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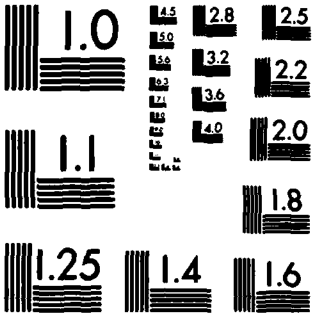

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Installation Restoration Program

AD-A145 352

Final Report
Phase II - Problem Confirmation Study
Westover Air Force Base
Chicopee, Massachusetts

Contract F33615-80-D-4006

Prepared For:

United States Air Force
Occupational and Environmental Health Laboratory (OEHL)
Brooks Air Force Base, Texas

May 1984

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EXECUTIVE SUMMARY

INTRODUCTION

Roy F. Weston, Inc. (WESTON) was retained by the U. S. Air Force Occupational and Environmental Health Laboratory (OEHL) under Contract No. F33615-80-D-4006 to provide general engineering, hydrogeological and analytical services. These services were applied to the Installation Restoration Program (IRP) Phase II effort at Westover Air Force Base under Task Order 19 of this basic contract.

In 1976 the Department of Defense (DoD) devised a comprehensive Installation Restoration Program (IRP). The purpose of the IRP is to assess and control both potential and actual migration of environmental contamination that may have resulted from past operations and disposal practices on DoD facilities. In response to the Resource Conservation and Recovery Act of 1976 (RCRA) and in anticipation of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or "Superfund"), the DoD issued a Defense Environmental Quality Program Policy Memorandum (DEQPPM) dated June, 1980 (DEQPPM 80-6), requiring identification of past hazardous waste disposal sites on DoD agency installations. The U.S. Air Force implemented DEQPPM 80-6 by message in December, 1980. The program was revised by DEQPPM 81-5 (11 December 1981) which reissued and amplified all previous directives and memoranda on the IRP. The Air Force implemented DEQPPM 81-5 by message on 21 January 1982. The Installation Restoration Program has been developed as a four-phase program as follows:

Phase I: - Problem Identification/Records Search;
Phase II: - Problem Confirmation and Quantification;
Phase III: - Technology Base Development;
Phase IV: - Corrective Action,

Only the Phase II Problem Confirmation portion of the IRP effort at Westover Air Force Base was part of this Task Order.

SCOPE OF WORK

Westover Air Force Base (WAFB) is located in the Connecticut River Valley near Chicopee, Massachusetts. Field operations under this Task Order were limited to three sites shown on

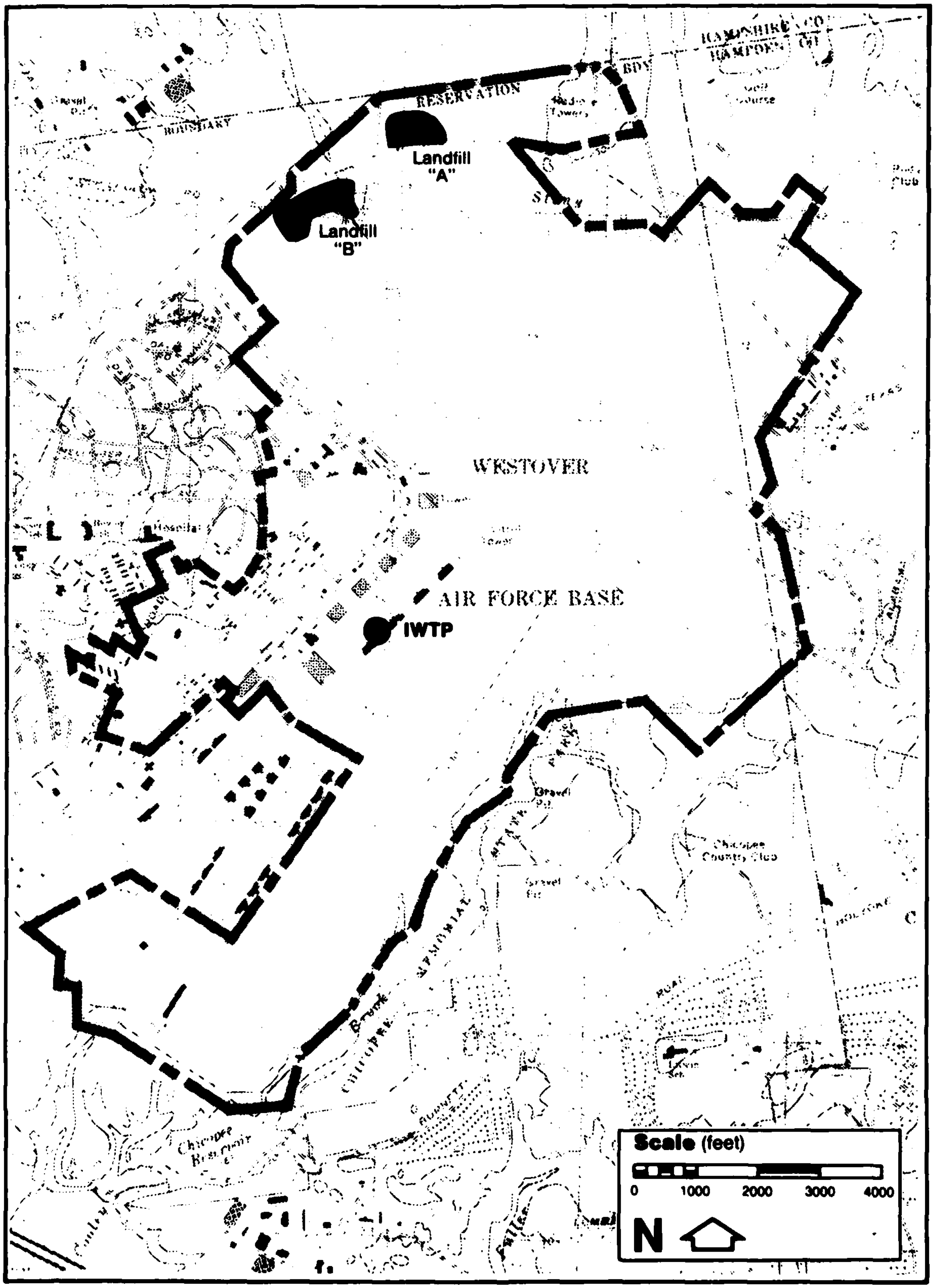


FIGURE S-1 MAP OF WESTOVER AIR FORCE BASE SHOWING LOCATIONS OF ALL PHASE II SITES

Figure S-1: Site No. 1 (Sanitary Landfill B) and Site No. 2 (Sanitary Landfill A) are located near the north boundary of the Base, while Site No. 15 (Industrial Waste Treatment Plant) is located in the west-central area of the Base. A total of ten monitor wells were constructed in the shallow, deltaic aquifer: seven at Site No. 1, two at Site No. 2 and one at Site No. 15. Slug or recovery tests were conducted on six of the monitor wells at the landfills to determine the aquifer characteristics within the upper, permeable zones of saturation. All wells were surveyed for location and elevation with respect to Air Force bench marks traceable to U. S. Geological Survey (USGS) benchmarks. One round of water samples were obtained for chemical analysis from all ten monitor wells and from three surface water staff gage stations on Stony Brook, east of the landfills. All water quality analyses were accomplished in the WESTON Laboratory under rigorous Quality Assurance procedures and in accordance with USEPA Standard Methods. All data were analyzed to produce as complete an assessment of ground and surface water contamination as possible within the limits of the program conducted.

MAJOR FINDINGS

Based on the analyses performed, the background water quality in the shallow aquifer at WAFB is of very good quality, with Specific Conductance readings ranging from a high in the most contaminated well of 205 to a low of only 20 umhos/cm in the uncontaminated wells.

Landfill B was found to be contributing contaminants to groundwater, as shown by water quality data for monitor Well 2 (the central downgradient well). These contaminants are manifested in elevated concentrations not only of typical landfill leachate constituents such as TOC (215 mg/l), COD (978 mg/l), iron (483 mg/l) and chloride ion (52.5 mg/l), but also of several volatile organic compounds (methylene chloride, 16.0 ug/l; 1,2-dichlorobenzene, 101.0 ug/l, 1,1,1-trichloroethane, 9.2 ug/l; 1,1-dichloroethane, 34.6 ug/l; trichloroethylene, 26.1 ug/l; o-dichlorobenzene, 7.5 ug/l; and several others). Mass flux computations of water flow-through beneath Landfill B indicate that as much as 30,000 gallons per day of potentially contaminated groundwater may be flowing in an easterly direction toward Stony Brook.

One of the monitor wells at Landfill A (Well A-1) was found to be mildly contaminated with landfill leachate constituents (TOC, 76.5 mg/l; iron, 34.0 mg/l; and chloride ion 27.0 mg/l). This contamination was attributable to penetration by that well of about two feet of burn/fill refuse below the water table. Low levels of several volatile organic compounds were also found (1,2 dichloroethane, 1.8 ug/l; 1,1-dichloroethane, 1.8 ug/l; 1,1-dichloroethylene, 1.2 ug/l). Well A-2 at Landfill A exhibited no evidence of landfill leachate constituents, but did contain low levels of two volatile organic compounds (1,2-dichloroethane, 3.2 ug/l; and chloroform, 4.5 ug/l). The source area for these solvents is as yet undetermined.

Testing of the skim waste storage tank and nearby monitor well IW-1 at the Industrial Waste Treatment Plant revealed an oil and grease level in the tank of 11,131 mg/l, while oil and grease in the well was 0.16 mg/l. This result would tend to indicate that the storage tank is not leaking, but since oil and grease is a non-specific test a small amount of additional testing will be needed to verify this result.

Water quality testing of the surface water from Stony Brook indicated that the staff gage at the Base boundary contains slightly elevated levels of TOC (11.5 mg/l) and sulfate (32.4 mg/l), as well as low levels of two volatile organic compounds (1,2-dichloroethane, 2.1 mg/l; 1,1-dichloroethylene, 2.1 mg/l). These constituents are in transport in an off-post direction. The two upstream staff gage samples, obtained upstream of any probable influence of the two landfills, also contained elevated volatile organic compounds. The source or sources for these elevated solvent concentrations is as yet undetermined, but the solvents appear to be from a source or sources other than the landfills.

Based on the Phase II Confirmation Study, the following key conclusions have been drawn:

1. Groundwater occurs under shallow, water table conditions in and around the three sites investigated. Groundwater gradients (lateral) typically average about 0.005, reflecting the very low topographic relief at WAFB. Consequently, the hydraulic driving force for contaminant dispersion is very small. Vertically downward hydraulic gradients greater than 0.01 were measured at all three couplet wells. Contaminants, if present, can be expected to disperse into deeper flow systems, especially at Landfill B where mounding of groundwater is expected to be significant.

2. Localized groundwater flow from Landfills B and A is generally in an easterly direction; groundwater from the sites can discharge into the Stony Brook drainage basin which flows to the north from the north boundary of WAFB. Whether the regional flow direction of groundwater follows the deranged surface drainage pattern is, at best, uncertain. Therefore, the direction of contaminant dispersal in groundwater cannot be predicted with confidence.

3. Of the nine monitoring wells constructed around the two landfill sites, only deep monitor well B-2 at Landfill B revealed what could be considered elevated concentrations of landfill derived contamination. This finding is important because it indicates, preliminarily, that neither landfill appears to be contributing to a major groundwater quality problem that can adversely impact off-site groundwater resources.

4. The present extent of contamination cannot be mapped because water quality results in many of the landfill perimeter wells was, in conclusion, quite good. The scope of the groundwater investigation and available monitor well array could not provide sufficient data to develop an isopleth map of a plume of contamination at either landfill.

5. For the landfill indicator analytes only lead (Pb) has a health related limit. Any lead which may have been present in the monitor wells and surface water samples was present well below the 0.05 mg/l health related limit.

6. No State or Federally adopted drinking water standards apply for the compounds detected, although an unpublished Federal policy "action level" for trichloroethylene of 4.5 ppb, based on an NAS cancer risk study, was exceeded in Well B-2. The Well B-2 sample results indicate moderately elevated levels of several organic compounds exceeding the 1×10^{-6} lifetime ingestion cancer risk criteria listed in Water Quality Criteria Documents (28 November 1980).

7. The organic analytes detected in the stream samples demonstrate that contamination from WAFB crosses installation boundaries through surface water

pathways. The 1,1-dichloroethylene level of 2.1 ug/l at surface water staff gage SG-1 exceeds the 0.033 ug/l incremental Cancer Risk of 1×10^{-6} for lifetime ingestion of water and aquatic organisms contaminated with dichloroethylene. The source or sources of organic contamination in Stony Brook cannot be verified by the sampling conducted to date. Besides discharge from Landfills B and A, both the old, North Fire Training Area and the Current Fire Training Area are potential sources for solvents crossing the Base boundary to the north in Stony Brook.

RECOMMENDATIONS

WESTON has recommended that the Phase II IRP study at Westover Air Force Base be continued with a Quantification Stage effort focussed on the northern portion of the Base. Specific recommendations are tabulated in Table S-1.

Table S-1

RECOMMENDED QUANTIFICATION STAGE ACTIONS

Site	Recommended Action	Rationale
Landfill B	Resample existing monitor points	Verification of initial analysis and establishment of parameters
	Construct additional wells to monitor extent of contamination and position of the landfill and the water table	These wells will enable quantification of the extent of contamination and will indicate the viability of certain remedial options, if deemed necessary
	Establish Interim Quarterly Monitoring Plan	Monitor water quality at site perimeter and installation boundary until decision made on permanent closure
	Resample existing monitor points (ground and surface waters)	Verification of initial analysis and identify the parameters of concern
Landfill A	Expand surface water sampling stations	Necessary in order to identify source areas of contaminants noted in Stony Brook
	Incorporate surface water sampling into the Interim Quarterly Monitoring Plan	Will enable an assessment of the ground/surface water flow regime
IWTP Storage Tank	Resample tank and adjacent well with expanded analysis	Required to verify initial results and assure that hazardous substances are not present in groundwater
Additional Sites	Drill additional wells; one at North Fire Training Area, one at Current Fire Training Area	Necessary to assess source locations of contamination detected in ground and surface waters on northern portion of Base

SECTION 1

INTRODUCTION

1.1 INSTALLATION RESTORATION PROGRAM

In 1976 the Department of Defense (DoD) devised a comprehensive Installation Restoration Program (IRP). The purpose of the IRP is to assess and control both potential and actual migration of environmental contamination that may have resulted from past operations and disposal practices on DoD facilities. In response to the Resource Conservation and Recovery Act of 1976 (RCRA) and in anticipation of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA or "Superfund"), the DoD issued a Defense Environmental Quality Program Policy Memorandum (DEQPPM) dated June, 1980 (DEQPPM 80-6), requiring identification of past hazardous waste disposal sites on DoD agency installations. The U.S. Air Force implemented DEQPPM 80-6 by message in December, 1980. The program was revised by DEQPPM 81-5 (11 December 1981) which reissued and amplified all previous directives and memoranda on the IRP. The Air Force implemented DEQPPM 81-5 by message on 21 January 1982. The Installation Restoration Program has been developed as a four-phase program as follows:

Phase I - Problem Identification/Records Search
Phase II - Problem Confirmation and Quantification
Phase III - Technology Base Development
Phase IV - Corrective Action

1.2 PROGRAM HISTORY AT WESTOVER

Roy F. Weston, Inc. (WESTON) has been retained by the United States Air Force Occupational and Environmental Health Laboratory (OEHL) under a Basic Ordering Agreement (BOA) Contract Number F33615-80-D-4006, to provide general engineering, hydrogeological and analytical services. The Phase I, Problem Identification/Records Search for Westover Air Force Base (WAFB) was accomplished by CH2M Hill in early 1982, and their Final Report was dated April 1982. In response to the findings contained in the CH2M Hill Phase I Final Report, the OEHL issued Task Order 0012 to WESTON, directing that a pre-survey site inspection be conducted at WAFB. The purpose of this pre-survey was to obtain sufficient information to develop a work scope and cost estimate for the conduct of a Phase II, Problem Confirmation Study at WAFB.

The Pre-Survey Report was submitted in December 1982. Following modifications in the scope of work, Task Order 0019, dated 25 July 1983, was issued ordering a Phase II Problem Confirmation Study for three sites at WAFB. A copy of the formal task order and scope of work are included here as Appendix B.

On 26 September 1983 WESTON met with WAFB CSG/DEEV and DEE participants in the project to explain the goals of the investigation, contact WAFB staff responsible for site access and safety, and review drilling locations, procedures, and schedules. Exploratory boring and monitoring well construction commenced on 4 October 1983 and was completed by 17 October. Sampling of wells and other monitoring points commenced on the week of 7 November 1983 and was completed along with the survey work by 11 November. This report documents the procedures and findings of the work accomplished during the Phase II Study.

1.3 BASE PROFILE

Westover Air Force Base (WAFB) encompasses 2,545 acres of an original 4,800-acre tract of land located in central Massachusetts, about two miles north of Springfield and Interstate Highway I-90, and about three miles east of Holyoke and Interstate Highway I-91. Figure 1-1 is an index map showing the location of WAFB. The current missions of WAFB are several:

1. Organize, recruit and train Air Force Reservists.
2. Maintain operationally ready aircraft, crews and support personnel through the 439 Tactical Airlift Wing (TAW).
3. Direct, maintain and supervise airfield activities through the 439 Combat Support Group (CSG).

The Base was operated by the Strategic Air Command (SAC) through 1974, and then it was reassigned to the Air Force Reserve (AFRES).

According to the Phase I IRP findings, the majority of the industrial operations at WAFB involving hazardous chemicals and wastes had been in existence since 1941. These activities included general aircraft maintenance, pneudraulics repair, Aerospace Ground Equipment (AGE) maintenance, battery shop activities, propulsion shop activities, and wheel and tire maintenance. After the SAC assumed control of the Base in 1955, several other major industrial operations were activated, including aircraft

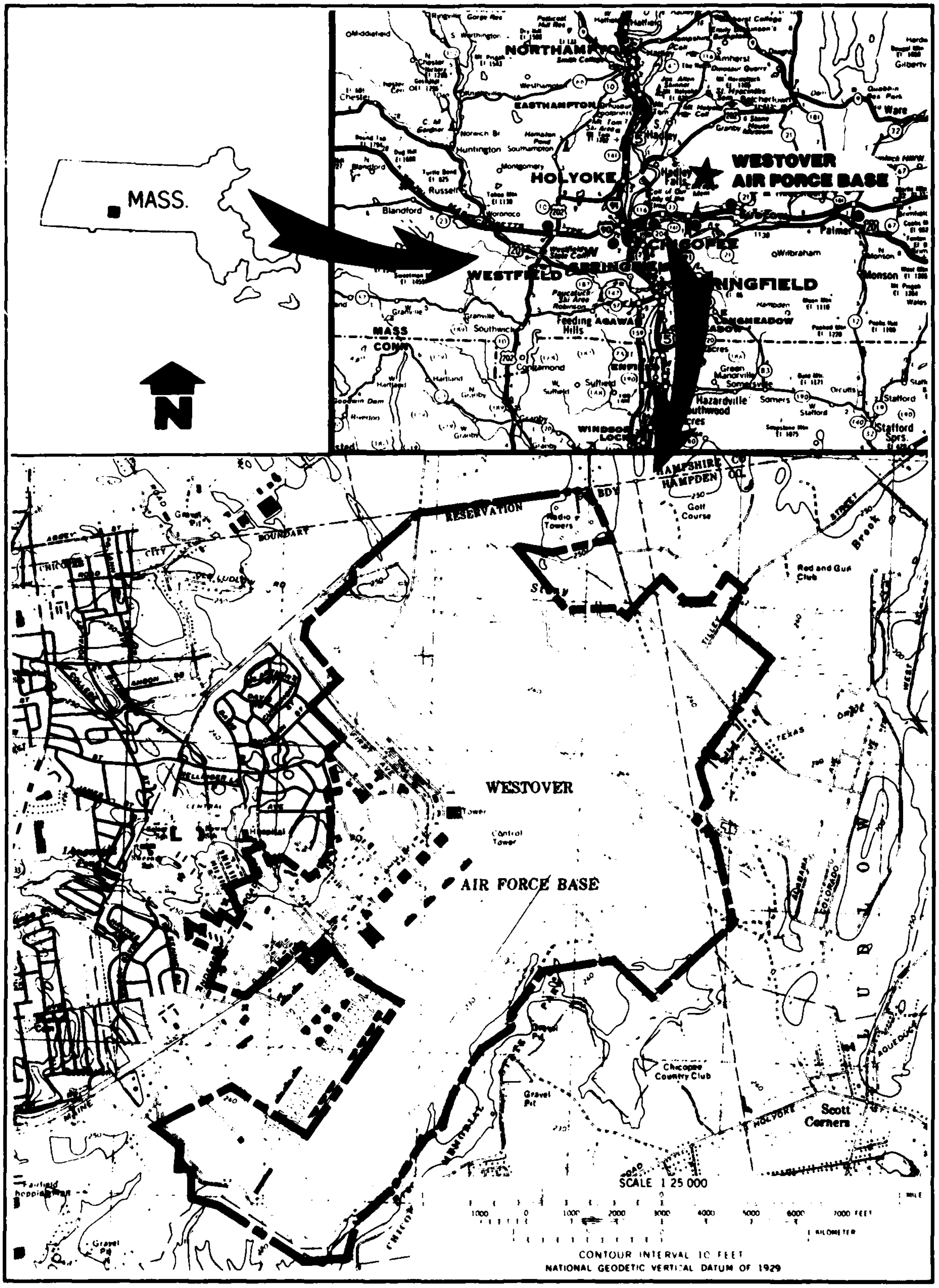


FIGURE 1-1 INDEX MAP SHOWING THE LOCATION OF WESTOVER AIR FORCE BASE

corrosion control, avionics maintenance and the Non-Destructive Inspection (NDI) laboratory activities. Since no large-scale industrial operations have been conducted at WAFB, the quantities of waste oils, solvents, paint residues, and thinners generated have been small in comparison to those at bases having significant aircraft overhaul and maintenance missions (Phase I, IRP, 1982).

Past Air Force activities at WAFB in support of Operational missions have resulted in the occurrence on the site of several waste disposal sites of potential concern. Each of these sites was rated by CH2M Hill during Phase I activities in accordance with the IRP Hazard Assessment Rating Method (HARM). The results of these ratings are summarized in Table 1 (from the CH2M Hill report). Figure 1-2 is a map of WAFB showing locations of all sites rated during Phase I activities. Based upon these ratings and all other pertinent data, Phase II activities were recommended at Site 1 (Sanitary Landfill B), Site 2 (Sanitary Landfill A) and Site 15 (Skim Waste Storage Tank at the Industrial Waste Treatment Plant).

1.3.1 History and Description of Site No. 1 (Sanitary Landfill B)

According to the Records Search Report, Landfill B, shown on Figure 1-3, was used for the disposal of domestic refuse and general Base refuse such as empty containers and 55-gallon drums resulting from industrial operations during the period from 1960 until 1974. The Phase I IRP investigation revealed that there is a potential that some of the containers and drums contained residual liquid and may have contained (unconfirmed) paint residues and thinners, phenolic paint strippers, methylethylketone (MEK), trichloroethylene (TCE), o-dichlorobenzene, and other miscellaneous aircraft cleaning compounds. There is also a potential that this site received leaded sludge from fuel tank bottoms and leaded fuel filters.

Landfill B occupies an area of approximately 14 acres on the north side of the Base. The northwest corner of the landfill is within 100 feet of the installation boundary. Slopes around the perimeter of the site are generally less than 3%. Relief on the landfill ranges from 10 to 15 feet above the surrounding land surface or between 240 and 255 feet above mean sea level (MSL). Landfill B may be characterized as a sand covered, poorly graded mound of refuse. Cover material is predominantly coarse-grained sandy local materials with a sparse to moderately dense vegetative cover of grasses and brush. Refuse, including several crushed drums and demolition debris, is exposed at the land surface in several places. The eastern portion of Landfill B typically has a

Table 1-1

Priority Listing Of Disposal Sites

Site No.	Site Description	HARM Score
1	Sanitary Landfill B	68
2	Sanitary Landfill A	61
8	Current Fire Training Area	57
3	"Christmas Tree" Fire Training Area	56
5	North Fire Training Area	54
15	Industrial Waste Treatment Plant	45
6	Sewage Treatment Plant Area	44
4	Radioactive Waste Site	44
11	Battery Shop Leaching Pit	42
7	Facility 1900 Leaching Pit	41

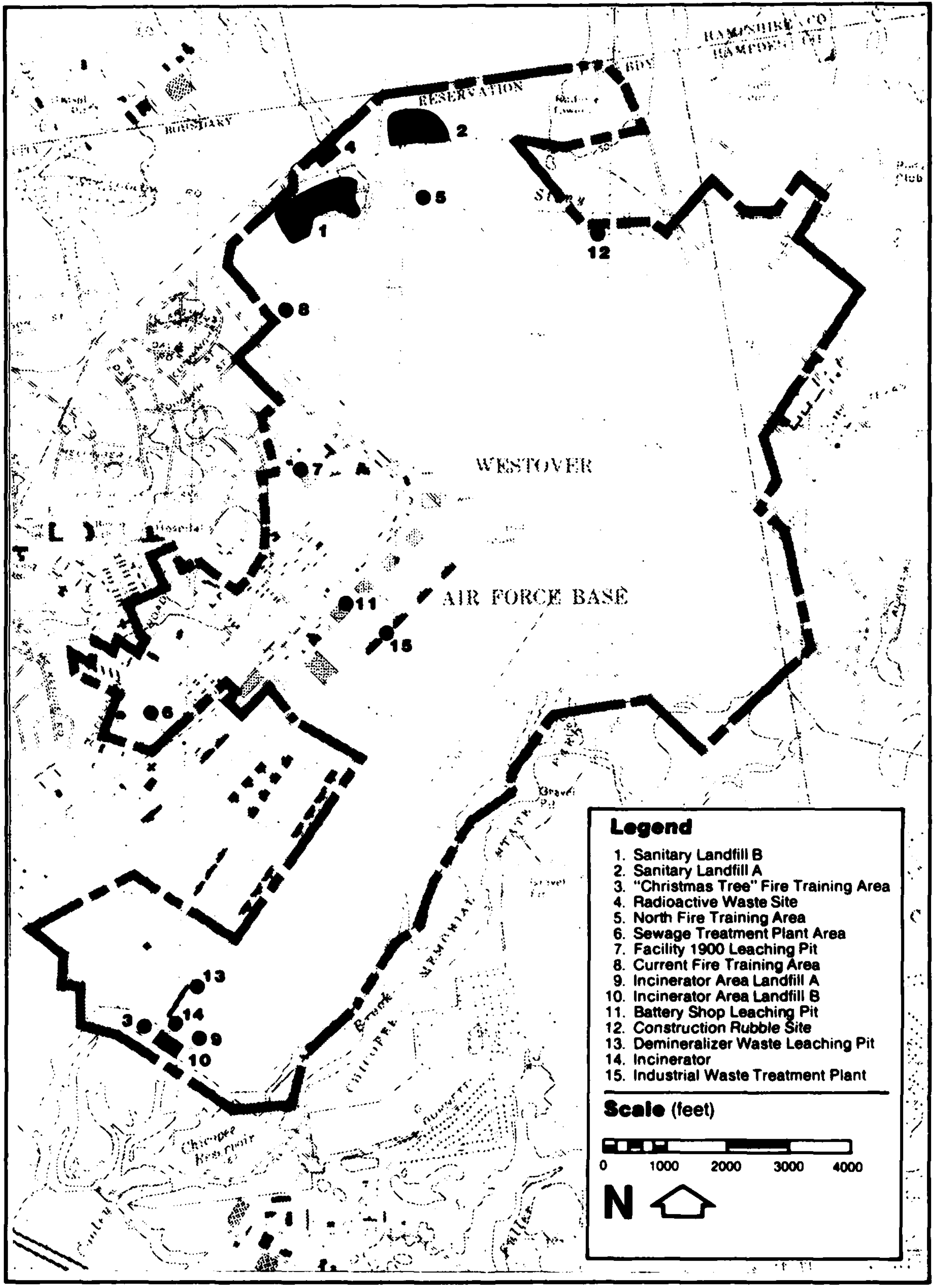


FIGURE 1-2 MAP OF WESTOVER AIR FORCE BASE SHOWING LOCATIONS OF ALL PAST WASTE DISPOSAL SITES RECEIVING HARM SCORES DURING PHASE I

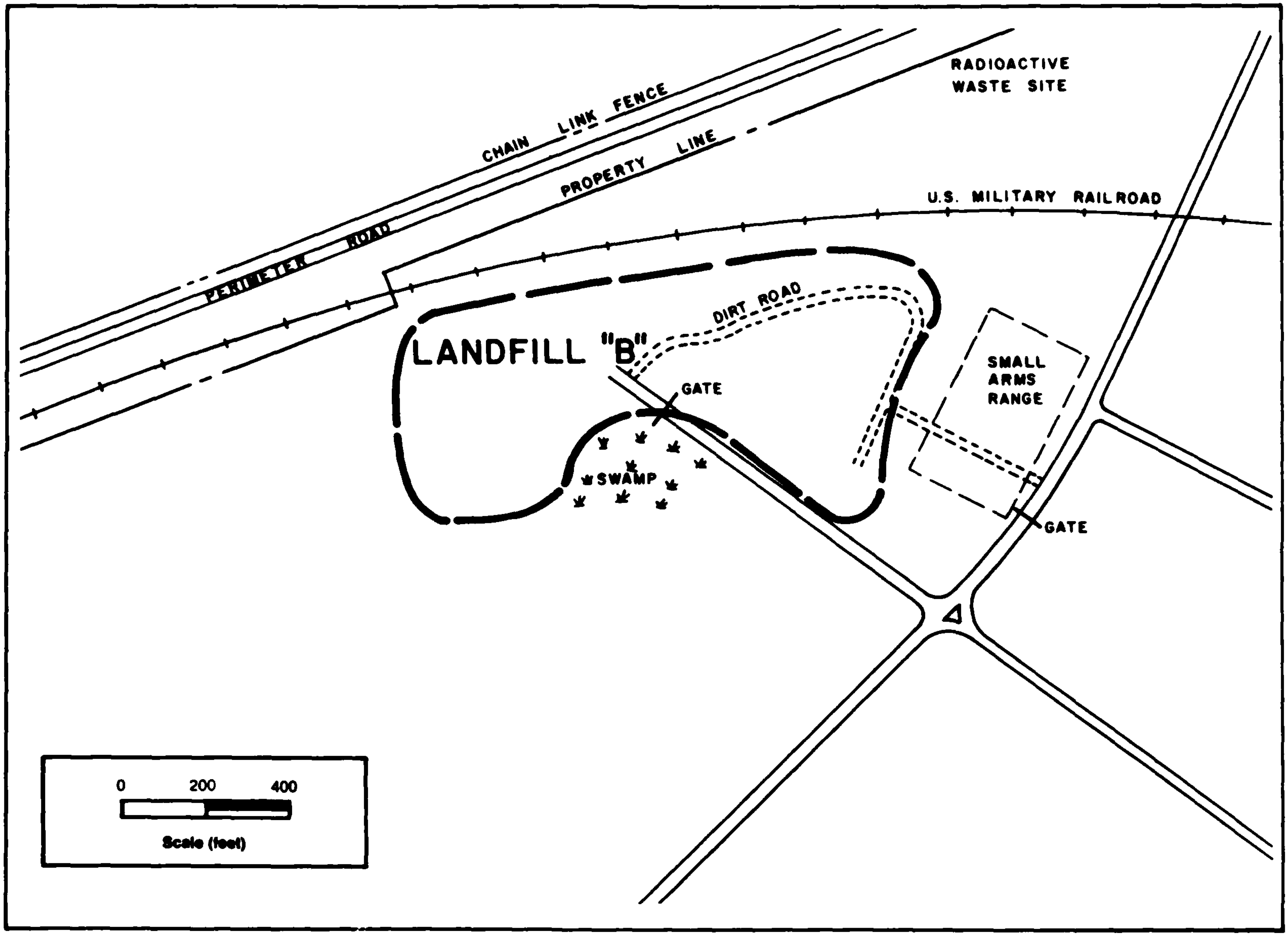


FIGURE 1-3 GENERAL SITE MAP OF LANDFILL B

better soil cover and a better established vegetative growth than the western portion.

A small swampy area on the south side of Landfill B drains the landfill southward into a network of storm sewers on Base. These storm sewers convey drainage to Stony Brook, a surface water course which drains the northern portion of the Base, and exits the Base flowing in a northerly direction. Figure 1-4 summarizes surface drainage patterns on the Base, and illustrates drainage in the vicinity of Landfill B.

1.3.2 History and Description of Site No. 2 (Landfill A)

According to the Phase I IRP report Sanitary Landfill A, shown on Figure 1-5, was operated from approximately 1958 until 1960 as a burn and bury operation. This site received primarily domestic refuse, general Base refuse and ashes from the coal-fired heating plant. During the Phase I effort interviewees reported that Sanitary Landfill A received empty containers and drums. The short period this site was in use was partially due to the depth of the groundwater table in the immediate vicinity of the landfill. The shallow water table, reported to be from 5 to 10 feet below land surface, restricted the available space for refuse disposal. The trenches excavated for refuse disposal were reportedly excavated below the level of the groundwater table, indicating that the refuse was sometimes disposed into standing water, and giving rise to concern as to the potential for groundwater contamination to occur.

Landfill A occupies an estimated area of approximately 12 acres, although the site is poorly defined from available records. Because fill operations were not conducted to any great extent above land surface datum, it is difficult to define the perimeter boundaries of this old site. The site lies to the east of Landfill B and its eastern boundary lies within about 150 feet of Stony Brook. Ground surface elevations range from about 220 at Stony Brook to over 235 feet on the western portions of the landfill site. Slopes across the site are less than 3%. Vegetative cover is highly variable from sparse grass to dense tall brush and trees. Surface drainage is to the north and east, as shown in Figure 1-4.

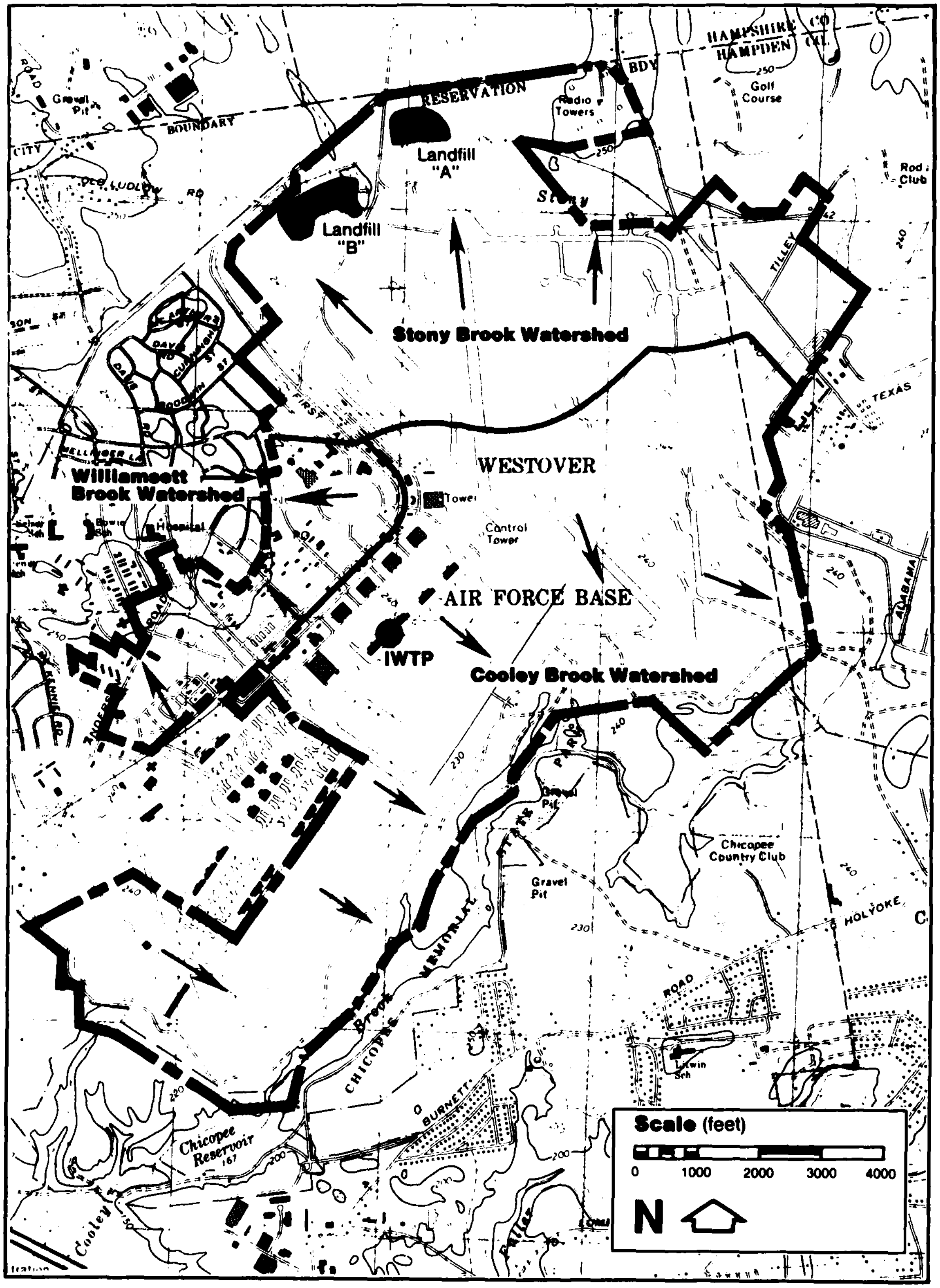


FIGURE 1-4 SURFACE DRAINAGE PATTERNS AT WESTOVER AIR FORCE BASE

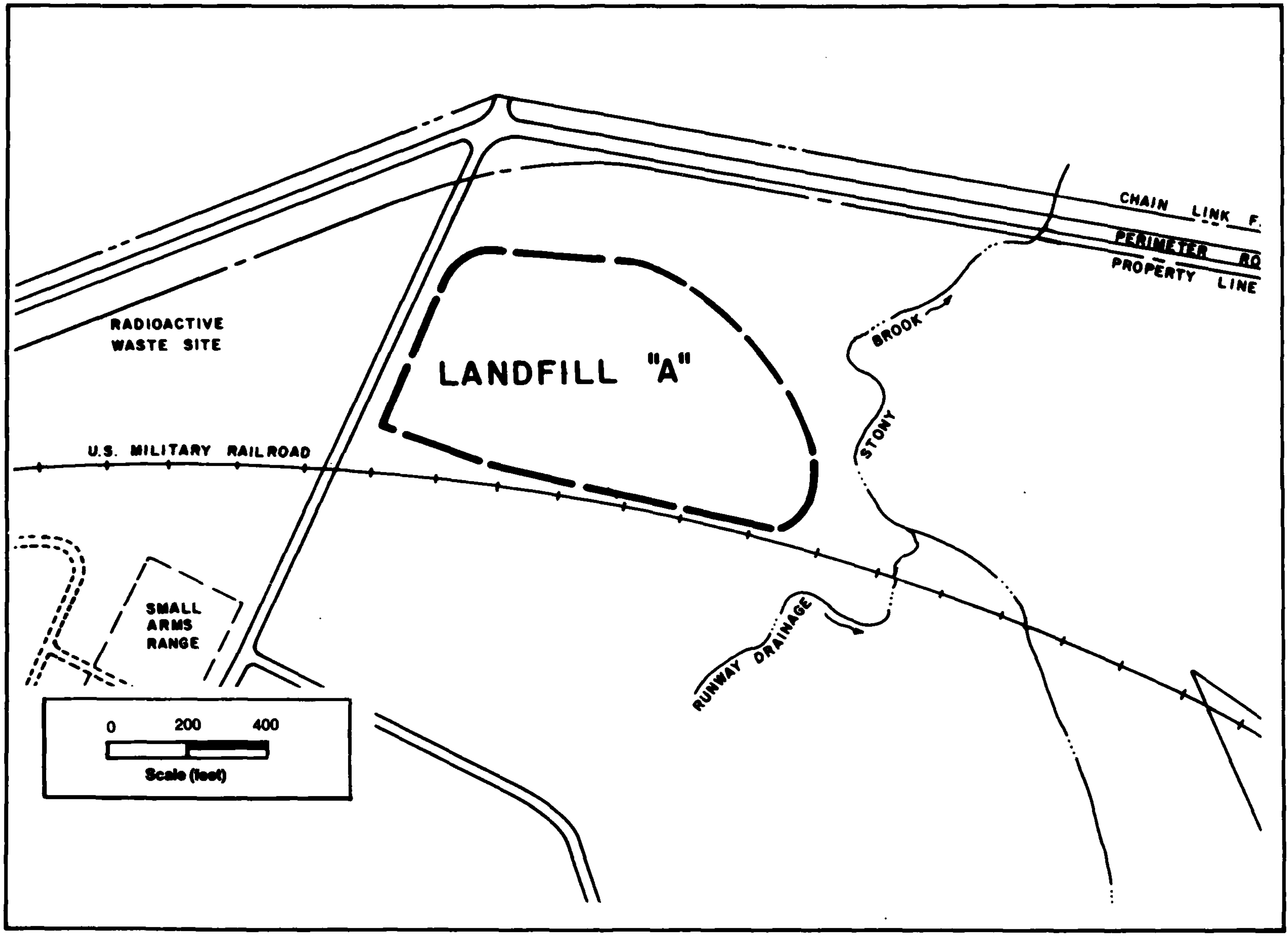


FIGURE 1-5 GENERAL SITE MAP OF LANDFILL A

1.3.3 History and Description of Site No. 15 (Industrial Waste Treatment Plant Skim Waste Storage Tank)

The Industrial Waste Treatment Plant (IWTP) located at Facility 7052, as shown in Figure 1-6, was built in 1956 and is currently in operation. As reported in the Records Search, the IWTP receives the discharge directly from Nosedock areas 32 and 34 (Facilities 7051 and 7053). Other industrial operations collect their wastes in drums and holding tanks and intermittently truck them to the IWTP. The IWTP has a design capacity of 30,000 gallons per day (gpd). The industrial wastewater is treated by separation and settling of grit and heavy particles. Floating oils are removed by skimming, and separation of emulsified oils is accomplished by chemical treatment, flotation, and skimming. The oils that are skimmed off are stored in a 6,000-gallon underground concrete skim waste storage tank under Building 7052. It was reported that the 6,000-gallon storage tank was cleaned intermittently while WAFB was under SAC control (until 1974), but has not been cleaned since the Base was taken over by AFRES in 1974. For this reason the integrity of the storage tank was questioned during Phase I activities and a determination was made to include it in the Phase II Confirmation Study. Facility 7052 is located in the west central portion of the Base about 1,800 feet northwest of Runway 05.

Ground surface in the area of the IWTP is approximately 240 feet above MSL. There is essentially no topographic relief in this heavily developed portion of the Base. A network of storm sewers convey surface water runoff from this area to the south, and eventually runoff discharges into Cooley Brook, as shown in Figure 1-4. The entire area around the IWTP is developed. A series of subsurface petroleum storage tanks are located between Runway 05 and the IWTP. General aircraft maintenance shops as well as battery, hydraulic and propulsion shops are located in the vicinity of the IWTP.

1.4 CONTAMINATION PROFILE

No large scale industrial operations generating large quantities of hazardous wastes have been conducted at WAFB in the past. The generation of waste oils and solvents from cleaning and painting operations has been small in comparison to other bases having significant aircraft maintenance and overhaul missions. Much of the combustible wastes have either been burned in fire training exercises or discharged to the IWTP. Waste oils reportedly have been sold to off-site contractors since 1974; waste solvents have been contracted for approved off-site disposal since October 1981 (Phase I, IRP, 1982).

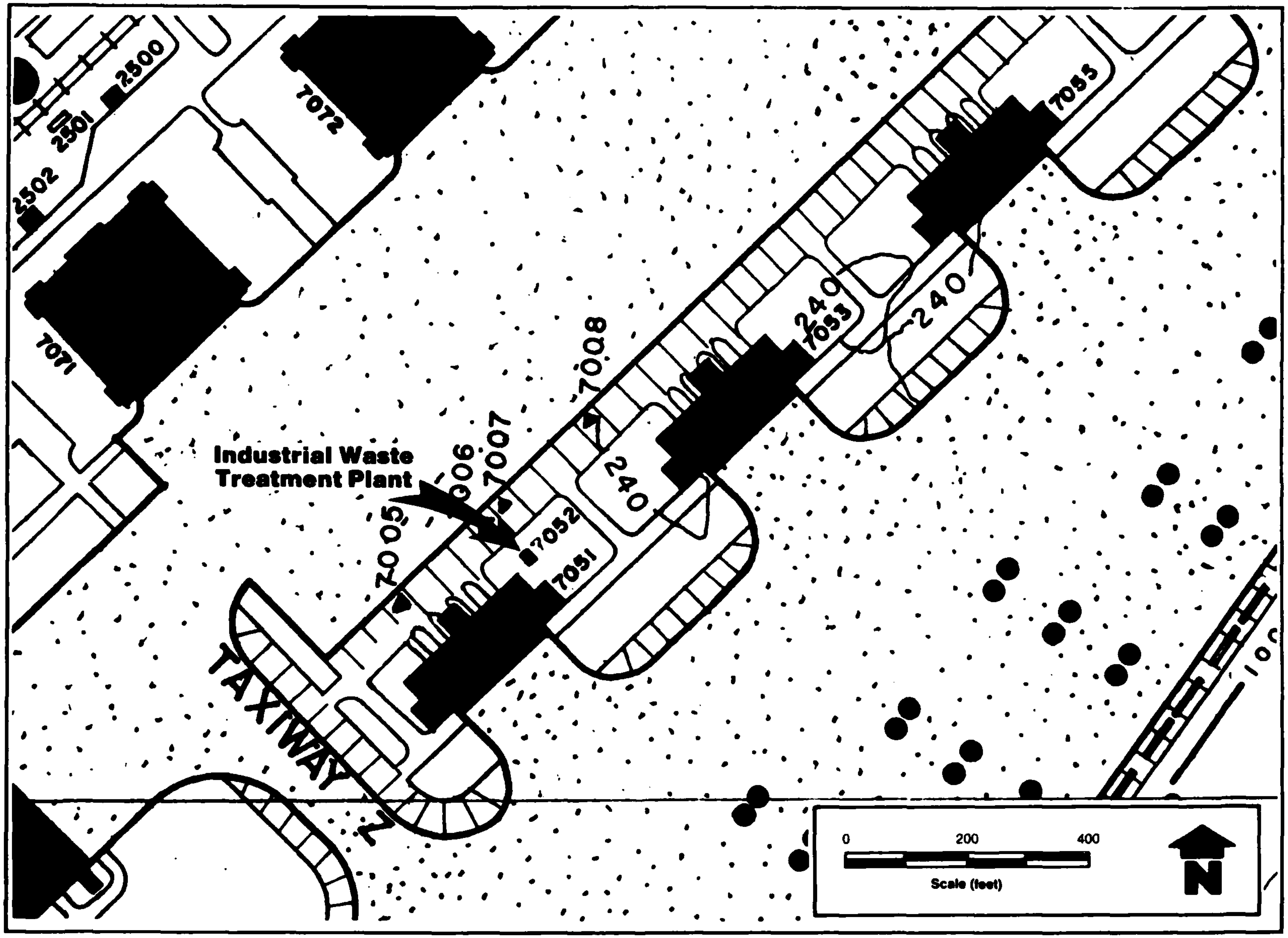


FIGURE 1-6 GENERAL SITE MAP OF THE IWTP AREA, WESTOVER AIR FORCE BASE

Based on the Phase I Records Search Report, the key chemical parameters of potential concern at Westover Air Force Base were oils and greases, lead and volatile organics. To develop an initial determination of whether or not past disposal practices have adversely impacted the environment, ground and surface waters in and around the two landfills were sampled for the parameters listed in Table 1-2. In addition, samples for oil and greases were collected from the Skim Waste Storage Tank and a well installed immediately adjacent to that storage tank. The details of the field work are described in Section 3 of this report.

1.5 FIELD TEAM

The Phase II Confirmation Study at WAFB was conducted by staff personnel of Roy F. Weston, Inc., and was managed through WESTON's Regional Office in Concord, New Hampshire. The following personnel served lead functions in this project.

MR. PETER J. MARKS, PROGRAM MANAGER: Corporate Vice President and Manager of Laboratory Services, MS. in Environmental Science, 18 years of experience in laboratory analysis and applied environmental sciences.

MR. RICHARD L. KRAYBILL, PROJECT MANAGER: Regional Geologist for New England, M.S. in Geological Sciences, with over 14 years of experience of applied geology and hydrogeology.

MR. DAVID WOODHOUSE, P.G., PROJECT GEOLOGIST: Registered Professional Geologist, M.A. in Geological Sciences, with over 18 years of experience in applied and engineering geology and hydrogeology.

MR. WALTER M. LEIS, P.G., GEOTECHNICAL QUALITY ASSURANCE OFFICER: Corporate Vice President and Manager of the Geosciences Department, M.S. in Geological Sciences, Registered Professional Geologist, over 10 years of experience in hydrogeology and applied geological sciences.

MR. JAMES S. SMITH, PH.D., LABORATORY QUALITY ASSURANCE OFFICER: Ph.D. in Chemistry, over 16 years of experience in laboratory analysis.

MR. THEODORE F. THEM, PH.D., PROJECT CHEMIST: Ph.D. in Analytical Chemistry, over 10 years of experience in laboratory analysis.

Professional profiles of these key personnel, as well as other project personnel are contained in Appendix C.

TABLE 1-2

LANDFILL ANALYTICAL PROTOCOL

Parameter	Rationale
COD, TOC, Oil and Grease	Indicates non-specific gross contamination
Phenol, Volatile Organic Compounds, Lead	Includes specific hazardous waste substances which might have been disposed at WAFB
Iron, Chloride, Sulfate	Indicates possible contamination from landfill leachate.

1.6 FACTORS OF CONCERN

Several factors of concern should be highlighted at the outset of this Confirmation Study Report. These factors should be considered in the review of subsequent sections.

First, the Base overlies permeable sands which are generally saturated at depths less than 20 feet below land surface. These glacial deltaic deposits are generally moderate to high yielding aquifers (Walker and Caswell, 1977) and are used by many individuals in the vicinity of WAFB as domestic, potable water supplies. These supplies are primarily north of the Base. The unconsolidated deposits do not comprise a "Sole Source Aquifer" in the context either of Section 214e of the Safe Drinking Water Act of 1974, as amended, or of generic classification. However, the unconsolidated deposits are valuable for their potential availability for water supply.

Second, the stream drainage pattern in the vicinity of WAFB is characteristically disrupted, or deranged due not only to glacial activity within the last 10,000 years, but also due to the network of manmade drainageways on Base. A significant portion of the Base runoff drains northward via Stony Brook. This sub-basin flow is contrary to the regional southward surface drainage system of the Connecticut River. Surface water flow directions can be precisely defined; groundwater flows, however, may not replicate surface water flow patterns. This complicating factor may be significant when drawing conclusions concerning contaminant transport and dispersion patterns.

Third, the two landfills which were investigated are located on the northern boundary of the Base with only narrow buffer zones between the fill boundaries and the WAFB property line. Depending on localized groundwater flow directions, a potential exists for contaminant transport offsite with a minimum travel time factor.

SECTION 2

ENVIRONMENTAL SETTING

2.1 REGIONAL GEOLOGY

Westover Air Force Base is located in the Connecticut Valley lowland subdivision of the New England Upland Physiographic Province of the Northern Appalachian Mountain System (Thornbury, 1965). The surface of the New England Province has undergone a complex development throughout geological history. Mountain-building episodes occurred in the region during Ordovician and Silurian times (between 500 and 400 million years ago) and during Pennsylvanian and Permian times (Between 310 and 230 million years ago). Since those events a combination of fluvial and marine erosion has sculpted the mountainous regional landscape into a series of upland terraces, as shown in Figure 2-1. WAFB is located in an area which was, then, originally a part of the Goshen Terrace.

In the late Triassic Period (approximately 180 million years ago) the New England Upland was subjected to regional faulting as a result of plate tectonic tensions which caused the rifting of the ancestral Atlantic Ocean. This faulting resulted in the development of the large-scale, north-south trending fault block structures (grabens) which dissected the upland terraces and form much of the present day Connecticut River Valley. During formation of these grabens, intermittent vulcanism accompanied by increasing erosional activities on uplands adjacent to the grabens resulted in the deposition of red sandstones and shales and igneous rocks of basaltic composition within the fault-bounded valley. These rocks form the bedrock deposits beneath WAFB today.

During Pleistocene Time (between 1.7 million and 11,000 years ago) the region underwent a third major event in the form of a series of continental glaciations. The most recent of these glaciation events, the Wisconsin Glacier is most directly responsible for the present geological conditions in the immediate vicinity of WAFB. The Wisconsin Glacier covered all of Canada and much of the northern United States by about 20,000 years ago. In New England the glacier extended as far south as Long Island, and in the vicinity of WAFB the ice thickness may have ranged upward from 2,000 feet. Alternating recessions and advances probably occurred during the next several thousand years, with the final recession being well underway by about 14,000 years ago.

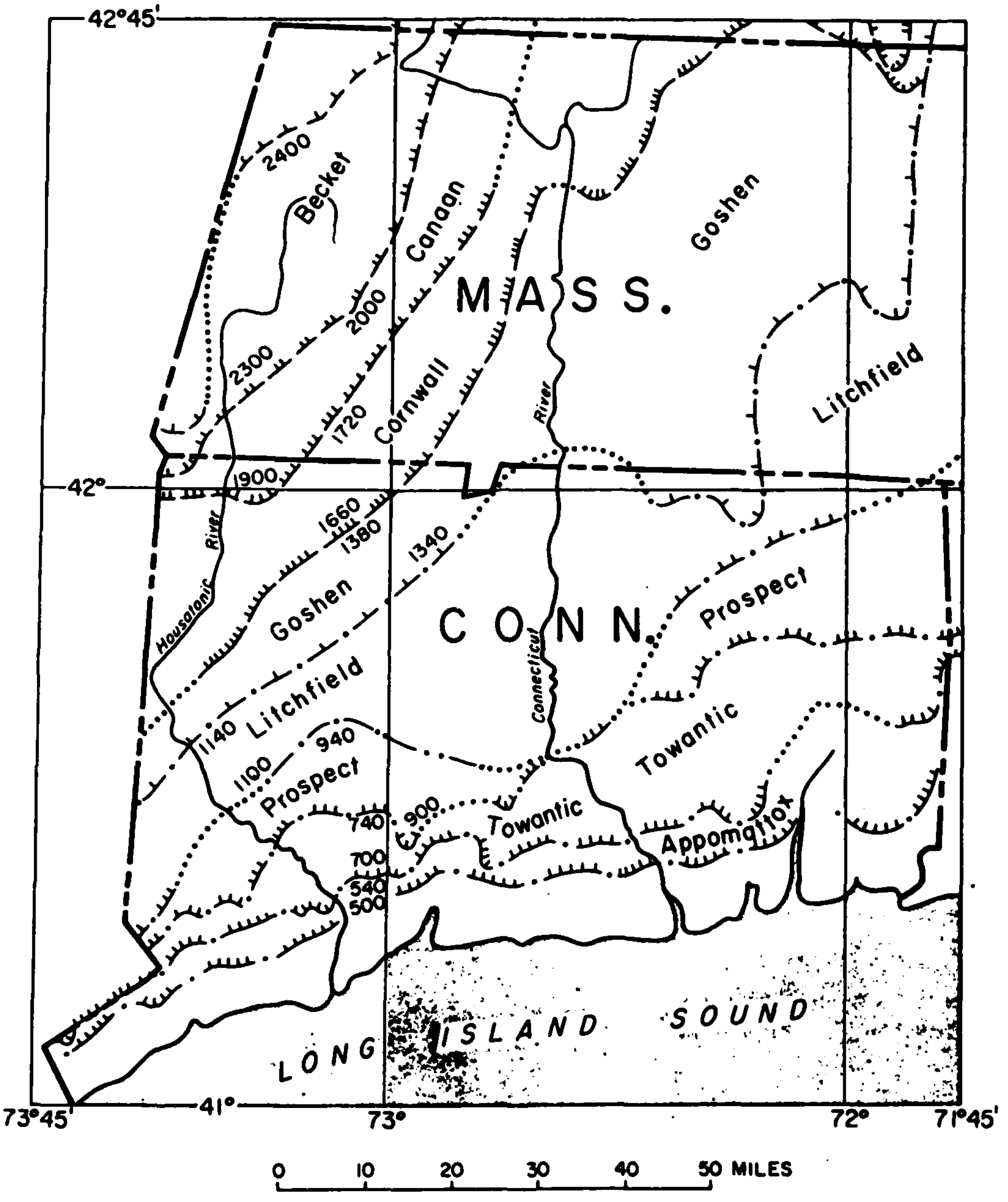


FIGURE 2-1 LOCATIONS AND ELEVATIONS OF UPLAND TERRACES IN THE NEW ENGLAND UPLAND PROVINCE (AFTER THORNBURY, 1965)

During recession the glacier melted, generally from toeward (south) to headward (north), with the result that all the rock particles entrained in the ice dropped virtually in-place. In the area of WAFB rock particles dropped from the receding glacier were deposited in a relatively continuous layer of glacial till consisting of poorly sorted silt, clay, sand and gravel deposits directly overlying the Triassic age sandstone and shale bedrock. These till deposits vary in thickness near WAFB from only a few inches to perhaps a few tens of feet -- a well log from a boring at Building 1900 at WAFB indicates that the till is about 10 feet thick there.

South of WAFB, at Rocky Hill, Connecticut, the glacial recession deposited a large glacial drift deposit across the Connecticut Valley Graben, which resulted in the damming of meltwater flow southward down the valley toward Long Island Sound, and the formation of a large meltwater lake (or up to three smaller ones) behind the dam. This lake, most often called the Connecticut Valley Lake (Thornbury, 1965) or Lake Hitchcock (Flint, 1971), extended from the Hartford, Connecticut, area in the south as far north as Lyme, New Hampshire. This lake had a surface elevation of about 300 feet above MSL, and initially may have been as much as 250 feet deep in the WAFB area. Meltwater from the northward head of the glacier carried fine-grained particles with it into the lake, and deposits of lacustrine silts and clays accumulated in the lake during the approximately 4,000 years during which the lake existed (Jahns and Willard, 1942). These deposits, which overlie the basal glacial till, range in thickness throughout the valley from only a few feet to over 250 feet (Langer, 1979) -- in the WAFB area these fine-grained deposits are about 80 feet thick, as documented by the well boring at Building 1900.

The glacial drift dam was breached about 10,000 years ago, the lake level receded and regional surface drainage patterns started reestablishing themselves. Following draining of the glacial lake, a dramatic lowering in the land surface base level occurred, and the resulting down-cutting in surface channels caused alluvial reworking of glacial deposits as well as headward erosion of upland areas. These erosional activities have reworked and redeposited discontinuous layers of coarse-gained glacio-fluvial deposits overlying the fine-grained lacustrine sediments. Many of these coarse-grained deposits have taken the form of alluvial fans and deltaic deposits in the area. WAFB is situated upon one such deltaic deposit formed by deposition of materials eroded from upland valley walls to the east of the Base.

Figure 2-2 presents a generalized stratigraphic column for the vicinity of WAFB, and represents those geological materials most likely to be encountered by drilling operations at WAFB. Figure 2-3 presents a generalized geologic cross-section across the Connecticut River Valley at WAFB (from the Phase I Report) and illustrates in vertical section the lithologic results of the sequence of geological events discussed above.

2.2 TOPOGRAPHY

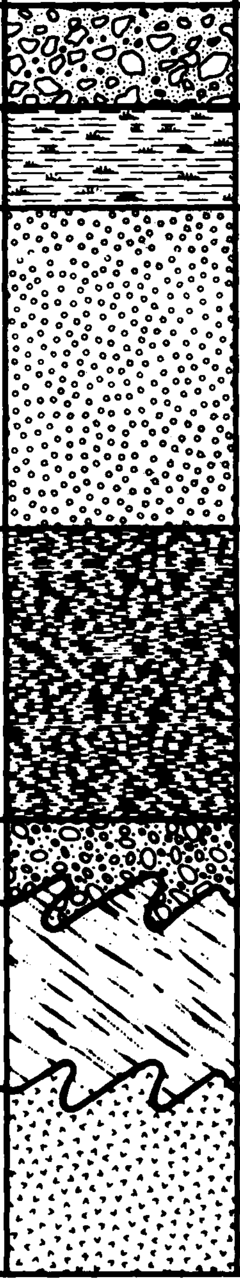
WAFB is located atop a coarse-grained deltaic deposit of materials derived from erosion of upland valley walls to the east of the Base. The valley walls to the east of the Base reach elevations of approximately 660 feet above MSL, while the valley walls on the western side of the Connecticut River Valley reach elevations of about 1,100 feet above MSL. The surface of the Connecticut River near WAFB is at an approximate elevation of 50 feet above MSL. Topography at the Base is gently undulating in undeveloped areas, with land surface elevations ranging from about 200 to 250 feet above MSL.

2.3 SURFACE DRAINAGE

A fairly extensive drainage system consisting of manmade ditches, storm sewers and natural swales conveys stormwater runoff from the Base into three different brooks; Cooley Brook draining the southern portion of the Base, Stony Brook draining the northern portion; and Williamansett Brook draining the west-central portion. The water quality designation by the Massachusetts Department of Environmental Quality Engineering (DEQE) of all three brooks is Class B. Class B is defined as inland waters suitable for:

1. bathing and other primary contact recreation;
2. agricultural and certain industrial process cooling uses;
3. excellent fish and wildlife habitat; and
4. excellent aesthetic value.

These brooks eventually discharge into the Connecticut River. The approximate watershed boundaries and directions of flow are shown on Figure 1-4.



Era	Period	Epoch	Unit	Columnar Section	Thickness in Feet	Typical Lithologic Characteristics
Cenozoic	Quaternary	Recent	Fill/Landfill		0-15′	Fine to Medium Loose Sand Trace - Gravel
			Swamp		0-3.5′	Peat, Fibers, Fine Sand and Silt
		Pleistocene	Deltaic Deposits		0-70′ ±	Brown to Gray, Fine to Coarse Sand, None to Trace, Gravel and Silt, Grading Finer with Depth
			Lacustrine Deposits		10-250′ ±	Gray Varved Clays Fine Sand and Silt Laminae
			Glacial Till Large Unconformity		0-20′ ±	Nonstratified Gravel, Sand, Silt, Clay Admixtures - Poorly Sorted
Mesozoic	Triassic		Triassic Bedrock Large Nonconformity			Sedimentary Strata with Many Crevices
Paleozoic	Pretriassic		Crystalline Bedrock			Metamorphic Strata with Few Crevices

FIGURE 2-2 GENERALIZED STRATIGRAPHIC COLUMN

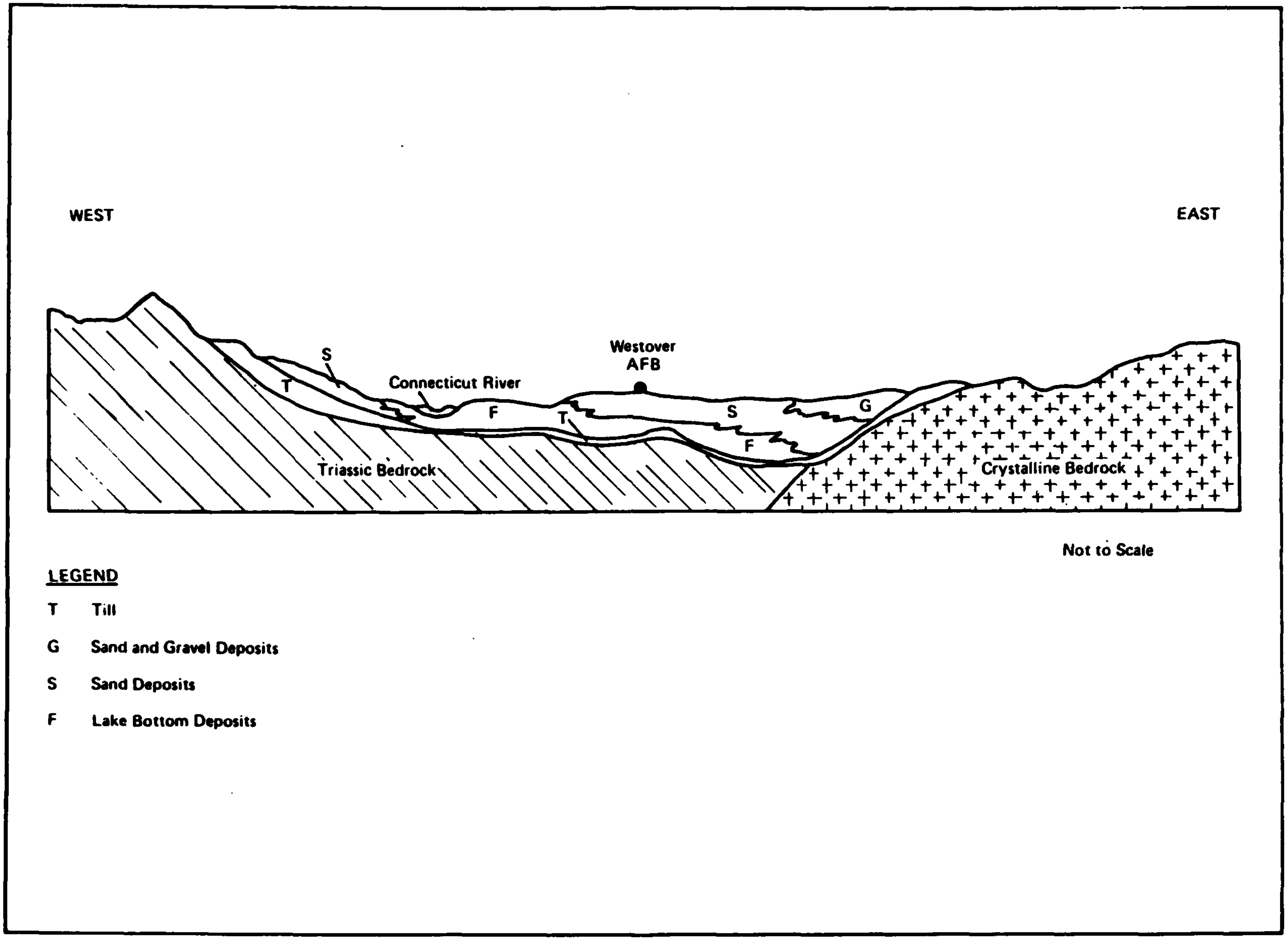


FIGURE 2-3 GENERALIZED GEOLOGIC CROSS-SECTION OF THE CONNECTICUT RIVER VALLEY AT WESTOVER AIR FORCE BASE (FROM THE PHASE I REPORT)

As can be seen from Figure 1-4, the three brooks drain the Base in three virtually orthogonal directions, and such a pattern is not characteristic of the otherwise mature drainage patterns elsewhere in the New England Upland Province. This almost random drainage pattern is typical of the deranged drainage patterns which develop atop recently glaciated terrains.

While there are no lakes or ponds on the Air Force property, there are some low-lying swampy areas that collect and retain water temporarily until it either evaporates, percolates into the ground, or is transmitted to surface brooks. An example of such an area is immediately south of Landfill B, where a swampy area collects southerly-directed runoff from the Landfill prior to discharging to Stony Brook.

Oil/water separators have been installed at the points of discharge of three storm sewers that discharge into Cooley Brook but none are installed at storm sewer discharge points in the Stony Brook or Williamansett drainage areas. The locations of the oil/water separators are also shown on Figure 2-4. These sewers collect runoff from the apron, aircraft maintenance, taxiway and runway areas. Those areas of the runways and taxiways which are located in the Stony Brook Watershed drain into Stony Brook and not into Cooley Brook.

2.4 HYDROGEOLOGY

There are several water-bearing aquifers in the area of WAFB. Triassic age bedrock shales and sandstones provide probably the most extensively tapped groundwater resource in the Connecticut Valley. The groundwater supply wells at the Base penetrate into this bedrock aquifer, and yields of off-Base bedrock wells are reported to be up to 300 gpm. In most Triassic Valley type deposits in the northeastern United States a yield of up to 300 gpm would be on the high side of average. There is no way to know with data currently available whether these 300 gpm wells are yielding entirely from bedrock, or whether there is leakage from the overlying deposits to augment yields. Figure 2-5 shows the location of existing and abandoned groundwater production wells at WAFB, all of which were completed in the Triassic aquifer. Only the well located in the antenna farm area is currently operational. The remaining wells near Building 1900 have been abandoned in favor of municipal water provided from surface water supplies by the City of Chicopee.

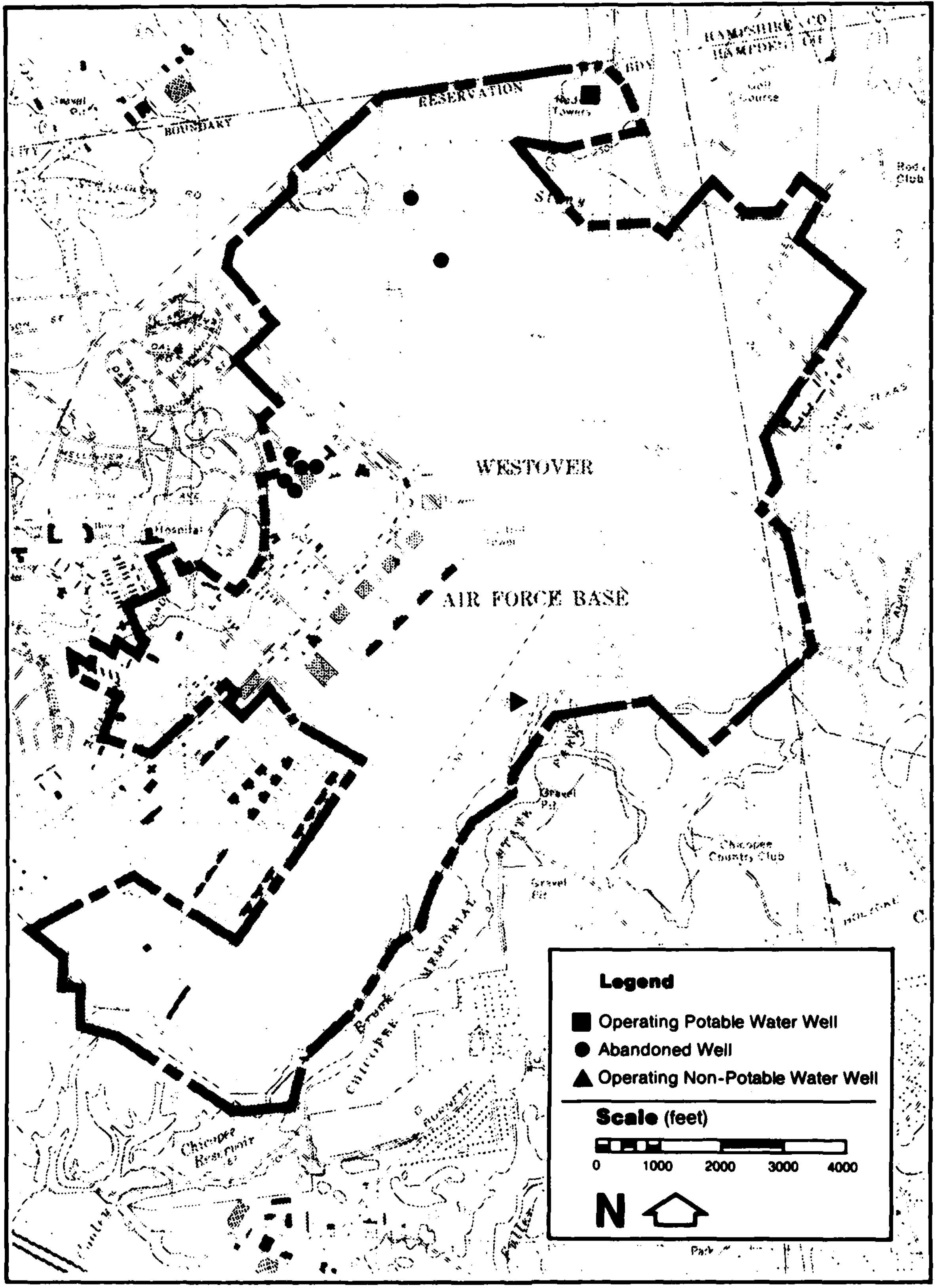


FIGURE 2-4 LOCATIONS OF EXISTING AND ABANDONED ON-BASE WATER SUPPLY WELLS (AFTER THE PHASE I REPORT)

The glacial till directly overlying the bedrock is a virtually undeveloped and untested aquifer. The known number of wells completed in this unit is small, and only a few yields have been reported to range from a few gallons per minute to over 1,000 gpm. The Town of South Hadley augments its municipal surface water supplies with groundwater obtained from a 110-foot deep, gravel packed well. From the data in Langer (1979) it would appear that such a well would tap the till aquifer. The yield of this well is unknown. The till aquifer is protected from contamination from surface sources in most areas by the presence of the lacustrine silt and clay confining layer.

The deltaic sands and gravels deposited over lacustrine silt and clay confining zones is the last of the aquifer zones available for potential water supply usage. This aquifer unit is widespread in the valley, is fairly coarse-grained and in many areas is upwards of 70 feet thick. Well yields of between 25 and 50 gpm in the thicker areas are quite common. Since the depth to water is generally less than 20 feet, water from this unit would be very inexpensive to tap by a private domestic well. Considering the relatively advanced ages of communities around WAFB, one would expect there to be literally thousands of such wells in existence near the Base whether or not municipal supplies are available in any given neighborhood. It was not within this scope of work to conduct the off-base survey necessary to prepare a map showing locations of these wells. The principal concern with using this aquifer as a potable water supply is that, since it is a water table aquifer, it would be quite vulnerable to contamination from activities at land surface.

SECTION 3

FIELD PROGRAM

3.1 PROGRAM DEVELOPMENT

Based on the conclusions of the Phase I Records Search and the overall relative HARM score ratings, Landfill B was determined to be the only site warranting a confirmatory field investigation. An additional recommendation to pressure test the waste storage tank at the IWTP was made in the recommendations section of the Phase I report.

On 19 October 1982, WESTON conducted a pre-survey site inspection of WAFB and the 15 identified sites listed in the Phase I report. At that time, representatives of OEHL requested that WESTON prepare a work scope which would include a limited monitoring program at Landfill A as well as the other elements recommended in the Phase I report.

Following the 19 October 1982 pre-survey inspection, WESTON prepared a Pre-Survey Report (December 1982) addressing the three sites. The location of the sites investigated are illustrated on Figure 3-1.

3.1.1 Landfill B

The WESTON Pre-Survey Report recommended certain modifications to the Phase I recommendations. The drilling program at Landfill B was expanded from 3 shallow monitor wells (20 foot average depth) to a total of seven wells at four locations. Three locations were selected for deep exploratory drilling (65 foot average depth) and well construction. Since a thick sequence of permeable sandy deposits were believed to occur beneath the site, there was a recognized potential for vertical contaminant migration to lower flow zones.

3.1.2 Landfill A

At Landfill A two monitoring wells were proposed in combination with stream sampling of the adjacent Stony Brook. Two forty-foot exploratory holes with monitor wells were projected to monitor a representative thickness of the saturated permeable deposits between the old burn/fill site and the stream. Since Landfill B is near Landfill A, the proposed wells at each site were believed useful in obtaining the level of information necessary for a Confirmation Stage investigation.

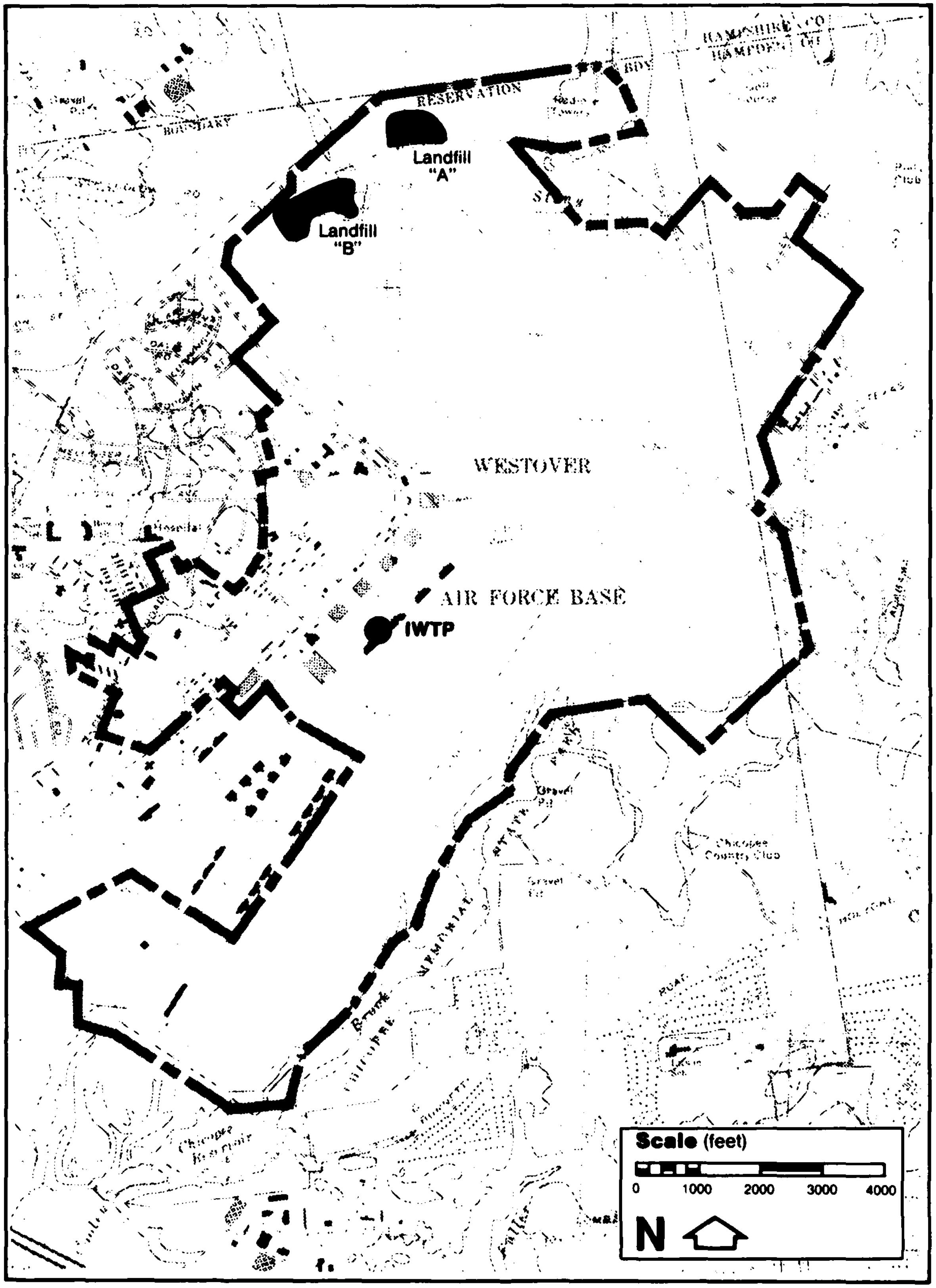


FIGURE 3-1 MAP OF WESTOVER AIR FORCE BASE SHOWING LOCATIONS OF ALL PHASE II SITES

3.1.3 IWTP Skim Waste Storage Tank

The skim waste storage tank was recommended for pressure testing. The pre-survey site inspection revealed that the partially buried, in-plant concrete tank was not amenable to pressure testing. An elaborate hydrostatic test procedure was devised and submitted in the Pre-Survey Report (December, 1982). It was later decided that a more cost effective initial approach would be to install and sample a shallow monitoring well immediately adjacent to the storage tank. A sample collected from the storage tank was also scheduled for comparison with the groundwater sample.

3.1.4 Analytical Protocol

An analytical protocol was selected for the landfill sites to provide indicators of specific and non-specific contamination. These are listed in Table 1-2.

The analytical protocol for the IWTP samples was restricted to oil and grease analysis. The storage tank received floating scum from the clarifiers at the IWTP. These were predominantly oils and greases. Presumably if the storage tank were leaking to an extent to cause adverse environmental impacts, the presence of oil and grease would be detected in adjacent groundwaters.

3.1.5 Formal Scope of Work

Task Order 0019 is included in Appendix B. This Task Order was the basis for the implementation of the field program described subsequently.

3.2 HYDROGEOLOGIC FIELD INVESTIGATION

A field investigation has been conducted to define the hydrogeologic and geologic setting at the Base and to assess the possible presence of hazardous environmental contaminants that may have resulted from past landfilling and industrial wastewater treatment operations at Westover Air Force Base. Information regarding potential or real impacts of the landfills and of the industrial wastewater sludge storage tank on area groundwater and surface water was obtained from ten on-site monitoring wells and three on-site surface water locations. The monitoring wells were installed to provide groundwater flow direction and gradient information and also serve as groundwater sampling locations. To enhance the hydrogeologic investigation and provide surface water to groundwater ties, sampling and staff gage locations were established on Stony Brook and its runway drainage tributary. A monitoring well was installed in close proximity to the industrial wastewater treatment plant to evaluate the integrity of the sludge storage tank.

3.2.1 Drilling Program

The hydrogeologic investigation of Landfills B and A and of the IWTP storage tank was initiated in October, 1983. Ten monitoring wells were installed between 4 October and 17 October 1983. The drilling work was accomplished under subcontract by D.L. Maher Company of North Reading, Massachusetts under the direct supervision of an on-site WESTON geologist. The monitoring well locations were selected to define groundwater flow directions, hydraulic gradients, site geology and to provide discrete upgradient and downgradient sampling points.

3.2.1.1 Landfill B

Three monitoring well couplets, consisting of paired shallow and deep monitor wells, and a fourth shallow well were installed at Landfill B. The wells were installed at the locations shown on Figure 3-2, and encompass the entire landfill perimeter. The deep wells, B-1, B-2 and B-3 extend through the complete section of deltaic sand deposits present, terminating at an average depth of 60 feet atop the lower permeability lacustrine deposits of silt and clay. Each of the deep wells is coupled with a shallow well, B-1A, B-2A, B-3A, averaging 22 feet in depth and penetrating approximately 10 feet into the saturated zone. Monitoring well B-4 on the northwest corner is a shallow well 25 feet deep and serves to complete the hydrogeologic information necessary for analysis of Landfill B. The three monitoring well couplets provide vertical hydraulic gradient information as well as shallow and deep groundwater samples for analytical comparison. Couplet No. 1 is located upgradient from the landfill area and serves to provide background analytical groundwater information. Construction details of these wells are summarized in Table 3-1. Boring logs and well completion details are contained in Appendix D.

3.2.1.2 Landfill A

Two monitoring wells were installed on the surficially downgradient side of Landfill A; one in the northeast corner (Well A-2), and one in the southeast corner (Well A-1) as shown on Figure 3-3. The latter extends to a depth of 30 feet. It initially penetrated decomposed remains of the ash burning fill and peat. The well then penetrates deltaic

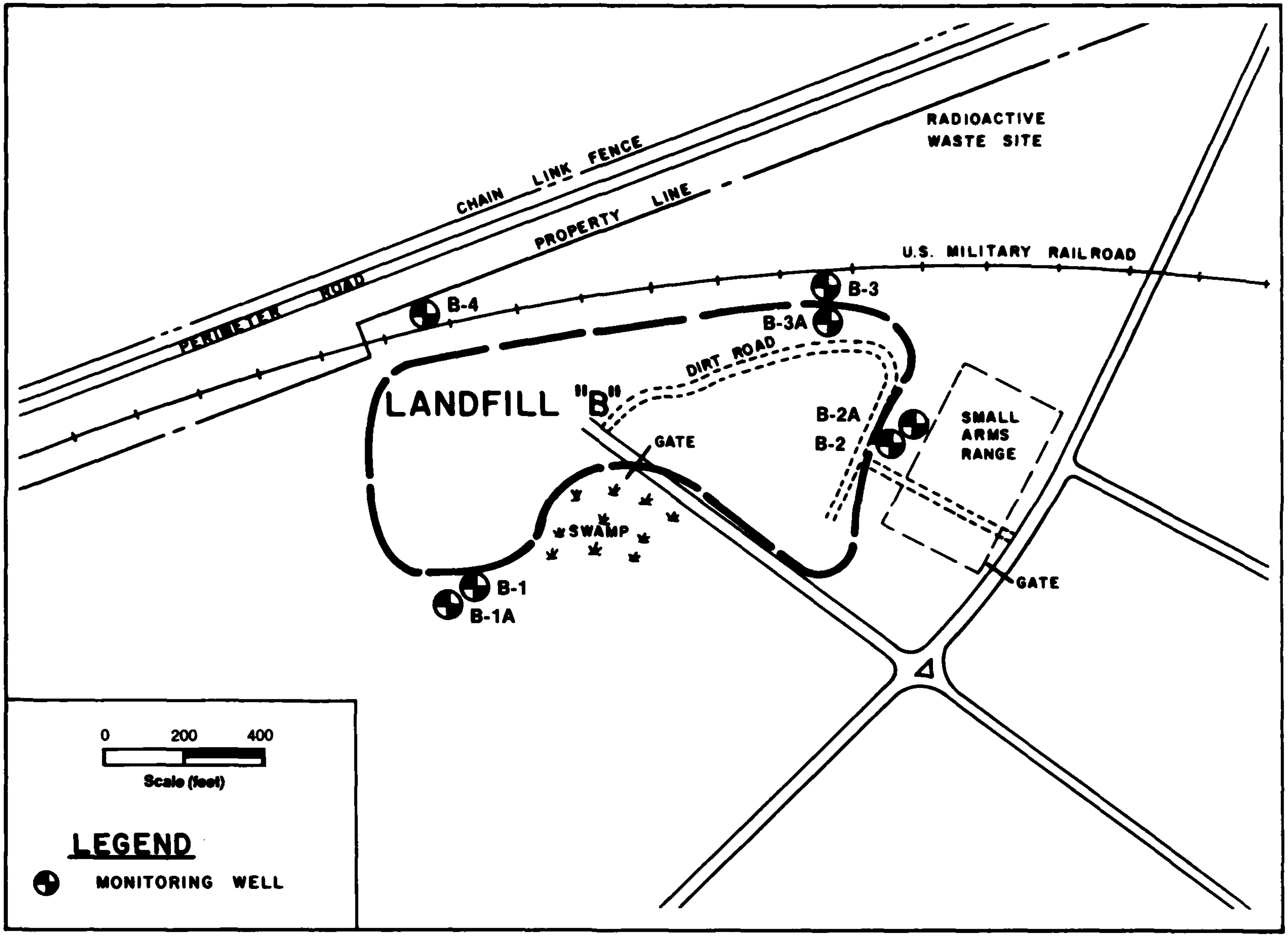


FIGURE 3-2 SITE MAP OF LANDFILL B SHOWING LOCATIONS OF PHASE II MONITOR WELLS

TABLE 3-1

SUMMARY OF WELL CONSTRUCTION DETAILS

Well	Approximate Land Surface Elevation (ft)	TOC (ft)	Below Ground Surface Screened Interval (ft)	Below Ground Surface Sandpacked Interval (ft)	Geology of Screened Zone
B-1	241.9	245.01	40-50	31-50	f.SAND, sSiltySand; D/L
B-1A	242.0	245.18	5-15	4-15	f-mSAND,lcSand,trGravel;D
B-2	252.9	255.90	50-60	43-60	f-cSAND,trGravel,trSilt;D
B-2A	252.6	255.81	17-27	15-27	f-cSAND,trGravel,trSilt;D
B-3	248.5	251.82	60-70	56-70	f-mSAND,trSilt;D
B-3A	248.2	252.18	13-23	10-23	m-cSAND,trf-mGravel,lfS;D
B-4	251.0	254.33	14-24	10-24	f-cSAND,trSilt;D
A-1	234.9	238.75	20-30	5-18 Natural 18-30	f-SAND,lSilt,trClay;D
A-2	235.7	239.30	20-40	5-18 Natural 18-40	fSAND;D
IW-1	240.9	244.16	13-23	10-23	f-mSAND;D

EXPLANATION:

TOC=Top of Casing
c=coarse
m=medium
f=fine

s=some
l=little
tr=trace

D=Deltaic
L=Lacustrine

Note: The sandpacked interval material is Ottawa Sand unless otherwise noted.

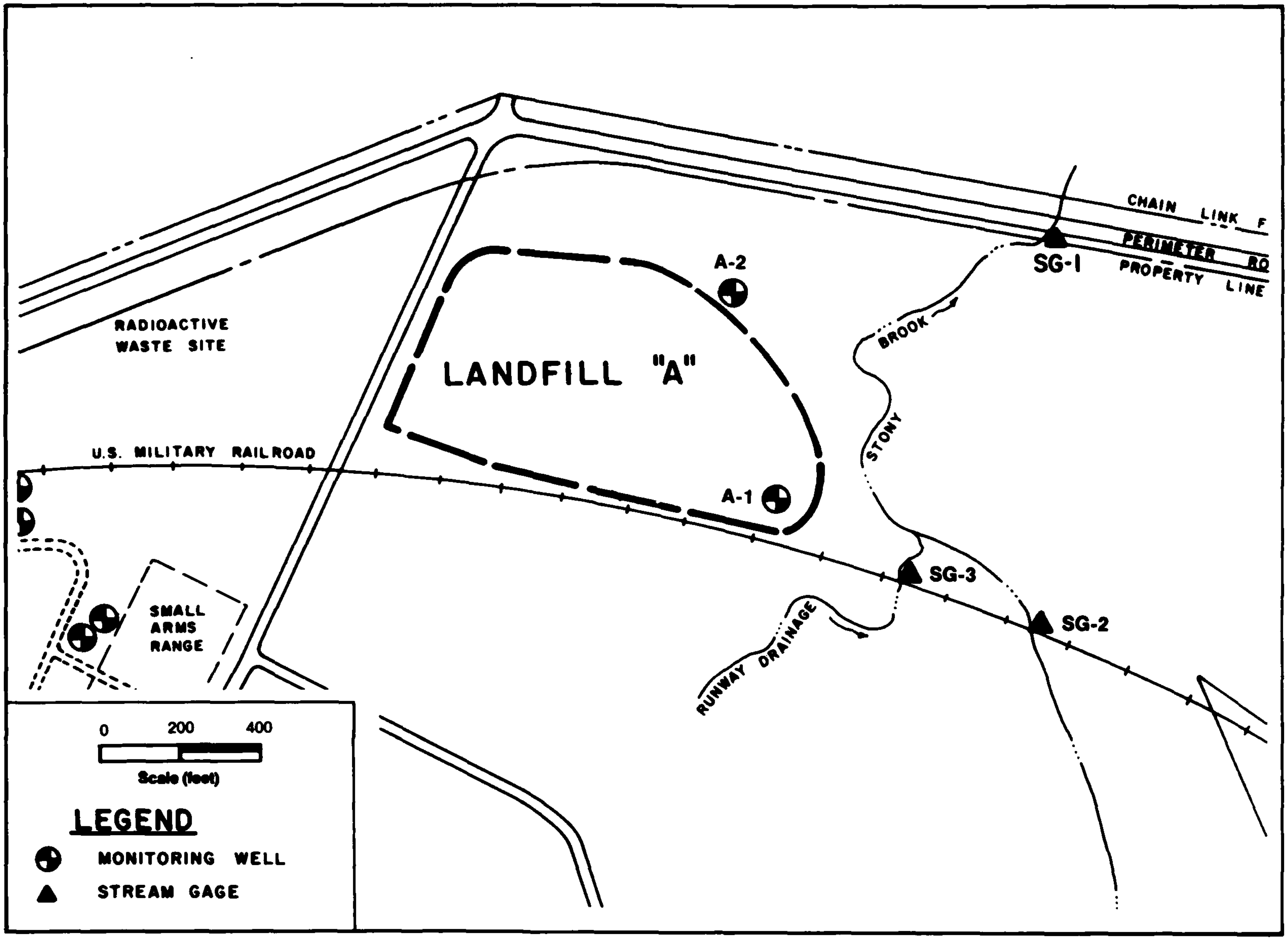


FIGURE 3-3 SITE MAP OF LANDFILL A SHOWING LOCATIONS OF PHASE II MONITOR WELLS AND STREAM STAFF GAGE STATIONS

sands and gravels and terminates atop fine sand and silt lacustrine deposits. A ten-foot screen is present in Well A-1 in the interval from 20 to 30 feet below grade. Well A-2 extends 40 feet through deltaic sands with a twenty-foot screen installed across the interval from 20 to 40 feet below grade. Construction details of these wells are summarized in Table 3-1. Boring logs and well completion details are contained in Appendix D.

3.2.1.3 Industrial Wastewater Treatment Plant

Monitoring well IW-1 was installed to evaluate the integrity of the skim waste storage tank inside the industrial wastewater treatment plant. It is a shallow well 23-feet deep penetrating approximately 10 feet of saturated deltaic deposits. It is located approximately 10 feet from the center of the tank on the southeast side of the building. Figure 3-4 depicts the approximate location of Well IW-1. Construction details of this well are summarized in Table 3-1. The boring log and well completion details are contained in Appendix D.

3.2.1.4 Typical Monitoring Well Installation Summary

All wells were constructed in the unconsolidated deltaic sand and gravel deposits overlying the lacustrine silt and clay confining layer (See Figure 2-2). Each boring was advanced with a Gus Pech drill rig from the ground surface using hollow stem auger techniques. Soils in all borings, except B-1A, B-2A, and B-3A, were sampled at standard five-foot intervals with a two-inch diameter, two-foot long split spoon sampler using Standard Penetration Test (SPT) Techniques (ASTM Standard Method No. D-1586). The shallow couplets were not sampled since the soils encountered were described by the samples from their deep well counterparts. All soil samples were retained in archives at the WESTON Office in Concord, New Hampshire. During each sampling operation an HNu Model PI-101 organic vapor photo-ionization detector was used to screen and detect any vapors down the well or emanating from the split spoon samples. No HNu readings above background were recorded in any boring.

Within each boring, a monitoring well was constructed using 2-inch diameter Schedule 80 Polyvinylchloride (PVC) pipe outfitted with No. 10 (0.010 inch) machine slotted well screen. All wells were installed with 10 feet of screen except for well A-2 where 20 feet was used. This extra length of screen was installed in order to monitor a more complete aquifer section, since lacustrine deposits were not encountered in the exploratory boring. The deep wells B-1, B-2,

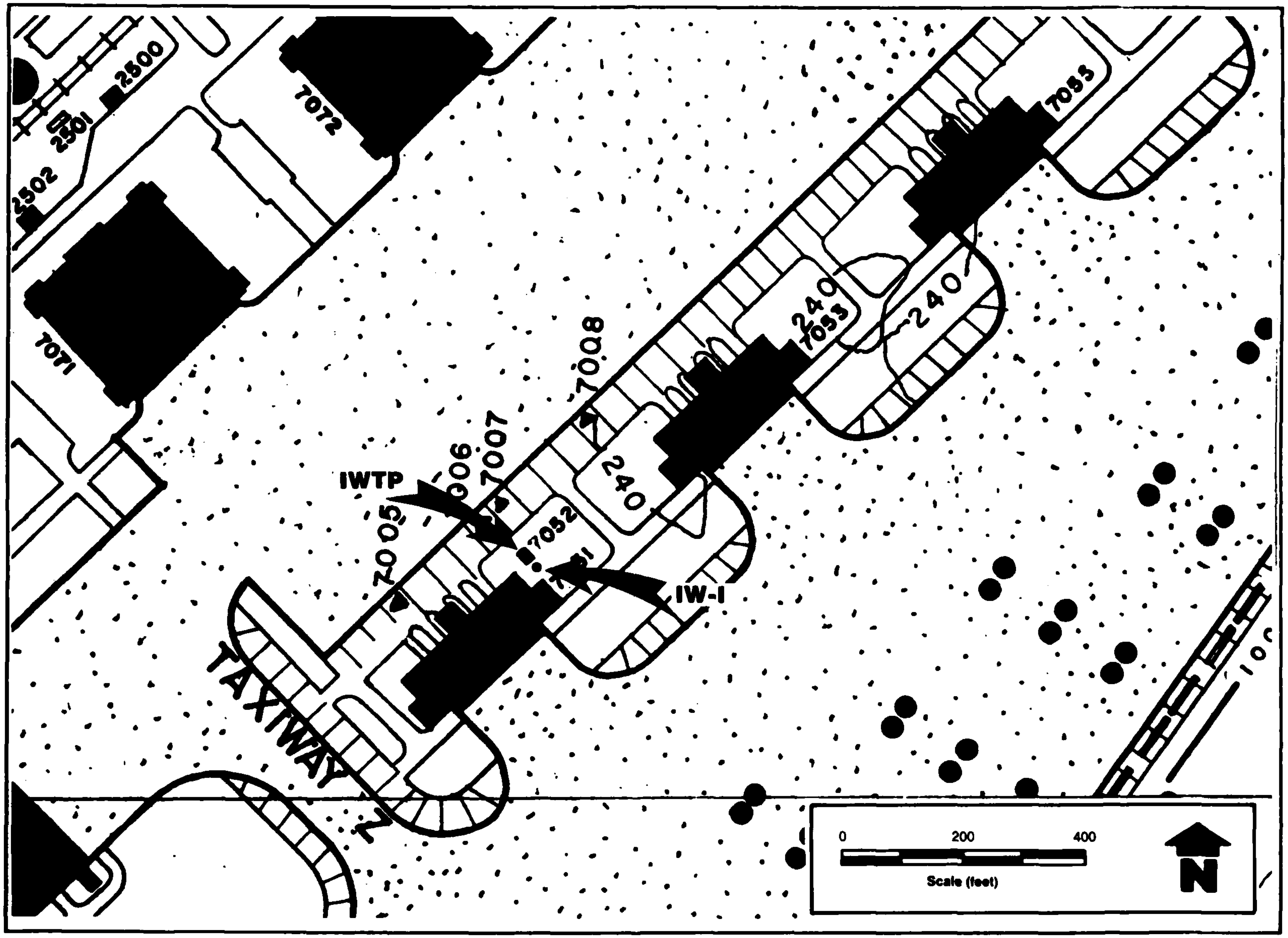


FIGURE 3-4 SITE MAP OF THE IWTP AREA SHOWING LOCATION OF PHASE II MONITOR WELL

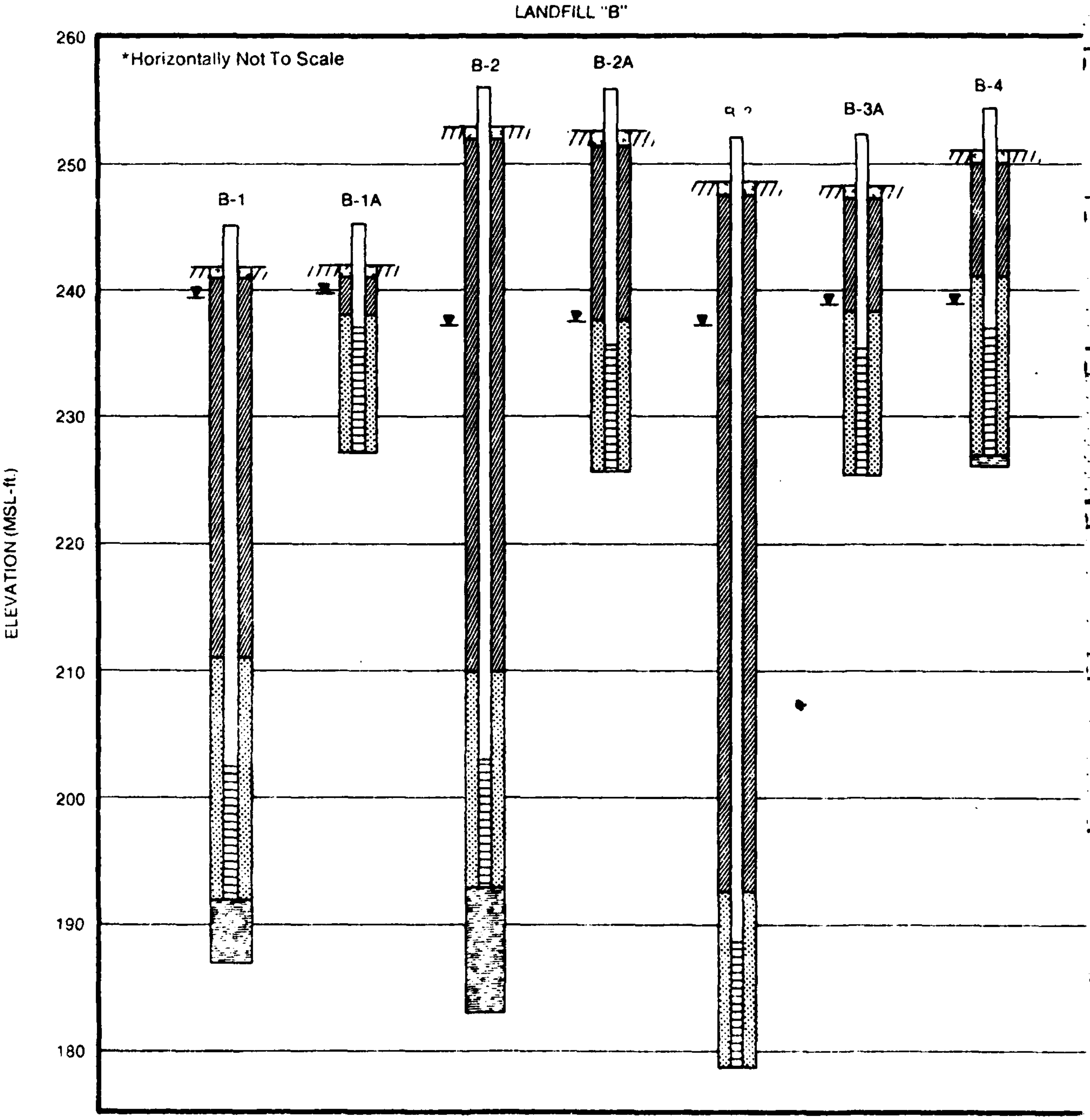
B-3, and well A-1 were installed such that the bottom of the screen was approximately located at the boundary between deltaic sands and gravels and lacustrine silts and clays. Borings B-1, B-2, and A-1 were advanced slightly deeper than the desired depth for the bottom of well in order to verify the boundary between these two units. Prior to installation of PVC casing and screen in each well the hollow stem auger was withdrawn such that the depth to the auger bit coincided with the desired well depth. This procedure allowed for natural collapse of in situ material into the deeper extremities of the boring beneath the PVC screen bottom.

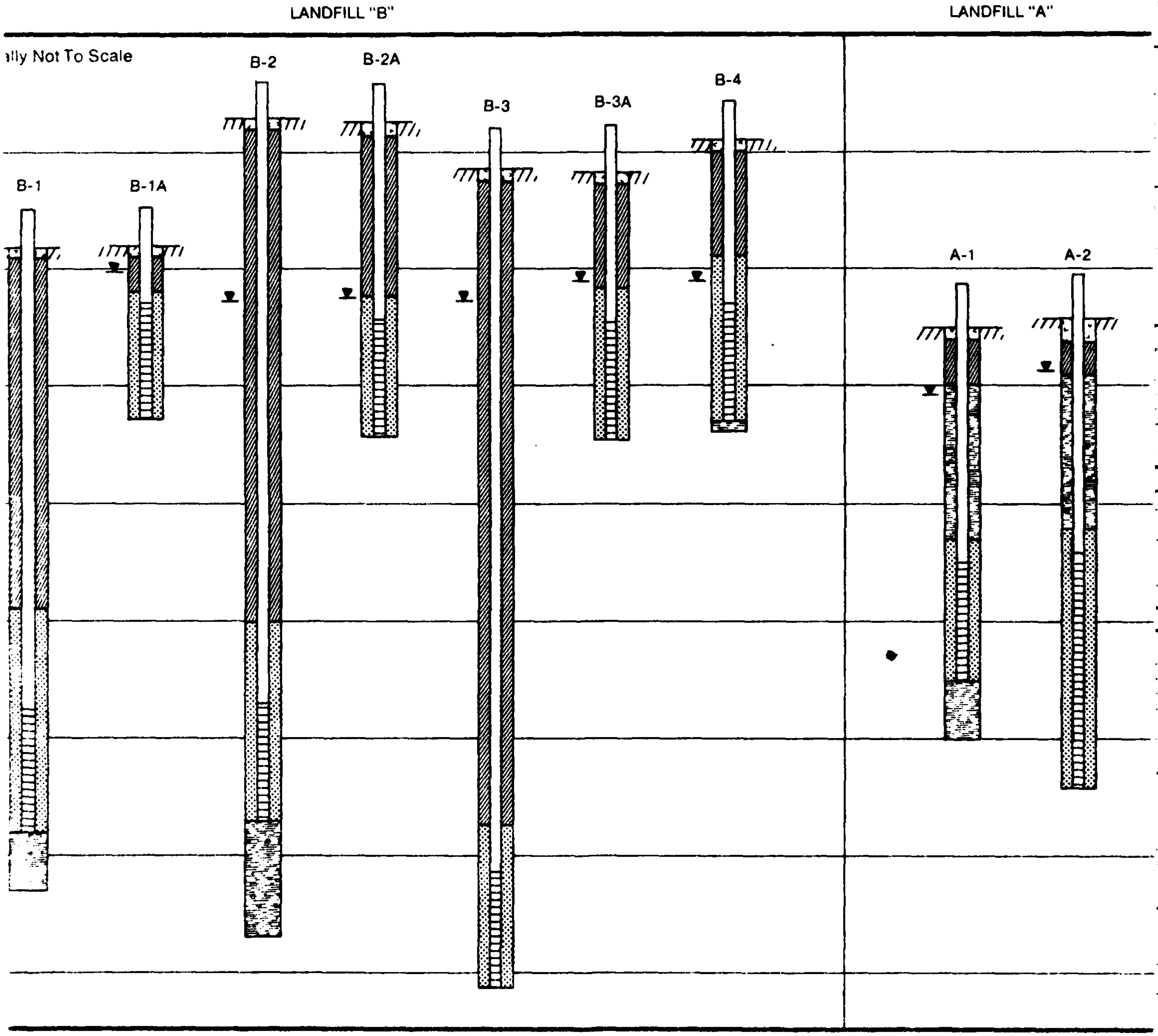
After the entire PVC monitoring well was in place within the hollow stem auger down the boring, the entire screened zone plus an average of five feet above the top of the screen was packed with Ottawa sand as the hollow stem augers were withdrawn. Above the Ottawa sand pack in Wells A-1 and A-2 the auger was pulled back to the static water level to allow natural deltaic sands to collapse around the blank PVC riser pipe. A cement and bentonite grout mixture was emplaced above the static water level using tremie methods to seal the well annulus and prevent leakage of surface water down the PVC blank riser pipe into the screened zone. In Boring A-1, fill deposits were encountered below the static water level. The well construction in A-1 was structured to monitor direct effects of the fill debris on water quality. Each monitoring well was outfitted with a steel protective casing and locking cap secured in place with concrete.

Each well was developed by pumping with a two-inch diameter, gas-powered centrifugal pump after its construction was complete. Continuous pumping was maintained for a minimum of one hour or until the pump effluent was clean to the satisfaction of the on-site WESTON geologist. Upon completion of well development each security casing was locked in order to preserve chain of custody. Figure 3-5 contains a well completion diagram for each Phase II monitor well constructed at WAFB.

3.2.2 Surface Water Program

On 8 and 9 November 1983, three surface water sampling locations and stream staff gages were established at the locations shown on Figure 3-2. Two stream gages are located on Stony Brook, and one on a runway drainage tributary. Sites SG-2 and SG-3 provided upgradient background data, above Landfill A. Sampling point SG-3 is, presumably, upgradient from both Landfills B and A. SG-1 is located downgradient from Landfill A, provides data after Stony Brook has been


LANDFILL "B"
*Horizontally Not To Scale
ELEVATION (MSL-ft.)
260
250
240
230
220
210
200
190
180
B-1
B-1A
B-2
B-2A
B-3A
B-4


LANDFILL "B"
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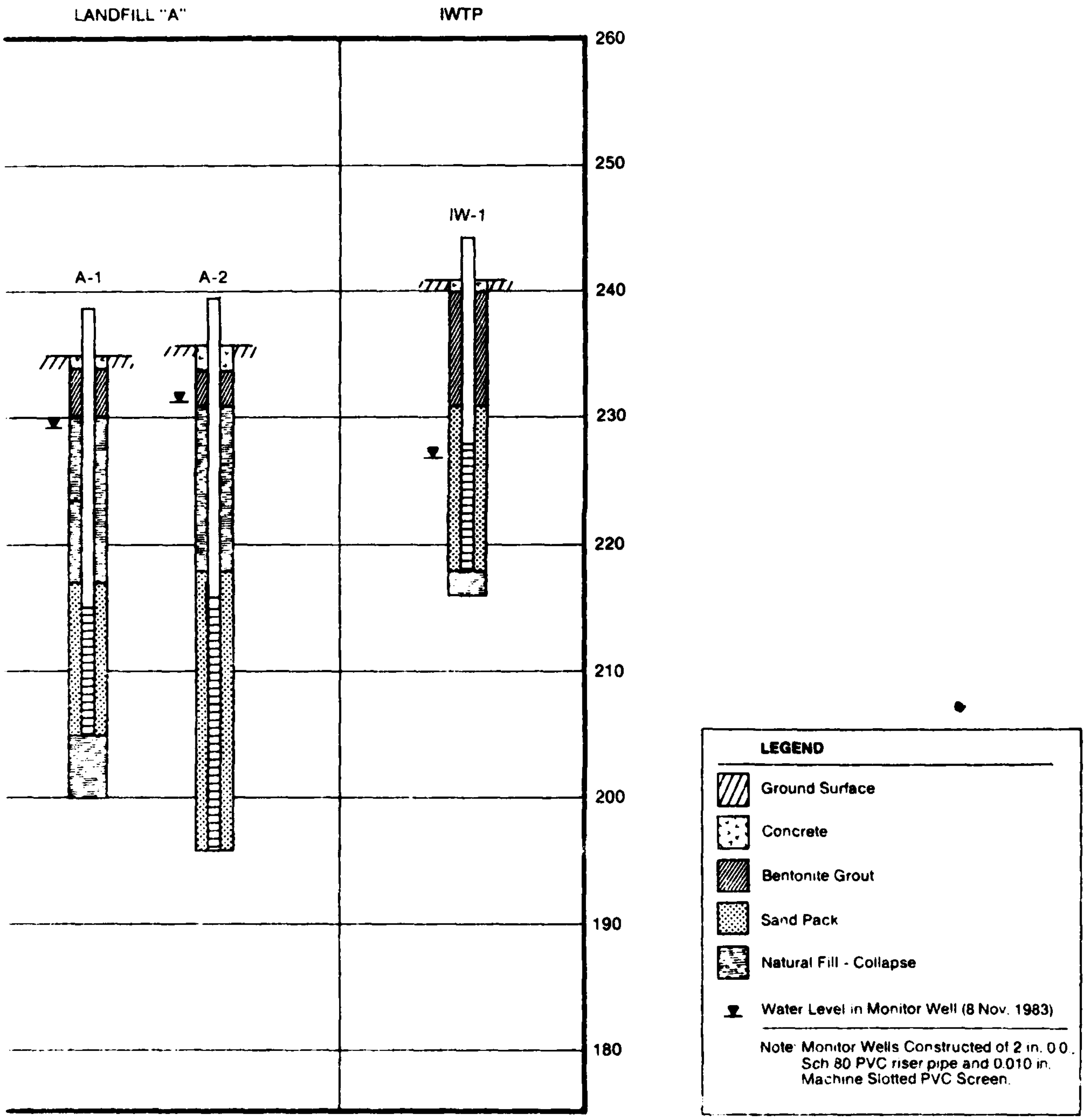


FIGURE 3-5 WELL COMPLETION DIAGRAM FOR ALL PHASE II MONITOR WELLS AT WESTOVER AIR FORCE BASE

joined by the tributary, and is intended to monitor potential surface water quality impacts from the landfills or other potential contaminant sources on the north side of WAFB.

3.2.3 Field Testing

In order to maximize the data collected from each of the installed monitoring wells, various field tests and testing techniques were used. Field testing involved: surveying of top-of-casing and staff gage elevations to provide water level elevation control; water level measurements to provide hydrogeologic and hydraulic gradient data; permeability tests to provide data for determination of aquifer characteristics in the vicinity of the well screens; and field water quality testing to provide pH, temperature and specific conductance data. Each of these field tests is described in the following paragraphs.

3.2.3.1 Surveying

A complete survey of all wells and staff gages was accomplished during the week of 8 November. A Dietzgen Top-Site 6140 30-second Transit was used for horizontal location to an accuracy of ± 10 feet. A Kern GKO-A Automatic Level was used for all elevations to an accuracy of ±0.05 feet. MSL datum was used for all surveying and USAF benchmarks provided initial survey control points. These benchmarks were: 1) Station 12+00, 137.50 feet LT-CL Taxiway G; elevation 239.626 feet MSL and 2) Station Y4+50, elevation 243.755 feet MSL. The survey included top of casing of all monitoring wells, stream gages, and any other important topographic information such as roads, streams, crossings, landfill boundaries, etc. Table 3-2 documents the results of these surveying activities.

3.2.3.2 Water Level Measurements

On 14 October, after all monitoring wells were installed, a complete round of water level measurements was conducted using the wetted tape method. A second complete round of water level measurements was conducted simultaneously with the water sampling program on 8 and 9 November. On that occasion a battery operated Soil Test Model DR-760A Water Level Probe was used. All readings were obtained with respect to the top of the PVC casing. Table 3-2 contains a listing of all readings and calculated water level elevations.

Table 3-2

SURVEY AND WATER LEVEL ELEVATION DATA

Monitoring Point Number	Reference Point Top of Casing (ft)	Ground Surface Elevation (ft)	14 October 83		8 November 83	
			Reading (ft)	Elevation (ft)	Reading (ft)	Elevation (ft)
B-1	245.01	241.9	5.56	239.45	5.62	239.39
B-1A	245.18	242.0	5.19	239.99	5.25	239.93
B-2	255.90	252.9	18.59	237.31	18.72	237.18
B-2A	255.81	252.6	18.17	237.64	18.27	237.54
B-3	251.82	248.5	14.33	237.49	14.53	237.29
B-3A	252.18	248.2	12.69	239.49	12.89	239.29
B-4	254.33	251.0	12.67	241.66	12.86	241.47
A-1	238.75	234.9	9.45	229.3	9.63	229.12
A-2	239.30	235.7	8.10	231.2	8.18	231.12
IW-1	244.16	240.9	17.09	227.07	17.28	226.88
SG-1	225.55				1.35	224.20
SG-2	229.44				3.61	225.83
SG-3	229.57				3.81	225.76

3.2.3.3 Permeability Testing

In situ permeability testing was conducted on Wells B-1, B-2, B-3, B-4, A-1 and A-2 on 10 and 11 November. The testing techniques used were developed by the United States Department of the Navy, Naval Facilities Engineering Command and are described in Cedergren (1977). The essential procedures are as follows:

a. The static water level in the well to be tested was measured and recorded.

b. Either

Slug Test - water added to bring the level to the top of the casing

or

Recovery Test - water pumped from the well to the maximum pull of the pump.

Both tests were initiated by causing an instantaneous change in well water level by the sudden introduction (slug test) or removal (recovery test) of a known volume of water.

c. As the water level returned to the static position, the elapsed time and level readings were recorded until the level returned to at least 90% of the static level.

Results obtained from *in situ* permeability testing are summarized in Table 3-3. These results are described in Section 4.2.5 of this report.

3.2.3.4 Field Water Quality Testing

Field water quality testing was conducted twice on each well. Specific conductance and temperature were measured in the field using a Yellow Springs Instrument Company Model 33 Meter. The pH was measured in the field using an Analytical Measurements Model 107 pH Meter. Water quality testing was conducted first at the initial water contact in each boring during well drilling in October. The second occasion was during water sampling on 8 and 9 November, during which time all monitoring wells and surface water sampling points were tested for field water quality parameters. Table 3-4 contains a complete list of all field water quality testing data.

TABLE 3-3

RESULT OF IN SITU PERMEABILITY TESTING

Monitor Point	Type Test	Hydraulic Conductivity (ft/sec)	Transmissivity (ft^2/sec)	Principal Formation Description
B-1	Slug	1.9×10^{-4}	9.1×10^{-3}	Fine Sand
B-2	Slug	1.2×10^{-5}	5.3×10^{-4}	Fine-Coarse Sand
B-3	Recovery	7.5×10^{-6}	4.7×10^{-4}	Fine Sand
B-4	Recovery	9.2×10^{-6}	5.5×10^{-4}	Fine-Medium Sand
A-1	Recovery	1.1×10^{-5}	6.4×10^{-4}	Fine Sand
A-2	Recovery	4.9×10^{-6}	2.9×10^{-4}	Fine-Medium Sand

Table 3-4

FIELD WATER QUALITY TEST RESULTS

	October 1983		November 1983		
Well	Temperature (°C)	Conductivity (umhos/cm)	Temperature (°C)	Conductivity (umhos/cm)	pH (std. units)
B-1	21	45	12	35	5.8
B-1A			13	60	5.9
B-2	16	100	11	145	6.1
B-2A			13	205	6.1
B-3			9	77	6.1
B-3A			12.5	72	5.7
B-4	22	60	15	20	5.8
A-1	17.5	70	11	80	6.1
A-2	17.5	32	9	20	6.0
IW-1	21	75	17	70	5.8
SG-1			9	60	6.5
SG-2			8	60	6.4
SG-3			12	70	6.4
SG-3			12	70	6.4

3.2.4 Water Quality Sampling

The purpose of the water quality sampling program was to identify, insofar as possible at the level of a confirmation survey, the location, concentration and areal extent of any contamination present in the hydrogeologic environment. From this information it would be possible to deduce the general direction in which these contaminants are migrating and their probable origin. To achieve these goals efficiently, specific field procedures were developed for purging the wells, collecting the samples, and ensuring field quality control. These procedures have been used to obtain a single complete set of representative samples for chemical analysis from the monitoring wells, stream gages, and the industrial wastewater treatment plant sludge storage tank. The sampling and quality assurance plans used to accomplish these goals are contained in Appendix E. Sample chain-of-custody documentation is contained in Appendix F. Standard laboratory analysis protocols used in the analysis of these samples are contained in Appendix G.

SECTION 4

RESULTS

4.1 SITE INTERPRETIVE GEOLOGY

A detailed review of available geologic data obtained during the Records Search and subsequent on-site data generated during the Phase II investigation revealed that WAFB is underlain by a thick sequence of stratified glacial deposits that unconformably overlie Triassic shales and sandstones. A geologic column, Figure 2-2, represents the general subsurface conditions. As seen in Figure 2-2 WAFB is immediately underlain by permeable coarse-to-fine sands of deltaic or glaciofluvial origin. These deposits are underlain by fine grained sediments of lacustrine origin. The Confirmation Stage program focused on geologic exploration and monitoring well construction in the upper permeable sands. Drilling at Landfill B encountered sandy deltaic deposits at depths up to approximately 70 feet. The full extent of underlying fine grained lacustrine deposits was not penetrated.

In well B-1, a typical split spoon sample collected between 13-15 feet indicated:

> "gray brown fine to coarse SAND, trace Gravel, loose, saturated"

grading at 28 feet to:

> "gray brown fine to coarse SAND, trace Gravel."

These, in turn, were underlain by finer sediments of lacustrine origin typically described as:

> "gray fine SAND with interbeds of SILTY sand and Gray Clay Laminae"

grading to:

> "Gray CLAY with little fine Sand and Silt Laminae."

Geologic findings of the boring exploration program at Landfill A were similar to those at Landfill B. Finer grained sands with silt and clay laminae were penetrated within 29 feet of land surface in well A-1. The geologic section shown in Figure 4-1 illustrates a typical section through the landfills.

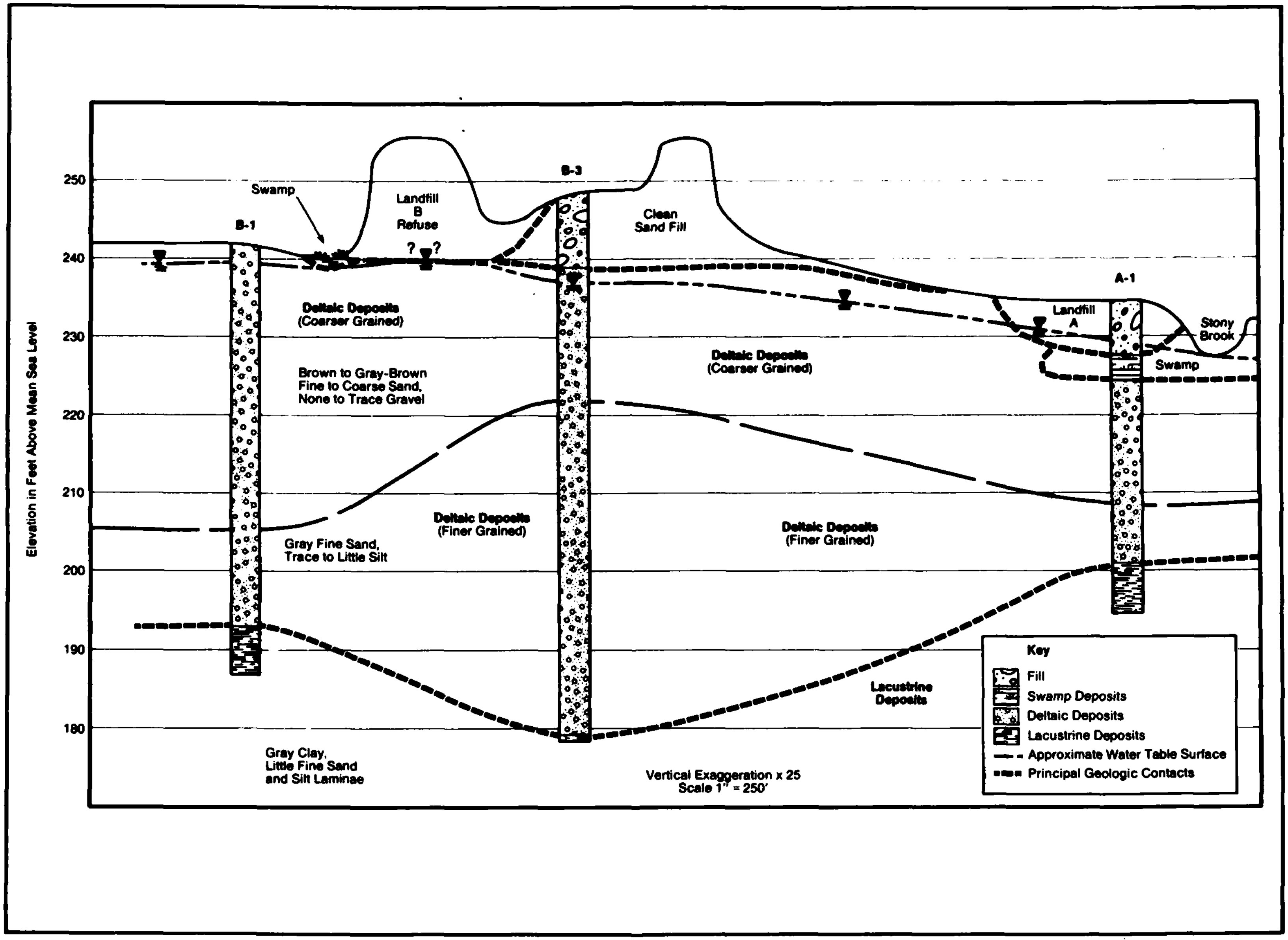


FIGURE 4-1 GEOLOGICAL CROSS-SECTION THROUGH LANDFILLS B AND A

The objective of the exploratory boring at the IWTP was to install a monitoring well penetrating the upper 10 to 15 feet of saturated deposits adjacent to the skim waste storage tank. Therefore the full stratigraphic thickness of permeable sands was not drilled. Geologic logs of all borings performed for the Phase II Study are included in Appendix D. These logs illustrate the consistent nature of the permeable, saturated deposits encountered.

4.2 SITE GROUNDWATER CONDITIONS

The results of water level readings from the newly installed wells at the landfills and the IWTP demonstrate that groundwater occurs under shallow, water table conditions within the deltaic deposits underlying WAFB. Groundwater elevations are less than 20 feet below land surface at all wells (Table 3-2). Since water level readings were taken in October and November 1983, the results probably represent seasonal low conditions.

4.2.1 Groundwater Flow - Landfill B

Figure 4-2 illustrates the shallow water table elevation readings for November 1983 based on data from shallow wells B-1A, B-2A, B-3A, and B-4. From the data in Table 3-2, a southeasterly flow component is suggested by the water level readings in the perimeter wells. Since the water table may be impacted by groundwater mounding within the refuse mass the potential exists for multi-directional or radial flow from the landfill mound to surrounding areas of lower relief.

The gradient of the shallow flow system at Landfill B averages about 0.005. Under these conditions any slight variations in subsurface lithology could also impact flow component directions within the groundwater flow system.

Groundwater flow, as measured in deep wells B-1, B-2, and B-3, exhibits an easterly flow component around the perimeter of Landfill B as illustrated in Figure 4-3. The hydraulic gradient measured between the deep wells also averages about 0.005. Thus, a minimal driving force is exerted by natural lateral head losses within the flow system.

Measurements of water table elevations at the three well couplets around Landfill B have revealed that a vertical component of flow occurs around the perimeter of Landfill B. Shallow wells typically exhibit higher head elevations than

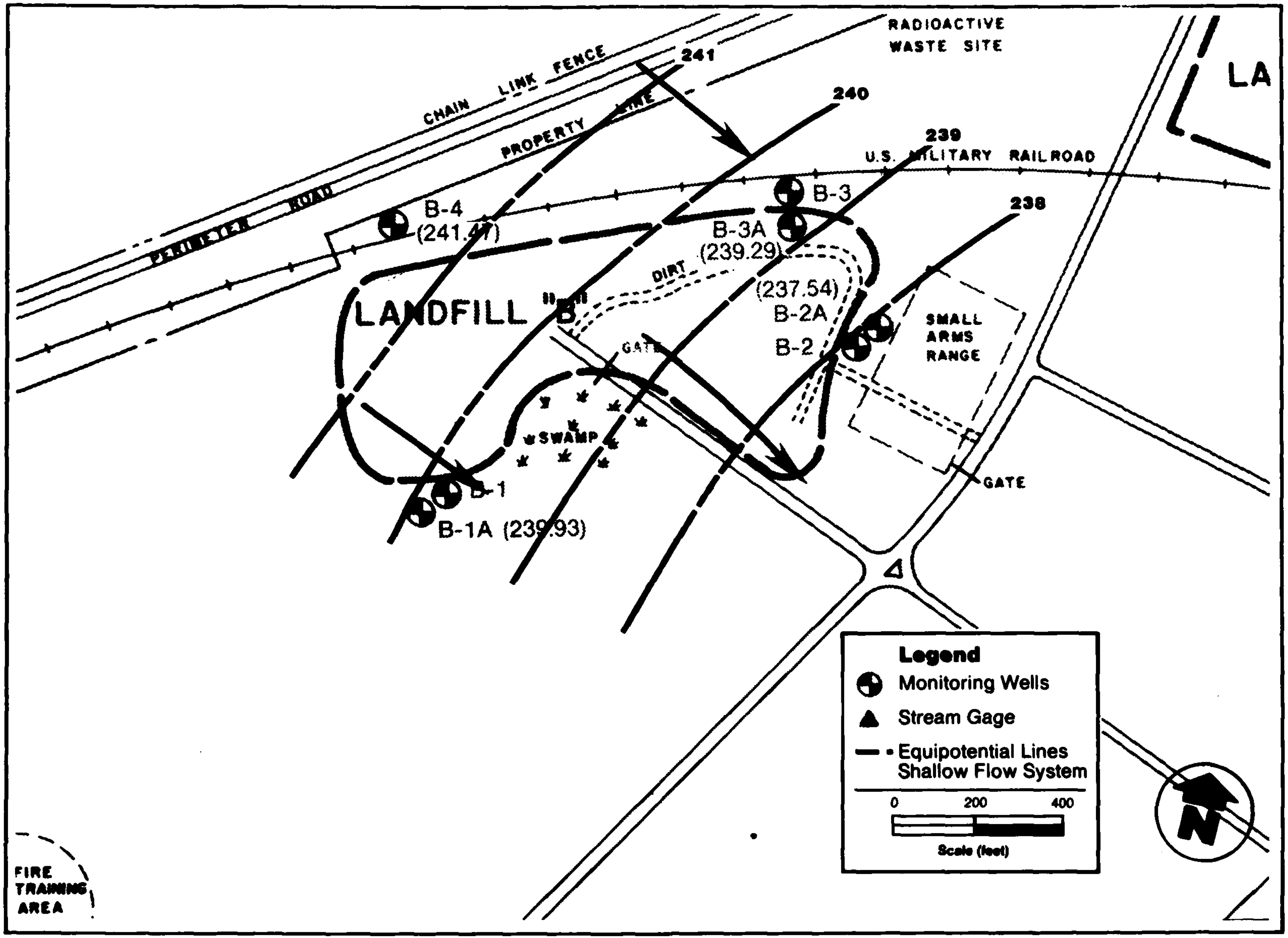


FIGURE 4-2 SHALLOW WATER TABLE MAP FOR LANDFILL B

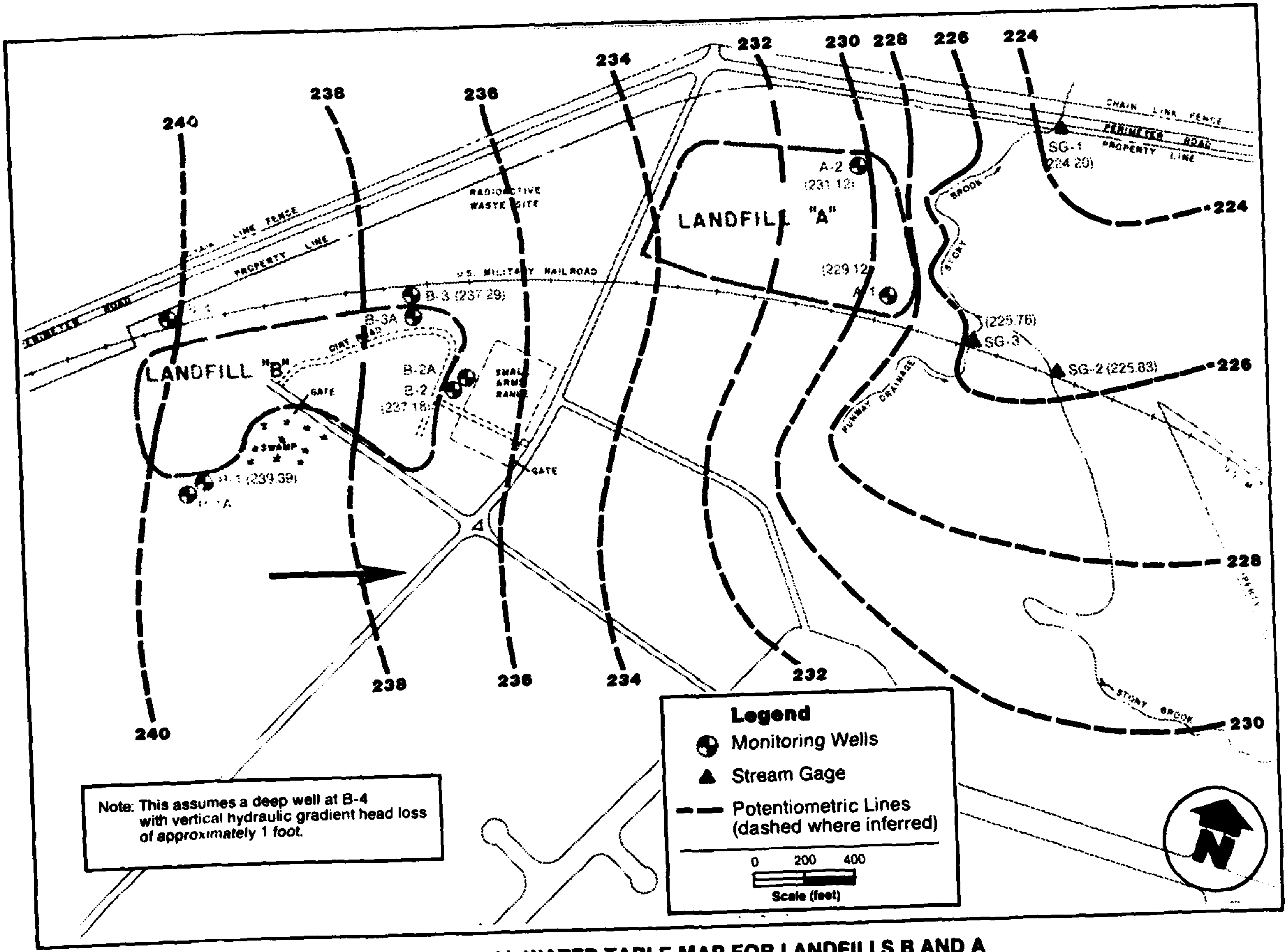


FIGURE 4-3 GENERAL WATER TABLE MAP FOR LANDFILLS B AND A

Note: This assumes a deep well at B-4 with vertical hydraulic gradient head loss of approximately 1 foot.

the deeper adjacent couplet wells indicating a downward or recharge flow component. Head losses between 0.3 and 2.0 feet have been recorded to date. The maximum head loss of 2.0 feet was recorded between wells B-3 and B-3A northeast and downgradient of Landfill B. This head loss translates to a gradient of greater than 0.04, according to the relationship:

$$i = \frac{\Delta h}{L}$$

i = hydraulic gradient
h = change in head (2 feet)
L = distance across which head loss occurs (~47 feet)

This substantial vertically downward gradient (approximately 4 times the local horizontal gradient) in the vicinity of wells B-3 and -3A is likely the result of the effects of mounding within the more permeable fill mass. This ratio is atypical of laminar flow conditions in unconsolidated sediment aquifers. The strong downward component of flow here is capable of driving landfill derived constituents to deeper flow zones.

4.2.2 Groundwater Flow - Landfill A

Groundwater elevations measured in Wells A-1 and A-2 and surface water elevations recorded at staff gage stations SG-1, SG-2, and SG-3 in November 1983 indicate a predominantly easterly flow from Landfill A to Stony Brook. Figure 4-3 illustrates the probable flow based on data obtained to date, and shows that groundwater occurring immediately beneath the landfill is capable of recharging directly to Stony Brook. Between the perimeter of the landfill and Stony Brook the hydraulic gradient may be between 0.02 and 0.03. However, the overall hydraulic gradient through the landfill proper is probably less than 0.01 based on comparisons with water level measurements from Landfill B (see Figure 4-2).

Boring A-1 encountered fill debris to a depth of approximately 7 feet. Saturated conditions were encountered approximately 6 feet below land surface. Thus, at least a portion of Landfill A has been shown to intersect the unconfined, shallow water table aquifer.

4.2.3 Groundwater Flow at IWTP

Since only one well was installed adjacent to the skim waste storage tank, information on localized groundwater flow is unavailable for this area. Water table elevations in IW-1 were approximately 227 feet MSL. The hydrostatic heads recorded from IW-1 are lower than those recorded at all other wells around Landfills A and B. This finding has potentially important implications concerning the analysis of groundwater flow from the Base in general and the suspect sites in particular, since it could indicate a general, regional groundwater flow trend to the south at WAFB.

4.2.4 Groundwater Flow at WAFB

Generally groundwater tables follow a subdued image of surface topography; flow lines trend toward major groundwater discharge zones. However, in certain areas such as glaciated terrains, this condition does not always prevail. In the case of WAFB the regional trend of the groundwater flow system is predicted to be to the south and southwest toward the major discharge points of the Chicopee and Connecticut Rivers. However, the northern portion of WAFB surficially discharges northward to Stony Brook, which continues to flow northerly for about seven miles prior to discharging to the Connecticut River. The location of a groundwater divide between the north flow component and southwestward predicted regional pathway cannot be defined with available reference points. Even with numerous other shallow monitor points throughout WAFB, the task of determining actual groundwater divides would be complex, if not impractical. Therefore, water quality results from perimeter monitoring wells become critically important in defining true flow directions on both a localized and regional (WAFB property) scale.

4.2.5 Groundwater Flow Rate Calculations

Hydraulic conductivities were obtained from *in situ* slug and recovery tests on partially and fully penetrating wells at Landfills B and A. Data was reduced and computed using a Tektronix Model 4054 Computer. The model was used based on hydraulic conductivity formulations derived by Bouwer and Rice (1976). Figure 4-4 illustrates a typical computer-generated plot. Other plots are included in Appendix H.

Hydraulic conductivities ranged between 4.9×10^{-6} and 1.9×10^{-4} feet/second or roughly between 1.50 and 6,000 feet per year (ft/yr) under a gradient of unity (1). Four of the six computations, based upon tests in materials most typical of the deltaic deposits, ranged between 200-400 feet per year.

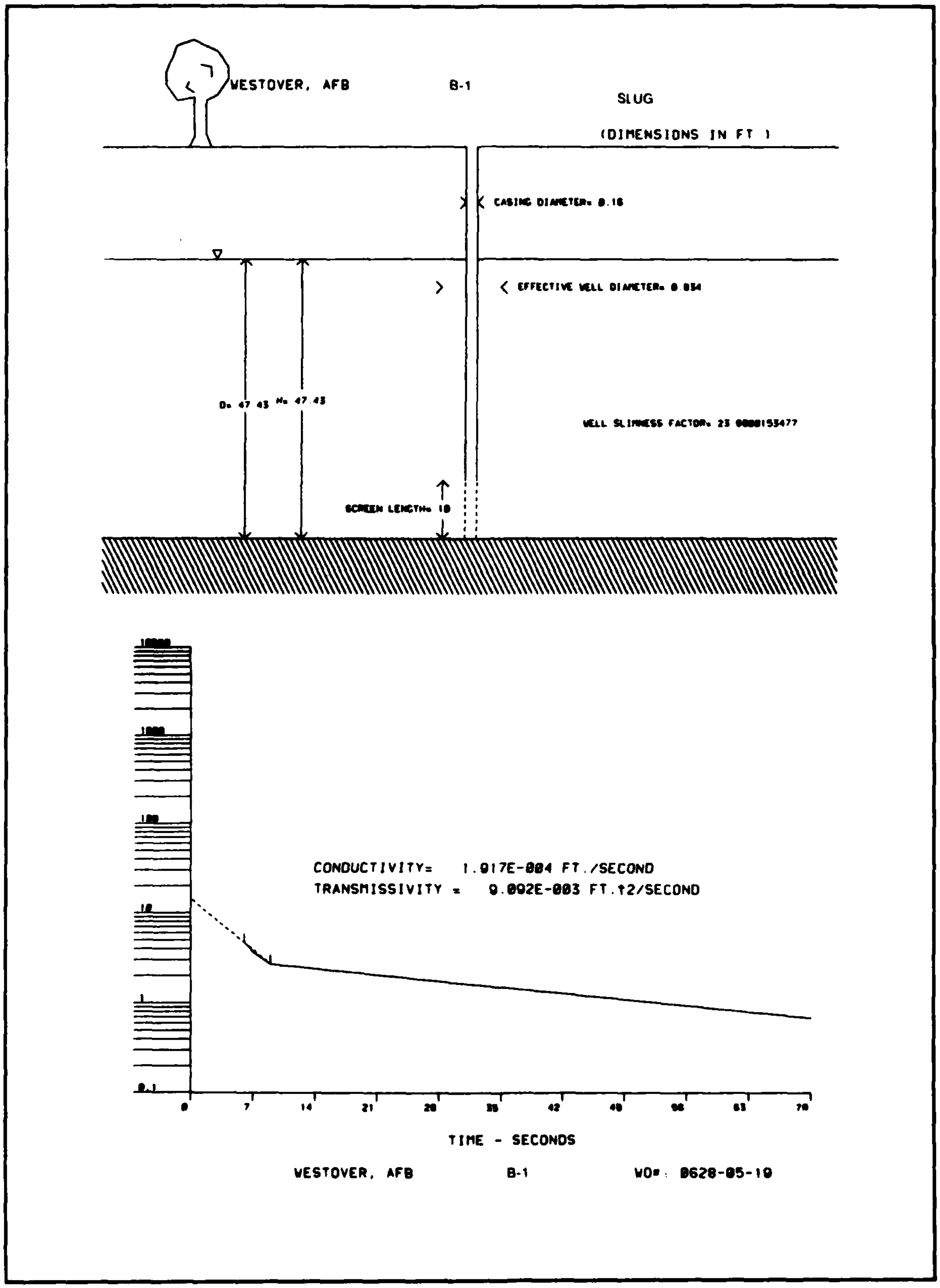


FIGURE 4-4 TYPICAL COMPUTER GENERATED SLUG TEST CURVE

The average seepage velocity is given by the equation:

$$Vs = \frac{Ki}{N_e}$$

Where

Vs = seepage flow velocity (L/T)
K = average hydraulic conductivity (L/T)
i = hydraulic gradient (dimensionless)
N_e = effective porosity (dimensionless)

Assuming an effective N_e of 0.3, and using an i of 0.005 (measured from Figure 4-3) and a K of 1,500 ft/yr (the most conservative worst case senario), the estimated flow velocity through the aquifer is as little as 25 ft/yr. This extremely low computed velocity is entirely a function of the lack of driving gradient within the areas monitored. Groundwater flow velocities of much less than one foot per day are probably the rule rather than the exception.

Computations concerning time travel of groundwater quality constituents to installation boundaries from Landfills B and A are highly speculative, especially where flow conditions are not definitive. A strong northerly flow component from Landfills B and A could result in groundwater from those sites reaching installation boundaries in as little as two years.

Groundwater flows from Landfills B and A which discharge in a southerly direction could take decades to reach installation boundaries. Shallow stormwater systems can intercept the upper zones of saturation and convey contaminants off base almost immediately. If groundwater quality at the perimeters of Landfills B and A are largely non-impacted, the probability will be that conditions will remain static based on the hydrogeologic conditions noted to date.

In addition to the seepage velocity data generated from the hydraulic conductivity testing, a preliminary analysis of the potential flow volume through the aquifer was also computed. This information is relevent where estimates of the total volume of contaminant migration needs to be estimated. A brief discussion of the nature of the underlying aquifer is presented below.

Groundwater discharge (Q) is given by the following equation:

$$Q = KiA$$

K = 6,000 ft/yr - highest recorded hydraulic conductivity
i = average gradient 0.005 in vicinity of B-1 where K = 6,000 ft/yr ±
A = one square foot cross section of aquifer

This would compute to approximately 0.60 gallons per day per square foot of aquifer. Using an estimated cross sectional area of 48,000 feet (800 foot width across landfill by 60 foot average saturated thickness), a computation of approximately 30,000 gallons per day (GPD) of flow-through towards Stony Brook is calculated to occur beneath landfill B. Since this is based on the highest hydraulic conductivity measurement, it represents a conservative worst-case value.

The interpretation of available flow information generated to date indicates WAFB is underlain by shallow water table conditions under an extremely low gradient. Potential flow pathways in this regime can be multi-directional based on natural lithologic variations and manmade structures. The key to improving definition of groundwater flow determinations around Landfills A and B is through an analysis of water quality variations in existing and, possibly, supplemental monitoring wells. The following discussion presents the results of the water quality sampling conducted for the Phase II Study.

4.3 WATER QUALITY RESULTS - GENERAL

The principal objective of the Phase II Confirmation Study was to determine whether past hazardous waste operations or disposal practices had resulted in environmental degradation. The analytical results of the Phase II study represent a single round of sampling at selected surface water quality stations and newly installed monitoring wells. The conclusions drawn from this information should be evaluated with this understanding.

Groundwater quality results are in Table 4-1; sampling results of Stony Brook are presented in Table 4-2. Appendix I includes all analytical results from monitoring the landfills and the IWTP. Appendix J contains a complete listing of Federal and State drinking water and human health standards, criteria and guidelines applicable in the State of Massachusetts.

Table 4-1

GROUND-WATER QUALITY DATA - WESTOVER AIR FORCE BASE

Analyte	Unit	B-1	B-1A	B-2	B-2A	B-3	B-3A	B-4	A-1	A-2
COD	mg/l	7.5	21.0	978.0	108.0	10.0	30.0	15.0	<5.0	7.5
TOC	mg/l	<1.0	<1.0	215.0	30.1	11.5	15.0	<1.0	76.5	<1.0
Oil & Grease	mg/l	1.50	1.20	11.70	1.10	1.80	0.49	<0.10	0.17	0.16
Phenol	mg/l	<0.005	<0.005	1.0	0.070	<0.005	0.018	<0.005	<0.005	<0.005
Iron	mg/l	0.53	0.47	483.00	219.00	30.00	15.70	<0.10	34.00	<0.10
Lead	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chloride	mg/l	2.9	4.0	52.5	58.7	2.7	<1.0	<1.0	<1.0	<1.0
Sulfate	mg/l	8.2	58.8	3.5	3.5	23.0	12.3	5.5	27.0	<1.0
Methylene Chloride	µg/l	<0.25	<0.25	16.00	<0.25	<0.25	<0.25	4.70	<0.25	<0.25
1,2-dichloroethane	µg/l	2.60	2.10	9.10	<0.03	2.00	<0.03	2.60	1.80	3.20
Chloroform	µg/l	0.4	<0.05	34.30	<0.05	<0.05	<0.05	<0.05	<0.05	4.50
Chloroethane	µg/l	<0.52	<0.52	2.40	<0.52	<0.52	<0.52	<0.52	<0.52	<0.52
(Trans) 1,2-dichloroethylene	µg/l	<0.10	<0.10	101.00	<0.10	<0.10	<0.10	<0.10	0.50	<0.10
1,1,1-trichloroethane	µg/l	<0.03	<0.03	9.20	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Tetrachloroethylene	µg/l	<0.03	<0.03	2.50	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Monochlorobenzene	µg/l	<0.25	<0.25	1.70	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
1,1-dichloroethane	µg/l	<0.07	<0.07	34.60	<0.07	<0.07	<0.07	<0.07	1.80	<0.07
Trichloroethylene	µg/l	<0.12	<0.12	26.10	<0.12	<0.12	<0.12	0.38	0.37	<0.12
1,1-dichloroethylene	µg/l	<0.13	<0.13	1.90	<0.13	<0.13	<0.13	<0.13	1.20	<0.13
0-dichlorobenzene	µg/l	<0.15	<0.15	7.50	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Unidentified Peaks	µg/l	0	0	6	0	0	0	0	1	0

TABLE 4-2

SURFACE WATER QUALITY DATA, WESTOVER AFB

STREAM SAMPLING SITES

Analyte	*Units*	*SG-1*	*SG-2*	*SG-3*
COD	mg/l	30.0	6.0	< 5.0
TOC	mg/l	11.5	6.5	< 1.0
Oil & Grease	mg/l	0.36	< 0.10	2.50
Phenol	mg/l	< 0.001	< 0.001	< 0.001
Iron	mg/l	< 0.1	< 0.1	1.48
Lead	mg/l	< 0.01	< 0.01	< 0.01
Chloride	mg/l	4.4	3.7	3.7
Sulfate	mg/l	32.4	35.8	5.8
1,2-*Dichloroethane*	mg/l	2.10	2.00	7.70
1,1-Dichloroethylene	mg/l	2.10	< 0.13	0.30
(Trans)1,2-Dichloroethylene	mg/l	0.30	< 0.10	3.00
Trichloroethylene	mg/l	< 0.12	< 0.12	0.30
1,1,1-Trichloroethane	mg/l	< 0.03	< 0.03	3.00
Tetrachloroethylene	mg/l	< 0.03	< 0.03	0.50
Unidentified Peaks	mg/l	0	1	1

On November 28, 1980, the US Environmental Protection Agency issued criteria for 64 toxic pollutants or pollutant categories which could be found in surface waters. The criteria established recommended maximum concentrations for acute and chronic exposure to these pollutants for both human and aquatic life. The derivation of these exposure values was based upon cancer risk, toxic properties, and organoleptic properties.

The limits set for cancer risk are not based upon a "safe" level for carcinogens in water. The criteria state, that for maximum protection of human health, the concentration should be zero. However, where this cannot be achieved, a range of concentrations corresponding to incremental cancer risks of from one in ten million to one in one hundred thousand was presented (10^{-7} to 10^{-5}).

Toxic limits were established at levels for which no adverse effects would be produced.

These are the health related limits which have been used in this report to evaluate potential impacts. It should be noted that the cancer risk column is based upon one cancer case in one million, (10^{-6}). EPA's evaluation criteria under CERCLA (Annex XIII) *for selecting contaminant* levels to protect public health call for the remedial action to "attain levels of contamination which represent an incremental risk of contracting cancer between 10^{-5} and 10^{-6}." The 10^{-6} value was used to achieve the maximum protection to the public.

In addition to the cancer risk assessment criteria, the US EPA Office of Drinking Water provides advice on health effects upon request, concerning unregulated contaminants found in drinking water supplies. This information suggests the level of a contaminant in drinking water at which adverse health effects would not be anticipated with a margin of safety; it is called a SNARL (Suggested No Adverse Response Level). Normally values are provided for one-day, 10-day and longer-term exposure periods where available data exists. A SNARL does not condone the presence of a contaminant in drinking water, but rather provides useful information to assist in the setting of control priorities in cases when they have been found.

SNARLs are not legally enforceable standards; they are not issued as an official regulation, and they may or may not lead ultimately to the issuance of a national standard or Maximum Contamination Level (MCL). The latter must take into account occurrence and relative source contribution factors, in addition to health effects. It is quite conceivable that the concentration set for SNARL purposes might differ from an eventual MCL. The SNARLs may also change as additional information becomes available. In short SNARLs are offered as advice to assist those that are dealing with specific contamination situations to protect public health.

The above information concerning SNARLs was taken directly from guidance documentation authored by the EPA and made available to WESTON. The SNARLs levels for various compounds were also used in evaluating the results of ground and surface water sampling.

4.3.1 Water Quality Findings - Landfill B

Of the seven wells that were installed at four locations around the perimeter of Landfill B, indicator parameters of contamination derived from landfill leachate (Table 1-2) were apparent in wells B-2 and B-2A located in a downgradient position from the fill site. These two wells contained much higher levels of COD, TOC, oil and grease, phenol, iron, and chloride than the other perimeter wells. The indicator parameters from these two wells, taken collectively, represent contamination derived from former landfill operations.

As depicted on Table 4-3, all other wells at Landfill B exceed certain standards for the criteria categories listed, with respect to phenol, oil and grease, and iron. Although the remaining perimeter wells around Landfill B exhibited minor indications of leachate derived contamination, the collective results of the indicator parameters did not suggest significant groundwater degradation in the areas monitored.

The volatile organic results of analysis from Landfill B (Table 4-1) indicate that downgradient deep well B-2 is contaminated with hazardous substances. No volatile organics contamination was detected in shallow wells B-2A and B-3A and only trace quantities of organic contamination were noted in B-1, B-1A, B-3 and B-4. The presence of these compounds in up-gradient wells B-1, B-1A, and B-4 is most likely caused by radial flow induced by mounding of groundwater within the landfill.

Table 4-4 illustrates the various criteria guidelines for the organic compounds detected and identifies those wells which exceeded the guidance criteria. The general absence of elevated volatile compounds and leachate indicator para-

TABLE 4-3

COMPARISON OF LEACHATE INDICATOR PARAMETERS WITH DRINKING WATER STANDARDS

Parameter mg/l unless noted	Drinking Water Standards Massachusetts & Federal	Quality Criteria for Water	Monitoring Points Exceeding Standard
COD	-	-	-
TOC	-	-	-
Oil & Grease	-	.01 (1)	B-1,B-1A,B-2,B-2A, B-3,B-3A,B-4,A-1,A-2, IW-1,SG-1,SG-2,SG-3
Phenol	-	0.001(2)	B-2,B-2A,B-3(4)
Iron	0.30	0.30 (2)	B-1,B-1A,B-2,B-2A, B-3,B-3A,A-1,SG-3
Lead	0.05(3)	0.05 (3)	None
Chloride	250. (2)	250. (2)	None
Sulfate	250. (2)	250. (2)	None

(1) Virtually free of Oil & Grease for domestic water supply
(2) Welfare (Taste & Odor)
(3) Health Related
(4) Health Related Standard: 3.5 mg/l (Water Quality Criteria Documents - Nov., 1980)

Table 4-4

COMPARISON OF HAZARDOUS WASTE ANALYTES WITH WATER QUALITY GUIDANCE CRITERIA

Analyte (in µg/l)	Water Quality Criteria Documents 10-6 Cancer Risk	Toxic Properties	Monitoring Points Exceeding Criteria	SNARLS Lifetime Exposure	Monitoring Points Exceeding SNARLS Criteria
Methylene Chloride	0.19	--	B-2, B-4	150	None
1,2-dichloroethane	0.94	--	B-1, B-1A, B-2, B-3, B-4, A-1, A-2	--	--
Chloroform	0.19	--	B-1, B-2, A-2	--	--
1,2-dichloroethylene	--	--	--	270[1]	None
1,1,1-trichloroethane	--	--	--	1000	None
Tetrachloroethylene	0.80	--	B-2	40	None
Trichloroethylene	2.7	--	B-2	75	None
0-dichlorobenzene	--	400	--	--	--
Chloroethane	1.0	--	B-2	--	--
Monochlorobenzene	--	--	--	--	--
1,1-dichloroethane	1.0	--	B-2, A-1	--	--
1,1-dichooroethylene	0.033	--	SG-1, SG-3, B-2, A-1	70	None

---

[1] 10-day exposure

meters in B-3, B-3A and B-4 on the north perimeter of Landfill B is an especially important finding with respect to concerns of potential contaminant migration to nearby installation boundaries.

4.3.2 Water Quality Findings - Landfill A

Two wells were installed to monitor Landfill A in conjunction with surface water monitoring at three stream gage stations (Figure 3-2). The results (Tables 4-1 and 4-2) demonstrate low level volatile organic impacts to ground and surface water quality in the vicinity of Landfill A. Table 4-4 shows which organic analyte concentrations exceed guidance criteria. No definitive group of indicator parameters of Landfill derived contaminants were noted in A-1 and A-2. Therefore Landfill A is not concluded to be a source of leachate generation based on data obtained to date.

From the previous flow analysis, both ground and surface waters discharge towards A-1, A-2 and Stony Brook from Landfill B and the northern portions of WAFB. The organic contamination in A-1, A-2 and Stony Brook cannot be pinpointed as to source with available data, but it could represent flow under Landfill A from Landfill B, or it could represent contaminants from either the old north or the current fire training areas nearby.

Elevated levels of TOC and total iron (Fe) were monitored in well A-1. However, a corresponding increase in COD and chloride, typical of landfill leachate, was not noted. Exploratory boring A-1 penetrated swampy deposits containing peat. The elevated TOC and iron analytes are probably attributable to the natural geologic environment in which well A-1 was constructed (see boring logs, Appendix D).

4.3.3 Water Quality Results - IWTP

Using oil and grease as an indicator parameter, the skim waste tank at the IWTP and adjacent well IW-1 were monitored for evaluating the integrity of the tank. Comparative concentrations of oil and grease are shown in Table 4-5.

TABLE 4-5

IWTP SKIM WASTE TANK MONITORING RESULTS

Location	Oil and Grease Concentrations (mg/l)
IWTP-Skim Waste Tank	11,131
Monitor Well IW-1	0.16

The oil and grease concentration in well IW-1 suggests that the skim waste storage tank is intact based upon relative oil and grease concentrations monitored at the above points.

While some environmental scientists consider that oil and grease concentrations of less than one mg/l represent background conditions, no literature sources have been found to document this assertion. WESTON considers that since the concentration of oil and grese in Well IW-1 is 16 times higher than the esthetic criterion of 0.01 mg/l, shown in Table 4-3, further limited water quality testing should be undertaken to establish whether or not this oil and grease reading is truly background, as opposed to being related to fuel products in the storage tank.

4.4 SIGNIFICANCE OF FINDINGS

Based on the Phase II Confirmation Study, the following key conclusions have been drawn:

1. Groundwater occurs under shallow, water table conditions in and around the three sites investigated. Groundwater gradients (lateral) typically average about 0.005, reflecting the very low topographic relief at WAFB. Consequently, the hydraulic driving force for lateral contaminant dispersion is very small. Vertically downward hydraulic gradients greater than 0.01 were measured at all three couplet wells. Contaminants, if present, can be expected to disperse into deeper flow systems, especially at Landfill B where mounding of groundwater is expected to be significant.

2. Localized groundwater flow from Landfills B and A is generally in an easterly direction; groundwater from the sites can discharge into the Stony Brook drainage basin which flows to the north from the

north boundary of WAFB. Whether the regional flow direction of groundwater follows the deranged surface drainage pattern is, at best, uncertain. Therefore, the direction of contaminant dispersal in groundwater cannot be predicted with confidence.

3. Of the nine monitoring wells constructed around the two landfill sites, only deep monitor well B-2 at Landfill B revealed what could be considered elevated concentrations of landfill derived contamination. This finding is important because it indicates, preliminarily, that neither landfill appears to be contributing to a major groundwater quality problem that can adversely impact off-site groundwater resources.

4. The present extent of contamination cannot be mapped because water quality results in many of the landfill perimeter wells was, in conclusion, quite good. The scope of the groundwater investigation and available monitor well array could not provide sufficient data to develop an isopleth map of a plume of contamination at either landfill.

5. For the landfill indicator analytes (Table 1-2) only lead (Pb) has a health related limit. Any lead which may have been present in the monitor wells and surface water samples was present well below the 0.05 mg/l health related limit.

6. Table 4-4 presents the criteria for priority pollutant organic analytes and the corresponding wells and surface waters exceeding the guidance criteria from various source references. No State or Federally adopted drinking water standards apply for the compounds detected, although an unpublished Federal policy "action level" for trichloroethylene of 4.5 ppb, based on an NAS cancer risk study, (See Appendix J) was exceeded in Well B-2. The Well B-2 sample results indicate moderately elevated levels of several organic compounds exceeding the 1 x 10^{-6} lifetime ingestion cancer risk criteria listed in Water Quality Criteria Documents (28 November 1980).

7. The organic analytes detected in the stream samples demonstrate that contamination from WAFB crosses installation boundaries through surface water pathways. The 1,1-dichloroethylene level of 2.1 ug/l

at surface water staff gage SG-1 exceeds the 0.033 ug/l 1×10^{-6} incremental Cancer Risk for lifetime ingestion of water and aquatic organisms contaminated with dichloroethylene. The source or sources of organic contamination in Stony Brook cannot be verified by the sampling conducted to date. Besides discharge from Landfills B and A, both the old, North Fire Training Area and the Current Fire Training Area (Phase I Sites No.1 5 and 8, respectively, on Table 1-1 and Figure 1-2) are potential sources for solvents crossing the Base boundary to the north in Stony Brook.

SECTION 5

ALTERNATIVE MEASURES

5.1 GENERAL

The principal goal of this Phase II Confirmation Study was to determine whether or not environmental degradation was occurring as a result of past practices of waste disposal at WAFB. The work scope directed that an initial round of samples be collected. The basis for many of the above conclusions is, therefore, predicated on this set of analyses. That only one well at Landfill B contained elevated levels of halogenated organics is an important preliminary finding which requires quantification. The presence of halogenated organics in the Stony Brook surface water samples also requires further evaluation.

Concept engineering evaluation of remedial action alternatives was not a part of this scope of work. The alternative measures discussed below focus mainly upon problem definition aspects of environmental contamination detected at WAFB. The alternative actions to be taken at this point generally fall into the following categories:

Actions	Sites
1. Quantification Stage Monitoring at Existing Monitoring Points	All Sites
2. Alternate Analysis	IWTP Storage Tank
3. Expanding Groundwater Monitoring Network	Landfill B
4. Expanding Surface Water Monitoring Points	Landfill A
5. Interim Quarterly Monitoring	All Sites
6. Preliminary On-site Analysis	Landfill B
7. Preliminary Concept Engineering Evaluation	Landfill B
8. Off-site Resource Analyses/Monitoring	All Sites

These alternate measures are generally in the order of prior-

5.1.1 Landfill B - Alternative Measures

All wells at Landfill B should be resampled and analyzed according to the original analytical protocol. Depending on the results of analysis, a decision must be made whether or not to expand the groundwater monitoring network beyond the immediate perimeter of Landfill B. If results are duplicated, an expanded monitoring network beyond Landfill B would be recommended in conjunction with a revised analytical protocol focusing on a limited suite of key indicator parameters and analytes of public health concern. The revised analytical protocol would constitute the Interim Monitoring Plan for Landfill B which would be implemented until such time that a determination was made on the closure status of the landfill.

If an expanded monitoring network were undertaken, on-site drilling within Landfill B would be warranted to establish the relationship of fill deposits to the water table. This information would have an important bearing on the viability of future closure actions should they be determined to be necessary.

5.1.2 Landfill A - Alternative Measures

The wells and surface waters at Landfill A need to be resampled. Analytical results of groundwater samples at A-1 and A-2 are not, in our view, a cause for concern which would lead to a quantification study. If the monitoring network is expanded beyond Landfill B, it would be appropriate to position a fully penetrating well north of Landfill A at that time.

Surface water sampling points should be expanded for the second round of analysis to attempt to isolate sources of halogenated organics to Stony Brook. This will form the rationale for an Interim Monitoring Plan, if necessary.

5.1.3 IWTP Storage Tank - Alternative Measures

The integrity of the skim waste storage tank was not found suspect based on the single sample collected from IW-1 for oil and grease. The concentration of oil and grease in the storage tank was, in fact, substantially different than the level noted in well IW-1. A resampling of this well and the storage tank is warranted for confirmation of a non-impact conclusion.

An alternate supporting analysis for organics should be considered to resolve any concerns about the discharge of hazardous substances from this tank.

5.2 SUMMARY

Supplementary actions concerning water resource analysis and monitoring are not believed to be necessary based on the data obtained to date. They are included in the alternative measure category in the event that substantial migration of contaminants is detected in subsequent monitoring. Similarly, the need for Preliminary Concept Engineering Evaluation of remedial actions has not yet been documented. Such an evaluation has been included in the alternatives list in the event that such a need is demonstrated as a result of Quantification Stage activities. Section 6 contains specific recommendations for future actions.

SECTION 6

RECOMMENDATIONS

6.1 GENERAL

The findings of the Phase II Study at three sites on WAFB indicate the need for follow-on work. This work includes the following:

1. General verification of the initial round of water quality sampling and analysis.

2. An expanded monitoring program developed collectively for Landfills B and A with an emphasis on determining the nature and extent of contamination by priority pollutants.

The recommended actions, discussed by site, are intended to establish the data base for evaluation of what, if any, remedial actions might be necessary for each given site. The recommendations are presented in prioritized order.

6.1.1 Landfill B - Recommendations

The following supplemental work is recommended at Landfill B based on the results obtained to-date.

1. All existing monitoring points should be resampled for verification of the initial sampling results. The analytical protocol for the second round samples should be the same as the first round (Table 1-2). In addition, a full priority pollutant analysis should be performed on groundwaters from monitor well B-2. This should include volatiles, acid and base/neutral extractables, herbicides and pesticides, priority pollutant metals, phenol and cyanide.

   The rationale for the additional analysis from the most contaminated well is to establish, with reasonable certainty, the chemical parameters of concern. The resampling and review of results should precede any subsequent on-site work.

2. Additional monitoring to establish the extent of contamination and groundwater quality at the installation boundary is recommended following the verifi-

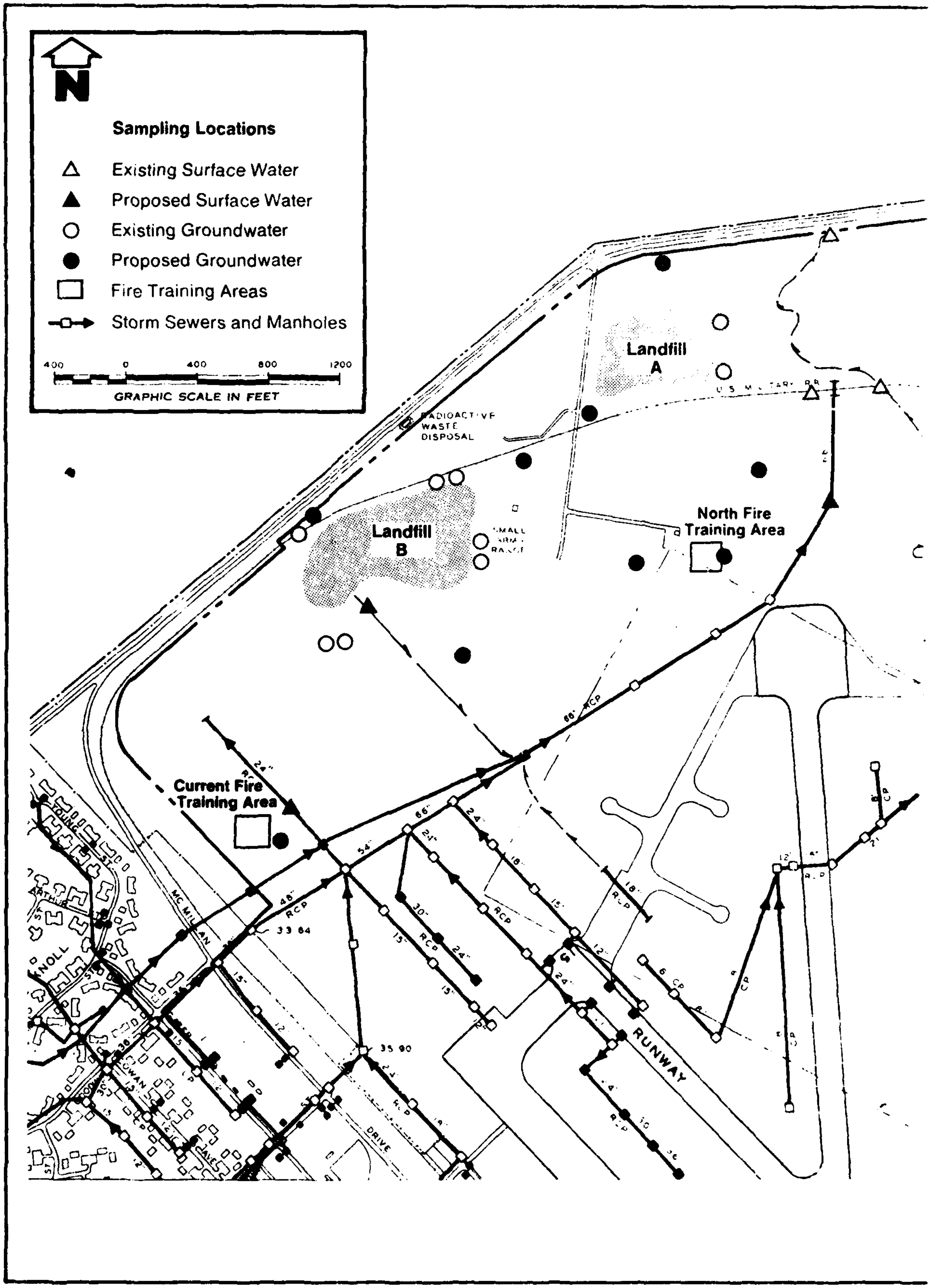
cation sampling. Until the verification sampling is complete, the precise number and locations of wells is indefinite. Figure 6-1 illustrates seven candidate sites for well construction. These locations will enable quantifying the extent of contamination between and downgradient from both Landfills.

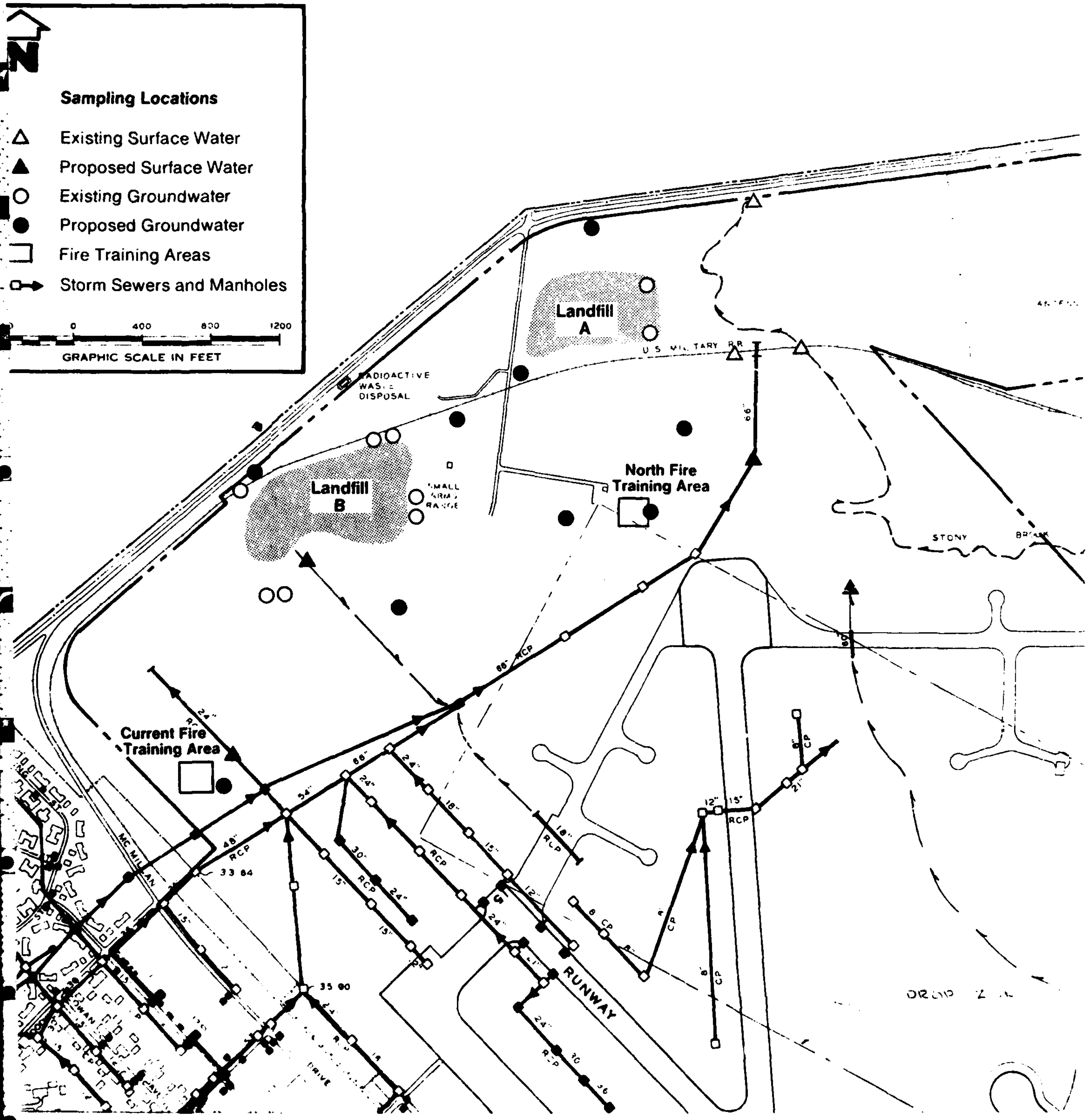
Seven additional monitor wells are contemplated including a deep couplet at the B-4 location. All seven wells should penetrate to the lacustrine deposits and be screened throughout to permit representative analysis of groundwater quality.

In addition to the seven projected monitor wells, two exploratory borings should be performed through Landfill B to characterize the extent of filling and the relationship of fill deposits with the seasonally high water table. The exploratory borings should penetrate the top several feet of the zone of saturation. Piezometers should be set within each of these borings. It is envisioned that the screen length would range between three and five feet and be set in saturated deposits immediately below the refuse/soil interface. The remainder of the hole would be tremie grouted to eliminate preferential flow of contaminants through the well bore.

In situ piezometers within the fill are necessary to determine the practicality of various remedial options which might be necessary in the future. The Massachusetts Department of Environmental Quality Engineering (DEQE) should be consulted prior to drilling through waste deposits in order to ensure regulatory compliance on this matter.

3. Following the supplemental well construction, an Interim Quarterly Monitoring Program is recommended. The monitoring program is identified as an "Interim" program until determinations are made regarding site(s) status. Among the concerns to be resolved is the issue of whether or not Landfill B will be categorized as a "hazardous waste" site from a regulatory perspective. This characterization has broad implications regarding future monitoring and closure activities. For hazardous waste sites the DEQE has adopted


N
Sampling Locations
△ Existing Surface Water
▲ Proposed Surface Water
○ Existing Groundwater
● Proposed Groundwater
☐ Fire Training Areas
Storm Sewers and Manholes
400
0
400
800
1200
GRAPHIC SCALE IN FEET
Landfill A
Landfill B
RADIOACTIVE WASTE DISPOSAL
SMALL ARMS RANGE
North Fire Training Area
Current Fire Training Area
U.S. MILITARY R.R.
66" RCP
54"
48" RCP
24" RCP
18" RCP
33 64
35 90
MC MILLAN DRIVE
RUNWAY
KNOLL ST
ARTHUR ST
YOUNG ST


N
Sampling Locations
△ Existing Surface Water
▲ Proposed Surface Water
○ Existing Groundwater
● Proposed Groundwater
Fire Training Areas
Storm Sewers and Manholes
0 400 800 1200
GRAPHIC SCALE IN FEET
Landfill A
Landfill B
RADIOACTIVE WASTE DISPOSAL
U S MILITARY RR
SMALL ARMS RANGE
North Fire Training Area
Current Fire Training Area
STONY BROOK
66"
66" RCP
24" RCP
54"
48" RCP
33 64
35 90
30" RCP
15"
18"
12"
21"
18" RCP
8 CP
6" CP
12" 15" RCP
RUNWAY
MC MILLAN
DRIVE
DROP ZONE

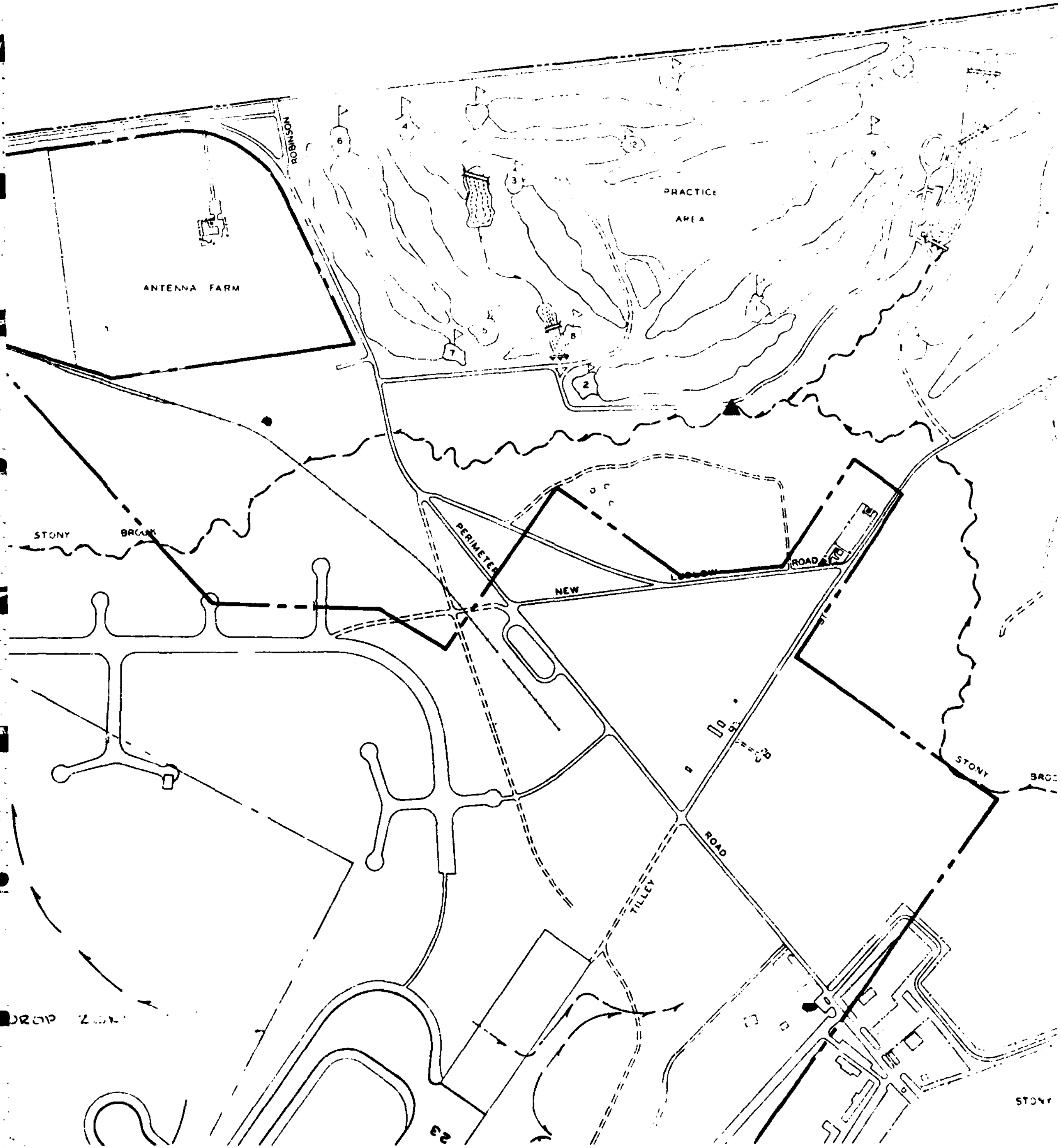


FIGURE 6-1 SITES FOR RECOMMENDED ADDITIONAL GROUNDWATER MONITOR WELL CONSTRUCTION AND SURFACE WATER SAMPLING

monitoring requirements in accordance with RCRA, as summarized in Appendix J.

The presently proposed quarterly monitoring plan is based on the findings to date. It most probably will be revised in terms of analytes and monitoring stations. The presently recommended analytical protocol consists of the following parameters:

Phenol
Iron (dissolved)
Chloride
NH_4-N & NO_3-N
Boron

pH
Specific Conductance
Volatile Organic Compounds (Methods 601 and 602)
Quantification of up to 3 as yet undetermined analytes from the Priority Pollutant Scan

The existing wells at Landfills A and B are recommended to be incorporated into the Interim Program. Following an initial analysis of the supplemental monitoring wells for the above protocol, a selection of several key monitoring wells can be made for incorporation into the ongoing quarterly monitoring program.

As stated earlier an expanded surface water monitoring plan for the northern portion of WAFB is discussed under "Landfill A - Recommendations."

6.1.2 Landfill A - Recommendations

The following supplemental work at Landfill A is recommended.

1. In conformance with recommendation no. 1 for Landfill B, wells A-1 and A-2 and surface water sampling stations SG-1, SG-2, and SG-3 should be resampled for verification purposes. Sampling should be scheduled in two evolutions, one during a period of seasonal high water table conditions when storm water flow rates are comparatively higher than the November 1983 sampling period, and one during base flow conditions (i.e., no rain for a minimum period of seven days). The analytical protocols should be the same as for the initial sampling round (Table 1-2).

2. The additional well construction advised for Landfill B will include coverage for Landfill A. This collective monitoring system should enable quantification of the nature and distribution of contaminants potentially capable of migrating off-post.

3. An expanded surface water sampling program is recommended to incorporate storm drainage monitoring from Landfill B and other suspect sites (NFTA and CFTA) into the monitoring plan. Figure 6-1 illustrates the probable additional surface water sampling points. These points should be adjusted following additional site reconnaissance work conducted during the scheduled resampling in item 1 above.

The presently recommended protocol for surface water monitoring consists of the following parameters:

- pH
- Specific Conductivity
- Priority Pollutant Volatile Organic Compounds (Methods 602 and 603) with provisions for quantitating up to three unknown peaks.

The expanded quarterly surface water sampling program should be run in conjunction with the Interim Monitoring Program for groundwater.

6.1.3 IWTP Storage Tank - Recommendations

The skim waste storage tank at the IWTP has not been found to be contributing to groundwater quality degradation based on a single oil and grease analysis from well IW-1. On this basis the following limited recommendation is made to verify the Phase II Study results and IR Program objectives:

1. Resampling of the concrete skim waste storage tank and adjacent well IW-1 is recommended to verify the initial findings of the Phase II Study. The analysis should not only include oil and grease but also should include priority pollutant volatile organics according to Method 601 and 602. Benzene and toluene are included in the list of parameters; xylene should be added as an additional constituent. If the results are consistent with the initial findings, then no further investigative work would be recommended at this site.

6.1.4 Other Sites -Recommendations

In Section 4 (Significance of Findings), it was concluded that the surface water sample results could have been impacted by previous waste disposal activities at sites other than Landfills A and B. The North Fire Training Area (NFTA) and the Current Fire Training Area (CFTA) are both within the storm water drainage system discharging to Stony Brook.

Since both areas received HARM Scores higher than 50, limited exploratory drilling and well construction at these sites is recommended to aid in differentiation of significant sources of groundwater contamination.

One well is recommended for each fire training area. This will help to quantify the nature, extent and probable source or sources of contamination in the expanded monitoring program. In considering this recommendation it should also be noted that the "Christmas Tree" Fire Training Area (CTFTA) on the south side of WAFB also received a HARM Score above 50 points. Based on findings at other bases, fire training areas rate particularly high as probable sources of solvent contamination. Therefore, a single well at the CTFTA is advised.

The above recommendations are based on the findings made to date in accordance with the goals of Phase II of the IR Program. Action levels for supplemental work are based on the initial analytical results, and especially those from well B-2 and surface water station SG-1. As additional water quality data from the existing monitoring locations is generated, the supplemental work scope will probably require some revisions.

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APPENDIX A

Acronyms, Definitions, Nomenclature and Units of Measurement

AFB	Air Force Base
AFRES	Air Force Reserve
AGE	Aerospace Ground Equipment
ASTM	American Society for Testing and Materials
Bldg.	Building
CERCLA	Comprehensive Environmental Response Compensation and Liability Act of 1980
cm/s	centimeters per second
COD	Chemical Oxygen Demand
CSG	Combat Support Group
DEQE	Massachusetts Department of Environmental Quality Engineering
DEQPPM	Defense Environmental Quality Program Policy Memorandum
Deranged drainage	A distinctively disordered drainage pattern in a recently glaciated area whose former surface and preglacial drainage has been remodeled and effaced, and in which the new drainage system shows a complete lack of underlying structural and bedrock control. It is characterized by irregular streams that flow into and out of lakes, by only a few short tributaries, and by swampy interstream areas (Gary, McAfee and Wolf, 1974).
DoD	Department of Defense
°C	Degrees Centigrade
°F	Degrees Fahrenheit
ft/min	feet per minute
gpm	gallons per minute
HARM	Hazard Assessment Rating Method
hr	hour
in	inches
IRP	Installation Restoration Program
IWTP	Industrial Wastewater Treatment Plant
MS	Master of Science Degree
MEK	Methylisobutylketone
ug/l	micrograms per liter (equivalent to parts per billion in water)
umho/cm	micromhos per centimeter (units of Specific Conductance)

mg/l	milligrams per liter (equivalent to parts per million in water)
mgd	million gallons per day
MSL	Mean Sea Level Datum
N	North
NDI	Non-Destructive Inspection
No.	Number
O & G	Oil and Grease
OEHL	Occupational and Environmental Health Laboratory
%	percent
P.G.	Registered Professional Geologist
Ph.D.	Doctor of Philosophy Degree
ppb	parts per billion (equivalent to ug/l in water)
ppm	parts per million (equivalent to mg/l in water)
QA/QC	Quality Assurance/Quality Control
RCRA	Resource Conservation and Recovery Act of 1976
SAC	Strategic Air Command
TAW	Tactical Airlift Wing
TCE	trichloroethylene
TOC	Total Organic Carbon
USAF	United States Air Force
USEPA	United States Environmental Protection Agency
WAFB	Westover Air Force Base

APPENDIX B

Technical Scope of Work, Task Order 0019

Installation Restoration Program

Phase IIB Field Evaluation

Westover AFB MA

I. Description of Work

The purpose of this task is to determine if environmental contamination has resulted from waste disposal practices at Westover AFB MA; and to provide estimates of the magnitude and extent of contamination, should contamination be found.

The presurvey report (mailed under separate cover) and Phase I IRP report (mailed under separate cover) incorporate all background and description of the site for this task. To accomplish this investigation, the contractor shall take the following actions:

A. General:

1. Determine the areal extent of each site by reviewing available aerial photos of the base, both historical and the most recent panchromatic and infrared.

2. Locations where surface water or leachate samples are collected shall be marked with a permanent marker, and the location recorded on a project map for the zone.

3. Water sampling shall be accomplished only once at each location.

4. Unless otherwise specified in site specific action, surface water and groundwater samples shall be analyzed for Chemical Oxygen Demand (COD), Total Organic Compounds (TOC), oils and greases using IR Method, Phenol, Volatile Organics (using EPA Methods 601 and 602), Lead, Iron, Chloride and Sulfate. The required limits of detection for the above analyses is given in attachment 1. All water samples 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: Examination of Water and Wastewater, 15th Ed. (1980), pp. 35-42; ASTM, Part 31, pp. 72-82, (1976), Method D-3370; and Methods for Chemical Analysis of Waters and Wastes, EPA Manual 600/4-79-020, pp. xiii to xix (1979).

5. Sample bottles shall be prepared in the laboratory prior to sampling in accordance with EPA 601 and 602 protocol methods for volatile organics. Chain-of-custody records for all samples, field blanks and quality control duplicates will be maintained.

6. Groundwater monitoring wells installed during this effort shall be drilled using Hollow-stem augers, or case and wash techniques for the deep wells. All final well construction shall satisfy all requirements of the U.S. EPA and State of Massachusetts.

Split-spoon samples shall be collected at standard five-foot intervals and at lithologic changes to characterize subsurface stratigraphy and hydrogeologic conditions. The wells shall be constructed of two-inch diameter, Schedule 40 PVC flush joint pipe using threaded fittings. The screened zone in each well will consist of 0.010 inch commercial PVC screen. The annulus of the screened zone will be sand packed with Ottawa sand. The screened and sand packed zone of the shallow wells would extend through the entire saturated thickness encountered in the 20-foot boring. A 10-foot screen shall be set at the bottom of the deep wells. All wells shall be tremie grouted from the top of the gravel pack back to the ground surface with a Bentonite and Portland cement grout mixture. Each well shall be completed with the installation of a black iron protective casing and a locking cap. After construction, the wells will be purged by pumping or bailing until the well bore is purged of suspended solids. Following well construction, the top of well casing elevations will be level surveyed to an accuracy of 0.05 feet and horizontally located to an accuracy of 10 feet. After development, survey and an additional time for water level stabilization, synoptic groundwater level measurements shall be recorded on a project map and specific zone map.

A complete round of water level measurements will be taken prior to any water quality sampling. A minimum of three volumes of standing water from each well will be removed using a bottom-fill stainless steel/teflon bailer or all stainless steel submersible sampling pump. Chemical sampling will be performed with a stainless steel and teflon bailer only.

7. Field data collected at the site shall be plotted and mapped. The nature of contamination and magnitude and potential for contaminant flow to receiving ground waters shall be determined or estimated. Upon completion of the sampling and analysis, the data shall be tabulated in the next R&D status report as specified in Item VI below.

B. In addition to items delineated in A above, conduct the following specific actions at these sites identified on Westover AFB.

1. Site 1, Landfill B

a. Four shallow and three deep monitoring wells shall be constructed around Landfill B. The shallow wells shall average 20 feet in depth and the deep wells will average 65 feet in depth. The deep monitoring wells shall be constructed as shallow-deep couplets, with three of the shallow downgradient wells.

b. Locations of these wells shall be as proposed in Figure 1, Landfill B (Atch 2).

c. One ground water sample shall be collected from each well.

2. Site 2, Landfill A

a. Two monitor wells shall be constructed down gradient from Landfill A, at an average depth of 40 feet.

b. Locations of these wells shall be as proposed in Figure 1, Landfill A (Atch 2).

c. One groundwater sample shall be taken from each well.

d. Due to the close proximity of Landfill A to Stoney Brook, one surface water sample shall be taken at each of the following locations:

- Approximately 250 feet upstream from the landfill
- Adjacent to the landfill
- Approximately 250 feet downstream from the landfill

3. Site 15, POL Storage Tank, Industrial Waste Treatment Plant

a. One shallow monitoring well approximately 20 feet in depth shall be drilled immediately adjacent to the southeast side of the storage tank.

b. One groundwater sample shall be taken from the well.

c. One water sample shall be taken from the storage tank.

d. Water samples at this site are to be analyzed for only oils and grease using IR Method.

E. Well Installation and Cleanup

Well installations shall be cleaned up following the completion of the well. Drill cuttings shall be removed and the general area cleaned.

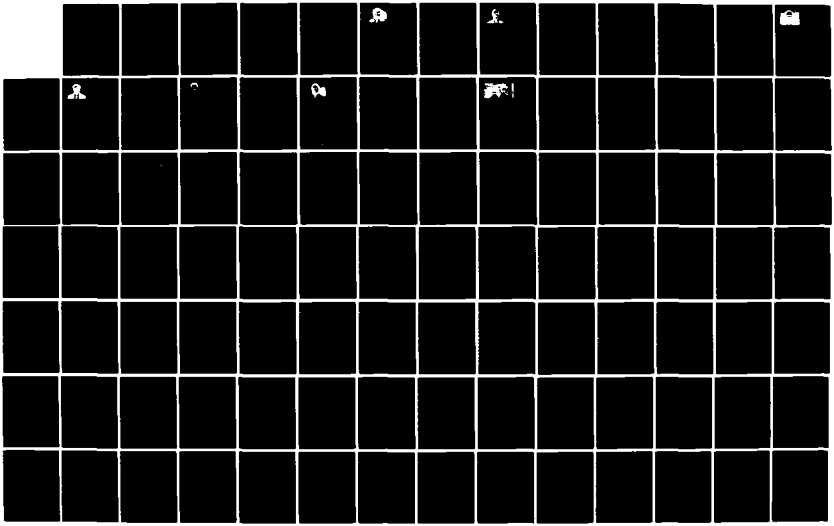
F. Data Review

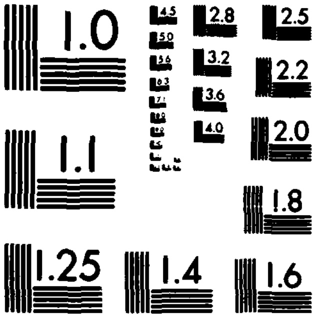
Results of sampling and analysis shall be tabulated and incorported in the monthly R&D status report and forwarded to the USAF OEHL for review as soon as they become available as specified in Item VI below.

G. Reporting

1. A draft report delineating all findings of this field investigations 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 hydrogeology, well logs of projects wells, data from water level surveys, water quality analysis results, available geohydrologic cross sections, ground water surface and gradient maps, vertical and horizontal flow vectors and laboratory quality assurance information. The report shall follow the USAF OEHL supplied format (mailed under separate cover).

AD-A145 352 INSTALLATION RESTORATION PROGRAM PHASE II PROBLEM 2/3
CONFIRMATION STUDY WESTOVER AFB CHICOPEE MASSACHUSETTS
(U) WESTON (ROY F) INC WEST CHESTER PA MAY 84
UNCLASSIFIED F33615-80-D-4006 F/G 5/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

2. Estimates shall be made of the magnitude, extent and direction of movement of contaminants discovered. Potential environmental consequences of discovered contaminations shall be identified and estimated.

3. Specific requirements, if any, for future ground water and surface water monitoring must be identified.

II. Site Location and Dates:

Westover AFB MA
Dates to be established

III. Base Support: None

IV. Government Furnished Property: None

V. Government Points of Contact:

1. Captain Robart W. Bauer
USAF OEHL/CVT
Brooks AFB TX 72835
(512) 536-2158/2159

2. Maj Kenneth Hundley
HQ AFRES/SGPB
Robins AFB GA 31098
(912) 926-6441

3. Maj Gary Fishburn
USAF OEHL/ECQ
Brooks AFB TX 78235
(512) 536-3305

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

Seq Nr	Block 10	Block 11	Block 12	Block 13	Block 14
4	One/R	84JAN08	84FEB08	84MAY08	*

*Contractor shall supply the USAF OEHL with 20 copies of draft report and 50 copies plus original camera ready copy of the final report.

REQUIRED LIMITS OF DETECTION
FOR ANALYSES

COD - 5 milligram/l

TOC - 1 milligram/l

Oils and Grease (IR method) - 0.10 milligram/l

Phenols - 1 milligram/l

Volatile Organics - detection limits as specified for compounds listed in EPA Methods 601 & 602

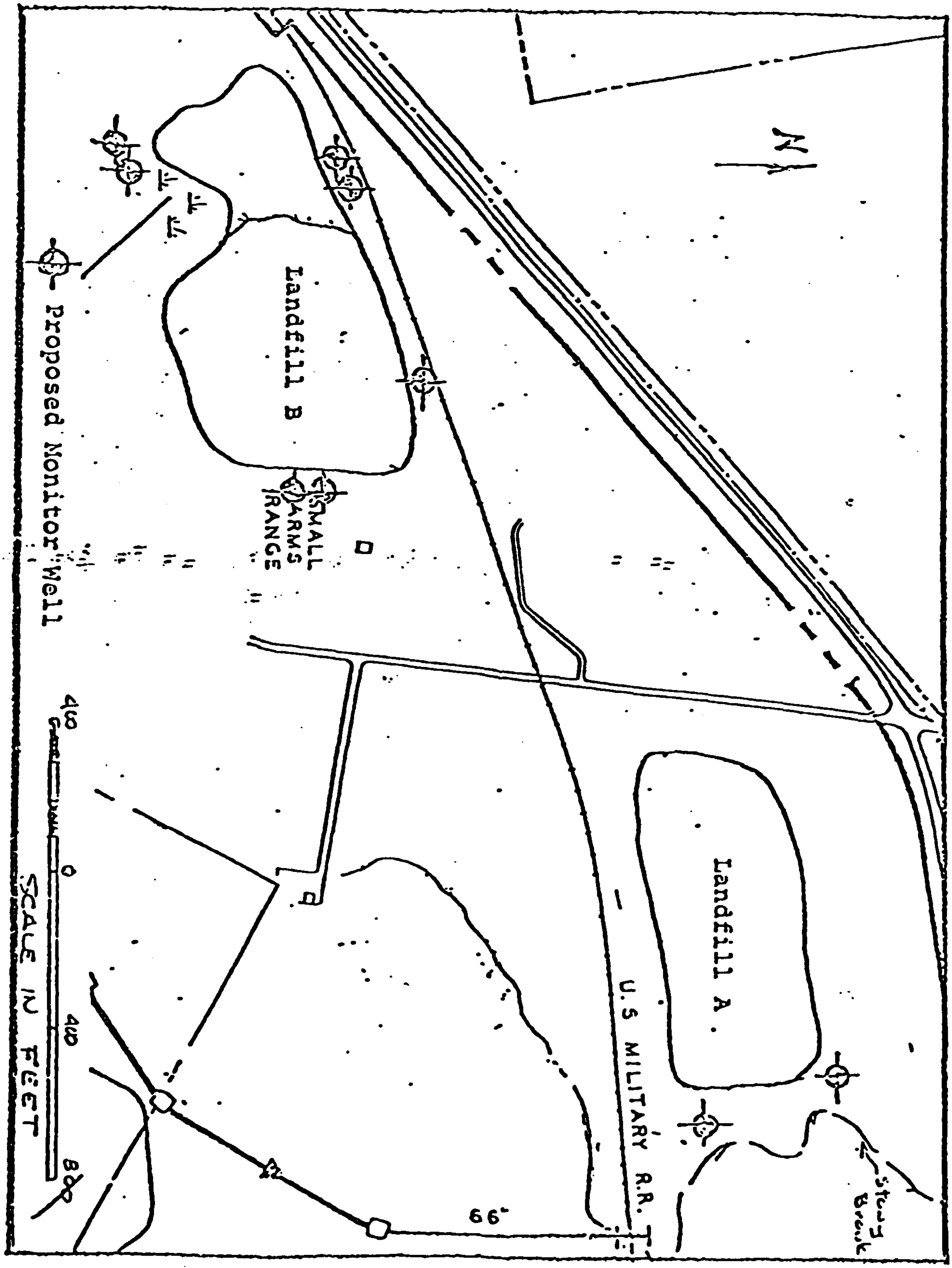
Lead - 20 microgram/l

Chloride - 1 milligram/l

Sulfate - 1 milligram/l

Figure 1

Locations of Proposed Monitor Wells at WAFB Landfill A and B



APPENDIX C

Professional Profiles of Project Personnel

Peter J. Marks

Fields of Competence

Project management; environmental analytical laboratory analysis; hazardous waste, groundwater and soil contamination; source emissions/ambient air sampling; wastewater treatment; biological monitoring methods; and environmental engineering.

Experience Summary

Eighteen years in Environmental Laboratory and Environmental Engineering as Project Scientist, Project Engineer, Process Development Supervisor, and Manager of Environmental Laboratory with WESTON. Experience in analytical laboratory, wastewater surveys, hazardous waste, groundwater and soil contamination, DoD-specific wastes, stream surveys, process development studies, and source emission and ambient air testing. In-depth experience in pulp and paper, steel, organic chemicals, pharmaceutical, glass, petroleum, petrochemical, metal plating, food industries and DoD.

Applied research on a number of advanced wastewater treatment projects funded by Federal EPA.

Credentials

B.S., Biology—Franklin and Marshall College (1963)

M.S., Environmental Engineering and Science—Drexel University (1965)

American Society for Testing and Materials

Water Pollution Control Federation

Water Pollution Control Association of Pennsylvania

Employment History

1965-Present	WESTON
1963-1964	Lancaster County General Hospital Research Laboratory for Analytical Methods Development

Key Projects

USAF/OEHL Brooks AFB. Program Manager for this three-year BOA contract provides technical support in environmental engineering surveys, wastewater characterization programs, geological investigations, hydrogeological studies, landfill leachate monitoring and landfill siting investigations, bioassay studies, wastewater and hazardous waste treatability studies, and laboratory testing and/or field investigations of environmental instrumentation/equipment. Collection, analysis, and reporting of contaminants present in water and wastewater samples in support of Air Force Environmental Health Programs.

United States Army Toxic and Hazardous Materials Agency (USATHAMA), Aberdeen Proving Ground, Maryland. Program Manager for three-year basic ordering agreement contract to provide research and development for technology in support of the DOD Installation Restoration Program. The objective of the Program is to identify and develop treatment methods/technology for containment and/or remedial action. Technology development for remedial action is to include groundwater, soils, sediments, and sludges.

Confidential Client, Ohio. Project Manager of an on-going contract to conduct corporate environmental testing and special projects at client's U.S. and overseas plants. WESTON must be able to assign up to four professionals to a project within a two week notice.

Confidential Client (Inorganic and Organic Chemicals). Product Manager of a current contract to conduct wastewater sampling and analysis of plant effluent for priority pollutants. The project also includes a wastewater treatability study to evaluate a number of process alternatives for removal of priority pollutants from the present effluent.

Confidential Client, Utah. Technical Project Manager for in-depth wastewater survey, in-plant study, treatability study, and concept engineering study in support of the client's objectives to meet 1983 effluent limitations. WESTON had two project engineers, two chemists, five technicians and an operating laboratory in the field. Field effort is six months duration.

Professional Profile

In conjunction with University of Delaware College, WESTON analyzed more than 500 biological and marine sediment samples for eleven constituent trace metals as part of a program to identify and trace the migration of metals from ocean dumping of sludges on the continental shelf off the coast of the State of Delaware, acted as Technical Project Manager.

Project Manager in charge of a wastewater analysis and biological treatability project for industrial client for the identification and degradation of six pesticide-containing wastewaters.

U.S. EPA Environmental Monitoring and Support Laboratory. Multi-year contract to provide reference laboratory analysis on QA/QC samples produced from the EPA Analytical Laboratory QA/QC program.

Publications

"Microbiological Inhibition Testing Procedure," Biological Methods for the Assessment of Water Quality, A.S.T.M. Publication STP 528.

"Heat Treatment of Waste Activated Sludge" (with V.T. Stack).

"Biological Monitoring in Activated Sludge Treatment Process," a joint paper with Stover/Woldman.

Richard L. Kraybill

Fields of Competence

Hydrogeologic and geotechnical investigations of hazardous waste sites and landfills; evaluations of potential site use for solid and liquid waste disposal and secure land burial facilities; hydrogeologic analyses of remedial alternatives for groundwater contamination problems. Management of hydrogeologic projects involving groundwater resource evaluation, monitoring, development, and protection; analyses of groundwater quality trends as compared to land use.

Experience Summary

Fifteen years of professional experience in the field of groundwater pollution control. Expertise in providing technical guidance and advice to industry and public and governmental agencies on hydrogeologically related problems of groundwater management, protection, and development.

Prepared hydrogeologic reports assessing groundwater availability and suitability for supply; conducted investigations of groundwater pollution incidents and developed reports with specific recommendations relating to serious pollution problems and large scale water resource issues.

Coordinated and supervised subsurface exploratory work for hydrogeologic investigations relating to landfills, hazardous waste sites, groundwater injection systems, and other projects affecting groundwater; organized and performed studies utilizing advanced hydrogeologic methods such as ionic tracers, earth resistivity, and remote sensing; utilized mathematical principles of groundwater flow in hydrogeologic investigations.

Participated in planning, coordination and development of groundwater recovery and treatment projects where groundwater has been polluted.

Provided consultation and expert testimony on hydrogeologic aspects of disposal of hazardous and non-hazardous wastes. Managed group of geologists involved in hydrogeologic-geotechnical investigations.

Credentials

B.A., Geology—Lafayette College (1967)

M.S., Geology—Rutgers University (1977)

Affiliations

National Water Well Association, Technical Division

Water Pollution Control Federation

Pennsylvania Water Pollution Control Association, Eastern Section

Geological Society of America, Hydrogeologic and Engineering Divisions

Employment History

1981-Present	WESTON
1979-1981	Wehran Engineering Earth Sciences Group
1967-1979	Commonwealth of Pennsylvania

Key Projects

Senior Project Hydrogeologist on study involving the containment of PCB migration from five sites known to have received large quantities of materials containing PCB's.

Senior Project Hydrogeologist on the closure and cut-off wall certification of a large hazardous waste disposal site in a wetlands area in Michigan.

Project Manager for the hydrogeologic study and remediation analysis of a hazardous waste disposal site in Chester, PA, under contract with the PA Department of Environmental Resources and the EPA.

Developed and managed a site feasibility assessment and major detailed hydrogeologic-geotechnical investigation for the design of a secure landfill in Model City, NY.

Managed the investigation, design remediation and closure of an uncontrolled hazardous waste disposal site.

Professional Profile

Senior Hydrogeologist and Project Manager for an insitu closure of a plating waste impoundment.

Senior Hydrogeologist for investigation and design of a secure sewage sludge disposal facility involving groundwater cutoff by slurry trench methods.

Senior Hydrogeologist for five U.S. Air Force projects developing work scopes for investigating impacts at suspect hazardous waste disposal sites under the USAF-IRP program.

At one USAF Base, performed a detailed preliminary investigation of an existing groundwater pollution problem with the objective of assessing potential impacts on a nearly public water supply resource.

Project Manager and Senior Hydrogeologist pertaining to the environmental assessment and disposal of hazardous wastes at the largest metal finishing industry in Maine. Portions of project involved evaluation, risk assessment and concept closure of a hazardous waste impoundment; EPA sludge delisting; and hazardous waste Part B applications.

Project Manager and Hydrogeologist for landfill development, closure and site permitting.

Publications

"Groundwater Quality, Variation, and Trends as Compared to Land Use in a Critical Carbonate Recharge Area." Presented at the NWWA Exposition—Technical Division Annual Meeting, Boston, Massachusetts, 1977.

"Regulatory—Technical Aspects of Sewage Sludge Disposal on the Land Surface." Presented at the Pennsylvania Water Pollution Control Association Annual Convention, 1977.

"Hydrogeologic Considerations and Remedial Alternatives Assessment at Uncontrolled Hazardous Waste Disposal Sites." Vanderbilt University-sponsored Technical Program for Environmental Protection Agency, Region V, Cincinnati, Ohio, 1981.

"In-situ Remediation and Closure of a Plating Waste Impoundment", *Toxic and Hazardous Waste*. Proceedings of the Fifteenth Mid-Atlantic Industrial Waste Conference, June 1983.

DAVID WOODHOUSE, P.G.

Registration

Registered Professional Geologist in the States of Georgia, Oregon, and Delaware

Fields of Competence

Geological projects; foundation engineering; ground water studies; drilling and other exploration program and procedure design for soil and rock sampling; marketing services; and geologic problems and effects on foundation engineering.

Experience Summary

Seventeen years of project management experience in the fields of engineering geology, geotechnical engineering, and geohydrology; soil and rock testing; instrumentation; geologic reports and technical presentations; quality assurance; and geologic mapping.

As Geology Manager and Chief Engineering Geologist, reviewed work and technical reports of geologists and engineers. Project Manager for numerous projects involving geology, foundation engineering, and ground water studies. Designed drilling and other exploration programs and procedures for soil and rock sampling. Responsible for firm's geophysical activities. Conducted extensive marketing of firm's services. Consultant to engineering staff on solving geologic problems and their effects on foundation engineering.

Credentials

B.A., Geology -- Boston University (1962)

M.A., Geology -- Boston University (1964)

Supplementary Education

Rock Mechanics Seminar -- Harvard University (1973)

Persuasive Technical and Executive Speaking -- Management Development Institute (1981)

Geotechnical Lecture Series on Ground Water Hydrology -- MIT (1981)

Professional Liability Courses -- Risk Analysis Institute (1976, 1981)

Geotechnical Lecture Series on Engineering Geology -- MIT (1982)

American Institute of Professional Geologists

Boston Society of Civil Engineers

Association of Engineering Geologists

Professional Profile

DAVID WOODHOUSE, P.G.
(continued)

Geological Society of America

United States Committee on Large Dams

Employment History

1982-Present	WESTON
1981-1982	Manager of Geology and Chief Engineering Geologist Goldberg-Zoino & Associates, Inc.
1979-1980	Senior Engineering Geologist Goldberg-Zoino & Associates, Inc. Soil and Rock Instrumentation Division Goldberg-Zoino & Associates, Inc.
1977-1979	Senior Geologist and Project Administrator Weston Geophysical Research, Inc.
1976	Consulting Geologist
1973-1976	Senior Geologist Geotechnical Engineers, Inc.
1968-1973	Assistant Manager of Geological Services Haley & Aldrich, Inc.
1965-1968	Staff Geologist Haley & Aldrich, Inc.
1964-1965	Instructor of Geology Boston University

Key Projects

Ground Water Projects

Surficial mapping to locate potential new ground water supplies for Town of Acton. Report review and consultation to define geology and extent of groundwater contamination.

Examination of potential new ground water supplies for City of Brockton.

Responsible for exploration program to define contamination plume for computer firm. Field testing of soil and water samples.

Review of fracture trace analysis for New Hampshire Landfill. Geologic mapping to define paths of contamination. Rock core logging. Consultation with State and EPA officials.

Expert testimony in landmark eminent domain case involving municipal water supplies from Town of Sandwich.

Geologic study to determine most suitable sites for spray irrigation/wastewater management study for Town of Jackman, Maine.

Conducted geohydrological investigation for City of Peabody.

Field studies to assess feasibility of waste lagoons for Pratt & Whitney in Berwick, Maine.

Field mapping, logging of rock cores to determine geologic conditions for Lincoln, Rhode Island.

Landfill feasibility study in Shirley, Massachusetts.

Ground-water contamination study to determine geologic conditions for Nuclear Metals, Concord.

Ground-water contamination by leachate from landfill in West Newbury, Massachusetts.

Engineering Geology Studies

Extensive bedrock mapping, structural and slope stability analysis of buildings on rock slopes and highway cuts.

Project geologist for dam liquefaction study for Corps of Engineers in New England.

Extensive bedrock mapping and investigations for the Pennacook Low Head Hydro Dam and Underground Power House in New Hampshire.

Responsible for investigations and field supervision of geotechnical studies for South Station Transportation Center, Boston, Massachusetts.

Investigations and field supervision for numerous sites for high-technology firms in New England.

Publications

"Stress Detection in Soil and Rock by Acoustic Emission Sensing," by D. Woodhouse, ASCE Annual Meeting, October 1978.

"The Effects of a Chemical Leachate Plume on Construction Criteria for a Rapid Transit Tunnel," by D. Woodhouse, J.E. Ayres, and M.J. Barvenik, AEG Annual Meeting, October 1980.

"The Geology of the City of Boston," edited by D. Woodhouse, AEG Series, Geology of the Cities of the World (in press).

"Influence of Geology in Engineering Design in the Area of Boston, Massachusetts," by D. Woodhouse and R.M. Simon. Presented at Association of Engineering Geologists, New England Section, Sixth Annual Symposium, February 1982.

Walter M. Leis, P.G.

Registration

Registered Professional Geologist in the States of Georgia (No. 440) and Indiana.

Fields of Competence

Detection and abatement of groundwater contamination; design of artificial recharge wells; deep well disposal; simulation of groundwater systems; hydrogeologic evaluation of hazardous waste sites and landfills; practical applications of geophysical surveys to hydrologic systems, site investigations, and borehole geophysical surveys. Geochemical studies of acid mine drainage and hazardous wastes.

Experience Summary

Sixteen years experience as field hydrogeologist, field supervisor, project director, research director. Six years research involving two consecutive projects: 1) application of geophysical techniques in evaluating groundwater supplies in fractured rock terrain in Delaware and Pennsylvania; 2) project director for an artificial recharge and deep well disposal study. Provided consultation for waste disposal and aquifer quality problems for coastal communities.

Developed geochemical sampling techniques for deep mine sampling. Evaluated synthetic and field hydrologic data for deep formulational analysis in coal field projects.

Earlier research experience involved developing techniques for mapping subsurface regional structures having interstate hydrologic significance, and defining ore bodies by geochemical prospecting.

Credentials

B.S., Biochemistry—Albright College (1966)

M.S., Hydrogeology—University of Delaware (1975)

Cooperative Program Environmental Engineering—University of Pennsylvania

Additional special course work in Geology and Hydrology, Franklin and Marshall College and Pennsylvania State University

Remote Sensing Data Processing Training, Goddard Space Center (1978)

OWRR Research Fellow, 1973

National Water Well Association, Technical Division.

Geological Society of America, Engineering Geological Division.

Society of Economic Paleontologists and Mineralogists

Employment History

1974-Present	WESTON
1973-1974	University of Delaware Water Resources Center
1971-1973	University of Delaware
1967-1971	Pennsylvania Department of Environmental Resources

Key Projects

Definition of groundwater contamination from sanitary landfill leachate and recovery of contaminants to protect heavily used aquifer in Delaware.

Field design studies for artificial recharge and waste disposal wells.

Design and construction of hydrologic isolation systems for various class hazardous wastes.

Design and supervision of chemical and physical rehabilitation of groundwater collection systems in fractured rock and coastal plain areas.

Principal investigator for six projects involving subsurface migration of PCB's in New York, New Jersey, Pennsylvania, and Oklahoma.

Design and construction supervision of hydrocarbon recovery wells in Pennsylvania.

Professional Profile

Geochemical evaluation of coal mine pools in West Virginia.

Geochemistry of subsurface migration of toxic substances.

Principal investigator for eight projects involving migration of volatile chlorinated hydrocarbons in groundwater.

Mineable reserve evaluations for coal, sand and gravel, limestone, clay deposits, mine reclamation, and monitoring.

Design geophysical and remote sensing assessments of hazardous waste disposal areas.

Publications

Leis, W., and R.R. Jordan, 1974, "Geologic Control of Groundwater Movement in a Portion of the Delaware Piedmont", OWRR—DEL 20.

Leis, W., 1976, "Artificial Recharge for Coastal Sussex County, Delaware", University of Delaware Press, Water Resources Center.

Leis, W., D.R. Clark, and A. Thomas, 1976, "Control Program for Leachate Affecting a Multiple Aquifer System, Army Creek Landfill, New Castle County, Delaware", National Conference on Management and Disposal of Residue on Land.

Leis, W., W.F. Beers, J.M. Davidson, and G.D. Knowles, 1978, "Migration of PCB's by Groundwater Transport—A Case Study of Twelve Landfills & Dredge Disposal Sites on the Upper Hudson Valley, New York", Proceedings of the 1st Annual Conference of Applied Research & Practice on Municipal and Industrial Waste.

Leis, W., R.D. Moose, and W.F. Beers, "Critical Area Maps, a Regional Assessment for Karst Topography", Association of Engineering Geologists 1978 Annual Meeting.

Leis, W., and W.F. Beers, "Soil Isotherm Studies to Predict PCB Migration Within Groundwater", (Abstract) ASTM 1979 Annual Meeting, Philadelphia, Pennsylvania.

Thomas, A., and W. Lein, "Physical & Chemical Rehabilitation of Contaminant Recovery Wells", Association of Engineering Geologists 1978 Annual Meeting.

Leis, W., W.F. Beers, and F. Benenati, "Migration of PCB's from Landfills and Dredge Disposal Sites in the Upper Hudson River Valley", New York Academy of Science Symposium on PCB's in the Hudson River.

Leis, W., "Subsurface Reclamation by Counter Pumping Systems: Geologic and Geotechnical Aspects of Land Reclamation", ASCE/AEG 1979 Symposium.

Leis, W., and A. Metry, "Field Characterization of Leachate Quality", Water Pollution Control Federation 1979 Annual Meeting.

Leis, W., and A. Metry, "Multimedia Pathways of Contaminant Migration", Water Pollution Control Federation 1980 Annual Meeting.

Leis, W., and K. Sheedy, "Geophysical Location of Abandoned Waste Disposal Sites", 1980 National Conference on Management of Uncontrolled Hazardous Waste Sites.

Sheedy, K., and W. Leis, 1982, "Hydrogeological Assessment in Karst Environments (chapter)."

James S. Smith, Ph.D.

Fields of Competence

Analytical laboratory management; organic chemistry; mass spectrometry, GC/MS/DS, high and low resolution, chemical ionization and special techniques; gas chromatography including capillary column techniques; high performance liquid chromatography (HPLC); the uses of NMR, IR, UV, visible, inorganic analyses, electrochemical, thermal techniques and surface methodologies (SEM, ESCA, SIMS) to solve industrial problems; the development of quality control measures in analytical protocols; the testing of laboratory safety methodologies; innovation of new analytical techniques and methods to solve industrial, product liability, production and environmental problems.

Experience Summary

Eleven years experience in the supervision of an analytical group involved in solving all types of industrial problems including environmental, product safety, production, research and development. The main emphasis was on the innovative development of analytical methods utilizing instrumental technologies. In-depth experience in the organic chemicals, inorganic chemicals polymer, fiber, tire, solvent, fluorine chemicals, coke and coal tar industries. Numerous scientific presentations. Contributor to three Chemical Manufacturers Association Task Groups: Environmental Monitoring, Groundwater, and Hazardous Waste Response Center.

Taught general chemistry, analytical chemistry, organic chemistry, and instrumental analysis for four years at Eastern Michigan University and the University of Illinois.

Credentials

B.A., Chemistry—Williams College (1960)

Ph.D., Organic Chemistry—Iowa State University (1964)

Postdoctoral Organic Chemistry—University of Illinois (1966)

Postdoctoral Mass Spectroscopy—Cornell University (1969)

American Chemical Society

American Society for Testing Materials

American Society of Mass Spectroscopists

Employment History

1981-Present	WESTON
1969-1981	Allied Chemical Corporation Corporate Research Center
1966-1968	Eastern Michigan University Assistant Professor of Chemistry
1965-1966	University of Illinois

Key Projects

Directed analytical group for five years of intensive sampling and analysis of a toxic insecticide. Analyses involved soil, air, water, sludge, blood, bile, feces, urine, animal feed, and plant samples to detect the compound at the low parts-per-billion level. The project involved rapid development of new and accurate analytical methods.

Developed an industrumental analytical laboratory consisting of trace environmental analyses, gas chromatography, high performance liquid chromatography, mass spectrometry, surface analyses, X-ray photoelectron spectroscopy and nuclear magnetic resonance spectroscopy including the design and manufacture of instrument modifications, purchasing instruments, and hiring of key personnel.

Isolated, identified, and developed a method of analysis for a colored impurity on a bulk chemical product. Synthesized the colorant for proof of identification and as a standard for future analysis. Proved the mechanism of the development of the color from the packaging materials. Designed new specifications eliminating the problem.

Conducted corporate plant environmental laboratory QA/QC audits including the development of a corporate QA/QC manual.

Professional Profile

Provided an inexpensive and accurate method of analysis of lead for a manufacturing plant effluent. A published methodology in kit form was modified for plant personnel use to measure soluble and total lead in a waste stream without use of excessive manpower or capital. QA/QC procedures were included as well as the use of performance samples.

Supervision of analytical technological advances that lead to either patents and new products in the fields of coal tar chemicals, food packaging and transformer manufacturing.

Publications

Smith, J., A. Weston, and C. Wezwick, "Tire Cord Emission Studies, Conclusion", The International Society of Industrial Yarn Manufacturers, Savannah, Georgia, 3-4 November 1977.

Hanrahan, J., E. McCarthy, D. Richton, J. Smith, and A. Weston, "Identification of an Interfering Compound is the Determination of Dimethylnitrosamine by Gas Chromatography-Mass Spectrometry", 26th Annual Conference on Mass Spectrometry and Allied Topics, St. Louis, Missouri, 28 May to 2 June 1978.

Brozowski, E., D. Jerolamon, D. Richton, D. Smith, J. Smith, and A. Weston, "Industrial Applications of Chemical Ionization with the Ammonium Ion", 26th Annual Conference on Mass Spectrometry and Allied Topics, St. Louis, Missouri, 28 May to 2 June 1978.

Mueller, B.W., L. Palmer, G. Rebyak, and J. Smith, "Analysis of Alpha and Beta Naphthalene Sulfonic Acids by High Performance Liquid Chromatography", North Jersey A.C.A. Chromatography Discussion Group, Nutley, New Jersey, 14 March 1979.

French, C., L. Palmer, and J. Smith, "Analysis of Polymer Oligomers by High Performance Liquid Chromatography", Middle Atlantic Regional A.C.S. Meeting, West Long Branch, New Jersey, 19-23 March 1979.

Burkitt, D. and J. Smith, "A Simple Chromatographic Modification Providing for Rapid Interchange of Capillary and Packed Columns", Middle Atlantic Regional A.C.S. Meeting, West Long Branch, New Jersey, 19-23 March 1979.

Brozowski, E., D. Jerolamon, D. Richton, D. Smith, and J. Smith, "A Convenient Method for the Evaporation of Solvent in the Priority Pollutant Program," Middle Atlantic Regional A.C.S. Meeting, West Long Branch, New Jersey, 19-23 March 1979.

Mady, N., D. Smith, J. Smith, and C. Wezwick, "The Analysis of Kepone in Biological Samples", Proceedings of the 9th Materials Research Symposium, Gaithersburg, Maryland, 10-12 April 1978.

Mueller, B., L. Palmer, and J. Smith, "A High Performance Liquid Chromatographic Method for the Analysis of Bis-phenol-A and Its Impurities", Middle Atlantic Regional A.C.S. Meeting, West Long Branch, New Jersey, 19-23 March 1979.

Gabriel, M., J. Hanrahan, and J. Smith, "A Sensitive Method for the Quantitative Analysis of Pyridine at the Low PPM Level", Middle Atlantic Regional A.C.S. Meeting, West Long Branch, New Jersey, 19-23 March 1979.

Burkitt, D., J. Hanrahan, and J. Smith, "Analysis of Hexachloroacetone and Hexafluoroacetone in Industrial Wastewater", Proceedings of the A.S.T.M. Committee D-19 Symposium, "The Measurement of Organic Pollutants in Water and Wastewater", Denver, Colorado, 19-20 June 1978.

Brozowski, E., D. Burkitt, M. Gabriel, E. McCarthy, J. Hanrahan, and J. Smith, "A Simple, Sensitive Method for the Quantitative Analysis of Carbon Tetrachloride and Chloroform in Water at the Parts Per Billion Level", Proceedings of the 9th Materials Research Symposium, Gaithersburg, Maryland, 10-12 April 1978.

Theodore F. Them, Ph.D.

Fields of Competence

Inorganic and organic chemistry; instrumental analytical techniques; synthesis of organic chemicals; laboratory management; chemical research and education.

Experience Summary

Nine years experience in inorganic and organic chemistry with strong synthetic organic and instrumental analytical background. Experienced researcher and teacher. Background in conceptualizing, founding, effecting, and administering a chemical consulting firm.

Credentials

M.S., Chemistry—University of New Mexico (1975)

Ph.D., Chemistry—University of New Mexico (1977)

American Chemical Society

The Society of Sigma Xi

Southwest Association of Forensic Scientists—Associate Member

Society of Applied Spectroscopy, Rio Grande Section

Employment History

1982-Present	WESTON
1981-1982	Bell Petroleum Services, Inc.
1982-1982	Bell Petroleum Laboratories
1977-1981	AnaChem, Inc. Co-Founder, Vice President
1975-1977	University of New Mexico

Practical Experience

Familiarity with use, maintenance, and operation of gas chromatographs with flame ionization, electron capture, thermal conductivity, and photoionization detectors. Experience includes methods development, separation optimization, and data reduction.

Familiarity with use, maintenance, and operation of gas chromatograph/mass spectrometer/data system (GC/MS/DS) in separations and identifications of complex mixtures and molecules. Experience includes methods development, separation enhancement, packed and capillary column techniques, and data reduction.

Familiarity with use and operation of various infrared, nuclear magnetic resonance (NMR), atomic absorption (AA), and liquid chromatographic (LC) instrumentation.

Familiarity with use, maintenance, and operation of Tekmar Models LSC-2 and ALS purge/trap and liquid sample concentrator devices and associated gas chromatographic methods.

Familiarity with use, maintenance, and operation of Fisher Model 490 Coal Analyzer for analysis of moisture, volatiles and ash in coal.

Familiarity with use, maintenance, and operation of Fisher Sulfur Analyzer System for analysis of sulfur in coal and hydrocarbon fuels.

Familiarity with use, maintenance, and operation of Parr Adiabatic Bom Calorimeter and associated Master Controller in calorimetric analysis of coal and coke, foodstuffs, and fuels.

Familiarity with use, maintenance, and operation of Fisher Models Titralyzer II (Fixed End Point) and Tritrimeter II automatic titration systems for analysis of water by pH or millivolt-sensitive methods.

Publications

Hazardous Properties and Environmental Effects of Materials Used in Solar Heating and Cooling (SHAC) Technologies: Interim Handbook, J.Q. Search (ed.), August 1978. Sandia Laboratories report Sand 78-0842, available from National Technical Information Service, Springfield, Virginia.

Professional Profile

"Isomerism in Complexes of Bidentate Ligands with Enantiotopic Donor Atoms", R.E. Tapscott, J.D. Mather, and T.F. Them, *Coordination Chemistry Reviews,* Vol. 19, Nos. 2/3, September 1979.

"Stereochemical Studies on Diastereomers of Tris (2,3-butanediamine)-Colbalt (III)", C.J. Hilleary, T.F. Them, R.E. Tapscott, *Inorganic Chemistry*, Vol. 19, No. 102, 1980.

"Staying Abreast of PCB Regulations: TESTING", R.M. Holland and T.F. Them, *Professional Trade Publication,* June 1980.

"Stereochemistry of Arsenic (III) and Antimony (III) 1,2-DihydroxyEychohexane-1,2-dicarboxylates," D. Marcovich, E.N. Duesler, R.E. Tapscott, and T.F. Them, *Inorganic Chemistry*, 1982.

Frederick Bopp III, Ph.D., P.G.

Registration

Registered Professional Geologist in the State of Indiana

Fields of Competence

Groundwater resources evaluation; hydrogeologic evaluation of sanitary landfills and other waste disposal sites; detection and abatement of groundwater pollution; digital modeling of groundwater flow and solute transport; statistical analysis of geological and geochemical data; geochemical prospecting; estuarine geology and geochemistry; trace metal and aqueous geochemistry.

Experience Summary

Seven years experience in hydrogeology and geochemistry, involving such activities as: assessment of subsurface water and soil contamination; development of contamination profiles; evaluation of remediation actions for groundwater quality restoration; quantitative chemical analysis of water and soil; ore assay and ore body evaluation; drilling supervisor; hydrogeologic assessment; pollution detection and abatement; estuarine pollution analysis; application of flow and solute transport computer models; computer programming; project management; teaching environmental geology and geochemistry.

Credentials

B.A., Geology—Brown University (1966)

M.S., Geology—University of Delaware (1973)

Ph.D., Geology—University of Delaware (1979)

Sigma Xi, The Scientific Research Society of North America

Geological Society of America, Hydrology Division

National Water Well Association, Technical Division

American Association for the Advancement of Science

Estuarine Research Federation: Atlantic Estuarine Research Society

Employment History

1979-Present	WESTON
1977-1979	U.S. Army Corps of Engineers Waterways Experiment Station
1976-1977	University of South Florida Department of Geology
1970-1976	University of Delaware Department of Geology
1974-1976	Earth Quest Associates President and Principal Partner
1974 (Summer)	WESTON
1966-1970	United States Navy Commissioned Officer

Key Projects

Project manager on seven task orders for environmental assessment services at United States Air Force facilities in nine states.

Task manager for a Superfund site evaluation in Ohio.

Site manager for drum recovery operations in Pennsylvania and New Jersey.

Project manager for site assessments of oil and fuel spills in four states.

Project manager for closure plan development at a hazardous waste landfill in New Jersey.

Definition and abatement of groundwater contamination from chemical manufacturing in Delaware.

Flow and solute transport digital model of a heavily-pumped regional aquifer in southern New Jersey.

Definition and abatement of groundwater contamination from chemical manufacturing in the Denver area.

Hydrogeologic impact assessment of on-land dredge spoil disposal in coastal North Carolina.

Geochemical prospecting and ore body analysis in Arizona.

Professional Profile

Definition and abatement of groundwater contamination from a hazardous waste site in northern New England.

Definition and abatement of groundwater contamination from plating and foundry wastes in eastern Pennsylvania.

Operational test and evaluation of new naval mine ordinances in southern Florida.

Publications

"Metals in Estuarine Sediments: Factor Analysis and Its Environmental Significance". *Science*, 214 (1981): 441-443.

"The Remobilization of Trace Metals from Suspended Sediments Entering the Delaware Estuary". Presented at the 27th Annual Meeting, Southeastern Section, Geological Society of America, Chattanooga, Tennessee, April 1978.

"Trace Metals in Delaware Bay Sediments and Oysters". Presented at the International Conference on Heavy Metals in the Environment, Toronto, Canada, October 1975.

STEVEN I. MICHELSON

Registration

Engineer-In-Training

Fields of Competence

Field investigations; ground-water resource evaluations; hydrogeologic investigations of landfills and potential water resource impacts; geologic mapping; regional and local structural and geomorphological analyses; microscopic identification of minerals; foundation and structural concrete design; surveying; analysis of soil stability and mechanics; small systems analysis and design; CBM generation; Fortran IV program design and analysis.

Experience Summary

1983-Present	WESTON
1982	Getty Refining and Marketing
1981	Geological Mapping and Interpretation Wyoming-Idaho Rockies

Credentials

B.S., Geology -- Lehigh University (1982)

B.S., Civil Engineering -- Lehigh University (1982)

Key Projects

Assisted in the evaluation of contaminant migration to a future Bedford, Massachusetts well-water site as part of a U.S. Air Force-sponsored project at Hanscom Field.

Technical supervision and participation in the scheduled operation and disassembly of pilot treatment plant. Conducted sampling and field studies in support of pilot treatment unit.

Participated in procedural design and operation of field sampling and analysis of a chemical waste impoundment.

Assisted in design and evaluation for fresh water storage in Lincoln, New Hampshire. Organized written and plan specifications for contract bidding.

Assisted in the evaluation of the environmental impact of present landfill leachate and seepage.

Conducted site design, evaluation, and construction cost estimations for wastewater treatment plant in North Andover, Massachusetts.

Joseph R. Althouse

Fields of Competence

Data collection; wastewater sampling; flow measurement in house treatability systems; analytical methods in wet laboratory; air pollution testing; maintenance of laboratory and field equipment for field projects; infiltration and inflow programs; construction estimating; quantity take-off; pricing; and on-site sewer construction inspection.

Experience Summary

Eight years experience in coordinating field equipment and supplies on various projects ranging from stream surveys to air pollution testing. Experience in developing and fabricating equipment for wastewater sampling. Sampling technician for infiltration/inflow studies, fish bioassays; air pollution, and wastewater sampling, construction estimating and on-site construction inspection.

Employment History

1980-Present	WESTON
1979-1980	Charles E. Moore Associates
1974-1979	Rexnord Instrument Products
1967-1974	WESTON
1965-1967	Lukens Steel Company
1963-1965	Firestone Tire and Rubber Company

Key Projects

Sewer construction inspection for West Whiteland Township, Pennsylvania.

Infiltration/inflow analyses and sewer system evaluation studies, including surface inspection, physical inspection and flow measurements for a township.

Source emissions and ambient air testing of air pollutants.

Wastewater survey of a major steel producing plant in Texas including collecting flow data and wastewater samples and constructing and maintaining test equipment.

Wastewater survey of 2 major electric power companies in Pennsylvania collecting flow data and wastewater samples for National Pollution Discharge Elimination System.

Professional Profile

APPENDIX D

Boring Logs and Well Completion Summaries

WESTON

TEST BORING LOG

BORING NO. B-1

PROJECT : Westover AFB - Phase II IRP	**SHEET NO** 1 **OF** 2
CLIENT : USAF- OEHL	**JOB NO.** 06280519
BORING CONTRACTOR : D.L. Maher	**ELEVATION** 241.9
GROUND WATER :	**DATE STARTED** 10-4-83
	DATE FINISHED 10-5-83
	DRILLER Bill Canty
	INSPECTOR S. Michelson
	F.B. - 101

DATE	TIME	WATER EL.	SCREEN

	CAS.	SAMP.	CORE	TUBE
TYPE		SS		
DIA.		2"		
WT.		140		
FALL		30"		

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
Con crete	0				DELTAIC DEPOSITS ▽ 2.8'	
D E L T A I C Bent-onite	5	S-1	SS	9-11 11-12	brown fine to medium SAND	h-nu = 1.0
Slurry	10	S-2	SS	7-10 8-11	gray-brown fine to medium SAND trace gravel minor iron stains	oil-type sheen on spoon rinse water h-nu = 1.5
	15	S-3	SS	9-11 13-14	gray brown medium to coarse SAND trace gravel	loose h-nu = 1 Water sample 45 µmhos @ 21°C
	20	S-4	SS	2-4 3-3	gray brown medium SAND.	h-nu = 0
Bent-onite SCH 80 PVC BLANK RISER D E P O S I T S						loose
Grout	25	S-5	SS	2-4 6-3	medium+ to coarse SAND	h-nu = 0.5
	30	S-6	SS	3-6 6-5	gray brown fine to coarse SAND trace gravel	loose h-nu = 0.5
	35	S-7	SS	8-13 24-30	gray brown fine to medium SAND trace silt	h-nu = 0
Ottowa					— — — — — —	
	40	S-8	SS	6-18 30	gray fine SAND, fine silty-sand laminae	h-nu = 0.5
SCREEN 0.010" Sand					color change	
	45	S-9	SS	4-9 11-14	gray fine SAND minor silty sand laminae	h-nu = 0.5

WESTON DESIGNERS CONSULTANTS

TEST BORING LOG	
BORING NO.	B-1
PROJECT: Westover AFB - Phase II IRP	**SHEET NO.** 2 **OF** 2
CLIENT: USAF - OEHL	**JOB NO.** 06280519

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
DELTAIC SCREEN OTTOWA SAND	45				gray fine SAND, trace laminae of fine silty sand and gray clay	Sand is loose pack h-nu = 0
		S-10	SS	3-7 10-11	49'	
LACUSTRINE Bottom of well	50				LACUSTRINE DEPOSITS	
		S-11	SS	2-6 12-17	gray CLAY, little fine sand and silt laminae	dense, h-nu = 0
Bottom of hole	55				55' END OF HOLE	
	60					
	65					
	70					
	75					
	80					
	85					
	90					
	95					

WESTON

TEST BORING LOG

BORING NO. B-1A

SHEET NO 1 **OF** 1

JOB NO. 06280519

ELEVATION 242.0

DATE STARTED 10-5-83

DATE FINISHED 10-5-83

DRILLER -Bill Canty

INSPECTOR S. Michelson

F.B. - 101

PROJECT : WESTOVER AFB - PHASE II IRP

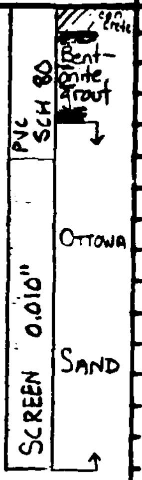
CLIENT : USAF-OEHL

BORING CONTRACTOR : D.L. MAHER

GROUND WATER :

DATE	TIME	WATER EL.	SCREEN

	CAS.	SAMP.	CORE	TUBE
TYPE				
DIA.				
WT.				
FALL				

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
	0					
					⊽ 2'8"	
	5					
	10					
	15				15' END OF HOLE	
	20					
	25					
	30					
	35					
	40					
	45					

WESTON

TEST BORING LOG

BORING NO. B-2

PROJECT :	WESTOVER AFB - PHASE II IRP
CLIENT :	USAF - OEHL
BORING CONTRACTOR :	D.L. MAHER
SHEET NO	1 **OF** 2
JOB NO.	06280519
ELEVATION	252.9
DATE STARTED	10-6-83
DATE FINISHED	10-7-83
DRILLER	BILL CANTY
INSPECTOR	S. MICHELSON
F.B. -	101

GROUND WATER :

DATE	TIME	WATER EL.	SCREEN		CAS.	SAMP.	CORE	TUBE
				TYPE		SS		
				DIA.		2"		
				WT.		140		
				FALL		30"		

WELL CONSTRUCTION			DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
DELTAIC		CONCRETE	0				DELTAIC DEPOSITS	
		BENTONITE SLURRY	5	S-1	SS	5-10 12-19	light brown fine SAND	damp. loose h-nu=0.5
			10	S-2	SS	4-8 12-20		loose, h-nu=0
			15	S-3	SS	3-9 30	brown fine to medium SAND trace^{+} silt ∇—15'	dense moist h-nu=0
DEPOSITS	PVC BLANK RISER SCH 80	BENTONITE	20	S-4	SS	6-13 20-24	brown medium to coarse SAND little^{-} Gravel, trace silt	saturated loose h-nu=0.5
			25	S-5	SS	9-11 13-14		water sample 100 µmho @ 16°C slight odor h-nu=0.5
		GROUT	30	S-6	SS	10-18 16-20	gray-brown fine to coarse SAND trace Gravel	loose
			35	S-7	SS	8-16 17-20	gray fine to medium SAND	slight odor h-nu=1.0
			40	S-8	SS	4-6 10-13		h-nu=0
		OTTOWA SAND	45	S-9	SS	3-7 9-10	gray fine^{+} to medium SAND trace Silt	h-nu=0.5 loose

WESTON DESIGNERS CONSULTANTS

TEST BORING LOG

BORING NO. B-2

PROJECT: Westover AFB - Phase II IRP

SHEET NO. 2 OF 2

CLIENT: USAF - OEHL

JOB NO. 06280519

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
DELTAIC DEPOSITS OTTOWA	45					
		S-10	SS			h-nu: 0.5
SAND	50					
SCREEN 0.010"		S-11	SS		gray medium to coarse SAND trace gravel	loose slight odor h-nu: 1.0
	55					
		S-12	SS		gray fine to medium SAND trace silt	loose hnu: 0.5
LACUSTRINE Bottom of well	60				60' LACUSTRINE DEPOSITS	
		S-13	SS		gray varve CLAY fine sandy silt laminae	h-nu: 0.5 dense
	65					
		S-14	SS		gray varve CLAY, fine sandy silt and fine sand laminae	h-nu: 0.5
	70				70' END OF HOLE	
	75					
	80					
	85					
	90					
	95					

WESTON

TEST BORING LOG

BORING NO. B-2A

SHEET NO 1 **OF** 1

JOB NO. 06280519

ELEVATION 752.6

DATE STARTED 10-7-83

DATE FINISHED 10-7-83

DRILLER Bill Canty

INSPECTOR S Michelson

F.R.# 101

PROJECT : Westover AFB - Phase II IRP

CLIENT : USAF - OEHL

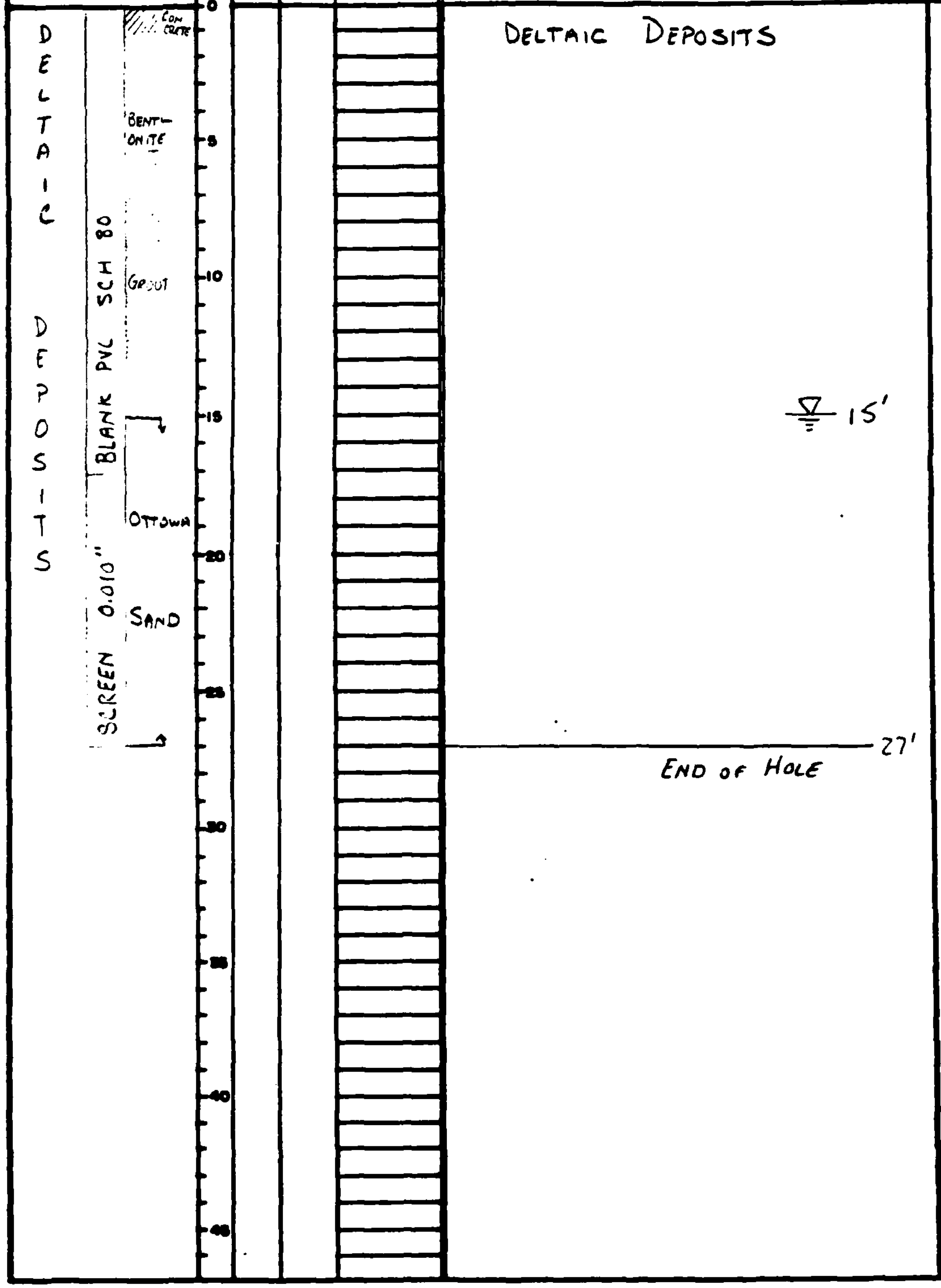
BORING CONTRACTOR : D.L. Maher

GROUND WATER :

DATE	TIME	WATER EL.	SCREEN

	CAS.	SAMP.	CORE	TUBE
TYPE				
DIA.				
WT.				
FALL				

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS



WESTON

PROJECT : Westover AFB- Phase II IRP	**TEST BORING LOG** **BORING NO.** B-3
CLIENT : USAF - OEHL	**SHEET NO** 1 **OF** 2
BORING CONTRACTOR : D.L. Maher	**JOB NO.** 06280519
	ELEVATION 248.5

GROUND WATER :

DATE	TIME	WATER EL.	SCREEN
-			

	CAS.	SAMP.	CORE	TUBE
TYPE		SS		
DIA.		2"		
WT.		140		
FALL		30"		

DATE STARTED 10-11-83
DATE FINISHED 10-12-83
DRILLER Bill Canty
INSPECTOR S. Michelson
F.B. #101

WELL CONSTRUCTION			DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
FILL		ON CRETE	0				FILL (no refuse)	NOT IN LANDFILL
		BENT-ONITE	5	S-1	SS	2-3 3-4	fine to medium SAND, tan trace- fine Gravel	Dry, loose h-nu=0.5
DELTAIC DEPOSITS			10	S-2	SS	3-15 30-R	▽ 10' DELTAIC DEPOSITS gray medium to coarse SAND trace Gravel	h-nu=0.5 organic Sand some slight [illegible] of decomposing organics [illegible] marsh, [illegible] have other [illegible] odors. loose
			15	S-3	SS	3-5 8-11		
	SCH 80	GROUT	20	S-4	SS	3-5 8-9	gray-brown medium to coarse SAND little fine to medium Gravel trace- Silt	loose, Spoon wash leaves chemical film sheen on water
			25	S-5	SS	1-3 4-8		organic odor h-nu=0.5
			30	S-6	SS	2-5 7-13	gray fine SAND	h-nu=0
			35	S-7	SS		gray-brown fine+ to medium SAND trace- Silt	slight odor h-nu=0 moderate pack
	BLANK PVC		40	S-8	SS	4-10 18-21	gray brown fine SAND trace- Silt	h-nu=0.5
			45	S-9	SS	5-9 9-13	gray fine+ to medium SAND trace- Silt	slight odor moderate pack h-nu=1.0

WESTON
DESIGNERS CONSULTANTS

TEST BORING LOG
BORING NO. B-3

PROJECT: WESTOVER AFB- PHASE II IRP
CLIENT: USAF - OEHL
SHEET NO. 2 **OF** 2
JOB NO. 06280519

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
DELTAIC DEPOSITS BLANK PVC RISER BENTONITE	45					
		S-10	SS	3-7 14-15	gray fine SAND trace- Silt	slight odor moderate pack h-nu=0
GROUT	50					
		S-11	SS	4-18 27-41		h-nu=0
	55					
OTTOWA		S-12	SS	8-14 19-24		
SCREEN 0.010	60					
SAND		S-13	SS	8-11 18-24		h-nu=0
	65					
LACUSTRINE		S-14	SS	8-11 15-21	69.5' LACUSTRINE DEPOSITS gray SANDY SILT laminations of fine to medium SAND, little Clay laminae 70' Bottom of Hole	h-nu=0.5 dense
	70					
	75					
	80					
	85					
	90					
	95					

WESTON

TEST BORING LOG

BORING NO. B-3A

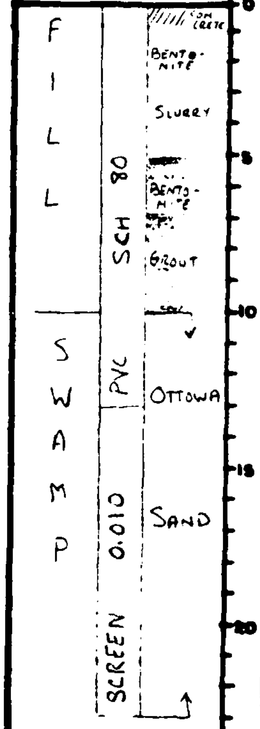
PROJECT : WESTOVER AFB- PHASE II IRP
CLIENT : USAF - OEHL
BORING CONTRACTOR : D.L. MAHER
SHEET NO 1 OF 1
JOB NO. 06280519
ELEVATION 248.2
DATE STARTED 10-12-83
DATE FINISHED 10-12-83
DRILLER BILL CAREY
INSPECTOR S. MICHELSON
F.B # 101

GROUND WATER :

DATE	TIME	WATER EL.	SCREEN

	CAS.	SAMP.	CORE	TUBE
TYPE				
DIA.				
WT.				
FALL				

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
	0					IN LANDFILL AUGER BROUGHT UP BURIED WASTE
	5					
	10				▽ 10'	
	15					
	20					
					23' END OF HOLE	
	25					
	30					
	35					
	40					
	45					



WESTON

TEST BORING LOG

BORING NO. B-4

PROJECT : WESTOVER AFB- PHASE II IRP
CLIENT : USAF - OEHL
BORING CONTRACTOR : D.L. MAHER

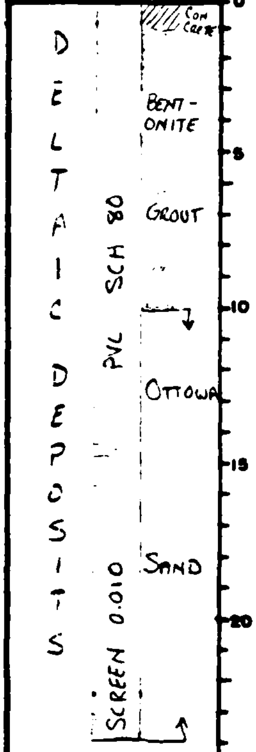
SHEET NO 1 **OF** 1									
JOB NO. 06-80514									
ELEVATION 251.0									

GROUND WATER :

DATE	TIME	WATER EL.	SCREEN		CAS.	SAMP.	CORE	TUBE
				TYPE		SS		
				DIA.		2"		
				WT.		140		
				FALL		30"		

DATE STARTED 10-7-83
DATE FINISHED 10-7-83
DRILLER BILL CANTY
INSPECTOR S. MICHELSON
F.B. # 101

WELL CONSTRUCTION



DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
0				DELTAIC DEPOSITS	
5	S-1	SS	3-6 4-5	brown fine to medium SAND trace Silt	damp, loose no odor h-nu= 0
10	S-2	SS	4-6 7-7	fine to coarse SAND ▽ 10'	moderate pack h-nu= 0.5
15	S-3	SS	13-22 16-20		water Sample 60 µmhos @ 22°C
20	S-4A S-4B	SS	9-17 23-30	fine to medium SAND, trace Silt	moderate pack h-nu= 0.5
	S-5	SS	11-19 31-38	medium to coarse SAND	very loose pack
25				25' Bottom of Hole	
30					
35					
40					
45					

WESTON

TEST BORING LOG

BORING NO. A-1

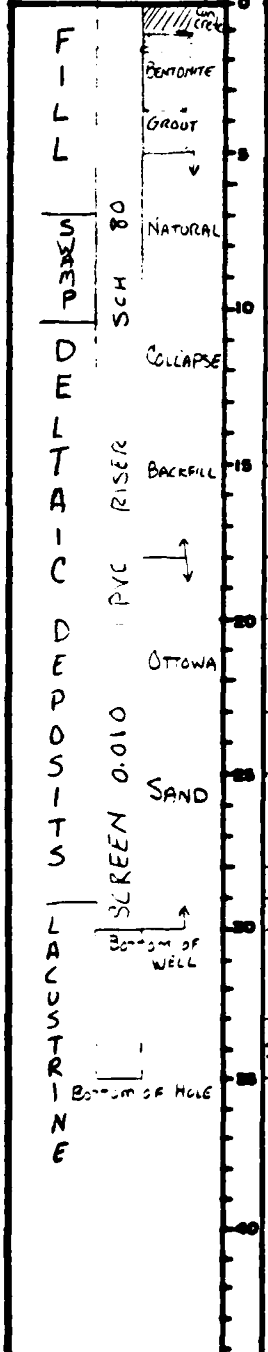
PROJECT :	Westover AFB - Phase II IRP
CLIENT :	USAF - OEHL
BORING CONTRACTOR :	D.L. Maher
SHEET NO	1 **OF** 1
JOB NO.	06280519
ELEVATION	234.9
DATE STARTED	10-14-83
DATE FINISHED	10-14-83
DRILLER	B. L. Canty
INSPECTOR	S. Michelson
F.B.#	101

GROUND WATER :

DATE	TIME	WATER EL.	SCREEN

	CAS.	SAMP.	CORE	TUBE
TYPE		SS		
DIA.		2"		
WT.		140		
FALL		30"		

WELL CONSTRUCTION



SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
			FILL	
S-1	SS	5-1 7-R	Ash, fine to coarse SAND ▽ - 6' 7'	burned material Dense h-nu = 0.5
			SWAMP DEPOSITS PEAT, fibers, fine Sand and Silt	h-nu = 0.5
S-2A S-2B	SS	3-5 11-14	grading to 10.5' DELTAIC DEPOSITS	h-nu = 0.5
S-3	SS	3-7 10-8	gray-brown fine to coarse SAND trace fine to medium Gravel trace Silt	dense h-nu = 0.5 water sample 70 µmhos 7.5°C
S-4	SS	3-11 13-17	lens of brown fine Sand trace+ Silt	
S-5	SS	7-16 26-21	brown fine SAND, little silt trace fine sandy silt and clay laminae	moderate pack
S-6A S-6B	SS	3-7 10-9	gray fine SAND, little Silt grading to 29' LACUSTRINE DEPOSITS	h-nu = 0
S-7	SS	4-9 11-4	gray-pink fine micaceous SAND, silt and silty clay laminae	dense
			35' BOTTOM OF HOLE	

WESTON

TEST BORING LOG

BORING NO. A-2

PROJECT : WESTOVER AFB - PHASE II IRP

CLIENT : USAF - OEHL

BORING CONTRACTOR : D.L. MAHER

SHEET NO 1 **OF** 1

JOB NO. 06280519

ELEVATION 235.7

DATE STARTED 10-14-88

DATE FINISHED 10-17-88

DRILLER B[illegible]

INSPECTOR S. [illegible]

F.B # 101

GROUND WATER :

DATE	TIME	WATER EL.	SCREEN

	CAS.	SAMP.	CORE	TUBE
TYPE		SS		
DIA.		2"		
WT.		140		
FALL		30"		

WELL CONSTRUCTION	DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	SAMPLE BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
DELTAIC DEPOSITS Con crete Bentonite Grout	0				DELTAIC DEPOSITS ▽ 4'	
Natural	5	S-1	SS	4-7 6-8	brown medium to coarse SAND little Gravel	loose, h-nu: 0
SCH 80 Collapse	10	S-2	SS	5-2 3-10	gray-brown fine to medium SAND	
Backfill		S-3	SS	4-6 7-11	trace+ Silt trace Clay laminae	moderate pack
PVC	15				- - - - - - - -	water Sample 33 μmhos @ 17.5°C
		S-4	SS	2-8 9-10	gray fine+ to medium SAND	moderate pack HNU ~ 0
Ottawa	20					
		S-5	SS	4-5 7-12	some iron staining gray fine SAND	
Sand	25					
SCREEN 0.010		S-6	SS	7-10 9-14		h-nu: 0
	30					
		S-7	SS	2-5 10-11		
	35	S-8	SS	4-7 11-9	some micaceous laminae	h-nu: 0
	40				40' Bottom of Hole	
	45					

WESTON

TEST BORING LOG

BORING NO. IW-1

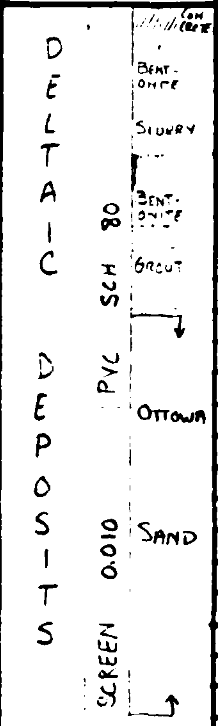
PROJECT : Westover AFB- Phase II IRP
CLIENT : USAF - OEHL
BORING CONTRACTOR : D.L. Maher
SHEET NO 1 **OF** 1
JOB NO. 06280519
ELEVATION 240.9
DATE STARTED 10-13-83
DATE FINISHED 10-13-83
DRILLER Bill Canty
INSPECTOR S. M[illegible]
F.B. # 101

GROUND WATER :

DATE	TIME	WATER EL.	SCREEN

	CAS.	SAMP.	CORE	TUBE
TYPE		SS		
DIA.		2"		
WT.		140		
FALL		30"		

WELL CONSTRUCTION



DEPTH FEET	SAMPLE NO.	SAMPLE TYPE	BLOWS PER 6 INCHES	CLASSIFICATION	REMARKS
0				DELTAIC DEPOSITS	
5	S-1	SS	1-4 4-5	tan medium SAND trace Gravel some laminations	damp, loose h-nu=0
10	S-2	SS	7-9 14-15	brown medium to coarse SAND and GRAVEL ▽ 12.5 laminae of fine gray Sand	hnu=0.5 moderate pack
	S-3	SS	5-10 14-19		
15					loose
	S-4	SS	4-8 11-12	gray-brown fine to medium SAND	water sample 75 μmhos @ 21°C h-nu = 0
20					
	S-5	SS	8-9 13-16	lens of brown fine SANDY SILT 25' END OF HOLE	
25					
30					
35					
40					
45					

APPENDIX E

Sampling and Quality Assurance Procedures

APPENDIX E

SAMPLING AND QA/QC PLANS

E-1.1 MONITORING WELL PURGING

All groundwater sampling was accomplished after the installed monitoring wells were properly developed and had stabilized for a period of at least two weeks. Prior to collecting samples, each well was purged by pumping a minimum of three volumes of standing water in the well using a Johnson-Keck submersible pump. This ensured that a representative sample of the aquifer is collected during the sampling process. The field procedures used for monitoring well purging included the following guidelines:

1. Prior to placing any equipment into the well, the equipment was scrubbed with Alconox (detergent) solution and rinsed with distilled water.

2. Before purging, the depth to water from the referenced measuring point on the top of the well casing was measured and recorded.

3. The volume of water to be purged based on the amount of standing water in the well casing was calculated.

4. The well was purged by pumping, removing at least three times the calculated volume of standing water in the well casing.

5. The pump was disconnected and removed from the well. The equipment was decontaminated by scrubbing with Alconox and flushed with deionized water.

6. The protective caps were secured.

E-1.2 MONITOR WELL SAMPLE COLLECTION

Groundwater sampling was directed towards the detection of:

1. Inorganic anions
2. Metals
3. Volatile Organics.
4. COD, TOC, and oil and grease.

All required sample containers and preservatives were prepared and supplied by WESTON Laboratories in accordance with standard U.S. EPA procedures and protocols.

After well purging, sampling activities consisted of the following procedures:

1. A 3/4 inch diameter, 4-foot long stainless steel and teflon bailer was decontaminated with Alconox and copious amounts of distilled water. The field filtering equipment consisting of a 0.45 micron-filter, filtration apparatus and vacuum lines were similarly decontaminated.

2. The cleaned bailer was slowly lowered into the well using a new, clean nylon rope and was allowed to fill with well water. The bailer was retrieved and emptied. This procedure was repeated three times. After the fourth bailer full, the well water sample was filtered in the field for only the metals through a 0.45 microfilter. Samples for all organic and anion analyses were recovered in similar fashion, but were not filtered.
   At surface water locations a plastic bucket was substituted for the bailer and was lowered into the stream. It was subjected to the same decontamination and rinsing procedures.

3. Each sample bottle was filled with an appropriate sample. The sample containers used were:

   - Volatile organics - two 40 ml septum seal glass vials (analyzed by EPA methods 601 and 602).

   - COD, TOC, Oil and Grease - one 1-liter amber glass bottle for each analyte.

   - Phenolics - one, 250 ml amber glass bottle preserved with $CuSO_4$ (copper sulfate) and H_3PO_4 (phosphoric acid).

   - Metals (Iron and Lead) - one, 1-liter plastic bottle preserved with nitric acid.

   - Anions CI^-, SO_4^- - one, 1-liter plastic bottle.

4. A grab sample was taken for immediate field measurement of temperature, pH, and conductivity.

5. The sample containers were wrapped in packaging material and placed in a thermal chest packed with enough ice to insure cooling to 4°C.

E-2.0 QUALITY ASSURANCE PLAN

WESTON Analytical Services enforces a rigid QA/QC program toward maintenance of validity and reliability of all analytical data. The Laboratory QA/QC Manual (Table of Contents thereof is Attachment No. 1 to this appendix) outlines the specifics of the QA/QC plan. This plan is patterned after the EPA Handbook for Analytical Quality Control in Water and Wastewater Laboratories (EPA-600/4-79-019, March 1979), augmented by general applicable experience and interaction with the QA/QC plan of the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). All methods and procedures followed by WESTOn are either USEPA or ASTM-approved. Any variations from such procedures, regardless of cause, are documented by the responsible analyst(s) and are documentable, and, literature-traceable. A general review of this QA/QC plan is in the following paragraphs.

Although specific QA/QC measures for each method are designated in WESTON's Laboratory Quality Assurance Manual, the general QA/QC program normally includes:

- EPA-acceptable sample preparation and analytical methods.
- Instrument calibration via use of Standard Analytical Reference Materials (SARMS).
- Regular equipment maintenance and servicing.
- Use of SARMS and QA/QC samples (spikes, laboratory blanks, replicates, and splits) to ascertain overall precision.
- Statistical evaluation of data to delineate acceptable limits.
- Documentation of system/operator performance.
- Suitable chain-of-custody procedures.
- Maintenance and archiving of all records, charts, and logs generated in the above.
- Proper reporting.

Acceptable analyses at WESTON's Analytical Laboratory Services include, but are not limited to, the above.

In general, WESTON's QA/QC sequence follows the following diagram (Figure E-1). Documentation (as available from instrument recordings and technicians' notebooks) is sufficient to validate each step in the sequence.

E.2.2 CONTAINER PREPARATION

Another consideration in this, or any, analytical project is that of sample container preparation. Accordingly, all appropriate sample bottles shall be cleaned in a manner mandated by the U.S. EPA to insure maximal cleanliness (and minimal contamination) before the containers go to the field. Sufficient bottles to accommodate both laboratory and field blank requirements will be preferred in a single batch mode for each monthly sampling requirement.

E.2.3 VERIFICATION/VALIDATION

In the laboratory, the analytical scheme begins with initial verification, which is comprised of:

- Lab Blanks - To insure that no background level of specific analytes is introduced by laboratory procedures.
- Standard Analytical Reference Materials (SARMS) - To determine the accuracy and precision of procedures.
- Spikes - To determine the percent recovery of analyte(s).

If the laboratory QA/QC program is extended to the field, it includes a fifth item:

- Field Blanks - To provide a check on contamination of containers and/or preservatives and to establish "practical" detection limits.

WESTON has used all of the above in this project. All data resulting from these verification media have been archived for future reference, retrieval, or processing. (QA/QC data from WESTON's above-described, internal QA/QC plan normally are not available to clientele without associated reimbursement to WESTON).

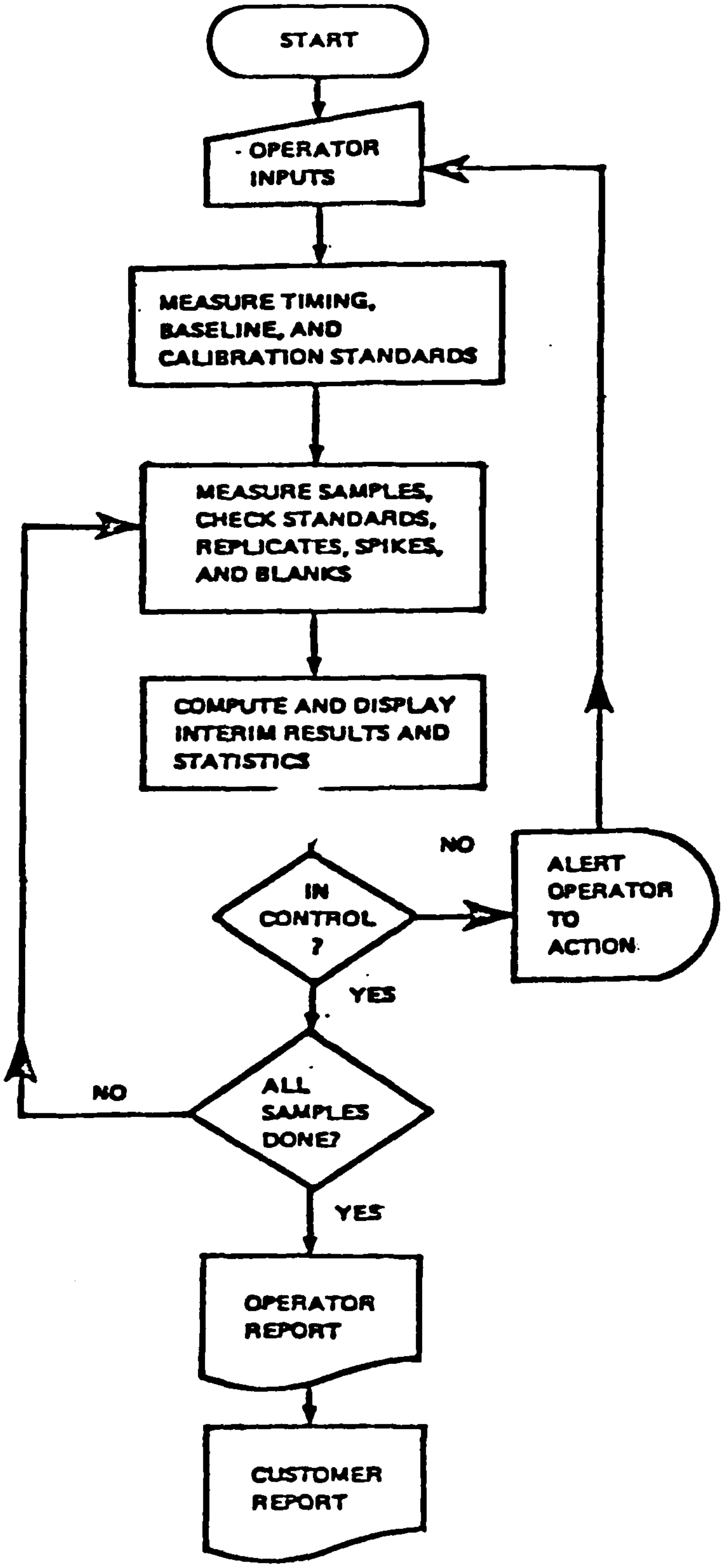


Figure E-1: Flow Chart of the Sequence of Events during a Controlled Series of Laboratory Measurements.

E.2.4 DATA HANDLING - LABORATORY

Use of any analytical data should be preceded by an assessment of its quality. The assessment should be based on accuracy, precision, completeness, representativeness, and comparability. These criteria are, in turn, assessed as follows:

- Accuracy - Is it acceptable for the planned use? QA/QC shall measure the accuracy of all data.

- Precision - Is it acceptable for the planned use? QA/QC shall reflect the reproducibility of the measurements.

- Completeness - Are the data sufficient for the planned use? QA/QC shall identify the quantity of data needed to match the goals.

- Representativeness -Do the data accurately reflect actual site conditions, sampling procedures, and analytical method? QA/QC shall ensure this.

- Comparability - Is the report self-consistent in format, units, and standardization of methods used to generate it? QA/QC shall ensure this.

Additionally, statistical methods outlined in the QA/QC program have been applicable to data evaluation.

The Laboratory Supervisor and the Laboratory QA/QC Officer have been responsible for the evaluation of the above criteria and for enforcement of analytical protocols that will necessarily lead to acceptable data quality. The signature of the Supervisor and QA/QC Officer accompany each laboratory analytical report and serve to ensure the overall validity of the reported data.

E.2.5 SAMPLE PLAN/LOG

Normal protocol demands client-and /or site-specific logging of all sample batches delivered to WESTON. Basic information -- such as client name, address, etc.; client phone number; reporting/invoicing instructions; site descriptions; and parameter-specifications and total requirements -- is initiated here. Additionally, sample storage/disposal instructions as well as turnaround requirements and sample collection requirements are addressed at this point.

The appropriate number of method blanks is also logged at this point, and in-house chain-of-custody documentation is initiated here.

E.2.6 SAMPLE RESULTS

WESTON's analytical protocols generally require five-point calibration curve plus a reagent blank s the basis for quantification analytes from a linear calibration curve. (A three-point plus blank curve vs. the original five point one is acceptable if it falls within the QA/QC requirements of ± 3 standard deviation of the original curve.) Linear regression analysis is then performed. Method- and detection limit-specific data are accessed for quantitation and report-writing from each such data set. For reporting accuracy, the algorithm

$$\frac{\begin{matrix}\text{Linear-Regressed}\\\text{Raw Concentration}\\\text{from Calibration Curve}\end{matrix}\quad\begin{matrix}\text{Solid Sample}\\\text{Extract Volume}\\\text{If Solid}\end{matrix}\quad\begin{matrix}\text{Concentration}\\\text{or}\\\text{Dilution Factor}\end{matrix}}{\begin{matrix}\text{Solid Sample}\\\text{Mass If Solid}\end{matrix}\quad\begin{matrix}\text{Fraction}\\\text{Solids If Solid}\end{matrix}} = \begin{matrix}\text{Final}\\\text{Concentration}\end{matrix}$$

is used for all quantitations. (All such algorithm input data are archived for long-term storage.) Detection limits for solids are generated on a per-sample basis and calculated by replacing "LINEAR-REGRESSED RAW CONCENTRATION FROM CALIBRATION CURVE" with "DETECTION LIMIT OF ANALYTE IN LIQUID MATRIX" in the above equation.

E.2.7 CHAIN-OF-CUSTODY

Since they document the history of samples, chain-of-custody procedures are a crucial part of a sampling/analysis program. Chain-of-custody documentation enables identification and tracking of a sample from collection to analysis to reporting.

WESTON's chain-of-custody program necessitates the use of EPA-approved sample labels, secure custody, and attendant recordkeeping. Depending on the client's requirements, WESTON also offers container sealing during unattended transportation of samples.

In essence, WESTON considers a sample in custody if it: is in a WESTON employee's physical possession; it is in view of that WESTON employee; is secured by that WESTON employee to prevent tampering; or is secured by that WESTON employee in an area that is restricted to authorized personnel.

Each time a sample is relinquished from one analyst to another or from one major location to another, WESTON's analytical personnel are required to make appropriate entries. Personnel-specific initials are used as identifiers of analysts, as are location codes for various locations (refrigerators, extraction areas, analytical areas, etc.) within the laboratory. Each transaction for each sample is accompanied by a specific reason for transfer. Chain-of-custody documentation is given in Appendix F.

E.2.8 QA/QC OFFICER

Toward maintenance of a rigid, credible QA/QC regimen, WESTON Analytical Services maintains a full-time, in-house QA/QC officer who retains independent authority to declare out-of-control situations, thereby precluding reporting of unacceptable data. The QA/QC officer has been available, as needed, on the project.

APPENDIX F

Chain-of-Custody Documentation

CHAIN OF CUSTODY RECORD

Shipper Name: JOSEPH R. ALTHOUSE

Address: WESTON WAY WESTCHESTER PA 19380
Number Street City State Zip

Collector's Name: JOSEPH R. ALTHOUSE **Telephone** (215) 692-3030

Address of Collection: WESTOVER A.F.B. 0628-05-19-00

Collector Sample Number	Date of Collection	Time of Collection	Collection Location	Analyses Requested
MW-1	11-8-83	9:00	B-1	COD, TOC, O/G, Phen, VOA, Fe, Pb, Cl
MW-1A		9:15	B-1A	SC
MW-3		10:05	B-3	
MW-3D		10:35	B-3 (DUPE.)	
MW-3A		11:00	B-3A	
MW-3A-D		11:45	B-3A (DUPE.)	

Sample Receiver:

1. ROY F. WESTON INC WESTCHESTER PA.
Name and address of organization receiving sample
2.
3.
4.

Chain of Possession:

1. Joseph R Althouse — Field Lead — 11-8 - 11/12
Signature — Title — Inclusive Dates
2. John C [illegible] — Data Management Coordinator — 11-12-83
Signature — Title — Inclusive Dates
3.
Signature — Title — Inclusive Dates
4.
Signature — Title — Inclusive Dates

CHAIN OF CUSTODY RECORD

Shipper Name: JOSEPH R. ALTHUSE

Address: WESTON WAY WESTCHESTER PA 19380
Number Street City State Zip

Collector's Name: JOSEPH R. ALTHUSE **Telephone** (215) 692-3030

Address of Collection: WESTOVER AFB 0628-05-19-01

Collector Sample Number	Date of Collection	Time of Collection	Collection Location	Analyses Requested
MW-4	11-8-83	1:30	B-4	COD, TOC, O/G, PHEN, VOA, Fe, Pb, Cl, S
MW-4D		3:10	B-4 (DUPE)	
MW-2	11-9-83	8:35	B-2	
MW-2-D		9:20	B-2 (DUPE)	
MW-2A		9:45	B-2A	
A-1		10:30	A-1	
A-2		12:10	A-2	

Sample Receiver:

1. ROY F. WESTON INC
Name and address of organization receiving sample
2.
3.
4.

Chain of Possession:

Signature	Title	Inclusive Dates
1. Joseph R. Althuse	Field Tech	11-8 - 11/12
2. John C. [illegible]	Data Management Coordinator	11-12-83
3.		
4.		

CHAIN OF CUSTODY RECORD

Shipper Name: JOSEPH R. ALTHOUSE

Address: WESTON WAY WESTCHESTER PA 19380
Number Street City State Zip

Collector's Name: JOSEPH R. ALTHOUSE **Telephone** (215) 692-3030

Address of Collection: WESTOVER AFB 0628-05-19-00

Collector Sample Number	Date of Collection	Time of Collection	Collection Location	Analyses Requested
A-2D	11-9-83	1:00	A-2 (DUPE.)	COD, TOC, O/G, Phen, VOA, Fe, Pb, Cl, SO4
PCL-1	↓	1:40.	Sludge Tank	← O/G only
POL-1	↓	1:50	Wel (IW-1)	← O/G only
SG-1	↓	2:35	Stream	COD, TOC, O/G, Phen, VOA, Fe, Pb, Cl, SO4
SG-2	↓	3:00	Stream	↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓
SG-4	↓	3:45	Stream (SG-3)	↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓

Sample Receiver:

1. Roy F. WESTON INC
Name and address of organization receiving sample
2.
3.
4.

Chain of Possession:

1. Joseph R. Althouse — Field Tech. — 11/8 - 11/12
Signature Title Inclusive Dates
2. John C. Holmes — Data Management Coordinator — 11-12-83
Signature Title Inclusive Dates
3.
Signature Title Inclusive Dates
4.
Signature Title Inclusive Dates

APPENDIX G

Standard Laboratory Analytical Protocols

CHEMICAL OXYGEN DEMAND

Method 410.4 (Colorimetric, Automated; Manual)

STORET NO. 00340

1. Scope and Application

   1.1 This method covers the determination of COD in surface waters, domestic and industrial wastes.

   1.2 The applicable range of the automated method is 3–900 mg/1 and the range of the manual method is 20 to 900 mg/1.

2. Summary of Method

   2.1 Sample, blanks and standards in sealed tubes are heated in an oven or block digestor in the presence of dichromate at 150°C. After two hours, the tubes are removed from the oven or digestor, cooled and measured spectrophotometrically at 600 nm.

3. Sample Handling and Preservation

   3.1 Collect the samples in glass bottles if possible. Use of plastic containers is permissible if it is known that no organic contaminants are present in the containers.

   3.2 Samples should be preserved with sulfuric acid to a pH < 2 and maintained at 4°C until analysis.

4. Interferences

   4.1 Chlorides are quantitatively oxidized by dichromate and represent a positive interference. Mercuric sulfate is added to the digestion tubes to complex the chlorides.

5. Apparatus

   5.1 Drying oven or block digestor, 150°C

   5.2 Corning culture tubes, 16 x 100 mm or 25 x 150 mm with Teflon lined screw cap

   5.3 Spectrophotometer or Technicon AutoAnalyzer

   5.4 Muffle furnace, 500°C.

6. Reagents 10.216g (for high level: 100-1000ppm)

   6.1 Digestion solution: Add 10.2 g $K_2Cr_2O_7$, 167 ml conc. H_2SO_4 and 33.3 g $HgSO_4$ to 500 ml of distilled water, cool and dilute to 1 liter. (1.0216g $K_2Cr_2O_7$ for low level: 10-100ppm

   6.2 Catalyst solution: Add 22 g Ag_2SO_4 to a 4.09kg bottle of conc. H_2SO_4. Stir until dissolved.

   6.3 Sampler wash solution: Add 500 ml of conc H_2SO_4 to 500 ml of distilled water.

   6.4 Stock potassium acid phthalate: Dissolve 0.850 g in 800 ml of distilled water and dilute to 1 liter. 1 ml = 1 mg COD

      6.4.1 Prepare a series of standard solutions that cover the expected sample concentrations by diluting appropriate volumes of the stock standard.

7. Procedure

   7.1 Wash all culture tubes and screw caps with 20% H_2SO_4 before their first use to prevent contamination. Trace contamination may be removed from the tubes by igniting them in a muffle oven at 500°C for 1 hour.

Issued 1978

7.2 Automated

7.2.1 Add 2.5 ml of sample to the 16 x 100 mm tubes.

7.2.2 Add 1.5 ml of digestion solution (6.1) and mix.

7.2.3 Add 3.5 ml of catalyst solution (6.2) carefully down the side of the culture tube.

7.2.4 Cap tightly and shake to mix layers.

7.2.5 Process standards and blanks exactly as the samples.

7.2.6 Place in oven or block digestor at 150°C for two hours.

7.2.7 Cool, and place standards in sampler in order of decreasing concentration. Complete filling sampler tray with unknown samples.

7.2.8 Measure color intensity on AutoAnalyzer at 600 nm.

7.3 Manual

7.3.1 The following procedure may be used if a larger sample is desired or a spectrophotometer is used in place of an AutoAnalyzer.

7.3.2 Add 10 ml of sample to 25 x 150 mm culture tube.

7.3.3 Add 6 ml of digestion solution (6.1) and mix.

7.3.4 Add 14 ml of catalyst solution (6.2) down the side of culture tube.

7.3.5 Cap tightly and shake to mix layers.

7.3.6 Place in oven or block digestor at 150°C for 2 hours.

7.3.7 Cool, allow any precipitate to settle and measure intensity in spectrophotometer at 600 nm. Use only optically matched culture tubes or a single cell for spectrophotometric measurement.

8. Calculation

8.1 Prepare a standard curve by plotting peak height or percent transmittance against known concentrations of standards.

8.2 Compute concentration of samples by comparing sample response to standard curve.

9. Precision and Accuracy

9.1 Precision and accuracy data are not available at this time.

Bibliography

1. Jirka, A. M., and M. J. Carter, "Micro-Semi-Automated Analysis of Surface and Wastewaters for Chemical Oxygen Demand." Anal. Chem. 47:1397, (1975).

10
Std: 25 100
50 250
75 500
100 750
900

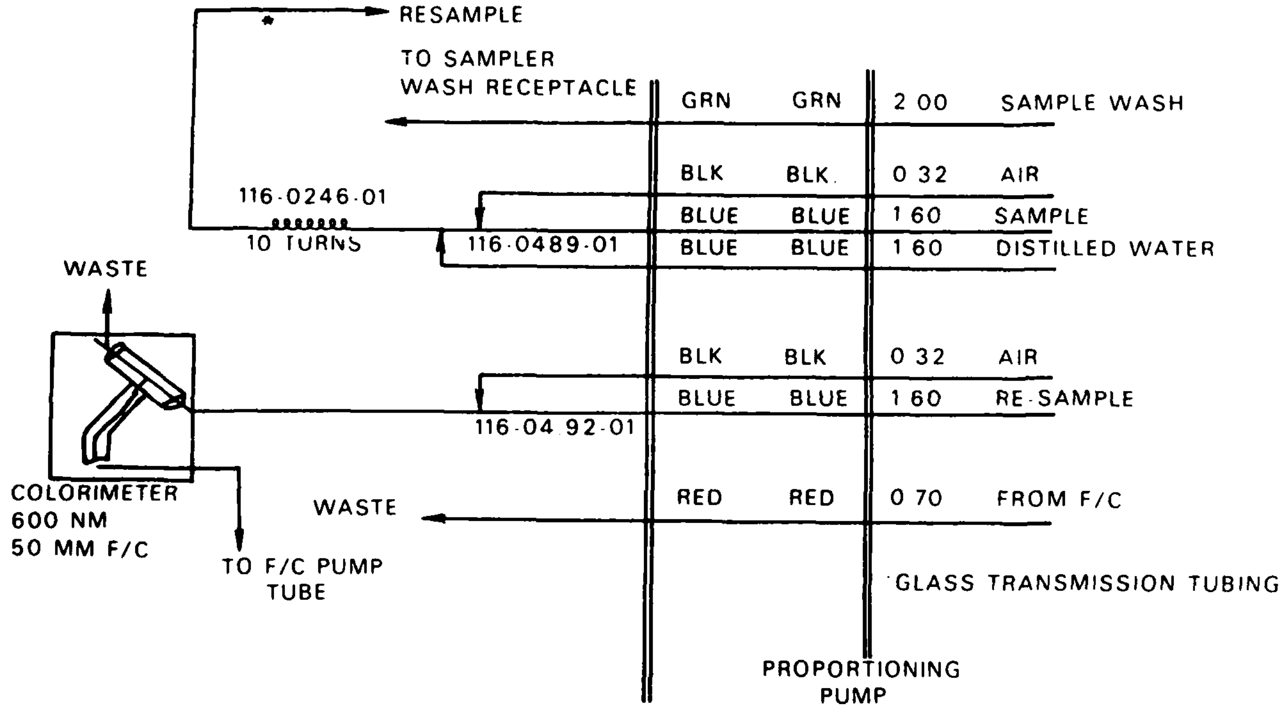


FIGURE 1 C O D MANIFOLD AA1 OR AA 11

ORGANIC CARBON, TOTAL

Method 415.1 (Combustion or Oxidation)

STORET NO. Total 00680
Dissolved 00681

1. Scope and Application
   1.1 This method includes the measurement of organic carbon in drinking, surface and saline waters, domestic and industrial wastes. Exclusions are noted under Definitions and Interferences.
   1.2 The method is most applicable to measurement of organic carbon above 1 mg/1.
2. Summary of Method
   2.1 Organic carbon in a sample is converted to carbon dioxide (CO_2) by catalytic combustion or wet chemical oxidation. The CO_2 formed can be measured directly by an infrared detector or converted to methane (CH_4) and measured by a flame ionization detector. The amount of CO_2 or CH_4 is directly proportional to the concentration of carbonaceous material in the sample.
3. Definitions
   3.1 The carbonaceous analyzer measures all of the carbon in a sample. Because of various properties of carbon-containing compounds in liquid samples, preliminary treatment of the sample prior to analysis dictates the definition of the carbon as it is measured. Forms of carbon that are measured by the method are:
      A) soluble, nonvolatile organic carbon; for instance, natural sugars.
      B) soluble, volatile organic carbon; for instance, mercaptans.
      C) insoluble, partially volatile carbon; for instance, oils.
      D) insoluble, particulate carbonaceous materials, for instance; cellulose fibers.
      E) soluble or insoluble carbonaceous materials adsorbed or entrapped on insoluble inorganic suspended matter; for instance, oily matter adsorbed on silt particles.
   3.2 The final usefulness of the carbon measurement is in assessing the potential oxygen-demanding load of organic material on a receiving stream. This statement applies whether the carbon measurement is made on a sewage plant effluent, industrial waste, or on water taken directly from the stream. In this light, carbonate and bicarbonate carbon are not a part of the oxygen demand in the stream and therefore should be discounted in the final calculation or removed prior to analysis. The manner of preliminary treatment of the sample and instrument settings defines the types of carbon which are measured. Instrument manufacturer's instructions should be followed.

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4. Sample Handling and Preservation

4.1 Sampling and storage of samples in glass bottles is preferable. Sampling and storage in plastic bottles such as conventional polyethylene and cubitainers is permissible if it is established that the containers do not contribute contaminating organics to the samples.
NOTE 1: A brief study performed in the EPA Laboratory indicated that distilled water stored in new, one quart cubitainers did not show any increase in organic carbon after two weeks exposure.

4.2 Because of the possibility of oxidation or bacterial decomposition of some components of aqueous samples, the lapse of time between collection of samples and start of analysis should be kept to a minimum. Also, samples should be kept cool (4°C) and protected from sunlight and atmospheric oxygen.

4.3 In instances where analysis cannot be performed within two hours (2 hours) from time of sampling, the sample is acidified ($pH \leq 2$) with HCl or H_2SO_4.

5. Interferences

5.1 Carbonate and bicarbonate carbon represent an interference under the terms of this test and must be removed or accounted for in the final calculation.

5.2 This procedure is applicable only to homogeneous samples which can be injected into the apparatus reproducibly by means of a microliter type syringe or pipette. The openings of the syringe or pipette limit the maximum size of particles which may be included in the sample.

6. Apparatus

6.1 Apparatus for blending or homogenizing samples: Generally, a Waring-type blender is satisfactory.

6.2 Apparatus for total and dissolved organic carbon:

6.2.1 A number of companies manufacture systems for measuring carbonaceous material in liquid samples. Considerations should be made as to the types of samples to be analyzed, the expected concentration range, and forms of carbon to be measured.

6.2.2 No specific analyzer is recommended as superior.

7. Reagents

7.1 Distilled water used in preparation of standards and for dilution of samples should be ultra pure to reduce the carbon concentration of the blank. Carbon dioxide-free, double distilled water is recommended. Ion exchanged waters are not recommended because of the possibilities of contamination with organic materials from the resins.

7.2 Potassium hydrogen phthalate, stock solution, 1000 mg carbon/liter: Dissolve 0.2128 g of potassium hydrogen phthalate (Primary Standard Grade) in distilled water and dilute to 100.0 ml.

NOTE 2: Sodium oxalate and acetic acid are not recommended as stock solutions.

7.3 Potassium hydrogen phthalate, standard solutions: Prepare standard solutions from the stock solution by dilution with distilled water.

7.4 Carbonate-bicarbonate, stock solution, 1000 mg carbon/liter: Weigh 0.3500 g of sodium bicarbonate and 0.4418 g of sodium carbonate and transfer both to the same 100 ml volumetric flask. Dissolve with distilled water.

7.5 Carbonate-bicarbonate, standard solution: Prepare a series of standards similar to step 7.3.

NOTE 3: This standard is not required by some instruments.

7.6 Blank solution: Use the same distilled water (or similar quality water) used for the preparation of the standard solutions.

8. Procedure

8.1 Follow instrument manufacturer's instructions for calibration, procedure, and calculations.

8.2 For calibration of the instrument, it is recommended that a series of standards encompassing the expected concentration range of the samples be used.

9. Precision and Accuracy

9.1 Twenty-eight analysts in twenty-one laboratories analyzed distilled water solutions containing exact increments of oxidizable organic compounds, with the following results:

Increment as TOC mg/liter	Precision as Standard Deviation TOC, mg/liter	Accuracy as	
		Bias, %	Bias, mg/liter
4.9	3.93	+15.27	+0.75
107	8.32	+ 1.01	+1.08

(FWPCA Method Study 3, Demand Analyses)

Bibliography

1. Annual Book of ASTM Standards, Part 31, "Water", Standard D 2574–79, p 469 (1976).
2. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 532, Method 505, (1975).

OIL AND GREASE, TOTAL RECOVERABLE

Method 413.2 (Spectrophotometric, Infrared)

STORET NO. 00560

1. Scope and Application
    1.1 This method includes the measurement of fluorocarbon-113 extractable matter from surface and saline waters, industrial and domestic wastes. It is applicable to the determination of hydrocarbons, vegetable oils, animal fats, waxes, soaps, greases and related matter.
    1.2 The method is applicable to measurement of most light petroleum fuels, although loss of about half of any gasoline present during the extraction manipulations can be expected.
    1.3 The method covers the range from 0.2 to 1000 mg/1 of extractable material.
    1.4 While this method can be used to obtain an estimate of the oil and grease that would be measured gravimetrically, in many cases the estimate more accurately describes the parameter, as it will measure volatiles more effectively and is not susceptible to interferences such as extractable sulfur. It can be used with the Petroleum Hydrocarbon procedure to obtain an oil and grease value and a petroleum hydrocarbon value on the same sample.
2. Summary of Method
    2.1 The sample is acidified to a low pH (<2) and extracted with fluorocarbon-113. The oil and grease is determined by comparison of the infrared absorbance of the sample extract with standards.
3. Definitions
    3.1 The definition of oil and grease is based on the procedure used. The source of the oil and/or grease, and the presence of extractable non-oily matter will influence the material measured and interpretation of results.
4. Sampling and Storage
    4.1 A representative sample of 1 liter volume should be collected in a glass bottle. If analysis is to be delayed for more than a few hours, the sample is preserved by the addition of 5 ml HCl (6.1) at the time of collection and refrigerated at 4°C.
    4.2 Because losses of grease will occur on sampling equipment, the collection of a composite sample is impractical. Individual portions collected at prescribed time intervals must be analyzed separately to obtain the average concentration over an extended period.
5. Apparatus
    5.1 Separatory funnel, 2000 ml, with Teflon stopcock.
    5.2 Infrared spectrophotometer, scanning. Non-scanning instruments may also be used but can be subject to positive interferences in complex chemical wastewaters.
    5.3 Cells, 10 mm, 50 mm, and 100 mm path length, sodium chloride or infrared grade glass.
    5.4 Filter paper, Whatman No. 40, 11 cm.

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6. Reagents

6.1 Hydrochloric acid, 1:1. Mix equal volumes of conc. HCl and distilled water.

6.2 Fluorocarbon-113, (1,1,2-trichloro-1,2,2-trifluoroethane), b. p. 48°C.

6.3 Sodium sulfate, anhydrous crystal.

6.4 Calibration mixtures:

6.4.1 Reference oil: Pipet 15.0 ml n-hexadecane, 15.0 ml isooctane, and 10.0 ml chlorobenzene into a 50 ml glass stoppered bottle. Maintain the integrity of the mixture by keeping stoppered except when withdrawing aliquots.

6.4.2 Stock standard: Pipet 1.0 ml reference oil (6.4.1) into a tared 200 ml volumetric flask and immediately stopper. Weigh and dilute to volume with fluorocarbon-113.

6.4.3 Working standards: Pipet appropriate volumes of stock standard (6.4.2) into 100 ml volumetric flasks according to the cell pathlength to be used. Dilute to volume with fluorocarbon-113. Calculate concentration of standards from the stock standard.

7. Procedure

7.1 Mark the sample bottle at the water meniscus for later determination of sample volume. If the sample was not acidified at time of collection, add 5 ml hydrochloric acid (6.1) to the sample bottle. After mixing the sample, check the pH by touching pH-sensitive paper to the cap to insure that the pH is 2 or lower. Add more acid if necessary.

7.2 Pour the sample into a separatory funnel.

7.3 Add 30 ml fluorocarbon-113 (6.2) to the sample bottle and rotate the bottle to rinse the sides. Transfer the solvent into the separatory funnel. Extract by shaking vigorously for 2 minutes. Allow the layers to separate.

7.4 Filter the solvent layer into a 100 ml volumetric flask through a funnel containing solvent-moistened filter paper.

NOTE: An emulsion that fails to dissipate can be broken by pouring about 1 g sodium sulfate (6.3) into the filter paper cone and slowly draining the emulsion through the salt. Additional 1 g portions can be added to the cone as required.

7.5 Repeat (7.3 and 7.4) twice more with 30 ml portions of fresh solvent, combining all solvent in the volumetric flask.

7.6 Rinse the tip of the separatory funnel, filter paper, and the funnel with a total of 5–10 ml fluorocarbon-113 and collect the rinsings in the flask. Dilute the extract to 100 ml, and stopper the flask.

7.7 Select appropriate working standards and cell pathlength according to the following table of approximate working ranges:

Pathlength	Range
10 mm	2–40 mg
50 mm	0.4–8 mg
100 mm	0.1–4 mg

7.8 Scan standards and samples from 3200 cm^{-1} to 2700 cm^{-1} with fluorocarbon-113 in the reference beam and record the results on absorbance paper. The absorbances of samples and standards are measured by constructing a straight baseline over the range of the scan and measuring the absorbance of the peak maximum at 2930 cm^{-1} and subtracting the baseline absorbance at that point. For an example of a typical oil spectrum and baseline construction, see Gruenfeld(3). Non-scanning instruments should be operated according to manufacturer's instructions, although calibration must be performed using the standards described above (6.4). If the absorbance exceeds 0.8 for a sample, select a shorter pathlength or dilute as required.

7.9 Use a calibration plot of absorbance vs. mg oil prepared from the standards to determine the mg oil in the sample solution.

8. Calculation

8.1 mg/l total oil and grease $= \frac{R \times D}{V}$

where:

R = oil in solution, determined from calibration plot, in milligrams.
D = extract dilution factor, if used.
V = volume of sample, determined by refilling sample bottle to calibration line and correcting for acid addition if necessary, in liters.

9. Precision and Accuracy

9.1 The two oil and grease methods in this manual were tested by a single laboratory (EMSL) on sewage. This method determined the oil and grease level in the sewage to be 17.5 mg/l. When 1 liter portions of the sewage were dosed with 14.0 mg of a mixture of #2 fuel oil and Wesson oil, the recovery was 99% with a standard deviation of ±1.4 mg/l.

Bibliography

1. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 516, Method 502B, (1975).
2. American Petroleum Institute, "Manual on Disposal of Refinery Wastes", Vol. IV, Method 733-58 (1958).
3. Gruenfeld, M., "Extraction of Dispersed Oils from Water for Quantitative Analysis by Infrared Spectroscopy", Environ. Sci. Technol. 7, 636 (1973).

PHENOLICS, TOTAL RECOVERABLE

Method 420.1 (Spectrophotometric, Manual 4-AAP with Distillation)

STORET NO. 32730

1. Scope and Application
   1.1 This method is applicable to the analysis of drinking, surface and saline waters, domestic and industrial wastes.
   1.2 The method is capable of measuring phenolic materials at the 5 ug/l level when the colored end product is extracted and concentrated in a solvent phase using phenol as a standard.
   1.3 The method is capable of measuring phenolic materials that contain more than 50 ug/l in the aqueous phase (without solvent extraction) using phenol as a standard.
   1.4 It is not possible to use this method to differentiate between different kinds of phenols.
2. Summary of Method
   2.1 Phenolic materials react with 4-aminoantipyrine in the presence of potassium ferricyanide at a pH of 10 to form a stable reddish-brown colored antipyrine dye. The amount of color produced is a function of the concentration of phenolic material.
3. Comments
   3.1 For most samples a preliminary distillation is required to remove interfering materials.
   3.2 Color response of phenolic materials with 4-amino antipyrine is not the same for all compounds. Because phenolic type wastes usually contain a variety of phenols, it is not possible to duplicate a mixture of phenols to be used as a standard. For this reason phenol has been selected as a standard and any color produced by the reaction of other phenolic compounds is reported as phenol. This value will represent the minimum concentration of phenolic compounds present in the sample.
4. Sample Handling and Preservation
   4.1 Biological degradation is inhibited by the addition of 1 g/l of copper sulfate to the sample and acidification to a pH of less than 4 with phosphoric acid. The sample should be kept at 4°C and analyzed within 24 hours after collection.
5. Interference
   5.1 Interferences from sulfur compounds are eliminated by acidifying the sample to a pH of less than 4 with H_3PO_4 and aerating briefly by stirring and adding $CuSO_4$.
   5.2 Oxidizing agents such as chlorine, detected by the liberation of iodine upon acidification in the presence of potassium iodide, are removed immediately after sampling by the addition of an excess of ferrous ammonium sulfate (~~6.5~~ 7.5). If chlorine is not removed, the phenolic compounds may be partially oxidized and the results may be low.

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6. Apparatus

6.1 Distillation apparatus, all glass consisting of a 1 liter pyrex distilling apparatus with Graham condenser.
6.2 pH meter.
6.3 Spectrophotometer, for use at 460 or 510 nm.
6.4 Funnels.
6.5 Filter paper.
6.6 Membrane filters.
6.7 Separatory funnels, 500 or 1,000 ml.
6.8 Nessler tubes, short or long form.

7. Reagents

7.1 Phosphoric acid solution, 1 + 9: Dilute 10 ml of 85% H_3PO_4 to 100 ml with distilled water.
7.2 Copper sulfate solution: Dissolve 100 g $CuSO_4 \cdot 5H_2O$ in distilled water and dilute to 1 liter.
7.3 Buffer solution: Dissolve 16.9 g NH_4Cl in 143 ml conc. NH_4OH and dilute to 250 ml with distilled water. Two ml should adjust 100 ml of distillate to pH 10.
7.4 Aminoantipyrine solution: Dissolve 2 g of 4AAP in distilled water and dilute to 100 ml.
7.5 Potassium ferricyanide solution: Dissolve 8 g of $K_3Fe(CN)_6$ in distilled water and dilute to 100 ml.
7.6 Stock phenol solution: Dissolve ~~1.0 g~~ 1.00g phenol in freshly boiled and cooled distilled water and dilute to 1 liter. 1 ml = 1 mg phenol.
7.7 Working solution A: Dilute 10 ml stock phenol solution to 1 liter with distilled water. 1 ml = 10 ug phenol.
7.8 Working solution B: Dilute 100 ml of working solution A to 1000 ml with distilled water. 1 ml = 1 ug phenol.
7.9 Chloroform

8. Procedure

8.1 Distillation

8.1.1 Measure 500 ml sample into a beaker. Lower the pH to approximately 4 with 1 + 9 H_3PO_4 (7.1), add 5 ml $CuSO_4$ solution (7.2) and transfer to the distillation apparatus. Omit adding H_3PO_4 and $CuSO_4$ if sample was preserved as described in 4.1.
8.1.2 Distill 450 ml of sample, stop the distillation, and when boiling ceases add 50 ml of warm distilled water to the flask and resume distillation until 500 ml have been collected.
8.1.3 If the distillate is turbid, filter through a prewashed membrane filter.

8.2 Direct photometric method

8.2.1 Using working solution A (7.7), prepare the following standards in 100 ml volumetric flasks.

ml of working solution A	Conc. *ug/l*
0	0.0
0.5	50.0
1.0	100.0
2.0	200.0
5.0	500.0
8.0	800.0
10.0	1000.0

8.2.2 To 100 ml of distillate or an aliquot diluted to 100 ml and/or standards, add 2 ml of buffer solution (7.3) and mix. The pH of the sample and standards should be 10 ±0.2.

8.2.3 Add 2.0 ml aminoantipyrine solution (7.4) and mix.

8.2.4 Add 2.0 ml potassium ferricyanide solution (7.5) and mix.

8.2.5 After 15 minutes read absorbance at 510 *nm*.

8.3 Chloroform extraction method

8.3.1 Using working solution B (7.8), prepare the following standards. Standards may be prepared by pipetting the required volumes into the separatory funnels and diluting to 500 ml with distilled water.

ml of working solution B	Conc. ug/l
0.0	0.0
3.0	6.0
5.0	10.0
10.0	20.0
20.0	40.0
25.0	50.0

8.3.2 Place 500 ml of distillate or an aliquot diluted to 500 ml in a separatory funnel. The sample should not contain more than 25 *ug* phenol.

8.3.3 To sample and standards add 10 ml of buffer solution (7.3) and mix. The pH should be 10 ±0.2.

8.3.4 Add 3.0 ml aminoantipyrine solution (7.4) and mix.

8.3.5 Add 3.0 ml potassium ferricyanide solution (7.5) and mix.

8.3.6 After three minutes, extract with 25 ml of chloroform (7.9). Shake the separatory funnel at least 10 times, let $CHCl_3$ settle, shake again 10 times and let chloroform settle again.

8.3.7 Filter chloroform extracts through filter paper. Do not add more chloroform.

8.3.8 Read the absorbance of the samples and standards against the blank at 460 nm.

9. Calculation

9.1 Prepare a standard curve by plotting the absorbance value of standards versus the corresponding phenol concentrations.

9.2 Obtain concentration value of sample directly from standard curve.

10. Precision and Accuracy

10.1 Using the extraction procedure for concentration of color, six laboratories analyzed samples at concentrations of 9.6, 48.3, and 93.5 ug/l. Standard deviations were ±0.99, ±3.1 and ±4.2 ug/l, respectively.

10.2 Using the direct photometric procedure, six laboratories analyzed samples at concentrations of 4.7, 48.2 and 97.0 mg/l. Standard deviations were ±0.18, ±0.48 and ±1.58 mg/l, respectively.

Bibliography

1. Annual Book of ASTM Standards, Part 31, "Water", Standard D1783–70, p553 (1976).
2. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p574–581, Method 510 through 510C, (1975).

Appendix IV.—Inductively Coupled Plasma Optical Emission Spectrometric Method (ICP) for Trace Element Analysis of Water and Wastes

Inductively Coupled Plasma (ICP) Optical Emission Spectrometric Method for Trace Element Analysis of Water and Wastes

Interim

U.S. Environmental Protection Agency,
Environmental Monitoring and Support
Laboratory, Cincinnati, Ohio 45268

October 1979.

Foreword

This method has been prepared by the staff of the Environmental Monitoring and Support Laboratory—Cincinnati, with the cooperation of the EPA–ICP Users Group. Their cooperation and support is gratefully acknowledged.

This method represents the current state-of-the-art, but as time progresses, improvements are anticipated. Users are encouraged to identify problems and assist in updating the method by contacting the Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268.

Inductively Coupled Plasma (ICP) Optical Emission Spectrometric Method for Trace Element Analysis of Water and Wastes

1. Scope and Application.

1.1 This method may be used for the determination of dissolved, suspended, or total elements in surface water, drinking water, and domestic and industrial wastewaters.

1.2 Dissolved elements are determined in filtered and acidified samples. Appropriate steps must be taken to ensure that potential interference are taken into account when dissolved solids exceed 1500 mg/l. (See 4.2)

1.3 Total elements are determined after appropriate digestion procedures are performed. Since digestion techniques increase the dissolved solids content of the samples, appropriate steps *must* be taken to correct for potential interference effects.

1.4 Table 1 lists elements for which this method applies along with recommended wavelengths and typical estimated instrumental detection limits. Actual working detection limits are sample dependent and as the sample matrix varies, these concentrations may also vary. In time, other elements may be added as more information becomes available.

1.5 Because of the differences between various makes and models of satisfactory instruments, no detailed instrumental operating instructions can be provided. Instead, the analyst is referred to the instructions provided by the manufacturer of the particular instrument.

Table 1—*Recommended Wavelengths* [1] and Estimated Instrumental Detection Limits

Element	Wavelength, nm	Estimated detection limit, μg/l [2]
Aluminum	308.2	45
Arsenic	193.7	53
Barium	455.5	2
Beryllium	313.0	0.3
Boron	249.8	5
Cadmium	226.5	4
Calcium	317.9	10
Chromium	267.7	7
Cobalt	228.6	7
Copper	324.7	6
Iron	259.9	7
Lead	220.3	42
Lithium	670.7	4
Magnesium	279.1	30
Manganese	257.6	2
Molybdenum	202.0	8
Nickel	231.6	15
Potassium	766.4	see [3]
Selenium	196.0	75
Silica (SiO$_2$)	288.1	27
Silver	328.0	7
Sodium	588.0	29
Strontium	407.7	0.5
Vanadium	292.4	8
Zinc	213.8	2

[1] The wavelengths listed are recommended because of their sensitivity and overall acceptance. Other wavelengths may be substituted if they can proved the needed sensitivity and are treated with the same corrective techniques for spectral interference. (See 4.1.1).

[2] The estimated instrumental detection limits as shown are taken from "Inductively Coupled Plasma-Optical Emission Spectroscopy Prominent Lines," EPA-600/4-79-017. Detection limits are sample dependent and as the sample matrix varies, these concentration values may also vary.

[3] Highly dependent on operating conditions and plasma position.

2. Summary of Method.

2.1 The method describes a technique for the simultaneous of sequential multielement determination of trace elements in solution. The basis of the method is the measurement of atomic emission by an optical spectroscopic technique. Samples are nebulized and the aerosol that is produced is transported to the plasma torch where excitation occurs. Characteristic atomic-line emission spectra are produced by a radio-frequency inductively coupled plasma (ICP). The spectra are dispersed by a grating spectrometer and the intensities of the lines are monitored by photomultiplier tubes. The photocurrents from the photomultiplier tubes are processed and controlled by a computer system. A background correction technique is required to compensate for variable background contribution to the determination of trace elements. Background must be measured adjacent to analyte lines on samples during analysis. Additional interferences named in 4.1 should also be recognized and appropriate corrections made.

3. Definitions.

3.1 *Dissolved*—Those elements which will pass through a 0.45 μm membrane filter.

3.2 *Suspended*—Those elements which are retained by a 0.45 μm membrane filter.

3.3 *Total*—The concentration determined on an unfiltered sample following vigorous digestion (Section 8.3), or the sum of the dissolved plus suspended concentrations (Section 8.1 plus 8.2).

3.4 *Total recoverable*—The concentration determined on an unfiltered sample following treatment with hot, dilute mineral acid (Section 8.4).

3.5 *Instrumental detection limit*—The concentration equivalent to a signal, due to the analyte, which is equal to three times the standard deviation of a series of ten replicate measurements of a reagent blank signal at the same wavelength.

3.6 *Sensitivity*—The slope of the analytical curve, i.e. funtional relationship between emission intensity and concentration.

3.7 *Instrument check standard*—A multielement standard of known concentrations prepared by the analyst. Should be included in the analytical scheme with a frequency of 10%. (See 6.6.1.)

3.8 *Reference standard*—A solution obtained from an outside source having known, verified values. Must be used initially to verify the calibration standards and analyzed thereafter as a blind sample on a weekly frequency. (See 6.6.2.)

3.9 *Calibration standards*—A series of known standard solutions used by the analyst for calibration of the instrument (i.e., preparation of the analytical curve). (See 6.4.)

3.10 *Linear dynamic range*—The concentration range over which the analytical curve remains linear.

3.11 *Reagent blank*—A volume of deionized, distilled water containing the same acid matrix as the calibration standards carried through the entire analytical scheme. (See 6.5.2.)

3.12 *Calibration blank*—A volume of deionized, distilled water acidified with HNO_3 and HCl. (See 6.5.1.)

3.13 *Method of standard addition*—The standard addition technique involves the use of the unknown and the unknown plus a known amount of standard. (See 9.6.1.)

4. Interferences.

4.1 Several types of interference effects may contribute to inaccuracies in the determination of trace elements. They can be summarized as follows:

4.1.1 *Spectral interferences* can be categorized as (1) overlap of a spectral line from another element; (2) unresolved overlap of molecular band spectra; (3) background contribution from continuous or recombination phenomena; and (4) background contribution from stray light from the line emission of high concentration elements. The first of these effects can be compensated by utilizing a computer correction of the raw data, requiring measurement of the interfering element. The second effect may require selection of an alternate wavelength. The third and fourth effects can usually be compensated by a background correction adjacent to the analyte line.

4.1.2 *Physical interferences* are generally considered to be effects associated with the sample nebulization and transport processes. Such properties as change in viscosity and surface tension can cause significant inaccuracies especially in samples which may contain high dissolved solids and/or acid concentrations. (See Note 1.) If these types of interferences are operative, they must be reduced by dilution of the sample and/or utilization of standard addition techniques.

Note 1.—The use of a peristaltic pump may lessen these interferences.

4.1.3 *Chemical interferences* are characterized by molecular compound formation, ionization effects and solute vaporization effects. Normally these effects are not pronounced with the ICP technique, however, if observed they can be minimized by careful selection of operating conditions (that is, incident power, observation position, and so forth), by buffering of the sample, by matrix matching, and by standard addition procedures. These types of interferences can be highly dependent on matrix type and the specific analyte element.

4.2 It is recommended that whenever a new or unusual sample matrix is encountered, a series of tests be performed prior to reporting concentration data for analyte elements. These tests, as outlined in 4.2.1 through 4.2.4, will ensure the analyst that neither positive nor negative interference effects are operative on any of the analyte elements thereby distorting the accuracy of the reported values.

4.2.1 *Serial dilution*—If the analyte concentration is sufficiently high (minimally a factor of 10 above the instrumental detection limit after dilution), an analysis of a dilution should agree within 5 percent of the original determination (or within some acceptable control limit (13.3) that has been established for that matrix). If not, a chemical or physical interference effect should be suspected.

4.2.2 *Spike addition*—The recovery of a spike addition added at a minimum level of 10X the instrumental detection limit (maximum 100X) to the original determination should be recovered to within 90 to 110 percent or within the established control limit for that matrix. If not, a matrix effect should be suspected. The use of a standard addition analysis procedure can usually compensate for this effect.

Caution.—*The standard addition technique does not detect coincident spectral overlap. If suspected, use of an alternate wavelength or comparison with an alternate method is recommended (See 4.2.3).*

4.2.3 *Comparison with alternate method of analysis*—When investigating a new sample matrix, comparison tests may be performed with other analytical techniques such as atomic absorption spectrometry, or other approved methodology.

4.2.4 *Wavelength scanning of analyte line region*—If the appropriate equipment is available, wavelength scanning can be performed to detect potential spectral interferences.

5. Apparatus.

5.1 Inductively Coupled Plasma (ICP) Optical Emission Spectrometer.

5.1.1 Computer controlled atomic emission spectrometer with background correction.

5.1.2 Radiofrequency generator.

5.1.3 Argon gas supply, welding grade or better.

5.2 Operating conditions—Because of the differences between various makes and models of satisfactory instruments, no detailed operating instructions can be provided. Instead, the analyst should follow the instructions provided by the manufacturer of the particular instrument. Sensitivity, instrumental detection limit, precision, linear dynamic range, and interference effects must be investigated and established for each individual analyte line on that particular instrument.

6. Reagents and standards.

6.1 Acids used in the preparation of standards and for sample processing must be ultra-high purity grade or equivalent. Redistilled acids are acceptable.

6.1.1 *Acetic acid*, conc. (sp gr 1.06).

6.1.2 *Aqua regia:* Mix cautiously 3 parts conc. HCl (sp gr 1.19) and 1 part conc. HNO_3 (sp gr 1.41) just before use.

6.1.3 *Hydrochloric acid*, conc. (sp gr 1.19).

6.1.4 *Hydrochloric acid*, (1+1): Add 500 ml conc. HCl (sp gr 1.19) to 400 ml deionized, distilled water and dilute to 1 liter.

6.1.5 *Nitric acid*, conc. (sp gr 1.41).

6.1.6 *Nitric acid*, (1+1): Add 500 ml conc. HNO_3 (sp gr 1.41) to 400 ml deionized, distilled water and dilute to 1 liter.

6.2 *Deionized, distilled water:* Prepare by passing distilled water through a mixed bed of cation and anion exchange resins. Use deionized, distilled water for the preparation of all reagents, calibration standards and as dilution water.

6.3 *Standard stock solutions* may be purchased or prepared from ultra high purity grade chemicals or metals

(Caution: See Note 2). All salts must be dried for 1 h at 105° C unless otherwise specified.

Note 2.—Many metal salts are extremely toxic and may be fatal if swallowed. Wash hands thoroughly after handling.

Typical stock solution preparation procedures follow:

6.3.1 *Aluminum solution, stock,* 1 ml=100 μg Al: Dissolve 0.100 g of aluminum metal in an acid mixture of 4 ml of (1+1) HCl and 1 ml of conc. HNO_3 in a beaker. Warm gently to effect solution. When solution is complete, transfer quantitatively to a liter flask, add an additional 10 ml of (1+1) HCl and dilute to 1,000 ml with deionized, distilled water.

6.3.2 *Arsenic solution, stock,* 1 ml=100 μg As: Dissolve 0.1320 g of As_2O_3 in 100 ml of deionized, distilled water containing 0.4 g NaOH. Acidify the solution with 2 ml conc. NHO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.3 *Barium solution, stock,* 1 ml=100 μg Ba: Dissolve 0.1516 g $BaCl_2$ in 10 ml deionized, distilled water with 1 ml (1+1) HCl. Add 10.0 ml (1+1) HCl and dilute to 1,000 ml with deionized, distilled water.

6.3.4 *Beryllium solution, stock,* 1 *ml=100 μg Be: Dissolve 1.127 g* $Be_4O(C_2H_3O_2)_6$, beryllium acetate basic, in a minimum amount of conc. acetic acid. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.5 *Boron solution, stock,* 1 ml=100 μg B: Dissolve 0.5716 g anhydrous H_3BO_3 in deionized, distilled water and dilute to 1,000 ml. Because H_3BO_3 loses weight on drying at 105° C, use a reagent meeting ACS specifications and keep the bottle tightly stoppered to prevent the entrance of atmospheric moisture.

6.3.6 *Cadmium solution, stock,* 1 ml=100 μg Cd: Dissolve 0.1142 g CdO in a minimum amount of (1+1) HNO_3. Heat to increase rate of dissolution. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.7 *Calcium solution, stock,* 1 ml=100 μg Ca: Suspend 0.2498 g $CaCO_3$ dried at 180° C for 1 h before weighing in deionized, distilled water and dissolve cautiously with a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.8 *Chromium solution, stock,* 1 ml=100 μg Cr: Dissolve 0.1923 g of CrO_3 in deionized, distilled water. When solution is complete, acidify with 10 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.9 *Cobalt solution, stock,* 1 *ml*=100 μg Co: Dissolve 0.1407 g Co_3O_4 in a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.10 *Copper solution, stock,* 1 ml=100 μg Cu: Dissolve 0.1252 g CuO in a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.11 *Iron solution, stock,* 1 ml=100 μg Fe: Dissolve 0.1430 g Fe_2O_3 in 10 ml deionized, distilled water with 1 ml (1+1) HCl. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.12 *Lead solution, stock,* 1 ml=100 μg Pb: Dissolve 0.1599 g $Pb(NO_3)_2$ in a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.13 *Lithium solution, stock,* 1 ml=100 μg Li: Dissolve 0.5323 g Li_2CO_3 slowly in a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.14 *Magnesium solution, stock,* 1 ml=100 μg Mg: Dissolve 0.1658 g MgO in a minimum amount of (1+1) HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.15 *Manganese solution, stock,* 1 ml=100 μg Mn: Dissolve 0.5225 g $Mn(NO_3)_2<6H_2O$ (do not dry) in *deionized, distilled water. Add 10.0 ml* conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.16 *Molybdenum solution, stock,* 1 ml = 100 μg Mo: Dissolve 0.2043 g $(NH_4)_2MoO_4$ in deionized, distilled water and dilute to 1,000 ml.

6.3.17 *Nickel solution, stock,* 1 ml = 100 μg Ni: Dissolve 0.4953 g $Ni(NO_3)_2<6H_2O$ in deionized, distilled water. Add 10 ml of conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.18 *Potassium solution, stock,* 1 ml = 100 μg K: Dissolve 0.1907 g KCl, dried at 110° C, in deionized, distilled water dilute to 1,000 ml.

6.3.19 *Selenium solution, stock,* 1 ml = 100 μg Se: Dissolve 0.1727 g H_2SeO_3 in deionized, distilled water and dilute to 1,000 ml.

6.3.20 *Silica solution, stock,* 1 ml = 100 μg SiO_2: *Do not dry.* Dissolve 0.4730 g $Na_2SiO_3<9H_2O$ in deionized, distilled water. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.21 *Silver solution, stock,* 1 ml = 1 μg Ag: Dissolve 0.1575 g $AgNO_3$ in 100 ml of deionized, distilled water and 10 ml conc. HNO_3. Dilute to 1,000 ml with deionized, distilled water.

6.3.22 *Sodium solution, stock,* 1 ml = 100 μg Na: Dissolve 0.2542 g NaCl in deionized, distilled water. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water

6.3.23 *Strontium solution, stock,* 1 ml = 100 μg Sr: Dissolve 0.2416 g $Sr(NO_3)_2$ in deionized, distilled water. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.24 *Vanadium solution, stock,* 1 ml = 100 μg V: Dissolve 0.2297 NH_4VO_3 in a minimum amount of conc. HNO_3. Heat to increase rate of dissolution. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.3.25 *Zinc solution, stock,* 1 ml = 100 μg Zn: Dissolve 0.1245 g ZnO in a minimum amount of dilute HNO_3. Add 10.0 ml conc. HNO_3 and dilute to 1,000 ml with deionized, distilled water.

6.4 *Mixed calibration standard solutions*—Prepared mixed calibration standard solutions by combining appropriate volumes of the stock solutions in volumetric flasks. (See 6.4.1 thru 6.4.6) Add 2 ml of (1+1) HNO_3 and 2 ml of (1+1) HCl and dilute to 100 ml with deionized, distilled water. Prior to preparing the mixed standards, each stock solution should be analyzed separately to determine possible spectral interference. Care should be taken when preparing the mixed standards that the elements are compatible and stable. Transfer the mixed standard solutions to a TFE fluorocarbon bottle for storage. Fresh mixed standards should be prepared weekly. Some typical combinations follow:

6.4.1 *Mixed standard solution I*—Iron, manganese, cadmium, lead, and zinc.

6.4.2 *Mixed standard solution II*—Beryllium, copper, strontium, vanadium, and cobalt.

6.4.3 *Mixed standard solution III*—Molybdenum, silica, lithium, and barium.

6.4.4 *Mixed standard solution IV*—Calcium, magnesium, sodium, and potassium.

6.4.5 *Mixed standard solution V*—Aluminum, arsenic, boron, chromium, nickel, and selenium.

6.4.6 *Mixed standard solution Vi*—Silver.

6.5 Two types of blanks are required for the analysis. The calibration blank (3.12) is used in establishing the analytical curve while the reagent blank (3.11) is used to correct for possible contamination resulting from varying amounts of the acids used in the sample processing.

6.5.1 *The calibration blank* is prepared by diluting 2 ml of (1 + 1) HNO_3 and 2 ml of (1 + 1) HCl to 100 ml with deionized, distilled water. Prepare a sufficient quantity to be used to flush the system between standards and samples.

6.5.2 *The reagent blank* must contain all the reagents and in the same volumes as used in the processing of the samples. The reagent blank must be carried through the complete procedure and contain the same acid concentration in the final solution as the sample solution used for analysis.

6.6 In addition to the calibration standards, an instrument check standard (3.7) and a reference standard (3.8) are also required for the analyses.

6.6.1 *The instrument check standard* is prepared by the analyst by combining compatible elements at a concentration equivalent to the midpoint of their respective calibration curves. This standard should be included in the analytical scheme with a frequency of 10%.

6.6.2 *The reference standard* should be prepared according to the instructions provided by the supplier. Following initial verification of the calibration standards, analyze weekly.

7. Sample handling and preservation.

7.1 For the determination of trace elements, contamination and loss are of prime concern. Dust in the laboratory environment, impurities in reagents and impurities on laboratory apparatus which the sample contacts are all sources of potential contamination. Sample containers can introduce either positive or negative errors in the measurement of trace elements by (a) contributing contaminants through leaching or surface desorption and (b) by depleting concentrations through adsorption. Thus the collection and treatment of the sample prior to analysis requires particular attention. Laboratory glassware including the sample bottle (whether linear polyethylene, polyproplyene or TFE-fluorocarbon) should be thoroughly washed with detergent and tap water; rinsed with (1+1) nitric acid, tap water, (1+1) hydrochloric acid, tap and finally deionized, distilled water in that order. (See Notes 3 and 4).

Note 3.—*Chromic acid may be useful to remove organic deposits from glassware; however, the analyst should be cautioned that the glassware must be thoroughly rinsed with water to remove the last traces of chromium. This is especially important if chromium is to be included in the analytical scheme. A commercial product, NOCHROMIX, available from Godax Laboratories, 6 Varick St., New York, NY 10013, may be used in place of chromic acid. Chromic acid should not be used with plastic bottles.*

Note 4.—If it can be documented through an active analytical quality control program using spiked samples and reagent blanks, that certain steps in the cleaning procedure are not required for routine samples, those steps may be eliminated from the procedure.

7.2 Before collection of the sample a decision must be made as to the type of data desired, that is dissolved, suspended or total, so that the appropriate preservation and pretreatment steps may be accomplished. Filtration, acid preservation, etc., are to be performed at the time the sample is collected or as soon as possible thereafter.

7.2.1 For the determination of dissolved elements the sample must be filtered through a 0.45-µm membrane filter as soon as practical after collection. (Glass or plastic filtering apparatus is recommended to avoid possible contamination.) Use the first 50–100 ml to rinse the filter flask. Discard this portion and collect the required volume of filtrate. Acidify the filtrate with (1+1) HNO_3 to a pH of 2 or less. Normally, 3 ml of (1+1) acid per liter should be sufficient to preserve the sample.

7.2.2 For the determination of suspended elements a measured volume of unpreserved sample must be filtered through a 0.45-µm membrane filter as soon as practical after collection. The filter plus suspended material should be transferred to a suitable container for storage and/or shipment. No preservative is required.

7.2.3 For the determination of total or total recoverable elements, the sample is acidified with 5 ml conc. HNO_3 per liter (pH 2) as soon as possible, preferably at the time of collection. The sample is not filtered before processing.

8. Sample Preparation.

8.1 For the determinations of dissolved elements, the filtered, preserved sample may often be analyzed as received. The acid matrix and concentration of the samples and calibration standards must be the same. If a precipitate formed upon acidification of the sample or during transit or storage, it must be redissolved before the analysis by adding additional acid and/or by heat as described in 8.3.

8.2 For the determinaton of suspended elements, transfer the membrane filter containing the insoluble material to a 250-ml Griffin beaker and add 3 ml conc. HNO_3. Cover the beaker with a watch glass and heat gently. The warm acid will soon dissolve the membrane. Increase the temperature of the hot plate and digest the material. When the acid has nearly evaporated, cool the beaker and watch glass and add another 3 ml of conc. HNO_3. Cover and continue heating until the digestion is complete, generally indicated by a light colored digestate. Evaporate to near dryness (DO NOT BAKE), cool, add 2 ml of (1+1) HNO_3 and 2 ml HCl (1+1) per 100 ml dilution and warm the beaker gently to dissolve any soluble material. Wash down the watch glass and beaker walls with deionized distilled water and filter the sample to remove insoluble material that could clog the nebulizer. Adjust the volume based on the expected concentrations of elements present. This volume will vary depending on the elements to be determined. The sample is now ready for analysis. Concentrations so determined shall be reported as "suspended."

8.3 For the determination of total elements, choose a measured, volume of the well mixed acid preserved sample appropriate for the expected level of elements and transfer to a Griffin beaker. (See Note 5.) Add 3 ml of conc HNO_3. Place the beaker on a hot plate and evaporate to near dryness cautiously, making certain that the sample does not boil. (DO NOT BAKE.) Cool the beaker and add another 3 ml portion of conc. HNO_3. Cover the beaker with a watch glass and return to the hot plate. Increase the temperature of the hot plate so that a gentle reflux action occurs. Continue heating, adding additional acid as necessary, until the digestion is complete (generally indicated when the digestate is light in color or does not change in appearance with continued refluxing.) Again, evaporate to near dryness and cool the beaker. Add 2 ml of 1+1 HNO_3 and 2 ml of 1+1 HCl per 100 ml of final solution and warm the beaker to dissolve any precipitate or residue resulting from evaporation. Wash down the beaker walls and watch glass with deionized distilled water and filter the sample to remove insoluble material that could clog the nebulizer. Adjust the volume based on the expected concentrations of elements present. The sample is now ready for analysis. Concentrations so determined shall be reported as "total."

Note 5.—*If low determinations of boron are critical, quartz glassware should be used.*

8.4 For the determination of total recoverable elements, choose a measured volume of a well mixed, acid preserved sample appropriate for the expected level of elements and transfer to a Griffin beaker. (See Note 5.) Add 1 ml of HNO_3 (1+1) and 2 ml of HCl (1+1) to the sample and heat on a steam bath or hot plate until the volume has been reduced to 15–20 ml making certain the sample does not boil. After this treatment the sample is filtered to remove insoluble material that could clog the nebulizer, and the volume adjusted to 100 ml. The sample is then ready for analysis. Concentrations so determined shall be reported as "total."

9. Procedure.

9.1 Set up instrument with proper operating parameters established in Section 5.2. Instrument must be allowed to stabilize for at least 30 min prior to operations.

9.2 Initiate appropriaate operating configuration of computer.

9.3 Profile and calibrate instrument according to instrument manufacturer's recommended procedures, using the typical mixed calibration standard solutions described in Section 6.4. Flush the system with the calibration blank (6.5.1) between each standard. (See note 6.) (The use of the average intensity of multiple exposures for both standardization and sample analysis has been found to reduce random error.)

NOTE 6.—For boron concentrations greater than 500 µg/l extended flush times of 1 to 2 minutes may be required.

9.4 Before beginning the sample run, reanalyze the highest mixed calibration standard as if it were a sample. Concentration values obtained should not deviate from the actual values by more than 2 percent (or the established control limits). If they do, follow the recommendations of the instrument manufacturer to correct for this condition.

9.5 Begin the sample run flushing the system with the calibration blank (6.5.1) between each sample. (See Note 6.) Analyze an instrument check standard (6.6.1) each 10 samples.

9.6 If it has been found that methods of standard addition are required, the following procedure is recommended.

9.6.1 The standard addition technique (13.2) involves preparing new standards in the sample matrix by adding known amounts of standard to one or more aliquots of the processed sample solution. This technique compensates for a sample constituent that enhances or depresses the analyte signal thus producing a different slope from that of the calibration standards. It will not correct for additive intererence which causes a baseline shift. The simplest version of this technique is the single-addition method. The procedure is as follows. Two identical aliquots of the sample solution, each of volume V_x, are taken. To the first (labeled A) is added a small volume V_s of a standared analyte solution of concentration c_s. To the second (labeled B) is added the same volume V_s of the solvent. The analytical signals of A and B are measured and corrected for nonanalyte signals. The unknown sample concentration c_x is calculated:

$$C_x = \frac{S_B V_s c_s}{(S_A - S_B)\, V_x}$$

where S_A and S_B are the analytical signals (corrected for the blank) of solutions A and B, respectively. V_s and c_s should be chosen so that S_A is roughly twice S_B on the average. It is best if V_s is made much less than V_x, and thus c_s is much greater than c_x, to avoid excess dilution of the sample matrix. If a separation or concentration step is used, the additions are best made first and carried through the entire procedure. For the results from this technique to be valid, the following limitations must be taken into consideration:

1. The analytical curve must be linear.
2. The chemical form of the analyte added must respond the same as the analyte in the sample.
3. The interference effect must be constant over the working range of concern.
4. The signal must be corrected for any additive interference.

10. *Calculation.*

10.1 Reagent blanks (6.5.2) should be subtracted from all samples. This is particularly important for digested samples requiring large quantities of acids to complete the digestion.

10.2 If dilutions were performed, the appropriate factor must be applied to sample values.

10.3 Results should be reported to the nearest µg/l, up to three significant figures, except calcium, magnesium, sodium, and potassium which are reported to the nearest 0.1 mg/l.

11. Quality Control (Instrumental).

11.1 Check the instrument standardization by analyzing appropriate quality control check standards as follow:

11.1.1 Analyze the instrument check standard (6.6.1) made up of all the elements of interest at a frequency of 10%. This check standard is used to determine instrument drift. If agreement is not within ± 2% of the expected values or within the established control limits, the analysis is out of control.

11.1.2 For the purpose of verifying interelement and/or background correction factors, analyze a second check standard, prepared in the following manner. Select a representative sample which contains minimal concentrations of the elements of interest. Spike this sample with the analytes of interest at or near 100 µg/l. (For effluent samples of expected high concentrations, spike at an appropriate level.) Values should fall within the established control levels of 1.5 times the standard deviation of the mean value of the check standard. If not, repeat the standardization.

11.1.3 A reference standard (6.6.2) from an outside source, but having known concentration values, should be analyzed as a blind sample on a weekly frequency. Values should be within the established quality control limits. If not, prepare new stock standards.

12. *Precision and Accuracy.*

12.1 In an EPA round phase 1 study, seven laboratories applied the ICP technique to acid-distilled water matrices that had been dosed with various metal concentrates. Table II lists the true value, the mean reported value and the mean % relative standard deviation.

Table II.—*ICP Precision and Accuracy Data*

Element	Sample No. 1			Sample No. 2			Sample No. 3		
	True value µg/l	Mean reported value µg/l	Mean percent RSD	True value µg/l	Mean reported value µg/l	Mean percent RSD	True value µg/l	Mean reported value µg/l	Mean percent RSD
Be	750	733	0.2	20	20	9.8	180	176	5.2
Mn	350	345	2.7	15	15	6.7	100	99	3.3
V	750	749	1.8	70	69	2.9	170	169	1.1
As	200	208	7.5	22	19	23	60	63	17
Cr	150	149	3.8	10	10	18	50	50	3.3
Cu	250	235	5.1	11	11	40	70	67	7.9
Fe	600	594	3.0	20	19	15	180	178	6.0
Al	700	696	5.6	60	62	33	160	161	13
Cd	50	48	12	2.5	2.9	16	14	13	16
Co	500	512	10	20	20	4.1	120	108	21
Ni	250	245	5.8	30	28	11	60	55	14
Pb	250	236	16	24	30	32	80	80	14
Zn	200	201	5.6	16	19	45	80	82	9.4
Se	40	32	21.9	6	8.5	42	10	8.5	8.3

Not all elements were analyzed by all laboratories.

13. References.

13.1 Winge, R. K., V. J. Peterson, and V. A. Fassel. "Inductively Coupled Plasma-Optical Emission Spectroscopy: *Prominent Lines*. EPA-600/4-79-017.

13.2 Winefordner, J. D., "Trace Analysis: Spectroscopic Methods for Elements." *Chemical Analysis*. Vol. 46, pp. 41-42.

13.3 Handbook for Analytical Quality Control in Water and Wastewater Laboratories. EPA-600/4-79-019.

13.4 Carbarino, J. R. and Taylor, H. E. "An Inductively-Coupled Plasma Optical Emission Spectrometric Method for Routine *Water Quality Testing*." Applied Spectroscopy 33, No. 3 (1979).

13.5 "Methods for Chemical Analysis of Water and Wastes." EPA-600/4-79-020.

LEAD

Method 239.2 (Atomic Absorption, furnace technique)

STORET NO. Total 01051
Dissolved 01049
Suspended 01050

Optimum Concentration Range: 5–100 ug/1
Detection Limit: 1 ug/1

Preparation of Standard Solution

1. Stock solution: Prepare as described under "direct aspiration method".
2. Lanthanum Nitrate Solution: Dissolve 58.64 g of ACS reagent grade La_2O_3 in 100 ml conc. HNO_3 and dilute to 1000 ml with deionized distilled water. 1 ml = 50 mg La.
3. Working Lead Solution: Prepare dilutions of the stock lead solution to be used as calibration standards at the time of analysis. Each calibration standard should contain 0.5% (v/v) HNO_3. To each 100 ml of diluted standard add 10 ml of the lanthanum nitrate solution.

Sample Preservation

1. For sample handling and preservation, see part 4.1 of the Atomic Absorption Methods section of this manual.

Sample Preparation

1. Prepare as described under "direct aspiration method". Sample solutions for analysis should contain 0.5% (v/v) HNO_3.
2. To each 100 ml of prepared sample solution add 10 ml of the lanthanum nitrate solution.

Instrument Parameters (General)

1. Drying Time and Temp: 30 sec–125°C.
2. Ashing Time and Temp: 30 sec–500°C.
3. Atomizing Time and Temp: 10 sec–2700°C.
4. Purge Gas Atmosphere: Argon
5. Wavelength: 283.3 nm
6. Other operating parameters should be set as specified by the particular instrument manufacturer.

Analysis Procedure

1. For the analysis procedure in the calculation see "Furnace Procedure", part 9.3 of the Atomic Absorption Methods section of this manual.

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Notes

1. The above concentration values and instrument conditions are for a Perkin-Elmer HGA-2100, based on the use of a 20 ul injection, continuous flow purge gas and non-pyrolytic graphite. Smaller size furnace devices or those employing faster rates of atomization can be operated using lower atomization temperatures for shorter time periods than the above recommended settings.
2. The use of background correction is recommended.
3. Greater sensitivity can be achieved using the 217.0 nm line, but the optimum concentration range is reduced. The use of a lead electrodeless discharge lamp at this lower wavelength has been found to be advantageous. Also a lower atomization temperature (2400°C) may be preferred.
4. To suppress sulfate interference (up to 1500 ppm) lanthanum is added as the nitrate to both samples and calibration standards. (Atomic Absorption Newsletter Vol. 15, No. 3, p 71, May-June 1976.)
5. Since glassware contamination is a severe problem in lead analysis, all glassware should be cleaned immediately prior to use, and once cleaned, should not be open to the atmosphere except when necessary.
6. For every sample matrix analyzed, verification is necessary to determine that method of standard addition is not required (see part 5.2.1 of the Atomic Absorption Methods section of this manual).
7. For quality control requirements and optional recommendations for use in drinking water analyses, see part 10 of the Atomic Absorption Methods section of this manual.
8. If method of standard addition is required, follow the procedure given earlier in part 8.5 of the Atomic Absorption Methods section of this manual.
9. Data to be entered into STORET must be reported as ug/1.

Precision and Accuracy

1. In a single laboratory (EMSL), using Cincinnati, Ohio tap water spiked at concentrations of 25, 50, and 100 ug Pb/1, the standard deviations were ±1.3, ±1.6, and ±3.7, respectively. Recoveries at these levels were 88%, 92%, and 95% respectively.

CHLORIDE

Method 325.3 (Titrimetric, Mercuric Nitrate)

STORET NO. 00940

1. Scope and Application
   1.1 This method is applicable to drinking, surface, and saline waters, domestic and industrial wastes.
   1.2 The method is suitable for all concentration ranges of chloride content; however, in order to avoid large titration volume, a sample aliquot containing not more than 10 to 20 mg Cl per 50 ml is used.
   1.3 Automated titration may be used.
2. Summary of Method
   2.1 An acidified sample is titrated with mercuric nitrate in the presence of mixed diphenylcarbazone-bromophenol blue indicator. The end point of the titration is the formation of the blue-violet mercury diphenylcarbazone complex.
3. Comments
   3.1 Anions and cations at concentrations normally found in surface waters do not interfere.
   3.2 Sulfite interference can be eliminated by oxidizing the 50 ml of sample solution with 0.5 to 1 ml of H_2O_2.
4. Apparatus
   4.1 Standard laboratory titrimetric equipment including a 1 ml or 5 ml microburet with 0.01 ml graduations.
5. Reagents
   5.1 Standard sodium chloride, 0.025 N: Dissolve 1.4613 ±0.0002 g (dried at 600°C for 1 hour) in chloride-free water in a 1 liter volumetric flask and dilute to the mark.
   5.2 Nitric acid, HNO_3 solution (3 + 997)
   5.3 Sodium hydroxide solution, NaOH, (10 g/1)
   5.4 Hydrogen peroxide (30%), H_2O_2
   5.5 Hydroquinone solution (10 g/liter): Dissolve 1 g of purified hydroquinone in water in a 100 ml volumetric and dilute to the mark.
   5.6 Mercuric nitrate titrant (0.141 N): Dissolve 25 g $Hg(NO_3)_2 \cdot H_2O$ in 900 ml of distilled water acidified with 5.0 ml conc. HNO_3 in a 1 liter volumetric flask and dilute to the mark with distilled water. Filter if necessary. Standardize against standard sodium chloride solution (5.1) using procedure 6. Adjust to exactly 0.141 N and check. Store in a dark bottle. A 1.00 ml aliquot is equivalent to 5.00 mg of chloride.
   5.7 Mercuric nitrate titrant (0.025 N): Dissolve 4.2830 g $Hg(NO_3)_2 \cdot H_2O$ in 50 ml of distilled water acidified with 0.5 ml conc. HNO_3 (sp. gr. 1.42) in a 1 liter volumetric flask and dilute to the mark with distilled water. Filter if necessary. Standardize against standard

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sodium chloride solution (5.1) using procedure 6. Adjust to exactly 0.025 N and check. Store in a dark bottle.

5.8 Mercuric nitrate titrant (0.0141 N): Dissolve 2.4200 g $Hg(NO_3)_2 \cdot H_2O$ in 25 ml of distilled water acidified with 0.25 ml of conc. HNO_3 (sp. gr. 1.42) in a 1 liter volumetric flask and dilute to the mark with distilled water. Filter if necessary. Standardize against standard sodium chloride solution (5.1) using procedure 6. Adjust to exactly 0.0141 N and check. Store in a dark bottle. A 1 ml aliquot is equivalent to 500 ug of chloride.

5.9 Mixed indicator reagent: Dissolve 0.5 g crystalline diphenylcarbazone and 0.05 g bromophenol blue powder in 75 ml 95% ethanol in a 100 ml volumetric flask and dilute to the mark with 95% ethanol. Store in brown bottle and discard after 6 months.

5.10 Alphazurine indicator solution: Dissolve 0.005 g of alphazurine blue-green dye in 95% ethanol or isopropanol in a 100 ml volumetric and dilute to the mark with 95% ethanol or isopropanol.

6. Procedure

6.1 Place 50 ml of sample in a vessel for titration. If the concentration is greater than 20 mg/l chloride, use 0.141 N mercuric nitrate titrant (5.6) in step 6.6 or dilute. If the concentration is less than 2.5 mg/l of chloride, use 0.0141 N mercuric nitrate titrant (5.8) in step 6.6, a 1 ml or 5 ml microburet, and determine an indicator blank on 50 ml chloride-free water using procedure 6.6. If the concentration is less than 0.1 mg/l of chloride concentrate an appropriate volume to 50 ml.

6.2 Add 5 to 10 drops of mixed indicator reagent (5.9), shake or swirl solution.

6.3 If a blue-violet or red color appears add HNO_3 solution (5.2) dropwise until the color changes to yellow.

6.4 If a yellow or orange color forms immediately on addition of the mixed indicator, add NaOH solution (5.3) dropwise until the color changes to blue-violet; then add HNO_3 solution (5.2) dropwise until the color changes to yellow.

6.5 Add 1 ml excess HNO_3 solution (5.2).

6.6 Titrate with 0.025 N mercuric nitrate titrant (5.7) until a blue-violet color persists throughout the solution. See 6.1 for choice of titrant normality. Alphazurine indicator solution (5.10) may be added with the indicator to sharpen the end point. This will change color shades. Practice runs should be made.

6.7 Additional steps to eliminate particular interferences:

6.7.1 If chromate is present at < 100 mg/l and iron is not present, add some alphazurine indicator solution (5.10) and acidify to pH 3 (indicating paper). End point will then be an olive-purple color.

6.7.2 If chromate is present at > 100 mg/l and iron is not present, add 2 ml of fresh hydroquinone solution (5.5).

6.7.3 If ferric ion is present use volume containing no more than 2.5 mg of ferric ion or ferric ion plus chromate ion. Add 2 ml fresh hydroquinone solution (5.5).

6.7.4 If sulfite ion is present, add 0.5 ml of H_2O_2 solution (5.4) to 50 ml sample and mix for 1 minute.

7. Calculation

$$\text{mg chloride/l} = \frac{(A - B)N \times 35.450}{\text{ml of sample}}$$

where:
A = ml titrant for sample
B = ml titrant for blank
N = normality mercuric nitrate titrant

mg NaCl/l = mg chloride/l x 1.65

8. Precision and Accuracy

8.1 Forty two analysts in eighteen laboratories analyzed synthetic water samples containing exact increments of chloride, with the following results:

Increment as Chloride mg/liter	Precision as Standard Deviation mg/liter	Accuracy as Bias, %	Bias, mg/liter
17	1.54	+2.16	+0.4
18	1.32	+3.50	+0.6
91	2.92	+0.11	+0.1
97	3.16	-0.51	-0.5
382	11.70	-0.61	-2.3
398	11.80	-1.19	-4.7

(FWPCA Method Study 1, Mineral and Physical Analyses)

8.2 In a single laboratory (EMSL), using surface water samples at an average concentration of 34 mg Cl/1, the standard deviation was ±1.0.

8.3 A synthetic unknown sample containing 241 mg/1 chloride, 108 mg/1 Ca, 82 mg/1 Mg, 3.1 mg/1 K, 19.9 mg/1 Na, 1.1 mg/1 nitrate N, 0.25 mg/1 nitrite N, 259 mg/1 sulfate and 42.5 mg/1 total alkalinity (contributed by $NaHCO_3$) in distilled water was analyzed in 10 laboratories by the mercurimetric method, with a relative standard deviation of 3.3% and a relative error of 2.9%.

Bibliography

1. Annual Book of ASTM Standards, Part 31, "Water", Standard D512–67, Method A, p 270 (1976).

SULFATE

Method 375.4 (Turbidimetric)

STORET NO. Total 00945

1. Scope and Application
   1.1 This method is applicable to drinking and surface waters, domestic and industrial wastes.
   1.2 The method is suitable for all concentration ranges of sulfate; however, in order to obtain reliable readings, use a sample aliquot containing not more than 40 mg $SO_4/1$.
   1.3 The minimum detectable limit is approximately 1 mg/1 sulfate.
2. Summary of Method
   2.1 Sulfate ion is converted to a barium sulfate suspension under controlled conditions. The resulting turbidity is determined by a nephelometer, filter photometer or spectrophotometer and compared to a curve prepared from standard sulfate solutions.
   2.2 Suspended matter and color interfere. Correct by running blanks from which the barium chloride has been omitted.
   2.3 Silica in concentrations over 500 mg/1 will interfere.
3. Comments
   3.1 Proprietary reagents, such as Hach Sulfaver or equivalent, are acceptable.
   3.2 Preserve by refrigeration at 4°C.
4. Apparatus
   4.1 Magnetic stirrer, variable speed so that it can be held constant just below splashing. Use identical shape and size magnetic stirring bars.
   4.2 Photometer: one of the following which are given in order of preference.
      4.2.1 Nephelometer
      4.2.2 Spectrophotometer for use at 420 nm with light path of 4 to 5 cm.
      4.2.3 Filter photometer with a violet filter having a maximum near 420 nm and a light path of 4 to 5 cm.
   4.3 Stopwatch, if the magnetic stirrer is not equipped with an accurate timer.
   4.4 Measuring spoon, capacity 0.2 to 0.3 ml.
5. Reagents
   5.1 Conditioning reagent: Place 30 ml conc. HCl, 300 ml distilled water, 100 ml 95% ethanol or isopropanol and 75 g NaCl in solution in a container. Add 50 ml glycerol and mix.
   5.2 Barium chloride, $BaCl_2$, crystals, 20 to 30 mesh.
   5.3 Sodium carbonate solution (approximately 0.05N): Dry 3 to 5 g primary standard Na_2CO_3 at 250°C for 4 hours and cool in a desiccator. Weigh 2.5 ±0.2 g (to the nearest mg), transfer to a 1 liter volumetric flask and fill to the mark with distilled water.

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5.4 Standard sulfate solution (1.00 ml = 100 μg SO_4): Prepare by either 5.4.1 or 5.4.2.

5.4.1 Standard sulfate solution from H_2SO_4

5.4.1.1 Standard sulfuric acid, 0.1N: dilute 3.0 ml conc. H_2SO_4 to 1 liter with distilled water. Standardize versus 40.00 ml of 0.05 N Na_2CO_3 solution (5.3) with about 60 ml distilled water by titrating potentiometrically to pH about 5. Lift electrodes and rinse into beaker. Boil gently for 3–5 minutes under a watch glass cover. Cool to room temperature. Rinse cover glass into beaker. Continue titration to the pH inflection point. Calculate normality using

$$N = \frac{A \times B}{53.00 \times C}$$

where:

A = g Na_2CO_3 weighed into 1 liter
B = ml Na_2CO_3 solution
C = ml acid used to inflection point

5.4.1.2 Standard acid, 0.02 N: Dilute appropriate amount of standard acid, 0.1 N (5.4.1.1) to 1 liter (200.00 ml if 0.1000 N). Check by standardization versus 15 ml of 0.05 N Na_2CO_3 solution (5.3).

5.4.1.3 Place 10.41 ml standard sulfuric acid, 0.02 N (5.4.1.2) in a 100 ml volumetric and dilute to the mark.

5.4.2 Standard sulfate solution from Na_2SO_4: Dissolve 147.9 mg anhydrous Na_2SO_4 in distilled water in a 1 liter volumetric flask and dilute to the mark with distilled water.

6. Procedure

6.1 Formation of barium sulfate turbidity

6.1.1 Place 100 ml sample, or a suitable portion diluted to 100 ml, into a 250 Erlenmeyer flask.

6.1.2 Add exactly 5.0 ml conditioning reagent (5.1).

6.1.3 Mix in the stirring apparatus.

6.1.4 While the solution is being stirred, add a measuring spoonful of $BaCl_2$ crystals (5.2) and begin timing immediately.

6.1.5 Stir exactly 1.0 minutes at constant speed.

6.2 Measurement of barium sulfate turbidity

6.2.1 Immediately after the stirring period has ended, pour solution into absorbance cell.

6.2.2 Measure turbidity at 30 second intervals for 4 minutes.

6.2.3 Record the maximum reading obtained in the 4 minute period.

6.3 Preparation of calibration curve.

6.3.1 Prepare calibration curve using standard sulfate solution (5.4).

6.3.2 Space standards at 5 mg/1 increments in the 0–40 mg/1 sulfate range.

6.3.3 Above 50 mg/l the accuracy decreases and the suspensions lose stability.

6.3.4 Check reliability of calibration curve by running a standard with every 3 or 4 samples.

6.4 Correction for sample color and turbidity.

6.4.1 Run a sample blank using the procedure 6.1 and 6.2 without the addition of barium chloride (6.1.4).

7. Calculations

7.1 Read mg SO_4 from calibration curve

$$\text{mg } SO_4/l = \frac{\text{mg } SO_4 \times 1{,}000}{\text{ml sample}}$$

8. Precision and Accuracy

8.1 Thirty-four analysts in 16 laboratories analyzed six synthetic water samples containing exact increments of inorganic sulfate with the following results:

Increment as Sulfate mg/liter	Precision as Standard Deviation mg/liter	Accuracy as Bias, %	Accuracy as Bias mg/liter
8.6	2.30	-3.72	-0.3
9.2	1.78	-8.26	-0.8
110	7.86	-3.01	-3.3
122	7.50	-3.37	-4.1
188	9.58	+0.04	+0.1
199	11.8	-1.70	-3.4

(FWPCA Method Study 1, Mineral and Physical Analyses).

8.2 A synthetic unknown sample containing 259 mg/l sulfate, 108 mg/l Ca, 82 mg/l Mg, 3.1 mg/l K, 19.9 mg/l Na, 241 mg/l chloride, 0.250 mg/l nitrite N, 1.1 mg/l nitrate N, and 42.5 mg/l total alkalinity (contributed by $NaHCO_3$) was analyzed in 19 laboratories by the turbidimetric method, with a relative standard deviation of 9.1% and a relative error of 1.2%.

Bibliography

1. Annual Book of ASTM Standards, Part 31, "Water", Standard D516-68, Method B, p 430 (1976).
2. Standard Methods for the Examination of Water and Wastewater, 14th Edition, p 496, Method 427C, (1975).

United States
Environmental Protection
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Environmental Monitoring and
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Research and Development

Test Method

Purgeable Halocarbons— Method 601

1. Scope and Application

1.1 This method covers the determination of 29 purgeable halocarbons. The following parameters may be determined by this method:

Parameter	STORET No.	CAS No.
Bromodichloromethane	32101	75-27-4
Bromoform	32104	75-25-2
Bromomethane	34413	74-83-9
Carbon tetrachloride	32102	56-23-5
Chlorobenzene	34301	108-90-7
Chloroethane	34311	75-00-3
2-Chloroethylvinyl ether	34576	100-75-8
Chloroform	32106	67-66-3
Chloromethane	34418	74-87-3
Dibromochloromethane	32105	124-48-1
1,2-Dichlorobenzene	34536	95-50-1
1,3-Dichlorobenzene	34566	541-73-1
1,4-Dichlorobenzene	34571	106-46-7
Dichlorodifluoromethane	34668	75-71-8
1,1-Dichloroethane	34496	75-34-3
1,2-Dichloroethane	34531	107-06-2
1,1-Dichloroethene	34501	75-35-4
trans-1,2-Dichloroethene	34546	156-60-5
1,2-Dichloropropane	34541	78-87-5
cis-1,3-Dichloropropene	34704	10061-01-5
trans-1,3-Dichloropropene	34699	10061-02-6
Methylene chloride	34423	75-09-2
1,1,2,2-Tetrachloroethane	34516	79-34-5
Tetrachloroethene	34475	127-18-4
1,1,1-Trichloroethane	34506	71-55-6
1,1,2-Trichloroethane	34511	79-00-5
Trichloroethene	39180	79-01-6
Trichlorofluoromethane	34488	75-69-4
Vinyl chloride	39175	75-01-4

1.2 This is a purge and trap gas chromatographic 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 identification 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 major modifications 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 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 5-mL water sample contained in a specially-designed 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 out-gassing 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 8.5. The use of non-TFE plastic tubing, non-TFE thread sealants, or flow controllers with rubber components in the purging device should be avoided.

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(4-6) 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, equipped with a screw cap with hole in center (Pierce #13075 or equivalent). Detergent wash, rinse cap 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 one hour before use.

5.2 Purge and trap device—The purge and trap device consists of three separate pieces of equipment: the sample purger, trap, and the desorber. Several complete devices are now commercially available.

5.2.1 The sample purger 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 sample purger, 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 inch. The trap must be packed to contain the following minimum lengths of adsorbents: 1.0 cm of methyl silicone coated backing (Section 6.3.3), 7.7 cm of 2,6-diphenylene oxide polymer (Section 6.3.2), 7.7 cm of silica gel, 7.7 gm of coconut charcoal (Section 6.3.1). If it is not necessary to analyze for dichlorodifluroromethane, 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 220 °C. The desorber design, illustrated in Figure 2, meets these criteria.

5.2.4 The purge and trap device 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 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 × 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 × 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. These types of detectors have proven effective in the analysis of wastewaters for the parameters listed in the scope. The electrolytic conductivity detector was used to develop the method performance statements and MDL listed in Tables 1 and 2. Guidelines for the use of alternate detectors are provided in Section 10.1.

5.4 Syringes — 5-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 be generated by passing tap water through a carbon filter bed containing about 1 lb. of activated carbon (Filtrasorb-300 or equivalent (Calgon Corp.)).

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 minutes. Subsequently, while maintaining the temperature at 90 °C, bubble a contaminant-free inert gas through the water for one hour. 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 Coconut charcoal (6/10 mesh sieved to 26 mesh), (Barnaby Chaney, 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 60/80 mesh Chromosorb-W or equivalent.

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

6.4 Methyl Alcohol — 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 methyl alcohol using assayed liquids or gas cylinders 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 methyl alcohol into a 10-mL ground glass stoppered volumetric flask. Allow the flask to stand, unstoppered, for about 10 minutes 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 Liquids — Using a 100-µL 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, chloroethane, chloromethane, dichlorodifluoromethane, 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 methyl alcohol meniscus. Slowly introduce the reference standard above the surface of the liquid (the heavy gas will rapidly dissolve into the methyl alcohol).

6.5.3 Reweigh, dilute to volume, stopper, then mix by inverting the flask several times. Calculate the concentration in micrograms per microliter 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 indicate a problem.

6.6 Secondary dilution standards — Using stock standard solutions, prepare secondary dilution standards in methyl alcohol 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. Quality control check standards that can be used to determine the accuracy of calibration standards will be available from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, in Cincinnati, Ohio.

7. Calibration

7.1 Assemble a purge and trap device 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. Prior to use, daily condition traps 10 minutes while backflushing at 180 °C.

7.2 Connect the purge and trap device to a gas chromatograph. The gas chromatograph must be operated using temperature and flow rate parameters equivalent to those 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-µL syringe with a 0.006 inch ID needle should be used for this operation. One of the external standards should be at a concentration near, but above, the method detection limit (See 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 hours, if held in sealed vials with zero headspace as described in Section 9.2. If not so stored, they must be discarded after one hour.

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.

7.3.3 The working calibration curve or calibration factor must be verified on each working day by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ± 10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve or calibration factor must be prepared for that parameter.

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 µg/mL of each internal standard compound. The addition of 10µL 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.

Eq. 1 $RF = (A_s C_{is})/(A_{is} C_s)$

where:

A_s = Response for the parameter to be measured.

A_{is} = Response for the internal standard.

C_{is} = Concentration of the internal standard.

C_s = 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_s/A_{is}, vs. RF.

7.4.4 The working calibration curve or RF must be verified on each working day by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ± 10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve must be prepared for that compound.

8. 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 the analysis of spiked samples as a continuing check on performance. The laboratory is required to maintain performance records to define the quality of data that is generated. Ongoing performance checks must be compared with established performance criteria to determine if the results of analyses are within accuracy and precision limits expected of the method.

8.1.1 Before performing any analyses, the analyst must demonstrate 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 the rapid advances that are occurring in chromatography, the analyst is permitted certain options to improve the separations or lower the cost of measurements. Each time such modifications are made to the method, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 The laboratory must spike and analyze a minimum of 10% of all samples to monitor continuing laboratory performance. This procedure is described in Section 8.4.

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

8.2.1 Select a representative spike concentration for each compound to be measured. Using stock standards, prepare a quality control check sample concentrate in methyl alcohol 500 times more concentrated than the selected concentrations. Quality control check sample concentrates, appropriate for use with this method, will be available from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268.

8.2.2 Using a syringe, add 10 µL of the check sample concentrate to each of a minimum of four 5-mL aliquots of reagent water. A representative wastewater may be used in place of the reagent water, but one or more additional aliquots must be analyzed to determine background levels, and the spike level must exceed twice the background level for the test to be valid. Analyze the aliquots according to the method beginning in Section 10.

8.2.3 Calculate the average percent recovery, (R), and the standard deviation of the percent recovery (s), for the results. Wastewater background corrections must be made before R and s calculations are performed.

8.2.4 Using Table 2, note the average recovery (X) and standard deviation (p) expected for each method parameter. Compare these to the calculated values for R and s. If $s > 2p$ or $|X - R| > 2p$, review potential problem areas and repeat the test.

8.3 The analyst must calculate method performance criteria and define the performance of the laboratory for each spike concentration and parameter being measured.

8.2.5 The U.S. Environmental Protection Agency plans to establish performance criteria for R and s based upon the results of interlaboratory testing. When they become available, these criteria must be met before any samples may be analyzed.

8.3.1 Calculate upper and lower control limts for method performance:

Upper Control Limit (UCL) = R + 3s
Lower Control Limit (LCL) = R − 3s

where R and s are calculated as in Section 8.2.3. The UCL and LCL can be used to construct control charts(7) that are useful in observing trends in performance. The control limits above must be replaced by method performance criteria as they become available from the U.S. Environmental Protection Agency.

8.3.2 The laboratory must develop and maintain separate accuracy statements of laboratory performance for wastewater samples. An accuracy statement for the method is defined as R ± s. The accuracy statement should be developed by the analysis of four aliquots of wastewater as described in Section 8.2.2, followed by the calculation of R and s. Alternately, the analyst may use four wastewater data points gathered through the requirement for continuing quality control in Section 8.4. The accuracy statements should be updated regularly.(7)

8.4 The laboratory is required to collect a portion of their samples in duplicate to monitor spike recoveries. The frequency of spiked sample analysis must be at least 10% of all samples or one sample per month, whichever is greater. One aliquot of the sample must be spiked and analyzed as described in Section 8.2. If the *recovery for a particular parameter* does not fall within the control limits for method performance, the results reported for that parameter in all samples processed as part of the same set must be qualified as described in Section 11.3. The laboratory should monitor the frequency of data so qualified to ensure that it remains at or below 5%.

8.5 Each day, the analyst must demonstrate through the analysis of reagent water, that interferences from the analytical system are under control.

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 monitor the precision of the sampling technique. 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 perform analysis of standard reference materials and participate in relevant performance evaluation studies.

8.7 The analyst should maintain constant surveillance of 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 blank with surrogate halocarbons. A combination of bromochloromethane, *2-bromo-1-chloropropane, and* 1,4-dichlorobutane is recommended to encompass the range of the temperature program used in this method. From stock standard solutions prepared as above, add a volume to give 7500 μg of each surrogate to 45 mL of reagent water contained in a 50-mL volumetric flask, mix and dilute to volume (15 ng/μL). 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). 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.

9. Sample Collection, Preservation, and Handling

9.1 All samples must be iced or refrigerated from the time of collection until extraction. If the sample contains free or combined chlorine, add sodium thiosulfate preservative (10 mg/40 mL is sufficient for up to 5 ppm Cl_2) to the empty sample bottle just prior to shipping to the sampling site. USEPA methods 330.4 and 330.5 may be used for measurement of residual chlorine.(8) 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 one minute. Maintain the hermetic seal on the sample bottle until time of analysis.

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

10. Sample Extraction and Gas Chromatography

10.1 Table 1 summarizes the recommended operating conditions for the gas chromatograph. Included in this Table are estimated retention times and method detection limits that can be achieved by this method. 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 device to purge. Open the syringe valve located on the purging device sample introduction needle.

10.4 Allow 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 (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 11.0 ± .1 minutes at ambient temperature.

10.7 After the 11-minute purge time, attach the trap to the chromatograph, adjust the device to the desorb mode, 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 four minutes. If rapid heating of the trap cannot be achieved, the gas chromatographic column must be used as a secondary trap by cooling it to 30 °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 flushes of reagent water.

10.9 After desorbing the sample for four minutes recondition the trap by returning the purge and trap device to the purge mode. Wait 15 seconds 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 seven minutes turn off the trap heater and open the syringe valve to stop the gas flow through the trap. When cool the trap is ready for the next sample.

10.10 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 the 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 material 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 was used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.4.3 and equation 2.

Eq. 2.

$$\text{Concentration } \mu g/L = (A_s C_{is})/(A_{is})(RF)$$

where:

A_s = Response for the parameter to be measured.

A_{is} = Response for the internal standard.

C_s = Concentration of the internal standard.

11.2 Report results in micrograms per liter. When duplicate and spiked samples are analyzed, report all data obtained with the sample results.

11.3 For samples processed as part of a set where the spiked sample recovery falls outside of the control limits which were established according to Section 8.3, data for the affected parameters must be labeled as suspect.

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 up to 1000 × MDL. Direct aqueous injection techniques should be used to measure concentration levels above 1000 × MDL.

12.3 In a single laboratory (Monsanto Research), using reagent water and wastewaters spiked at or near background levels, the average recoveries presented in Table 2 were obtained.(9) The standard deviation of the measurement in percent recovery is also included in Table 2(9).

12.4 The U.S. Environmental Protection Agency is in the process of conducting an interlaboratory method study to fully define the performance of this method.

References

1. See Appendix A.

2. Bellar, T.A., and Lichtenberg, J.J. *Journal American Water Works Association, 66,* 739, (1974).

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

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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).

Table 1. Chromatographic Conditions and Method Detection Limits

	Retention Time (min.)		Method Detection Limit
Parameter	*Column 1*	*Column 2*	*µg/L*
Chloromethane	1.50	5.28	0.08
Bromomethane	2.17	7.05	1.18
Dichlorodifluoromethane	2.62	nd	1.81
Vinyl chloride	2.67	5.28	0.18
Chloroethane	3.33	8.68	0.52
Methylene chloride	5.25	10.1	0.25
Trichlorofluoromethane	7.18	nd	nd
1,1-Dichloroethene	7.93	7.72	0.13
1,1-Dichloroethane	9.30	12.6	0.07
trans-1,2-Dichloroethene	10.1	9.38	0.10
Chloroform	10.7	12.1	0.05
1,2-Dichloroethane	11.4	15.4	0.03
1,1,1-Trichloroethane	12.6	13.1	0.03
Carbon tetrachloride	13.0	14.4	0.12
Bromodichloromethane	13.7	14.6	0.10
1,2-Dichloropropane	14.9	16.6	0.04
trans-1,3-Dichloropropene	15.2	16.6	0.34
Trichloroethene	15.8	13.1	0.12
Dibromochloromethane	16.5	16.6	0.09
1,1,2-Trichloroethane	16.5	18.1	0.02
cis-1,3-Dichloropropene	16.5	18.0	0.20
2-Chloroethylvinyl ether	18.0	nd	0.13
Bromoform	19.2	19.2	0.20
1,1,2,2-Tetrachloroethane	21.6	nd	0.03
Tetrachloroethene	21.7	15.0	0.03
Chlorobenzene	24.2	18.8	0.25
1,3-Dichlorobenzene	34.0	22.4	0.32
1,2-Dichlorobenzene	34.9	23.5	0.15
1,4-Dichlorobenzene	35.4	22.3	0.24

nd = not determined

Column 1 conditions: Carbopack B 60/80 mesh coated with 1% SP-1000 packed in an 8 ft × 0.1 in ID stainless steel or glass column with helium carrier gas at 40 mL/min flow rate. Column temperature held at 45 °C for 3 min. then programmed at 8 °C/min. to 220° and held for 15 min.

Column 2 conditions: Porasil-C 100/120 mesh coated with n-octane packed in a 6 ft × 0.1 in ID stainless steel or glass column with helium carrier gas at 40 mL/min flow rate. Column temperature held at 50 °C for 3 min then programmed at 6 °C/min to 170° and held for 4 min.

Table 2. *Single Operator Accuracy and Precision*

Parameter	Average Percent Recovery	Standard Deviation %	Spike Range (µg/L)	Number of Analyses	Matrix Types
Bromodichloromethane	100.9	5.0	0.43-46.7	21	3
Bromoform	89.5	9.0	1.45-50	20	3
Bromomethane	105.0	17.3	3.39-49.2	21	3
Carbon tetrachloride	82.5	25.6	0.55-50	19	3
Chlorobenzene	93.9	8.9	2.21-50	20	3
Chloroethane	91.5	22.4	3.95-50	21	3
2-Chloroethylvinyl ether	96.3	9.9	4.39-133	20	3
Chloroform	101.7	20.6	0.44-50	20	3
Chloromethane	91.4	13.4	0.55-23.9	21	3
Dibromochloromethane	98.3	6.5	0.75-93.0	21	3
1,2-Dichlorobenzene	10.20	2.0	4.89-154	21	3
1,3-Dichlorobenzene	91.6	4.3	2.94-46.7	21	3
1,4-Dichlorobenzene	97.5	9.3	2.99-51.6	21	3
Dichlorodifluoromethane	87.8	18.0	2.18-43.4	21	3
1,1-Dichloroethane	102.3	5.5	0.44-46.7	21	3
1,2-Dichloroethane	97.8	4.8	0.44-46.7	21	3
1,1-Dichloroethene	101.1	21.7	0.37-50	19	3
trans-1,2-Dichloroethene	91.0	19.3	0.44-98.0	20	3
1,2-Dichloropropane	97.7	8.8	0.29-39.0	21	3
cis-1,3-Dichloropropene	86.7	6.0	0.44-46.7	21	3
trans-1,3-Dichloropropene	73.5	17.2	0.43-50	20	3
Methylene chloride	97.9	2.6	0.73-46.7	21	3
1,1,2,2-Tetrachloroethane	91.9	15.0	0.46-46.7	21	3
Tetrachloroethene	94.1	18.1	0.50-35.0	21	3
1,1,1-Trichloroethane	75.1	12.5	0.37-29.0	21	3
1,1,2-Trichloroethane	91.0	25.1	0.45-50	21	3
Trichloroethene	106.1	7.4	0.38-46.7	21	3
Trichlorofluoromethane	89.3	13.9	149	14	2
Vinyl chloride	101.9	11.4	0.82-32.3	21	3

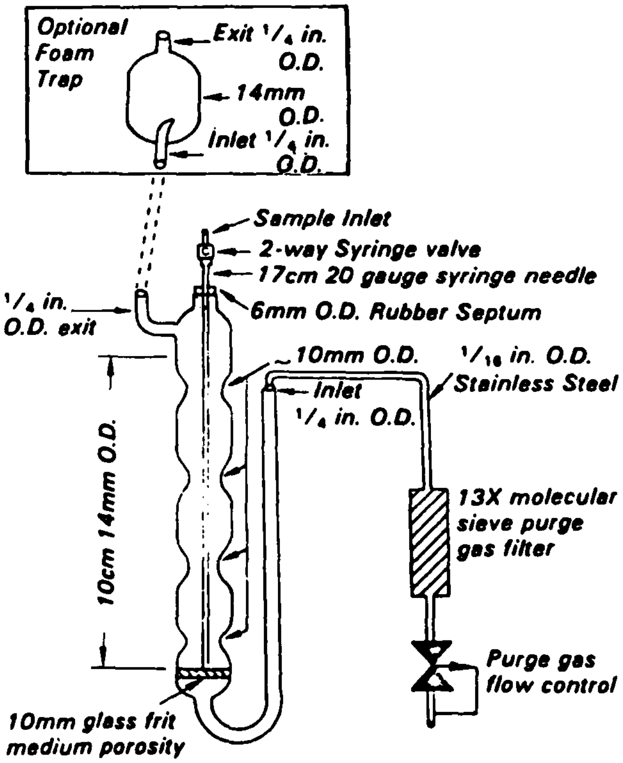

Figure 1. *Purging device*

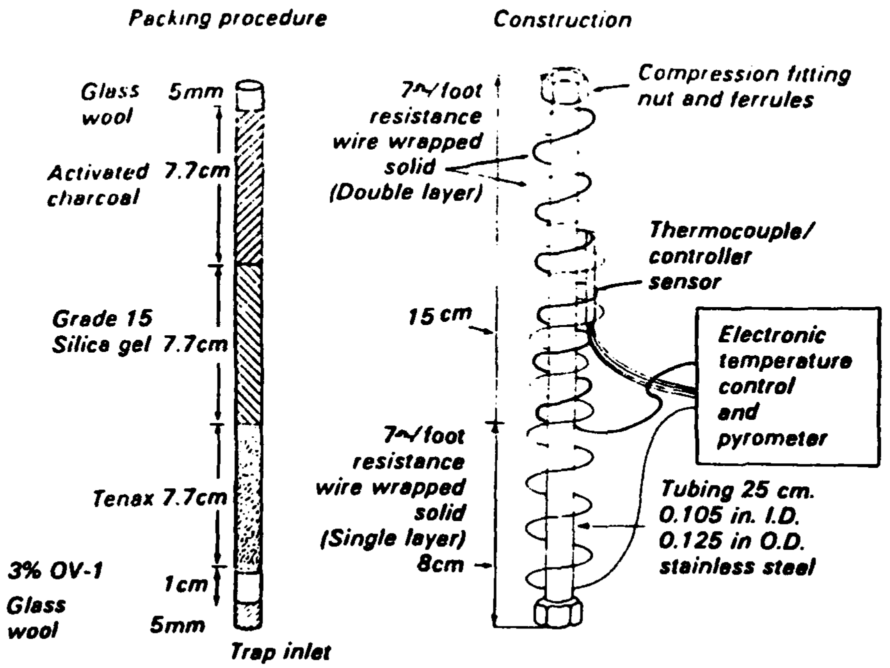

Figure 2. *Trap packings and construction to include desorb capability*

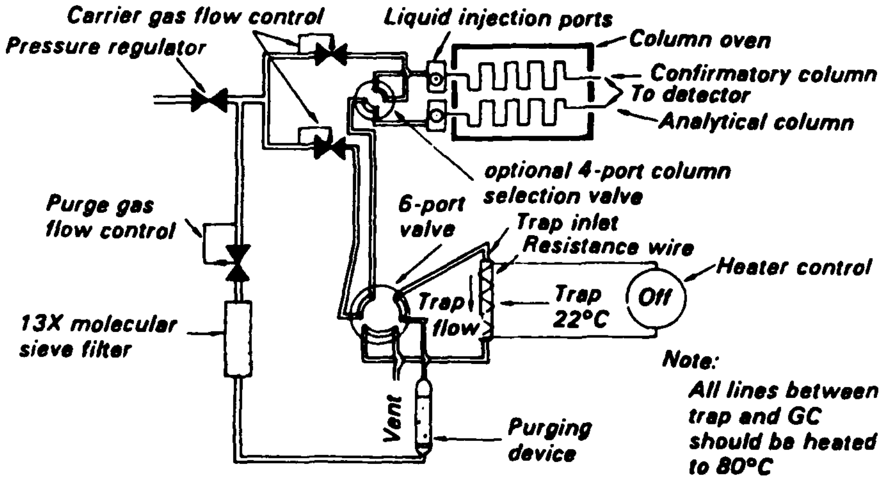

Figure 3. *Schematic of purge and trap device — purge mode*

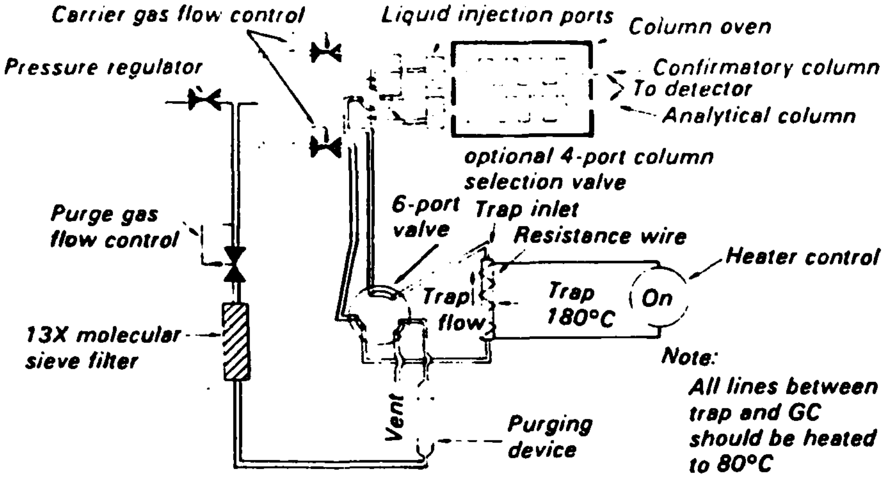

Figure 4. *Schematic of purge and trap device — desorb mode*

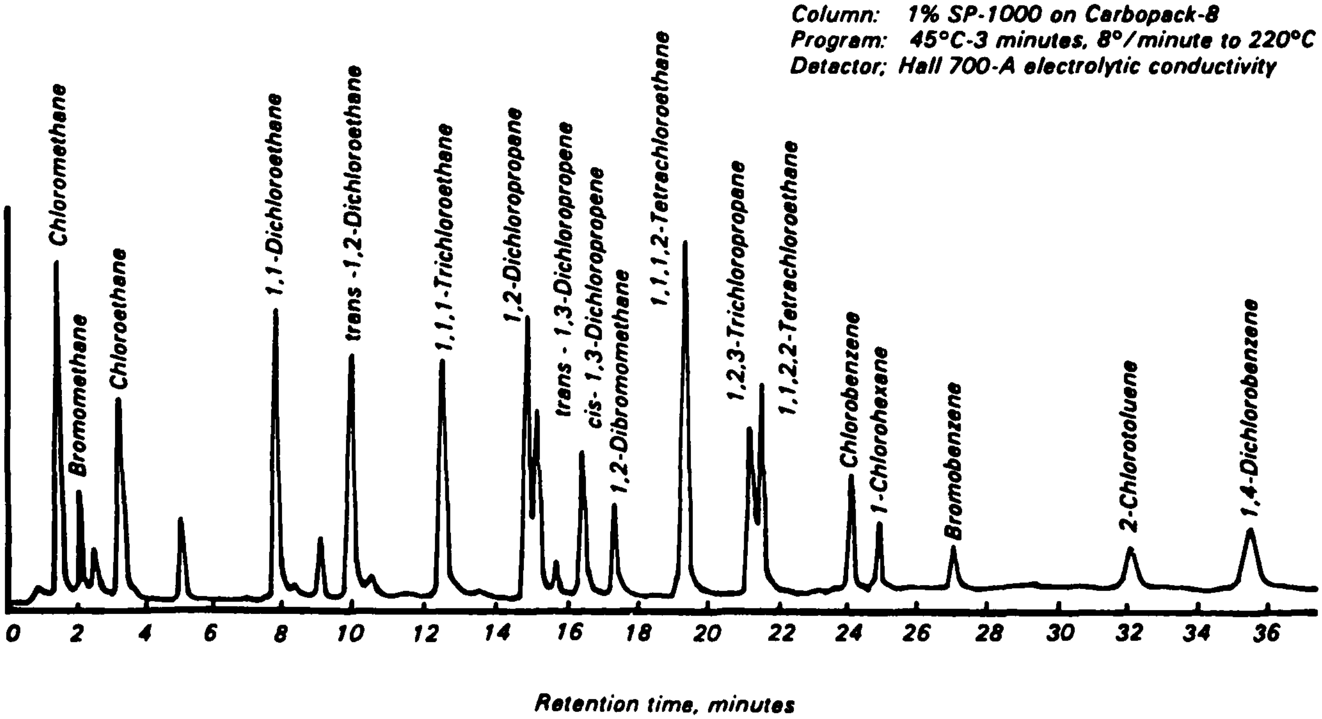

Figure 5. *Gas chromatogram of purgeable halocarbons*

United States
Environmental Protection
Agency

Environmental Monitoring and
Support Laboratory
Cincinnati OH 45268

Research and Development

Test Method

Purgeable Aromatics— Method 602

1. Scope and Application

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

Parameter	STORET No.	CAS No.
Benzene	34030	71-43-2
Chlorobenzene	34301	108-90-7
1,2-Dichlorobenzene	34536	95-50-1
1,3-Dichlorobenzene	34566	541-73-1
1,4-Dichlorobenzene	34571	106-46-7
Ethylbenzene	34371	100-41-4
Toluene	34010	108-88-3

1.2 This is a purge and trap gas chromatographic 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 these 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 major modifications subject to application and approval for 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 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 5-mL water sample contained in a specially-designed 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 chromatographic column. The 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 out-gassing 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 8.5. The use of non-TFE plastic tubing, non-TFE thread sealants, or flow controllers with rubber components in the purging device 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 out 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(4-6) 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 1,4-dichlorobenzene. Primary standards of these toxic compounds should be prepared in a hood. An 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 hole in 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 one hour before use.

5.2 Purge and trap device—The purge and trap device consists of three separate pieces of equipment: the sample purger, trap, and the desorber. Several complete devices are now commercially available.

5.2.1 The sample purger 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 sample purger, 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 inch.

5.2.2.1 The trap is packed with 1 cm of methyl silicone and 23 cm 2,6-diphenylene oxide polymer 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 design, illustrated in Figure 2, meets these criteria.

5.2.4 The purge and trap device 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—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 stripchart recorder. A data system is recommended for measuring peak areas.

5.3.1 Column 1—6 ft long × 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 and the MDLs listed in Tables 1 and 2. Guidelines for the use of alternate column packings are provided in Section 10.1.

5.3.2 Column 2—8 ft long × 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, and was used to develop the performance statements in Section 12. Guidelines for the use of alternate detectors are provided in Section 10.1.

5.4 Syringes—5-mL glass hypodermic with Luerlok tip (two each), if applicable to the purge 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 Bottle—15-mL screw-cap with Teflon cap liner.

5.8 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 be generated by passing tap water through a carbon filter bed containing about 1 lb. of activated carbon. (Filtrasorb-300 or equivalent (Calgon Corp.)).

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 minutes. Subsequently, while maintaining the temperature at 90 °C, bubble a contaminant-free inert gas through the water for one hour. 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 Hydrochloric acid (1 + 1)—Add 50 mL of concentrated HCl to 50 mL of reagent water.

6.4 Trap Materials

6.4.1 2,6-Diphenylene oxide polymer-Tenax, (60/80 mesh) chromatographic grade or equivalent.

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

6.5 Methyl alcohol—Pesticide quality or equivalent.

6.6 Stock standard solutions—Stock standard solutions may be prepared from pure standard materials or purchased as certified solutions. Prepare stock standard solutions in methyl alcohol using assayed liquids. Because benzene and 1,4-dichlorobenzene are suspected carcinogens, primary dilutions of these materials should be prepared in a hood.

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

6.6.2 Using a 100-µL 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.

6.6.3 Reweigh, dilute to volume, stopper, then mix by inverting the flask several times. Calculate the concentration in micrograms per microliter from the net gain in weight. When compound purity is certified at 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.

6.6.4 Transfer the stock standard solution 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 indicate a problem.

6.7 Secondary dilution standards—Using stock standard solutions, prepare secondary dilution standards in methyl alcohol 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. Quality control check standards that can be used to determine the accuracy of calibration standards will be available from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, in Cincinnati, Ohio.

7. Calibration

7.1 Assemble a purge and trap device 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. Prior to use, daily condition traps 10 minutes while backflushing at 180 °C.

7.2 Connect the purge and trap device to a gas chromatograph. The gas chromatograph must be operated using temperature and flow rate parameters equivalent to those 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-µL syringe with a 0.006 inch ID needle should be used for this operation. One of the external standards should be at a concentration near, but above, the MDL (see 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.

7.3.3 The working calibration curve or calibration factor must be verified on each working day by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ±10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve or calibration factor must be prepared for that parameter.

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, α,α,α-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 Sections 6.6 and 6.7. It 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 as indicated in 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.

$$\text{Eq. 1}\quad RF = (A_s C_{is})/(A_{is} C_s)$$

where:

A_s = Response for the parameter to be measured.

A_{is} = Response for the internal standard.

C_{is} = Concentration of the internal standard.

C_s = 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_s/A_{is}, vs. RF.

7.4.4 The working calibration curve or RF must be verified on each working day by the measurement of one or more calibration standards. If the response for any parameter varies from the predicted response by more than ± 10%, the test must be repeated using a fresh calibration standard. Alternatively, a new calibration curve must be prepared for that compound.

8. 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 the analysis of spiked samples as a continuing check on performance. The laboratory is required to maintain performance records to define the quality of data that is generated. Ongoing performance checks must be compared with established performance criteria to determine if the results of analyses are within accuracy and precision limits expected of the method.

8.1.1 Before performing any analyses, the analyst must demonstrate 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 the rapid advances that are occurring in chromatography, the analyst is permitted certain options to improve the separations or lower the cost of measurements. Each time such modifications are made to the method, the analyst is required to repeat the procedure in Section 8.2.

8.1.3 The laboratory must spike and analyze a minimum of 10% of all samples to monitor continuing laboratory performance. This procedure is described in Section 8.4.

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

8.2.1 Select a representative spike concentration for each compound to be measured. Using stock standards, prepare a quality control check sample concentrate in methyl alcohol 500 times more concentrated than the selected concentrations. Quality control check sample concentrates, appropriate for use with this method, will be available from the U.S. Environmental Protection Agency, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268.

8.2.2 Using a syringe, add 10 μL of the check sample concentrate to each of a minimum of four 5-mL aliquots of reagent water. A representative wastewater may be used in place of the reagent water, but one or more additional aliquots must be analyzed to determine background levels, and the spike level must exceed twice the background level for the test to be valid. Analyze the aliquots according to the method beginning in Section 10.

8.2.3 Calculate the average percent recovery, (R), and the standard deviation of the percent recovery (s), for the results. Wastewater background corrections must be made before R and s calculations are performed.

8.2.4 Using Table 2, note the average recovery (X) and standard deviation (p) expected for each method parameter. Compare these to the calculated values for R and s. If $s > 2p$ or $|X - R| > 2p$, review potential problem areas and repeat the test.

8.2.5 The U.S. Environmental Protection Agency plans to establish performance criteria for R and s based upon the results of interlaboratory testing. When they become available, these criteria must be met before any samples may be analyzed.

8.3 The analyst must calculate method performance criteria and define the performance of the laboratory for each spike concentration and parameter being measured.

8.3.1 Calculate upper and lower control limits for method performance:

$$\text{Upper Control Limit (UCL)} = R + 3s$$
$$\text{Lower Control Limit (LCL)} = R - 3s$$

where R and s are calculated as in Section 8.2.3

The UCL and LCL can be used to construct control charts[7] that are useful in observing trends in performance. The control limits above must be replaced by method performance criteria as they become available from the U.S. Environmental Protection Agency.

8.3.2 The laboratory must develop and maintain separate accuracy statements of laboratory performance for wastewater samples. An accuracy statement for the method is defined as R ± s. The accuracy statement should be developed by the analysis of four aliquots of wastewater as described in Section 8.2.2, followed by the calculation of R and s. Alternately, the analyst may use four wastewater data points gathered through the requirement for continuing quality control in Section 8.4. The accuracy statements should be updated regularly[7].

8.4 The laboratory is required to collect a portion of their samples in duplicate to monitor spike recoveries. The frequency of spiked sample analysis must be at least 10% of all samples or one sample per month, whichever is greater. One aliquot of the sample must be spiked and analyzed as described in Section 8.2. If the recovery for a particular parameter does not fall within the control limits for method performance, the results reported for that parameter in all samples processed as part of the same set must be qualified as described in Section 11.3. The laboratory should monitor the frequency of data so qualified to ensure that it remains at or below 5%.

8.5 Each day, the analyst must demonstrate through the analysis of reagent water, that interferences from the analytical system are under control.

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 monitor the precision of the sampling technique. 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 perform analysis of standard reference materials and participate in relevant performance evaluation studies.

8.7 The analyst should maintain constant surveillance of 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 blank with surrogate compounds (e.g. α,α,α,-trifluorotoluene). From stock standard solutions prepared as above, add a volume to give 7500 μg of each surrogate to 45 mL of organic-free water contained in a 50-mL volumetric flask, mix and dilute to volume (15 ng/μL). 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). Dose 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.

9. Sample Collection, Preservation, and Handling

9.1 The samples must be iced or refrigerated from the time of collection until extraction. If the sample contains free or combined chlorine, add sodium thiosulfate preservative (10 mg/40 mL is sufficient for up to 5 ppm Cl_2) to the empty sample bottles just prior to shipping to the sampling site. USEPA Methods 330.4 or 330.5 may be used to measure residual chlorine(8). Field Test Kits are available for this purpose.

9.2 Collect about 500 mL sample in a clean container. Adjust the pH of the sample to about 2 by adding 1 + 1 HCl while stirring gently. 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. Sample Extraction and Gas Chromatography

10.1 Table 1 summarizes the recommended operating conditions for the gas chromatograph. Included in this table are estimated retention times and method detection limits that can be achieved by this method. 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 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 device to purge. Open the syringe valve located on the purging device sample introduction needle.

10.4 Allow sample to come to ambient temperature prior to introducing it into 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 ± 0.1 minutes at ambient temperature.

10.7 After the 12-minute purge time, disconnect the purge chamber from the trap. Dry the trap by maintaining a flow of 40 mL/min of dry purge gas through it for six minutes. See Figure 4. A dry purger should be inserted into the device to minimize moisture in the gas. Attach the trap to the chromatograph, adjust the device to the desorb mode, 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 four minutes. If rapid heating cannot be achieved, the gas chromatographic 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 onto the GC 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 four minutes, recondition the trap by returning the purge and trap device to the purge mode. Wait 15 seconds 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 seven minutes, turn off the trap heater and open the syringe valve to stop the gas flow through the trap. When cool, the trap is ready for the next sample.

10.10 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 the 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 material 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 was used, calculate the concentration in the sample using the response factor (RF) determined in Section 7.4.3 and equation 2.

Eq. 2.

$$\text{Concentration } \mu g/L = (A_sC_{is})/(A_{is})(RF)$$

where:

A_s = Response for the parameter to be measured.

A_{is} = Response for the internal standard.

C_{is} = Concentration of the internal standard.

11.2 Report results in micrograms per liter. When duplicate and spiked samples are analyzed, report all data obtained with the sample results.

11.3 For samples processed as part of a set where the spiked sample recovery falls outside of the control limits which were described in Section 8.3, data for the affected parameters must be labeled as suspect.

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.

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

12.3 In a single laboratory (Monsanto Research), using reagent water and wastewaters spiked at or near background levels, the average recoveries presented in Table 2 were obtained(9). The standard deviation of the measurement in percent recovery is also included in Table 2.

12.4 The Environmental Protection Agency is in the process of conducting an interlaboratory method study to fully define the performance of this method.

References

1. See Appendix A

2. Bellar, T.A., and Lichtenberg, J.J. *Journal American Water Works Association, 66,* 739, (1974).

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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 Safety, 3rd Edition, 1979.

7. "Handbook for Analytical Quality Control in Water and Wastewater Laboratories," EPA-600/4-79-019, U.S. Environmental Protection Agency, Office of Research and Development, Environmental Monitoring and Support Laboratory, Cincinnati, Ohio 45268. March 1979.

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*

Parameter	*Retention Time (min.)*		*Method Detection Limit µg/L*
	Column 1	*Column 2*	
Benzene	*3.33*	*2.75*	*0.2*
Toluene	*5.75*	*4.25*	*0.2*
Ethylbenzene	*8.25*	*6.25*	*0.2*
Chlorobenzene	*9.17*	*8.02*	*0.2*
1,4-Dichlorobenzene	*16.8*	*16.2*	*0.3*
1,3-Dichlorobenzene	*18.2*	*15.0*	*0.4*
1,2-Dichlorobenzene	*25.9*	*19.4*	*0.4*

Column 1 conditions: Supelcoport 100/120 mesh coated with 5% SP-1200 and 1.75% Bentone-34 packed in a 6 ft. × 0.085 in ID stainless steel column with helium carrier gas at 36 cc/min flow rate. Column temperature held at 50°C for 2 min. then programmed at 6°C/min to 90°C for a final hold.

Column 2 conditions: Chromosorb W-AW 60/80 mesh coated with 5% 1,2,3-Tris(2-cyanoethyoxy)propane packed in a 6 ft. × 0.085 in ID stainless steel column with helium carrier gas at 30 cc/min flow rate. Column temperature held at 40°C for 2 min then programmed at 2°C/min to 100°C for a final hold.

Table 2. *Single Operator Accuracy and Precision*

Parameter	*Average Percent Recovery*	*Standard Deviation %*	*Spike Range (µg/L)*	*Number of Analyses*	*Matrix Types*
Benzene	*91*	*10.0*	*0.5-9.7*	*21*	*3*
Chlorobenzene	*97*	*9.4*	*0.5-100*	*21*	*3*
1,2-Dichlorobenzene	*104*	*27.7*	*0.5-10.0*	*21*	*3*
1,3-Dichlorobenzene	*97*	*20.0*	*0.5-4.8*	*21*	*3*
1,4-Dichlorobenzene	*120*	*20.4*	*0.5-10.0*	*21*	*3*
Ethylbenzene	*98*	*12.4*	*0.5-9.9*	*21*	*3*
Toluene	*77*	*12.1*	*0.5-100*	*21*	*3*

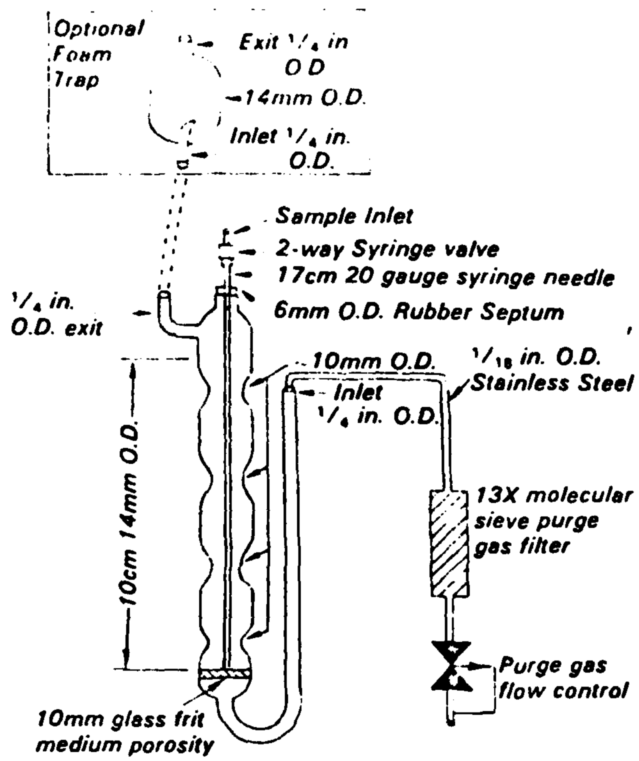


Figure 1. *Purging device*

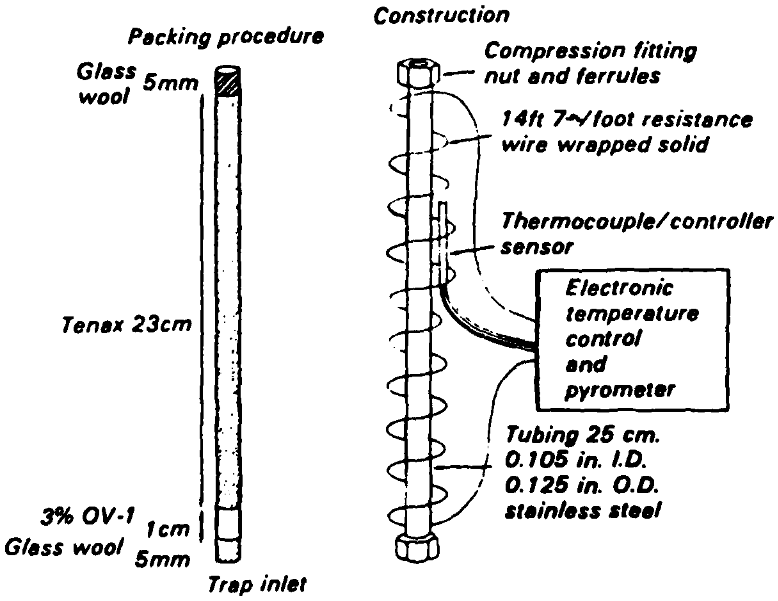


Figure 2. *Trap packings and construction to include desorb capability*

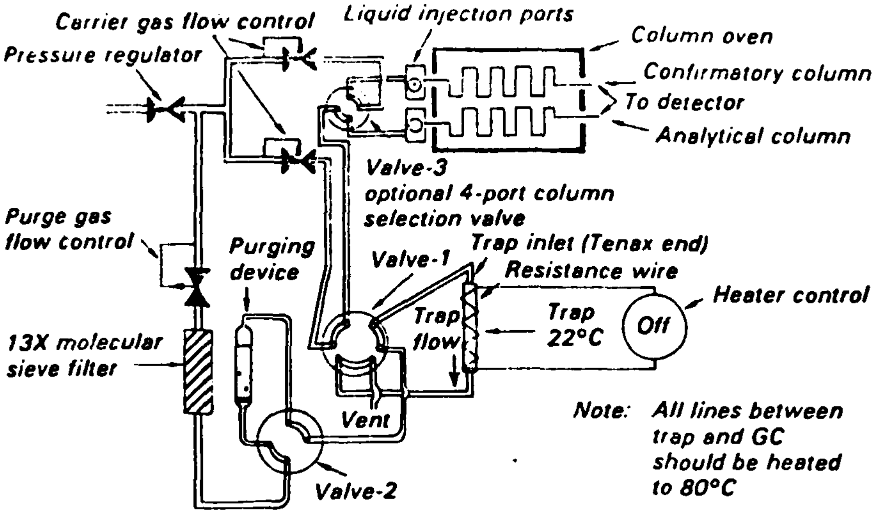


Figure 3. *Purge-trap system (Purge-sorb Mode)*

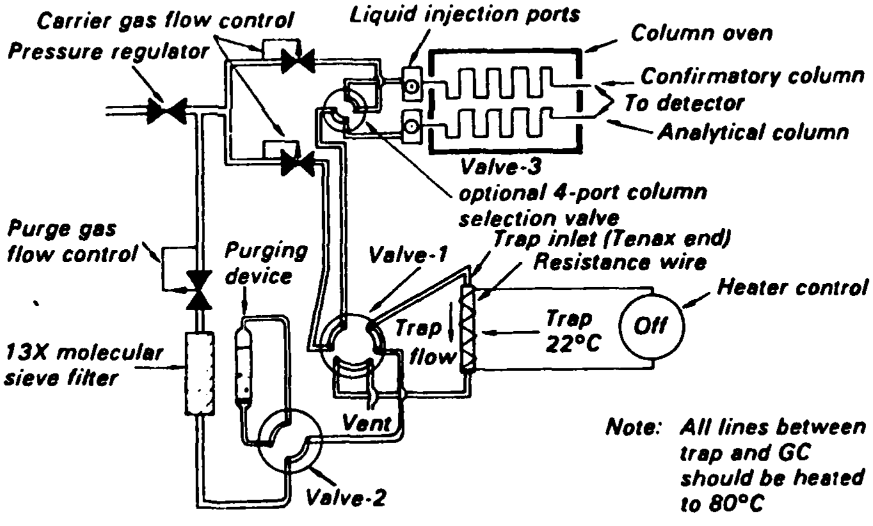


Figure 4. *Purge-trap system (Trap-dry Mode).*

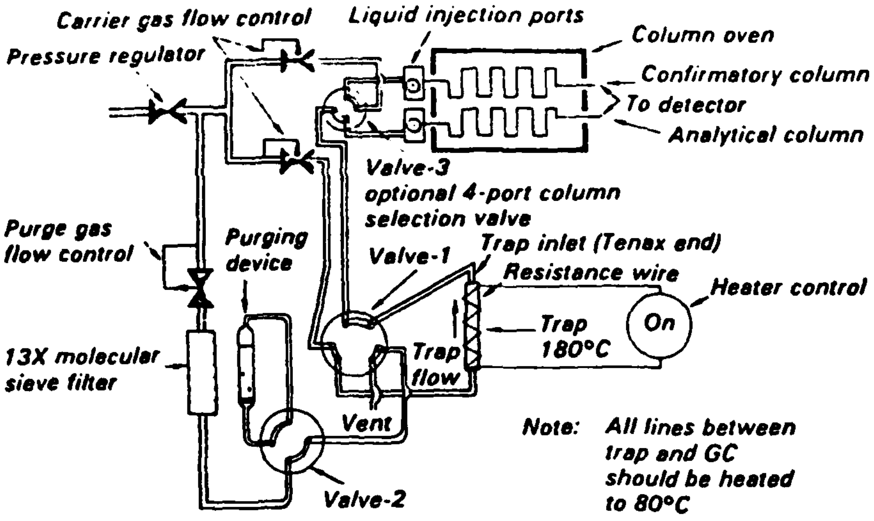


Figure 5. *Purge-trap system (Desorb Mode).*

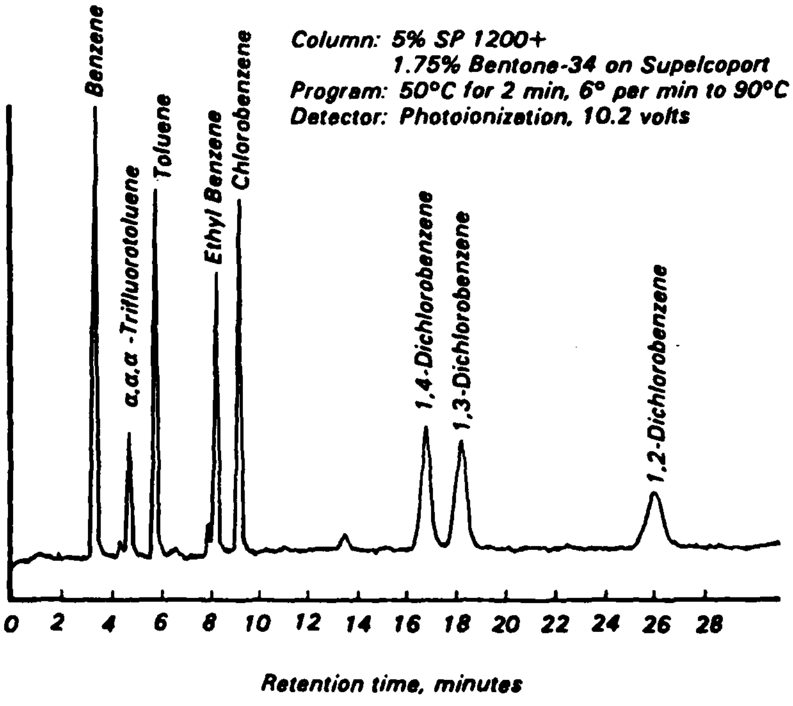
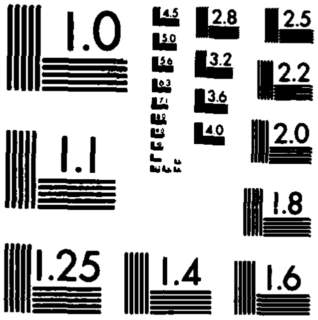


Figure 6. *Gas chromatogram of purgeable aromatics.*

AD-A145 352   INSTALLATION RESTORATION PROGRAM PHASE II PROBLEM   3/3
CONFIRMATION STUDY WESTOVER AFB CHICOPEE MASSACHUSETTS
(U) WESTON (ROY F) INC WEST CHESTER PA   MAY 84
UNCLASSIFIED   F33615-80-D-4006   F/G 5/1   NL

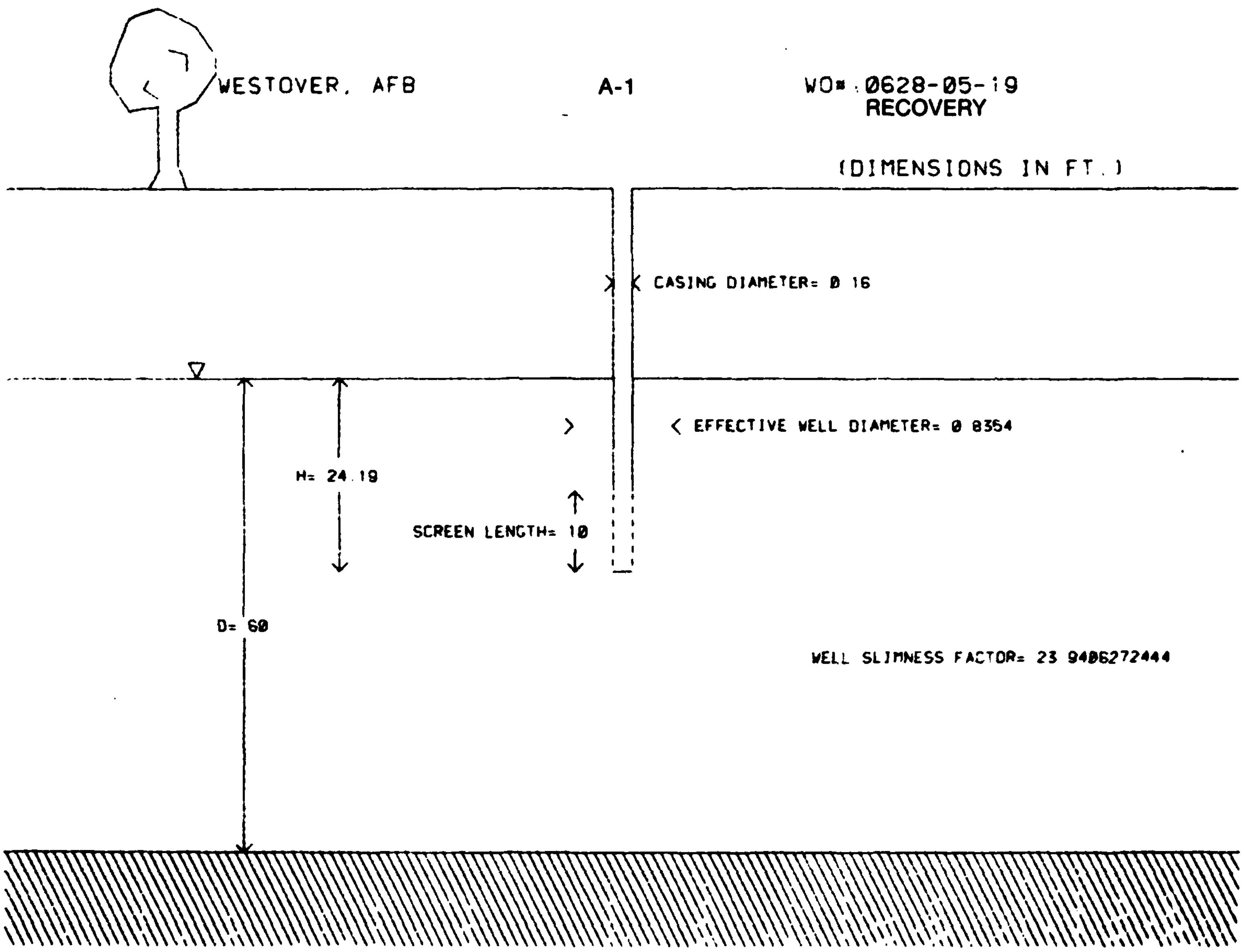
END
FILMED



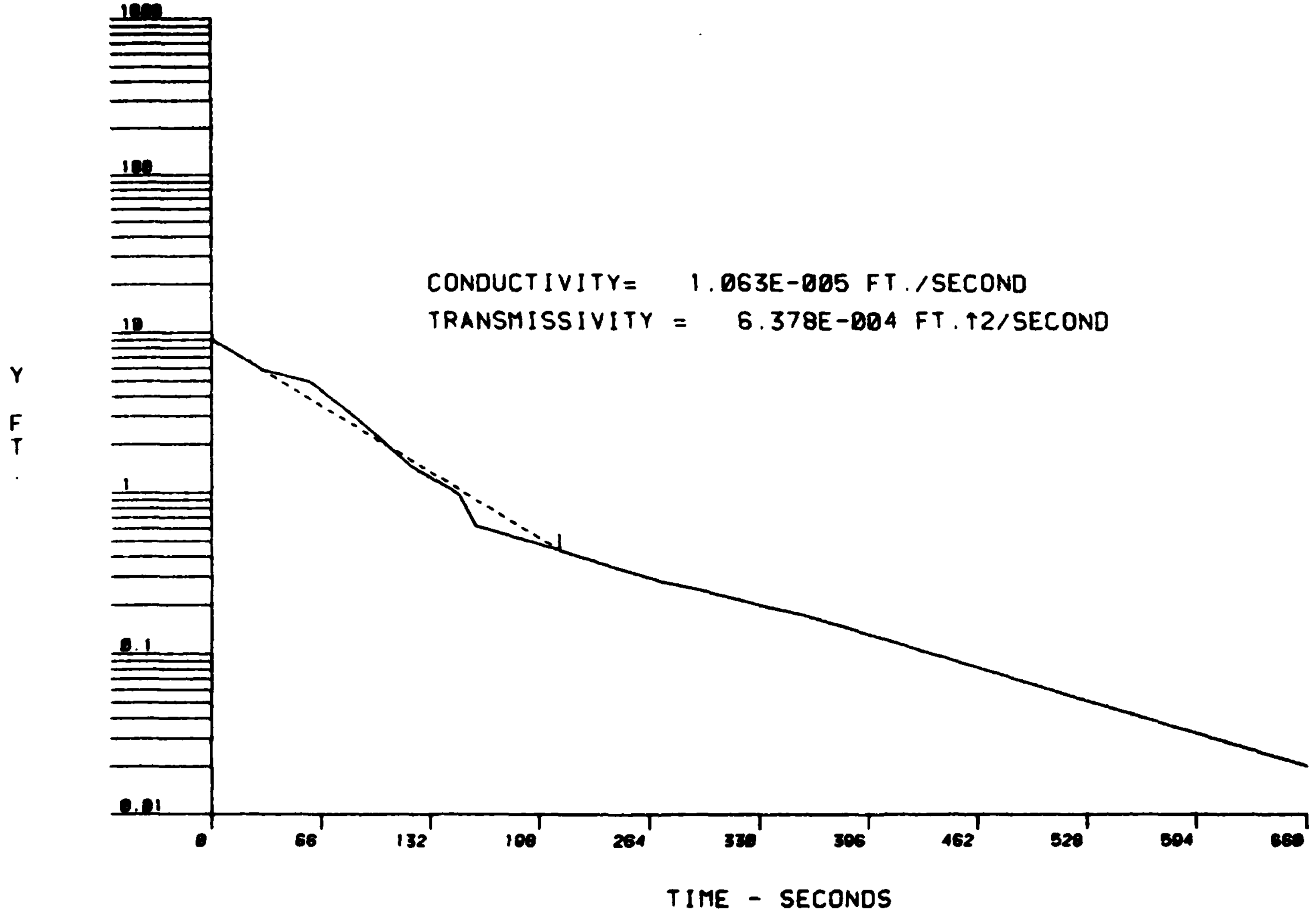
MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX H

Computer Results--Slug and Recovery Tests


WESTOVER, AFB
A-1
WO# 0628-05-19
RECOVERY
(DIMENSIONS IN FT.)
CASING DIAMETER= 0 16
EFFECTIVE WELL DIAMETER= 0 8354
H= 24.19
SCREEN LENGTH= 10
D= 60
WELL SLIMNESS FACTOR= 23 9406272444

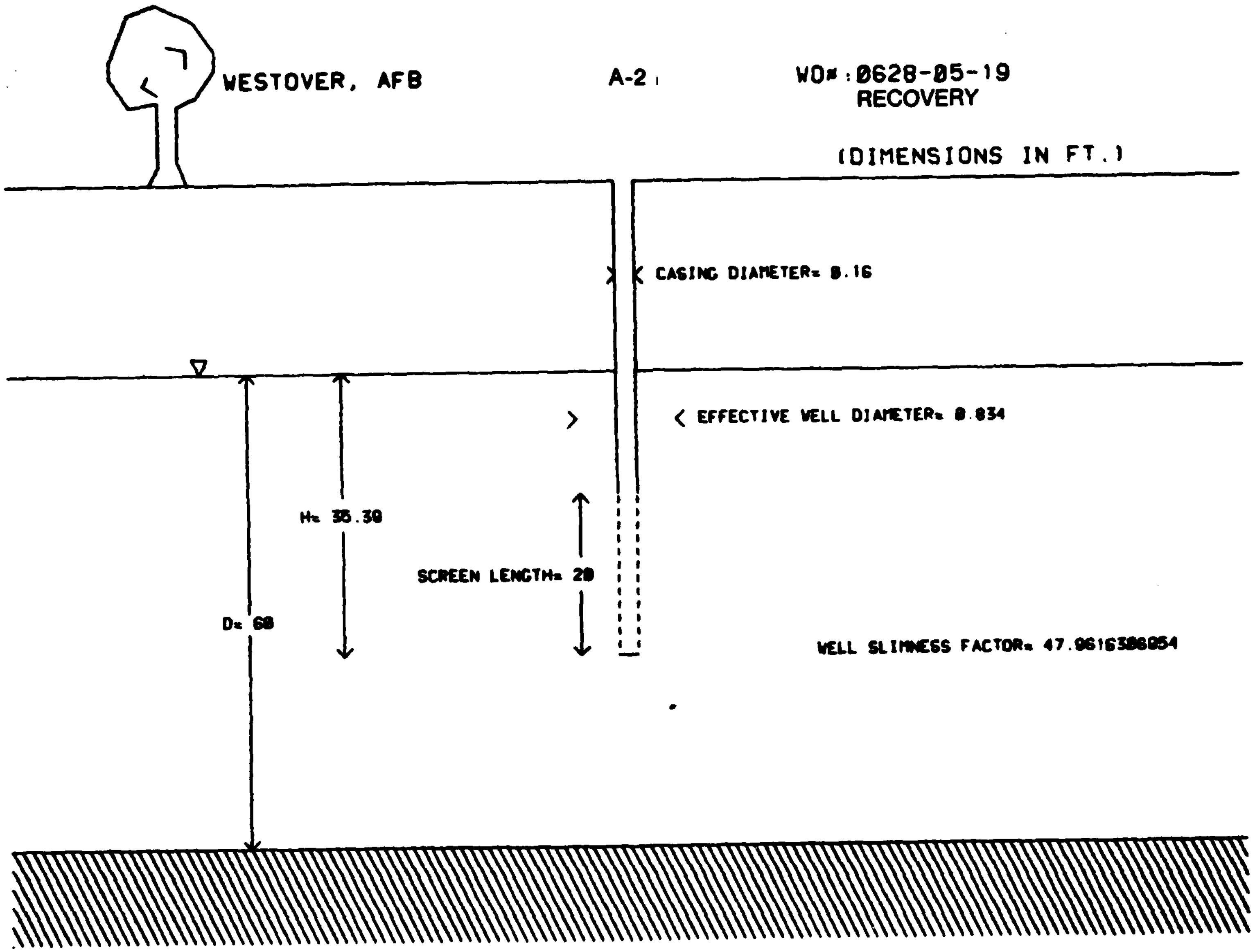
```
WESTOVER, AFB            A-1          WO*:0628-05-19

                   'Y' READINGS      TIME (SECONDS)

       1              8.97              0
       2              5.84              30
       3              4.84              60
       4              2.76              90
       5              1.48              120
       6              0.97              150
       7              0.62              160
       8              0.44              210
       9              0.35              240
      10              0.28              270
      11              0.24              300
      12              0.2               330
      13              0.17              360
      14              0.02              660
```



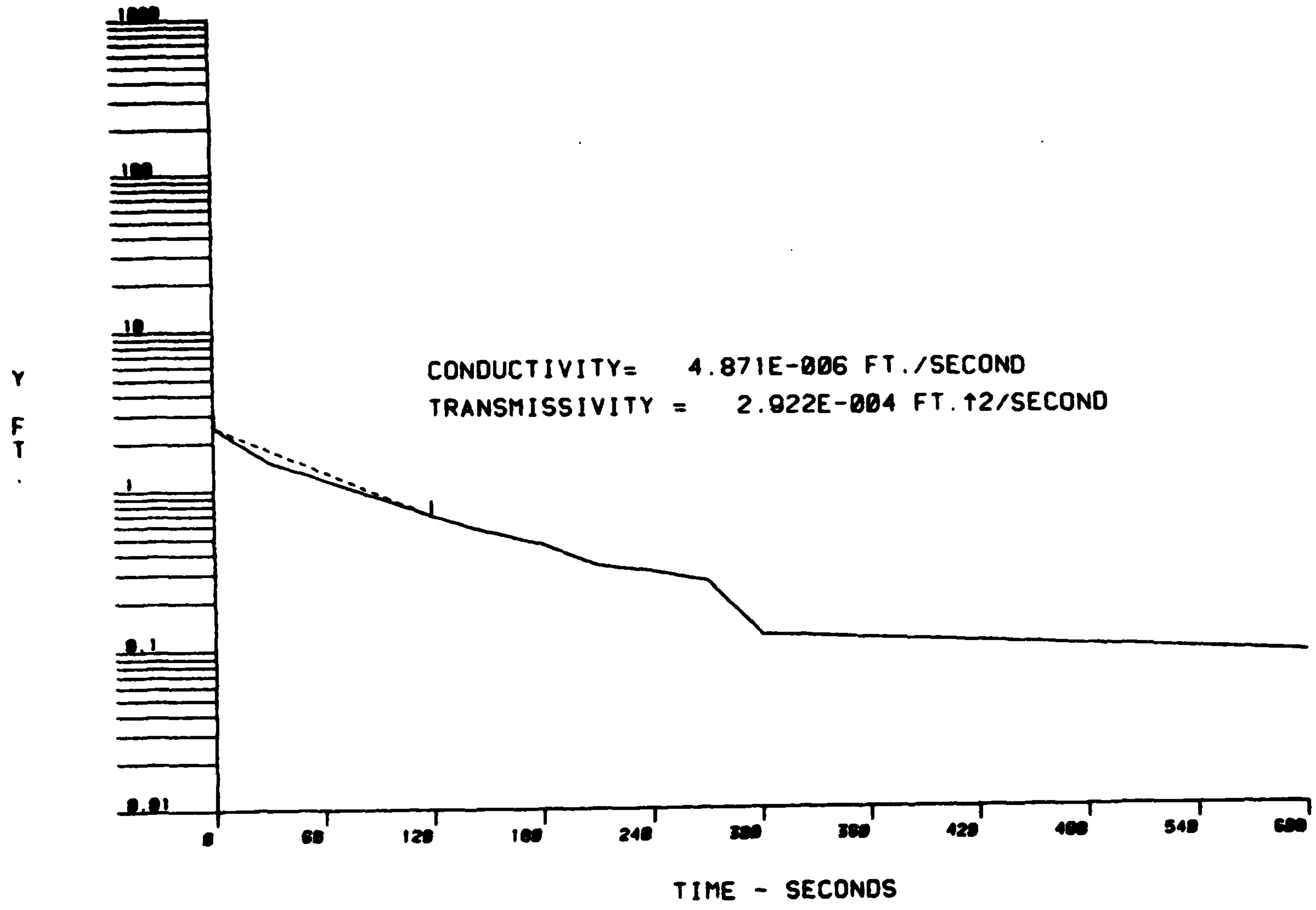
CONDUCTIVITY= 1.063E-005 FT./SECOND

TRANSMISSIVITY = 6.378E-004 FT.↑2/SECOND

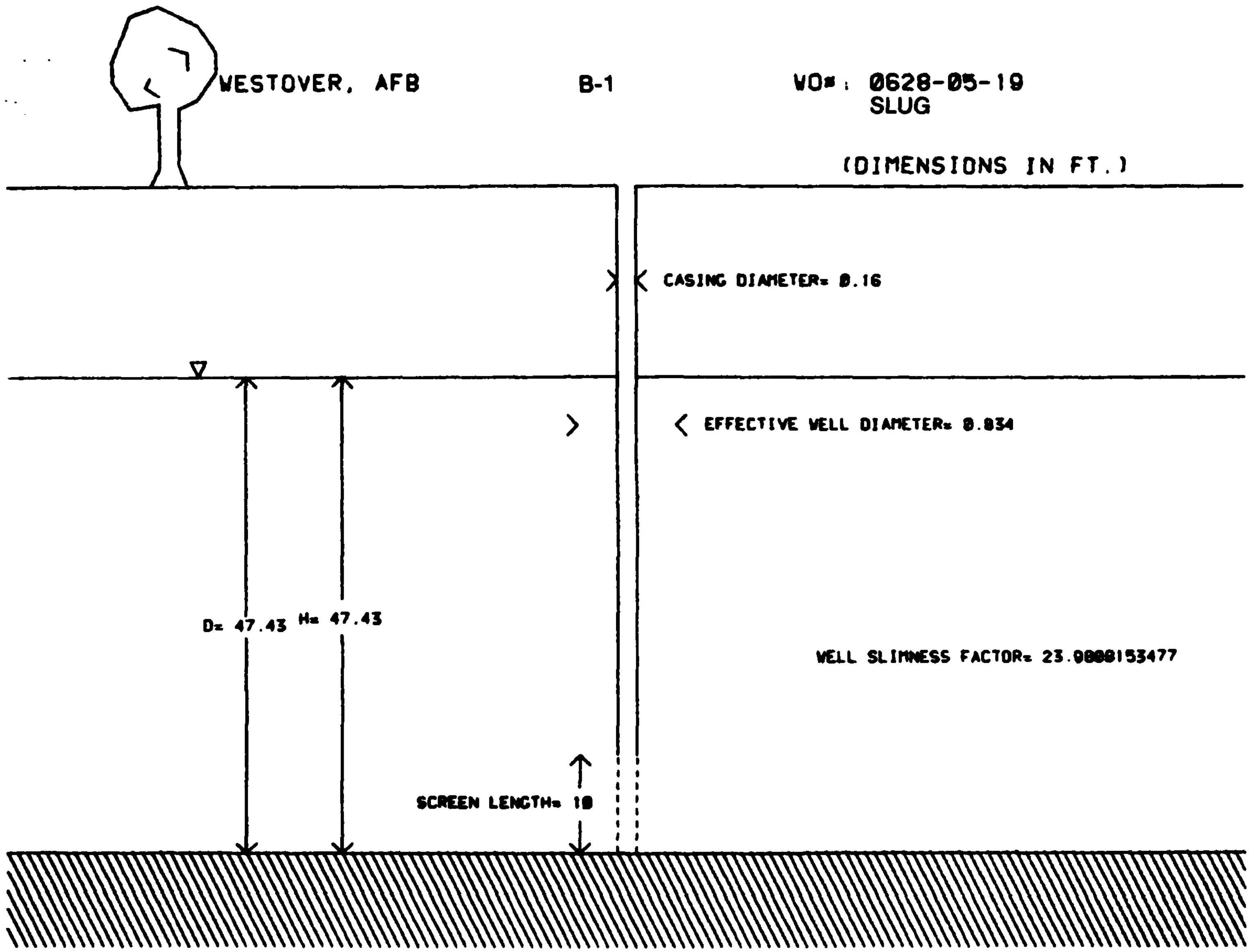
WESTOVER, AFB A-1 WO#:0628-05-19

WESTOVER, AFB
A-2
WO#: 0628-05-19
RECOVERY
(DIMENSIONS IN FT.)
CASING DIAMETER= 0.16
EFFECTIVE WELL DIAMETER= 0.834
H= 35.30
SCREEN LENGTH= 20
D= 60
WELL SLIMNESS FACTOR= 47.9616306954

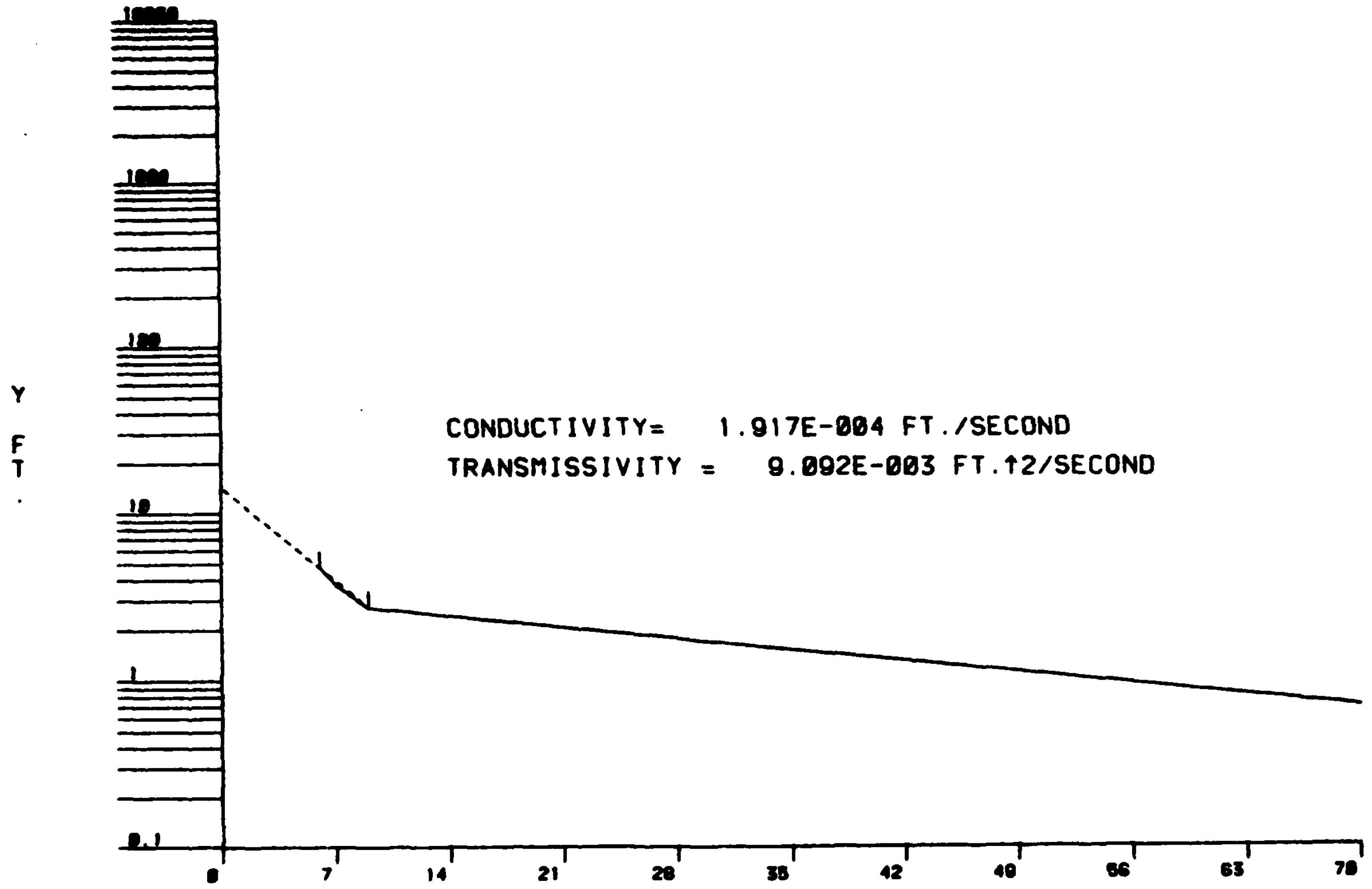
```
WESTOVER, AFB          A-2          WO#:0628-05-19

                  'Y' READINGS     TIME (SECONDS)

      1              2.47              0
      2              1.5               30
      3              0.89              90
      4              0.68              120
      5              0.54              150
      6              0.45              180
      7              0.33              210
      8              0.3               240
      9              0.26              270
      10             0.12              300
      11             0.09              600
```



WESTOVER, AFB A-2 WO#:0628-05-19

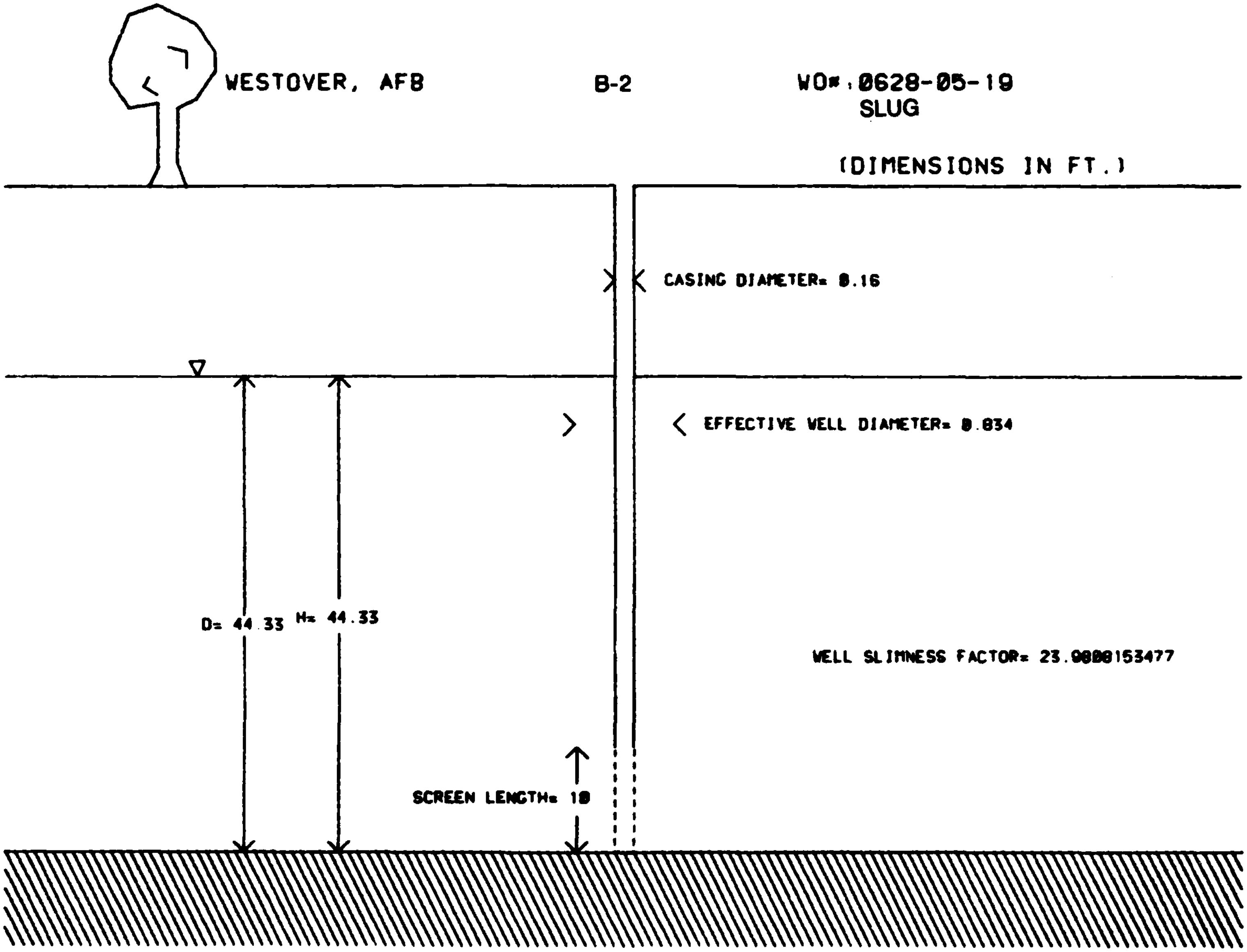

WESTOVER, AFB
B-1
WO#: 0628-05-19
SLUG
(DIMENSIONS IN FT.)
CASING DIAMETER= 0.16
EFFECTIVE WELL DIAMETER= 0.834
D= 47.43
H= 47.43
WELL SLIMNESS FACTOR= 23.0000153477
SCREEN LENGTH= 10

```
WESTOVER, AFB          B-1          WO#: 0628-05-19

                 'Y' READINGS      TIME (SECONDS)

        1            4.69             6
        2            3.69             7
        3            2.69             9
        4            0.69             70
```



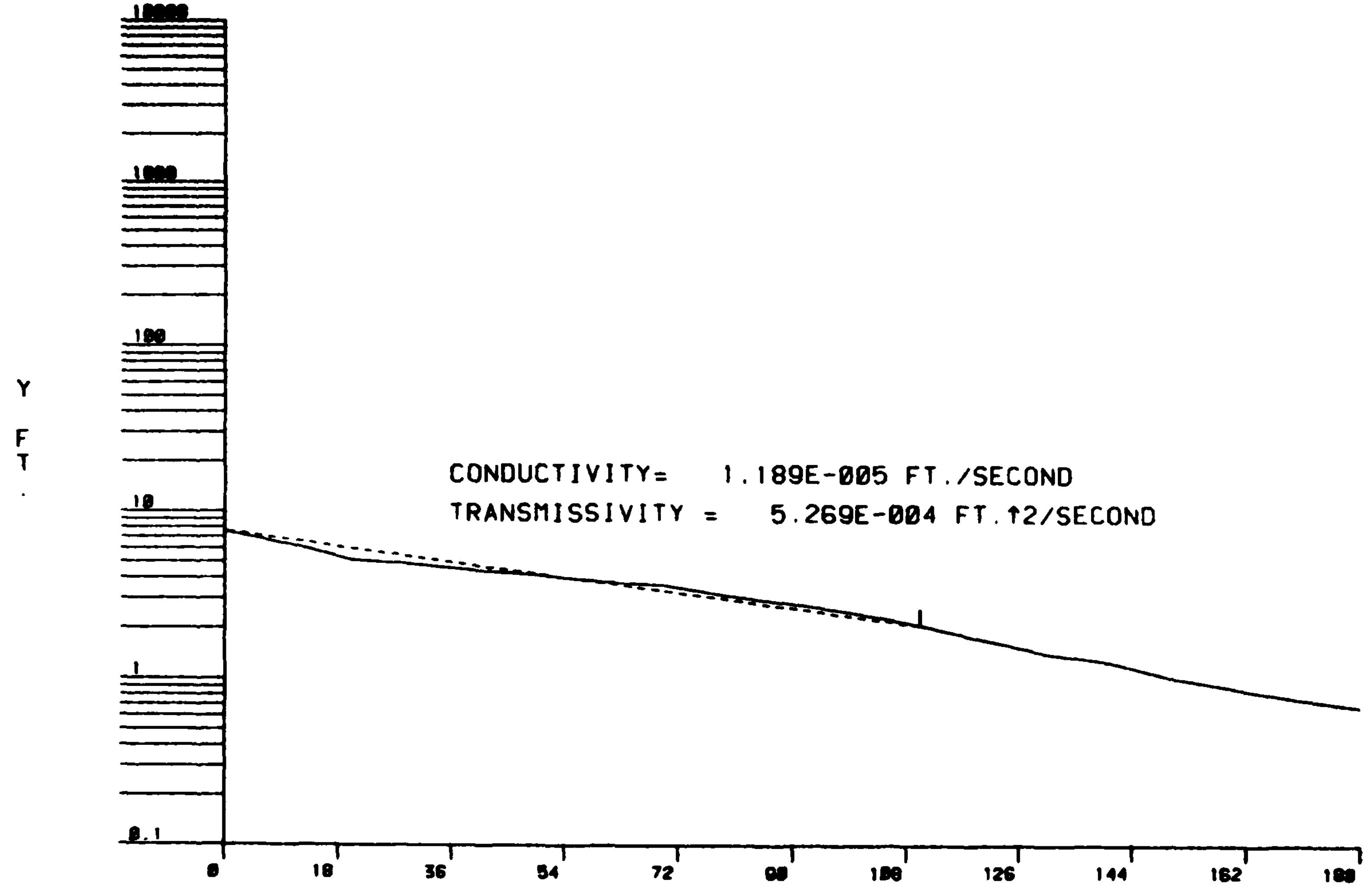
CONDUCTIVITY= 1.917E-004 FT./SECOND
TRANSMISSIVITY = 9.092E-003 FT.↑2/SECOND

WESTOVER, AFB B-1 WO#: 0628-05-19


WESTOVER, AFB
B-2
WO#:0628-05-19
SLUG
(DIMENSIONS IN FT.)
CASING DIAMETER= 0.16
EFFECTIVE WELL DIAMETER= 0.834
D= 44.33
H= 44.33
WELL SLIMNESS FACTOR= 23.0000153477
SCREEN LENGTH= 10

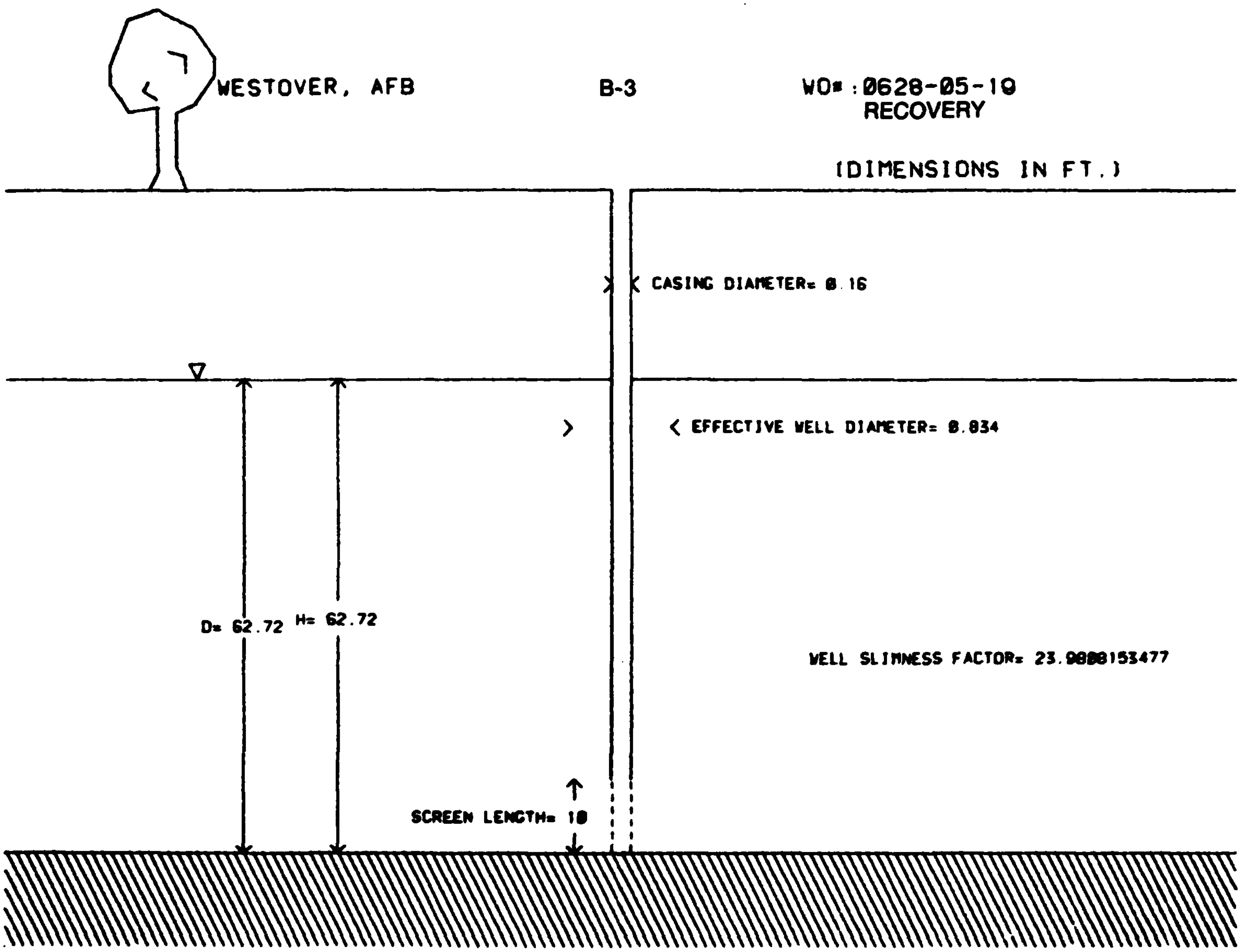
WESTOVER, AFB B-2 WO*:0628-05-19

	'Y' READINGS	TIME (SECONDS)
1	7.57	0
2	6.37	10
3	5.13	20
4	4.83	30
5	4.44	40
6	4.17	50
7	3.82	60
8	3.63	70
9	3.14	80
10	2.82	90
11	2.49	100
12	2.11	110
13	1.74	120
14	1.44	130
15	1.28	140
16	1.03	150
17	0.89	160
18	0.77	170
19	0.69	180

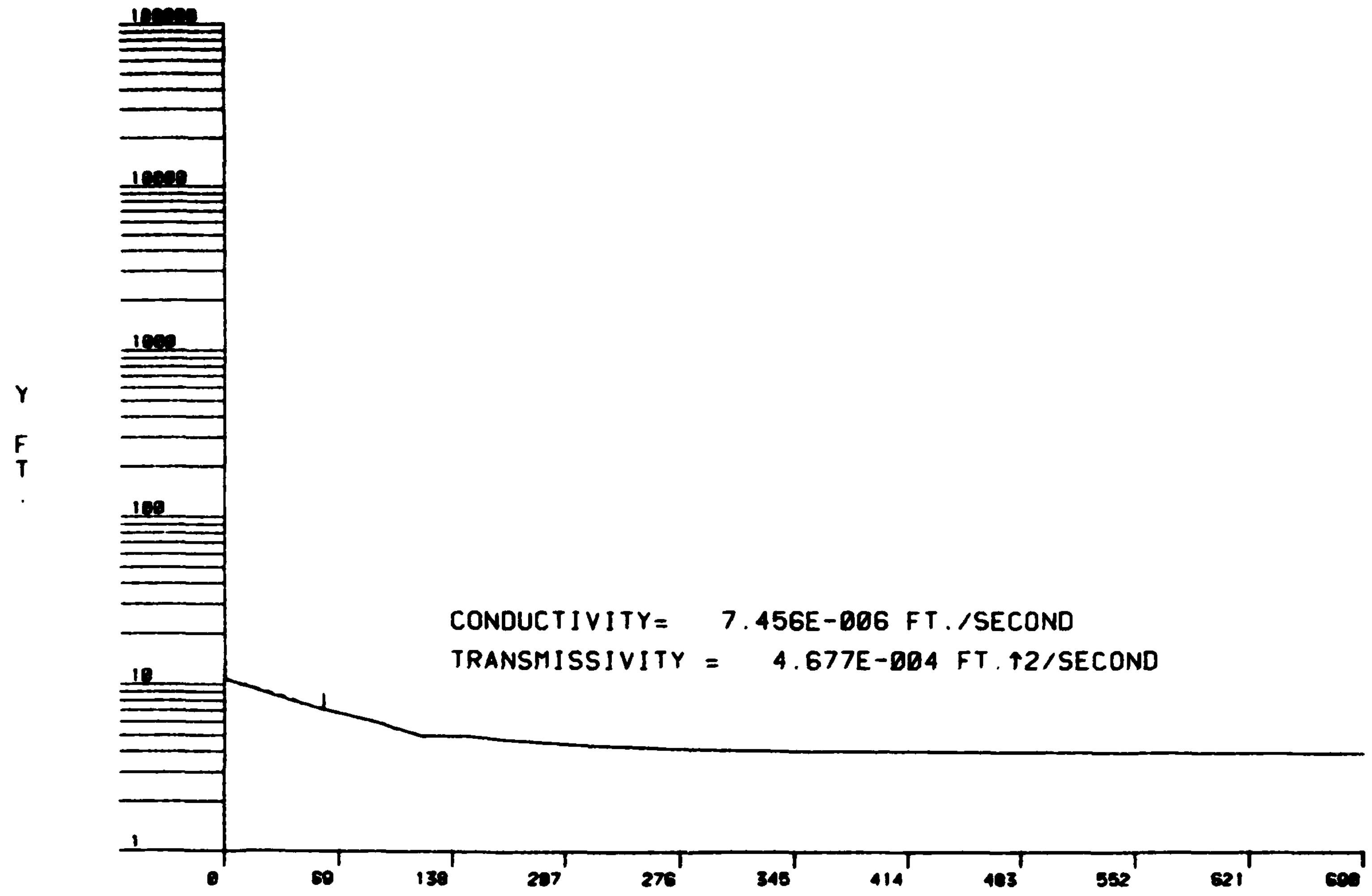


CONDUCTIVITY= 1.189E-005 FT./SECOND
TRANSMISSIVITY = 5.269E-004 FT.↑2/SECOND

WESTOVER, AFB B-2 WO#:0628-05-19

WESTOVER, AFB
B-3
WO# :0628-05-19
RECOVERY
(DIMENSIONS IN FT.)
CASING DIAMETER= 0.16
EFFECTIVE WELL DIAMETER= 0.834
D= 62.72
H= 62.72
WELL SLIMNESS FACTOR= 23.9008153477
SCREEN LENGTH= 10

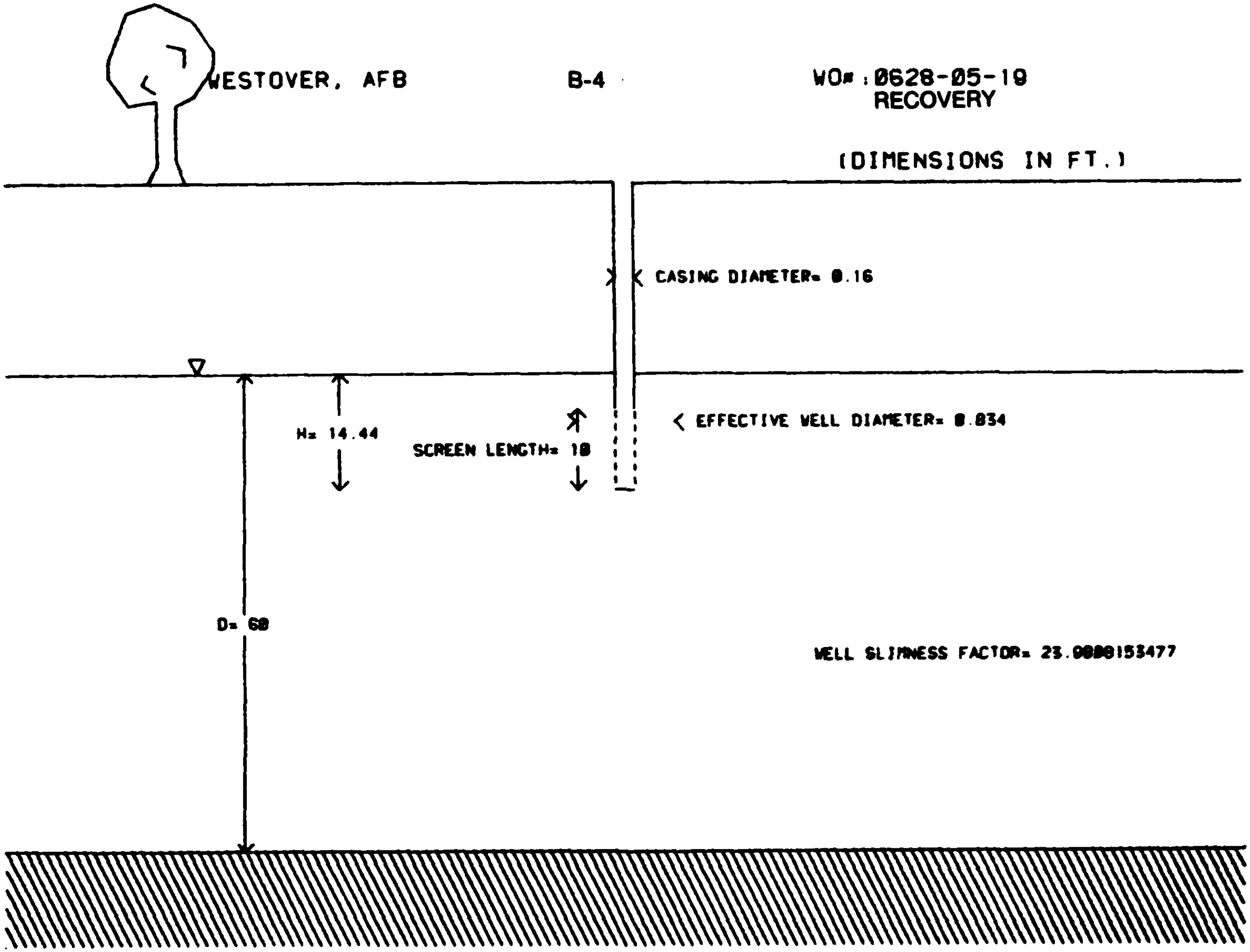
```
WESTOVER, AFB          B-3         WO#:0628-05-10

                'Y' READINGS      TIME (SECONDS)

      1              10.76             0
      2               8.68             30
      3               7.11             60
      4               6.04             90
      5               4.95             120
      6               4.91             150
      7               4.64             180
      8               4.42             210
      9               4.3              240
      10              4.18             270
      11              4.12             300
      12              4.07             330
      13              4.04             360
      14              4.02             390
      15              3.92             690
```



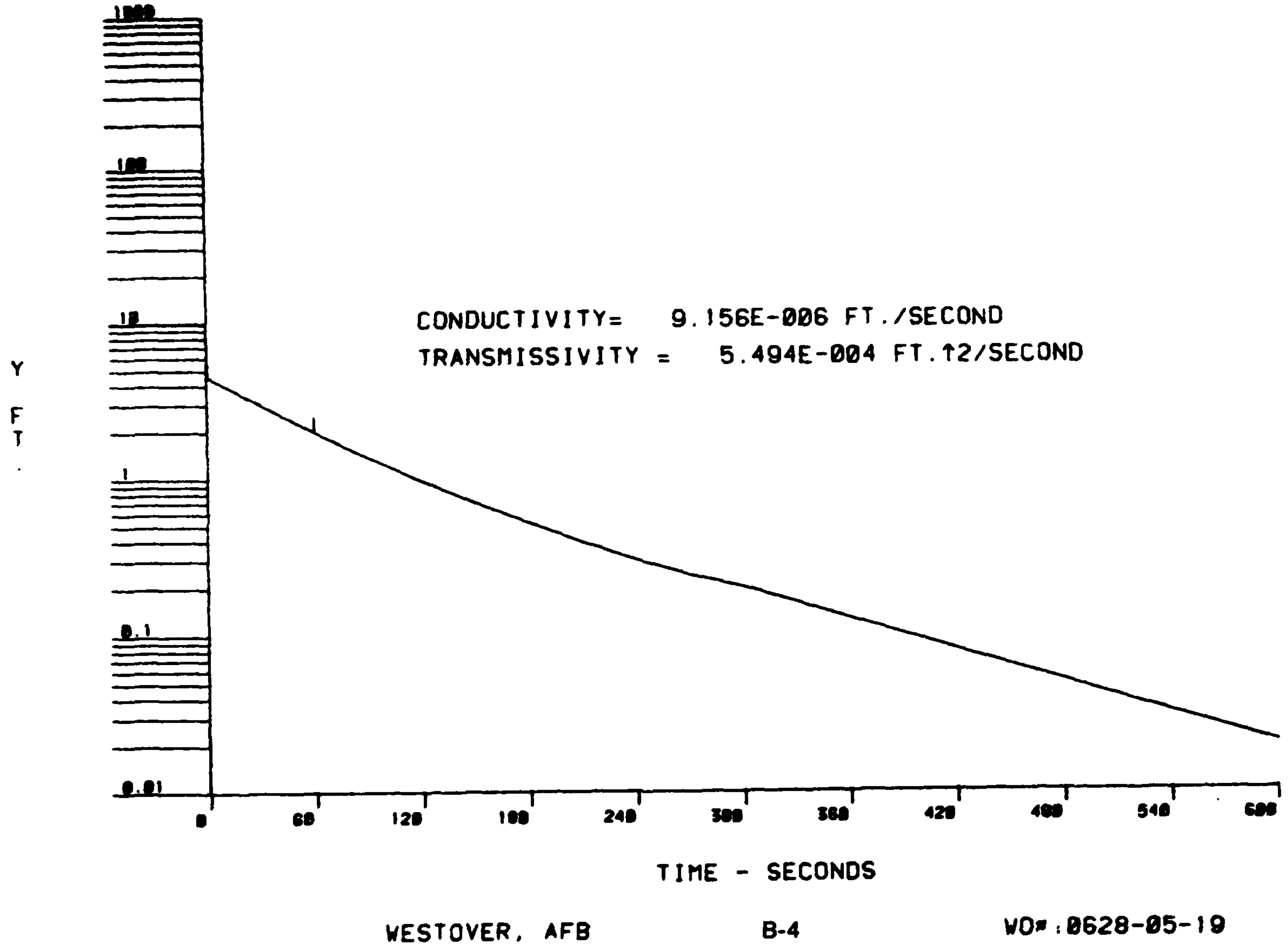
CONDUCTIVITY= 7.456E-006 FT./SECOND

TRANSMISSIVITY = 4.677E-004 FT.↑2/SECOND

WESTOVER, AFB B-3 WO#:0628-05-10


WESTOVER, AFB
B-4
WO# :0628-05-19
RECOVERY
(DIMENSIONS IN FT.)
CASING DIAMETER= 0.16
EFFECTIVE WELL DIAMETER= 0.834
H= 14.44
SCREEN LENGTH= 10
D= 60
WELL SLIMNESS FACTOR= 23.0000153477

```
WESTOVER, AFB          B-4          WO#:0628-05-19

                  'Y' READINGS      TIME (SECONDS)

     1                4.52             0
     2                3                30
     3                2                60
     4                1.37             90
     5                0.97             120
     6                0.7              150
     7                0.52             180
     8                0.39             210
     9                0.3              240
     10               0.24             270
     11               0.2              300
     12               0.02             600
```


CONDUCTIVITY= 9.156E-006 FT./SECOND
TRANSMISSIVITY = 5.494E-004 FT.↑2/SECOND
Y
FT.
1000
100
10
1
0.1
0.01
0
60
120
180
240
300
360
420
480
540
600
TIME - SECONDS
WESTOVER, AFB
B-4
WO#:0628-05-19

APPENDIX I

Raw Water Quality Data

Table I-1

FIELD WATER QUALITY TEST RESULTS

Well	October 1983 Temperature (°C)	October 1983 Conductivity (umhos/cm)	November 1983 Temperature (°C)	November 1983 Conductivity (umhos/cm)	pH (std. units)
B-1	21	45	12	35	5.8
B-1A			13	60	5.9
B-2	16	100	11	145	6.1
B-2A			13	205	6.1
B-3			9	77	6.1
B-3A			12.5	72	5.7
B-4	22	60	15	20	5.8
A-1	17.5	70	11	80	6.1
A-2	17.5	32	9	20	6.0
IW-1	21	75	17	70	5.8
SG-1			9	60	6.5
SG-2			8	60	6.4
SG-3			12	70	6.4
SG-3			12	70	6.4

Table I-2

GROUND-WATER QUALITY DATA - WESTOVER AIR FORCE BASE

Analyte	Unit	B-1	B-1A	B-2	B-2A	B-3	B-3A	B-4	A-1	A-2
COD	mg/l	7.5	21.0	978.0	108.0	10.0	30.0	15.0	<5.0	7.5
TOC	mg/l	<1.0	<1.0	215.0	30.1	11.5	15.0	<1.0	76.5	<1.0
Oil & Grease	mg/l	1.50	1.20	11.70	1.10	1.80	0.49	<0.10	0.17	0.16
Phenol	mg/l	<0.005	<0.005	1.0	0.070	<0.005	0.018	<0.005	<0.005	<0.005
Iron	mg/l	0.53	0.47	483.00	219.00	30.00	15.70	<0.10	34.00	<0.10
Lead	mg/l	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Chloride	mg/l	2.9	4.0	52.5	58.7	2.7	<1.0	<1.0	<1.0	<1.0
Sulfate	mg/l	8.2	58.8	3.5	3.5	23.0	12.3	5.5	27.0	<1.0
Methylene Chloride	µg/l	<0.25	<0.25	16.00	<0.25	<0.25	<0.25	4.70	<0.25	<0.25
1,2-dichloroethane	µg/l	2.60	2.10	9.10	<0.03	2.00	<0.03	2.60	1.80	3.20
Chloroform	µg/l	0.4	<0.05	34.30	<0.05	<0.05	<0.05	<0.05	<0.05	4.50
Chloroethane	µg/l	<0.52	<0.52	2.40	<0.52	<0.52	<0.52	<0.52	<0.52	<0.52
(Trans) 1,2-dichloroethylene	µg/l	<0.10	<0.10	101.00	<0.10	<0.10	<0.10	<0.10	0.50	<0.10
1,1,1-trichloroethane	µg/l	<0.03	<0.03	9.20	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Tetrachloroethylene	µg/l	<0.03	<0.03	2.50	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
Monochlorobenzene	µg/l	<0.25	<0.25	1.70	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
1,1-dichloroethane	µg/l	<0.07	<0.07	34.60	<0.07	<0.07	<0.07	<0.07	1.80	<0.07
Trichloroethylene	µg/l	<0.12	<0.12	26.10	<0.12	<0.12	<0.12	0.38	0.37	<0.12
1,1-dichloroethylene	µg/l	<0.13	<0.13	1.90	<0.13	<0.13	<0.13	<0.13	1.20	<0.13
0-dichlorobenzene	µg/l	<0.15	<0.15	7.50	<0.15	<0.15	<0.15	<0.15	<0.15	<0.15
Unidentified Peaks	µg/l	0	0	6	0	0	0	0	1	0

TABLE I-3

SURFACE WATER QUALITY DATA, WESTOVER AFB

STREAM SAMPLING SITES

Analyte	Units	SG-1	SG-2	SG-3
COD	mg/l	30.0	6.0	5.0
TOC	mg/l	11.5	6.5	1.0
Oil & Grease	mg/l	0.36	0.10	2.50
Phenol	mg/l	0.001	0.001	0.001
Iron	mg/l	0.1	0.1	1.48
Lead	mg/l	0.01	0.01	0.01
Chloride	mg/l	4.4	3.7	3.7
Sulfate	mg/l	32.4	35.8	5.8
1,2-Dichloroethane	mg/l	2.10	2.00	7.70
1,1-Dichloroethylene	mg/l	2.10	0.13	0.30
(Trans)1,2-Dichloroethylene	mg/l	0.30	0.10	3.00
Trichloroethylene	mg/l	0.12	0.12	0.30
1,1,1-Trichloroethane	mg/l	0.03	0.03	3.00
Tetrachloroethylene	mg/l	0.03	0.03	0.50
Unidentified Peaks	mg/l	0.	1.	1.

APPENDIX J

Federal and State Drinking Water and Human Health Standards, Criteria and Guidelines Applicable in the State of Massachusetts

GUIDE TO GROUND-WATER STANDARDS OF THE UNITED STATES

API PUBLICATION 4366

JULY 1983

Prepared by
Ecological Analysts, Inc.
15 Loveton Circle
Sparks, Maryland 21152

3. *FEDERAL PROTECTION OF GROUND-WATER QUALITY*

The federal programs dealing with the protection of ground-water quality are administered largely by the Environmental Protection Agency (EPA). The federal programs which provide the framework for state regulations are summarized in this section.

3.1 GROUND-WATER PROTECTION POLICY

At this writing, February 1983, U.S. EPA's final policy on ground-water protection, scheduled for September 1982 release, has not been published. Based on the proposed strategy published by EPA in November 1980 and recent press releases, it appears that EPA will be implementing a policy that would give the states lead responsibility in the protection of ground-water quality. EPA's efforts apparently will be focused in three major areas:

1. Development of an internally consistent federal approach to ground-water protection
2. Monitoring, research and development efforts directed toward more comprehensive problem definition and new detection, controls, and clean-up technology development
3. Guidance, coordination, and assistance to states in the development of state policies

A significant component of EPA's policy is expected to be a ground-water classification system which could be used to determine the degree of protection needed for various types of ground water. Ground-water classification is discussed in Chapter 4.

3.2 CLEAN WATER ACT

This statute refers to ground-water protection in municipal waste water treatment, planning, and research programs. Its principal regulatory programs, however, focus on surface water. Section 303 empowers EPA to approve states' water quality standards which are based on the states' classification of rivers and streams. Many states have included ground water in their definition of "waters of the state" for purposes of this act (state summaries). On this basis the National (state) Pollutant Discharge Elimination System (NPDES/SPDES) permitting process may be invocable for purposes of ground-water protection. In addition the act empowers EPA to

1. Develop a comprehensive program for ground-water pollution control [Section 102(a)]
2. In cooperation with states, equip and maintain a surveillance system for monitoring ground-water quality [Section 104(a)(5)]
3. Provide grants to states and area-wide agencies to develop ground-water quality management plans to identify salt water intrusion and control disposal of pollutants in subsurface excavations, and control disposition of wastes. (May include authority for comprehensive ground-water management plans, including conjunctive use with surface water) [Section 102(c), 208(b)]
4. Require development of Best Management Practices (BMP) to control nonpoint source pollution problems to ground-water quality [Section 208(b)]
5. Develop criteria for ground-water quality considering kind and extent of effects on health and welfare from the presence of pollutants [Section 304(a)]
6. Determine information necessary to restore and maintain chemical, physical, and biological integrity of ground water [Section 304(a)]
7. Issue information on the factors necessary to restore and maintain chemical, physical, and biological integrity of ground water [Sections 304(a)(2)]

3.3 SAFE DRINKING WATER ACT

This statute authorizes EPA to set maximum contaminant levels (MCLs) and monitoring requirements for public water systems and provides for the protection of underground sources of drinking water. The MCLs regulate the quality of "finished" water, i.e., water as delivered, not the quality of the source water. As discussed below, the MCLs have been utilized by EPA and the states as the basis for other regulations dealing with ground-water quality and protection.

3.3.1 National Interim Primary Drinking Water Regulations

EPA initiated a detailed study of the health effects of various contaminants in water soon after the Safe Drinking Act (SDWA) was signed into law. So that the regulations could include the findings of this and other studies, the primary drinking water regulations were to be developed in two stages: an interim version and a final version. The interim version of the regulation became effective 24 June 1977. SDWA provides for delegation of authority to the states. State Primary Drinking Water Regulations must be at least as stringent as the federal regulations.

The National Interim Primary Drinking Water Regulations define Maximum Contaminant Level as the maximum permissible level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system, except in the case of turbidity (applicable to surface water only) where the maximum permissible level is measured at the point of entry to the distribution system. The MCLs are provided with the state summaries.

3.3.2 National Secondary Drinking Water Regulations

These regulations control contaminants in drinking water that primarily affect the aesthetic qualities relating to the public acceptance of drinking water. At considerably higher concentrations of these contaminants, health implications may also exist as well as aesthetic degradation. The National Secondary Drinking Water Regulations are not federally enforceable but are intended as guidelines for the states.

Secondary Maximum Contaminant Levels (SMCLs) are defined as the maximum permissible level of a contaminant in water which is delivered to the free-flowing outlet of the ultimate user of a public water system. Federal and state SMCLs are provided in the state summaries. The states may establish higher or lower levels which may be appropriate depending upon local conditions such as unavailability of alternate sources of water or other compelling factors, provided the public health and welfare are not adversely affected.

3.3.3 Sole Source Aquifer

The Sole Source Aquifer provisions of SDWA allow EPA to designate an aquifer as the sole source of drinking water for an area thereby guaranteeing protection from contamination by federally assisted activities. Local, regional, or state agencies can petition EPA for sole source designation. The EPA Administrator may designate an aquifer which is a sole or principal drinking water source if its contamination would create a significant hazard to public health. If the designation is made, no federal money or financial commitment may be made for any project which the Administrator determines may contaminate the designated aquifer through its recharge zone.

At this writing, February 1983, EPA has designated the following ten sole source aquifers:

Biscayne Aquifer - Florida
Buried Valley Aquifer - New Jersey
Edwards Aquifer - Texas
Camano Island—Whidbey Island Aquifer - Washington
Spokane-Rathdrum Aquifer - Washington and Idaho
Nassau and Suffolk counties - New York
Cape Cod - Massachusetts
Fresno - California
Ten Mile Creek - Maryland
Northern Guam Lens - Guam

The following eighteen are under consideration:

- Arizona
  - Santa Cruz, Upper Santa Cruz, Aura-Altar Basins
  - California
  - Scotts Valley
- Delaware
  - New Castle County
- Florida
  - Volusia - Floridan Aquifer
- Idaho
  - Snake River Plain
- Louisiana
  - Baton Rouge
  - DeSota Parish
- New Jersey
  - Coastal Plain
  - Ridgewood
  - Upper Rockaway
- New York
  - Kings and Queens counties
  - Sardinia
  - Schenectady
  - Vestal
- Pennsylvania
  - Seven Valleys
- Texas
  - Carrizo-Wilcox Aquifer
- Texas and New Mexico
  - Delaware Basin
- Wisconsin
  - Niagara Aquifer

3.6 RESOURCE CONSERVATION AND RECOVERY ACT

The Solid Waste Disposal Act and the Resource Recovery Act of 1970, as amended by the Resource Conservation and Recovery Act of 1976 (RCRA), require EPA to establish a national program to regulate the management of waste materials.

3.6.1 Solid Waste

Subtitle D of RCRA established a broad-based national program to improve solid waste management through the development of state and regional solid waste management plans. The act offered federal financial assistance to states interested in developing and implementing a solid waste management plan. The state plans, under federal guidelines, identify respective responsibilities of local, state, and regional authorities, and encourage resource recovery and conservations and the application and enforcement of environmentally sound disposal practices.

A major element of the Subtitle D program is the open dump inventory. Section 4005 of RCRA prohibits open dumping. Federal criteria for classifying solid waste management facilities are provided in 40 CFR 257. EPA cannot approve a state solid waste management program with less stringent criteria. Solid waste management facilities failing to satisfy the criteria are considered open dumps. In order to satisfy these criteria, a facility or practice (in addition to other environmental considerations) shall not contaminate an underground drinking water source beyond the solid waste boundary or beyond an alternative boundary established by the state or in court persuant to the stipulations of 40 CFR 257.3-4. The federal criteria define contamination as an exceedence of the MCLs provided in the National Interim Primary Drinking Water Regulations or an increase in concentration of any parameter for which the ambient concentration exceed the MCL.

3.6.2 Hazardous Waste

EPA has issued a series of hazardous waste regulations under Subtitle C of RCRA (40 CFR 260 to 267 and 122 to 124). On 19 May 1980, EPA issued a comprehensive set of standards for generators and transporters of hazardous waste and "interim status" standards for facilities in existence on 19 November 1980, that treat, store, or dispose of hazardous waste. Such facilities were allowed to operate under interim status until they received an RCRA permit. Subsequently, EPA issued standards for granting RCRA permits to treatment and storage facilities. Standards for land disposal facilities were issued on 26 July 1982—virtually completing the program for controlling hazardous waste under RCRA.

The standards for permitting land disposal facilities were issued after a wide range of regulatory options were considered. Over a period of several years, EPA proposed two different sets of land disposal standards and solicited comments on various issues. On 13 February 1981, EPA issued temporary standards for new land disposal facilities. The 26 July regulations replace those temporary standards except for Class I underground injection wells. These will remain subject to the temporary standards until final standards are issued.

The regulations consist primarily of two complementary sets of performance standards:

1. A set of design and operating standards tailored to each of four types of facilities
2. Ground-water monitoring and response regulations applicable to all land disposal facilities

The design and operating standards implement a liquids management strategy that has two goals:

1. Minimize leachate generated at the facility
2. Remove leachate generated to minimize its chance of reaching ground water

The major requirements include

1. Liner
   - Requirement: design to prevent migration of waste out of the facility during its active life
   - Applicability: landfills, surface impoundments, and waste piles
2. Leachate collection and removal
   - Requirement: collect and remove leachate from the facility and ensure that leachate depth over the liner does not exceed 30 centimeters (1 foot)
   - Applicability: landfills and waste piles

3. Run-on and runoff control systems
   - Requirement: design to control flow during at least 25-year storm
   - Applicability: landfills, waste piles, land treatment
4. Wind dispersal controls
   - Requirement: cover waste or otherwise manage unit to control wind dispersal
   - Applicability: landfills, waste piles, and land treatment units that contain particulate matter
5. Overtopping controls
   - Requirement: prevent overtopping or overfilling
   - Applicability: surface impoundments
6. Disposal unit closure
   - Requirement: final cover (cap) over waste unit designed to minimize *infiltration of precipitation*
   - Applicability: landfills and surface impoundments (if used for disposal)
7. Storage unit closure
   - Requirement: remove waste and decontaminate
   - Applicability: surface impoundments used for treatment or storage and waste piles
8. Postclosure Care
   - Maintain effectiveness of final cover
   - Operate leachate collection and removal system
   - Maintain ground-water monitoring system (and leak detection system where double liner is used)
   - Continue 30 years after closure

The goal of the ground-water monitoring and response program is to detect and correct any ground-water contamination. There are four main elements:

1. A detection monitoring program which requires the permittee to install a system to monitor ground water in the uppermost aquifer to determine if a leachate plume has reached the edge of the waste management area.
2. A ground-water protection standard is set when a hazardous constituent is detected. The standard specifies concentration limits, compliance point, and compliance period.
3. A compliance monitoring program determines if the facility is complying with its ground-water protection standard.
4. Corrective action is required when the ground-water protection standard is violated. The permittee must either remove the contamination or treat it in place to restore ground-water quality.

Until hazardous waste management facilities are issued permits, existing facilities will continue to operate under interim status standards. Facilities operating under interim status will be required to file Part B applications for final permits.

Under Subtitle C of RCRA, EPA approves state hazardous waste management programs in two phases. Phase I authorization gives states the right to control transportation and generation of hazardous wastes within their borders and to regulate existing treatment, storage, and disposal facilities. Phase II authorization includes the permitting of new facilities.

3.7 COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT

This statute (CERCLA), commonly referred to as Superfund, authorizes EPA to respond to releases or threatened releases into the environment, including ground water, of any hazardous substance which may present an imminent and substantial danger to public health. The act provides funds for emergency action and has cost recovery provisions.

3.3.4 Underground Injection Control

The Underground Injection Control (UIC) program regulates the uses of underground injection wells to protect an underground source of drinking water (USDW). USDW means an aquifer or its portion which

1. supplies any public water system or contains a sufficient quantity of ground water to supply a public water system;
2. currently supplies drinking water for human consumption or contains less than 10,000 mg/liter total dissolved solids; and
3. is not an exempted aquifer (40 CFR 146.04 provides criteria for exemption).

SDWA requires any state designated by EPA as requiring a UIC program to develop and submit a state UIC program for EPA approval. EPA has designated each of the fifty states.

The federal program classifies injection wells as follows:

Class I—Wells used to inject hazardous waste, or other industrial and municipal disposal wells which inject fluids beneath the lower-most formation containing a USDW within one-quarter mile of the well bore.

Class II—Wells that inject fluids

1. which are brought to the surface as part of conventional oil or natural gas production and may be mixed with production waste waters from gas plants, unless those waters are classified as a hazardous waste at the time of injection;
2. for enhanced recovery of oil or natural gas; and
3. for storage of hydrocarbons which are liquid at standard temperature and pressure.

Class III—Wells that inject for extraction of minerals including

1. mining of sulfur by the Frasch process;
2. in situ production of uranium or other metals. This category includes only in situ production from ore bodies which have not been conventionally mined. Solution mining of conventional mines such as stopes leaching is included in Class V; and
3. solution mining of salts or potash.

Class IV—Wells used to dispose of hazardous or radioactive waste into or above a formation which contains a USDW within one-quarter mile of the well. Also, wells used to inject hazardous waste that cannot be classified as Class I or Class IV under the above criteria are Class IV wells.

Class V—All other injection wells (40 CFR 146.05(e) and 146.51 provide specific information and exemptions).

Underground injection is controlled through the permitting process. Construction, operation, monitoring and reporting activities are controlled. Individual state programs are based upon, and must be essentially equivalent to, the federal criteria and standards (40 CFR 146).

3.4 TOXIC SUBSTANCE CONTROL ACT

This statute (TSCA) authorizes EPA to restrict or prohibit the manufacture, distribution, and use of products which may result in unreasonable risk to health and the environment. Although ground water is not specifically named in the Act, EPA has taken the position that the protection of health and the environment includes the protection of ground water.

3.5 FEDERAL INSECTICIDE, FUNGICIDE, RODENTICIDE ACT

This statute (FIFRA) gives EPA the responsibility to control the sale and use of all pesticides to prevent unreasonable adverse environmental and health effects. The use and disposal of pesticide packages and containers is also regulated. In deciding whether to register, cancel, suspend, or change the classification of a pesticide, EPA considers a broad range of environmental impacts including those affecting ground water.

MASSACHUSETTS

Classification–Ground water is included in the definition of "Waters of the Commonwealth" as found in the Massachusetts Clean Waters Act. No ground-water classification system is currently in effect. The Water Resources Commission is investigating such a system as part of a statewide Ground-Water Management Plan.

Quality Standards–There are no ground-water standards in effect at the present; they are under consideration as part of a classification system.

Drinking Water Standards–The Department of Environmental Quality Engineering has adopted the federal primary and secondary drinking water standards.

Appropriation–The Common Law system governs ground-water allocations in Massachusetts. There are no permit requirements or limits on the amounts withdrawn by any user. A permit system is under consideration, however, for the purpose of management and protection of ground-water resources.

Controlled Use Areas–There are none at the present.

Well Construction–Public supply wells must be constructed according to standards of the Department of Environmental Quality Engineering.

Underground Injection Control–Massachusetts has developed a state UIC program that has been submitted for EPA approval. The Department of Environmental Quality Engineering will be the lead agency in the program. All injection wells except for Class V wells will not be permitted.

Waste Management Facilities–The solid and hazardous waste management programs are administered by the Department of Environmental Quality Engineering.

> **Solid Waste**–The Massachusetts Solid Waste Regulations do not state minimum ground-water monitoring requirements. Permit requirements for siting and operation of disposal sites are such as to prevent ground-water contamination. Ground-water monitoring may be required on a case-by-case basis.
>
> **Hazardous Waste**–Massachusetts has received interim status authority for RCRA Phase I and is seeking Phase II authority. The Massachusetts Hazardous Waste Regulations have incorporated EPA ground-water monitoring requirements (40 CFR 265 Subpart F) by reference.

Sole Source Aquifers–Cape Cod has been designated as such by EPA.

Geological Surveys–
Division of Waterways
Department of Environmental
Quality Engineering
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State Geologist:
Mr. Joseph A. Sinnot

Water Resources Division
U.S. Geological Survey
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617-223-2822
District Chief:
I.C. James II

Note: New England District Office for Massachusetts, Maine, New Hampshire, Rhode Island, and Vermont.

References–
Massachusetts Clean Waters Act
(Mass. Gen. Laws, Chap. 21, Secs. 26-53)

Massachusetts Solid Waste Regulations
(CMR, Title 310, Chap. 19)

Massachusetts Hazardous Waste Regulations
(CMR, Title 315, Chap. 2)

Contacts–
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No comments on this summary were received from the Commonwealth of Massachusetts.

MASSACHUSETTS

Parameter (mg/l unless noted)	Drinking Water Standards		Quality Standards	Monitoring Requirements	
	Federal	State		Solid Waste	Hazardous Waste
Arsenic	0.05	0.05			M
Barium	1.0	1.0			M
Cadmium	0.010	0.010			M
Chromium	0.05	0.05			M
Lead	0.05	0.05			M
Mercury	0.002	0.002			M
Selenium	0.01	0.01			M
Silver	0.05	0.05			M
Fluoride	1.4–2.4	1.4–2.4			M
Nitrate (as N)	10.0	10.0			M
Endrin	0.0002	0.0002			M
Lindane	0.004	0.004			M
Methoxychlor	0.1	0.1			M
Toxaphene	0.005	0.005			M
2,4-D	0.1	0.1			M
2,4,5-TP Silvex	0.01	0.01			M
Trihalomethanes	0.1	0.1			
Turbidity (TU)	1.0	1.0			
Coliform bacteria — membrane filter test (#/100 ml)	1.0	1.0			M
Gross alpha (pCi/l)	15.0	15.0			M
Combined Radium 226 and Radium 228	5.0	5.0			M
Beta and photon particle activity (mrem/yr)	4.0	4.0			M
Sodium	M	M			M
Chloride	250.0	250.0			M
Color (units)	15.0	15.0			
Copper	1.0	1.0			
Corrosivity	Noncorrosive	Noncorrosive			
Foaming agents	0.5	0.5			
Iron	0.3	0.3			M
Manganese	0.05	0.05			M
Odor (threshold no.)	3.0	3.0			
pH (units)	6.5–8.5	6.5–8.5			M
Sulfate	250.0	250.0			M
Total dissolved solids	500.0	500.0			
Zinc	5.0	5.0			
Phenols					M
Specific conductance					M
Total organic carbon					M
Total organic halogen					M

Note: "M" denotes monitoring requirement. See Section 4.3.

ENVIRONMENTAL PROTECTION AGENCY NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

(40 CFR 141; 40 FR 59565, December 24, 1975; Amended by 41 FR 28402, July 9, 1976; 44 FR 68641, November 29, 1979; Corrected by 45 FR 15542, March 11, 1980; 45 FR 57342, August 27, 1980)

Title 40—Protection of Environment
CHAPTER I—ENVIRONMENTAL PROTECTION AGENCY
SUBCHAPTER D—WATER PROGRAMS
PART 141—NATIONAL INTERIM PRIMARY DRINKING WATER REGULATIONS

Subpart A—General

Subpart B—Maximum Contaminant Levels

Subpart C—Monitoring and Analytical Requirements

Subpart D—Reporting Public Notification, and Record-keeping

Subpart E—Special Monitoring Regulations for Organic Chemicals

Authority: Secs. 1412, 1414, 1445, and 1450 of the Public Health Service Act, 88 Stat. 1660 (42 U.S.C. 300g-1, 300g-3, 300j-4, and 300j-9).

Subpart A—General

§ 141.1 Applicability.

This part establishes primary drinking water regulations pursuant to section 1412 of the Public Health Service Act, as amended by the Safe Drinking Water Act (Pub. L. 93-523); and related regulations applicable to public water systems.

§ 141.2 Definitions.

As used in this part, the term:

(a) "Act" means the Public Health Service Act, as amended by the Safe Drinking Water Act, Pub. L. 93-523.

(b) "*Contaminant*" means any physical, chemical, biological, or radiological substance or matter in water.

(c) "Maximum contaminant level" means the maximum permissible level of a contaminant in water which is delivered to the free flowing outlet of the ultimate user of a public water system, except in the case of turbidity where the maximum permissible level is measured at the point of entry to the distribution system. Contaminants added to the water under circumstances controlled by the user, except those resulting from corrosion of piping and plumbing caused by water quality, are excluded from this definition.

(d) "Person" means an individual, corporation, company, association, partnership, State, municipality, or Federal agency.

(e) "Public water system" means a system for the provision to the public of piped water for human consumption, if such system has at least fifteen service connections or regularly serves an average of at least twenty-five individuals daily at least 60 days out of the year. Such term includes (1) any collection, treatment, storage, and distribution facilities under control of the operator of such system and used primarily in connection with such system, and (2) any collection or pretreatment storage facilities not under such control which are used primarily in connection with such system. A public water system is either a "community water system" or a ", community water system."

(i) "Community water system" m a public water system which serve least 15 service connections used by y round residents or regularly serve least 25 year-round residents.

(ii) "Non-communty water sys means a public watersystem that i a community water system.

(f) "Sanitary survey" means an site review of the water source, f ties, equipment, operation and ma nance of a public water system fo purpose of evaluating the adequa such source, facilities, equipment eration and maintenance for prod and distributing safedrinking wate

(g) "Standard sample" means aliquot of finished drinking water t examined for the presence of col bacteria.

(h) "State" mean the agency State government which has jur tion over public water systems. I any period when a State does not primary enforcement respons pursuant to Section 1413 of the Ac term "State" mean the Regiona ministrator, U.S. Environmental P tion Agency.

(i) "Supplier of water" mean person who owns or operates a water system.

(j) "Dose equivalent" means the uct of the absorbed dose from io radiation and such factors as accou differences in biological effectivene to the type of radiaton and its di tion in the body as specified by t ternational Commission on Radio Units and Measurements (ICRU).

(k) "Rem" means the unit o equivalent from ionizing radiation total body or any internal organ or system. A "milliren (mrem)" is of a rem.

(l) "Picocurie (pCi" means that tity of radioactive material pro 2.22 nuclear transformations per m

(m) "Gross alpha particle ac means the total radioactivity c alpha particle emission as inferre measurements on a dry sample.

(n) "Man-made beta particle an ton emitters" means all radion emitting beta particles and/or p

[Sec. 14 2(n)]

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listed in Maximum Permissible Body Burdens and Maximum Permissible Concentration of Radionuclides in Air or Water for Occupational Exposure. NBS Handbook 69, except the daughter products of thorium-232, uranium-235 and uranium-238.

(o) "Gross beta particle activity" means the total radioactivity due to beta particle emission as inferred from measurements on a dry sample.

[41 FR 28402, July 9, 1976]
[141.2 (p)-(t) added by 44 FR 68641, November 29, 1979]

(p) "Halogen" means one of the chemical elements chlorine, bromine or iodine.

(q) "Trihalomethane" (THM) means one of the family of organic compounds, named as derivatives of methane, wherein three of the four hydrogen atoms in methane are each substituted by a halogen atom in the molecular structure.

(r) "Total trihalomethanes" (TTHM) means the sum of the concentration in milligrams per liter of the trihalomethane compounds (trichloromethane [chloroform], dibromochloromethane, bromodichloromethane and tribromomethane [bromoform]), rounded to two significant figures.

(s) "Maximum Total Trihalomethane Potential (MTP)" means the maximum concentration of total trihalomethanes produced in a given water containing a disinfectant residual after 7 days at a temperature of 25° C or above.

(t) "Disinfectant" means any oxidant, including but not limited to chlorine, chlorine dioxide, chloramines, and ozone added to water in any part of the treatment or distribution process, that is intended to kill or inactivate pathogenic microorganisms.

§ 141.3 Coverage.

This part shall apply to each public water system, unless the public water system meets all of the following conditions:

(a) Consists only of distribution and storage facilities (and does not have any collection and treatment facilities);

(b) Obtains all of its water from, but is not owned or operated by, a public water system to which such regulations apply;

(c) Does not sell water to any person; and

(d) Is not a carrier which conveys passengers in interstate commerce.

§ 141.4 Variances and exemptions.

Variances or exemptions from certain provisions of these regulations may be granted pursuant to Sections 1415 and 1416 of the Act by the entity with primary enforcement responsibility. Provisions under Part 142, *National Interim Primary Drinking Water Regulations Implementation*—subpart E (Variances) and subpart F (Exemptions)—apply where EPA has primary enforcement responsibility.

§ 141.5 Siting requirements.

Before a person may enter into a financial commitment for or initiate construction of a new public water system or increase the capacity of an existing public water system, he shall notify the State and, to the extent practicable, avoid locating part or all of the new or expanded facility at a site which:

(a) Is subject to a significant risk from earthquakes, floods, fires or other disasters which could cause a breakdown of the public water system or a portion thereof; or

(b) Except for intake structures, is within the floodplain of a 100-year flood or is lower than any recorded high tide where appropriate records exist.
The U.S. Environmental Protection Agency will not seek to override land use decisions affecting public water systems siting which are made at the State or local government levels.

§ 141.6 Effective dates.

[141.6 revised by 44 FR 68641, November 29, 1979]

(a) Except as provided in paragraph (b) of this section, the regulations set forth in this part shall take effect on June 24, 1977.

(b) The regulations for total trihalomethanes set forth in § 141.12(c) shall take effect 2 years after the date of promulgation of these regulations for community water systems serving 75,000 or more individuals, and 4 years after the date of promulgation for communities serving 10,000 to 74,999 individuals.

(c) The regulations set forth in 141.11 (a), (c) and (d); 141.14(a)(1); 141.14(b)(1)(c); 141.14(b)(2)(i); 141.14(d); 141.21 (a), (c) and (i); 141.22 (a) and (e); 141.23 (a)(3) and (a)(4); 141.23(f); 141.24(a)(3); 141.24 (e) and (f); 141.25(e); 141.27(a); 141.28 (a) and (b); 141.31 (a), (c), (d) and (e); 141.32(b)(3); and 141.32(d) shall take effect immediately upon promulgation.

(d) The regulations set forth in 141.41 shall take effect 18 months from the date of promulgation. Suppliers must complete the first round of sampling and reporting within 12 months following the effective date.

(e) The regulations set forth in 141.42 shall take effect 18 months from the date of promulgation. All requirements in 141.42 must be completed within 12 months following the effective date.

[141.6 (c)-(e) added by 45 FR 57342, August 27, 1980]

Subpart B—Maximum Contaminant Levels

§ 141.11 Maximum contaminant levels for inorganic chemicals.

(a) The MCL for nitrate is applicable to both community water systems and non-community water systems except as provided by in paragraph (d). The levels for the other organic chemicals apply only to community water systems. Compliance with MCLs for inorganic chemicals is calculated pursuant to § 141.23.

[141.11(a) amended by 45 FR 57342, August 27, 1980]

(b) The following are the maximum contaminant levels for inorganic chemicals other than fluoride:

Contaminant	Level, milligrams per liter
Arsenic	0.05
Barium	1.
Cadmium	0.010
Chromium	0.05
Lead	0.05
Mercury	0.002
Nitrate (as N)	10.
Selenium	0.01
Silver	0.05

(c) When the annual average of the maximum daily air temperatures for the location in which the community water system is situated is the following, the maximum contaminant levels for fluoride are:

Temperature Degrees Fahrenheit	Degrees Celsius	Level, milligrams per liter
53.7 and below	12.0 and below	2.4
53.8 to 58.3	12.1 to 14.6	2.2
58.4 to 63.8	14.7 to 17.6	2.0
63.9 to 70.6	17.7 to 21.4	1.8
70.7 to 79.2	21.5 to 26.2	1.6
79.3 to 90.5	26.3 to 32.5	1.4

(c) Fluoride at optimum levels in drinking water has been shown to have beneficial effects in reducing the occurrence of tooth decay.

[141.11 (c) amended by 45 FR 57342, August 27, 1980]

(d) At the discretion of the State, nitrate levels not to exceed 20 mg/l may be allowed in a non-community water system if the supplier of water demonstrates to the satisfaction of the State that:

(1) Such water will not be available to children under 6 months of age; and

(2) There will be continuous posting of the fact that nitrate levels exceed 10 mg/l and the potential health effects of exposure; and

(3) Local and State public health authorities will be notified annually of nitrate levels that exceed 10 mg/l; and

(4) No adverse health effects shall result.

[141.11 (d) added by 45 FR 57342, August 27, 1980]

§ 141.12 Maximum contaminant levels for organic chemicals.

[141.12 revised by 44 FR 68641, November 29, 1979]

The following are the maximum contaminant levels for organic chemicals. The maximum contaminant levels for organic chemicals in paragraphs (a) and (b) of this section apply to all community water systems. Compliance with the maximum contaminant levels in paragraphs (a) and (b) is calculated pursuant to § 141.24. The maximum comtaminant level for total trihalomethanes in paragraph (c) of this section applies only to community water systems which serve a population of 10,000 or more individuals and which add a disinfectant (oxidant) to the water in any part of the drinking water treatment process. Compliance with the maximum contaminant level for total trihalomethanes is calculated pursuant to § 141.30.

	Level, milligrams per liter
(a) Chlorinated hydrocarbons:	
Endrin (1,2,3,4,10, 10-hexachloro-6,7-epoxy-1,4, 4a,5,6,7,8,8a-octahydro-1,4-endo, endo-5,8-dimethano naphthalene).	0.0002 0.2 ppb
Lindane (1,2,3,4,5,6-hexachlorocyclohexane, gamma isomer).	0.004 4 ppb
Methoxychlor (1,1,1-Trichloro-2, 2-bis [p-methoxyphenyl] ethane).	0.1 100 ppb
Toxaphene ($C_{10}H_{10}Cl_8$-Technical chlorinated camphene, 67-69 percent chlorine).	0.005 5 ppb
(b) Chlorophenoxys:	
2,4-D, (2,4-Dichlorophenoxyacetic acid).	0.1 100 ppb
2,4,5-TP Silvex (2,4,5-Trichlorophenoxypropionic acid).	0.01 10 ppb

(c) Total trihalomethanes (the sum of the concentrations of bromodichloromethane, dibromochloromethane, tribromomethane (bromoform) and trichloromethane (chloroform) 0.10 mg/1.

[141.12(c) added by 44 FR 68641, November 29, 1979]

§ 141.13 Maximum contaminant levels for turbidity.

The maximum contaminant levels for turbidity are applicable to both community water systems and non-community water systems using surface water sources in whole or in part. *The maximum* contaminant levels for turbidity in drinking water, measured at a representative entry point(s) to the distribution system, are:

(a) One turbidity unit (TU), as determined by a monthly average pursuant to § 141.22, except that five or fewer turbidity units may be allowed if the supplier of water can demonstrate to the State that the higher turbidity does not do any of the following:

(1) Interfere with disinfection;

(2) Prevent maintenance of an effective disinfectant agent throughout the distribution system; or

(3) Interfere with microbiological determinations.

(b) *Five* turbidity units based *on an* average for two consecutive days *pursuant* to § 141.22.

§ 141.14 Maximum microbiological contaminant levels.

The maximum contaminant levels for coliform bacteria, applicable to community water systems and non-community water systems, are as follows:

(a) When the membrane filter technique pursuant to § 141.21(a) is used, the number of coliform bacteria shall not exceed any of the following:

[141.14(a)(1) revised by 45 FR 57342, August 27, 1980]

(1) One per 100 milliliters as the arithmetic mean of all samples examined per compliance period pursuant to § 141.21(b) or (c), except that, at the primacy Agency's discretion systems required to take 10 or fewer samples per month may be authorized to exclude one positive routine sample per month from the monthly calculation if: (i) as approved on a case-by-case basis *the State determines and indicates in* writing to the public water system that no unreasonable risk to health existed under the conditions of this modification. This determination should be based upon a number of factors not limited to the following: (A) the system provided and had maintained an active disinfectant residual in the distribution system, (B) the potential for contamination as indicated by a sanitary survey, and (C) the history of the water quality at the public water system (e.g. MCL or monitoring violations); (ii) the supplier initiates a check sample on each of two *consecutive days* from the same sampling point within 24 hours after notification that the routine sample is positive, and each of these check samples is negative; and (iii) the original positive routine sample is reported and recorded by the supplier pursuant to § 141.31(a) and § 141.33(a). The supplier shall report to the State its compliance with the conditions specified in this *paragraph* and a summary of the corrective action taken to resolve the prior positive sample result. If a positive routine sample is not used for the monthly calculation, another routine sample must be analyzed for compliance purposes. This provision may be used only once during two consecutive compliance periods.

(2) Four per 100 milliliters in more than one sample when less than 20 are examined per month; or

(3) Four per 100 milliliters in more than *five percent of* the *samples* when 20 or more are examined per month.

(b)(1) When the fermentation tube *method* and 10 milliliter standard portions pursuant to § 141.21(a) are used, coliform bacteria shall not be present in any of the following:

[141.14(b)(1)(i) revised by 45 FR 57342, August 27, 1980]

(i) More than 10 percent of the *portions* (tubes) in any one month pursuant to § 141.21 (b) or (c) except that, at the State's discretion, systems required to take 10 or fewer samples per month may be authorized to exclude one positive routine sample resulting in one or more positive tubes per month from the monthly calculation if: (A) as approved on a case-by-case basis the State determines and indicates in writing to the public water system that no unreasonable risk to health existed under the conditions of this modification. This *determination* should be based upon a number of factors not limited to the following: (*1*) the system provided and had maintained an active disinfectant residual in the distribution system, (*2*) the potential for contamination as indicated by a sanitary survey, and (*3*) the history of the water quality at the public water system (e.g. MCL or monitoring violations); (B) the supplier initiates a check sample on each of two consecutive days from the sampling *point* within 24 hours after notification that the routine sample is positive, and each of these check samples is negative; and (C) the original positive routine sample is reported and recorded by the supplier pursuant to § 141.31(a) and § 141.33(a). The supplier shall report to the State its compliance with the conditions specified in this paragraph and report the action taken to resolve the prior positive sample result. If a positive routine sample is not used for the monthly calculation, another routine sample must be analyzed for compliance purposes. This provision may be used only once during two consecutive compliance periods.

(ii) three or more portions in more than one sample when less than 20 samples are examined per month; or

(iii) three or more portions in more than five percent of the samples when 20 or more samples are examined per month.

(2) When the fermentation tube

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November 28, 1980

Part V

Environmental Protection Agency

Water Quality Criteria Documents; Availability

ENVIRONMENTAL PROTECTION AGENCY

[FRL 1623-3]

Water Quality Criteria Documents; Availability

AGENCY: Environmental Protection Agency.

ACTION: Notice of Water Quality Criteria Documents.

SUMMARY: EPA announces the availability and provides summaries of water quality criteria documents for 64 toxic pollutants or pollutant categories. These criteria are published pursuant to section 304(a)(1) of the Clean Water Act.

AVAILABILITY OF DOCUMENTS: Summaries of both aquatic-based and health-based criteria from the documents are published below. Copies of the complete documents for individual pollutants may be obtained from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, VA 22161, (703-487-4650). A list of the NTIS publication order numbers for all 64 criteria documents is published below. These documents are also available for public inspection and copying during normal business hours at: Public Information Reference Unit, U.S. Environmental Protection Agency, Room 2404 (rear), 401 M St. S.W., Washington, D.C. 20460. As provided in 40 CFR Part 2, a reasonable fee may be charged for copying services. Copies of these documents are also available for review in the EPA Regional Office libraries.

[redacted] below. Requests sent to that office will be forwarded to NTIS or returned to the sender.

1. Acenaphthene, PB81-117269.
2. Acrolein, PB81-117277.
3. Acrylonitrile, PB81-117285.
4. Aldrin/Dieldrin, PB81-117301.
5. Antimony, PB81-117319.
6. Arsenic, PB81-117327.
7. Asbestos, PB81-117335.
8. Benzene, PB81-117293.
9. Benzidine, PB81-117343.
10. Beryllium, PB81-117350.
11. Cadmium, PB81-117368.
12. Carbon Tetrachloride, PB81-117376.
13. Chlordane, PB81-117384.
14. Chlorinated benzenes, PB81-117392.
15. Chlorinated ethanes, PB81-117400.
16. Chloroalkyl ethers, PB81-117418.
17. Chlorinated naphthalene, PB81-117426.
18. Chlorinated phenols, PB81-117434.
19. Chloroform, PB81-117442.
20. 2-chlorophenol, PB81-117459.
21. Chromium, PB81-117467.
22. Copper, PB81-117475.
23. Cyanides, PB81-117483.
24. DDT, PB81-117491.
25. Dichlorobenzenes, PB81-117509.
26. Dichlorobenzidine, PB81-117517.
27. Dichloroethylenes, PB81-117525.
28. 2,4-dichlorophenol, PB81-117533.
29. Dichloropropanes/propenes, PB81-117541.
30. 2,4-dimethylphenol, PB81-117558.
31. Dinitrotoluene, PB81-117566.
32. Diphenylhydrazine, PB81-117731.
33. Endosulfan, PB81-117574.
34. Endrin, PB81-117582.
35. Ethylbenzene, PB81-117590.
36. Fluoranthene, PB81-117608.
37. Haloethers, PB81-117616.
38. Halomethanes, PB81-117624.
39. Heptachlor, PB81-117632.
40. Hexachlorobutadiene, PB81-117640.
41. Hexachlorocyclohexane, PB81-117657.
42. Hexachlorocyclopentadiene, PB81-117665.
43. Isophorone, PB81-117673.
44. Lead, PB81-117681.
45. Mercury, PB81-117699.
46. Naphthalene, PB81-117707.
47. Nickel, PB81-117715.
48. Nitrobenzene, PB81-117723.
49. Nitrophenols, PB81-117749.
50. Nitrosamines, PB81-117756.
51. Pentachlorophenol, PB81-117764.
52. Phenol, PB81-117772.
53. Phthalate esters, PB81-117780.
54. Polychlorinated biphenyls (PCBs), PB81-117798.
55. Polynuclear aromatic hydrocarbons, PB81-117806.
56. Selenium, PB81-117814.
57. Silver, PB81-117822.
58. Tetrachloroethylene, PB81-117830.
59. Thallium, PB81-117848.
60. Toluene, PB81-117855.
61. Toxaphene, PB81-117863.
62. Trichloroethylene, PB81-117871.
63. Vinyl chloride, PB81-117889.
64. Zinc, PB81-117897.

FOR FURTHER INFORMATION CONTACT: Dr. Frank Gostomski, Criteria and Standards Division (WH-585), United States Environmental Protection [redacted]

SUPPLEMENTARY INFORMATION:

Background

Pursuant to section 304(a)(1) of the Clean Water Act, 33 U.S.C. 1314(a)(1), EPA is required to periodically review and publish criteria for water quality accurately reflecting the latest scientific knowledge:

(A) on the kind and extent of all identifiable effects on health and welfare including, but not limited to, plankton, fish, shellfish, wildlife, plant life, shorelines, beaches, esthetics, and recreation which may be expected from the presence of pollutants in any body of water, including groundwater, (B) on the concentration and dispersal of pollutants, or their byproducts, through biological, physical, and chemical processes, and (C) on the effects of pollutants on biological community diversity, productivity, and stability, including information on the factors affecting rates of eutrophication and rates of organic and inorganic sedimentation for varying types of receiving waters.

EPA is today announcing the availability of criteria documents for 64 of the 65 pollutants designated as toxic under section 307(a)(1) of the Act. The document on TCDD (Dioxin) will be published within the next month after review of recent studies. Criteria for the section 307(a)(1) toxic pollutants being published today will replace the criteria for those same pollutants found in the EPA publication, *Quality Criteria for Water*, (the "Red Book.") Criteria for all other pollutants and water constituents found in the "Red Book" remain valid. The criteria published today have been derived using revised methodologies for determining pollutant concentrations that will, when not exceeded, reasonably protect human health and aquatic life. Draft criteria documents were made available for public comment (44 FR 15926, March 15, 1979, 44 FR 43660, July 25, 1979, 44 FR 56628, October 1, 1979). These final criteria have been derived after consideration of all comments received.

These criteria documents are also issued in satisfaction of the Settlement Agreement in *Natural Resources Defense Council, et al.* v. *Train*, 8 E.R.C. 2120 (1976), modified, 12 E.R.C. 1833 (D.D.C. 1979). Pursuant to paragraph 11 of that agreement, EPA is required to publish criteria documents for the 65 pollutants which Congress, in the 1977 amendments to the Act, designated as toxic under section 307(a)(1). These documents contain recommended maximum permissible pollutant concentrations consistent with the protection of aquatic organisms, human health, and some recreational activities. Although paragraph 11 imposes certain obligations on the Agency, it does not create additional authority.

The Development of Water Quality Criteria

Section 304(a)(1) criteria contain two essential types of information: (1) discussions of available scientific data on the effects of pollutants on public health and welfare, aquatic life and recreation, and (2) quantitative concentrations or qualitative assessments of the pollutants in water which will generally ensure water quality adequate to support a specified water use. Under section 304(a)(1), these criteria are based solely on data and scientific judgments on the relationship between pollutant concentrations and environmental and human health effects. Criteria values do not reflect considerations of economic or technological feasibility.

Publication of water quality criteria of this type has been an ongoing process which EPA, and its predecessor Agency, the Federal Water Pollution Control Administration, have been engaged in since 1968. At that time the first Federal compilation of water quality criteria, the so-called "Green Book" *(Water Quality Criteria)*, was published. As now, these criteria contained both narrative discussions of the environmental effects of pollutants on a range of possible uses and concentrations of pollutants necessary to support these uses. Since that time, water quality criteria have been revised and expanded with publication of the "Blue Book" *(Water Quality Criteria 1972)* in 1973 and the "Red Book" *(Quality Criteria for Water)* in 1976.

Since publication of the Red Book there have been substantial changes in EPA's approach to assessing scientific data and deriving section 304(a)(1) criteria. Previous criteria were derived from a limited data base. For many pollutants, an aquatic life criterion was derived by multiplying the lowest concentration known to have acute lethal effect on half of a test group of an aquatic species (the LC50 value) by an application factor in order to protect against chronic effects. If data showed a substance to be bioaccumulative or to have other significant long-term effects, a factor was used to reduce the indicated concentrations to a level presumed to be protective. Criteria for the protection of human health were similarly derived by considering the pollutants' acute, chronic, and bioaccumulative effects on non-human mammals and humans.

Although a continuation of the process of criteria development, the criteria published today were derived using revised methodologies (Guidelines) for calculating the impact of pollutants on human health and aquatic organisms. These Guidelines consist of systematic methods for assessing valid and appropriate data concerning acute and chronic adverse effects of pollutants on aquatic organisms, non-human mammals, and humans. By use of these data in prescribed ways, criteria are formulated to protect aquatic life and human health from exposure to the pollutants. For some pollutants, bioconcentration properties are used to formulate criteria protective of aquatic life uses. For almost all of the pollutants, bioconcentration properties are used to assess the relative extent of human exposure to the pollutant either directly through ingestion of water or indirectly through consumption of aquatic organisms. Human health criteria for carcinogens are presented as incremental risks to man associated with specific concentrations of the pollutant in ambient water. The Guidelines used to derive criteria protective of aquatic life and human health are fully described in appendices B and C, respectively, of this Notice.

The Agency believes that these Guidelines provide criteria which more accurately reflect the effects of these pollutants on human health and on aquatic organisms and their uses. They are based on a more rational and consistent approach for using scientific data. These Guidelines were developed by EPA scientists in consultation with scientists from outside the Agency and they have been subjected to intensive public comment.

Neither the Guidelines nor the criteria are considered inflexible doctrine. Even at this time, EPA is taking action to employ the resources of peer review groups, including the Science Advisory Board, to evaluate recently published data, and EPA is conducting its own evaluation of new data to determine whether revisions to the criteria documents would be warranted.

The criteria published today are based solely on the effect of a single pollutant. However, pollutants in combination may have different effects because of synergistic, additive, or antagonistic properties. It is impossible in these documents to quantify the combined effects of these pollutants, and persons using criteria should be aware that site-specific analysis of actual combinations of pollutants may be necessary to give more precise indications of the actual environmental impacts of a discharge.

Relationship of the Section 304(a)(1) Criteria to Regulatory Programs

Section 304(a)(1) criteria are not rules and they have no regulatory inpact. Rather, these criteria present scientific data and guidance on the enviromental effect of pollutants which can be useful to derive regulatory requirements based on considerations of water quality impacts. Under the Clean Water Act, these regulatory requirements may include the promulgation of water quality-based effluent limitations under section 302, water quality standards under section 303, or toxic pollutant effluent standards under section 307. States are encouraged to begin to modify or, if necessary, develop new programs necessary to support the implementation of regulatory controls for toxic pollutants. As appropriate, States may incorporate criteria for toxic pollutants, based on this guidance, into their water quality standards.

Section 304(a)(1) criteria have been most closely associated with the development of State water quality standards, and the "Red Book" values have, in the past, been the basis for EPA's assessments of the adequacy of State requirements. However, EPA is now completing a major review of its water quality standards policies and regulations. After consideration of comments received on an Advance Notice of Proposed Rulemaking (43 FR 29588, July 10, 1978) and the draft criteria documents, the Agency intends to propose, by the end of this year, a revised water quality standards regulation which will clarify the Agency's position on a number of significant standards issues.

With the publication of these criteria, however, it is appropriate to discuss EPA's current thinking on standards issues relating to their use. This discussion does not establish new regulatory requirements and is intended as guidance on the possible uses of these criteria and an indication of future rulemaking the Agency may undertake. No substantive requirements will be established without further opportunity for public comment.

Water Quality Standards

Section 303 of the Clean Water Act provides that water quality standards be developed for all surface waters. A water quality standard consists basically of two parts: (1) A "designated use" for which the water body is to be protected (such as "agricultural," "recreation" or "fish and wildlife"), and (2) "criteria" which are numerical pollutant concentration limits or narrative statements necessary to preserve or achieve the designated use. *A water quality standard is developed* through State or Federal rulemaking proceedings and must be translated into enforceable effluent limitations in a point source (NPDES) permit or may form the basis of best management practices applicable to nonpoint sources under section 208 of the Act.

Relationship of Section 304(a)(1) Criteria to the Criteria Component of State Water Quality Standards:

In the ANPRM, EPA announced a policy of "presumptive applicability" for section 304(a)(1) criteria codified in the "Red Book." Presumptive applicability meant that a State had to adopt a criterion for a particular water quality parameter at least as stringent as the recommendation in the Red Book unless the State was able to justify a less stringent criterion based on: natural - background conditions, more recent scientific evidence, or local, site-specific information. EPA is rescinding the policy of presumptive applicability because it has proven to be too inflexible in actual practice.

Although the section 304(a)(1) criteria represent a reasonable estimate of pollutant concentrations consistent with the maintenance of designated water uses, States may appropriately modify these values to reflect local conditions. In certain circumstances, the criteria may not accurately reflect the toxicity of a pollutant because of the effect of local water quality characteristics or varying sensitivities of local populations. For example, in some cases, ecosystem adaptation may enable a viable, balanced aquatic population to exist in waters with high natural background levels of certain pollutants. Similarly, certain compounds may be more or less toxic in some waters because of differences in alkalinity, temperature, hardness, and other factors.

Methods for adjusting the section 304(a)(1) criteria to reflect these local differences are discussed below.

Relationship of Section 304(a)(1) Criteria to Designated Water Uses:

The criteria published today can be used to support the designated uses which are generally found in State standards. The following section discusses the relationship between the criteria and individual use classifications. Where a water body is designated for more than one use, criteria necessary to protect the most sensitive use should be applied.

1. *Recreation:* Recreational uses of water include such activities as swimming, wading, boating and fishing. Although insufficient data exist on the effects of toxic pollutants resulting from exposure through such primary contact as swimming, section 304(a)(1) criteria based on human health effects may be used to support this designated use where fishing is included in the State definition of "recreation." In this situation only the portion of the criterion based on fish consumption should be used.

2. *Protection and Propagation of Fish and Other Aquatic Life:* The section 304(a)(1) criteria based on toxicity to aquatic life may be used directly to support this designated use.

3. *Agricultural and Industrial Uses:* The section 304(a)(1) criteria were not specifically developed to reflect the impact of pollutants on agricultural and industrial uses. However, the criteria developed for human health and aquatic life are sufficiently stringent to protect these other uses. States may establish criteria specifically designed to protect these uses.

4. *Public Water Supply:* The drinking water exposure component of the human health effects criteria can apply directly to this use classification or may be appropriately modified depending upon whether the specific water supply system falls within the auspices of the Safe Drinking Water Act's (SDWA) regulatory control, and the type and level of treatment imposed upon the supply before delivery to the consumer. The SDWA controls the presence of toxic pollutants in finished ("end-of-tap") drinking water. A brief description of relevant sections of this Act is necessary to explain how the SDWA will work in conjunction with section 304(a)(1) criteria in protecting human health from the effects of toxics due to consumption of water.

Pursuant to section 1412 of the SDWA, EPA has promulgated "National Interim Primary Drinking Water Standards" for certain organic and inorganic substances. These standards establish "maximum contaminant levels" ("MCLs") which specify the maximum permissible level of a contaminant in water which may be delivered to a user of a public water system now defined as serving a minimum of 25 people. MCLs are established based on consideration of a range of factors including not only the health effects of the contaminants but also technological and economic feasibility of the contaminants' removal from the supply. EPA is required to establish revised primary drinking water regulations based on the effects of a contaminant on human health, and include treatment capability, monitoring availability, and costs. Under Section 1401(1)(D)(i) of the SDWA, EPA is also allowed to establish the minimum quality criteria for water which may be taken into a public water supply system.

Section 304(a)(1) criteria provide estimates of pollutant concentrations protective of human health, but do not consider treatment technology, costs and other feasibility factors. The section 304(a)(1) criteria also include fish bioaccumulation and consumption factors in addition to direct human drinking water intake. These numbers were not developed to serve as "end of tap" drinking water standards, and they have no regulatory significance under the SDWA. Drinking water standards are established based on considerations, including technological and economic feasibility, not relevant to section 304(a)(1) criteria. Section 304(a)(1) criteria may be analogous to the recommended maximum contaminant levels (RMCLs) under section 1412(b)(1)(B) of the SDWA in which, based upon a report from the National Academy of Sciences, the Administrator should set target levels for contaminants in drinking water at which "no known or anticipated adverse effects occur and which allows an adequate margin of safety". RMCLs do not take treatment, cost, and other feasibility factors into consideration. Section 304(a)(1) criteria are, in concept, related to the health-based goals specified in the RMCLs. Specific mandates of the SDWA such as the consideration of multi-media exposure, as well as different methods for setting maximum contaminant levels under the two Acts, may result in differences between the two numbers.

MCLs of the SDWA, where they exist, control toxic chemicals in finished drinking water. However, because of variations in treatment and the fact that only a relatively small number of MCLs have been developed, ambient water criteria may be used by the States as a supplement to SDWA regulations. States will have the option of applying MCLs, section 304(a)(1) human health effects criteria, modified section 304(a)(1) criteria or controls more stringent than these three to protect against the effects of toxic pollutants by ingestion from drinking water.

For untreated drinking water supplies, States may control toxics in the ambient water through either use of MCLs (if they exist for the pollutants of concern), section 304(a)(1) human health effects criteria, or a more strigent contaminant level than the former two options.

For treated drinking water supplies serving less than 25 people, States may choose toxics control through application of MCLs (if they exist for the pollutants of concern and are attainable by the type of treatment) in the finished drinking water. States also have the options to control toxics in the ambient water by choosing section 304(a)(1.) criteria, adjusted section 304(a)(1) criteria resulting from the reduction of the direct drinking water exposure component in the criteria calculation to the extent that the treatment procedure reduces the level of pollutants, or a more stringent contaminant level than the former three options.

For treated drinking water supplies serving 25 people or greater, States *must* control toxics down to levels at least as stringent as MCLs (where they exist for the pollutants of concern) in the finished drinking water. However, States also have the options to control toxics in the ambient water by choosing section 304(a)(1) criteria, adjusted section 304(a)(1) criteria resulting from the reduction of the direct drinking water exposure component in the criteria calculation to the extent that the treatment process reduces the level of pollutants, or a more stringent contaminant level than the former three options.

Inclusion of Specific Pollutants in State Standards:

To date, EPA has not required that a State address any specific pollutant in its standards. Although all States have established standards for most conventional pollutants, the treatment of toxic pollutants has been much less extensive. In the ANPRM, EPA suggested a policy under which States would be required to address a set of pollutants and incorporate specific toxic pollutant criteria into water quality standards. If the State failed to incorporate these criteria, EPA would promulgate the standards based upon these criteria pursuant to section 303(c)(4)(B).

In the forthcoming proposed revision to the water quality standard regulations, a significant change in policy will be proposed relating to the incorporation of certain pollutants in State water quality standards. This proposal will differ from the proposal made in the ANPRM. The ANPRM proposed an EPA-published list of pollutants for which States would have had to develop water quality standards. This list might have contained some (or all) of the 65 toxic pollutants. However, the revised water quality standards regulation will propose a process by which EPA will assist States in identifying specific toxic pollutants required for assessment for possible inclusion in State water quality standards. For these pollutants, States will have the option of adopting the published criteria or of adjusting those criteria based on site-specific analysis.

These pollutants would generally represent the greatest threat to sustaining a healthy, balanced ecosystem in water bodies or to human health due to exposure directly or indirectly from water. EPA is currently developing a process to determine which pollutants a State must assess for possible inclusion in its water quality standards. Relevant factors might include the toxicity of the pollutant, the frequency and concentration of its discharge, its geographical distribution, the breadth of data underlying the scientific assessment of its aquatic life and human health effects, and the technological and economic capacity to control the discharge of the pollutant. For some of the pollutants, all States may be required to assess them for possible inclusion in their standards. For others, assessment would be restricted to States or limited to specific water bodies where the pollutants pose a particular site-specific problem.

Criteria Modification Process

Flexibility is available in the application of these and any other valid water quality criteria to regulatory programs. Although in some cases they may be used by the States as developed, the criteria may be modified to reflect local environmental conditions and human exposure patterns before incorporation into programs such as water quality standards. If significant impacts of site-specific water quality conditions in the toxicities of pollutants can be demonstrated or significantly different exposure patterns of these pollutants to humans can be shown, section 304(a)(1) criteria may be modified to reflect these local conditions. The term "local" may refer to any appropriate geographic area where common aquatic environmental conditions or exposure patterns exist. Thus, "local" may signify a Statewide, regional, river reach, or entire river basin area. On the other hand, the criteria of some pollutants might be applicable nationwide without the need for adaptation to reflect local conditions. The degree of toxicity toward aquatic organisms and humans characteristic of these pollutants would not change significantly due to local water quality conditions.

EPA is examining a series of environmental factors or water quality parameters which might realistically be expected to affect the laboratory-derived water quality criterion recommendation for a specific pollutant. Factors such as hardness, pH, suspended solids, types of aquatic organisms present, etc. could impact on the chemical's effect in the aquatic environment. Therefore, local information can be assembled and analyzed to adjust the criterion recommendation if necessary.

The Guidelines for deriving criteria for the protection of aquatic life suggest several approaches for modifying the criteria. First, toxicity data, both acute and chronic, for local species could be substituted for some or all of the species used in deriving criteria for the water quality standard. The minimum data requirements should still be fulfilled in calculating a revised criterion. Second, criteria may be specifically tailored to a local water body by use of data from toxicity tests performed with that ambient water. A procedure such as this would account for local environmental conditions in formulating a criterion relevant to the local water body. Third, site-specific water quality characteristics resulting in either enhancement or mitigation of aquatic life toxicity for the pollutant could be factored into final formulation of the criterion. Finally, the criteria may be made more stringent to ensure protection of an individual species not otherwise adequately protected by any of the three modification procedures previously mentioned.

EPA does not intend to have States assess every local stream segment and lake in the country on an individual basis before determining if an adjustment is necessary. Rather, it is envisioned that water bodies having similar hydrological, chemical, physical, and biological properties will be grouped for the purpose of criteria adjustment. The purpose of this effort is to assist States in adapting the section 304(a) criteria to local conditions where needed, thereby precluding the setting of arbitrary and perhaps unnecessarily stringent or underprotective criteria in a water body. In all cases, EPA will still be required, pursuant to section 303(c), to determine whether the State water quality standards are consistent with the goals of the Act, including a determination of whether State-established criteria are adequate to support a designated use.

Criteria for the Protection of Aquatic Life

Interpretation of the Criteria

The aquatic life criteria issued today are summarized in Appendix A of this Federal Register notice. Criteria have been formulated by applying a set of Guidelines to a data base for each pollutant. The criteria for the protection of aquatic life specify pollutant concentrations which, if not exceeded, should protect most, but not necessarily all, aquatic life and its uses. The Guidelines specify that criteria should be based on an array of data from organisms, both plant and animal, occupying various trophic levels. Based on these data, criteria can be derived which should be adequate to protect the types of organisms necessary to support an aquatic community.

The Guidelines are not designed to derive criteria which will protect all life stages of all species under all conditions. Generally some life stage of one or more tested species, and probably some untested species, will have sensitivities below the maximum value or the 24-hour average under some conditions and would be adversely affected if the highest allowable pollutant concentrations and the worst conditions existed for a long time. In actual practice, such a situation is not likely to occur and thus the aquatic community as a whole will normally be protected if the criteria are not exceeded. In any aquatic community there is a wide range of individual species sensitivities to the effects of toxic pollutants. A criterion adequate to protect the most susceptible life stage of the most sensitive species would in many cases be more stringent than necessary to protect the overall aquatic community.

The aquatic life criteria specify both maximum and 24-hour average values. The combination of the two values is designed to provide adequate protection of aquatic life and its uses from acute and chronic toxicity and bioconcentration without being as restrictive as a one-number criterion would have to be to provide the same amount of protection. A time period of 24 hours was chosen in order to ensure that concentrations not reach harmful levels for unacceptably long periods. Averaging for longer periods, such as a week or a month for example, could permit high concentrations to persist long enough to produce significant adverse effects. A 24-hour period was chosen instead of a slightly longer or shorter period in recognition of daily fluctuations in waste discharges and of the influence of daily cycles of sunlight and darkness and temperature on both pollutants and aquatic organisms.

The maximum value, which is derived from acute toxicity data, prevents significant risk of adverse impact to organisms exposed to concentrations above the 24-hour average. Merely specifying the average value over a specified time period is insufficient because concentrations of chemicals higher than the average value can kill or cause irreparable damage in short periods. Furthermore, for some chemicals the effect of intermittent high exposures is cumulative. It is therefore necessary to place an upper limit on pollutant concentrations to which aquatic organisms might be exposed. The two-number criterion is intended to describe the highest average ambient water concentration which will produce a water quality generally suited to the maintenance of aquatic life while restricting the extent and duration of the excursions over that average to levels which will not cause harm. The only way to assure the same degree of protection with a one-number criterion would be to use the 24-hour average as a concentration that is not to be exceeded at any time in any place.

Since some substances may be more toxic in freshwater than in saltwater, or vice versa, provision is made for deriving separate water quality criteria for freshwater and for saltwater for each substance. However, for some substances sufficient data may not be available to derive one or both of these criteria using the Guidelines.

Specific aquatic life criteria have not been developed for all of the 65 toxic pollutants. In those cases where there were insufficient data to allow the derivation of a criterion, narrative descriptions of apparent threshold levels for acute and/or chronic effects based on the available data are presented. These descriptions are intended to convey a sense of the degree of toxicity of the pollutant in the absence of a criterion recommendation.

Summary of the Aquatic Life Guidelines

The Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life and its Uses were developed to describe an objective, internally consistent, and appropriate way of ensuring that water quality criteria for aquatic life would provide, on the average, a reasonable amount of protection without an unreasonable amount of overprotection or underprotection. The resulting criteria are not intended to provide 100 percent protection of all species and all uses of aquatic life all of the time, but they are intended to protect most species in a balanced, healthy aquatic community. The Guidelines are published as Appendix B of this Notice. Responses to public comments on these Guidelines are attached as Appendix D.

Minimum data requirements are identified in four areas: acute toxicity to animals (eight data points), chronic toxicity to animals (three data points), toxicity to plants, and residues. Guidance is also given for discarding poor quality data.

Data on acute toxicity are needed for a variety of fish and invertebrate species and are used to derive a Final Acute Value. By taking into account the number and relative sensitivities of the tested species, the Final Acute Value is designed to protect most, but not necessarily all, of the tested and untested species.

Data on chronic toxicity to animals can be used to derive a Final Chronic Value by two different means. If chronic values are available for a specified number and array of species, a final chronic value can be calculated directly. If not, an acute-chronic ratio is derived and then used with the Final Acute Value to obtain the Final Chronic Value.

The Final Plant Value is obtained by selecting the lowest plant toxicity value based on measured concentrations.

The Final Residue Value is intended to protect wildlife which consume aquatic organisms and the marketability of aquatic organisms. Protection of the marketability of aquatic organisms is, in actuality, protection of a use of that water body ("commercial fishery"). Two kinds of data are necessary to calculate the Final Residue Value: a bioconcentration factor (BCF) and a maximum permissible tissue concentration, which can be an FDA action level or can be the result of a chronic wildlife feeding study. For lipid soluble pollutants, the BCF is normalized for percent lipids and then the Final Residue Value is calculated by dividing the maximum permissible tissue concentration by the normalized BCF and by an appropriate percent lipid value. BCFs are normalized for percent lipids since the BCF measured for any individual aquatic species is generally proportional to the percent lipids in that species.

If sufficient data are available to demonstrate that one or more of the final values should be related to a water quality characteristic, such as salinity, hardness, or suspended solids, the final value(s) are expressed as a function of that characteristic.

After the four final values (Final Acute Value, Final Chronic Value, Final Plant Value, and Final Residue Value) have been obtained, the criterion is established with the Final Acute Value becoming the maximum value and the lowest of the other three values becoming the 24-hour average value. All of the data used to calculate the four final values and any additional pertinent information are then reviewed to determine if the criterion is reasonable. If sound scientific evidence indicates that the criterion should be raised or lowered, appropriate changes are made as necessary.

The present Guidelines have been revised from the earlier published versions (43 FR 21506, May 18, 1978; 43 FR 29028, July 5, 1978; 44 FR 15926, March 15, 1979). Details have been added in many places and the concept of a minimum data base has been incorporated. In addition, three adjustment factors and the species sensitivity factor have been deleted. These modifications were the result of the Agency's analysis of public comments and comments received from the Science Advisory Board on earlier versions of the Guidelines. These comments and the Resultant modifications are addressed fully in Appendix D to this notice.

Criteria for the Protection of Human Health

Interpretation of the Human Health Criteria

The human health criteria issued today are summarized in Appendix A of this Federal Register notice. Criteria for the protection of human health are presented for 62 of the 65 pollutants based on their carcinogenic, toxic, or organoleptic (taste and odor) properties. The meanings and practical uses of the criteria values are distinctly different depending on the properties on which they are based.

The objective of the health assessment portions of the criteria documents is to estimate ambient water concentrations which, in the case of non-carcinogens, prevent adverse health effects in humans, and in the case of suspect or proven carcinogens, represent various levels of incremental cancer risk.

Health assessments typically contain discussions of four elements: Exposure, pharmacokinetics, toxic effects, and criterion formulation.

The exposure section summarizes information on exposure routes: ingestion directly from water, indirectly from consumption of aquatic organisms found in ambient water, other dietary sources, inhalation, and dermal contact. Exposure assumptions are used to derive human health criteria. Most criteria are based solely on exposure from consumption of water containing a specified concentration of a toxic pollutant and through consumption of aquatic organisms which are assumed to have bioconcentrated pollutants from the water in which they live. Other multimedia routes of exposure such as air, non-aquatic diet, or dermal are not factored into the criterion formulation for the vast majority of pollutants due to lack of data. The criteria are calculated using the combined aquatic exposure pathway and also using the aquatic organism ingestion exposure route alone. In criteria reflecting both the water consumption and aquatic organism ingestion routes of exposure, the relative exposure contribution varies with the propensity of a pollutant to bioconcentrate, with the consumption of aquatic organisms becoming more important as the bioconcentration factor (BCF) increases. As additional information on total exposure is assembled for pollutants for which criteria reflect only the two specified aquatic exposure routes, adjustments in water concentration values may be made. The Agency intends to publish guidance which will permit the States to identify significantly different exposure patterns for their populations. If warranted by the demonstration of significantly different exposure patterns, this will become an element of a process to adapt/modify human health-based criteria to local conditions, somewhat analogous to the aquatic life criteria modification process discussed previously. It is anticipated that States at their discretion will be able to set appropriate human health criteria based on this process.

The pharmacokinetics section reviews data on absorption, distribution, metabolism, and excretion to assess the biochemical fate of the compounds in the human and animal system. The toxic effects section reviews data on acute, subacute, and chronic toxicity, synergistic and antagonistic effects, and specific information on mutagenicity, teratogenicity, and carcinogenicity. From this review, the toxic effect to be protected against is identified taking into account the quality, quantity, and weight of evidence characteristic of the data. The criterion formulation section reviews the highlights of the text and specifies a rationale for criterion development and the mathematical derivation of the criterion number.

Within the limitations of time and resources, current published information of significance was incorporated into the human health assessments. Review articles and reports were used for data evaluation and synthesis. Scientific judgment was exercised in reviewing and evaluating the data in each criteria document and in identifying the adverse effects for which protective criteria were published.

Specific health-based criteria are developed only if a weight of evidence supports the occurrence of the toxic effect and if dose/response data exist from which criteria can be estimated.

Criteria for suspect or proven carcinogens are presented as concentrations in water associated with a range of incremental cancer risks to man. Criteria for non-carcinogens represent levels at which exposure to a single chemical is not anticipated to produce adverse effects in man. In a few cases, organoleptic (taste and odor) data form the basis for the criterion. While this type of criterion does not represent a value which directly affects human health, it is presented as an estimate of the level of a pollutant that will not produce unpleasant taste or odor either directly from water consumption or indirectly by consumption of aquatic organisms found in ambient waters. A criterion developed in this manner is judged to be as useful as other types of criteria in protecting designated water uses. In addition, where data are available, toxicity-based criteria are also presented for pollutants with derived organoleptic criteria. The choice of criteria used in water quality standards for these pollutants will depend upon the designated use to be protected. In the case of a multiple use water body, the criterion protecting the most sensitive use will be applied. Finally, for several pollutants no criteria are recommended due to a lack of information sufficient for quantitative criterion formulation.

Risk Extrapolation

Because methods do not now exist to establish the presence of a threshold for carcinogenic effects, EPA's policy is that there is no scientific basis for estimating "safe" levels for carcinogens. The criteria for carcinogens, therefore, state that the recommended concentration for maximum protection of human health is zero. In addition, the Agency has presented a range of concentrations corresponding to incremental cancer risks of 10^{-7} to 10^{-5} (one additional case of cancer in populations ranging from ten million to 100,000, respectively). Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Summary of the Human Health Guidelines

The health assessments and corresponding criteria published today were derived based on *Guidelines and Methodology Used in the Preparation of Health Effect Assessment Chapters of the Consent Decree Water Criteria Documents* (the Guidelines) developed by EPA's Office of Reserch and Development. The estimation of health risks associated with human exposure to environmental pollutants requires predicting the effect of low doses for up to a lifetime in duration. A combination of epidemiological and animal dose/response data is considered the preferred basis for quantitative criterion derivation. The complete Guidelines are presented as Appendix C. Major issues associated with these Guidelines and responses to public comments are presented as Appendix E.

No-effect (non-carcinogen) or specified risk (carcinogen) concentrations were estimated by extrapolation from animal toxicity or human epidemiology studies using the following basic exposure assumptions: a 70-kilogram male person (*Report of the Task Group on Reference Man,* International Commission for Radiation Protection, November 23, 1957) as the exposed individual; the average daily consumption of freshwater and estuarine fish and shellfish products equal to 6.5 grams/day; and the average ingestion of two liters/day of water (*Drinking Water and Health,* National Academy of Sciences, National Research Council, 1977). Criteria based on these assumptions are estimated to be protective of an adult male who experiences average exposure conditions.

Two basic methods were used to formulate health criteria, depending on whether the prominent adverse effect was cancer or other toxic manifestations. The following sections detail these methods.

Carcinogens

Extrapolation of cancer responses from high to low doses and subsequent risk estimation from animal data is performed using a linearized multi-stage model. This procedure is flexible enough to fit all monotonically-increasing dose response data, since it incorporates several adjustable parameters. The multi-stage model is a linear non-threshold model as was the "one-hit" model originally used in the proposed criteria documents. The linearized multi-stage model and its characteristics are described fully in Appendix C. The linear non-threshold concept has been endorsed by the four agencies in the Interagency Regulatory Liaison Group and is less likely to underestimate risk at the low doses typical of environmental exposure than other models that could be used. Because of the uncertainties associated with dose response, animal-to-human extrapolation and other unknown factors, because of the use of average exposure assumptions, and because of the serious public health consequences that could result if risk were underestimated, EPA believes that it is prudent to use conservative methods to estimate risk in the water quality criteria program. The linearized multistage model is more systematic and invokes fewer arbitrary assumptions than the "one-hit" procedure previously used.

It should be noted that extrapolation models provide estimates of risk since a varitey of assumptions are built into any model. Models using widely different assumptions may produce estimates ranging over several orders of magnitude. Since there is at present no way to demonstrate the scientific validity of any model, the use of risk extrapolation models is a subject of debate in the scientific community. However, risk extrapolation is generally recognized as the only tool available at this time for estimating the magnitude of health hazards associated with non-threshold toxicants and has been endorsed by numerous Federal agencies and scientific organizations, including EPA's Carcinogen Assessment Group, the National Academy of Sciences, and the Interagency Regulatory Liaison Group as a useful means of assessing the risks of exposure to various carcinogenic-pollutants.

Non-Carcinogens

Health criteria based on toxic effects of pollutants other than carcinogenicity are estimates of concentrations which are not expected to produce adverse effects in humans. They are based upon Acceptable Daily Intake (ADI) levels and are generally derived using no-observed-adverse-effect-level (NOAEL) data from animal studies although human data are used wherever available. The ADI is calculated using safety factors to account for uncertainties inherent in extrapolation from animal to man. In accordance with the National Research Council recommendations (*Drinking Water and Health,* National Academy of Sciences, National Research Council, 1977), safety factors of 10, 100, or 1,000 are used depending on the quality and quantity of data. In some instances extrapolations are made from inhalation studies or limits to approximate a human response from ingestion using the Stokinger-Woodward model (Journal of American Water Works Association, 1958). Calculations of criteria from ADIs are made using the standard exposure assumptions (2 liters of water, 6.5 grams of edible aquatic products, and an average body weight of 70 kg).

Dated: October 24, 1980.

Douglas M. Costle,

Administrator.

Appendix A—Summary of Water Quality Criteria

Acenaphthene

Freshwater Aquatic Life

The available data for acenaphthene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 1,700 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of acenaphthene to sensitive freshwater aquatic animals but toxicity to freshwater algae occur at concentrations as low as 520 μg/l.

Saltwater Aquatic Life

The available data for acenaphthene indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 970 and 710 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. Toxicity to algae occurs at concentrations as low as 500 μg/l.

Human Health

Sufficient data is not available for acenaphthene to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 20 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Acrolein

Freshwater Aquatic Life

The available data for acrolein indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 68 and 21 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for acrolein indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 55 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of acrolein to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of acrolein ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 320 μg/l.

For the protection of human health from the toxic properties of acrolein ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 780 μg/l.

Acrylonitrile

Freshwater Aquatic Life

The available data for acrylonitrile indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 7,550 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of acrylonitrile to sensitive freshwater aquatic life but mortality occurs at concentrations as low as 2,600 µg/l with a fish species exposed for 30 days.

Saltwater Aquatic Life

Only one saltwater species has been tested with acrylonitrile and no statement can be made concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of acrylonitrile through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .58 µg/l, .058 µg/l and .006 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 6.5 µg/l, .65 µg/l, and .065 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Aldrin-Dieldrin

Dieldrin

Freshwater Aquatic Life

For dieldrin the criterion to protect fresh water aquatic life as derived using the Guidelines is 0.0019 µg/l as a 24-hour average and the concentration should not exceed 2.5 µg/l at any time.

Saltwater Aquatic Life

For dieldrin the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0019 µg/l as a 24-hour average and the concentration should not exceed 0.71 µg/l at any time.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of dieldrin through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .71 ng/l, .071 ng/l, and .0071 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are .76 ng/l, .076 ng/l, and .0076 ng/l respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Aldrin

Freshwater Aquatic Life

For freshwater aquatic life the concentration of aldrin should not exceed 3.0 µg/l at any time. No data are available concerning the chronic toxicity of aldrin to sensitive freshwater aquatic life.

Saltwater Aquatic Life

For saltwater aquatic life the concentration of aldrin should not exceed 1.3 µg/l at any time. No data are available concerning the chronic toxicity of aldrin to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of aldrin through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .74 ng/1, .074 ng/1, and .0074 ng/1, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are .79 ng/1, .079 ng/1, and .0079 ng/1, respectively. Other concentrations respresenting different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Antimony

Freshwater Aquatic Life

The available data for antimony indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 9,000 and 1,600 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. Toxicity to algae occurs at concentrations as low as 610 µg/l.

Saltwater Aquatic Life

No saltwater organisms have been adequately tested with antimony, and no statement can be made concerning acute or chronic toxicity.

Human Health

For the protection of human health from the toxic properties of antimony ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 146 µg/l.

For the protection of human health from the toxic properties of antimony ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 45,000 µg/l.

Arsenic

Freshwater Aquatic Life

For freshwater aquatic life the concentration of total recoverable trivalent inorganic arsenic should not exceed 440 µg/l at any time. Short-term effects on embryos and larvae of aquatic vertebrate species have been shown to occur at concentrations as low as 40 µg/l.

Saltwater Aquatic Life

The available data for total recoverable trivalent inorganic arsenic indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 508 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of trivalent inorganic arsenic to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of arsenic through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 22 ng/l, 2.2 ng/l, and .22 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 175 ng/l, 17.5 ng/l, and 1.75 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Asbestos

Freshwater Aquatic Life

No freshwater organisms have been tested with any asbestiform mineral and no statement can be made concerning acute or chronic toxicity.

Saltwater Aquatic Life

No saltwater organisms have been tested with any asbestiform mineral and no statement can be made concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of asbestos through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 300,000 fibers/l, 30,000 fibers/l, and 3,000 fibers/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Benzene

Freshwater Aquatic Life

The available data for benzene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 5,300 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of benzene to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for benzene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 5,100 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of benzene to sensitive saltwater aquatic life, but adverse effects occur at concentrations as low as 700 µg/l with a fish species exposed for 168 days.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of benzene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 6.6 µg/l, .66 µg/l, and .066 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 400 µg/l, 40.0 µg/l, and 4.0 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Benzidine

Freshwater Aquatic Life

The available data for benzidine indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 2,500 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of benzidine to sensitive freshwater aquatic life.

Saltwater Aquatic Life

No saltwater organisms have been tested with benzidine and no statement can be made concerning acute and chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of benzidine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 1.2 ng/l, .12 ng/l, and .01 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 5.3 ng/l, .53 ng/l, and .05 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Beryllium

Freshwater Aquatic Life

The available data for beryllium indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 130 and 5.3 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. Hardness has a substantial effect on acute toxicity.

Salt water Aquatic Life

The limited saltwater data base available for beryllium does not permit any statement concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of beryllium through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 37 ng/l, 3.7 ng/l, and .37 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 641 ng/l, 64.1 ng/l, and 6.41 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Cadmium

Freshwater Aquatic Life

For total recoverable cadmium the criterion (in µg/l) to protect freshwater aquatic life as derived using the Guidelines is the numerical value given by $e^{(1.05 [\ln(\text{hardness})] - 8.53)}$ as a 24-hour average and the concentration (in μg/l) should not exceed the numerical value given by $e^{(1.05 [\ln(\text{hardness})] - 3.73)}$ at any time. For example, a hardnesses of 50, 100, and 200 mg/l as $CaCO_3$ the criteria are 0.012, 0.025, and 0.051 μg/l, respectively, and the concentration of total recoverable cadmium should not exceed 1.5, 3.0 and 6.3 μg/l, respectively, at any time.

Saltwater Aquatic Life

For total recoverable cadmium the criterion to protect saltwater aquatic life as derived using the Guidelines is 4.5 μg/l as a 24-hour average and the concentration should not exceed 59 μg/l at any time.

Human Health

The ambient water quality criterion for cadmium is recommended to be identical to the existing drinking water standard which is 10 μg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Carbon Tetrachloride

Freshwater Aquatic Life

The available date for carbon tetrachloride indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 35,200 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of carbon tetrachloride to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for carbon tetrachloride indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 50,000 μg/l and would occur at lower concentrations among species that are more sensitive that those tested. No data are available concerning the chronic toxicity of carbon tetrachloride to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of carbon tetrachloride through ingestion of contaminated water and contaminated aquatic organisms the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 4.0μg/l, .40 μg/l, and .04 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 69.4 μg/l, 6.94 μg/l, and .69 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Chlordane

Freshwater Aquatic Life

For chlordane the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.0043 μg/l as a 24-hour average and the concentration should not exceed 2.4 μg/l at any time.

Saltwater Aquatic Life

For chlordane the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0040 μg/l as a 24-hour average and the concentration should not exceed 0.09 μg/l at any time.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of chlordane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 4.6 ng/l, .46 ng/l, and .046 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 4.8 ng/l, .48 ng/l, and .048 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Chlorinated Benzenes

Freshwater Aquatic Life

The available data for chlorinated benzenes indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 250 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of the more toxic of the chlorinated benzenes to sensitive freshwater aquatic life but toxicity occurs at concentrations as low as 50 μg/l for a fish species exposed for 7.5 days.

Saltwater Aquatic Life

The available data for chlorinated benzenes indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 160 and 129 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of hexachlorobenzene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding recommended criteria are 7.2 ng/l, .72 ng/l, and .072 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 7.4 ng/l, .74 ng/l, and .074 ng/l, respectively.

For the protection of human health from the toxic properties of 1,2,4,5-tetrachlorobenzene ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 38 μg/l.

For the protection of human health from the toxic properties of 1,2,4,5-tetrachlorobenzene ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 48 μg/l.

For the protection of human health from the toxic properties of pentachlorobenzene ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 74 μg/l.

For the protection of human health from the toxic properties of pentachlorobenzene ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 85 μg/l.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for trichlorobenzene.

For comparison purposes, two approaches were used to derive criterion levels for monochlorobenzene. Based on available toxicity data, for the protection of public health, the derived level is 488 µg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 20 µg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Chlorinated Ethanes

Freshwater Aquatic Life

The available freshwater data for chlorinated ethanes indicate that toxicity increases greatly with increasing chlorination, and that acute toxicity occurs at concentrations as low as 118,000 µg/l for 1,2-dichloroethane, 18,000 µg/l for two trichloroethanes, 9,320 µg/l for two tetrachloroethanes, 7,240 µg/l for pentachloroethane, and 980 µg/l for hexachloroethane. Chronic toxicity occurs at concentrations as low as 20,000 µg/l for 1,2-dichloroethane, 9,400 µg/l for 1.1.2-trichloroethane, 2,400 µg/l for 1.1.2.2,-tetrachloroethane, 1,100 µg/l for pentachloroethane, and 540 µg/l for hexachloroethane. Acute and chronic toxicity would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available saltwater data for chlorinated ethanes indicate that toxicity increases greatly with increasing chlorination and that acute toxicity to fish and invertebrate species occurs at concentrations as low as 113,000 µg/l for 1.2-dichloroethane, 31,200 µg/l for 1.1.1-trichloroethane, 9,020 µg/l for 1.1.2.2-tetrachloroethane, 390 µg/l for pentachloroethane, and 940 µg/l for hexachloroethane. Chronic toxicity occurs at concentrations as low as 281 µg/l for pentachloroethane. Acute and chronic toxicity would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1.2-dichloroethane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 9.4 µg/l, .94 µg/l, and .094 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 2,430 µg/l, 243 µg/l, and 24.3 µg/l respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the protection of human health from the toxic properties of 1.1.1-trichloroethane ingested through water and contaminated aquatic organism, the ambient water criterion is determined to be 18.4 mg/l.

For the protection of human health from the toxic properties of 1.1.1.-trichloroethane ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 1.03 g/l.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1.1.2-trichloroethane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 6.0 µg/l, .6 µg/l, and .06 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 418 µg/l, 41.8 µg/l, and 4.18 µg/l respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1.1.2.2-tetrachloroethane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 1.7 µg/l, .17 µg/l, and .017 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 107 µg/l, 10.7 µg/l, and 1.07 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of hexachloroethane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 19 µg/l, 1.9 µg/l, and .19 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 87.4 µg/l, 8.74 µg/l, and .87 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for monochloroethane.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for 1.1.-dichloroethane.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for 1.1.1.2-tetrachloroethane.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for pentachloroethane.

Chlorinated Naphthalenes

Freshwater Aquatic Life

The available data for chlorinated naphthalenes indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 1,600 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of chlorinated naphthalenes to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for chlorinated napthalenes indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 7.5 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of chlorinated naphthalenes to sensitive saltwater aquatic life.

Human Health

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for chlorinated napthalenes.

Chlorinated Phenols

Freshwater Aquatic Life

The available freshwater data for chlorinated phenols indicate that toxicity generally increases with increasing chlorination, and that acute toxicity occurs at concentrations as low as 30 μg/l for 4-chloro-3-methylphenol to greater than 500,000 μg/l for other compounds. Chronic toxicity occurs at concentrations as low as 970 μg/l for 2,4,6-trichlorophenol. Acute and chronic toxicity would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available saltwater data for chlorinated phenols indicate that toxicity generally increases with increasing chlorination and that acute toxicity occurs at concentrations as low as 440 μg/l for 2,3,5,6-tetrachlorophenol and 29,700 μg/l for 4-chlorophenol. Acute toxicity would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of chlorinated phenols to sensitive saltwater aquatic life.

Human Health

Sufficient data is not available for 3-monochlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 0.1 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 4-monochlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 0.1 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 2,3-dichlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is .04 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 2,5-dichlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is .5 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 2,6-dichlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is .2 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 3,4-dichlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is .3 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 2,3,4,6-tetrachlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 1 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

For comparison purposes, two approaches were used to derive criterion levels for 2,4,5-trichlorophenol. Based on available toxicity data, for the protection of public health, the derived level is 2.6 mg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 1.0 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 2,4,6-trichlorophenol through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the *non-threshold assumption for this* chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 12 μg/l, 1.2 μg/l, and .12 μg/l respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 36 μg/l, 3.6 μg/l, and .36 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 2 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 2-methyl-4-chlorophenol to derive a level which would protect against any potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 1800 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 3-methyl-4-chlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 3000 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Sufficient data is not available for 3-methyl-6-chlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 20 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Chloroalkyl Ethers

Freshwater Aquatic Life

The available data for chloroalkyl ethers indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 238,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of chloroalkyl ethers to sensitive freshwater aquatic life.

Saltwater Aquatic Life

No saltwater organisms have been tested with any chloroalkyl ether and no statement can be made concerning acute and chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of bis-(chloromethyl)-ether through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .038 ng/l, .0038 ng/l, and .00038 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 18.4 ng/l, 1.84 ng/l, and .184 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of bis (2-chloroethyl) ether through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .3 μg/l, .03 μg/l, and .003 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 13.6 μg/l, 1.36 μg/l, and .136 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the protection of human health from the toxic properties of bis (2-chloroisopropyl) ether ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 34.7 μg/l.

For the protection of human health from the toxic properties of bis (2-chloroisopropyl) ether ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 4.36 mg/l.

Chloroform

Freshwater Aquatic Life

The available data for choloroform indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 28,900 μg/l, and would occur at lower concentrations among species that are more sensitive than the three tested species. Twenty-seven-day LC50 values indicate that chronic toxicity occurs at concentrations as low as 1,240 μg/l, and could occur at lower concentrations among species or other life stages that are more sensitive than the earliest life cycle stage of the rainbow trout.

Saltwater Aquatic Life

The data base for saltwater species is limited to one test and no statement can be made concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of chloroform through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 1.90 μg/l, .19 μg/l, and .019 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 157 μg/l, 15.7 μg/l, and 1.57 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

2-Chlorophenol

Freshwater Aquatic Life

The availabe data for 2-chlorophenol indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 4,380 μg/l and would occur at lower concentrations among species that are more sensitive that those tested. No definitive data are available concerning the chronic toxicity of 2-chlorophenol to sensitive freshwater aquatic life but flavor impairment occurs in one species of fish at concentrations as low as 2,000 μg/l.

Saltwater Aquatic Life

No saltwater organisms have been tested with 2-chlorophenol and no statement can be made concerning acute and chronic toxicity.

Human Health

Sufficient data is not available for 2-chlorophenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 0.1 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Chromium

Freshwater Aquatic Life

For total recoverable hexavalent chromium the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.29 µg/l as a 24-hour average and the concentration should not exceed 21 µg/l at any time.

For freshwater aquatic life the concentration (in µg/l) of total recoverable trivalent chromium should not exceed the numerical value given by "e(1.08[ln(hardness)]+3.48)" at any time. For example, at hardnesses of 50, 100 and 200 mg/l as $CaCO_3$ the concentration of total recoverable trivalent chromium should not exceed 2,200, 4,700, and 9,900 µg/l, respectively, at any time. The available data indicate that chronic toxicity to freshwater aquatic life occurs at concentrations as low a 44 µg/l and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

For total recoverable hexavalent chromium the criterion to protect saltwater aquatic life as derived using the Guidelines is 18 µg/l as a 24-hour average and the concentration should not exceed 1,260 µg/l at any time.

For total recoverable trivalent chromium, the availabe data indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 10,300 µg/l, and would occur at lower concentrations amoung species that are more sensitive than those tested. No data are available concerning the chronic toxicity of trivalent chromium to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of Chromium III ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 170 mg/l.

For the protection of human health from the toxic properties of Chromium III ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 3433 mg/l.

The ambient water quality criterion for total Chromium VI is recommended to be identical to the existing drinking water standard which is 50 µg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Copper

Freshwater Aquatic Life

For total recoverable copper the criterion to protect freshwater aquatic life as derived using the Guidelines is 5.6 µg/l as a 24-hour average and the concentration (in µg/l) should not exceed the numerical value given by e(0.94[ln(hardness)]-1.23) at any time. For example, at hardnesses of 50, 100, and 200 mg/l $CaCO_3$ the concentration of total recoverable copper should not exceed 12, 22, and 43 µg/l at any time.

Saltwater Aquatic Life

For total recoverable copper the criterion to protect saltwater aquatic life as derived using the Guidelines is 4.0 µg/l as a 24-hour average and the concentration should not exceed 23 µg/l at any time.

Human Health

Sufficient data is not available for copper to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 1 mg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Cyanide

Freshwater Aquatic Life

For free cyanide (sum of cyanide present as HCN and CN^-, expressed as CN) the criterion to protect freshwater aquatic life as derived using the Guidelines is 3.5 µg/l as a 24-hour average and the concentration should not exceed 52 µg/l at any time.

Saltwater Aquatic Life

The available data for free cyanide (sum of cyanide present as HCN and CN^-, expressed as CN) indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 30 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. If the acute-chronic ratio for saltwater organisms is similar to that for freshwater organisms, chronic toxicity would occur at concentrations as low as 2.0 µg/l for the tested species and at lower concentrations among species that are more sensitive than those tested.

Human Health

The ambient water quality criterion for cyanide is recommended to be identical to the existing drinking water standard which is 200 µg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

DDT and Metabolites

Freshwater Aquatic Life

DDT

For DDT and its metabolites the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.0010 µg/l as a 24-hour average and the concentration should not exceed 1.1 µg/l at any time.

TDE

The available data for TDE indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 0.6 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of TDE to sensitive freshwater aquatic life.

DDE

The available data for DDE indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 1,050 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of DDE to sensitive freshwater aquatic life.

Saltwater Aquatic Life

DDT

For DDT and its metabolites the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0010 µg/l as a 24-hour average and the concentration should not exceed 0.13 µg/l at any time.

TDE

The available data for TDE indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 3.6 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of TDE to sensitive saltwater aquatic life.

DDE

The available data for DDE indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 14 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of DDE to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of DDT through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .24 ng/l, .024 ng/l, and .0024 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are .24 ng/l, .024 ng/l, and .0024 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment of an "acceptable" risk level.

Dichlorobenzenes

Freshwater Aquatic Life

The available data for dichlorobenzenes indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 1,120 and 763 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for dichlorobenzenes indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 1,970 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of dichlorobenzenes to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of dichlorobenzenes (all isomers) ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 400 µg/l.

For the protection of human health from the toxic properties of dichlorobenzenes (all isomers) ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 2.6 mg/l.

Dichlorobenzidines

Freshwater Aquatic Life

The data base available for dichlorobenzidines and freshwater organisms is limited to one test on bioconcentration of 3,3'-dichlorobenzidine and no statement can be made concerning acute or chronic toxicity.

Saltwater Aquatic Life

No saltwater organisms have been tested with any dichlorobenzidine and no statement can be made concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of dichlorobenzidine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero base on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .103 µg/l, .0103 µg/l, and .00103 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are .204 µg/l, .0204 µg/l, and .00204 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Dichloroethylenes

Freshwater Aquatic Life

The available data for dichloroethylenes indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 11,600 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of dichlorethylenes to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for dichlorethylenes indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 224,000 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity dichloroethylenes to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1,1-dichloroethylene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .33 µg/l, .033 µg/l, and .0033 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 18.5 µg/l, 1.85 µg/l, and .185 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficency in the available data for 1,2-dichloroethylene.

2,4-Dichlorophenol

Freshwater Aquatic Life

The available data for 2,4-dichlorophenol indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 2,020 and 365 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive that those tested. Mortality to early life stages of one species of fish occurs at concentrations as low as 70 µg/l.

Saltwater Aquatic Life

Only one test has been conducted with saltwater organisms on 2,4-dichlorophenol and no statement can be made concerning acute or chronic toxicity.

Human Health

For comparison purposes, two approaches were used to derive criterion levels for 2,4-dichlorophenol.

Based on available toxicity data, for the protection of public health, the derived level is 3.09 mg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 0.3 µg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Dichloropropanes/Dichloropropenes

Freshwater Aquatic Life

The available data for dichloropropanes indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 23,000 and 5,700 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

The available data for dichloropropenes indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 6,060 and 244 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for dichloropropanes indicate that acute and chronic toxicity to saltwater aquatic life occurs at concentrations as low as 10,300 and 3,040 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

The available data for dichloropropenes indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low a as 790 µg/l, and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of dichloropropenes to sensitive saltwater aquatic life.

Human Health

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for dichloropropanes.

For the protection of human health from the toxic properties of dichloropropenes ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 87 µg/l.

For the protection of human health from the toxic properties of dichloropropenes ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 14.1 mg/l.

2,4-Dimethylphenol

Freshwater Aquatic Life

The available data for 2,4-dimethylphenol indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 2,120 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of dimethylphenol to sensitive freshwater aquatic life.

Saltwater Aquatic Life

No saltwater organisms have been tested with 2,4-dimethylphenol and no statement can be made concerning acute and chronic toxicity.

Human Health

Sufficient data are not available for 2,4-dimethylphenol to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undersirable taste and odor quality of ambient water, the estimated level is 400 µg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

2,4-Dinitrotoluene

Freshwater Aquatic Life

The available data for 2,4-dinitrotoluene indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 330 and 230 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for 2,4-dinitrotoluenes indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 590 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of 2,4-dinitrotoluenes to sensitive saltwater aquatic life but a decrease in algal cell numbers occurs at concentrations as low as 370 µg/l.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 2,4-dinitrotoluene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 1.1 µg/l, 0.11 µg/l, and 0.011 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 91 µg/l, 9.1 µg/l, and 0.91 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

1,2-Diphenylhydrazine

Freshwater Aquatic Life

The available data for 1,2-diphenylhydrazine indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 270 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of 1,2-diphenylhydrazine to sensitive freshwater aquatic life.

Saltwater Aquatic Life

No saltwater organisms have been tested with 1,2-diphenylhydrazine and no statement can be made concerning acute and chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of 1,2-diphenylhydrazine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 422 ng/l, 42 ng/l, and 4 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 5.6 µg/l, 0.56 µg/l, and 0.056 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Endosulfan

Freshwater Aquatic Life

For endosulfan the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.056 μg/l as a 24-hour average and the concentration should not exceed 0.22 μg/l at any time.

Saltwater Aquatic Life

For endosulfan the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0087 μg/l as a 24-hour average and the concentration should not exceed 0.034 μg/l at any time.

Human Health

For the protection of human health from the toxic properties of endosulfan ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 74 μg/l.

For the protection of human health from the toxic properties of endosulfan ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 159 μg/l.

Endrin

Freshwater Aquatic Life

For endrin the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.0023 μg/l as a 24-hour average and the concentration should not exceed 0.18 μg/l at any time.

Saltwater Aquatic Life

For endrin the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0023 μg/l as a 24-hour average and the concentration should not exceed 0.037 μg/l at any time.

Human Health

The ambient water quality criterion for endrin is recommended to be identical to the existing drinking water standard which is 1 μg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Ethylbenzene

Freshwater Aquatic Life

The available data for ethylbenzene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 32,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of ethylbenzene to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for ethylbenzene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 430 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of ethylbenzene to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of ethylbenzene ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 1.4 mg/l.

For the protection of human health from the toxic properties of ethylbenzene ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 3.28 mg/l.

Fluoranthene

Freshwater Aquatic Life

The available data for fluoranthene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 3980 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of fluoranthene to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for fluoranthene indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 40 and 16 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For the protection of human health from the toxic properties of fluoranthene ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 42 μg/l.

For the protection of human health from the toxic properties of fluoranthene ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 54 μg/l.

Haloethers

Freshwater Aquatic Life

The available data for haloethers indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 360 and 122 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

No saltwater organisms have been tested with any haloether and no statement can be made concerning acute or chronic toxicity.

Human Health

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for haloethers.

Halomethanes

Freshwater Aquatic Life

The available data for halomethanes indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 11,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of halomethanes to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for halomethanes indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 12,000 and 6,400 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. A decrease in algal cell numbers occurs at concentrations as low as 11,500 μg/l.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of chloromethane, bromomethane, dichloromethane, bromodichloromethane, tribromomethane, dichlorodifluoromethane, trichlorofluoromethane, or combinations of these chemicals through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result i incremental increase of cancer risk, ove the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are

1.9 µg/l, 0.19 µg/l, and 0.019 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 157 µg/l, 15.7 µg/l, and 1.57 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Heptachlor

Freshwater Aquatic Life

For heptachlor the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.0038 µg/l as a 24-hour average and the concentration should not exceed 0.52 µg/l at any time.

Saltwater Aquatic Life

For heptachlor the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.0036 µg/l as a 24-hour average and the concentration should not exceed 0.053 µg/l at any time.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of heptachlor through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 2.78 ng/l, .28 ng/l, and .028 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 2.85 ng/l, .29 ng/l, and .029 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Hexachlorobutadiene

Freshwater Aquatic Life

The available data for hexachlorobutadiene indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 90 and 9.3 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for hexachlorobutadiene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 32 µg/l and would occur at lower concentrations among species that are more sensitive that those tested. No data are available concerning the chronic toxicity of hexachlorobutadiene to sensitive saltwater aquatic life

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of hexachlorobutadiene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 4.47 µg/l, 0.45 µg/l, and 0.045 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 500 µg/l, 50 µg/l, and 5 µg/l respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Hexachlorocyclohexane

Lindane

Freshwater Aquatic Life

For Lindane the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.080 µg/l as a 24-hour average and the concentration should not exceed 2.0 µg/l at any time.

Saltwater Aquatic Life

For saltwater aquatic life the concentration of lindane should not exceed 0.16 µg/l at any time. No data are available concerning the chronic toxicity of lindane to sensitive saltwater aquatic life.

BHC

Freshwater Aquatic Life

The available date for a mixture of isomers of BHC indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 100 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of a mixture of isomers of BHC to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available date for a mixture of isomers of BHC indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 0.34 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of a mixture of isomers of BHC to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of alpha-HCH through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 92 ng/l, 9.2 ng/l, and .92 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 310 ng/l, 31.0 ng/l, and 3.1 ng/l respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of beta-HCH through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 163 ng/l, 16.3 ng/l, and 1.63 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 547 ng/l, 54.7 ng/l, and 5.47 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of tech-HCH through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 123 ng/l, 12.3 ng/l, and 1.23 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 414 ng/l, 41.4 ng/l, and 4.14 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of gamma-HCH through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentrations should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 186 ng/l, 18.6 ng/l, and 1.86 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 625 ng/l, 62.5 ng/l, 6.25 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for delta-HCH.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for epsilon-HCH.

Hexachlorocyclopentadiene

Freshwater Aquatic Life

The available data for hexachlorocyclopentadiene indicate that acute and chronic toxicity to freshwater aquatic life occurs at concentrations as low as 7.0 and 5.2 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data to hexachlorocyclopentadiene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 7.0 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of hexachlorocyclopentadiene to sensitive saltwater aquatic life.

Human Health

For comparison purposes, two approaches were used to derive criterion levels for hexachlorocyclopentadiene. Based on available toxicity data, for the protection of public health, the derived level is 206 μg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 1.0 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Isophorone

Freshwater Aquatic Life

The available data for isophorone indicate that acute toxicity to freshwater aquatic life ocurs at concentrations as low as 117,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of isophorone to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for isophorone indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 12,900 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of isophorone to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of isophorone ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 5.2 mg/l.

For the protection of human health from the toxic properties of isophorone ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 520 mg/l.

Lead

Freshwater Aquatic Life

For total recoverable lead the criterion (in μg/l) to protect freshwater aquatic life as derived using the Guidelines is the numerical value given by e(2.35[ln(hardness)]–9.48) as a 24-hour average and the concentration (in μg/l) should not exceed the numerical value given by e(1.22[ln(hardness)]–0.47) at any time. For example, at hardnesses of 50, 100, and 200 mg/l as $CaCO_3$ the criteria are 0.75, 3.8, and 20 μg/l, respectively, as 24-hour averages, and the concentrations should not exceed 74, 170, and 400 μg/l, respectively, at any time.

Saltwater Aquatic Life

The available data for total recoverable lead indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 668 and 25 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

The ambient water quality criterion for lead is recommended to be identical to the existing drinking water standard which is 50 μg/l. Analysis of the toxic effects data resulted in a calculated level which is protective to human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Mercury

Freshwater Aquatic Life

For total recoverable mercury the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.00057 μg/l as a 24-hour average and the concentration should not exceed 0.0017 μg/l at any time.

Saltwater Aquatic Life

For total recoverable mercury the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.025 μg/l as a 24-hour average and the concentration should not exceed 3.7 μg/l at any time.

Human Health

For the protection of human health from the toxic properties of mercury ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 144 ng/l.

For the protection of human health from the toxic properties of mercury ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 146 ng/l.

Note.—These values include the consumption of freshwater, estuarine, and marine species.

Naphthalene

Freshwater Aquatic Life

The available data to naphthalene indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 2,300 and 620 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for naphthalene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 2,350 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of naphthalene to sensitive saltwater aquatic life.

Human Health

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for naphthalene.

Nickel

Freshwater Aquatic Life

For total recoverable nickel the criterion (in µg/l) to protect freshwater aquatic life as derived using the Guidelines is the numerical value given by e(0.76 [ln (hardness)] +1.06) as a 24-hour average and the concentration (in µg/l) should not exceed the numerical value given by e(0.76[ln (hardness)] + 4.02) at any time. For example, at hardnesses of 50, 100, and 200 mg/l as $CaCO_3$ the criteria are 56, 96, and 160 µg/l, respectively, as 24-hour averages, and the concentrations should not exceed 1,100, 1,800, and 3,100 µg/l, respectively, at any time.

Saltwater Aquatic Life

For total recoverable nickel the criterion to protect saltwater aquatic life as derived using the Guidelines is 7.1 µg/l as a 24-hour average and the concentration should not exceed 140 µg/l at any time.

Human Health

For the protection of human health from the toxic properties of nickel ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 13.4 µg/l.

For the protection of human health from the toxic properties of nickel ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 100 µg/l.

Nitrobenzene

Freshwater Aquatic Life

The available data for nitrobenzene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 27,000 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No definitive data are available concerning the chronic toxicity of nitrobenzene to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for nitrobenzene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 6,680 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of nitrobenzene to sensitive saltwater aquatic life.

Human Health

For comparison purposes, two approaches were used to derive criterion levels for nitrobenzene. Based on available toxicity data, for the protection of public health, the derived level is 19.8 mg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 30 µg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have no demonstrated relationship to potential adverse human health effects.

Nitrophenols

Freshwater Aquatic Life

The available data for nitrophenols indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 230 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of nitrophenols to sensitive freshwater aquatic life but toxicity to one species of algae occurs at concentrations as low as 150 µg/l.

Saltwater Aquatic Life

The available data for nitrophenols indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 4,850 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of nitrophenols to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of 2,4-dinitro-o-cresol ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 13.4 µg/l.

For the protection of human health from the toxic properties of 2,4-dinitro-o-cresol ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 765 µg/l.

For the protection of human health from the toxic properties of dinitrophenol ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 70 µg/l.

For the protection of human health from the toxic properties of dinitrophenol ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 14.3 mg/l.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for mononitrophenol.

Using the present guidelines, a satisfactory criterion cannot be derived at this time due to the insufficiency in the available data for tri-nitrophenol.

Nitrosamines

Freshwater Aquatic Life

The available data for nitrosamines indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 5,850 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of nitrosamines to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for nitrosamines indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 3,300,000 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of nitrosamines to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of n-nitrosodimethylamine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 14 ng/l, 1.4 ng/l, and .14 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 160,000 ng/l, 16,000 ng/l, and 1,600 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure of n-nitrosodiethylamine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 8 ng/l, 0.8 ng/l, and 0.08 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 12,400 ng/l, 1,240 ng/l, and 124 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure in n-nitrosodi-n-butylamine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 64 ng/l 6.4 ng/l and .064 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 5,868 ng/l, 587 ng/l, and 58.7 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure in n-nitrosodiphenylamine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 49,000 ng/l 4,900 ng/l and 490 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 161,000 ng/l, 16,100 ng/l, and 1,610 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

For the maximum protection of human health from the potential carcinogenic effects due to exposure in n-nitrosopyrrolidine through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk, over the lifetimes are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 160 ng/l 16.0 ng/l and 1.60 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 919,000 ng/l, 91,900 ng/l, and 9,190 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Pentachlorophenol

Freshwater Aquatic Life

The available data for pentachlorophenol indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 55 and 3.2 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for pentachlorophenol indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 53 and 34 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For comparison purposes, two approaches were used to derive criterion levels for pentachlorophenol. Based on available toxicity data, for the protection of public health, the derived level is 1.01 mg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 30 μg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Phenol

Freshwater Aquatic Life

The available data for phenol indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 10,200 and 2,560 μg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for phenol indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 5,800 ug/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of phenol to sensitive saltwater aquatic life.

Human Health

For comparison purposes, two approaches were used to derive criterion levels for phenol. Based on available toxicity data, for the protection of public health, the derived level is 3.5 mg/l. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 0.3 mg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criterion have limitations and have no demonstrated relationship to potential adverse human health effects.

Phthalate Esters

Freshwater Aquatic Life

The available data for phthalate esters indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 940 and 3 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for phthalate esters indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 2944 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of phthalate esters to sensitive saltwater aquatic life but toxicity to one species of algae occurs at concentrations as low as 3.4 µg/l.

Human Health

For the protection of human health from the toxic properties of dimethyl-phthalate ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 313 mg/l.

For the protection of human health from the toxic properties of dimethyl-phthalate ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 2.9 g/l.

For the protection of human health from the toxic properties of diethyl-phthalate ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 350 mg/l.

For the protection of human health from the toxic properties of diethyl-phthalate ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 1.8 g/l.

For the protection of human health from the toxic properties of dibutyl-phthalate ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 34 mg/l.

For the protection of human health from the toxic properties of dibutyl-phthalate ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 154 mg/l.

For the protection of human health from the toxic properties of di-2-ethylhexyl-phthalate ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 15 mg/l.

For the protection of human health from the toxic properties of di-2-ethylhexyl-phthalate ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 50 mg/l.

Polychlorinated Biphenyls

Freshwater Aquatic Life

For polychlorinated biphenyls the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.014 µg/l as a 24-hour average. The available data indicate that acute toxicity to freshwater aquatic life probably will only occur at concentrations above 2.0 µg/l and that the 24-hour average should provide adequate protection against acute toxicity.

Saltwater Aquatic Live

For polychlorinated biphenyls the criterion to protect saltwater aquatic life as derived using the Guidelines is 0.030 µg/l as a 24-hour average. The available data indicate that acute toxicity to saltwater aquatic life probably will only occur at concentrations above 10 µg/l and that the 24-hour average should provide adequate protection against acute toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of PCBs through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are .79 ng/l, 0.79 ng/l, and .0079 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are .79 ng/l, .079 ng/l, and .0079 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Polynuclear Aromatic Hydrocarbons (PAHs)

Freshwater Aquatic Life

The limited freshwater data base available for polynuclear aromatic hydrocarbons, mostly from short-term bioconcentration studies with two compounds, does not permit a statement concerning acute or chronic toxicity.

Saltwater Aquatic Life

The available data for polynuclear aromatic hydrocarbons indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 300 ug/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of polynuclear aromatic hydrocarbons to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of PAHs through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 28 ng/l, 2.8 ng/l, and .28 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 311 ng/l, 31.1 ng/l, and 3.11 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Selenium

Freshwater Aquatic Life

For total recoverable inorganic selenite the criterion to protect freshwater aquatic life as derived using the Guidelines is 35 µg/l as a 24-hour average and the concentration should not exceed 260 µg/l at any time.

The available data for inorganic selenate indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 760 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of inorganic selenate to sensitive freshwater aquatic life.

Saltwater Aquatic Life

For total recoverable inorganic selenite the criterion to protect saltwater aquatic life as derived using the Guidelines is 54 µg/l as a 24-hour average and the concentration should not exceed 410 µg/l at any time.

No data are available concerning the toxicity of inorganic selenate to saltwater aquatic life.

Human Health

The ambient water quality criterion for selenium is recommended to be identical to the existing drinking water standard which is 10 µg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Silver

Freshwater Aquatic Life

For freshwater aquatic life the concentration (in µg/l) of total recoverable silver should not exceed the numerical value given by "e[1.72(ln (hardness)-6.52)]" at any time. For example, at hardnesses of 50, 100, 200 mg/l as $CaCO_3$ the concentration of total recoverable silver should not exceed 1.2, 4.1, and 13 µg/l, respectively, at any time. The available data indicate that chronic toxicity to freshwater aquatic life may occur at concentrations as low as 0.12 µg/l.

Saltwater Aquatic Life

For saltwater aquatic life the concentration of total recoverable silver should not exceed 2.3 µg/l at any time. No data are available concerning the chronic toxicity of silver to sensitive saltwater aquatic life.

Human Health

The ambient water quality criterion for silver is recommended to be identical to the existing drinking water standard which is 50 µg/l. Analysis of the toxic effects data resulted in a calculated level which is protective of human health against the ingestion of contaminated water and contaminated aquatic organisms. The calculated value is comparable to the present standard. For this reason a selective criterion based on exposure solely from consumption of 6.5 grams of aquatic organisms was not derived.

Tetrachloroethylene

Freshwater Aquatic Life

The available data for tetrachloroethylene indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 5,280 and 840 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Saltwater Aquatic Life

The available data for tetrachloroethylene indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations low as 10,200 and 450 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of tetrachloroethylene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 8 µg/l, .8 µg/l, and .08 µg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 88.5 µg/l, 8.85 µg/l, and .88 µg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Thallium

Freshwater Aquatic Life

The available data for thallium indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 1,400 and 40 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. Toxicity to one species of fish occurs at concentrations as low as 20 µg/l after 2,600 hours of exposure.

Saltwater Aquatic Life

The available data for thallium indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 2,130 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of thallium to sensitive saltwater aquatic life.

Human Health

For the protection of human health from the toxic properties of thallium ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 13 µg/l.

For the protection of human health from the toxic properties of thallium ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 48 µg/l.

Toluene

Freshwater Aquatic Life

The available data for toluene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 17,500 µg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of toluene to sensitive freshwater aquatic life.

Saltwater Aquatic Life

The available data for toluene indicate that acute and chronic toxicity to saltwater aquatic life occur at concentrations as low as 6,300 and 5,000 µg/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested.

Human Health

For the protection of human health from the toxic properties of toluene ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 14.3 mg/l.

For the protection of human health from the toxic properties of toluene ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 424 mg/l.

Toxaphene

Freshwater Aquatic Life

For toxaphene the criterion to protect freshwater aquatic life as derived using the Guidelines is 0.013 µg/l as a 24-hour average and the concentration should not exceed 1.6 µg/l at any time.

Saltwater Aquatic Life

For saltwater aquatic life the concentration of toxaphene should not exceed 0.070 µg/l at any time. No data are available concerning the chronic toxicity of toxaphene to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of toxaphene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 7.1 ng/l, .71 ng/l, and .07 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 7.3 ng/l, .73 ng/l, and .07 ng/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Trichloroethylene

Freshwater Aquatic Life

The available data for trichloroethylene indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 45,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of trichloroethylene to sensitive freshwater aquatic life but adverse behavioral effects occurs to one species at concentrations as low as 21,900 μg/l.

Saltwater Aquatic Life

The available data for trichloroethylene indicate that acute toxicity to saltwater aquatic life occurs at concentrations as low as 2,000 μg/l and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of trichloroethylene to sensitive saltwater aquatic life.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of trichloroethylene through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 27 μg/l, 2.7 μg/l, and .27 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 807 μg/l, 80.7 μg/l, and 8.07 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Vinyl Chloride

Freshwater Aquatic Life

No freshwater organisms have been tested with vinyl chloride and no statement can be made concerning acute or chronic toxicity.

Saltwater Aquatic Life

No saltwater organisms have been tested with vinyl chloride and no statement can be made concerning acute or chronic toxicity.

Human Health

For the maximum protection of human health from the potential carcinogenic effects due to exposure of vinyl chloride through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentration should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding criteria are 20 μg/l, 2.0 μg/l, and .2 μg/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 5,246 μg/l, 525 μg/l, and 52.5 μg/l, respectively. Other concentrations representing different risk levels may be calculated by use of the Guidelines. The risk estimate range is presented for information purposes and does not represent an Agency judgment on an "acceptable" risk level.

Zinc

Freshwater Aquatic Life

For total recoverable zinc the criterion to protect freshwater aquatic life as derived using the Guidelines is 47 μg/l as a 24-hour average and the concentration (in μg/l) should not exceed the numerical value given by $e^{(0.83[\ln(\text{hardness})]+1.95)}$ at any time. For example, at hardnesses of 50, 100, and 200 mg/l as $CaCO_3$ the concentration of total recoverable zinc should not exceed 180, 320, and 570 μg/l at any time.

Saltwater Aquatic Life

For total recoverable zinc the criterion to protect saltwater aquatic life as derived using the Guidelines is 58 μg/l as a 24-hour average and the concentration should not exceed 170 μg/l at any time.

Human Health

Sufficient data is not available for zinc to derive a level which would protect against the potential toxicity of this compound. Using available organoleptic data, for controlling undesirable taste and odor quality of ambient water, the estimated level is 5 mg/l. It should be recognized that organoleptic data as a basis for establishing a water quality criteria have limitations and have not demonstrated relationship to potential adverse human health effects.

Appendix B—Guidelines for Deriving Water Quality Criteria for the Protection of Aquatic Life and Its Uses

Introduction

This version of the Guidelines provides clarifications, additional details, and technical and editorial changes in the last version published in the Federal Register [44 FR 15970 (March 15, 1979)]. This version incorporates changes resulting from comments on previous versions and from experience gained during U.S. EPA's use of the previous versions. Future versions of the Guidelines will incorporate new ideas and data as their usefulness is demonstrated.

Criteria may be expressed in several forms. The numerical form is commonly used, but descriptive and procedural forms can be used if numerical criteria are not possible or desirable. The purpose of these Guidelines is to describe an objective, internally consistent and appropriate way of deriving numerical water quality criteria for the protection of the uses of, as well as the presence of, aquatic organisms.

A numerical criterion might be thought of as an estimate of the highest concentration of a substance in water which does not present a significant risk to the aquatic organisms in the water and their uses. Thus the Guidelines are intended to derive criteria which will protect aquatic communities by protecting most of the species and their uses most of the time, but not

SUMMARY

SNARLS

Assumptions:

1. Looking at sensitive population.
2. Using a child weighing 10 kg. who drinks one liter of water per day.
3. Considering only toxic effects. rather than carcinogenic

Health Advisories

Compound	Length of Exposure				
	1 day	7 days	10 days	1 month	life-time
trichloroethylene	2 mg/l		200 ug/l		75 ug/l
tetrachloroethylene	2.3 mg/l		180 ug/l		40 ug/l
1,1,1-trichloroethane					1 mg/l
benzene		350 ug/l			
polynuclear aromatic hydrocarbons		25 ug/l			

Cancer Risks

Assumptions:

1. There is some risk at any level of exposure, and the risk increases as lifetime exposure increases.
2. Using 70 kg. adult living 70 years who drinks two liters of water per day.

Compound	Excess Risk			
	One in 10^{-6}	One in 10^{-5}	Two in 10^{-5}	Six in 10^{-6}
trichloroethylene	4.5 ug/l	45 ug/l	75 ug/l	
tetrachloroethylene	3.5 ug/l	35 ug/l		20 ug/l

Draft SNARLS (not to be released)

Assumptions:

1. Looking at sensitive population.
2. Using a child weighing 10 kg. who drinks one liter of water per day.
3. Considering only toxic effects.

Compound	Length of Exposure				
	1 day	7 days	10 days	1 month	life-time
methylene chloride	13 mg/l		1.3-1.5 mg/l		150 ug/l 87u
carbon tetrachloride	200 ug/l		20 ug/l		
toluene			1 mg/l		
methyl ethyl ketone			1 mg/l		
acrylonitrile			35 ug/l	3 ug/l	
polychlorinated biphenyls				1 ug/l	0.3 ug/l
dibromochloropropane					0.05 ug/l
1,4-dioxane			20 ug/l		
xylenes	12 mg/l		1.4 mg/l		620 ug/l
chlordane	63 ug/l		63 ug/l		8 ug/l
1,1 Dichloroethylene	1.0 mg/l				70 ug/l
Trans-1,2 Dichloroethylene	2.7 mg/l		0.27 mg/l		
Cis-1,2 Dichloroethylene	4.0 mg/l		0.40 mg/l		
Ethylene Glycol	19 mg/l				5.5 mg/l

SNARL For Trichloroethylene
Health Effects Branch, Criteria and Standards Division
Office of Drinking Water
U.S. Environmental Protection Agency
Washington, D.C. 20460

The Office of Drinking Water has reviewed the current literature on the health effects of trichloroethylene. Both data from animal tests and some studies from high level exposure in humans were used as basis for extrapolating to levels in drinking water that would result in negligible risks to the general human population. When considering toxicity that does not include the risk of cancer, we generally use a child weighing 10 kg (22 pounds) and drinking one liter of water per day as the basis for calculations of short exposure (acute) toxicity and longer exposure (chronic) toxicity. These levels are derived using safety factors from classical toxicology and a logic similar to that used by the National Academy of Sciences in "Drinking Water and Health." When considering the possible cancer risk, where it is assumed that there is some risk at any level of exposure, and that the risk increases as the lifetime exposure increases, we use the 70 kg (154 pounds) adult living 70 years who drinks two liters of water as the base, and calculate the excess cancer risk above the normal background according to a mathematical model developed by the National Academy of Sciences in "Drinking Water and Health," and based on animal tests conducted by the National Cancer Institute.

The drinking water levels that we have calculated providing a margin of safety from likely toxic effects in humans (assuming that 100% of the exposure is from drinking water) were related to the length of time that water is being consumed, and range from short-term emergency levels to long-term chronic exposure. We have separately computed the potential additional cancer risk.

The computed drinking water guidance levels for effects excluding cancer risks are as follows:

Time	Concentration
1 day	2 mg/l
10 days	0.2 mg/l (200 ug/l)
Chronic (long-term)	75 ug/l

The computed excess lifetime cancer risks from the NAS model at various exposures assuming the 70 kg adult drinking two liters of water per day for 70 years at the indicated concentration are as follows:

Concentration	Excess Risk
4.5 ug/l	one in 1,000,000
45 ug/l	one in 100,000
75 ug/l	approximately two in 100,000

The development of a SNARL for trichloroethylene does not condone its presence in drinking water, but rather provides useful information to guide control priorities in cases where it is found as a contaminant. Human exposure to contaminants in drinking water such as trichloroethylene should be reduced to the extent feasible, to avoid the unnecessary risks from their presence as adulterants. The applicable treatment technologies include aeration and granular activated carbon.