666	75-71-8
1,1-Dichierosthens	34486	75-34-3
1,2-Dichloroethene	34531	107-06-2
1,1-Dichloroethene	34501	75-36-4
trans-1,2-Olchiorosthere	34546	156-60-5
1,2-Dichloropropene	34541	78-47-5
ce-1,3-Olchieropropene	34704	10081-01-6
trans-1,3-Olchioropropens	34666	10061-02-6
Methylana chiorida	34423	75-08-2
1,1,2,2-Tetrachioroethane	34616	78-34-5
Tetrachloroethene	34475	127-18-4
1,1,1-Trichloroethene	34606	71-55-6
1,1,2-Trichloroethane	34611	78-00-6
Tetrachioroethene	39160	78-01-6
Terichiorofiuoromethene	34488	75-88-4
Vinyl chlonde	30715	75-01-4

1.2 This is a purge and trap gas chromatographic (GC) method applicable to the determination of the compounds listed above in municipal and industrial discharges as provided under 40 CFR 136.1. When this method is used to analyze unfamiliar samples for any or all of the compounds above. compound identifications should be supported by at least one additional qualitative technique. This method describes analytical conditions for a second gas chromatographic column that can be used to confirm measurements made with the

primary column. Method 624 provides gas chromatograph/mass spectrometer (GC/MS) conditions appropriate for the qualitative and quantitative confirmation of results for most of the parameters listed above.

1.3 The method detection limit (MDL. defined in Section 12.1) ¹ for each parameter is listed in Table 1. The MDL for a specific wastewater may differ from those listed, depending upon the nature of interferences in the sample matrix.

1.4 Any modification of this method. beyond those expressly permitted, shall be considered as a major modification subject to application and approval of alternate test procedures under 40 CFR 136.4 and 136.5.

1.5 This method is restricted to use by or under the supervision of analysts experienced in the operation of a purge and trap system and a gas chromatograph and in the interpretation of gas chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method using the procedure described in Section 8.2.

### 2. Summary of Method

2.1 An inert gas is bubbled through a 5mL water sample contained in a speciallydesigned purging chamber at ambient temperature. The halocarbons are efficiently transferred from the aqueous phase to the vapor phase. The vapor is swept through a sorbent trap where the halocarbons are trapped. After purging is completed, the trap is heated and backflushed with the inert gas to desorb the halocarbons onto a gas chromatographic column. The gas chromatograph is temperature programmed to separate the halocarbons which are then detected with a halide-specific detector. 2.3

2.2 The method provides an optional gas chromatographic column that may be helpful in resolving the compounds of interest from interferences that may occur.

### 3. Interferences

3.1 Impurities in the purge gas and organic compounds outgassing from the plumbing ahead of the trap account for the majority of contamination problems. The analytical system must be demonstrated to be free from contamination under the conditions of the analysis by running laboratory reagent blanks as described in Section 8.1.3. The use of non-Teflon plastic tubing, non-Teflon thread sealants, or flow controllers with rubber components in the purge and trap system should be avoided.

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3.2 Samples can be contaminated by diffusion of volatile organics (particularly fluorocarbons and methylene chloride) through the septum seal into the sample during shipment and storage. A field reagent blank prepared from reagent water and carried through the sampling and handling protocol can serve as a check on such contamination.

3.3 Contamination by carry-over can occur whenever high level and low level samples are sequentially analyzed. To reduce carry-over, the purging device and sample syringe must be rinsed with reagent water between sample analyses. Whenever an unusually concentrated sample is encountered, it should be followed by an analysis of reagent water to check for cross contamination. For samples containing large amounts of water-soluble materials. suspended solids, high boiling compounds or high organohalide levels, it may be necessary to wash out the purging device with a detergent solution, rinse it with distilled water, and then dry it in a 105°C oven between analyses. The trap and other parts of the system are also subject to contamination; therefore, frequent bakeout and purging of the entire system may be required.

### 4. Safety

4.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined; however, each chemical compound should be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material data handling sheets should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety are available and have been identified ** for the information of the analyst.

4.2 "The following parameters covered by this method have been tentatively classified as known or suspected, human or mammalian carcinogens: carbon tetrachloride. chloroform. 1.4-dichlorobenzene. and vinyl chloride. Primary standards of these toxic compounds should be prepared in a hood. A NIOSH/MESA approved toxic gas respirator should be worn when the analyst handles high concentrations of these toxic compounds

### 5. Apparatus and Materials

5.1 Sampling equipment, for discrete sampling. 5.1.1 Vial-25-mL capacity or larger.

5.1.1 Vial-25-mL capacity or larger. equipped with a screw cap with a hole in the center (Pierce #13075 or equivalent). Detergent wash, rinse with tap and distilled water, and dry at 105 °C before use.

5.1.2 Septum—Teflon-faced silicone (Pierce #12722 or equivalent). Detergent wash, rinse with tap and distilled water, and dry at 105 °C for 1 h before use.

5.2 Purge and trap system—The purge and trap system consists of three separate pieces of equipment: a purging device, trap, and desorber. Several complete systems are now commercially available.

5.2.1 The purging device must be designed to accept 5-mL samples with a water column at least 3 cm deep. The gaseous head space between the water column and the trap must have a total volume of less than 15 mL. The purge gas must pass through the water column as finely divided bubbles with a diameter of less than 3 mm at the origin. The purge gas must be introduced no more than 5 mm from the base of the water column. The purging device illustrated in Figure 1 meets these design criteria.

5.2.2 The trap must be at least 25 cm long and have an inside diameter of at least 0.105 in. The trap must be packed to contain the following minimum lengths of adsorbents: 1.0 cm of methyl silicone coated packing (Section 6.3.3), 7.7 cm of 2.6-diphenylene oxide polymer (Section 6.3.2), 7.7 cm of silica gel (Section 6.3.4), 7.7 cm of coconut charcoal (Section 6.3.1). If it is not necessary to analyze for dichlorodifluoromethane, the charcoal can be eliminated, and the polymer section lengthened to 15 cm. The minimum specifications for the trap are illustrated in Figure 2.

5.2.3 The desorber must be capable of rapidly heating the trap to 180 °C. The polymer section of the trap should not be heated higher than 180 °C and the remaining sections should not exceed 200 °C. The desorber illustrated in Figure 2 meets these design criteris.

5.2.4 The purge and trap system may be assembled as a separate unit or be coupled to a gas chromatograph as illustrated in Figures 3 and 4.

5.3 Gas chromatograph—An analytical system complete with a temperature programmable gas chromatograph suitable for on-column injection and all required accessories includir q syringes, analytical columns, gases, detector, and strip-chart recorder. A data system is recommended for measuring peak areas.

5.3.1 Column 1-8 ft long x 0.1 in ID stainless steel or glass, packed with 1% SP-1000 on Carbopack B (60/80 mesh) or equivalent. This column was used to develop the method performance statements in Section 12. Guidelines for the use of alternate column packings are provided in Section 10.1.

5.3.2 Column 2---6 ft long x 0.1 in. ID stainless steel or glass, packed with chemically bonded n-octane on Porasil-C (100/120 mesh) or equivalent.

5.3.3 Detector—Electrolytic conductivity or microcoulometric detector. These types of detectors have proven effective in the analysis of wastewaters for the parameters listed in the scope (Section 1.1). The electrolytic conductivity detector was used to develop the method performance statements in Section 12. Guidelines for the use of alternate detectors are provided in Section 10.1.

5.4 Syringes—S-mL glass hypodermic with Luerlok tip (two each), if applicable to the purging device.

5.5 Micro syringes-25-µL, 0.006 in. ID needle.

5.6 Syringe valve-2-way, with Luer ends (three each).

5.7 Syringe-5-mL gas-tight with shut-off valve.

5.8 Bottle-15-mL screw-cap, with Teflon cap liner.

5.9 Balance—Analytical, capable of accurately weighing 0.0001 g.

### 6. Reagents

6.1 Reagent water—Reagent water is defined as a water in which an interferent is not observed at the MDL of the parameters of interest.

6.1.1 Reagent water can ge generated by passing tap water through a carbon filter bed containing about 1 lb of activated carbon (Filtrasorb-300, Calgon Corp., or equivalent).

6.1.2 A water purification system (Millipore Super-Q or equivalent) may be used to generate reagent water.

6.1.3 Reagent water may also be prepared by boiling water for 15 min. Subsequently, while maintaining the temperature at 90 °C, bubble a contaminant-free inert gas through the water for 1 h. While still hot, transfer the water to a narrow mouth screw-cap bottle and seal with a Teflon-lined septum and cap.

6.2 Sodium thiosulfate—(ACS) Granular. 6.3 Trap Materials:

6.3.1 Coconul charcoal—6/10 mesh sieved to 26 mesh. Barnebey Cheney, CA-580-26 lot # M-2649 or equivalent.

6.3.2 2,6-Diphenylene oxide polymer-Tenax. (60/80 mesh). chromatographic grade or equivalent.

6.3.3 Methyl silicone packing-3% OV-1 on Chromosorb-W (60/80 mesh) or equivalent.

6.3.4 Silica gel—35/60 mesh. Davison. grade-15 or equivalent.

6.4 Methanol—Pesticide quality or equivalent.

6.5 Stock standard solutions—Stock standard solutions may be prepared from pure standard materials or purchased as certified solutions. Prepare stock standard solutions in methanol using assayed liquids or gases as appropriate. Because of the toxicity of some of the organohalides, primary dilutions of these materials should be prepared in a hood. A NIOSH/MESA approved toxic gas respirator should be used when the analyst handles high concentrations of such materials.

6.5.1 Place about 9.8 mL of methanol into a 10-mL ground glass stoppered volumetric flask. Allow the flask to stand, unstoppered, for about 10 min or until all alcohol wetted surfaces have dried. Weigh the flask to the nearest 0.1 mg.

6.5.2 Add the assayed reference material: 6.5.2.1 Liquid—Using a 100  $\mu$ L syringe. immediately add two or more drops of assayed reference material to the flask, then reweigh. Be sure that the drops fall directly into the alcohol without contacting the neck of the flask.

6.5.2.2 Gases—To prepare standards for any of the six halocarbons that boil below 30 °C (bromomethane, chlorodifluoromethane, trichlorofluoromethane, vinyl chloride), fill a 5-mL valved gas-tight syringe with the reference standard to the 5.0-mL mark. Lower the needle to 5 mm above the methanol meniscus. Slowly introduce the reference standard above the surface of the liquid (the heavy gas will rapidly dissolve into the methanol).

6.5.3 Reweigh, dilute to volume, stopper, then mix by inverting the flask several times. Calculate the concentration in  $\mu g/\mu L$  from the net gain in weight. When compound purity is assayed to be 96% or greater, the weight can be used without correction to calculate the concentration of the stock standard. Commercially prepared stock standards can be used at any concentration if they are certified by the manufacturer or by an independent source.

6.5.4 Transfer the stock standard solution into a Teflon-sealed screw-cap bottle Store, with minimal headspace, at -10 to -20 °C and protect from light.

6.5.5 Prepare fresh standards weekly for the six gases and 2-chloroethylvinyl ether. All other standards must be replaced after one month, or sooner if comparison with check standards indicates a problem.

6.6 Secondary dilution standards—Using stock standard solutions, prepare secondary dilution standards in methanol that contain the compounds of interest, either singly or mixed together. The secondary dilution standards should be prepared at concentrations such that the aqueous calibration standards prepared in Sections 7.3.1 or 7.4.1 will bracket the working range of the analytical system. Secondary dilution standards should be stored with minimal headspace and should be checked frequently for signs of degradation or evaporation. especially just prior to preparing calibration standards from them.

6.7 Quality control check sample concentrate—See Section 8.2.1

### 7 Calibration

7.1 Assemble a purge and trap system that meets the specifications in Section 5.2 Condition the trap overnight at 180 °C by backflushing with an inert gas flow of at least 20 mL/min. Condition the trap for 10 min once daily prior to use.

7.2 Connect the purge and trap system to a gas chromatograph. The gas chromatograph must be operated using temperature and flow

rate conditions equivalent to those given in Table 1. Calibrate the purge and trap-gas chromatographic system using either the external standard technique (Section 7.3) or the internal standard technique (Section 7.4). 7.3 External standard calibration procedure:

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7.3.1 Prepare calibration standards at a miminum of three concentration levels for each parameter by carefully adding 20.0 µL of one or more secondary dilution standards to 100, 500, or 1000 mL of reagent water. A 25-µL syringe with a 0.006 in. ID needle should be used for this operation. One of the external standards should be at a concentration near. but above, the MDL (Table 1) and the other concentrations should correspond to the expected range of concentrations found in real samples or should define the working range of the detector. These aqueous standards can be stored up to 24 h, if held in sealed vials with zero headspace as described in Section 9.2. If not so stored, they must be discarded after 1 h.

7.3.2 Analyze each calibration standard according to Section 10, and tabulate peak height or area responses versus the concentration in the standard. The results can be used to prepare a calibration curve for each compound. Alternatively, if the ratio of response to concentration (calibration factor) is a constant over the working range (<10% relative standard deviation, RSD), linearity through the origin can be assumed and the average ratio or calibration factor can be used in place of a calibration curve.

7.4 Internal standard calibration procedure—To use this approach, the analyst must select one or more internal standards that are similar in analytical behavior to the compounds of interest. The analyst must further demonstrate that the measurement of the internal standard is not affected by method or matrix interferences. Because of these limitations, no internal standard can be suggested that is applicable to all samples. The compounds recommended for use as surrogate spikes in Section 8.7 have been used successfully as internal standards, because of their generally unique retention times.

7.4.1 Prepare calibration standards at a minimum of three concentration levels for each parameter of interest as described in Section 7.3.1.

7.4.2 Prepare a spiking solution containing each of the internal standards using the procedures described in Sections 6.5 and 6.6. It is recommended that the secondary dilution standard be prepared at a concentration of 15  $\mu$ g/mL of each internal standard compound. The addition of 10  $\mu$ L of this standard to 5.0 mL of sample or calibration standard would be equivalent to 30  $\mu$ g/L

7.4.3 Analyze each calibration standard according to Section 10, adding 10  $\mu$ L of internal standard spiking solution directly to the syringe (Section 10.4). Tabulate peak height or area responses against concentration for each compound and internal standard, and calculate response factors (RF) for each compound using Equation 1.

Equation 1.

$$RF = \frac{(A_s)(C_{ts})}{(A_{ts})(C_s)}$$

where:

- A.=Response for the parameter to be measured.
- Au=Response for the internal standard. Cu=Concentration of the internal standard.
- C.=Concentration of the parameter to be measured.

If the RF value over the working range is a constant (<10% RSD), the RF can be assumed to be invariant and the average RF can be used for calculations. Alternatively, the results can be used to plot a calibration curve of response ratios.  $A_a/A_{\mu\nu}$  vs. RF.

7.5 The working calibration curve, calibration factor, or RF must be verified on each working day by the measurement of a QC check sample.

7.5.1 Prepare the QC check sample as described in Section 8.2.2.

7.5.2 Analyze the QC check sample according to Section 10.

7.5.3 For each parameter, compare the response (Q) with the corresponding calibration acceptance criteria found in Table 2. If the responses for all parameters of interest fall within the designated ranges, analysis of actual samples can begin. If any individual Q falls outside the range, proceed according to Section 7.5.4.

Note: The large number of parameters in Table 2 present a substantial probability that one or more will not meet the calibration acceptance criteria when all parameters are analyzed.

7.5.4 Repeat the test only for those parameters that failed to meet the calibration acceptance criteria. If the response for a parameter does not fall within the range in this second test, a new calibration curve, calibration factor, or RF must be prepared for that parameter according to Section 7.3 or 7.4. & Quality Control

8.1 Each laboratory that uses this method is required to operate a formal quality control program. The minimum requirements of this program consist of an initial demonstration of laboratory capability and an ongoing analysis of spiked samples to evaluate and document data quality. The laboratory must maintain records to document the quality of data that is generated. Ongoing data quality checks are compared with established performance criteria to determine if the results of analyses meet the performance characteristics of the method. When results of sample spikes indicate atypical method performance, a quality control check standard must be analyzed to confirm that the measurements were performed in an incontrol mode of operation.

8.1.1 The analyst must make an initial, one-time, demonstration of the ability to generate acceptable accuracy and precision with this method. This ability is established as described in Section 8.2.

8.1.2 In recognition of advances that are occurring in chromatography, the analyst is permitted certain options (detailed in Section 10.1) to improve the separations or lower the cost of measurements. Each time such a

modification is made to the method, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 Each day, the analyst must analyze a reagent water blank to demonstrate that interferences from the analytical system are under control.

8.1.4 The laboratory must, on an ongoing basis, spike and analyze a minimum of 10% of all samples to monitor and evaluate laboratory data quality. This procedure is described in Section 8.3.

8.1.5 The laboratory must, on an ongoing basis, demonstrate through the analyses of quality control check standards that the operation of the measurement system is in control. This procedure is described in Section 8.4. The frequency of the check standard analyses is equivalent to 10% of all samples analyzed but may be reduced if spike recoveries from samples (Section 8.3) meet all specified quality control criteria.

8.1.6 The laboratory must maintain performance records to document the quality of data that is generated. This procedure is described in Section 3.5.

8.2 To establish the ability to generate acceptable accuracy and precision, the analyst must perform the following operations.

8.2.1 A quality control (QC) check sample concentrate is required containing each parameter of interest at a concentration of 10  $\mu g/mL$  in methanol. The QC check sample concentrate must be obtained from the U.S. **Environmental Protection Agency**, **Environmental Monitoring and Support** Laboratory in Cincinnati, Ohio, if available. If not available from that source, the QC check sample concentrate must be obtained from another external source. If not available from either source above, the OC check sample concentrate must be prepared by the laboratory using stock standards prepared independently from those used for calibration.

8.2.2 Prepare a QC check sample to contain 20 µg/L of each parameter by sdding 200 µL of QC check sample concentrate to 100 mL of reagent water.

8.2.3 Analyze four 5-mL aliquots of the well-mixed QC check sample according to Section 10.

8.2.4 Calculate the average recovery  $(\bar{X})$  in  $\mu g/L$ , and the standard deviation of the recovery (s) in  $\mu g/L$  for each parameter of interest using the four results.

8.2.5 For each parameter compare s and  $\hat{X}$  with the corresponding acceptance criteria for precision and accuracy, respectively, found in Table 2. If s and  $\hat{X}$  for all parameters of interest meet the acceptance criteria, the system performance is acceptable and analysis of actual samples can begin. If any individual  $\hat{X}$  falls outside the range for accuracy, then the system performance is unacceptable for that parameter.

Note: The large number of parameters in Table 2 present a substantial probability that one or more will fail at least one of the acceptance criteria when all parameters are analyzed.

8.2.6 When one or more of the parameters tested fail at least one of the acceptance

criteria, the analyst must proceed according to Section 8.2.6.1 or 8.2.8.2.

8.2.6.1 Locate and correct the source of the problem and repeat the test for all parameters of interest beginning with Section 8.2.3.

8.2.6.2 Beginning with Section 8.2.3, repeat the test only for those parameters that failed to meet criteria. Repeated failure, however, will confirm a general problem with the measurement system. If this occurs, locate and correct the source of the problem and repeat the test for all compounds of interest beginning with Section 8.2.3.

8.3 The laboratory must, on an ongoing basis, spike at least 10% of the samples from each sample site being monitored to assess accuracy. For laboratories analyzing one to ten samples per month, at least one spiked sample per month is required.

8.3.1 The concentration of the spike in the sample should be determined as follows:

8.3.1.1 If, as in compliance monitoring, the concentration of a specific parameter in the sample is being checked against a regulatory concentration limit, the spike should be at that limit or 1 to 5 times higher than the background concentration determined in Section 8.3.2, whichever concentration would be larger.

8.3.1.2 If the concentration of a specific parameter in the sample is not being checked against a limit specific to that parameter, the spike should be at 20  $\mu$ g/L or 1 to 5 times higher than the background concentration determined in Section 8.3.2, whichever concentration would be larger.

8.3.2 Analyze one 5-mL sample aliquot to determine the background concentration (B) of each parameter. If necessary, prepare a new QC check sample concentrate (Section 8.2.1) appropriate for the background concentrations in the sample. Spike a second 5-mL sample aliquot with 10  $\mu$ L of the QC check sample concentrate and analyze it to determine the concentration after spiking (A) of each parameter. Calculate each percent recovery (P) as 100(A-B)%/T, where T is the known true value of the spike.

8.3.3 Compare the percent recovery (P) for each parameter with the corresponding QC acceptance criteria found in Table 2. These acceptance criteria were calculated to include an allowance for error in measurement of both the background and spike concentrations, assuming a spike to background ratio of 5:1. This error will be accounted for to the extent that the analyst's spike to background ratio approaches 5:1.' If spiking was performed at a concentration lower than 20  $\mu$ g/L, the analyst must use either the QC acceptance criteria in Table 2. or optional QC acceptance criteria calculated for the specific spike concentration. To calculate optional acceptance criteria for the recovery of a parameter. (1) Calculate accuracy (X') using the equation in Table 3. substituting the spike concentration (T) for C: (2) calculate overall precision (S') using the equation in Table 3. substituting X' for  $\hat{X}$ ; (3) calculate the range for recovery at the spike concentration as (100 X'/T)±2.44(100 S'/ T)%.'

8.3.4 If any individual P falls outside the designated range for recovery, that parameter has failed the acceptance criteria. A check

### standard containing each parameter that failed the criteria must be analyzed as described in Section 8.4.

8.4 If any parameter fails the acceptance criteria for recovery in Section 8.3, a QC check standard containing each parameter that failed must be prepared and analyzed.

Note: The frequency for the required analysis of a QC check standard will depend upon the number of parameters being simultaneously tested, the complexity of the sample matrix, and the performance of the laboratory. If the entire list of parameters in Table 2 must be measured in the sample in Section 8.3, the probability that the analysis of a QC check standard will be required is high. In this case the QC check standard should be routinely analyzed with the spiked sample.

8.4.1 Prepare the QC check standard by adding 10 µL of QC check sample concentrate (Sections 8.2.1 or 8.3.2) to 5 mL of reagent water. The QC check standard needs only to contain the parameters that failed criteria in the test in Section 8.3.

8.4.2 Analyze the QC check standard to determine the concentration measured (A) of each parameter. Calculate each percent recovery ( $P_a$ ) as 100 (A/T)%, where T is the true value of the standard concentration.

8.4.3 Compare the percent recovery (P,) for each parameter with the corresponding QC acceptance criteria found in Table 2. Only parameters that failed the test in Section 8.3 need to be compared with these criteria. If the recovery of any such parameter falls outside the designated range, the laboratory performance for that parameter is judged to be out of control, and the problem must be immediately identified and corrected. The analytical result for that parameter in the unspiked sample is suspect and may not be reported for regulatory compliance purposes.

8.5 As part of the QC program for the laboratory, method accuracy for wastewater samples must be assessed and records must be maintained. After the analysis of five spiked wastewater samples as in Section 8.3, calculate the average percent recovery (P) and the standard deviation of the percent recovery (s_p). Express the accuracy assessment as a percent recovery interval from  $P - 2s_p$  to  $P + 2s_p$ . If p = 90% and  $s_p = 10\%$ , for example, the accuracy interval is expressed as 70-110%. Update the accuracy assessment for each parameter on a regular basis (e.g. after each five to ten new accuracy measurements).

8.6 It is recommended that the laboratory adopt additional quality assurance practices for use with this method. The specific practices that are most productive depend upon the needs of the laboratory and the nature of the samples. Field duplicates may be analyzed to assess the precision of the environmental measurements. When doubt exists over the identification of a peak on the chromatogram, confirmatory techniques such as gas chromatography with a dissimilar column, specific element detector, or mass spectrometer must be used. Whenever possible, the laboratory should analyze standard reference materials and participate in relevant performance evaluation studies.

8.7 The analyst should monitor both the performance of the analytical system and the

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effectiveness of the method in dealing with each sample matrix by spiking each sample. standard, and reagent water blank with surrogate halocarbons. A combination of bromochloromethane, 2-bromo-1chloropropane, and 1,4-dichlorobutane is recommended to encompass the range of the temperature program used in this method. From stock standard solutions prepared as in Section 6.5, add a volume to give 750 µg of each surrogate to 45 mL of reagent water contained in a 50-mL volumetric flask, mix and dilute to volume for a concentration of 15 ng/µL. Add 10 µL of this surrogate spiking solution directly into the 5-mL syringe with every sample and reference standard analyzed. Prepare a fresh surrogate spiking solution on a weekly basis. If the internal standard calibration procedure is being used. the surrogate compounds may be added directly to the internal standard spiking solution (Section 7.4.2).

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### 9. Sample Collection, Preservation, and Handling

9.1 All samples must be iced or refrigerated from the time of collection until analysis. If the sample contains free or combined chlorine, add sodium thiosulfate preservative (10 mg/40 mL is sufficient for up to 5 ppm Cl₂) to the empty sample bottle just prior to shipping to the sampling site. EPA Methods 330.4 and 330.5 may be used for measurement of residual chlorine.⁴ Field test kits are available for this purpose.

9.2 Grab samples must be collected in glass containers having a total volume of at least 25 mL. Fill the sample bottle just to overflowing in such a manner that no air bubbles pass through the sample as the bottle is being filled. Seal the bottle so that no air bubbles are entrapped in it. If preservative has been added, shake vigorously for 1 min. Maintain the hermetic seal on the sample bottle until time of analysis.

9.3 All samples must be analyzed within 14 days of collection.³

### 10. Procedure

10.1 Table 1 summarizes the recommended operating conditions for the gas chromatograph. Included in this table are estimated retention times and MDL that can be achieved under these conditions. An example of the separations achieved by Column 1 is shown in Figure 5. Other packed columns, chromatographic conditions, or detectors may be used if the requirements of Section 8.2 are met.

10.2 Calibrate the system daily as described in Section 7.

10.3 Adjust the purge gas (nitrogen or helium) flow rate to 40 mL/min. Attach the trap inlet to the purging device, and set the purge and trap system to purge (Figure 3). Open the syringe valve located on the purging device sample introduction needle.

10.4 Allow the sample to come to ambient temperature prior to introducing it to the syringe. Remove the plunger from a 5-mL syringe and attach a closed syringe valve. Open the sample bottle (or standard) and carefully pour the sample into the syringe barrel to just short of overflowing. Replace the syringe plunger and compress the sample. Open the syringe valve and vent any residual

air while adjusting the sample volume to 5.0 mL. Since this process of taking an aliquot destroys the validity of the sample for future analysis, the analyst should fill a second syringe at this time to protect against possible loss of data. Add 10.0  $\mu$ L of the surrogate spiking solution (Section 8.7) and 10.0  $\mu$ L of the internal standard spiking solution (Section 7.4.2), if applicable, through the valve bore, then close the valve.

10.5 Attach the syringe-syringe valve assembly to the syringe valve on the purging device. Open the syringe valves and inject the sample into the purging chamber. 10.6 Close both valves and purge the

simple for  $11.0\pm0.1$  min at ambient temperature.

10.7 After the 11-min purge time, attach the trap to the chromatograph, adjust the purge and trap system to the desorb mode (Figure 4), and begin to temperature program the gas chromatograph. Introduce the trapped materials to the GC column by rapidly heating the trap to 180 °C while backflushing the trap with an inert gas between 20 and 60 mL/min for 4 min. If rapid heating of the trap cannot be achieved, the GC column must be used as a secondary trap by cooling it to ::0 °C (subambient temperature, if poor peak geometry or random retention time problems persist) instead of the initial program temperature of 45 °C

10.8 While the trap is being desorbed into the gas chromatograph, empty the purging chamber using the sample introduction syringe. Wash the chamber with two 5-mL Rushes of reagent water.

10.9 After desorbing the sample for 4 min, recondition the trap by returning the purge and trap system to the purge mode. Wait 15 s then close the syringe valve on the purging device to begin gas flow through the trap. The trap temperature should be maintained at 180 °C After approximately 7 min, turn off the trap heater and open the syringe valve to stop the gas flow through the trap. When the trap is cool, the next sample can be analyzed.

10.10 Identify the parameters in the sample by comparing the retention times of the peaks in the sample chromatogram with those of the peaks in standard chromatograms. The width of the retention time window used to make identifications should be based upon measurements of actual retention time variations of standards over the course of a day. Three times the standard deviation of a retention time for a compound can be used to calculate a suggested window size; however, the experience of the analyst should weigh heavily in the interpretation of chromatograms. 10.11 If the response for a peak exceeds the working range of the system, prepare a dilution of the sample with reagent water from the aliquot in the second syringe and reanalyze.

### 11. Calculations

11.1 Determine the concentration of individual compounds in the sample.

11.1.1 If the external standard calibration procedure is used, calculate the concentration of the parameter being measured from the peak response using the calibration curve or calibration factor determined in Section 7.3.2.

11.1.2 If the internal standard calibration procedure is used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.4.3 and Equation 2

Equation 2.

Concentration (µg/L)=

### where:

A_s=Response for the parameter to be measured.

A_w=Response for the internal standard. C_w=Concentration of the internal standard.

11.2 Report results in  $\mu g/L$  without correction for recovery data. All QC data obtained should be reported with the sample results.

### 12. Method Performance

12.1 The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.¹ The MDL concentrations listed in Table 1 were obtained using reagent water.⁹ Similar results were achieved using representative wastewaters. The MDL actually achieved in a given analysis will vary depending on instrument sensitivity and matrix effects.

12.2 This method is recommended for use in the concentration range from the MDL to 1000 x MDL. Direct aqueous injection techniques should be used to measure concentration levels above 1000 x MDL

12.3 This method was tested by 20 laboratories using reagent water, drinking water, surface water, and three industrial wastewaters spiked at six concentrations over the range 8.0 to  $500 \ \mu g/L^{\circ}$  Single

operator precision, overall precision, and method accuracy were found to be directly related to the concentration of the parameter and essentially independent of the sample matrix. Linear equations to describe these relationships are presented in Table 3.

### References

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4. "Carcinogens... Working With Carcinogens." Department of Health. Education, and Welfare, Public Health Service. Center for Disease Control. National Institute for Occupational Safety and Health, Publication No. 77-206, August 1977.

5. "OSHA Safety and Health Standards. General Industry" (29 CFR 1910), Occupational Safety and Health Administration, OSHA 2206 (Revised. January 1976).

6. "Safety in Academic Chemistry Laboratories." American Chemical Society Publication, Committee on Chemical Safety. 3rd Edition, 1979.

7. Provost. L.P., and Elder. R.S. "Interpretation of Percent Recovery Data," *American Laboratory*, 15, 58-63 (1983). (The value 2.44 used in the equation in Section 8.3.3 is two times the value 1.22 derived in this report.)

8. "Methods 330.4 (Titrimetric, DPD-FAS) and 330.5 (Spectrophotometric, DPD) for Chlorine. Total Residual," Methods for Chemical Analysis of Water and Wastes, EPA 600/4-79-020, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268, March 1979.

9. "EPA Method Validation Study 23. Method 601 (Purgeable Halocarbons)." Report for EPA Contract 68-03-2856 (in preparation).

10. "Method Validation Data for EPA Method 601," Memorandum from B. Potter, U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268, November 10, 1983.

### TABLE 1.-CHROMATOGRAPHIC CONDITIONS AND METHOD DETECTION LIMITS

-					
4	Personalar		Retention time (min)		
· · · · · · · · · · · · · · · · · · ·		Column 1	Column 2	timit (µg/L)	
Chinomethese				1	
Bromomethene		1.50	5.26	0.08	
Ochiometic		2,17	7.05	1.18	
Vini chiotida		2.62	nd	1.81	
Chinesee		2.67	5.28	0.18	
Mathadaga ablanda		3.33	8.66	0.52	
Torbiosofi chief and		5.25	10.1	0.25	
11. Cintra and and		7.18	nd	nd.	
1 1. Dechiorene and		7.93	7.72	0 13	
1 Contraction		9.30	12.8	0.07	
· · · · · · · . «· · · · · · · · · · · ·		10.1	9.36	0 10	

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### TABLE 1, -- CHROMATOGRAPHIC CONDITIONS AND METHOD DETECTION LIMITS-CONTINUED

•		Astention time (mm)		
Permite	Column 1	Column 2	(با/ویر) Immit	
Chantierm	10.7	12.1	0.05	
1.2-Dichlorost and	11.4	15.4	0.03	
1 1 - Trachinganhane	12.6	13.1	0 03	
Carton Interchloride	13.0	14.4	0.12	
Beneric Storomethene	13.7	14.6	0.10	
12.0.000000000	14.9	16.6	0.04	
cm.13.Dichiermentene	15.2	16.6	0.34	
Technologie	15.8	13.1	0.12	
Discourse the Desident	16.5	16.6	0.09	
1 1 2 Trichesetters	16.5	18.1	0.02	
	16.5	18.0	0.20	
2 Characteristication attent	18.0	nd	0.13	
	19.2	19.2	0.20	
	21.6	nd	0.03	
	21.7	15.0	0.03	
	24.2	18.6	0.25	
	34.0	22.4	0.12	
	34.4	215	0.15	
	36.4	22.1	0.24	
		-		

d with 1% SP-1000 packed in an 8 ft z 0.1 m. 10 stanless steel or glass column with hetum carrier gas at 40 mL/mm flow rese d at 8 °C/mm to 220 °C and held for 15 mm. Carbopack 8 (60/60 ma at 45 °C for 3 mm than p Ponal-C (100/120 meeh) with n-actane packed in a 6 ft x 0.1 "C/min to 170 "C and held for 4 min. rate Col d at 50 °C

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TABLE 2 .- CALIBRATION AND QC ACCEPTANCE CRITERIA---METHOD 601 *

Peranutar	Range for Q (µg/L)	Limit for s (µg/L)	Range for X (µg/L)	Range P. P. (%)
	15.2-24.8	4.4	10 7-32 0	42-172
	147-263	47	50-29.3	11.150
District and the second s	11.7-21.3	7.8	34-245	0-144
	117-24.1	5.6	11.6-25.3	43-143
	14.4-25.6	50	10 2-27 4	36-150
	15.4-24.6	4.4	11 3-25.2	44-137
2.Chimathérini altar	12.0-28.0	6.	45-35.5	14-186
Chievelova	150-25.0	4.5	12.4-24.0	48-133
Chicrystelland	11.9-28.1	7.4	0-34.0	D-193
Obvinichoumethere	13.1-28.0	6.3	7.8-35.1	24-191
12-Octooperson	14.0-28.0	5.5	1.7-38.9	5-206
1 3-Oktionsbergens	0.9-30.1	0.1	8.2-32.6	7-187
1 Cichiorobenzene	13.8-26.1	5.5	11.5-25.5	42-143
1 - Cichioroshere	16.8-23.2	3.2	11.2-24.6	47-132
1.2-Oichigroethere	14.3-25.7	5.2	13.0-28.5	51-147
1.1 Okthoroethene	12.6-27.4	6.6	10.2-27 3	28-167
trans-1,2-Olchorosthene	12.8-27.2	8.4	11 4-27 1	38-155
1_2-Oichtoropropene	14.8-25.2	5.2	10.1-29.9	44-158
cas-1,3-Dichloroprozene	12.8-27.2	73	6.2-33.0	22-178
trans-1,3-Olchioropropere	12.8-27.2	7.3	6.2-33.8	22-176
Methylane chloride	15.5-24.5	4.0	7.0-27.6	25-162
1,122-Tetrachioroethene	9.8-30.2	9.2	6.6-31.8	8-184
Tetachioroathene	14.0-28.0	5.4	8.1-29.6	26-162
1,1,1-Trichprosthene	14.2-25.8	4.9	10.8-24.8	41-138
1,1.2-Trichbrosithene	16.7-24.3	3.9	9.6-25.4	39-136
TrichtorGethane	15.4-24.8	4.2	9.2-26.6	35-146
Trichlorofluoromethane	13.3-28.7	6.0	7.4-28.1	21-156
Viryl chloride	13.7-26.3	5.7	8.2-29.9	28-163

Q - Concentration m s - Standard deviation ared in QC check complet, in µg/L (Section 7.5.3).

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be gr ir then zero. La QC check semple concentration of 20 μg/L.

Note: These criteria are based directly upon the method performance data in Table 3. Where necessary, the limits for recovery have been broadened to assure applicability

of the limits to concentrations below those used to develop Table 3.

TABLE 3.-METHOD ACCURACY AND PRECISION AS FUNCTIONS OF CONCENTRATION-METHOD 601

		the second s	
Parameter	Accuracy. as recovery. X' (µg/	Single analyst precision, s, (µg/ L)	Overall precision, S' (µg/L)
Bromodichioromethere	12C-1.02	0118+0.04	0.208 + 1 00
Brancom	990C - 2.05 0.79C - 1.27	0.12X+0.58 0.28X+0.27	0.21X+2.41
Chiprobeneene	.00C - 1.23	0 15X - 0.02 0 14X - 0 13	0.188+1.21
2-Chiprotethylwm/ ether *	00C 83C-0 39	0.20X 0.13X+0.15	0 35X 0 19X - 0 02
Choromethane Choromethane	1.77C+0.16	0.28X - 0.31 0.11X + 1.10 0.20X - 0.97	0 52X + 1 31 0 24X + 1 68

### TABLE 3 .-- METHOD ACCURACY AND PRECISION AS FUNCTIONS OF CONCENTRATION-METHOD 601-Continued

Perameter	ACCURACY. as recovery. X' (ug/	Single analyst precision, s,' (µg/ L)	Overall precision, S' (µg/L)
	0.950+0.43	0 148 + 2 22	0.368 . 2.34
	0.93C-0.09	0.158+0.29	0.20X+0.41
( 1. Dichlorosthane	0.95C-1.08	0.082+0.17	0.148+0.94
1.2-Dichloroethane	1.04C-1.08	0.118+0.70	0.158+0.94
1, 1-ber Koroelhane	0.900-0.87	0.21X - 0.23	0.29X - 0.40
iane 12-Octation and *	1.00C	0.112 + 1.40	0.178+1.46
as 1.3 Dicharopropene *	1.00C	0.18%	0.328
tans-1,3-Dichloropropene *	1.00C	0.182	0.32%
Methylene childre	0.91C-0.83	0.118+0.33	0.21%+1.43
	0.950+0.19	0.14X+2.41	0.231 + 2.79
I T I Chicrostana	0.90C-0.16	0.158+0.04	0.208+0.37
() 2. Trichloroethere	0.86C+0.30	0.138-0.14	0.198+0.67
I nohiore streets	0.87C+0.48	0.138-0.03	0.238 + 0.30
	0.880 - 0.07	0.15X+0.67	0.26X + 0.91
	0.000-0.30	U. 13A + 0.00	U.2/A+U.4U

 $\hat{X}$  = Expected recovery for one or more measurements of a sample containing a concentration of C, in  $\mu g/L$ ,  $x_i$  = Expected single analysi standard deviation of measurements at an average concentration found of  $\hat{X}$  in  $\mu g/L$ . S^ = True value for the concentration, in  $\mu g/L$ .  $\hat{X}$  = Average recovery found for measurements of samples containing a concentration found of  $\hat{X}$  in  $\mu g/L$ .  $\hat{X}$  = Average recovery found for measurements of samples containing a concentration of C, in  $\mu g/L$ .  $\hat{X}$  = Average recovery found for measurements of samples containing a concentration of C, in  $\mu g/L$ .  $\hat{X}$  = Average tecovery found for measurements of samples containing a concentration of C, in  $\mu g/L$ .

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Figure 4. Purge and trap system - desorb mode.

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### Method 602-Purgeable Aromatics

### 1. Scope and Application

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1.1 This method covers the determination of various purgeable aromatics. The following parameters may be determined by this method:

Perameter	STORET No.	CAS No.
Benzene	34030	71-43-2
Chlorobenzene	34301	108-80-7
1.2-Dichlorobenzene	34536	95-50-1
1.3-Dichlorobenzene	34566	541-71-1
1.4-Dichlorobenzene	34571	108-48-7
Ethylongene	34371	100-41-4
Taluene		108-68-3

1.2 This is a purge and trap gas chromatographic (GC) method applicable to the determination of the compounds listed above in municipal and industrial discharges as provided under 40 CFR 136.1. When this method is used to analyze unfamiliar samples for any or all of the compounds above. compound identifications should be supported by at least one additional qualitative technique. This method describes analytical conditions for a second gas chromatographic column that can be used to confirm measurements made with the primary column. Method 624 provides gas chromatograph/mass spectrometer (GC/MS) conditions appropriate for the qualitative and quantitative confirmation of results for all of the parameters listed above.

1.3 The method detection limit (MDL, defined in Section 12.1) ¹ for each parameter is listed in Table 1. The MDL for a specific wastewater may differ from those listed, depending upon the nature of interferences in the sample matrix.

1.4 Any modification of this method, beyond those expressly permitted, shall be considered as a major modification subject to application and approval of alternate test procedures under 40 CFR 136.4 and 136.5.

1.5 This method is restricted to use by or under the supervision of analysts experienced in the operation of a purge and trap system and a gas chromatograph and in the interpretation of gas chromatograms. Each analyst must demonstrate the ability to generate acceptable results with this method using the procedure described in Section 8.2.

### 2. Summary of Method

2.1 An inert gas is bubbled through a 5mL water sample contained in sispeciallydesigned purging chamber at ambient temperature. The aromatics are efficiently transferred from the aqueous phase to the vapor phase. The vapor is swept through a sorbent trap where the aromatics are trapped. After purging is completed, the trap is heated and backflushed with the inert gas to desorb the aromatics onto a gas chromatograph is temperature programmed to separate the aromatics which are then detected with a photoionization detector 2.3

2.2 The method provides an optional gas chromatographic column that may be helpful in resolving the compounds of interest from interferences that may occur.

### 3. Interferences

3.1 Impurities in the purge gas and organic compounds outgassing from the plumbing ahead of the trap account for the majority of contamination problems. The analytical system must be demonstrated to be free from contamination under the conditions of the analysis by running laboratory reagent blanks as described in Section 8.1.3. The use of non-Teflon plastic tubing, non-Teflon thread sealants, or flow controllers with rubber components in the purge and trap system should be avoided.

3.2 Samples can be contaminated by diffusion of volatile organics through the septum seal into the sample during shipment and storage. A field reagent blank prepared from reagent water and carried through the sampling and handling protocol can serve as a check on such contamination.

3.3 Contamination by carry-over can occur whenever high level and low level samples are sequentially analyzed. To reduce carry-over, the purging device and sample syringe must be rinsed with reagent water between sample analyses. Whenever an unusually concentrated sample is encountered, it should be followed by an analysis of reagent water to check for cross contamination. For samples containing large amounts of water-soluble materials. suspended solids, high boiling compounds or high aromatic levels, it may be necessary to wash the purging device with a detergent solution, rinse it with distilled water, and then dry it in an oven at 105 °C between analyses. The trap and other parts of the system are also subject to contamination: therefore, frequent bakeout and purging of the entire system may be required.

### 4. Safety

4.1 The toxicity or carcinogenicity of each reagent used in this method has not been precisely defined; however, each chemical compound should be treated as a potential health hazard. From this viewpoint, exposure to these chemicals must be reduced to the lowest possible level by whatever means available. The laboratory is responsible for maintaining a current awareness file of OSHA regulations regarding the safe handling of the chemicals specified in this method. A reference file of material data handling sheets should also be made available to all personnel involved in the chemical analysis. Additional references to laboratory safety are available and have been identified ** for the information of the analyst

4.2 The following parameters covered by this method have been tentatively classified as known or suspected, human or mammalian carcinogens: benzene and 1.4dichlorobenzene. Primary standards of these toxic compounds should be prepared in a hood. A NIOSH/MESA approved toxic gas respirator should be worn when the analyst handles high concentrations of these toxic compounds.

### 5. Apparatus and Materials

5.1 Sampling equipment, for discrete sampling.

5.1.1 Vial-25-mL capacity or larger. equipped with a screw cap with a hole in the center (Pierce #13075 or equivalent). Detergent wash, rinse with tap and distilled water, and dry at 105 °C before use.

5.1.2 Septum—Teflon-faced silicone (Pierce #12722 or equivalent). Detergent wash. rinse with tap and distilled water, and dry at 105 °C for 1 h before use.

5.2 Purge and trap system—The purge and trap system consists of three separate pieces of equipment. A purging device, trap, and desorber. Several complete systems are now commercially available.

5.2.1 The purging device must be designed to accept 5-mL samples with a water column at least 3 cm deep. The gaseous head space between the water column and the trap must have a total volume of less than 15 mL. The purge gas must pass through the water column as finely divided bubbles with a diameter of less than 3 mm at the origin. The purge gas must be introduced no more than 5 mm from the base of the water column. The purging device illustrated in Figure 1 meets these design criteria.

5.2.2 The trap must be at least 25 cm long and have an inside diameter of at least 0.105 in.

5.2.2.1 The trap is packed with 1 cm of methyl silicone coated packing (Section 6.4.2) and 23 cm of 2.6-diphenylene oxide polymer (Section 6.4.1) as shown in Figure 2. This trap was used to develop the method performance statements in Section 12.

5.2.2.2 Alternatively, either of the two traps described in Method 601 may be used, although water vapor will preclude the measurement of low concentrations of benzene.

5.2.3 The desorber must be capable of rapidly heating the trap to 180 °C. The polymer section of the trap should not be heated higher than 180 °C and the remaining sections should not exceed 200 °C. The desorber illustrated in Figure 2 meets these design criteria.

5.2.4 The purge and trap system may be assembled as a separate unit or be coupled to a gas chromatograph as illustrated in Figures 3. 4. and 5.

5.3 Gas chromatograph—An analytical system complete with a temperature programmable gas chromatograph suitable for on-column injection and all required accessories including syringes, analytical columns, gases, detector, and strip-chart recorder. A data system is recommended for measuring peak areas.

5.3.1 Column 1—8 ft long x 0.082 in. ID stainless steel or glass, packed with 5% SP-1200 and 1.75% Bentone-34 on Supelcoport (100/120 mesh) or equivalent. This column was used to develop the method performance statements in Section 12. Guidelines for the use of alternate column packings are provided in Section 10.1.

5.3.2 Column 2—8 ft long x 0.1 in ID stainless steel or glass, packed with 5% 1.2.3. Tris(2-cyanoethoxy)propane on Chromosorb W-AW (60/80 mesh) or equivalent.

5.3.3 Detector—Photoionization detector (h-Nu Systems. Inc. Model PI-51-02 or equivalent). This type of detector has been proven effective in the analysis of wastewaters for the parameters listed in the scope (Section 1.1), and was used to develop the method performance statements in Section 12. Guidelines for the use of alternate detectors are provided in Section 10.1. 54 Syringes-5-mL glass hypodermic with Luerluk tip (two each), if applicable to the

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purging device. 5. Micro syringes-25-μL, 0.006 in. ID

ncedle.

5 B Syringe valve-2-way, with Luer ends (three each).

Bottle-15-mL, screw-cap, with Teflon . cap liner.

a Balance-Analytical, capable of

at curately weighing 0.0001 g.

### . Reagents

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n 1 Reugent water-Reagent water is defined as a water in which an interferent is not observed at the MDL of the parameters of interest

n 1 1 Reagent water can be generated by passing tap water through a carbon filter bed containing about 1 lb of activated carbon Hitrasurh-300. Calgon Corp., or equivalent).

0.1.2 A water purification system Millipore Super-Q or equivalent) may be

and to generate reagent water. na i Reigent water may also be prepared

the balance water for 15 min. Subsequently, while maintaining the temperature at 90 °C. hubble a contaminant-free inert gas through the water for 1 h. While still hot, transfer the water to a narrow mouth screw-cap bottle and seal with a Teflon-lined septum and cap.

n 2 Sodium thiosulfate-(ACS) Granular. n i Hydrochloric acid (1+1)-Add 50 mL

at concentrated HCl (ACS) to 50 mL of reasent water.

**5.4** Trap Materials:

A 4.1 2.6-Diphenylene oxide polymertenes. (10)/80 mesh), chromatographic grade 

- Chromosorh-W (60/80 mesh) or mussalent

An Methanol-Pesticide quality or equisalent

An Stock standard solutions-Stock standard solutions may be prepared from mere standard materials or purchased as centiled solutions. Prepare stock standard -dutions in methanol using assayed liquids. new ouse of the toxicity of benzene and 1.4de hierobenzene, primary dilutions of these meternels should be prepared in a hood. A SHINH/MESA approved toxic gas respirator when the analyst handles her concentrations of such materials.

AA1 Place about 9.8 mL of methanol into • 10 ml. ground glass stoppered volumetric Allow the flask to stand, unstoppersd. elevel 10 min or until all alcohol wetted -force have dried. Weigh the flask to the merest 0 1 mg.

sa 2 Using a 100-µL syringe, immediately and two or more drops of assayed reference estorial to the flask, then reweigh. Be sure the drops fall directly into the alcohol enthing contacting the neck of the flask.

AA3 Reweigh, dilute to volume, stopper, was by inverting the flask several times. t also the concentration in  $\mu g/\mu L$  from - I sein in weight. When compound Wy is assured to be 96% or greater, the At can be used without correction to what the concentration of the stock

standard. Commercially prepared stock standards can be used at any concentration if they are certified by the manufacturer or by an independent source.

Transfer the stock standard solution 6.6.4 into a Teflon-sealed screw-cap bottle. Store at 4 °C and protect from light.

6.6.5 All standards must be replaced after one month, or sooner if comparison with check standards indicates a problem.

6.7 Secondary dilution standards-Using stock standard solutions, prepare secondary dilution standards in methanol that contain the compounds of interest, either singly or mixed together. The secondary dilution standards should be prepared at concentrations such that the aqueous calibration standards prepared in Sections 7.3.1 or 7.4.1 will bracket the working range of the analytical system. Secondary solution standards must be stored with zero headspace and should be checked frequently for signs of degradation or evaporation, especially just prior to preparing calibration standards from them.

8.8 Quality control check sample concentrate-See Section 8.2.1.

### 7. Calibration

7.1 Assemble a purge and trap system that meets the specifications in Section 5.2. Condition the trap overnight at 180 °C by backflushing with an inert gas flow of at least 20 mL/min. Condition the trep for 10 min once daily prior to use.

7.2 Connect the purge and trap system to a gas chromatograph. The gas chromatograph must be operated using temperature and flow rate conditions equivalent to those given in Table 1. Calibrate the purge and trap-gas chromatographic system using either the external standard technique (Section 7.3) or the internal standard technique (Section 7.4). 7.3 External standard calibration

procedure:

7.3.1 Prepare calibration standards at a minimum of three concentration levels for each parameter by carefully adding 20.0 µL of one or more secondary dilution standards to 100, 500, or 1000 mL of reagent water. A 25-L syringe with a 0.006 in. ID needle should be used for this operation. One of the external standards should be at a concentration near, but above, the MDL (Table 1) and the other concentrations should correspond to the expected range of concentrations found in real samples or should define the working range of the detector. These aqueous standards must be prepared fresh daily.

7.3.2 Analyze each calibration standard according to Section 10, and tabulate peak height or area responses versus the concentration in the standard. The results can be used to prepare a calibration curve for each compound. Alternatively, if the ratio of response to concentration (calibration factor) is a constant over the working range (<10% relative standard deviation, RSD), linearity through the origin can be assumed and the average ratio or calibration factor can be used in place of a calibration curve.

7.4 Internal standard calibration procedure-To use this approach, the analyst must select one or more internal standards that are similar in analytical behavior to the

compounds of interest. The analyst must further demonstrate that the measurement of the internal standard is not affected by method or matrix interferences. Because of these limitations, no internal standard can be suggested that is applicable to all samples. The compound, a.a.a. trifluorotoluene. recommended as a surrogate spiking compound in Section 8.7 has been used successfully as an internal standard.

7.4.1 Prepare calibration standards at a minimum of three concentration levels for each parameter of interest as described in Section 7.3.1.

7.4.2 Prepare a spiking solution containing each of the internal standards using the procedures described in Section 6.6 and 8.7. I is recommended that the secondary dilution standard be prepared at a concentration of 15 µg/mL of each internal standard compound. The addition of 10 µl of this standard to 5.0 mL of sample or calibration standard would be equivalent to 30 µg/L

7.4.3 Analyze each calibration standard according to Section 10, adding 10 µL of internal standard spiking solution directly to the syringe (Section 10.4). Tabulate peak height or area responses against concentration for each compound and internal standard, and calculate response factors (RF) for each compound using Equation 1.

Equation 1.

 $RF = \frac{(A_s)(C_u)}{C_u}$ 

where:

A_s=Response for the parameter to be measured.

A_{in} = Response for the internal standard. C. = Concentration of the internal standard C_a=Concentration of the parameter to be measured.

If the RF value over the working range is a constant (<10% RSD), the RF can be assumed to be invariant and the average RF can be used for calculations. Alternatively, the results can be used to plot a calibration curve of response ratios, A./A., vs. RF.

7.5 The working calibration curve, calibration factor, or RF must be verified on each working day by the measurement of a QC check sample.

7.5.1 Prepare the QC check sample as described in Section 8.2.2.

7.5.2 Analyze the QC check sample according to Section 10.

7.5.3 For each parameter, compare the response (Q) with the corresponding calibration acceptance criteria found in Table 2. If the responses for all parameters of interest fall within the designated ranges, analysis of actual samples can begin. If any individual Q falls outside the range, a new calibration curve, calibration factor, or RF must be prepared for that parameter according to Section 7.3 or 7.4.

### 8. Quality Control

8.1 Each laboratory that uses this method is required to operate a formal quality control program. The mimimum requirements of this program consist of an initial demonstration of laboratory capability and an ongoing analysis of spiked samples to evaluate and document data quality. The laboratory must maintain records to document the quality of data that is generated. Ongoing data quality checks are compared with established performance criteria to determine if the results of analyses meet the performance characteristics of the method. When results of sample spikes indicate atypical method performance, a quality control check standard must be analyzed to confirm that the measurements were performed in an incontrol mode of operation.

8.1.1 The analyst must make an initial, one-time, demonstration of the ability to generate acceptable accuracy and precision with this method. This ability is established as described in Section 8.2.

8.1.2 In recognition of advances that are occurring in chromatography, the analyst is permitted certain options (detailed in Section 10.1) to improve the separations or lower the cost of measurements. Each time such a modification is made to the method, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 Each day, the analyst must analyze a reagent water blank to demonstrate that interferences from the analytical system are under control.

8.1.4 The laboratory must, on an ongoing basis, spike and analyze a minimum of 10% of all samples to monitor and evaluate laboratory data quality. This procedure is described in Section 8.3.

8.1.5 The laboratory must, on an ongoing basis, demonstrate through the analyses of quality control check standards that the operation of the measurement system is in control. This procedure is described in Section 8.4. The frequency of the check standard analyses is equivalent to 10% of all samples analyzed but may be reduced if spike recoveries from samplés (Section 8.3) meet all specified quality control criteria.

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> 8.1.6 The laboratory must maintain performance records to document the quality of data that is generated. This procedure is described in Section 8.5.

8.2 To establish the ability to generate acceptable accuracy and precision, the analyst must perform the following operations.

8.2.1 A quality control (QC) check sample concentrate is required containing each parameter of interest at a concentration of 10 µg/mL in methanol. The QC check sample concentrate must be obtained from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory in Cincinnati, Ohio, if available. If not available from that source, the QC check sample concentrate must be obtained from another external source. If not available from either source above, the QC check sample concentrate must be prepared by the laboratory using stock standards prepared independently from those used for calibration.

8.2.2 Prepare a QC check sample to contain 20 µg/L of each parameter by adding 200 µL of QC check sample concentrate to 100 mL of reagant water.

8.2.3 Analyze four 5-mL aliquots of the well-mixed QC check sample according to Section 10.

8.2.4 Calculate the average recovery (X) in  $\mu g/L$ , and the standard deviation of the recovery (s) in  $\mu g/L$ , for each parameter of interest using the four results.

8.2.5 For each parameter compare s and  $\hat{X}$  with the corresponding acceptance criteria for precision and accuracy, respectively, found in Table 2. If s and  $\hat{X}$  for all parameters of interest meet the acceptance criteria, the system performance is acceptable and analysis of actual samples can begin. If any individual s exceeds the precision limit or any individual  $\hat{X}$  falls outside the range for accuracy, the system performance is unacceptable for that parameter.

Note.—The large number of parameters in Table 2 present a substantial probability that one or more will fail at least one of the acceptance criteria when all parameters are analyzed.

8.2.6 When one or more of the parameters tested fail at least one of the acceptance criteria, the analyst must proceed according to Section 8.2.6.1 or 8.2.6.2

**8.2.6.1** Locate and correct the source of the problem and repeat the test for all parameters of interest beginning with Section 8.2.3.

8.2.6.2 Beginning with Section 8.2.3, repeat the test only for those parameters that failed to meet criteria. Repeated failure, however, will confirm a general problem with the measurement system. If this occurs, locate and correct the source of the problem and repeat the test for all compounds of interest beginning with Section 8.2.3.

8.3 The laboratory must, on an ongoing basis, spike at least 10% of the samples from each sample site being monitored to assess accuracy. For laboratories analyzing one to ten samples per month, at least one spiked sample per month is required.

8.3.1 The concentration of the spike in the sample should be determined as follows:

8.3.1.1 If, as in compliance monitoring, the concentration of a specific parameter in the sample is being checked against a regulatory-concentration limit, the spike should be at that limit or 1 to 5 times higher than the background concentration determined in Section 8.3.2, whichever concentration would be larger.

8.3.1.2 If the concentration of a specific parameter in the sample is not being checked against a limit specific to that parameter, the spike should be at 20  $\mu$ g/L or 1 to 5 times higher than the background concentration determined in Section 8.3.2, whichever concentration would be larger.

6.3.2 Analyze one S-mL sample aliquot to determine the background concentration (B) of each parameter. If necessary, prepare a new QC check sample concentrate (Section 6.2.1) appropriate for the background concentrations in the sample. Spike a second 5-mL sample eliquot with 10  $\mu$ L of the QC check sample concentrate and analyze it to determine the concentration after spiking (A) of each parameter. Calculate each percent recovery (P) as 100(A-B)%/T, where T is the known true value of the spike.

6.3.3 Compare the percent recovery (P) for each parameter with the corresponding QC acceptance criteria found in Table 2. These acceptance criteria were calculated to include an allowance for error in

measurement of both the background and spike concentrations, assuming a spike to background ratio of 5:1. This error will be accounted for to the extent that the analyst's spike to background ratio approaches 5:1.7 If spiking was performed at a concentration lower than 20  $\mu$ g/L, the analyst must use either the QC acceptance criteria in Table 2. or optional QC acceptance criteria calculated for the specific spike concentration. To calculate optional acceptance criteria for the recovery of a parameter. (1) Calculate accuracy (X') using the equation in Table 3. substituting the spike concentration (T) for C; (2) calculate overall precision (S') using the equation in Table 3. substituting X' for  $\bar{X}$ ; (3) calculate the range for recovery at the spike concentration as (100 X'/T)  $\pm$  2.44(100 S'/ י געוד

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8.3.4 If any individual P falls outside the designated range for recovery, that parameter has failed the acceptance criteria. A check standard containing each parameter that failed the criteria must be analyzed as described in Section 8.4.

8.4 If any parameter fails the acceptance criteria for recovery in Section 8.3, a QC check standard containing each parameter that failed must be prepared and analyzed.

Note: The frequency for the required analysis of a QC check standard will depend upon the number of parameters being simultaneously tested, the complexity of the sample matrix, and the performance of the laboratory.

8.4.1 Prepare the QC check standard by adding 10  $\mu$ L of QC check sample concentrate (Sections 8.2.1 or 8.3.2) to 5 mL of reagent water. The QC check standard needs only to contain the parameters that failed criteria in the test in Section 8.3.

8.4.2 Analyze the QC check standard to determine the concentration measured (A) of each parameter. Calculate each percent recovery ( $P_a$ ) as 100 (A/T)%, where T is the true value of the standard concentration.

8.4.3 Compare the percent recovery (P_a) for each parameter with the corresponding QC acceptance criteria found in Table 2. Only parameters that failed the test in Section 8.3 need to be compared with these criteria. If the recovery of any such parameter fails outside the designated range, the laboratory performance for that parameter is judged to be out of control, and the problem must be immediately identified and corrected. The analytical result for that parameter in the unspiked sample is suspect and may not be reported for regulatory compliance purposes.

8.5 As part of the QC program for the laboratory, method accuracy for wastewater samples must be assessed and records must be maintained. After the analysis of five spiked wastewater samples as in Section 8.3, calculate the average percent recovery (P) and the standard deviation of the percent recovery ( $a_{s}$ ). Express the accuracy assessment as a percent recovery interval from  $P - 2a_{s}$  to  $P + 2a_{s}$ . If P = 90% and  $a_{s} = 10\%$ , for example, the accuracy interval is expressed as 70-110%. Update the accuracy assessment for each parameter on a regular basis (e.g. after each five to ten new accuracy measurements) 8.6 It is recommended that the laboratory adopt additional quality assurance practices for use with this method. The specific practices that are most productive depend upon the needs of the laboratory and the nature of the samples. Field duplicates may be analyzed to assess the precision of the environmental measurements. When doubt exists over the identification of a peak on the chromatogram, confirmatory techniques such as gas chromatography with a dissimilar column, specific element detector, or mass spectrometer must be used. Whenever possible, the laboratory should analyze standard reference materials and participate in relevant performance evaluation studies.

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8.7 The analyst should monitor both the performance of the analytical system and the effectiveness of the method in dealing with each sample matrix by spiking each sample. standard, and reagent water blank with surrogate compounds (e.g. a, a, a,trifluorotoluene) recommended to encompass the range of the temperature program used in this method. From stock standard solutions prepared as in Section 6.6, add a volume to give 750 µg of each surrogate to 45 mL of reagent water contained in a 50-mL volumetric flask, mix and dilute to volume for a concentration of 15 mg/µL. Add 10 µL of this surrogate spiking solution directly into the 5-mL syringe with every sample and reference standard analyzed. Prepare a fresh surrogate spiking solution on a weekly basis. If the internal standard calibration procedure is being used, the surrogate compounds may be added directly to the internal standard spiking solution (Section 7.4.2).

### 9. Sample Collection, Preservation, and Handling

9.1 The samples must be iced or refrigerated from the time of collection until analysis. If the sample contains free or combined chlorine, add sodium thiosulfate preservative (10 mg/40 mL is sufficient for up to 5 ppm Cl₂) to the empty sample bottle just prior to shipping to the sampling site. EPA Method 330.4 or 330.5 may be used for measurement of residual chlorine.⁶ Field test kits are available for this purpose.

9.2 Collect about 500 mL of sample in a clean container. Adjust the pH of the sample to about 2 by adding 1+1 HCl while stirring. Fill the sample bottle in such a manner that no air bubbles pass through the sample as the bottle is being filled. Seal the bottle so that no air bubbles are entrapped in it. Maintain the hermetic seal on the sample bottle until time of analysis.

9.3 All samples must be analyzed within 14 days of collection.³

### 10. Procedure

10.1 Table 1 summarizes the recommended operating conditions for the gas chromatograph. Included in this table are estimated retention times and MDL that can be achieved under these conditions. An example of the separations achieved by Column 1 is shown in Figure 6. Other packed columns. chromatographic conditions, or detectors may be used if the requirements of Section 6.2 are met.

10.2 Calibrate the system daily as described in Section 7.

10.3 Adjust the purge gas (nitrogen or helium) flow rate to 40 mL/min. Attach the trap inlet to the purging device, and set the purge and trap system to purge (Figure 3). Open the syringe valve located on the purging device sample introduction needle.

10.4 Allow the sample to come to ambient temperature prior to introducing it to the syringe. Remove the plunger from a 5-mL syringe and attach a closed syringe valve. Open the sample bottle (or standard) and carefully pour the sample into the syringe barrel to just short of overflowing. Replace the syringe plunger and compress the sample. Open the syringe valve and vent any residual air while adjusting the sample volume to 5.0 mL. Since this process of taking an aliquot destroys the validity of the sample for future analysis, the analyst should fill a second syringe at this time to protect against possible loss of data. Add 10.0 µL of the surrogate spiking solution (Section 8.7) and 10.0 µL of the internal standard spiking solution (Section 7.4.2), if applicable, through the valve bore, then close the valve.

10.5 Attach the syringe-syringe valve assembly to the syringe valve on the purging device. Open the syringe valves and inject the sample into the purging chamber.

10.6 Close both valves and purge the sample for  $12.0 \pm 0.1$  min at ambient temperature.

10.7 After the 12-min purge time, disconnect the purging device from the trap. Dry the trap by maintaining a flow of 40 mL/ min of dry purge gas through it for 6 min (Figure 4). If the purging device has no provision for bypassing the purger for this step, a dry purger should be inserted into the device to minimize moisture in the gas. Attach the trap to the chromatograph, adjust the purge and trap system to the desorb mode (Figure 5), and begin to temperature program the gas chromatograph. Introduce the trapped materials to the GC column by rapidly heating the trap to 180 °C while backflushing the trap with an inert gas between 20 and 60 mL/min for 4 min. If rapid heating of the trap cannot be achieved, the GC column must be used as a secondary trap by cooling it to 30 *C (subambient temperature, if poor peak geometry and random retention time problems persist) instead of the initial program temperature of 50 °C.

10.8 While the trap is being desorbed into the gas chromatograph column, empty the purging chamber using the sample introduction syringe. Wash the chamber with two 5-mL flushes of reagent water.

10.9 After desorbing the sample for 4 min, recondition the trap by returning the purge and trap system to the purge mode. Wait 15 s, then close the syringe valve on the purging device to begin gas flow through the trap. The trap temperature should be maintained at 180 °C. After approximately 7 min, turn off the trap heater and open the syringe valve to stop the gas flow through the trap. When the trap is cool, the next sample can be analyzed.

10.10 Identify the parameters in the sample by comparing the retention times of the peaks in the sample chromatogram with those of the peaks in standard chromatograms. The width of the retention time window used to make identifications should be based upon measurements of actual retention time variations of standards over the course of a day. Three times the standard deviation of a retention time for a compound can be used to calculate a suggested window size; however, the experience of the analyst should weigh heavily in the interpretation of chromatograms.

10.11 If the response for a peak exceeds the working range of the system, prepare a dilution of the sample with reagent water from the aliquot in the second syringe and reanalyze.

### 11. Calculations

11.1 Determine the concentration of individual compounds in the sample.

11.1.1 If the external standard calibration procedure is used, calculate the concentration of the parameter being measured from the peak response using the calibration curve or calibration factor determined in Section 7.3.2.

11.1.2 If the internal standard calibration procedure is used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.4.3 and Equation 2. Equation 2.

# Concentration $(\mu g/L) = \frac{(A_o)(C_u)}{(A_u)(RF)}$

where:

A_e = Response for the parameter to be measured.

 $A_{in} = \text{Response for the internal standard.}$  $C_{in} = \text{Concentration of the internal}$ 

standard.

11.2 Report results in  $\mu g/L$  without correction for recovery data. All QC data obtained should be reported with the sample results.

### 12. Method Performance

12.1 The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured and reported with 99% confidence that the value is above zero.' The MDL concentrations listed in Table 1 were obtained using reagent water.' Similar results were achieved using representative wastewaters. The MDL actually achieved in a given analysis will vary depending on instrument sensitivity and matrix effects.

12.2 This method has been demonstrated to be applicable for the concentration range from the MDL to 1000 x MDL.⁹ Direct aqueous injection techniques should be used to measure concentration levels above 1000 x MDL.

12.3 This method was tested by 20 laboratories using reagent water, drinking water, surface water, and three industrial wastewaters spiked at six concentrations over the range 2.1 to  $550 \ \mu g/L^{\circ}$  Single operator precision, overall precision, and method accuracy were found to be directly related to the concentration of the parameter and essentially independent of the sample matrix. Linear equations to describe these relationships are presented in Table 3.

### References

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American Laboratory, 15, 58-63 (1983). (The value 2.44 used in the equation in Section 8.3.3. is two times the value 1.22 derived in this report.)

8."Methods 330.4 (Titrimetric, DPD-FAS) and 330.5 (Spectrophotometric, DPD) for Chlorine, Total Residual," Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020, U.S. Environmental Protection Agency, Office of Research and Development, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268. March 1979.

9."EPA Method Validation Study 24. Method 602 (Purgeable Aromatics)," Report for EPA Contract 68-03-2856 (In preparation).

### TABLE 1.---CHROMATOGRAPHIC CONDITIONS AND METHOD DETECTION LIMITS

Perameter		Retention time (min)	
		Column 2	imit (µg/L)
Bertere	3.33	2.75	0.2
	5.75	4.25	0.2
	8.25	6.25	3.2
1,4-Dichigrobenzene	16.8	16.2	0.3
1,3-Oichigrobergene	18.2	15.0	0.4
	25.9	19.4	0.4

m 5% SP-1200/1.75% B 6 ft x 0.065 in. 10 r e-34 pecked at a r a finel hold. 90 °C for a fir er oas at 36 mL/mm d at 6 "C/min h 5% 1,2,3-T ft x 0.085 in. ID stamlass st

Trie(2-cyanoethycky)propent packed in all 2 °C/min to 100 °C for a final hold

### TABLE 2 -- CALIBRATION AND QC ACCEPTANCE CRITERIA-METHOD 602 .

Parameter	Range for Cr (µg/1.)	Limit for # (µg/L)	Range for X (µg/L)	Range for P. P. (%)
Benzene	15.4-24.6	4.1	10.0-27.9	39-150
	16.1-23.9	3.5	12.7-25.4	55-135
	13.6-28.4	5.8	10.6-27.6	37-154
	14.5-25.5	5.0	12.8-25.5	50-141
	13.9-28.1	5.5	11.8-25.5	42-145
	12.6-27.4	6.7	10.0-28.2	32-160
	15.5-24.5	4.0	11.2-27.7	46-144

in  $\mu g/L$  (Section 7.5.3). ants, in  $\mu g/L$  (Section 8 ants, in  $\mu g/L$  (Section 8

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city upon the m mice Table 3.

TABLE 3.-METHOD ACCURACY AND PRECISION AS FUNCTIONS OF CONCENTRATION-METHOD 602

Personator	Accuracy, as recovery, X' (µg/L)	Single analyst precision, s' (µg/L)	Overall precision, S' (µg/L)
Bergane     Chorobergane       12-Otchorobergane     ````````````````````````````````````	0.92C+0.57 0.95C+0.02 0.93C+0.52 0.98C-0.04 0.93C+0.09 0.94C+0.31 0.94C+0.65	0.092+0.59 0.092+0.23 0.152-0.04 0.152-0.10 0.152+0.28 0.152+0.48 0.092+0.48	0.21

100

n, miµg/L

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## TOC Determinations in Ground Water

by Michael J. Barcelona⁴

### ABSTRACT

Determinations of total organic carbon (TOC) can provide valuable diagnostic evidence of the extent of ground-water contamination by organic compounds. The usefulness of conventional TOC results in monitoring efforts is limited by the bias introduced during the purging of inorganic carbon prior to analysis. A modified TOC procedure has been evaluated to permit the quantitation of the volatile organic carbon (VOC) fraction in water samples. The methodology consists of trapping the VOC in a manner analogous to commercial purge and trap instruments which are used for specific organic compound separations. The method has been found to be sensitive, accurate and reasonably precise for TOC determinations of standard solutions as well as on ground-water samples. Volatile organic carbon levels can range from 9-50% of the TOC in both uncontaminated and contaminated ground waters. The reporting of the volatile and nonvolatile fractions of the TOC will enhance both monitoring and research efforts, since it permits more complete characterization of the organic carbon content of ground-water samples

### INTRODUCTION

Monitoring total organic carbon (TOC) in ground-water samples is useful because contamination by synthetic organic compounds may be indicated when TOC concentrations are detected above background levels. This surrogate parameter provides a rapid, inexpensive indication of the extent of organic contamination and has been used extensively in studies of contaminant plume migration

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(Robertson and others, 1974; Spiker and Rubin, 1975; Leenheer and others, 1976; Kimmel and Braids, 1980). In this respect, TOC determinations permit the screening of samples prior to specific organic compound identification and quantitation.

TOC measurements are considered superior to laborious manual determinations of chemical (COD) or biological (BOD) oxygen demand as the latter methodologies may be significantly biased by the presence of reducing agents, refractory compounds or toxic materials. For these and other reasons, TOC determinations are frequently required by regulatory agencies for compliance monitoring (for example, RCRA, NPDES or CERCLA programs). The usefulness of TOC data has been limited though, because it is an operationally defined parameter which may be representative of the total dissolved organic carbon content of a water sample.

The nonvolatile organic carbon levels of uncontaminated ground water are generally observed to be quite low, 0.1-4 mg/l (Leenheer and others. 1974; Junk and others, 1980). Inorganic carbon, comprised of aqueous carbon dioxide, bicarbonate and carbonate ions, may exceed 100-200 mg/l, depending on the pH, temperature and partial pressure of  $CO_2$ . The routine TOC procedure consists of three steps. Firstly, acidification and purging of the water sample are performed to remove inorganic carbon species as CO₁ CO₂ purging is followed by an oxidation procedure to convert organic carbon to CO₂. The principal procedures in use are wet-chemical oxidation (Menzel and Vaccaro, 1964; Sharp, 1973, Goulden and Anthony, 1978) and ultraviolet photooxidation (Collins and Williams, 1977; Mueller and

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Bandaranayake, 1983), as well as high-temperature oxidation. The relative oxidation efficiencies of these procedures may vary relative to the mixture of organic compounds making up the TOC (Gershey and others, 1979). Thirdly, the quantitation of the  $CO_2$  produced in the oxidation step is then usually performed by infrared absorption spectrometry.

Regardless of the oxidation or quantitation steps employed in various instrumental methods, a common source of bias in TOC measurements results from purging volatile forms of organic carbon along with inorganic carbon. Variations in CO₂ purging methodologies may explain, in part, the poor interlaboratory comparisons of TOC measurement performance which has resulted in suggestions that TOC be dropped entirely from recommended methods for landfill leachate analysis (De Walle and others, 1981). Several authors have recognized the fact that such TOC data must be reported as a lower limit, since only the nonvolatile fraction of the organic carbon is available after purging (Baedeker and Back, 1979; Kimmel and Braids, 1980).

There are instruments commercially available which determine both the volatile (VOC, purged with CO₂ on acidification) and nonvolatile fractions of total dissolved organic carbon (NVOC). Several of these instrument designs are quite sensitive. These instruments convert the CO2 produced by oxidation of organic materials to methane which is then detected by a flame ionization detector. However, many laboratories have earlier instrument designs which are limited to the determination of NVOC. VOC concentrations have not been reported, since standard methodologies do not distinguish between the two fractions of TOC (USEPA, 1979). Therefore, the available data on the organic carbon content of ground water are biased by the omission of the VOC fraction.

Knowledge of the volatile organic carbon fraction of TOC in ground-water samples is important for several reasons. Interconversion of TOC between the volatile and nonvolatile fractions due to chemical reaction or microbial activity limits the capability to quantitatively assess net organic compound migration if only NVOC is reported. Moreover, volatile organic solvents are among the most frequently observed substances in untreated ground-water supplies for potable uses (Dyksen and Hess, 1982). These compounds are mobile in the subsurface since they are water-soluble, and they to quently appear is early indicators of con- L-30 Inchlorophenol fathing the price of an ansport. Observed levels of

volatile compounds in ground-water supplies have been reported to be two to three orders of magnitude higher than those in surface supplies (CEQ, 1981).

Therefore, a study was undertaken of the determination of TOC (VOC and NVOC) in ground-water samples. Emphasis was focused on the development and application of a precise, accurate methodology which was verifiable for volatile and nonvolatile organic compounds previously identified in ground water. It was therefore necessary to identify standard compounds which show comparable analytical performance in both carbon fractions.

### **METHODS AND MATERIALS**

The 12 compounds chosen for this study, in addition to the usual TOC standard, potassium hydrogen phthalate (KHP), are shown in Table 1. They range from volatile halocarbon and aromatic solvents frequently observed in ground-water samples to low molecular weight, carboxylic acids which have been identified in landfill leachate (Colenutt, 1979; Chian, 1977). Acetone and trichlorophenol were included as partially volatile standards for both the VOC and NVOC fractions.

The modified TOC procedure was developed on an Oceanography International Model 524 Total Organic Carbon Analyzer with standard direct injection module (DIM), purging and glass ampoule sealing units. Five ml water samples were first acidified and purged with oxygen for five minutes at 80 ml/min in a flow system incorporating a 25 cm × 2.5 mm i.d. stainless steel trap filled with Tenax-GC® support (60-80 mesh) which adsorbed the volatile organics and allowed  $H_2O$  and inorganic CO₂ to vent. The volatile compounds were desorbed from the trap in an oxygen stream (140 ml/min) into the combustion tube (950°C) of the DIM module for conversion to CO₂. The purging step and subsequent reversal of gas flow through the trap as it was heated (180°C) for five minutes (to desorb the volatiles) is analogous to

### Table 1. Model Compounds Used in This Study

Chloroform Trichloroethviene Ben/ene Dichloromethane Tolucne Acetone

Acetaldehyde Dimethylformamide Acetic acid Propanoic acid Pentanoic acid Portakur im hy fregen phonaiate
the routine purge and trap separation of volatile organics in the priority pollutant analytical protocols (Bellar and Lichtenberg, 1974; EPA, 1982) From the combustion tube, the gases passed through a series of columns to remove water (anhydrous magnesium perchlorate) and hydrochloric acid (finely divided tin particles) prior to entering the infrared detector. After purging the TOC samples of the volatile fraction and inorganic CO2, the ampoules were sealed and processed for NVOC by the usual persulfate wet oxidation procedure. Standard solutions (0.05-10 mg-C/l) of the model compounds were made by careful dilution of 50-1,000 mg-C/l stock solutions gravimetrically prepared in 10⁻³ N bicarbonate solution immediately prior to use. All standards and most samples were processed in triplicate where volume permitted. All TOC determinations on model compound solutions were calculated relative to calibration curves determined for KHP.

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# RESULTS AND DISCUSSION TOC Method Performance

The primary objectives of the work were to develop and apply a TOC methodology which would reproducibly recover the volatile organic carbon fraction of water samples. In the concentration range of 0.1 to 10.0 mg-Cl, acetone and trichlorophenol were found to be the most suitable combined VOC and NVOC standards. Both of these compounds exhibited better than 90% recovery throughout the TOC procedure and an average 30% higher sensitivity than did KHP

standards. Details of the relative performance of the method for acetone are shown in Table 2. The volatile fraction of aqueous acetone standards averaged 9% of the TOC. No significant differences in VOC were noted in parallel standard runs made with a 10⁻³ M NaHCO₃ background solution. Therefore, no observable carryover of inorganic CO2 occurred through the trapping, desorption and combustion steps. Trichlorophenol results were comparable to those for acctone. The slight losses of volatile organic carbon in the desorption and combustion steps were more than compensated for by the more complete wet oxidation of both trichlorophenol and acetone relative to KHP. Trichlorophenol standard solutions were found to be less stable than those for acetone and for this reason acetone was chosen as a more suitable volatile standard compound.

A comparison of the TOC results for the model compounds is presented in Table 3. The percent volatile carbon for each compound was determined by the difference between purged and unpurged standard solutions as described above. for acetone and trichlorophenol. In general, the volatile fraction observed for each volatile organic solvent standard was quite similar to that predicted from purging efficiencies reported by previous workers (Bellar and Lichtenberg, 1974; Kuo and others, 1977).

The sensitivity of the modified method for volatile compounds was found to be very dependent on the ease of persulfate oxidation. Compounds which were less volatile under the test

Standard o	concentration	Percent	High temperature combustion	– – – Percent – – Trapping/ desorption	Overall procedure
(mg-C/l)	(µg-C/5 ml)	volatile*	efficiency*	efficiency**	efficiency***
1.0	5	8.2	98	88	133
2.0	10	8.6	94	88	149
5.0	25	9.3	91	84	120
10.0	50	9.9	93	78	118
Mean		9.0	94	85	130 ± 11% (relative standard deviation)
(N)		(12)	(12)	(24)	(12)

### Table 2. Average Performance Data for Acetone in the TOC Procedure

Determined by difference between purged and unpurged standards after wet combustion relative to KHP.

Carbon recovered by vapor injections X 100

Volatile carbon

Carbon recovered by purging, trapping and desorption

Volarile carbon

** Instrument response for acetone (VOC + NVOC) relative to KHF

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100, corrected for combustion efficiency

Compound	. matile fraction (%)	Sensitivity* (integrator_counts/µg·(.)	Recovery** (% bias)	' mit or quantitation
Chloroform	84	143 ± 69	21	0.52
Trichloroethylene	59	115 ± 54	9.8	0.65
Benzene	53	$113 \pm 16$	-19	0.66
Dichloromethane	48	51 ± 28	-17	1.46
Toluene	46	91 ± 55	-13	0.82
Trichlorophenol	8.8	208 ± 80	9.1	0.36
Acetone	9.0	196 ± 38	10	0.38
Acetaldehyde	<0.1	178 ± 33	16	0.42
Dimethylformamide	<0.1	202 ± 32	21	0.37
Acetic acid	<0.1	199 ± 29	9.5	0.38
Propanoic acid	<0.1	165 ± 28	10	0.45
Pentanoic acid	<0.1	155 ± 21	-9.0	0.48
кнр	<0.1	150 ± 17	-	0.50
All compounds		151 ± 32	4.0	0.57

### Table 3. Average Performance Data for Model Compounds in the TOC Procedure (mg-C/I) (relative to KHP)

 Average sensitivity for TOC values between 1 and 10 mg-C/L. Mean value and the relative standard deviation in percent are tabulated.

* Recoveries calculated as percent bias from the mean value relative to KHP at the 1.0 mg-CA level.

^b Defined as the equivalent carbon content of 10⁻³ M NaHCO₃ solution blanks plus 10 times the standard deviation of the blank values.

conditions and resistant to persulfate oxidation showed marked reductions in sensitivity relative to KHP or acetone. Nonetheless, the sensitivity for all model compounds with the exception of dichloromethane and toluene was within two relative standard deviations of the value for KHP. The average recoveries varied ±20% from the KHP standard. The limits of quantitation (ACS, 1980) of the modified TOC procedure for the model compounds (excepting dichloromethane) were quite comparable to that of KHP, acetone or trichlorophenol. The average quantitation limit of 0.57 mg-C/l may be accepted as the lowest TOC concentration that can be reliably determined by infrared detection methods. Since most shallow ground-water samples have exhibited NVOC values alone greater than 0.5 mg-C/l, this is not a serious drawback for screening purposes.

The preceding performance data on the modified TOC procedure establish that, within experimental error, volatile organic carbon represented by a range of model compounds can be reliably determined on a routine basis. Overall, precision and accuracy for replicate carbon standards at 1.0-10 mg-C/l over an 18-month period averaged less than ± 20% relative standard deviation and ± 20% bias, respectively. Sample analysis times for the modified TOC procedure were approximately 20 minutes, excluding setup and overnight wer chemical oxidation. The need to individually process each sample for VOC results in longer.

sample analysis times, but the value of complete TOC data seems to be well worth it. This is particularly true when TOC is used as a surrogate parameter for contaminant plume definition (Leenheer and others, 1976), a contamination screening tool (Hughes and others, 1974), or as a basis for evaluating the reactivity of the organic carbon in ground-water samples—for example, sorption interactions (Humenick and Mattox, 1978).

### **TOC Determinations on Ground-Water Samples**

The analysis and reporting of both VOC and NVOC have potential application for the screening of volatile organic carbon contaminant plumes, particularly when "background" VOC levels are quite low. The modified TOC procedure described above was applied to selected ground-water samples. Ground-water samples were collected in 40-ml Teflon-sealed vials directly from the pump outputs. The intent in this part of the study was to determine both the amount of volatile organic carbon present in shallow ground-water samples in the absence of organic contamination, as well as in a situation where large amounts of organic matter have been introduced anthropogenically.

Replicate TOC determinations were made on 11 samples of ground water from a residential area in northern Illinois. The wells were privatelyowned, steel-cased wells, finished between 60-70 feet (18.3 m) in sand and gravel outwash deposits described by Berg and others (1981). The

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Table 4, TOC Detern	ninations mg-C}	i <mark>n Shallov</mark> :/l)	w Ground	i Water
Sample	COF	NVOC	roc	's Vol
1	0.23	3.20	3.43	6.6
2	0.21	2.24	2.45	8.4
3	0.39	3.57	3.96	9.8
4	0.33	2.34	2.67	12.3
5	0.31	3.25	3.56	8.6
6	0.18	2.60	2.78	6.6
7	0.10	2.60	2.70	3.7
8	0.25	2.10	2.35	10.5
9	0.31	2.16	2.47	12.6
10	0.35	2.72	3.07	11.4
11	0.31	2.68	2.99	10.4
Limit of quantitation*	0.10	0.24	0.34	-
Mean TOC			2.95	
Average percent VOC				9.2

⁶ Limit of quantitation defined as blank value in  $\mu$ g-C + 10  $\sigma$  (relative standard deviation) relative to the response for KHP.

analytical results from these samples are compiled in Table 4. The levels of TOC in these samples averaged 2.95 mg-C/l of which 0.27 mg-C/l or 9.2% was present as VOC. Precision of the modified TOC determination on these samples was better than ±5% (relative standard deviation) from triplicate analytical runs. The improved precision for natural samples relative to acetone (Table 2) was probably the result of less handling prior to analysis. Parallel determinations of conductivity, pH, TDS, nitrate and Kjeldahl nitrogen were performed on these samples, and the results showed essentially no correlation with the TOC data. Although the volatile organic carbon contents of these TOC results was low, each was above the limit of quantitation established for the procedure. Therefore, a significant percentage of VOC may be expected in uncontaminated ground-water samples.

Complete TOC determinations can provide valuable diagnostic evidence of contaminated subsurface situations. Two examples of the application of the modified TOC procedure include the investigation of the effects of organic drilling fluids and natural organic substances (petroleum) on ground-water organic content.

In the course of establishing a ground-water research field site near Havana, Illinois, in Mason County, an array of large-diameter PVC observation wells was installed in shallow sand and gravel deposits (Naymik and Sievers, 1983). Several of these wells were rotary drilled using an organic drilling fluid (Revert 90), while the bulk of the wells were constructed by either hollow-stem auger

or driven-sand point techniques. Those wells drilled with organic drilling fluids were chlorinated and developed when they were completed in March-1982 Figure 1 shows the results of TCC determinations on ground-water samples from the site for one year after construction. Augured or driven wells screened through two water-yielding strata showed an average background TOC level of 4.38 mg-C/l (N = 6) with a relative standard deviation (r.s.d.) of 11%. The VOC made up an average of 15 ± 40% r.s.d. of the total organic carbon. The wells drilled with the organic fluid, however, showed average TOC levels two to three times the background concentrations ( $\bullet$  SR1 and  $\circ$  SR2) during a three to six month period after construction. VOC made up nearly 95% of the TOC in / samples collected prior to November 1982. Thereafter, the TOC content of the rotary-drilled well samples increased to over five times the background, and the VOC fraction gradually decreased to within background levels of 0.4-1.0 mg/l. Although exhaustive pumping of wells SR1 and SR2 in April 1983 yielded samples that were only twice the background levels, the effect of the





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introduction of foreign organic matter during the drilling operation was clearly persistent. Major cations, anions and alkalinity showed little or no correlation with the variations in TOC or VOC concentrations. Total iron, however, showed significant increases which may be linked to organic carbon content.

The TOC results after well construction demonstrate the impact of organic drilling muds on ground-water quality. High levels of VOC during this period may have been the result of the initial breakdown of the drilling mud near the well bore by microorganisms. If this indeed occurred, then the TOC increases over the later study period may be due to the release of nonvolatile, soluble organic materials or other biotransformation products. The large increases in TOC over background levels could have important effects on the separation and identification of specific organic compounds, given the shift in organic carbon from predominately volatile to nonvolatile forms.

The second example of the diagnostic application of TOC determinations in contaminated shallow ground-water systems involved the investigation of a complaint of an abrupt change in taste and odor of a private well supply near Sullivan. Illinois, in rural Moultrie County. The 36 foot (11 m) steel-cased well was finished in glacial till, and provided the potable and livestock water for a farmstead. Initial measurements of TOC showed that 50% of the total organic carbon  $(1.4 \pm 0.2)$ mg-C/l) was volatile. Samples taken several months later were analyzed, and TOC levels were significantly higher than the previous results  $(3.23 \pm 0.1)$ mg-C/l). Greater than 95% of the observed increase, was due to volatiles (excluding methane which was present at 11 ml/l). It was known that investigation of shallow petroleum deposits in the area using seismic prospecting methods had been conducted about six months before the water quality change was noticed. Dynamiting during the prospecting activity may have permitted the migration of petroleum-related constituents into formations intercepted by the potable-water well

## CONCLUSIONS

The routine wet digestion IR detection procedure for TOC determinations in ground-water samples has been modified to include the colatile organic traction. The method was validated for models reaction. The method was validated for models reaction compounds and applied to relected ground water samples. The performance of the method for a surface to colater and reactions.

pounds was to and to be good and sol-

quite comparable to that observed for the asale. TOC standard, potassium hydrogen physicate

The value of TOC determinations at a screening tool for contaminated ground-water situations is markedly improved by the quantitation of VOC, as well as NVOC. The VOC fraction can make up from 9-50% of the total organic carbon in ground-water samples. The usefulness and reliability of future monitoring efforts can be significantly enhanced by the determination of volatile organic carbon.

## ACKNOWLEDGMENTS

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where  $P_{\rm eff} = \frac{1}{2\pi} \frac{1}{2} \frac$ 

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# MONITORING WELL CONSTRUCTION FOR HAZARDOUS-WASTE SITES IN GEORGIA

by

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William H. McLemore



Department of Natural Resources Environmental Protection Division Georgia Geologic Survey



Circular 5

# MONITORING WELL CONSTRUCTION FOR HAZARDOUS-WASTE SITES IN GEORGIA

by

William H. McLemore

Department of Natural Resources J. D. Tanner, Commissioner

Environmental Protection Division J. Leonard Ledbetter, Director

Georgia Geologic Survey William H. McLemore, State Geologist

1981

# MONITORING WELL CONSTRUCTION FOR HAZARDOUS-WASTE SITES IN GEORGIA

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# INTRODUCTION

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In the past year, the Georgia Geologic Survey has been called upon on several occasions either to drill or comment upon the drilling and construction of monitoring wells. Typically, these wells were designed to evaluate the hydrology and geochemistry of the groundwater regime at existing or proposed hazardous waste facilities. With the above in mind, it is appropriate that we delimit our philosophy by which we construct monitoring wells or by which we would evaluate monitoring wells constructed by others. Obviously, because monitoring wells are designed to "look-at" the ground-water regime as well as gather water samples, local geologic conditions will play an important role in actual well construction, and rigid adherence to any set of criteria is neither practical nor prudent. Rather, our only objective in summarizing our philosophy in this Circular is to establish a set of "side-boards" that would be expected in a monitoring well construction program, which nevertheless, could be modified as local conditions dictate. The approaches set forth in the following sections are based on the experiences of the author in drilling and constructing many hundreds of monitoring wells in various parts of the country. The parrative is written in simple practical terms for geologists or engineers already familiar with the science of ground-water hydrology as well as well-drilling procedures. Lengthy technical descriptions are not provided; rather, the reader is referred to numerous USGS, EPA (especially a document such as EPA Manual SW-611) and other technical documents for such descriptions.

# **DRILLING SUPERVISION**

Drilling and construction of monitoring wells should be under the close supervision of an experienced geologist or engineer. Changes in lithology, bedrock voids, pinchouts and so forth are rarely appreciated or observed by drillers. Obviously, as such variations affect hydrologic conditions, the geology of any site should be well understood.

For example, the author worked on a project to monitor a contamination plume at a manufacturing facility in the Coastal Plain of a mid-Atlantic state. At the manufacturing site, the shallow unconfined aquifer was separated from a deeper artesian aquifer by a dense clay. Also, the shallow aquifer was at a higher head than the deeper aquifer. Flow direction in the shallow aquifer was toward the northeast, whereas in the deeper aquifer, flow was toward the southwest. However, the detailed notes and observations of the field geologist indicated that the clay was thinning in a northeasterly direction; and apparently, the clay pinched-out immediately offsite and the two aquifers merged. As the site geologist had made careful observations and had taken good notes, it could be postulated that the plume was moving to the northeast, flowing over the lip of the pinchout into the deeper but lower head artesian aquifer, and thence moving to the southwest back underneath the manufacturing facility. Such an interpretation never could have been developed without having an experienced geologist continuously observing drilling operations and collecting cuttings.

Based on my experience, a single well-trained (i.e., at least one year of rig time) geologist or engineer can supervise two drilling rigs as long as they are not too far apart (i.e., a walk or drive of 5 minutes or less) and no other ancillary duties are required. If water sampling, pump testing, well development and so forth are scheduled, additional personnel would be necessary.

Drilling supervision by an experienced geologist or engineer also permits monitoring wells to be constructed to rather precise tolerances. By using a weighted steel measuring tape, sand/gravel packs, seals and so forth can be placed with an accuracy of  $\pm 4s$  foot. Similarly, a competent geologist or engineer should know the depth within  $\pm 1$  foot of the boring at any time. And by collecting cuttings or noting variations in drilling progress/speed, the geologist or engineer should be able to make accurate predictions regarding changes in lithology, in those portions of the boring where samples are not being collected.

# SELECTION OF THE DRILLING RIG

Selection of the drilling rig is extremely important. Because placement of screens and seals is extremely crucial in properly evaluating specific geologic horizons, the drill rig must have the capability to collect samples. Also, because porosity and permeability measurements, grain size, or strength tests may be necessary, the drill rig also should have the ability to collect undisturbed samples.

Cleanliness is another important criterion for the drill rig. Typically, drill rigs used for the construction of monitoring wells are contracted; and often they are covered with grease and grime from many different projects. As such grease and grime may contain a wide variety of solvents, metals or other chemicals, one cannot discount the possibility that trace amounts of contaminants may be introduced to the well. The author is aware of a situation where a drill rig was used for soil borings at a petrochemical complex in New Jersey and subsequently was employed for the construction of monitoring wells at a New York manufacturing plant. When unusual hydrocarbon compounds

were detected in some of the monitoring wells at the manufacturing plant, management became quite concerned, as these hydrocarbon compounds were neither used nor stored at the plant. Finally, after much frustration, it was recognized that the hydrocarbon compounds had been "carried" by the drill rig from the petrochemical complex to the manufacturing plant. Such a situation easily can be mitigated by using a clean drill rig. The simplest way to obtain a high level of cleanliness is to steam clean the drilling rig. Steam jennys can be found almost everywhere; and steam cleaning of the drill rig more or less eliminates the possibility of "carrying" contaminants onto the site.

Thirdly, any drill rig used in the drilling and construction of monitoring wells should be free of oil and fuel leaks. Any oil or fuel leaking into the mud pad or adjacent to the bore hole will almost certainly enter the well. If this were to occur, total organic carbon (TOC) levels or detection of fuels and greases in ground-water samples might be spurious. Introduction of oils and fuels into the ground-water regime can be prevented by the site geologist or engineer performing a daily inspection of the drill rig and insisting that the driller tighten all parts, replace gaskets, and so forth.

## SAMPLING

Sampling is especially important in any program of monitoring well construction. The reason for this is quite simple; namely, without a good understanding of lithologic variations, the screens and seals, which are so important in monitoring well construction, cannot be properly placed. Such samples also are useful in evaluating permeability, porosity, or subtle changes in facies. Moreover, an improperly constructed monitoring well can be a vehicle for interaquifer contamination. For example, as illustrated in Figure 1, an inappropriate sampling program can lead to an incorrect interpretation of stratigraphy, with resultant . improper well construction. The author has found that, at those sites where comprehensive and rigid sampling programs were performed. well construction problems were minimal. Conversely, where sampling was de-



emphasized, wells commonly were improperly drilled or located, and in some cases had to be drilled-out and plugged. The costs saved by curtailing or minimizing sampling are only imaginary. Drilling-out wells is prohibitively expensive as well as being emotionally quite frustrating. Rather, it is much more simple to initiate a comprehensive sampling program from the beginning.

# SELECTION OF MONITORING WELL SITES

One of the greatest mistakes any program of monitoring wells can incur is to "cut-corners" and drill an inadequate number of monitoring wells to properly assess or monitor the flow regime at the site. As an absolute minimum and where the site hydrology is simple and relatively well understood, five wells per aquifer system are necessary. Figure 2 illustrates a typical but yet quite simple arrangement of monitoring wells.

In the winter and spring of 1980, the Georgia Geologic Survey conducted a monitoring well program at a ten-acre hazardous waste facility in Wilkinson County, Georgia. The following description, which is from the report describing the results of this program, provides insight into how monitoring wells can be located:

.... The first three Tuscaloosa aquifer wells (#1, #3, and #5) were selected to bracket the waste disposal trenches and establish the general direction of groundwater flow. Well #1 was drilled upslope from the burial trenches in order to penetrate a maximum (complete) thickness of the Twiggs Clay. Wells #3 and #5 were positioned downslope from the burial trenches at locations which, from field observations, appeared compatible for intercepting any potential migrating leachate.

As these three wells generally form an equilateral triangle, true direction of ground-water flow within the Tuscaloosa can be established by performing a simple "3-point problem". (Note: from geometry, we know that 3 points determine a plane; hence the potentiometric surface, which is more or less a plane, also can be estimated.) Once the general direction of ground-water flow was established, wells #7 and #8 were drilled at locations that would be favorable for intercepting any leachate migrating from the trenches. In summary:

- Wells #1, #3 and #5 were used to establish the general direction of groundwater flow in the Tuscaloosa as well as serve as monitoring wells.
- (2) Wells #7 and #8 were located at positions (identified from the direction of ground-water flow) favorable for intercepting any potential migrating leachate.

.... Shallow wells \$2, \$4, and \$5 were designed to evaluate the sandy zone at the base of the "upper" Twiggs Clay. For convenience, the shallow wells were placed adjacent to existing Tuscaloosa wells.

Well depths for the first three Tuscaloosa wells were such that the wells penetrated a minimum of 20 feet of water bearing Tuscaloosa. After development, it was noticed that the water level in well #3 had dropped and was significantly lower than the levels in wells #1 and #5. This suggested perched water conditions; therefore, wells #7 and #6 were drilled through a minimum of 50 feet of water bearing Tuscaloosa. Also, in these latter two wells, steel casing was installed into a lignitic clay, thereby permitting us to assess the hydrogeological regime in the main water bearing zone of the Tuscaloosa beneath the lignitic clay....

In summary, indiscriminant drilling of monitoring wells on a site is counterproductive. Wells clearly need to be placed in locations favorable for intercepting any actual or potential plumes. Where the general flow patterns are not well understood, it is recommended that the initial wells be drilled to establish the hydrogeological regime. The latter wells, in turn, should be drilled to monitor specific facilities or potential contaminant sources. Considering the size of the facility in question, the number of potential onsite and offsite contaminant sources, as well as the geologic complexity of the site area, the number of wells could range from five to perhaps several hundred.



# MONITORING WELL CONSTRUCTION

# General

Monitoring wells may be of a variety of sizes. but 4-inch diameter wells are considered optimum as they are most versatile. A well of such diameter provides an opening adequate for the installation of a 3-inch submersible pump suitable for either well evacuation or water sampling. Also, such a diameter is amenable for gamma logging. Smaller diameter wells (i.e., 3-inch or 2-inch) are useful only where the water level is within about 30 feet of the surface as they typically are evacuated or sampled by means of a centrifugal pump.

The principal advantage of small diameter wells (namely 2-inch or smaller) is that they can be installed through the auger-flights of a hollow stem auger drilling rig. More complicated rotary drilling methods are required for 3 and 4 inch wells." On the other hand, augers have great difficulty penetrating gravel zones or saprock, which is the partially decomposed but still resistant bedrock characteristic of much of the Piedmont of Georgia. Tables I and II provide general guidelines used by the Georgia Geologic Survey regarding selection of drilling rig as well as selection of monitoring well diameter. The guidelines presented in Tables I and II are intended to be practical rather than actual. That is, a good driller with an inappropriate drilling rig probably can accomplish more than an incompetent driller with an ideal rig. Therefore, the guidelines should be considered merely as a tool for optimum drill rig and well diameter selection.

The following descriptions and illustrations are for 4-inch diameter wells: naturally, wells of other dimensiongwould be somewhat different. Nevertheless, the descriptions provide the reader with insight into the necessary precision expected of hazardous waste monitoring wells.

# Monitoring Wells in the Piedmont or Blue Ridge:

Typical Piedmont or Blue Ridge monitoring wells are illustrated in Figure 3. In general, ground water in these two physiographic provinces is unconfined, artesian conditions are rare, and the soil (either saprolite or colluvium) and rock aquifers are hydraulically interconnected. Three types of monitoring wells are anticipated in the Piedmont and Blue Ridge: (1) saprolite or colluvium wells. (2) combined soil and rock wells, and (3) rock wells. Each of these is described below:

- (1) Saprolite or Colluvium Wells -The recommended well construction involves:
  - Drilling an 8-inch diameter boring into hard rock;
  - Confirming that the boring has bottomed in hard rock (rather than saprock) by NX-coring 5 feet into hard rock with at least
    50 percent recovery.* (Note: a good driller often can accurately identify hard rock merely by "feeling" the change in drilling progress; if the driller is capable of making such identification, this coring step may be omitted).

[•] The author is aware that 6-inch hollow stem sugers are now available. Obviously such a large auger would be extremely versatile and could be used to construct 4-inch wells. Nevertheless, since 6-inch hollow stem augers are so rare in Georgia, I will not address them further.

[•] The author recognizes that rock coring at the base of a relatively large diameter boring is quite difficult and often involves the use of casing, which potentially may become stuck in the hole. It is not the intent of the author to add a burdensome or unnecessary drilling task, but rather to emphasize the importance of accurately defining the soil-rock interface. If coring can be avoided without compromising the identification of this interface, then by all means do so.

# Table I. Guidelines For Drilling Rig Selection

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Anticipated Drilling Conditions For	Optim	um Drill Rig
Well Construction Program	Auger	Rotary
(1) Shallow water table (less than 30 feet)	Yes	Yes
(2) Deep water table (greater than 30 feet)	No	Yes
(3) Gravel and resistant zones	No	Yes
(4) Loose sand or thick clays	Difficult	Yes
(5) Undisturbed samples required	Difficult	Yes
(6) Disturbed samples required	Yes	Yes
(7) Depth to bedrock less than 80 feet	Yes	Yes
(8) Depth to bedrock greater than 80 feet	Difficult	Yes
(9) Rock coring	Yes	Many rotary rigs are
		not capable of coring
(10) Seals and screens to be placed at specific		-
intervals	Difficult	Yes

# Table II. Guidelines For Selection Of Monitoring Well Diameter

Anticipated Drilling Conditions For	Monitor	ing Well I	Diameter
Well Construction Program	2-inch	<u>3-inch</u>	_4-inch_
(1) Shallow water table (less than 30 feet)	Yes	Yes	Yes
(2) Deep water table (greater than 30 feet)	· No	Possibly	Yes
(3) Well to be considered for decontamination or			
dewatering	No	Possibly	Yes
(4) Well to be sampled on frequent basis	Possibly	Possibly	Yes
(5) Water level recorder to be installed	No	Difficult	Yes
(6) Clayey soils that may be difficult to develop	No	Possibly	Yes
(7) Bedrock coring NX-sized or overburden to		-	
be cased-off.	No	No	Yes
(8) Gamma logging anticipated	No	Yes	Yes

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• Backfilling with expandable bentonite pellets to slightly above the soil-rock contact. By doing such, the boring can be hydraulically separated from the rock aquifer.

- Installing slotted PVC screen of appropriate size from the bottom of the boring to several feet above the water table. The base of the screen should be capped; and the top of the slotted portion of the screen should take into account both seasonal as well as multi-year fluctuations in water levels. Blank PVC casing is extended from the top of the screen to one or two feet above ground surface.
- Filling the annular space between the bore hole and the PVC screen with an appropriate sand/gravel pack.
- Placing a one or two foot thick bentonite pellet seal above the sand/gravel pack.
- Tremis-grouting a bentonitecement mixture to the ground surface in the annular space between the bore hole and the PVC casing.
- Cementing in a 5-foot (3-feet below ground and 2-feet above ground) section of protective 6inch steel pipe with a locking cap.
- (2) Combined Soil and Rock Wells - In this case, well construction is similar to that for saprolite/colluvium wells except that the NXsized coring is not stopped at 5 feet, but rather is continued until an adequate section of saturated rock is penetrated. (Based on the author's experience in Georgia, the saturated rock portion of the well should be at least 40 feet.)

Also, recommended at the base of the soil portion of the well is a 2-3 foot section of blank PVC casing, with a 2-3 foot bentonite pellet seal in the opposite annular space. Such casing and seal often are necessary to prevent rock and/or the sand/gravel pack from sloughing-off into the cored portion of the well. Combined soil and rock wells are difficult to drill and construct, and often it is most prudent to drill two separate wells (a soil well and a rock well) side by side at a few feet apart. 

- (3) Rock Wells For this type of well, the recommended well construction involves:
  - Drilling an 8-inch diameter boring into the hard rock.
  - Confirming that the boring has bottomed into hard rock by NXcoring 5 feet into rock with at least 50 percent recovery (refer to earlier descriptions regarding identification of soil/rock interface).
  - Cementing-in, by pressure grout methods, 4-inch steel casing.
  - NX-coring an appropriate depth into rock.
  - Attaching a locking cap to the 4-inch steel casing.

# Monitoring Wells in the Coastal Plain:

Typical Coastal Plain monitoring wells are illustrated in Figure 4. In the Georgia Coastal Plain, the shallow aquifer is typica..., unconfined and underlain by one or more artesian aquifers. Two types of monitoring wells are anticipated in the Coastal Plain: (1) shallow aquifer wells and (2) deeper (artesian) aquifer wells. The deeper wells are of two types; a simple construction and a more complex construc-



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tion, for which steel casing is extended into the confining unit separating the shallow from the deeper aquifer. USE OF STEEL PROTECTIVE CASING IS RECOMMENDED WHENEVER THERE IS ANY POTENTIAL. NO MATTER HOW SMALL, FOR CONTAMINATED WATER TO MOVE FROM ONE AQUIFER TO ANOTHER. SPECIAL CARE SHOULD BE EXERCISED SO THAT MONITORING WELLS DO NOT ACT AS PATHWAYS FOR CONTAM-INATION. Each of the aforementioned types of monitoring wells is described below:

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- (1) Shallow Aquifer Wells The recommended well contruction involves:
  - Drilling an 8-inch diameter boring to hard rock, to a lower confining unit (illustrated), or until an appropriate section of aquifer has been penetrated (at least 40 feet of saturated material).
  - Confirming the lithologic character of the geologic materials at the base of the boring. This may be done by coring, split spoon sampling, Shelby tubes, etc.
  - Backfilling with bentonite pellets to slightly above the contact between the shallow aquifer and the lower confining unit or the hard rock. This step may be omitted for those wells merely penetrating saturated material.
  - Installing slotted PVC screen of appropriate size from the bottom of the boring to several feet above the water table. The base of the screen should be capped; and the top of the slotted portion of the screen should take into account both seasonal and multi-year fluctuations in water levels. Blank PVC casing is extended from the top of the screen to one or two feet above ground surface.

- Filling the annular space between the bore hole and the PVC screen with an appropriate sand/gravel pack.
- Placing a one or two foot thick bentonite pellet seal above the sand/gravel pack.
- Tremie-grouting a bentonitecement mixture to the ground surface in the annular space between the bore hole and the PVC casing.
- Cementing in a 5-foot (3-feet below ground and 2-feet above ground) section of protective 6inch steel pipe with a locking cap.
- (2) Deeper (Artesian) Aquifer Wells - The recommended simple well involves:
  - Drilling an 8-inch diameter boring until an adequate section of the deeper aquifer is penetrated (at least 40 feet).
  - Confirming the lithologic character of the geologic materials at the base of the boring. This may be done by coring, split spoon sampling. Shelby tubes, etc.

- Installing slotted PVC screen of appropriate size from the base of the boring to slightly below the contact between the deeper aquifer and overlying confining unit. The base of the screen should be capped. Blank PVC casing is extended from the top of the screen to one or two feet above ground surface.
- Filling the annular space between the bore hole and the PVC screen with an appropriate sand/gravel pack.

- Placing a thick bentonite pellet seal above the sand/gravel pack. This seal is quite important in separating the shallow aquifer from the deeper aquifer. and should be of sufficient thickness to insure that the bore hole does not act as a pathway between the shallow and deeper aquifers.
- Tremie-grouting a bentonitecement mixture to the ground surface between the bore hole and the PVC casing.
- Cementing in a 5-foot (3-feet below ground and 2-feet above ground) section of protective 6inch steel pipe with a locking cap.

The recommended complex well construction is quite similar except that an oversized (about 12 inches) boring is drilled to the top of the confining unit. Once the presence of the confining unit is established by sampling, 8-inch steel casing is driven-in or spun-into the confining unit. Next, a bentonite-cement mixture is tremie-grouted into the annular space between the bore hole and the steel casing, thereby hydraulically separating the shallow aquifer from the bore hole. The remaining steps are identical to those described above for the simple well construction program except that the locking steel cap can be attached to the 8-inch casing.

# Monitoring Wells in the Valley and Ridge:

Typical monitoring wells in the Valley and Ridge are illustrated in Figure 5. From a general hydrogeologic point of view, Valley and Ridge aquifers are quite similar to Coastal Plain aquifers except that the former commonly are steeply dipping and characterized by fracture porosity. From a practical point of view, Valley and Ridge dips are of little consequence in monitoring well construction. When considering the relative small size of the well (only a few inches in diameter), geologic contacts only affect a few inches of bore hole and are of minor concern. Fractures in confining units can easily be isolated from the bore hole by careful use of bentonite pellet seals. For example, the reader should note that bentonite pellet seals illustrated for Valley and Ridge monitoring wells (Figure 5) are substantially thicker than the seals illustrated for Coastal Plain wells (Figure 4). Thus, except for seal placement, Valley and Ridge monitoring wells are constructed in a similar fashion to Coastal Plain monitoring wells.

# DEVELOPMENT

Development involves removal of drilling fluids and formational fines from around the bore hole so that the well will produce clear water.

Development adds an insurance factor to minimize the potential that trace amounts of contaminants will be "carried" from one bore hole to the next.* This is the result of fluids in closest proximity to the well (i.e., drilling fluids and ground water immediately outside the bore hole) being removed by the development process. Also, as development removes drilling fluids and formational fines, the water level within the well commonly changes as the well comes into more direct hydraulic intercommunication with the ground-water regime. Thus the water levels in the well more closely reflect the potentiometric surface. Moreover, some metals and organics will preferentially sorb onto fine particulates or be concentrated in the drilling process. Development, therefore, also insures that analytical bias will not occur and that the water samples collected for chemical analyses will be representative of ground water in the vicinity of the well. In summary, IT IS THE OPINION OF THE AUTHOR THAT CHEMICAL AND HYDROLOGIC MEASURE-MENTS MADE FROM UNDEVELOPED WELLS ARE SUSPECT AND CANNOT BE RELIED UPON.

[•] The anomalous hydrocarbon compounds previously discussed in the Selection of the Drilling Rig section were removed from the monitoring wells at the manufacturing plant by extensive well development.



REPRESENT NOT AN ARRANGE RESERVED IN THE REPORT 

# DOWNHOLE GEOPHYSICAL LOGGING

Borehole geophysical logging, such as spontaneous potential (SP), resistivity, or gamma, is recommended for all Coastal Plain wells and those wells in the Valley and Ridge where stratigraphic interpretations are important. On the other hand, borehole logging is not a particularly useful test in Piedmont and Blue Ridge wells where the saprolite-bedrock interface is gradational and/or ill-defined.

# **GENERAL SUMMARY**

The text and illustrations that have been presented are not meant to be inclusive; rather, the author is attempting merely to stress that monitoring wells for hazardous waste facilities should never be drilled in a haphazard fashion. The reader should clearly understand that monitoring wells are, in effect, rather sophisticated scientific instruments, and as such, require a high degree of technical expertise to be properly constructed.

Perhaps no greater mistake can be made than to regard monitoring wells as simply "wells", which can be more or less drilled by anyone. Such an attitude can, at worst, result in interaquifer contamination or, at best, result in the gathering of meaningless information. -----

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Red	Valley and Ridge mapping and structural regions
Dk. Purple	Piedmont and Blue Ridge mapping and structural geology
Mercon	Coastal Plain mapping and stratigraphy
Lt. Green	Paleontology
Lt. Blue	Coestal Zone studies
Dk. Green	Geochemical and geophysical studies
Dk. Blue	Hydrology
Olive	Economic geology
	Mining directory
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APPENDIX N MONITORING WELL INVENTORY FOR AIR FORCE PLANT 6

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MONITORING WELL INVENTORY AIR FORCE PLANT 6

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	WELL		GRID COOR	DINATES	GROUND	TOP CASING	WELL	BEDROCK
IDE	NTIFICATION	LOCATION	NORTH	EAST	ELEVATION	ELEVATION	DEPTH, FT	DEPTH, FT
	B-1/	Truck Fuel Farm	1,427,130	389,670	1085.10		40	66
	<b>B-2</b>	Truck Fuel Farm	1,427,050	389,310	1091.10		33	26
511e (66	B-4/	Truck Fuel Farm	1,427,240	389,600	1092.20		40	40+
10-10 1-10	) B-5	Truck Fuel Farm	1,427,100	389,470	1087.00		32	24
Aefat Ion B	B-8	Truck Fuel Farm	1,427,150	389,500	1088.00		35	35+
UISPO	B-9/	Truck Fuel Farm	1,427,130	389,450	1088.00		31	31+
	A-1/	Truck Fuel Farm	1,427,130	389,500	1086.90			
	A-2 /	Truck Fuel Farm	1,427,030	389,770	1082.90			
	B-1	Industrial Waste Disposal Basin	1,428,320	392,550	1064.60	1066.65	43	28
	B-2	Industrial Waste Disposal Basin	1,428,020	392,200	1052.40	1055.60	30	30+
	B-3	Industrial Waste Disposal Basin	1,427,970	392,350	1051.30	1052.57	35	35+
	B-4	Industrial Waste Disposal Basin	1,428,960	392,500	1050.00	1051.05	30	30+
	/ B-5	Industrial Waste Disposal Basin	1,428,560	392,530	1070.80	1082.30	43	33
Site Gl	B-6	Industrial Waste Disposal Basin	1,428,070	392,800		1057.10	34	35
Surface	B-7	Industrial Waste Disposal Basin	1,428,560	392,360		1066.61	56	57
Impoundment	D-1	Industrial Waste Disposal Basin	1,427,800	392,320		1029.87	30	25
	D-2	Industrial Waste Disposal Basin	1,427,890	392,670		1041.03	67	67
	D-3	Industrial Waste Disposal Basin	1,427,820	392,150		1036.39	40	46
	D-4	Industrial Waste Disposal Basin	1,427,690	392,520		1033.48	47	50
	D-5	Industrial Waste Disposal Basin	1,427,900	392,830		1054.22	75	80+
	D-6	Industrial Waste Disposal Basin	1,428,050	393,000		1036.51	46	48
	D-7	Industrial Waste Disposal Basin	1,427,390	392,850		1043.92	48	51
	E-1	Industrial Waste Disposal Basin	1,428,500	392,860	1052.52	1053.77	57	64
	E-2	Industrial Waste Disposal Basin	1,428,090	393,270	1031.20	1032.12	37	37
	E-3	Industrial Waste Disposal Basin	1,427,560	393,380	997.13	998.76	27	27
	E - 4	Industrial Waste Disposal Basin	1,427,540	392,170	1056.53	1058.63	48	48
	E-5	Industrial Waste Disposal Basin	1,427,870	391,870	1073.94	1058.63	52	50

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MONITORING WELL INVENTORY AIR FORCE PLANT 6 (Continued)

	MELL		GRID COOR	DINATES	GROUND	TOP CASING	WELL	BEDROCK
31	ENTIFICATION	TUCATION	HINON	EAST	ELEVATION	ELEVAT LUN	DEPTH, FT	La 'HIAGO
	, E-6	Industrial Waste Disposal Basin	1,428,370	391,930	1065.28	1067.20	45	40
S114 C1	E-7	Industrial Waste Disposal Basin	1,427,640	392,330	1019.75	1021.33	8.6 /	8+
Surface	E-8	Industrial Waste Disposal Basin	1,427,790	392,250	1029.28	1030.40	6.3	6+
Impoundment	8 BR-1	Industrial Waste Disposal Basin	1,428,480	392,370	1066.00	1067.10	63	21
	<b>BR-2</b>	Industrial Waste Disposal Basin	1,427,780	392,330	ĭ029.12	1030.22	80	18
	BR-3	Industrial Waste Disposal Basin	1,427,778	392,360	1029.91	1031.58	225	14
`	MW-12	Industrial Waste Disposal Basin	1,428,440	392,500	1070±		26	26+
:-2	1 MW-8	IWTF Aeration Basin	1,427,820	389,110	1109.38	1111.60	45	45+
Site 06	6-MM	IWTF Aeration Basin	1,427,580	389,750	1079.11	1081.30	34	34+
8-10 Aeratio	m MW-22	<b>IWFF</b> Aeration Basin	1,427,500	389,230	1097.96	1100.37	41	40
Basin	MW-23	IWTF Aeration Basin	1,427,260	389,750	1090.81	1094.11	40	40
	MW-24	IWTF Aeration Basin	1,427,290	389,880	1088.31	1091.19	45	45+
	( MW-25	IWTF Aeration Basin	1,427,450	389,840	1081.51	1083.97	37	37+
	, MW - 3	Fuel Tank SW of B-l Building	1,429,040	387,680			20	18
	MW-4	NW Side of B-l Building	1,429,910	388,510			35	25
Miscel laneou	S MW-10	B-64 Parking Lot (Avionics Bldg)	1,428,210	391,450	10801		42	17
tiG Fanks	MW-11	SW B-64 (Avionics Building)	1,428,140	391,330	1070±		24	17
	MW-19	Georgia Tech Parking Lot L-2	1,422,530	391,130			16	16+
	MW-20	North of L-11 Jet Star Assem.	1,421,180	392,030			22	22+
	MW-21	south of L-11 Jet Star Assem.	1,420,690	392,020			14	14+
	1 - MM /	West of B-30	1,430,120	390,110	10961		55	25
Site 69	MW-2	West of B-77	1,429,080	389,670	1111±		50	18
ICE Spill	MM-5	West of B-43	1,429,990	390,550	1087±		66	30
at B-76	MM-6	b-8 Gas Pumps	1,429,780	390,340	1107±		55	55+
	MW-26	B-76 Chemical Storage	1,429,600	389,940	1109.64	1112.39	50	50+

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MONITORING WELL INVENTORY AIR FORCE PLANT 6 (Continued)

Site (9     (M-2)     East of B-10     (1,429,990     390,800     1094.13     1097.25     5.5       if B-76     (M-27)     East of B-10     1,429,800     390,800     1074.40     1076.95     39.       stt B-76     (M-27)     East of B-10     1,430,800     390,800     1074.40     1076.95     39.       stt B-76     (M-27)     East of B-31     1,430,800     390,900     1074.26     39.       stt C5     (M-31)     Access Road to Basin #2     1,430,190     390,900     1053.10     1065.74     39.       stt cutton     (M-31)     B-96 Ftel Tanks     1,423,400     392,200     1030.76     1033.61     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66     393.66	IDE	WELL NTIFICATION	LOCATION	GRID COORI NORTH	DINATES	GROUND ELEVATION	TOP CASING ELEVATION	WELL DEPTH, FT	BEDROCK DEPTH, FT
$ \begin{array}{ccccc} \label{eq:constraint} \begin{array}{cccccccccccccccccccccccccccccccccccc$						1			•
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	Site (9	( MW-27	East of B-30	1,429,990	390,260	1094.13	1097.25	55	49
$ \begin{array}{c ccccc} \mbox{it $6^{-1}$6} & \mbox{modelended} & it, $10, $10, $30, $20, $103, $21, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $57, $32, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $52, $1030, $	TCE Spill	AM-28	Roadway East of B-43	1,429,870	390,800	1074.40	1076.95	34	35+
Site $(5,-)$ Mm-30     Dike of Stormwater Basin #2     1,430,190     390,980     1005.12     1000.57     22       Stormwater     Mm-31     Access Road to Basin #2     1,430,190     390,980     1063.10     1065.74     33       Stormwater     Mm-11     B-96 Fuel Tanks     1,423,570     392,640     1055.74     33       Site citical     Mm-18     Position 19     1,423,560     392,200     1003.54     33       Wittent     Mm-36     Position 19     1,423,560     392,200     1033.47     33       Wittent     Mm-36     Position 19     1,423,540     392,290     1033.47     33       Wittent     Mm-30     Position 19     1,423,540     392,290     1033.47     33       Wittent     Mm-40     Position 19     1,423,510     392,290     1033.47     33       Wittent     Mm-40     Position 19     1,423,510     392,290     1033.47     303     33       Wittent     Mm-40     Position 19     1,423,510     392,290     1033.47     303	at B-76	MW-29	Landfill Sedimentation Pond	1,430,440	390,820	1039.91	1042.84	30	30+
Stornwater [M-31] Access Road to Basin #2 1,430,190 390,980 1065.14 31 Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Retention Rete	Stre (5	06-WM	Dike of Stormwater Basin #2	1,430,800	391,070	1027.32	1030.57	25	25+
RetentionRetention $1^{22}$ Mw-16North Position 12 $1^{22}$ Mw-16North Position 12 $1^{22}$ Mw-16North Position 12 $1^{22}$ Mw-16North Position 12 $1^{22}$ Mw-16Position 19 $1^{22}$ Mw-17Position 19 $1^{22}$ Mw-18Position 19 $1^{22}$ Mw-19Position 19 $1^{22}$ Mw-12Position	Stormwater	MW-31	Access Road to Basin #2	1,430,190	390,980	1063.10	1065.74	30	30+
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	ket ention	-							
$ \begin{array}{c} \begin{array}{c} & \mbox{M}-17 & \mbox{B}-98 \ \mbox{Fuel Tanks} & \mbox{I}, \mbox{4}, \mbox{2}, \mbox{4}, \mbox{2}, \mb$	Basin No. 2	MW-16	North Position 22	1,423,570	392,640	1025±		12	12+
$ \begin{array}{c} \overset{\circ}{\operatorname{Site}} (14^{-1} \ \mbox{Wu-18} \ \ \operatorname{Position} \ 19 \ \ \operatorname{Position} \ 10 \ 10 \ 10 \ 10 \ 10 \ 10 \ 10 \ 1$		MW-17	B-98 Fuel Tanks	1,423,490	392,040	1057±		48	45
$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	N-	/ MW-18	Position 19	1,423,490	392,200	1030.5±		16	16+
Position     HW-36     Position 19     1,423,530     392,290     1032.84     393 $19$ Fuel     HW-37     Position 19     1,423,530     392,230     1033.47     333 $19$ Fuel     HW-38     Position 19     1,423,530     392,230     1033.51     1033.34 $10$ -tuel     HW-38     Position 19     1,423,430     392,190     1031.65     1033.52     2 $10$ -40     Position 19     1,423,420     392,180     1015.13     1019.70     3 $10$ -42     Position 19     1,423,420     392,180     1015.13     1019.70     3 $10$ -42     Position 19     1,423,470     392,180     1013.05     1031.05     1031.05     1031.05     3 $10$ -42     Position 19     1,423,470     392,180     1011.05     1018.33     3 $10$ -42     Position 19     1,423,470     392,180     1011.05     1011.05     1011.05     1011.05     1011.05     1011.05     1011.05     1011.05     1011.05     10118.21     1018.31     3<	4 Site 614	MW-35	Position 19	1,423,580	392,210	1030.78	1033.61	30	30+
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	Position	MW-36	Position 19	1,423,580	392,290	1029.91	1032.84	30	30+
$ \begin{array}{c cccc} hcfuel & FW-38 & Position 19 & 1,423,440 & 392,200 & 1030.51 & 1033.34 & 2 \\ \text{Station} & FW-39 & Position 19 & NN-41 & Position 19 & NI-423,510 & 392,190 & 1030.82 & 1033.52 & 2 \\ W-40 & Position 19 & NN-41 & Position 19 & I,423,510 & 392,180 & 1015.13 & 1019.70 & 3 \\ W-41 & Position 19 & I,423,470 & 392,100 & 1015.13 & 1019.70 & 3 \\ W-41 & Position 19 & I,423,470 & 392,100 & 1015.13 & 1019.70 & 3 \\ W-42 & Position 19 & I,420,720 & 394,400 & 1021.29 & 1024.33 & 3 \\ W-31 & C-5 Wash Racks & I,420,590 & 394,310 & 1015.61 & 1018.35 & 3 \\ W-31 & C-5 Wash Racks & I,420,590 & 394,310 & 1015.21 & 1018.33 & 3 \\ W-31 & C-5 Wash Racks & I,420,700 & 394,260 & 1014.26 & 1017.04 & 3 \\ W-41 & B-104 Gas Pump Area & I,420,700 & 394,260 & 1014.26 & 1017.04 & 3 \\ Site C(b & W-41 & B-104 Gas Pump Area & I,420,930 & 394,130 & 1015.21 & 1018.33 & 3 \\ W-44 & B-104 Gas Pump Area & I,420,930 & 394,130 & 1014.26 & 1017.04 & 3 \\ Site C(b & W-41 & B-104 Gas Pump Area & I,420,930 & 394,130 & 995.77 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 997.79 & 994.160 & 1011.54 & 1012.97 & 300 & 1009.61 & 10009.61 & 10009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.61 & 0009.$	19Fuel/	MW-37	Position 19	1,423,530	392,230	1030.76	1033.47	30	30+
Station MW-39 Position 19 Position 19 I, 423, 420 392, 190 1030.82 1033.52 2 MW-40 Position 19 Not Drilled) 1, 423, 510 392, 160 1015.13 1019.70 , MW-42 Position 19 I, 423, 470 392, 160 1015.13 1019.70 , MW-42 Position 19 I, 423, 470 392, 160 1011.05 1031.05 3 3 1019.70 , MW-42 Position 19 I, 420, 720 394, 400 1021.29 1024.33 3 $6^{-5}$ Wash Racks I, 420, 810 394, 320 1031.05 1031.05 3 3 2 Position 19 Position 19 I, 420, 700 394, 320 1015.63 1018.35 3 2 Position 19 Position 19 I, 420, 700 394, 320 1015.63 1018.35 3 2 Position 19 Position 19 I, 420, 700 394, 320 1015.63 1018.35 3 2 Position 19 Position 19 I, 420, 700 394, 320 1015.63 1018.35 3 1, 420, 900 394, 360 1014.26 1017.04 3 1, 420, 900 394, 460 995.77 997.79 10 Position Position Position Prov Area I, 420, 900 394, 460 995.77 997.79 10 Position Pump Area I, 420, 900 394, 460 995.77 997.79 10 Position Pump Area I, 420, 900 394, 460 995.77 997.79 10 Position Pump Area I, 420, 900 394, 460 995.77 997.79 10 Position Pump Area I, 420, 900 394, 460 995.77 997.79 10 Position Pump Area I, 420, 900 394, 460 995.77 997.79 10 Position Pump Area I, 420, 900 394, 460 995.77 997.79 10 Position Pump Area I, 420, 900 394, 460 995.77 997.79 10 Position Pump Area I, 420, 900 394, 460 995.77 997.79 10 Position Pump Area I, 420, 900 394, 460 995.77 997.79 10 Position Pump Area I, 420, 900 394, 460 995.77 997.79 907.79 900 200 200 200 200 200 200 200 200 20	Defuel	MW-38	Position 19	1,423,440	392,200	1030.51	1033.34	24	19
Mu-40     Position 19 (Not Drilled)     1,423,510     392,180       Mu-41     Position 19     1,423,420     392,160     1015.13     1019.70     392,160     1015.13     1019.70     392,160     1015.13     1019.70     392,160     1015.13     1019.70     392,160     1015.13     1019.70     392,160     1015.13     1019.70     392,160     1015.13     1019.70     392,160     1031.05     133     32     32     32     32     32     32     32     32     32     33     33     33     33     33     33     33     33     33     33     33     34     33     33     33     34     33     33     33     34     33     33     34     33     33     34     33     33     34     34     310     1014.26     1017.04     33     33     34     34     34     34     34     34     34     34     34     34     34     34     34     34     34     34 <td< td=""><th>Station</th><td>MW-39</td><td>Position 19</td><td>1,423,420</td><td>392,190</td><td>1030.82</td><td>1033.52</td><td>26</td><td>24</td></td<>	Station	MW-39	Position 19	1,423,420	392,190	1030.82	1033.52	26	24
MW-41     Position 19     1,423,420     392,160     1015.13     1019.70     3       MW-42     Position 19     1,423,470     392,300     1031.05     1031.05     3       Site $G/$ MW-14     C-5 Wash Racks     1,420,720     394,400     1021.29     1024.33     2       Position 65     MW-32     C-5 Wash Racks     1,420,700     394,320     1018.35     3       *-C-5 Wash     MW-33     C-5 Wash Racks     1,420,700     394,310     1018.35     3       *uck Pouds     MW-33     C-5 Wash Racks     1,420,700     394,260     1014.26     1017.04     3       *uck Pouds     MW-15     B-104 Gas Pump Area     1,420,800     394,120     1014.26     1017.04     3       Site offo-     MW-43     B-104 Gas Pump Area     1,420,800     394,120     1014.26     1017.04     3       Site offo-     MW-44     B-104 Gas Pump Area     1,420,800     394,120     1011.24     1012.16     3       ************************************	-	MW-40	Position 19 (Not Drilled)	1,423,510	392,180				
Mu-42     Position 19     1,423,470     392,300     1031.05     131.05     33       Site $G/-e$ Mu-14     C-5 Wash Racks     1,420,720     394,400     1021.29     1024.33     22       Position 65     Mu-32     C-5 Wash Racks     1,420,690     394,300     1016.35     3 $-C-5$ Wash Racks     1,420,700     394,310     1015.21     1018.35     3 $-C-5$ Wash Racks     1,420,700     394,300     1014.26     1017.04     3       Kack Ponds     Mu-34     C-5 Wash Racks     1,420,700     394,460     1017.04     3       Site G16-     Mu-15     B-104 Gas Pump Area     1,420,700     394,460     997.79     10       Site G16-     Mu-43     B-104 Gas Pump Area     1,420,800     394,460     997.79     10       Mu-44     B-104 Gas Pump Area     1,420,800     394,130     1009.51     1013.97     2       Pump     Mu-45     B-104 Gas Pump Area     1,420,900     394,120     1009.51     1013.97     2     2       Pump		MW-41	Position 19	1,423,420	392,160	1015.13	1019.70	٦ ،	7+
Site G/   Mw-14   C-5 Wash Racks   1,420,720   394,400   1021.29   1024.33   2     Position 65   Ww-32   C-5 Wash Racks   1,420,590   394,400   1021.29   1018.35   3     Position 65   Ww-32   C-5 Wash Racks   1,420,590   394,310   1015.21   1018.35   3     Position 65   Ww-33   C-5 Wash Racks   1,420,700   394,310   1015.21   1018.35   3     Rack Ponds   Ww-33   C-5 Wash Racks   1,420,700   394,310   1015.21   1018.35   3     Site cl6-   Mw-15   B-104 Gas Pump Area   1,420,700   394,130   1014.26   1017.04   3     Site cl6-   Mw-43   B-104 Gas Pump Area   1,420,800   394,120   1009.51   1012.16   3     Pump   Mw-45   B-104 Gas Pump Area   1,420,930   394,120   1009.51   1013.97   3     Pump   Mw-45   B-104 Gas Pump Area   1,420,930   394,120   10013.97   3   3   3   3   3   3   3   3   3   3   3   3 <t< td=""><th></th><td>MW-42</td><td>Position 19</td><td>1,423,470</td><td>392,300</td><td>1031.05</td><td>1031.05</td><td>30</td><td>30+</td></t<>		MW-42	Position 19	1,423,470	392,300	1031.05	1031.05	30	30+
$ \begin{array}{cccccc} & Ww-14 & C-5 \ Wash \ Racks & L,420,720 & 394,400 & 1021.29 & 1024.33 & 21 \\ & Position \ 65 \ Ww-32 & C-5 \ Wash \ Racks & L,420,810 & 394,310 & 1015.63 & 1018.35 & 3 \\ & -C-5 \ Wash \ Mw-33 & C-5 \ Wash \ Racks & L,420,590 & 394,310 & 1015.21 & 1018.33 & 3 \\ & Ww-34 & C-5 \ Wash \ Racks & L,420,590 & 394,310 & 1015.21 & 1018.33 & 3 \\ & Ww-34 & C-5 \ Wash \ Racks & L,420,800 & 394,360 & 1014.26 & 1017.04 & 3 \\ & Ww-43 & B-104 \ Gas \ Pump \ Area & L,420,800 & 394,130 \\ & B-104 \ Gas \ Pump \ Area & L,420,800 & 394,130 \\ & Ww-45 & B-104 \ Gas \ Pump \ Area & L,420,930 & 394,120 & 1009.51 & 1012.16 & 3 \\ & Pump & Ww-46 & B-104 \ Gas \ Pump \ Area & L,420,920 & 394,120 & 1009.51 & 1012.16 & 3 \\ & Ww-46 & B-104 \ Gas \ Pump \ Area & L,420,920 & 394,120 & 1009.51 & 1012.16 & 3 \\ & Ww-46 & B-104 \ Gas \ Pump \ Area & L,420,920 & 394,120 & 1009.51 & 1012.16 & 3 \\ & Ww-46 & B-104 \ Gas \ Pump \ Area & L,420,920 & 394,20 & 1001.54 & 1013.97 \\ & Ww-46 & B-104 \ Gas \ Pump \ Area & L,420,920 & 394,20 & 1001.54 & 1013.97 \\ & Ww-46 & B-104 \ Gas \ Pump \ Area & L,420,920 & 394,20 & 1001.54 & 1013.97 \\ & Ww-46 & B-104 \ Gas \ Pump \ Area & L,420,920 & 394,20 & 1006.61 & 10008.85 \\ & Ww-46 & B-104 \ Gas \ Pump \ Area & L,420,920 & 394,20 & 1001.54 & 1013.97 \\ & WW-46 & HW-46 & B-104 \ Gas \ Pump \ Area & L,420,920 & 394,20 & 0011.54 & 1013.97 \\ & WW-46 & HW-46 & HW-46$									
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		MW-14	C-5 Wash Racks	1,420,720	394,400	1021.29	1024.33	28	28+
Wurk Ponds   Mw-33   C-5 Wash Racks   1,420,590   394,310   1015.21   1018.33   3     Ruck Ponds   Mw-34   C-5 Wash Racks   1,420,700   394,260   1014.26   1017.04   3     Site Clb-   Mw-15   B-104 Gas Pump Area   1,420,870   394,130   997.79   1     Site Clb-   Mw-43   B-104 Gas Pump Area   1,420,800   394,130   997.79   1     B-104 Gas Pump Area   1,420,930   394,120   1009.51   1012.16   3     Pump   Mw-45   B-104 Gas Pump Area   1,420,930   394,120   1002.51   1012.16   3     Pump   Mw-46   B-104 Gas Pump Area   1,420,920   394,120   1002.51   1012.16   3     Pump   Mw-46   B-104 Gas Pump Area   1,420,920   394,120   1001.54   1013.97   2     Run 46   B-104 Gas Pump Area   1,420,920   394,230   1001.54   1013.97   2     Run<46		MW-32	C-5 Wash Racks	1,420,810	394,320	1015.63	1018.35	33	33+
Multick Founds     Mw-34     C-5 Wash Racks     1,420,700     394,260     1014.26     1017.04     3       Site Glb-     Mw-15     B-104 Gas Pump Area     1,420,870     394,130     997.79     1 $B-104$ Gas Pump Area     1,420,870     394,130     997.79     1 $B-104$ Gas Pump Area     1,420,800     394,120     1002.51     1012.16     3 $Pump$ Mw-45     B-104 Gas Pump Area     1,420,930     394,120     1002.51     1012.16     3 $Pump$ Mw-45     B-104 Gas Pump Area     1,420,930     394,120     1002.51     1012.16     3 $Pump$ Mw-46     B-104 Gas Pump Area     1,420,920     394,120     10015.97     2 $Num-46$ B-104 Gas Pump Area     1,420,920     394,230     1006.61     1008.85     3 $Num-46$ B-104 Gas Pump Area     1,420,920     394,230     1006.61     1008.85     3		)MW-33	C-5 Wash Racks	1,420,590	394,310	1015.21	1018.33	35	35+
Site G16   Mw-15   B-104 Gas Pump Area   1,420,870   394,130     B-104 Gas   B-104 Gas Pump Area   1,420,800   394,130     B-104 Gas   B-104 Gas Pump Area   1,420,800   394,120   1002.51   1012.16     Pump   Mw-45   B-104 Gas Pump Area   1,420,930   394,120   1009.51   1012.16   3     Pump   Mw-45   B-104 Gas Pump Area   1,420,930   394,120   1003.51   1012.16   3     Pump   Mw-45   B-104 Gas Pump Area   1,420,920   394,160   1011.54   1013.97   23     Station   Mw-46   B-104 Gas Pump Area   1,420,920   394,160   1011.54   1013.97   23     Mu-46   B-104 Gas Pump Area   1,420,920   394,160   1011.54   1008.85   3     Mu-46   B-104 Gas Pump Area   1,420,920   394,230   1006.61   1008.85   3	Kack Ponds	MM-34	C-5 Wash Racks	1,420,700	394,260	1014.26	1017.04	30	30+
B-104 Gas   Ww-43   B-104 Gas   B-104 Gas   B-104 Gas   Pump   Area   1,420,930   394,460   995.77   997.79   1     B-104 Gas   B-104 Gas   Pump   Area   1,420,930   394,120   1009.51   1012.16   3     Pump   Mw-45   B-104 Gas   Pump   Area   1,420,930   394,120   1009.51   1013.97   23     Pump   Mw-45   B-104 Gas   Pump   Area   1,420,920   394,160   1011.54   1013.97   23     Station   Mw-46   B-104 Gas   Pump   Area   1,420,920   394,230   1001.54   1013.97   23     Station   Mw-46   B-104 Gas   Pump   Area   1,420,920   394,230   1006.61   1008.85   3		/ MW-15	B-104 Gas Pump Area	1,420,870	394,130				
B-104 Gas     Mw-44     B-104 Gas     Pump     Area     1,420,930     394,120     1009.51     1012.16     3       Pump     Mw-45     B-104 Gas     Pump     Area     1,420,930     394,120     1009.51     1013.97     21       Station     Mw-45     B-104 Gas     Pump     Area     1,420,920     394,160     1011.54     1013.97     21       Station     Mw-46     B-104 Gas     Pump     Area     1,420,920     394,230     1006.61     1008.85     3		MW-43	B-104 Gas Pump Area	1,420,800	394,460	995.77	997.79	16	16+
Prump     Mw-45     B-104 Gas Pump Area     1,420,800     394,160     1011.54     1013.97     21       Station     Mw-46     B-104 Gas Pump Area     1,420,920     394,230     1006.61     1008.85     3       Mw-46     B-104 Gas Pump Area     1,420,920     394,230     1006.61     1008.85     3	B-104 Gus	MW-44	B-104 Gas Pump Area	1,420,930	394,120	1009.51	1012.16	35	35+
Multiplie     Multiplie     B-104 Gas Pump Area     1,420,920     394,230     1006.61     1008.85     3       Multiplie     Multipli     Multipli     Multipli <th>dun.</th> <td>MW-45</td> <td>B-104 Gas Pump Area</td> <td>1,420,800</td> <td>394,160</td> <td>1011.54</td> <td>1013.97</td> <td>28</td> <td>28</td>	dun.	MW-45	B-104 Gas Pump Area	1,420,800	394,160	1011.54	1013.97	28	28
	Dear roll	MW-46	B-104 Gas Pump Area	1,420,920	394,230	1006.61	1008.85	32	32+
		( MW - 4 7	B-104 Gas Pump Area	1,421,000	394,380	995.22	997.44	20	20+

	973.34	394 ,642	1.421.294	612-1
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# * DATUM IS TOP OF PVC CASING

NW-7 NW-52 MW-53 MW-54 MW-55 MW-56	NW-13	MW-48 MW-49	MW- 5() MW- 5 I		
Site GI5 B-58 Wing Tank Seal	Test Facility	Site G13	Position 58	Fuel/ Defuel	Stat ion

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ä	·	TABLE III-2 GROUNDWATER ELEVATIONS		
2	WELL	GROUND ELEVATION	DEPTH TO WATER	GROUNDWATER ELEVATION
1.12	1 2 3	1096± 1111±	41.0 26.8 18.2	1055± 1084
	4 5 6	1087± 1107±	23.8 40.6 49.8	1046± 1057
	7 8 9	1100± 1110± 1070±	21.2 31.3 15.5 22.5	1078± 1079 1054
	10 11 12 13	1070± 1070± 985±	9.5 20.5 11.7*	1057 1060 1049 973±
Ē	14 15 16	1026± 1006± 1025±	22.3 17.8 5.67*	1004± 988± 1019±
	17 18 19 20 21	1057± 1030±	29.75* 12.6* 10.6* 8.58* 3.92*	1027± 1017±
	Fuel Farm:		3.74"	
	Site G6 B-1   B-10 B-4   Aeration B-5   Basin B-8	1085.1 1091.1 1092.2 1087 1088	21.0 25.0 24.25 20.7 22.7	1064.1 1066.1 1067.9 1066.3 1065.3
	Basin (B-9 A-1 A-2	1088 1086.9 1082.9	21.7 21.2 23.3	1066.3 1065.7 1059.6
	Waste Basin:			
	Site GI Surface B-2 Impoundment B-3 B-4 B-5	1064.6 1052.4 1051.3 1050.0 1070.8	23.75 14.75 18.42 17.08 21.5	1040.8 1037.6 1032.9 1032.9 1049.3
	*Note: Top of field	of casing data. S data for approx:	Three feet is s imately ground	subtracted from reference.

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Table 6 SUMMARY OF MONITORING WELL LOCATIONS Ę

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1 Building B-30 2 West of Building B-77	41.5 23.0 18.0 22.5 Not Encountered
2 West of Building B-77	23.0 18.0 22.5 Not Encountered
	18.0 22.5 Not Encountered
3 Southwest of Building B-1	22.5 Not Encountered
A Northwest of Building B-1	Not Encountered
5 West of Building B-43	<b>C1</b> A
6 East of Building B-99	51.0
7 North of Building B-58	26.0
8 Northeast of Building B-27	31.0
9 Southeast of Building B-91	15.5
10 B-64 Parking Lot	24.0
11 Southwest of Building B-64	12.0
12 East of Building B-90	21.0
13 West of C-5 Fuel Storage	13.0
14 C-5 Washrack	24.0
15 Southwest of Building B-104	19.0
16 West of Fuel Weighing Station	6.5
17 Position 19	31.0
18 Position 19	12.5
19 Northeast of L-2	11.0
20 North of L-11	9.0
21 South of L-11	5.0
B-1 North of Surface Impoundment	28.6
B-2 South of Surface Impoundment	18.1
B-3 South of Surface Impoundment	22.9
B-4 South of Surface Impoundment	23.7
B-5 North of Surface Impoundment	27.0

bls = Below land surface.

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Source: Federer-Sailors and Associates, Inc. Ground-Water Monitoring Wells AF Plant 6 Marrietta, Georgia

and

Law Engineering Testing Company Report of Subsurface Exploration and Preliminary Ground-Water Monitoring Program AF Plant 6 Lockheed-Georgia Company Marrietta, Georgia APPENDIX O PORTIONS OF GROUND WATER QUALITY ASSESSMENT REPORT FROM WILSON AND CO.

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# LOCKHEED-GEORGIA COMPANY A DIVISION OF LOCKHEED CORPORATION MARIETTA, GEORGIA

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GROUNIWATER QUALITY ASSESSMENT REPORT SURFACE IMPOUNDMENT (Industrial Waste Sludge Disposal Basin)

# AIR FORCE PLANT NO. 6 MARIETTA, GEORGIA

By TM Christy BL Johnson



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10 OCTOBER 1984 (84-031) (84-9538) VUILSON ECOMPANY ENOMEERS & LARCHITETSI

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# SECTION I - EXECUTIVE SUMMARY

A groundwater quality assessment has been performed at the hazardous waste surface impoundment at Air Force Plant No. 6, Marietta, Georgia. This investigation was undertaken in response to previous analytical data gathered from an existing groundwater monitoring system installed at the subject surface impoundment. These data indicated that contamination may be emanating from the surface impoundment, triggering regulatory requirements for a groundwater quality assessment.

The groundwater quality assessment was performed in a hierarchial manner; beginning with indicator studies yielding information about the contaminant plume, expected groundwater flow patterns and water quality from various sources within the study area, and ending with the installation and sampling of monitor wells to confirm the limits of contamination proceeding from the impoundment.

Contamination is migrating from the surface impoundment. These migrating contaminants form a plume which flows southwest from the impoundment and discharge into an adjacent stream. The maximum extent of groundwater. contamination from the surface impoundment is approximately 600 feet south of the impoundment.

Contaminants migrating from the impoundment include heavy metals, organic priority pollutants, and common salts. The contaminant plume from the impoundment discharges into the stream where contaminants are both diluted and removed to environmentally safe levels. Data gathered during the course of this study indicate that the receiving stream meets all known safe drinking water limits prior to leaving the site.

The distribution of volatile compounds at the site was found to be extremely complex, owing to the apparent presence of several contaminant sources other than the subject hazardous waste surface impoundment.

This document satisfies the requirement for groudwater quality assessment, but does not include results of Appendix VIII analyses. These data will be furnished separately in the near future.

Recommendations presented in this report include the following:

<u>a</u>. Modifications should be made at the B-90 building in order to abate existing sources of contamination.

<u>b</u>. The extent of the volatile organic contaminant plume to the northeast of the impoundment should be determined. This determination is outside the scope of this project.

<u>c</u>. The source of the contaminant plume on the west bank of the impoundment should be determined and abated. This work is outside the scope of this project.

d. Regular monitoring should be performed at the stream prior to the point of exiting the study area in order to assure that the quality of this discharge does not exceed tolerable contaminant limits.

e. The treatment and delisting of the hazardous waste impoundment contents should be investigated as an alternate means of closing this facility.

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# SECTION IV - CONCLUSIONS AND RECOMMENDATIONS

# A. INTRODUCTION.

Previous sections of this report have presented investigative methodology and analytical data. Interpretation of these data has been limited to the development of flow patterns in the residual soil and bedrock in the surface impoundment area. This section provides assessment of the districution of contaminants across the site, their origin and eventual fate. 1

# B. DISTRIBUTION AND CONCENTRATION OF INORGANIC CONTAMINANTS.

The apparent distribution of inorganic contaminants is well-defined acress the site. Data suggest contaminants migrate from the surface impoundment and travel through the plume area indicated on Plate IV-1, discharging into the stream. The apparent boundaries for the discharge zone of this plume have been established by the stream survey. Apparent boundaries of this plume in the residual soil have been established by well analyses. The reader is referred to Section III for complete tabulations of analytical data from individual wells and stream points.

Data suggest Wells D-1, B-2, B-3 and B-4 are all contaminated with leachate from the surface impoundment. Concentrations of nearly all of the common ions are elevated within the plume area though sodium and sulfate are predominate. Sodium and chloride concentrations, useful tracers in the flow of contaminants in the impoundment area, are shown on Plate IV-2. By contrast, concentrations in monitor wells D-3, D-4, D-7 and E-4 are representative of background water quality. A band of elevated sodium and chloride concentrations does extend through B-1 and B-6. Flow patterns show that these slightly elevated concentrations are not from the surface impoundment. Their most likely source is the septic tank leach field east of the B-90 building.

Concentrations of zinc and cadmium are slightly elevated in the plume area. The maximum concentration of zinc is .22 mg/l in Well B-4. The maximum concentration of cadmium is .0009 mg/l in B-4, far below the drinking water limit for this metal.

Lead concentrations are also elevated in the plume area. The lead concentration in Well D-1 is 0.083 mg/l which exceeds the safe drinking water limit of 0.05 mg/l.

Analysis of Well BR-2 indicates that groundwater intercepted by the open bore hole interval in bedrock (29-79') is contaminated with inorganics from the surface impoundment. However, this contamination does not extend to the 180-229 foot bedrock interval monitored by Well BR-3.

# C. DISTRIBUTION AND CONCENTRATION OF ORGANIC CONTAMINANTS.

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Organic compounds encountered at the site include phenols and volatile, base neutral and acid priority pollutants. The occurrence and distribution of these compounds across the site indicate that sources of organic contaminants other than the surface impoundment are present.

A summary of organic compounds detected at the site is shown in Table IV-1. It should be noted that the "B" and "D" series wells along with ER-1 and BR-2 were analyzed for phenols and volatile, base neutral and acid cotpounds. The "E" series wells and BR-3 were analyzed for volatile and base neutral compounds only.

# TABLE IV-1 SUMMARY OF DETECTION LOCATIONS FOR ORGANIC COMPOUNDS

Compound	Detection Limit	Locations Detected
Phenols (mg/l)	.005	D-5, D-6, D-7, B-2, B-3, BE-2
Volatile Compounds (µg/l)	)	
Chlorobenzene	5.	B-2, B-4, B-6, E-5
1,1,2-Trichloroethane	5.	B-5, E-8
1,1-Dichloroethane	5.	D-1, B-2, B-3, B-4, BR-2, E-8
1,1-Dichloroethylene	5.	Pump 6, BR-2, E-1, D-1, E-1, B-2, B-3, B-4, B-5, E-3
Methylene Chloride	5.	D-1, D-2, E-5, D-4, B-4, Pump 6, BR-2, E-3
1,2-Transdichloroethyle	ene 5.	Pump 6, BR-2, E-5, D-1, D-2, E-7, E-8, SP-1, D-3, D-4, B-2, B-3, B-4
1,1,1-Trichlcroethane	5.	E-1, D-1, B-1, B-2, B-3, E B-5, BR-2, E-7, E-3
Trichloroethylene	5.	B-3, B-4, B-5, B-ć, B-7, ER-1, BR-2, E-1, E-5, D-1, D-2, D-3, D-4, D-5, D-6, B-1, B-2, E-6, E-7, E-8, SP-1
Vinyl Chloride	5.	E-5, D-1, D-2, B-1, B-2, E-3, B-4, Pump 6, BR-2, E-3
Chloroform	5.	D=2. D-4
1,2-Dichloroethane	5.	D-2, D-4, B-1, E-5, E-3, E- ⁻ , E-8
1,2-Dichloropropane	5.	D-2, D-4, D-6, B-4, B-6, E- ⁻ . E-8
Base Neutrals (µg/l)		
Bis (2-Ethylbexyl) Phth	calate 5.	B-7, BR-1, BR-2, E-6, E-4, E-7, E-8, E-2, E-3, D-1, D-2, D-3, D-5, B-1, B-3, B-4, B-5, B-6, Pond
TABLE IV-1 (Continued)

Compound	Detection Limit		Locations Detected	
Di-N-Butyl Phthalate 1,2-Dichlorobenzene Di-N-Octylphthalate	5. 5. 5.	D-1, D-2, B-1 B-7	D-3, D-5, B-1, B-5 D-4, BR-2, E-5, E-3	
Acid Compounds (µg/l) Pentachlorophenol	5.	BR-2	, B-3	

The distribution of organic compounds across the site, their origin and residence time, is a complex puzzle, the solution of which is beyond the scope of this project.

Two sources of organic compounds, besides the surface impoundment, are apparently present in the study area. A third extraneous source is suspected.

Analyses confirm that organic compounds have entered the groundwater at the B-90 building. This source is believed to have been in existence long enough to contribute organic compounds to the groundwater beneath the impoundment area prior to the construction of the impoundment. Onto this pre-existing plume is superimposed the impoundment leachate. The seepage mound of the impoundment precludes any further flow under the impoundment from the B-90 building, diverting the pre-existing plume to the east, creating a wider area of contamination.

A second source of contamination is believed to exit on the west bank of the stream. This source may be the materials landfilled in this area, or industrial leakage to the west and north.

A third source of organic contaminants may exist and be the source of contaminants in the (B-6)-(D-2)-(D-4) area. An alternate explanation is that these contaminants originated at the B-90 building. Flow patterns and inorganic analyses in the (B-6)-(D-2)-(D-4) area suggest that contaminants in this area are not from the impoundment.

The distribution of organic compounds across the site is not consistent with the distribution of inorganic compounds from the surface impoundment or the flow patterns in the impoundment area. Distributions for the various compounds are discussed individually in the following paragraphs:

1. <u>Phenols</u> were detected at only five locations among the "B" and "E' series wells. Although phenols do appear to be migrating from the organiment as indicated by their detection in wells B-2 and B-3, the detection of these compounds in wells D-5, D-6 and D-7 indicate the presence of a secial source. Flow from the impoundment does not appear to be capable of transporting phenols to D-5, D-6 and D-7. The concentration of phenol in B-2 and B-3 is 0.026 and 0.011 mg/1, respectively. The concentration of phenols at D-5 and D-6 is 0.005 and 0.006 mg/1, respectively.

The highest concentration of phenol is encountered above the seep area (point SA-1) near the head of the stream, apparently from an extraneous source. The phenol concentration at this point is 0.066 mg/l. Phenols are rapidly diluted after SA-1, but remain above the detection limit through stream station S-13. Phenols are below the detection limit (0.005 mg/l) at stream station S-1.

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2. <u>Volatile Priority Pollutants</u>. Twelve separate volatile compounds were detected in the study area. Distribution plots have been developed for the eight volatile compounds displaying the highest concentrations in the study area:

<u>a. 1,1-Dichloroethane</u>. A distribution plot for this compound is shown on Plate IV-3. This compound appears to be migrating from the surface impoundment. Detectable levels of this compound are not found outside of the impoundment plume.

b. <u>1.1-Dichloreethylene</u>. A distribution plot for this compound is shown on Plate IV-4. This compound is found across the site in a wide bind from E-1 southwest to the stream. Two separate plumes are shown for this compound, one apparently originating from the E-90 building and adjacent septic tank leach field, and one originating at the surface impoundment. Prevailing flow patterns should eventually carry this compound from the (B-1)-(E-1) area to Wells B-6, D-2, D-5 and D-6. 1,1,-Dichloroethylene is found in the stream in a pattern which confirms the distribution of the contaminant plume on Plate IV-1. The peak stream concentration being attained at the culvert (stream station S-18) and then diminishing from that point downstream.

<u>c. 1,1,1-Trichloroethane</u>. Plate IV-5 depicts the distribution of this compound in the study area. This plume is similar to the pattern obtained for 1,1-Dichloroethylene, contaminants being found in an area extending from the (E-5)-(E-1) area southwest to the stream. This plume appears to be the result of two separate sources. The northeast portion of the plume originating at the B-90 building and the southwest portion originating at the already established plume area south and east of the impoundment. The northeast portion of the plume can be expected to move south to the (D-2)-(E-6)-(D-6) area. The extreme northeast tip of the plume should move to the southeast.

d. <u>1.2-Dichloropropane</u>. This compound has a distribution concentrated in a narrow area southeast of the surface impoundment as shown on Plate IV-6. Because 1.2-Dichloropropane was not found in the impoundment pore waters it is doubtful that the concentration of 1.2-Dichloropropane in Well B-4 originated from the impoundment. The lack of any inorganic contamination in Wells D-4, D-2, D-5 and D-6 strongly implicate a second source. This plume probably originated in the landfill. This plume frees interact with the stream as indicated by the stream survey. 1.2-Dichloropropine in B-4 can be expected to move within the impoundment contaminant plume boundary in a southwest direction to the stream. The portion of the plume at D-6 can be expected to move southeast to be intercepted by the site secondary stream. e. <u>Trichloroethylene</u>. Analyses indicate the presence of four separate sources for this plume. Present data do not facilitate the development of isocons at each of these sources. However, the contamination from the surface impoundment is apparently well defined. Isocons have been drawn for the highest concentrations of trichloroethylene in the study area. These are shown on Plate IV-7.

One source of Trichloroethylene contamination is believed to occur at the B-90 building, resulting in low level concentrations in B-7, B-6, E-1 and BR-1. A second source or sources appears responsible for trichloroethylene contamination in E-5, D-3 and E-6. Both of the areas are located so as to preclude the flow of water from the surface impoundment. Inorganic constituents at both locations indicate that contamination from the surface impoundment has not occurred. Flow from the (E-5)-(E-6) area will be east to the secondary stream. Flow from the E-90 area should be south to the (D-2)-(B-6)-(D-6) area, with the cast side of the plume area at E-1 moving east.

Trichloroethylene in the (B-2)-(B-3)-(B-4)-(D-1) area is probably from the impoundment. The lack of any inorganic contaminants in the (D-5)-(D-1)-(D-4) area strongly favors a separate source for the contamination found in this area. The extent of trichloroethylene in areas downgradient and southeast of the surface impoundment has probably achieved its maximum extent, while contaminants at D-6 will apparently migrate southeast to be intercepted by the secondary stream.

<u>f.</u> <u>1,2-Transdichloroethylene</u>. The distribution of this compound is shown on Plate IV-8. Two basic areas of contamination are shown: an area south of the surface impoundment and an area on the west bank of the stream. The area on the west bank favors a source other than the surface impoundment.

## D. RATE AND EXTENT OF CONTAMINATION.

Wilson Laboratories believes that the actual extent of both inorganic and organic contamination from the surface impoundment is equivalent to the area defined on Plate IV-1. This area is surrounded on the north, east and southeast by contaminants apparently derived from other sources. It would appear that a plume or plumes from other sources also exists on the west bank of the stream.

The contaminant plume from the surface impoundment is believed to have established its maximum extent as shown on Plate IV-1. The rate of flow within this plume varies from approximately 17 to 90 feet per year. The splume is intersected by and discharges into the stream.

Data suggest constituents contributed to the stream by the impoundment ire either diluted, as in the case of inorganics, or removed, as in the case of volatile priority pollutants, prior to the stream leaving the study area. Data indicate the stream water leaving the site is free from harmful concentrations of any constituent and would be considered a safe drinking water supply by any standard. Data gathered from the three bedrock wells installed at the site indicate that contaminants from the residual soil mantle have entered the site bedrock. Contamination was detected in the upgradient position bedrock Well BR-1, which penetrated to a depth of 93 feet below ground surface. Contamination was found in downgradient Well BR-2 which penetrated to a depth of 79 feet below ground surface. Well BR-3 which penetrates to a depth of 230 feet was found to be free from contamination. This well sampled formation water at a depth of 133-223 feet.

As discussed in Section III, the flow pattern of groundwater through the bedrock is ill-defined.

In general, it can be said that the net transport of water through the bedrock will closely parallel flow in the residual soils; moving toward the center and down the valley. The impoundment plume is located adjacent to the stream which serves as a groundwater discharge zone from the beirick. For this reason solutes from the impoundment have little impetus to enter the bedrock. The bedrock surface is irregular and can be expected to be recharged from the directly overlying residual soils. The pumping of wells BR-1 and BR-2 for sampling purposes may have induced contaminant flow into these wells from the residual soils.

This document satisfies the requirements of the groundwater quality assetsment plan with the exception of Appendix VIII analysis data. Pursuant to the 21 September letter⁷ from Georgia EPD to Lockheed, these data will be provided separately in the near future.

## E. RECOMMENDATIONS.

The following recommendations are forwarded based on the analytical rejults and conclusion of this study:

1. The B-90 building should be modified such that the disposal of all industrial wastes will be to the Lockheed Industrial Waste Plant rather than to the existing septic tank-leach field system. In addition, an enclosed industrial solvent storage area should be constructed for this building and administrative steps taken to assure that all personnel are instructed in and carry out the safe disposal of solvents.

2. The extent and fate of the plume extending east from the B-90 building should be determined, but this is considered outside the scope of this project.

3. The source or sources of contaminants to the stream west bank shall be determined and, if possible, abated. This work is also outside the scope of this project.

4. The stream should be monitored at station S-O and analysis made for common ions, heavy metals, organic priority pollutants and phenolic compounds in order to assure that the present high quality of water leaving the site is maintained. This monitoring should be performed in accordance with Georgia EPD requirements. No remedial action other than that provided by the natural environment is recommended. 5. Analysis of the impoundment contents shows that these materials would not meet the definition of a hazardous waste if the organic priority pollutants were removed. Removal of these compounds and delisting of the sludge would allow the disposal of this sludge in a permitted industrial landfill. Such disposal would, in all probability, be more economical than disposal in a hazardous waste landfill, as well as being environmentally safer. For these reasons, we recommend that Lockheed-Georgia undertake an engineering and economic investigation of this treatment and disposal option.

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## GEOTECHNICAL ENGINEERING REPORT

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WASTE IMPOUNDMENT LOCKHEED-GEORGIA COMPANY MARIETTA, GEORGIA

Prepared By

Hanson Engineers Incorporated 1525 South Sixth Street Springfield, Illinois 62703

Prepared For

Wilson & Company 631 E. Crawford Avenue P.O. Box 1648 Salina, Kansas 67401

August 9, 1984

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Office Location 621 EAST CRAWFORD AVE.	1 Salina, Kansas 67401	An Equal Opportunity Employer	• 33
	Salina. Kansas	67402-1648 NEW ZIP CODE	ŝ

22 October 1984

Lockheed-Georgia Company 86 S. Cobb Drive Marietta, GA 30063

Attn: J.H. Lucas Dept. 49-11

Re: Dike Structural Integrity Groundwater Assessment Plan Implementation Purchase Order No. CA 95072 Register No. B5454 Subcontract Agreement No. 03 84 528 WCEA File: 84-031

Dear Mr. Lucas:

It is our opinion that the Geotechnical Engineering Report on Lockheed's Surface Impoundment prepared for us by Hanson Engineers, Incorporated, satisfies the intent of 40 CFR Part 264.226(c). This report is included in our Groundwater Quality Assessment Report as Appendix B.

Our opinion is based on the fact that the Hanson Report is a certified document by a qualified engineer (George F. Jameson, Georgia P.E., Registration No. 14604) who states the following:

- "The investigation and subsequent stability analyses indicated that adequate stability factors of safety exist for the idealized cross sections that were studied. Considerations of the seepage conditions (as they relate 'to the structural integrity of the embankments) indicate no apparent areas that may adversely influence the embankments' structural integrity." (Second and third sentences of the synopsis appearing immediately after the Table of Contents.)
- 2. ". . , it is Hanson Engineers' opinion that the embankment is in a structurally stable condition." (Portion of last sentence on page 17 of paragraph titled <u>Results</u>.)
- 3. "This seepage, though important in considering possible contamination of the groundwater, does not appear to adversely influence the embankment stability." (Fifth sentence on page 17 of paragraph titled Seepage Considerations.)

SALINA, KS · ALEUQUERQUE, NM

ERQUE. NM + COLORADO SPRINGS, CO

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J.H. Lucas 22 October 1984 Page 2

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4. "It is not considered necessary to modify the existing embankment to improve its structural integrity or seepage conditions (as they relate to stability)." (First sentence on page 18 of only paragraph in section entitled RECOMMENDATIONS.)

The Hanson Report addresses the horizontal stability of the dike and the affect of seepage and provides backup data and calculations to support the opinions therein as required by 40 CFR Part 264.226(c). We therefore submit that the entire Hanson Report included as Appendix B of our Groundwater Quality Assessment Plan is the required certification of dike stability by a qualified engineer.

In the eight copies of the report furnished you for permit application purposes, Mr. Jameson's seal did not reproduce. Therefore, we are enclosing ten copies of the page on which his seal did reproduce.

If you have any questions or require additional information, please contact us.

WILSON & COMPANY

Herbert H. Bassett, P.E.

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WILSON

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August 9, 1984

Wilson & Company 631 E. Crawford Avenue P.O. Box 1648 Salina, Kansas 67401

Re: Waste Impoundment Lockheed-Georgia Company Marietta, Georgia

Gentlemen:

Enclosed are four copies of our Geotechnical Engineering Report for the existing Waste Impoundment at the Lockheed Plant in Marietta, Georgia. This work was completed in accordance with your authorization for engineering services issued in April 1984.

We are pleased to have had the opportunity to perform this work. If you have any questions concerning the report, or if Hanson Engineers may be of additional service to you on this project, either during the finalization of remedial measures or during construction, please do not hesitate to call.

Very truly yours,

HANSON ENGINEERS INCORPORATED

avid E. Daueld

David E. Daniels Senior Associate

George F. Jamison Associate Partner Georgia P.E. No. 14604

Approved by Donald (). Oglesby Vice President

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Directors: Walter E. Hanson, Leo J. Dondanville, Jr., John M. Healy, John P. Hine, Richard W. Hiller, Donald D. Oglesby, Eugene R. Wilkinson

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APPENDIX I

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Field Boring Logs

APPENDIX II

Grain Size Distribution Data and Plots Permeability Test Data Direct Shear Envelopes Standard Proctor Curve 

# SYNOPSIS

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A geotechnical investigation was conducted by Hanson Engineers, Inc. to investigate the stability and seepage conditions for the embankments of the existing Waste Impoundment at the Lockheed-Georgia Company in Marietta, Georgia. The investigation and subsequent stability analyses indicated that adequate stability factors-of-safety exist for the idealized cross sections that were studied. Considerations of the seepage conditions (as they relate to the structural integrity of the embankments) indicate no apparent areas that may adversely influence the embankments' structural integrity. APPENDIX P REFERENCES

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#### APPENDIX P

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