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TECHNICAL MEMORANDUM NO. 2

HUMAN HEALTH RISK ASSESSMENT

PRESENT LANDFILL (IHSS 114), THE INACTIVE HAZARDOUS WASTE STORAGE AREA (IHSS 203), AND THE EAST LANDFILL POND AND ADJACENT SPRAY EVAPORATION AREAS OPERABLE UNIT NO. 7

MODEL DESCRIPTION

DRAFT FINAL
FEBRUARY 11, 1993

ROCKY FLATS PLANT

U.S. DEPARTMENT OF ENERGY
ROCKY FLATS PLANT
GOLDEN, COLORADO

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ENVIRONMENTAL MANAGEMENT DEPARTMENT

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EXECUTIVE SUMMARY

This technical memorandum describes the fate and transport models that will be used to estimate chemical exposure point concentrations for the Human Health Risk Assessment (HHRA), which is part of the Phase I Resource Conservation and Recovery Act (RCRA) Facility Investigation/Remedial Investigation (RFI/RI) for Operable Unit No. 7 (OU7) at the Rocky Flats Plant. Application of the selected models to site-specific conditions at OU7 will be included in the Phase I RFI/RI Report and is not addressed in this document.

OU7 consists of the following individual hazardous substance sites (IHSSs):

- Present Landfill (IHSS 114)
- Inactive Hazardous Waste Storage Area (IHSS 203)

Also included within the boundary of OU7 are the East Landfill Pond and adjacent banks where water from the East Landfill Pond was spray evaporated.

The objectives of the modeling are to:

1) Support the HHRA portion of the Phase I RFI/RI at OU7 by simulating the transport of chemicals of concern from OU7 to potential exposure points for human receptors under present and anticipated future site conditions.

2) Support the evaluation of potential remedial alternatives for the Corrective Measures Study/Feasibility Study (CMS/FS) for OU7.

Based on the available site characterization information, a conceptual site model (CSM) was developed to identify and evaluate the source areas, chemical release mechanisms, environmental transport media, potential human intake routes, and potential human receptors at OU7. In accordance with the Interagency Agreement (IAG), exposure pathways chosen for evaluation in the Phase I risk assessment are limited to (1) landfill gas/volatilization, (2) wind suspension, (3) vegetable/plant uptake, and (4) direct contact. Exposure pathways to be evaluated as part of the Phase II risk assessment include (1) erosion and storm runoff, (2) leachate migration, and (3) infiltration and percolation.

Exposure pathways chosen for quantitative evaluation in the risk assessment that require modeling of environmental fate and transport to estimate exposure point concentrations include landfill gas generation, soil gas transport, and airborne transport of wind-suspended particulates and gases.

Several models were evaluated for applicability to the site-specific conditions at OU7. Model selection was based on the following five criteria:

1) The selected models should be able to incorporate key environmental fate and transport processes and accurately reflect conditions known to occur at the site.

2) The selected models should be able to satisfy the objectives of the study.

3) The selected models should be verified using published equations and solutions.

4) The selected models should be complete, well documented, and preferably available in the public domain.

5) The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

The following models were selected to meet the requirements of the modeling study:

- The LANDFIL2 model for pressure-driven landfill gas emissions.

- The SEAM model for diffusive transport of soil gas contaminants.

- The Fugitive Dust Model (FDM) for transport of airborne particulates and vapor-phase contaminants from OU7 sources to onsite and offsite receptors.

Data from previous and ongoing investigations at RFP and OU7 and general literature were evaluated for use as input for the modeling activities. Tables 3-1, 3-2, and 3-3 summarize the data currently available to estimate model parameters. Additional data from the Phase I RFI/RI may also be used in the modeling effort once those data become available. If additional data are substantially different than those used in developing this technical memorandum become available, revisions to the modeling approach may become necessary.

The data presented in Tables 3-1, 3-2, and 3-3 are preliminary and, in some cases, are not site-specific. The data values or ranges of values are not intended to be fixed or final. The ranges are presented to convey what is currently known of the variability in the parameter values that may be used in the models.

1.0 INTRODUCTION

This document provides a description of the fate and transport models selected to estimate landfill gas generation, soil gas transport, and airborne transport of wind suspended particulates and gases for Operable Unit No. 7 (OU7). The results of the modeling will be used as exposure point concentrations in the HHRA, which is part of the OU7 Phase I RCRA Facility Investigation/Remedial Investigation (RFI/RI). The RFI/RI is pursuant to a Compliance Agreement between the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), and the State of Colorado Department of Health (CDH), dated July 31, 1986; and the Federal Facility Agreement and Consent Order (FFACO) (known as the Interagency Agreement [IAG]), dated January 22,1991. The DOE Environmental Restoration (ER) Program was formed to identify, investigate, and, if necessary, remediate contaminated sites at DOE facilities. The program, in fulfilling this mission, addresses RCRA and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) issues. In accordance with the IAG, the CERCLA terms "Remedial Investigation" and "Feasibility Study" in this document are considered equivalent to the RCRA terms "RCRA Facility Investigation" and "Corrective Measures Study," respectively.

This technical memorandum is meant to be reviewed in conjunction with the Exposure Assessment Technical Memorandum for OU7 (DOE 1993). The reader of this memorandum is referred to the Exposure Assessment Technical Memorandum for additional information or details on the exposure scenarios to be used for OU7.

The remainder of Section 1.0 includes a discussion of the purpose of this technical memorandum and the objectives of the modeling activities (Section 1.1), and a brief description of the site location and general site conditions (Section 1.2). Section 2.0 presents the conceptual site model and exposure pathways to be evaluated in the risk assessment for OU7. Section 3.0 provides model selection criteria and descriptions of the selected models for landfill gas/volatilization and air transport, and a summary of model input parameter values. Section 4.0 presents a summary of the technical memorandum and Section 5.0 provides a list of references used in preparing this document.

1.1 Purpose and Scope

The purpose of this document is to provide a description of appropriate landfill gas/volatilization and air transport models for use at OU7. This document fulfills the IAG requirements (1991, Section VII.D.1.b) that state:

> "... DOE shall submit for review and approval a description of the fate and transport models that will be utilized, including a summary of the data that will be used with these models. Representative data shall be utilized and the limitations, assumptions, and uncertainties associated with the models shall be documented."

The model selection process focuses on models appropriate for simulating processes affecting the migration of contaminants through soil material overlying landfill waste and the airborne transport of volatile organic and particulate contaminants. This document does not address the application of the selected models to the site-specific conditions at OU7; that will be included in the Phase I RFI/RI Report.

Modeling activity quality assurance (QA) is covered by the sitewide QA plan (EG&G 1991a). Modeling QA includes model verification, checks on calculations, and technical review of modeling methods, assumptions, results, and interpretations.

The objectives of the modeling efforts are as follows:

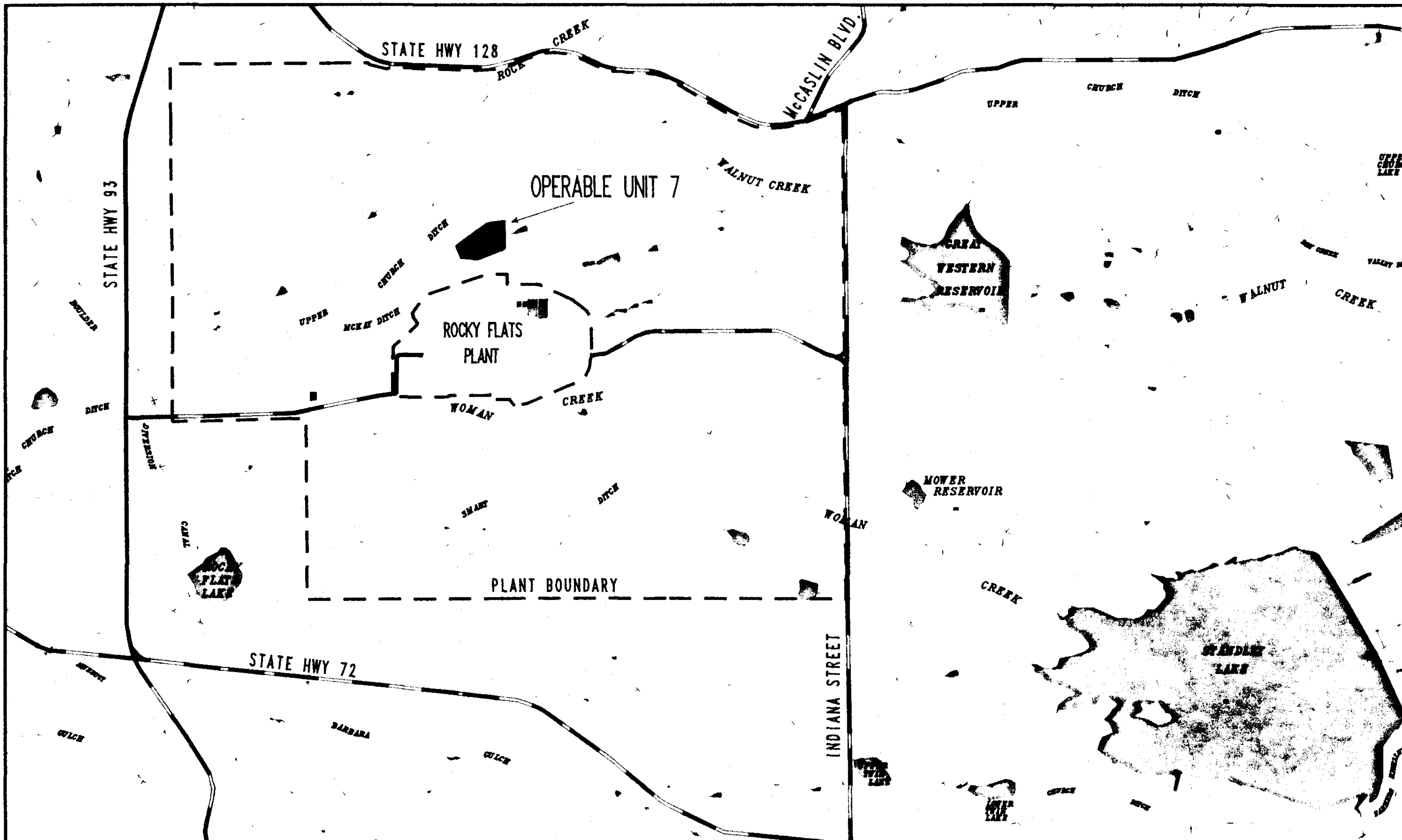
1) To support the HHRA portion of the RFI/RI Phase I Report at OU7. This will be accomplished by simulating the transport of chemicals of concern from OU7 to potential exposure points for human receptors under present and anticipated future site conditions.

2) To support the evaluation of potential remedial alternatives for the Corrective Measures Study/Feasibility Study (CMS/FS) for OU7.

1.2 Site Location and General Site Description

Rocky Flats Plant (RFP) is located on approximately 6,550 acres of federally owned land in northern Jefferson County, Colorado, approximately 16 miles northwest of Denver (Figure 1-1). Surrounding communities include Boulder, Superior, Broomfield, Westminster, and Arvada, which are located less than 10 miles to the northwest, north, northeast, and southeast, respectively. RFP includes an industrial complex of approximately 400 acres, surrounded by a buffer zone of approximately 6,150 acres. A general description of RFP is presented in this section. For a more detailed description, please refer to the Phase I RFI/RI Work Plan for OU7 (EG&G 1991b).

RFP is a government-owned and contractor-operated (GOCO) facility that is part of the nationwide nuclear weapons production complex. RFP was operated for the U.S. Atomic Energy Commission (AEC) from the time it was built in 1951 until the AEC was dissolved in January 1975. At that time, responsibility for RFP was assigned to the Energy Research and Development Administration (ERDA), which was succeeded by the Department of Energy (DOE) in 1977. Dow Chemical USA, an operating unit of the Dow Chemical Company, was the prime operating contractor of the facility from 1951 until June 30, 1975, when it was succeeded by Rockwell International. EG&G Rocky Flats, Inc. succeeded Rockwell International on January 1, 1990.



Approx. Scale 1" = 4000'

0 feet 4000 8000

LOCATION of the ROCKY FLATS PLANT and OPERABLE UNIT 7

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FIGURE 1-1

RFP's historical mission was to produce metal components for nuclear weapons. These components were fabricated from plutonium, uranium, and nonradioactive metals (principally beryllium and stainless steel) and shipped elsewhere for final assembly. When a nuclear weapon is determined to be obsolete, components of these weapons fabricated at RFP are returned for special processing to recover plutonium. Other activities at RFP have included research and development in metallurgy, machining, nondestructive testing, coatings, remote engineering, chemistry, and physics. Both radioactive and nonradioactive wastes have been generated in these research and production processes. Current waste handling practices involve onsite and offsite recycling of hazardous materials, onsite storage of hazardous and radioactive mixed wastes, and disposal of solid radioactive materials at another DOE facility. Historically, the operating procedures included both onsite storage and disposal of hazardous and radioactive wastes. Preliminary assessments under the ER Program identified some of the past onsite storage and disposal locations as potential sources of environmental contamination.

RFP is currently performing environmental restoration activities and transition planning for decontamination and decommissioning. In a recent speech given at RFP, the Secretary of Energy, James Watkins, outlined DOE's plans for the future use of RFP. Watkins characterized RFP as an attractive site for manufacturers and other businesses (Denver Post 1992).

A group of local business and government representatives, referred to as the Rocky Flats Local Impacts Initiative (RFLII), has been formed to identify and mitigate negative economic impacts associated with the transition currently occurring at the RFP. One of the goals of RFLII is to work with DOE and local economic development agencies to identify and attract businesses to occupy existing buildings at the site (RFLII 1992). To this end, RFLII recently drafted criteria to be applied in targeting businesses for future occupation of the RFP.

Another relatively recent development at RFP has been the realization of its value as wildlife habitat and a refuge for regionally limited plant and animal species. The ecological importance of the site has resulted from various geographic influences and the fact that the buffer zone has been protected from grazing and most other physical disturbances for many years.

1.3 History of OU7

OU7 comprises the Present Landfill (IHSS 114), the East Landfill Pond and adjacent spray evaporation areas, and the Inactive Hazardous Waste Storage Area (IHSS 203). Figure 1-2 illustrates the locations of these areas and the OU7 boundary. The following IHSS descriptions are based on the Phase I RFI/RI Work Plan for OU7. A more detailed description of each IHSS and the types of associated contamination can be found in the Phase I RFI/RI Work Plan for OU7 (EG&G 1991b).

1.3.1 Present Landfill (IHSS 114)

Operation of the landfill was initiated on August 14, 1968. A portion of the natural drainage was filled with soils from an onsite borrow area to a depth of up to 5 feet to construct a surface on which to start landfilling. The landfill was originally constructed to provide for disposal of the plant's nonradioactive solid wastes. Criteria originally used to define nonradioactive material are not known at present. Waste materials disposed in the landfill have included paper, rags, floor sweepings, cartons, mixed garbage and rubbish, demolition material, and miscellaneous items.

From 1968 to 1978, the landfill received approximately 20 cubic yards of compacted waste per day. By 1974, the landfill had expanded in surface area to approximately 300,000 square feet (7 acres). The volume occupied by the landfill was estimated to be approximately 95,000 cubic yards. Of this total, the cover material was estimated at 30,000 cubic yards. The remaining 65,000 cubic yards consisted of waste (approximately 40,000 cubic yards) intermixed with the daily cover material (approximately 15,000 cubic yards) placed during disposal. Estimates made in 1986 indicate that approximately 160,000 cubic yards of material had been placed between 1974 and 1986, for a total landfill volume of 255,000 cubic yards. This volume included solid wastes, wastes with hazardous constituents, and soil cover material. Between 1986 and 1988, waste was disposed at a rate of 115 cubic yards per work day (Rockwell 1988a). Using this rate and assuming 260 work days per year for four years, approximately 120,000 cubic yards of waste material have been disposed since 1986. Daily cover volumes have been estimated at approximately 25 percent of the volume of material disposed. Based on these assumptions, the present volume of material in the landfill is estimated to be approximately 405,000 cubic yards.

In September 1973, tritium was detected in leachate draining from the landfill. Subsequently, a sampling program was initiated to determine the location of the tritium source. Monitoring of waste prior to burial was initiated to prevent further disposal of radioactive material, and interim response measures were undertaken to control the generation and migration of the landfill leachate.

The disposal procedures currently employed at the landfill have not changed significantly since the landfill went into operation in 1968. Waste is delivered to the landfill throughout the morning and early afternoon. In mid-afternoon, waste is spread across the work area. Since the discovery in 1973 of a tritium source within the landfill wastes, a radiation monitoring program initiated by the Health Physics Operations at RFP has been implemented to prevent further disposal of radioactive material. After the waste is dumped, but before compaction and burial, measurements are obtained with a Field Instrument for Detection of Low Energy Radiation (FIDLER) probe. Radioactive items are removed and stored onsite.

After radiation monitoring is completed, the waste layer is compacted and covered with 6 inches of soil from onsite stockpiles. Waste disposal continues in this manner until the waste layer is within 3 feet of the final elevation. The lift is then completed by adding a layer of compacted soil 3 feet thick. In different sections of the landfill, the total landfill thickness consists of one to three such lifts. Based on visual observation (Rockwell 1988a), some areas of the landfill surface may not have received a full 3-feet of compacted soil.

1.3.2 East Landfill Pond and Adjacent Spray Evaporation Areas

Interim measures taken in response to the detection of tritium in the landfill leachate included construction of two ponds (Ponds #1 and #2) immediately east of the landfill, a subsurface interception system for diverting groundwater around the landfill, a subsurface leachate collection system, and surface water control ditches. Construction of these systems began in October 1974 and was completed in January 1975. The locations of the landfill structures constructed as interim response measures are shown in Figure 1-3.

The surface water control ditches intercept surface water runoff flowing toward the landfill and direct it away from the landfill. The purpose of Pond #1 (also referred to as the West Landfill Pond in some documents) was to provide a permanent structure to impound any leachate generated by the landfill. The purpose of Pond #2 was to provide a permanent structure to collect groundwater flowing from the groundwater diversion system. The leachate collection system drained only to Pond #1. Discharge of the intercepted groundwater could be directed to the west pond, east pond, or surface drainages downgradient of the east pond by a series of valves in the subsurface pipes.

In 1974, an engineered pond embankment was constructed to replace the temporary embankment of Pond #2. The engineered embankment included a low-permeability clay core keyed into bedrock. The area of the new pond, now called the East Landfill Pond, was approximately 2.5 acres.

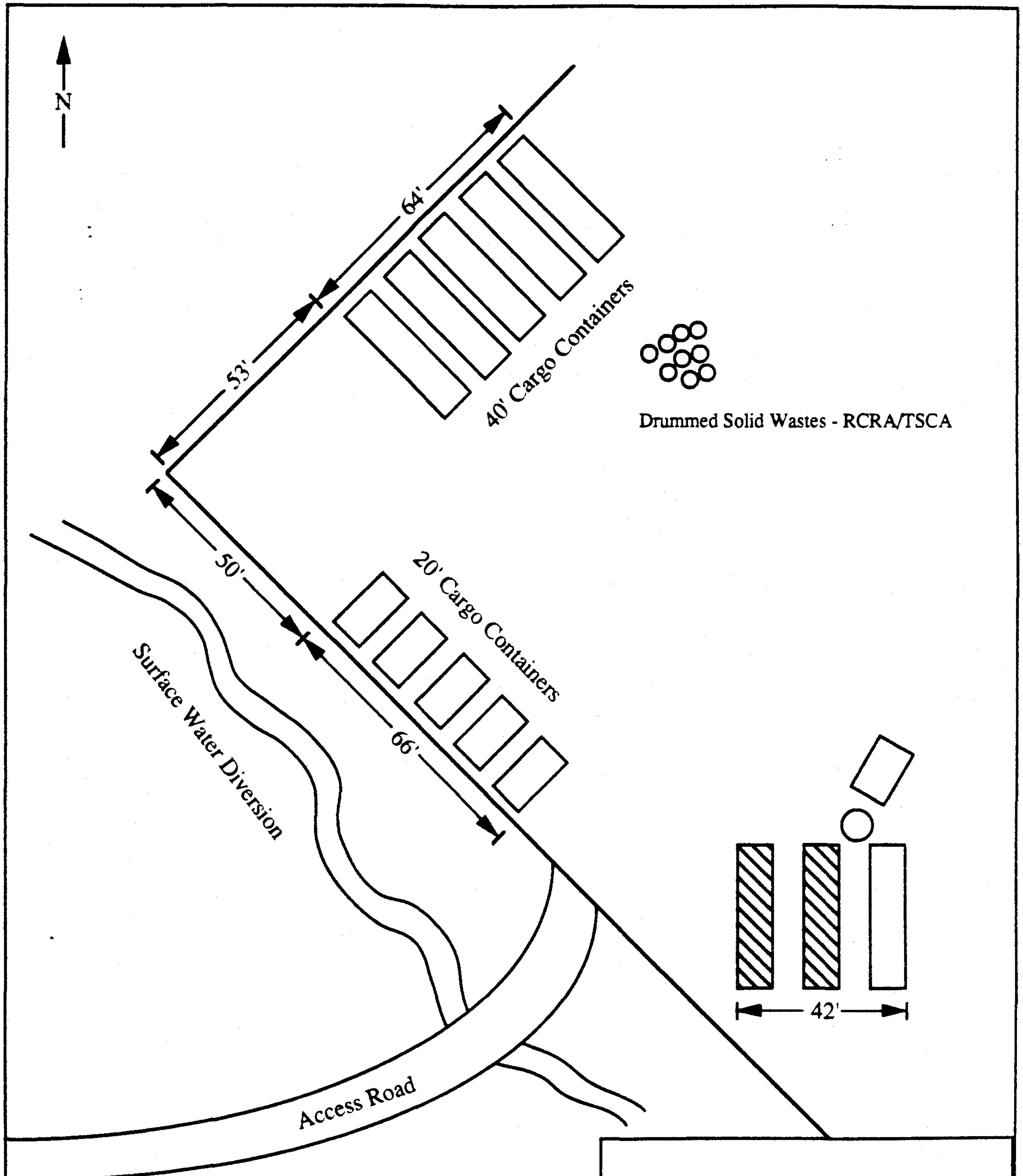
To prevent the two ponds from overfilling and discharging into the drainage, water was periodically sprayed in areas adjacent to the landfill to enhance evaporation. Areas where spray operations historically occurred were designated as IHSSs and incorporated into OU6. Water collected in Pond #1 was sprayed on a 3.9-acre plot, designated as IHSS 167.1 and located approximately 800 feet northeast of the pond. Two other spray fields, IHSSs 167.2 and 167.3, were located along the banks of the East Landfill Pond and were used for spray evaporation of water collected from that pond. Water from the East Landfill Pond is currently sprayed along the banks on south side of the pond in areas not designated as IHSSs but are considered to be part of OU7.

Between 1977 and 1981, portions of the leachate and groundwater diversion system were buried during landfill expansion. The eastward expansion covered the discharge points of the leachate collection system into Pond #1. The west embankment and Pond #1 were covered in May 1981 during further eastward expansion of the landfill. In 1982, two slurry walls were constructed to prevent groundwater migration into the expanded landfill area. These slurry walls were tied into the north and south arms of the groundwater diversion system.

1.3.3 Inactive Hazardous Waste Storage Area (IHSS 203)

The Inactive Hazardous Waste Storage Area is located at the southwestern corner of the Present Landfill. This area was actively used from 1986 to 1987 as a hazardous waste storage area for both drummed liquids and solids (Rockwell 1988b). Fifty-five-gallon containers with free liquids were stored in fourteen cargo containers. One additional container was used to store spill control items such as oil sorbent and sorbent pillows.

During maximum inventory, the hazardous waste area consisted of eight 20-foot-long cargo containers, each capable of holding eighteen 55-gallon drums, and six 40-foot-long cargo containers, each capable of holding forty 55-gallon drums. Fifty-five-gallon drums were placed and conveyed in the cargo containers on rollers constructed of aluminum. Two conveyors extended the full length of the cargo container. A 3-foot-wide aisle extended down the center of the cargo container to permit access and inspection. The rollers elevated the drums approximately 2 inches above the catch basin floor. The approximate location of the storage containers in IHSS 203 during maximum inventory is shown in Figure 1-4 (Baker 1988).



LEGEND

PCB Waste Cargo Container

Source: Rockwell International
1988c

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

Location of Containers in the
Inactive Hazardous Waste Storage Area
(IHSS 203)

Figure 1-4

The cargo containers were modified to meet the requirements for secondary containment in accordance with 6 CCR 1007-3 Section 264.175. Containers were fitted with signs, air vents, electrical grounding, and locks. A catch basin, constructed of 11-gauge steel with a welded steel rim and a minimum height of 6 inches, was placed within each cargo container to contain spills. The basins, as designed, were capable of containing at least 10 percent of the total volume of hazardous waste. The largest container stored in these cargo containers was 55 gallons. Drummed solids (in 55-gallon containers) were placed outside the cargo containers on the ground surface.

Total liquid storage capacity for the fourteen cargo containers was 21,120 gallons. Maximum inventory recorded for all wastes, including solids, is unknown (Rockwell 1988b). Because wastes were transferred between drums for consolidation, small spills may have occurred. However, no spills greater than reportable quantities occurred in this area during transfer operations (Rockwell 1988b).

RCRA-listed wastes were stored in twelve of the fourteen cargo containers and included solvents, coolants, machining wastes, cuttings, lubricating oils, organics, and acids. No information is available regarding the separation of waste types between the individual cargo containers. Two of the 20-foot-long cargo containers also were used to store soil and debris contaminated with polychlorinated biphenyl (PCB) as well as PCB-contaminated oil from transformers taken out of service (Baker 1988). During the first week of May 1987, all cargo containers were removed from the Inactive Hazardous Waste Storage Area. Hazardous materials are no longer stored at the site. However, drilling and monitoring well construction materials are presently stored at IHSS 203.

1.4 Physical Setting

The natural environment of RFP and vicinity is influenced primarily by its proximity to the Front Range of the Southern Rocky Mountains. RFP is located less than 2 miles east of the north-south trending Front Range and approximately 16 miles east of the Continental Divide. This transition zone between prairie and mountains is referred to as the Colorado Piedmont section of the Great Plains Province (Thornsbury 1965, Hunt 1967). The Colorado Piedmont is an area of dissected topography reflecting folding and faulting of bedrock along the edge of the Front Range uplift, subsequent pediment erosion and burial by fluvial processes, and more recent incision of drainages and removal of portions of the alluvial cap. Rocky Flats is the most extensive pediment surface in the area. RFP occupies the eastern edge of this pediment, which extends approximately 5 miles northeast from the mouth of Coal Creek Canyon. The surface of the Rocky Flats plain lies at an elevation of approximately 6,000 feet above mean sea level. In eastern portions of RFP, the gently sloping pediment gives way to low, rolling hills.

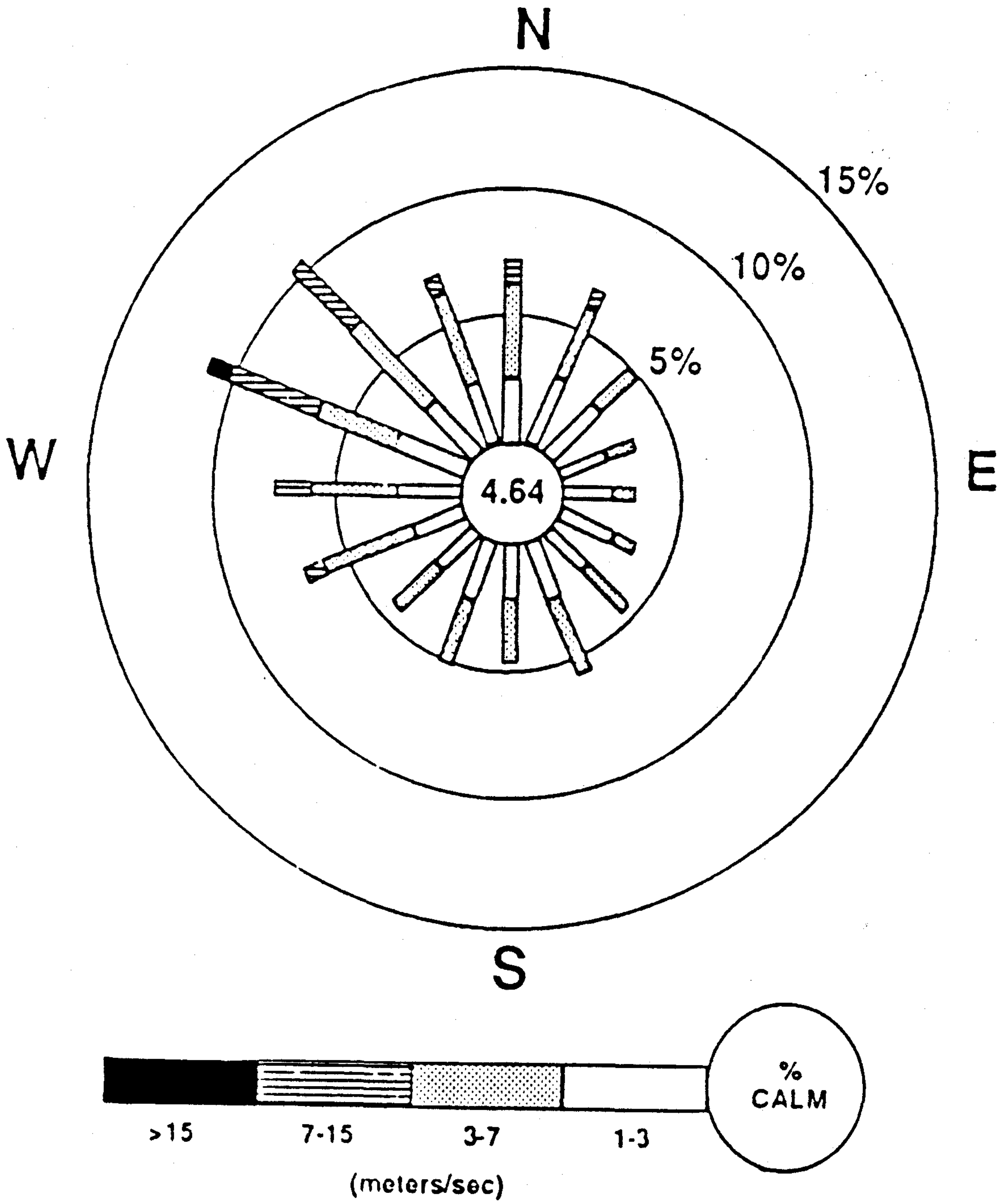
Three intermittent streams drain RFP, with flow toward the east or northeast. These drainages are Rock Creek, Walnut Creek, and Woman Creek. Rock Creek drains the northwestern corner of RFP and flows northeast through the buffer zone to its offsite confluence with Coal Creek. An east-west trending interfluve separates the Walnut and Woman Creek drainages. North and South Walnut Creeks and an unnamed tributary drain the northern portion of the protected area. These three forks of Walnut Creek join in the buffer zone and flow toward Great Western Reservoir, which is approximately one mile east of the confluence. Flow is currently routed around Great Western Reservoir by the Broomfield Diversion Canal operated by the City of Broomfield. Woman Creek drains the southern RFP buffer zone and flows eastward to Mower Reservoir and Standley Lake.

1.5 Meteorology

RFP has a highly continental, semi-arid climate. Mean annual precipitation of the RFP vicinity is approximately 18 inches. More than half of this total occurs as snowfall, which averages approximately 85 inches per year. Approximately 40 percent of the annual precipitation occurs in the spring, which is characterized by occasional heavy snow and periods of steady rain. Precipitation gradually declines through the summer, usually occurring as brief but occasionally intense thunderstorms. Approximately 75 percent of the total annual precipitation occurs during the 180-day growing season. Relative humidities are generally low throughout the year, with an annual average of approximately 50 percent. Annual free-water evaporation is approximately 45 inches (DOE 1992a), which is approximately 2.5 times the annual precipitation.

Temperatures at RFP exhibit large diurnal and annual ranges. Average minimum and maximum temperatures recorded at locations near RFP (Boulder and Lakewood, Colorado) are approximately 19°F and 45°F in January, and 59°F and 88°F in July. Temperatures as low as -25°F and as high as 105°F have been recorded at these monitoring locations. The mean annual temperature for Boulder and Lakewood is approximately 51.5°F.

RFP is noted for its strong winds. Gusty winds frequently occur with thunderstorms and the passage of weather fronts. The highest wind speeds occur during the winter as westerly windstorms known as "chinooks". The windstorm season at RFP extends from late November into April; the height of the season usually occurs in January. Windstorms at RFP typically last 8 to 16 hours and are very gusty in nature. RFP experiences wind speeds exceeding 75 mph in almost every season; gusts exceeding 100 mph are experienced every three to four years (Hodgin et al. 1990). Northwesterly wind directions and wind speeds under 7 meters per second (m/sec) are the predominant conditions at RFP. Moderately strong northerly or southerly winds are common in winter and summer, respectively, and easterly winds ("upslopes") may be associated with snowfall. The 1990 wind rose for RFP is shown in Figure 1-5. Mean wind speed for 1990 was 4.0 m/sec. The frequency of occurrence of atmospheric stability during 1990, in terms of Pasquill stability classes, was: 50.1 percent for neutral stability classes (Class D), 42.5 percent for stable classes (Class E



U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

Wind Rose for the Rocky Flats Plant
1990 Annual

Figure 1-5

and F), and 7.37 percent for unstable classes (Class A, B, and C).

1.6 Geology

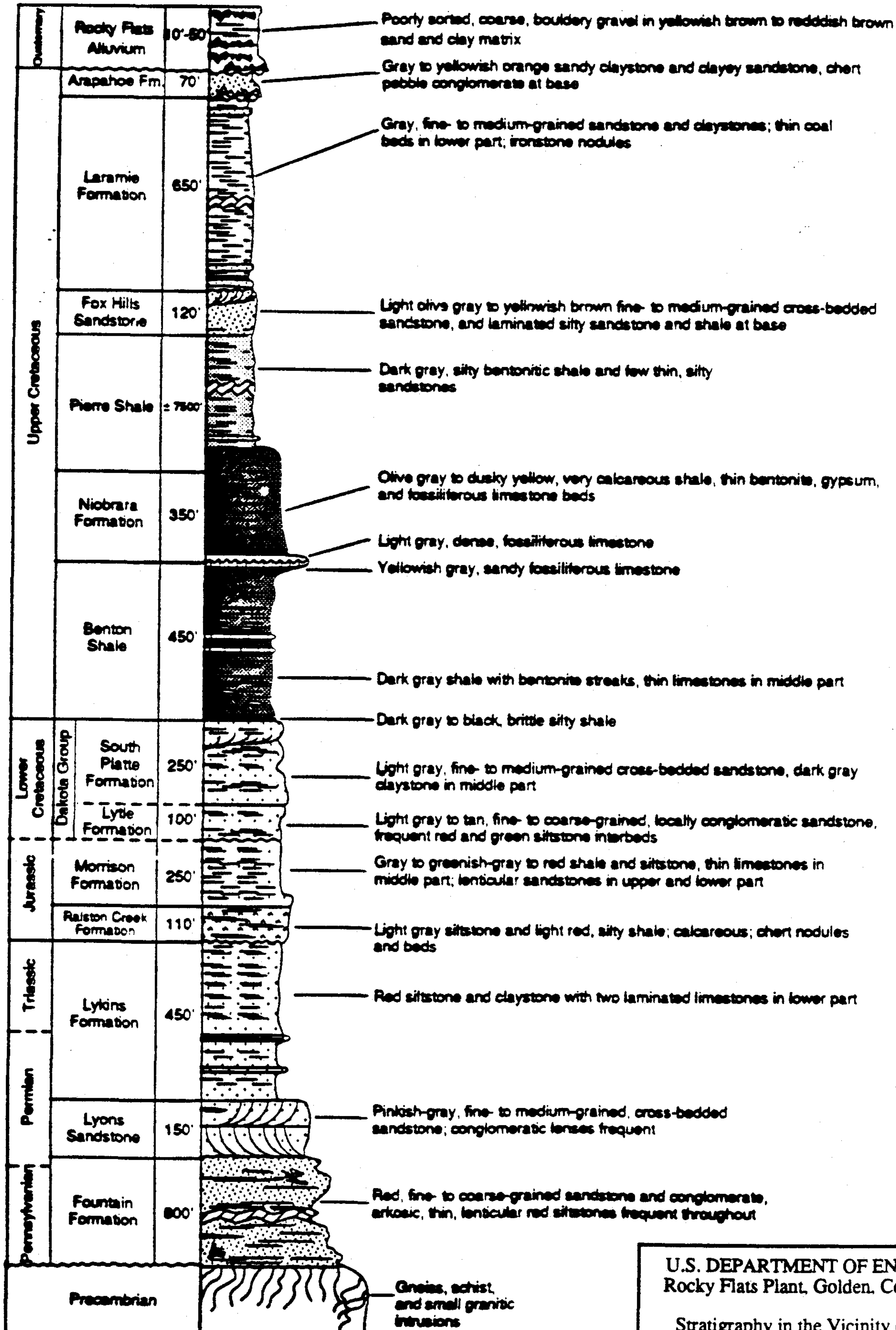
The description of the geology in the vicinity of OU7 is derived from previous studies performed at the site. Much of the information has been summarized from the Present Landfill Hydrogeologic Characterization Report (Rockwell 1988c). Additional information was obtained from data generated during the 1989 borehole drilling and well installation program and from the Draft Phase II Geologic Characterization Report (EG&G 1991c). The surficial geology map presented as Figure 1-6 is based on the surficial geology map presented in the 1988 Hydrogeologic Characterization Report, with recent field confirmation. Stratigraphy in the vicinity of RFP is shown in Figure 1-7.

1.6.1 Surficial Geology

Four distinct surficial deposits of Quaternary age are present in the vicinity of OU7: Rocky Flats Alluvium, colluvium (slope wash), valley-fill alluvium, and artificial fill or disturbed ground. These surficial deposits unconformably overlie the bedrock units. Rocky Flats Alluvium caps the interfluves (divides) north and south of the unnamed tributary to North Walnut Creek. As described previously, OU7 is located near the upper (western) end of this drainage. Colluvium covers the hillsides down to the drainage. Valley-fill alluvium is present along the channel of the unnamed tributary. The erosional surface on which the alluvium was deposited slopes gently eastward, truncating the Arapahoe and Laramie Formations. Artificial fill or disturbed surficial materials are present within the boundaries of the landfill, along man-made drainages surrounding the landfill, and northwest of the landfill. These surficial materials are described below.

Rocky Flats Alluvium. The Rocky Flats Alluvium is the oldest alluvial deposit present at RFP. In the area of the landfill, Rocky Flats Alluvium is described as poorly sorted, unconsolidated, and composed of clay, silt, sand, and gravel. Deposits of Rocky Flats Alluvium occur at a level approximately 200 feet above the level of modern creek beds including the unnamed tributary that drains the landfill area. Drill core logs from the landfill show thicknesses of Rocky Flats Alluvium ranging from 6.5 to 27.2 feet.

Colluvium. Colluvial materials cover hillsides along drainages that dissect the Rocky Flats Alluvium, including the unnamed tributary in which the landfill is located. the colluvium consists of poorly consolidated clay with common occurrences of silty clay, sandy clay, and gravelly clay. None of the monitoring wells at the landfill is completed in colluvial materials. In the areas that have been drilled, the thickness of colluvial deposits ranged from 3.0 to 7.1 feet.



Source: LeRoy and Weimer, 1971

U.S. DEPARTMENT OF ENERGY
Rocky Flats Plant, Golden, Colorado

Stratigraphy in the Vicinity of the Rocky Flats Plant

Figure 1-7

Valley-Fill Alluvium. The most recent deposit in the landfill area is valley-fill alluvium along the floor of the unnamed tributary channel. The unconsolidated valley fill consists of poorly sorted sand and gravel in a silty clay matrix. The valley-fill alluvium is derived from reworked and redeposited older alluvial and bedrock materials. Valley-fill alluvium was noted in five of the locations drilled east of the landfill, its thickness ranged from 0.9 to 6.2 feet.

Artificial Fill. Two types of artificial fill are present in the vicinity of the landfill. The first type is derived from the excavation of Church Ditch (located northwest of the landfill) and materials used to construct the dam that forms the East Landfill Pond. The core of the East Landfill Pond dam was constructed with compacted clay and claystone. The outer shell of the dam consists of clayey sands and gravels. Materials used to construct the groundwater intercept system (clay, coarse sand, and gravels) have also been encountered during drilling of a downgradient well.

The second type of artificial fill consists of waste and daily soil cover material. This fill is described as a mixture of clay, sand, and gravel containing asphalt, insulated wire, wood, construction ribbon, surgical gloves, saranex suits, and other materials associated with RFP landfilling activities. Thicknesses of landfill materials at drilling locations range from approximately 1.5 to 23.3 feet. A previous investigation by Woodward-Clevenger (1974) reported fill at a thickness of 27 feet (Rockwell 1988a).

1.6.2 Bedrock Geology

The Upper Cretaceous Arapahoe and Laramie Formations unconformably underlie surficial materials in the vicinity of the Present Landfill. The Arapahoe Formation is composed primarily of sandstones, siltstones, and claystones that are very similar lithologically to those in the underlying Laramie Formation. This similarity between the upper Laramie and Arapahoe has resulted in confusion distinguishing these two units. In the vicinity of the landfill, the base of the Arapahoe Formation occurs at elevations between 5920 and 5960 feet above mean sea level (EG&G 1992a). Only the lowest 20 feet of the Arapahoe Formation is present in the vicinity of the landfill and the Arapahoe Formation is not present where the bedrock has been eroded to lower stratigraphic levels along stream drainages.

The Laramie and Arapahoe Formations in the vicinity of the landfill are lithologically very similar. As a result, the well logs frequently contain inaccurate stratigraphic designations, even though lithologic descriptions are correct. Therefore, the bedrock lithology is described below without reference to formal stratigraphic nomenclature.

Seventeen wells have been completed in various zones of the bedrock during previous drilling and well installation programs. Bedrock units in this area consist of claystone frequently interbedded with siltstones and, occasionally, with sandstones. Contacts between contrasting lithologies are both gradational and sharp. Weathered bedrock was encountered directly beneath surficial materials in all of the boreholes drilled during previous investigations at the landfill. Weathering has been observed to penetrate up to approximately 30 feet into the bedrock. A thin shale layer interbedded with coal seams was noted on one borehole log at 13.8 to 15.0 feet below ground surface, and six distinct lignite layers were noted on another borehole log. These layers range in thickness from 0.3 to 1.7 feet and are interspersed at depths from 66.6 to 252.2 feet below ground surface.

Laramie/Arapahoe Claystone. Claystone was the most frequently encountered lithology in the bedrock immediately below the Quaternary/Cretaceous angular unconformity. Claystones present in the area are described as massive and blocky, containing occasional thin laminae and interbeds of sandstone and siltstone. Borehole logs indicate occasional vertical to subvertical fractures in both the unweathered and weathered claystones. Leaf fossils and black organic matter are commonly present within the claystone.

Laramie/Arapahoe Sandstone and Siltstone. During drilling, sandstones were encountered in the bedrock in fourteen wells. The sandstones were of variable thickness (0.2 to 40.5 feet) and occurred at depths from 7.5 to 251.5 feet. In general, sandstone beds are less than 10 feet thick with thicker sections of sandstone occurring at depths greater than 100 feet. Sandstones in the landfill area are described as composed of moderately to well sorted, subrounded to rounded, very fine- to medium-grained quartz sand. The sandstones are more commonly cemented at depth where they remain unweathered. Cementing agents in the sandstones are predominantly argillic with minor calcium carbonate and silica cement noted. Weathered sandstone is lithologically similar to the unweathered sandstone. During drilling, sandstones were encountered directly underlying surficial deposits in five wells. Thicknesses of these sandstones range from 0.2 to 6.5 feet. The sandstones are generally clayey in nature and are underlain by sandy claystones or claystones.

Shallow sandstones (within 15 feet of the Quaternary/Cretaceous unconformity) were encountered while drilling three wells. Thicknesses of the shallow sandstone beds range from 0.3 to 11 feet. The shallow sandstone beds encountered while drilling two of the wells were not fully penetrated.

During drilling, siltstones associated with the claystones and sandstones were encountered in five wells and had variable thicknesses (2.1 to 33 feet) and depths (34.5 to 177.8 feet). The siltstones are described as gradational units of clayey siltstone or sandy siltstone. Relatively homogeneous layers of unweathered siltstone were encountered while drilling wells 0986 and B207189. These siltstones are described as greenish gray to dark gray, clayey, with a trace of very fine sand, and laminated.

Results of previous investigations (Rockwell 1988a) suggested that the sandstone units beneath the landfill were continuous and possibly subcropped beneath the East Landfill Pond. These conclusions were based on an estimated regional eastward dip angle of 7 degrees for the bedrock strata and an interpretation, based on limited drill-core data, that sandstone units are laterally continuous. Recent sitewide investigations conducted by EG&G indicate that the bedrock strata dip approximately 2 degrees to the east and that the sandstone units may not be laterally continuous. Applying the 2-degree dip to the subcropping sandstones suggests that they may not subcrop beneath the East Landfill Pond as previously thought.

1.7 Hydrogeology

1.7.1 Groundwater Flow System

Groundwater moves through surficial material (Rocky Flats Alluvium, colluvium, valley-fill alluvium, and artificial fill) and Arapahoe sandstones and claystones in the area of the Present Landfill. The "uppermost hydrostratigraphic unit" (HSU) at OU7 consists of surficial materials and weathered bedrock units of the Arapahoe formation. In the vicinity of OU7, the hydraulic connection between the HSU and deeper sandstone lenses in the unweathered Arapahoe Formation is unknown and will be characterized during the Phase II RFI/RI. This discussion is based on Rockwell (1988c) and more recent groundwater level data presented by Rockwell (1989) and EG&G (1990b).

Groundwater is present in surficial materials at the Present Landfill under unconfined conditions. Recharge of shallow groundwater occurs as infiltration of incident precipitation and, in some areas, spray water from the landfill pond (intermittent spraying is conducted to enhance evaporation). Recharge also occurs as infiltration from ditches and creeks and probably as seepage from the landfill pond. However, the need for enhanced evaporation of the landfill pond indicates that seepage is low.

The surficial groundwater flow system is dynamic, with relatively large water level changes occurring in response to precipitation events and to stream and ditch flow (Hurr 1976). The saturated thickness of the surficial materials also varies seasonably.

In general, groundwater flows in surficial material toward the landfill is from the west (EG&G 1991b). Shallow groundwater flow toward the landfill pond has southwestern and northwestern components but is also mostly from the west (i.e., from the landfill). Groundwater flow directions in the weathered bedrock units during the first and second quarters of 1991 was similar to groundwater flow patterns in the surficial units. The potentiometric surfaces observed during 1991 were consistent with the potentiometric surfaces presented in EG&G (1991d) for 1990.

Groundwater elevations in surficial materials at the landfill are characterized by seasonal variations of up to approximately 8 feet. Groundwater elevations in the weathered claystone units typically show seasonal variations of less than 1 foot, although variations up to 8 feet have been observed in Well B206189 (EG&G 1990b).

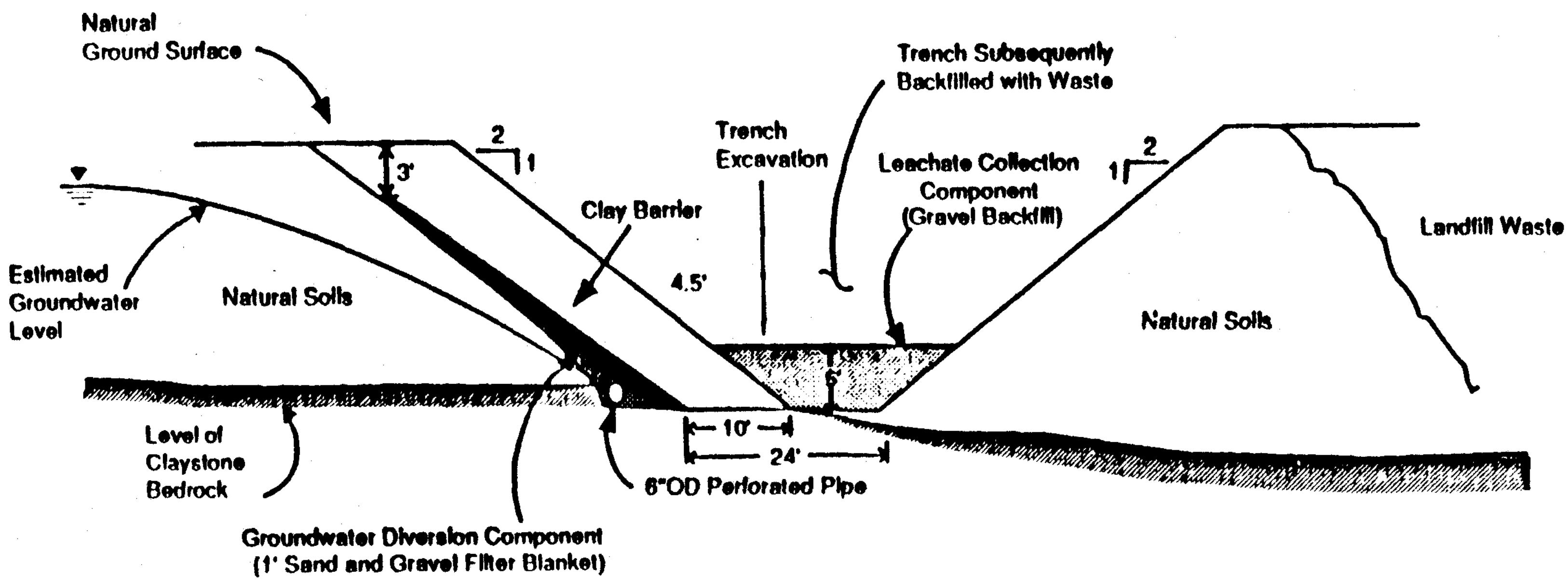
1.7.2 Subsurface Drainage Structures and East Pond Embankment

Subsurface Drainage Structures. A subsurface drainage control system was installed around the perimeter of the landfill in 1974 in response to the detection of tritium downstream of the landfill. The subsurface drainage system included both a leachate collection system located directly beneath the landfill wastes and a groundwater intercept system constructed between the surface water interceptor ditch and the landfill wastes. The leachate collection system was designed to collect and discharge leachate generated by the landfill and to lower fluid levels within the landfill. Leachate was discharged into Pond #1. The groundwater diversion system was designed to intercept and divert groundwater flow around the landfill. This system also provided an expanded disposal area.

The two-part system was constructed by excavating around the perimeter of the landfilled wastes to depths of 10 to 25 feet. The trench excavation for the system was 24 feet wide at the base, as shown in Figure 1-8.

The groundwater collection and diversion portion of the system was installed on the side of the trench away from the landfill waste. This system consisted of a 1-foot-thick sand and gravel filter blanket installed along the trench face. This filter blanket drain was designed to intercept groundwater and drain to a 6-inch-diameter perforated pipe installed in the bottom of the trench. The intercepted groundwater could then be discharged to Pond #1, the East Landfill Pond, or to surface drainage downslope of the East Landfill Pond. Control of discharge was accomplished by a series of valves. A 4.5-foot-thick clay barrier was placed on top of the sand and gravel filter blanket to separate the groundwater intercept system from the leachate collection system. The as-built sections and profile sheets indicate the bottom of the system to be above the bedrock surface approximately halfway between Wells B106089 and 6587 on the south side of the intercept system and approximately halfway between Wells B106089 and 6387 on the north side of the intercept system. Although the design drawings specified a 6-inch-diameter perforated pipe for the leachate collection system, as-built drawings indicate that the leachate collection system consisted of a 5-foot-thick gravel backfill placed in the bottom of the trench on the landfill side. Collected leachate drained into Pond #1, which was intended to retain the leachate without discharging to the east pond (Rockwell 1988a).

Between 1977 and 1981, the leachate collection and groundwater intercept system was buried beneath waste during landfill expansion. Lateral expansion of waste placement has resulted in wastes being located beyond the extent of the subsurface drains (Rockwell 1988a). Eastward expansion covered the points where the leachate collection system discharged into Pond #1.



Approximate Scale: 1" = 20'
Source: Rockwell International 1988b

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Design Section of Groundwater Intercept and Leachate Collection System

Figure 1-8

Slurry Walls. Two soil-bentonite slurry walls were constructed in 1982 to extend the groundwater intercept system already in place. These slurry walls were tied into the north and south arms of the groundwater intercept system constructed in 1974. The slurry walls were constructed to reduce groundwater migration from the north and south into the landfill as it expanded to the east. Details of the connection in the design drawings indicate that the west end of each slurry wall intersects but does not break the groundwater intercept system. At these intersections, the existing drainpipe was replaced with ductile iron pipe, which was joined with the existing drainpipe using mechanical compression joints. These sections of ductile iron pipe and the joints at each end were then encased with concrete poured against undisturbed bedrock at the bottom of the excavation. This concrete block interrupted the hydraulic continuity of the sand and gravel filter blanket located outside of the clay barrier, and the only hydraulic connection of the groundwater diversion drain across the slurry trench was through the new segment of pipe. As a result, if these pipes were to be damaged or clogged, there would be no outlet from the groundwater intercept system. The slurry walls extend eastward approximately 700 feet from these points of intersection. Based on as-built drawings, the slurry walls vary in depth from 10 to 25 feet.

East Landfill Pond Embankment. As mentioned above, two ponds were constructed as part of the interim response measure to control leachate generated by the landfill. These ponds were formed by constructing temporary berms in the drainage immediately downstream of the landfill. Both ponds were approximately 0.5 acres in size. Pond #1 impounded leachate generated by the landfill. Pond #2 provided a back-up system for any overflow from Pond #1 and was also used to collect intercepted groundwater, as needed.

In 1974, a new embankment was constructed for Pond #2 (the East Landfill Pond) in approximately the same location as the original dike. The new embankment was an engineered dam structure with a spillway designed to retain the majority of the water in the channel. A low-permeability clay core keyed into bedrock was constructed within the embankment to reduce seepage. The remaining shell of the embankment was constructed of more permeable silty to clayey granular soils. The East Landfill Pond is approximately 2.4 acres in size.

1.8 Surface Water Hydrology

Surface water at RFP is currently managed and monitored in accordance with a surface water management plan (EG&G 1991e). The surface water management program, which includes a National Pollutant Discharge Elimination System (NPDES) permit, is designed to protect public health and the environment from chemicals potentially occurring in surface water. This program approved by the EPA, provides for the treatment of surface water, as necessary, prior to release from the RFP.

The Present Landfill area is drained by an east-flowing unnamed tributary to North Walnut Creek. The East Landfill Pond, located immediately downstream of the Present Landfill on the unnamed tributary, collects both surface runoff and leachate from the landfill. The unnamed tributary joins North and South Walnut Creeks approximately 0.7 mile downstream of the eastern boundary of the plant security area before flowing offsite.

The surface of the landfill is generally poorly drained. Based on the topography shown in Figure 1-2, the average ground surface slope across the landfill is approximately 1.5 percent (downward to the east). The ground surface is irregular and hummocky, which impedes surface drainage. Standing water collects in many areas during precipitation and snowmelt. Surface flow to the landfill is controlled by a perimeter interceptor ditch constructed around the north, west, and south sides of the landfill during 1974. This ditch is 3-feet-deep, trapezoidal in cross-section, and has a 5-foot bottom width. The north and south branches of the ditch discharge into natural drainage features that drain to points downslope of the East Landfill Pond embankment.

The landfill pond is recharged by groundwater and surface runoff from the landfill and surrounding slopes to the north and south. However, surface water/groundwater interactions have not been quantified on the hillsides north and south of the landfill pond. Water loss from the pond consists of natural evaporation, which is enhanced by spraying water through fog nozzles over the pond and on the hillside to the south. The pond reportedly does not directly discharge surface water to the drainage downgradient (Rockwell 1988a).

1.9 Ecology

1.9.1 Vegetation

RFP is located immediately below the elevation at which plains grasslands grade abruptly into lower montane (foothills) forests. The present vegetation of Rocky Flats is dominated by mixed prairie showing some residual influence of previous grazing (Marr 1964, Clark et al. 1980). Prevalent upland grasses include blue grama, prairie junegrass, western wheatgrass, Canada bluegrass, and native Kentucky bluegrass. Some sites support remnants of midgrass and tallgrass prairie, including little bluestem, big bluestem, switchgrass, yellow Indiangrass, green needlegrass, needle-and-thread, and side-oats grama. Fringed sage, prairie sage, and common sage are locally abundant. Snowberry and wild rose may also be prevalent. Valley floors and seeps on adjacent slopes support various wetland communities ranging from sedges, rushes, or cattails to stands of mature cottonwoods and willows. The drainages also contain scattered clumps of wild plum, chokecherry, hawthorn, golden currant, and leadplant. Sideslopes of the deeper ravines contain skunkbrush and ninebark, two shrub species more characteristic of the lower foothills.

Weedy forbs and cheatgrass are locally prominent in disturbed or heavily grazed sites. Introduced pasture grasses, including smooth bone, intermediate wheatgrass, and crested wheatgrass, are present where attempts have been made to improve degraded range. Yucca and cacti are conspicuous in areas of prior heavy grazing and on sites with shallow, rocky soils. Individuals or small clumps of ponderosa pine occur on some rock outcrops.

1.9.2 Wildlife

As in most of the Front Range Urban Corridor, the wildlife of Rocky Flats has been greatly influenced by the increase in human activity and disturbance over the past 100 years. Most notable have been reductions in the number and diversity of ungulates (hoofed animals) and predators. However, the relative isolation and habitat diversity of Rocky Flats have resulted in a fairly rich animal community.

The Rocky Flats EIS (DOE 1980) reported that eight species of small mammals were captured during a live-trapping program in 1975. These species were listed as the deer mouse, harvest mouse, meadow vole, thirteen-lined ground squirrel, northern pocket gopher, hispid pocket mouse, silky pocket mouse, and house mouse. More recent studies have documented the occurrence of prairie voles, western jumping mice, and meadow jumping mice and clarified that both the plains harvest mouse and western harvest mouse are present. White-tailed jackrabbits and cottontails are also present onsite. The most abundant large mammal is the mule deer, with an estimated population of over one hundred. Carnivores present include coyotes, red foxes, raccoons, badgers, long-tailed weasels, and striped skunks.

Common grassland birds at Rocky Flats include western meadowlarks, horned larks, vesper sparrows, grasshopper sparrows, and both western and eastern kingbirds. Wetlands support song sparrows, common yellowthroats, red-winged blackbirds, common snipe, and sora rails. Black-billed magpies, northern orioles, yellow warblers, warbling vireos, American robins, indigo buntings, blue grosbeaks, and lesser and American goldfinches (among other species) nest in cottonwoods. Wooded draws attract foothills species, including MacGillivray's warblers, yellow-breasted chats, black-headed grosbeaks, green-tailed and rufous-sided towhees, and lazuli buntings. Common birds of prey in the area include American kestrels, northern harriers, red-tailed hawks, Swainson's hawks, great horned owls, and long-eared owls. Golden eagles and prairie falcons also occur, as do rough-legged hawks, short-eared owls, and occasional bald eagles during the winter.

The most abundant reptiles at RFP are the bullsnake, yellow-bellied racer, western terrestrial gartersnake, and prairie rattlesnake. Amphibians are discussed below.

1.9.3 Aquatic Organisms

Surface waters at Rocky Flats support a variety of aquatic macroinvertebrates, including snails and several orders of insects and crustaceans. Some of the ponds and stream reaches are inhabited by fathead minnows, creek chubs, golden shiners, and green sunfish. Largemouth bass occur in some ponds. The ponds also attract water birds such as mallards, gadwall, green-winged and blue-winged teal, pied-billed grebes, spotted sandpipers, killdeer, great blue herons, black-crowned night-herons, and double-crested cormorants. Muskrats and western painted turtles occur in some of the ponds. In addition, the ponds and creeks provide feeding habitat and water sources for various terrestrial species and breeding habitat for amphibians. Leopard frogs, Woodhouse's toads, and northern chorus frogs have all been observed at Rocky Flats.

1.9.4 Sensitive Habitats and Endangered Species

Federally listed endangered species potentially of interest in the RFP area are the black-footed ferret, peregrine falcon, and bald eagle (ASI 1991). Black-footed ferrets are not known to occur in the vicinity of RFP. Critical habitat for the black-footed ferrets consists primarily of colonies of its major food item, the prairie dog. Prairie dogs occur in only small members on or near RFP. Bald eagles occur occasionally in the RFP area, primarily as irregular visitors during the winter or migration seasons. No roost areas or nest sites exist at RFP. Peregrine falcons may occur as migrants, and a pair nested approximately 10 km to the northwest in 1991. It is possible that the hunting territory of nesting peregrines could include RFP, although suitable habitat occurs closer to the nest area.

Two "Category 2" species have been documented to occur at RFP: the ferruginous hawk and Preble's meadow jumping mouse. Ferruginous hawks have been observed throughout the year and appear to be vagrants. The species may nest near RFP and use the site for hunting. Potential nest sites in the vicinity of RFP include scattered trees and rocky ridgetops. Preble's meadow jumping mice were captured in small numbers along Woman Creek in 1991. Other Category 2 wildlife species potentially present at RFP include the white-faced ibis, mountain plover, long-billed curlew, and swift fox (ASI 1991). To date, these species have not been documented to occur at RFP.

Four plant species of special concern reported by ASI (1991) as potentially present include one threatened species (Ute lady's tresses), one Category 2 species (Colorado butterfly plant), and two species of concern in Colorado (forktip three-awn; toothcup). None of these species was found at RFP during the ASI (1991) survey. However, the forktip three-awn was reported along Woman Creek in 1973 and was documented in the same area during intensive vegetation investigations of Operable Unit 5 (Woman Creek) in 1991. The toothcup has been reported from a temporary pool about 4 miles east of Boulder, and the Ute lady's tresses has been reported near Clear Creek to the south of RFP and near South Boulder Creek to the north of RFP (ASI 1991). The Colorado butterfly plant has not been reported near RFP, but wetlands along the major creeks represent suitable habitat for both this species and the lady's tresses. Neither species was found during surveys of appropriate habitat in 1992.

Several wetlands identified at RFP come under the protection of state and federal laws (EG&G 1990c). Wetlands at RFP were identified in conjunction with the National Wetlands Inventory (1989) and field checked by U.S. Army Corp of Engineers personnel to verify their jurisdictional status. These wetlands consist of emergent, intermittently flooded stream channels and artificial, semipermanent ponds (wetland types PEMW and POWKF, respectively; see FWS 1979). Wetlands along the drainage in most areas of RFP are dominated by a narrow band of cattails, leadplant, or coyote willows with emergent trees. The later include plains cottonwoods hybrid (lanceleaf) cottonwoods, white poplars, reachleaf willows, and Siberian elm. Russian-olives are also common.

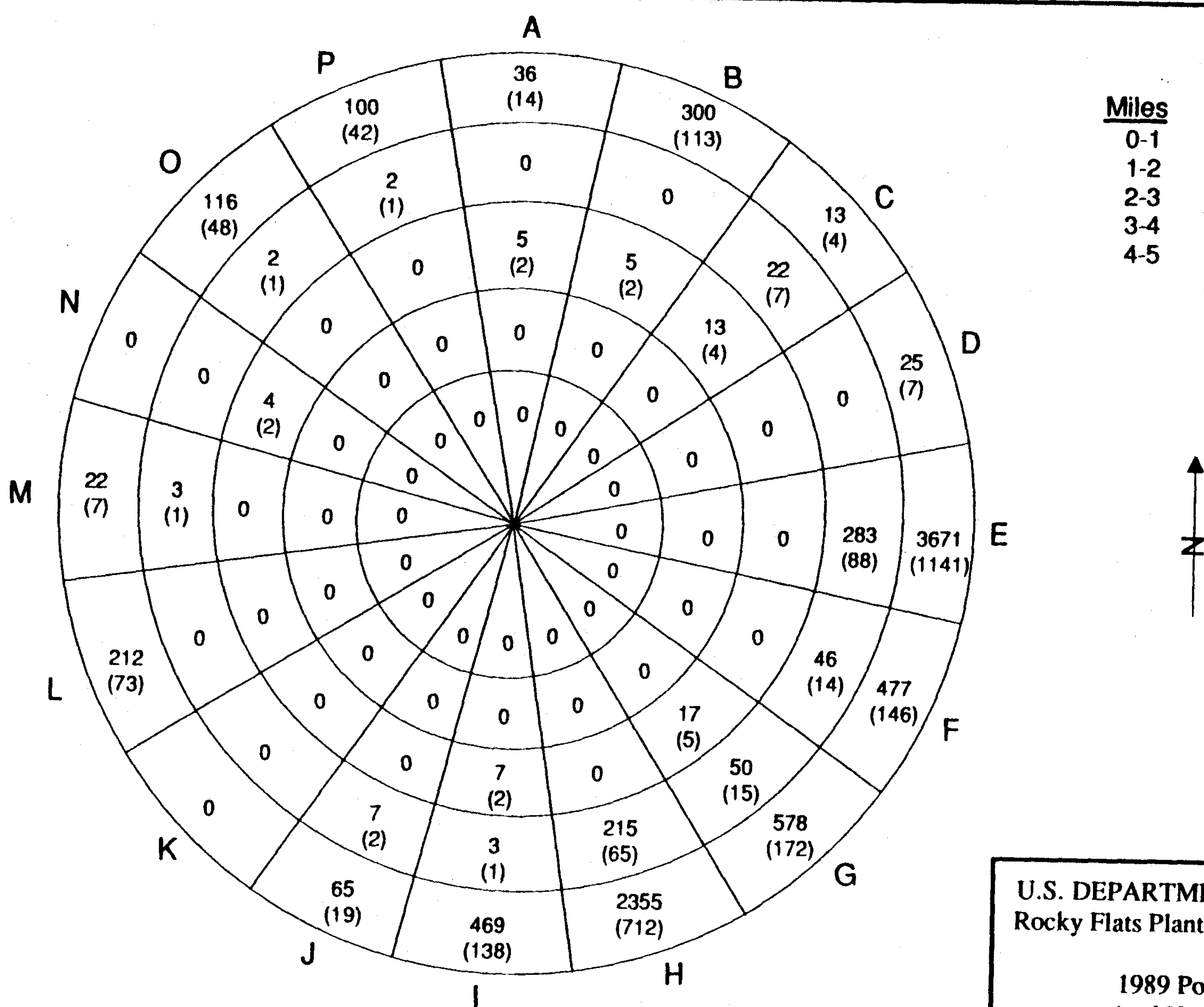
1.10 Land Use and Population Distribution

The "*1989 Population, Economic, and Land Use Data for Rocky Flats Plant*" (DOE 1990) was used to characterize land use and population distributions around the plant site. This study encompassed an area with a radius of 50 miles of area from the center of RFP and included all or part of 14 counties and 72 incorporated cities, with a 1989 combined population of 2,206,550. The study projected populations through the year 2010.

Figure 1-9 (taken from DOE 1990) illustrates the distribution of the residential population within a 5-mile radius of RFP in 1989. The projected residential population for the year 2010 is illustrated in Figure 1-10 (DOE 1990). Sectors (circumferences) 1 and 2 represent land within the RFP boundary and therefore are relevant to onsite scenarios. Sectors 3, 4, and 5 mostly include property outside the RFP boundary and thus are relevant to offsite scenarios. Radial Segments D through I, which lie in the predominant downwind directions from OU7, represent the primary areas relevant to upward exposure pathways.

The nearest drinking water supply is Great Western Reservoir, located approximately 2.3 miles east of the center of RFP. The City of Broomfield operates a water treatment facility immediately downstream from Great Western Reservoir. This facility supplies drinking water to approximately 28,000 persons. Standley Lake Park, a recreational area and a drinking water supply for the cities of Thornton, Northglenn, Westminster, and Federal Heights, is located 3.5 miles to the southeast of RFP. From Standley Lake, water is piped to each city's water treatment facility. Boating, picnicking, and limited overnight camping are permitted at Standley Lake Park.

Current land use surrounding RFP includes open space (recreational), agricultural, residential, and commercial/industrial. Northeastern Jefferson County, including RFP, is one of the most concentrated areas of industrial development in the Denver metropolitan area (Jefferson County 1989).



Miles	Sector Name
0-1	Sector 1
1-2	Sector 2
2-3	Sector 3
3-4	Sector 4
4-5	Sector 5

SOURCE: DOE, "1989 POPULATION, ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT",

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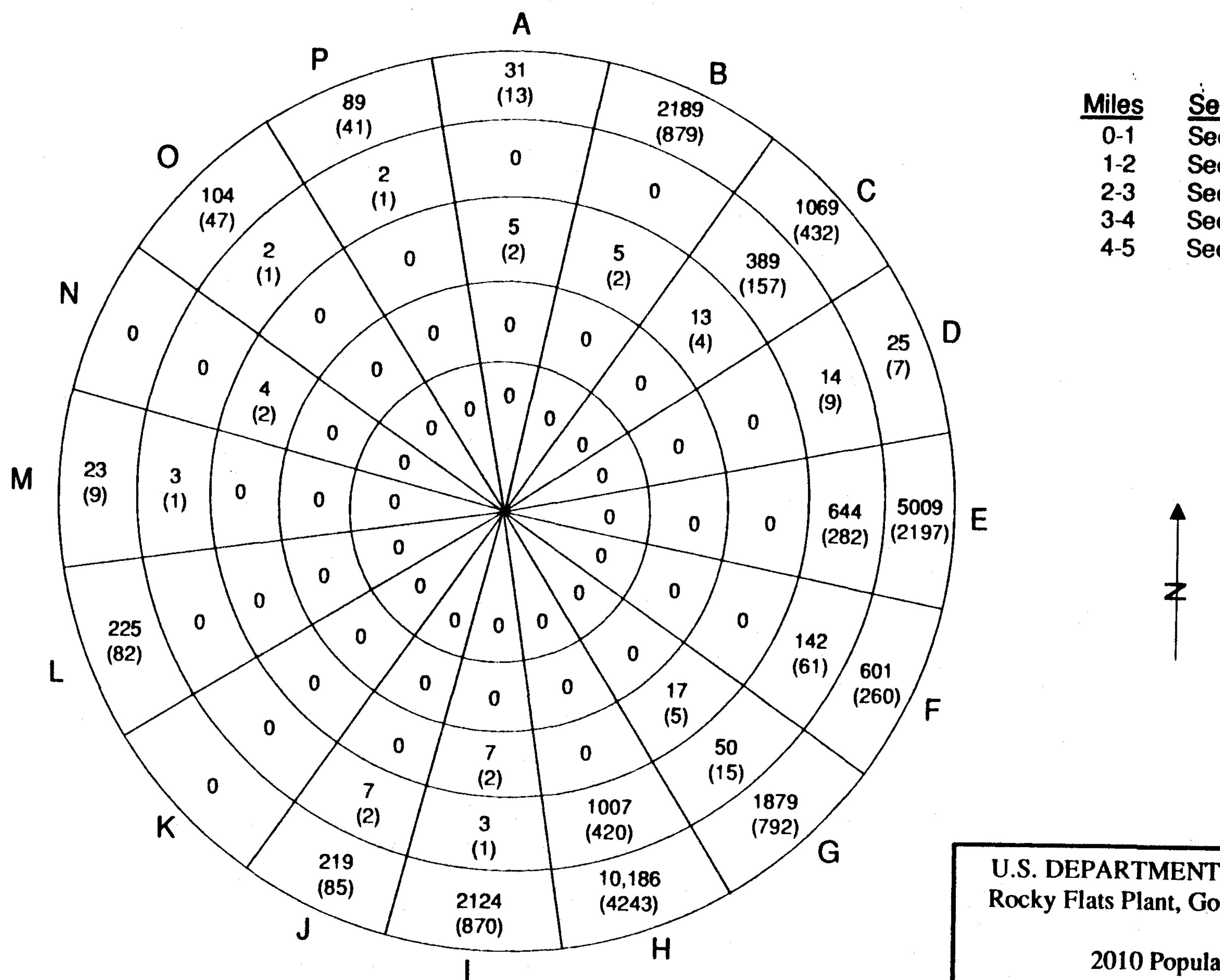
1989 Populations
(and Households),
Sectors 1-5

Figure 1-9



Miles	Sector Name
0-1	Sector 1
1-2	Sector 2
2-3	Sector 3
3-4	Sector 4
4-5	Sector 5

SOURCE: DOE, "1989 POPULATION, ECONOMIC AND LAND USE DATA BASE FOR ROCKY FLATS PLANT",

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2010 Populations
(and Households),
Sectors 1-5

Figure 1-10

Current land use in the area relevant to the OU7 exposure scenarios (immediately southeast of RFP and OU7) includes all of the uses mentioned above. Predominant uses appear to be open space, single-family detached dwellings, and horse-boarding operations. Two small cattle herds (approximately 10 to 20 cattle in each) were observed: one to the southeast, where 96th Avenue turns into Alkire and crosses Woman Creek; and one to the east of RFP, between Alkire and Simms Streets and north of 100th Avenue. Industrial facilities within the relevant area, include the TOSCO laboratory, Great Western Inorganics Plant, and Frontier Forest Products (EG&G 1991f). These facilities are located to the south, along Colorado Highway 72. Western Aggregate is the only industrial facility located to the north.

Future land use generally follows existing patterns. Jefferson County (1989) developed a baseline profile of growth and land use in the area as part of a socioeconomic study of its northeastern area (*Northeast Community Profile*). As a result of this study, Jefferson County expects that industrial land uses will continue to dominate the northeastern portion of the county. Along with the increase in industrial development, the county expects income and employment growth to increase dramatically, while household and population growth is expected to increase only moderately. In other words, with industrial growth, employment opportunities are expected to increase; yet, as the land is developed for industry, the availability of land for residential development decreases. As a result, household and population growth will be limited.

Future plans for RFP activities are discussed in the Nuclear Weapons Complex Reconfiguration Study (DOE 1991). The two preferred reconfiguration options in the study include relocation of RFP functions. The DOE has prepared a Formal Transition Plan to apprise Congress about proposed plans for changing the mission of the Rocky Flats Plant from nuclear-weapons manufacture to environmental cleanup (DOE 1992b). Several RFP facillities have a unique capability to perform plutonium analysis and to manufacture and assemble nuclear (plutonium) components for nuclear weapons on a production level. They will remain in the production contingency pending completion of the Programmatic Environmental Impact Statement for the Reconfiguration of the Nuclear-Weapons Complex.

Use of onsite production facilities by private industry is planned for the future at RFP, according to a June 12, 1992, speech by Secretary of Energy James Watkins. Watkins characterized RFP as an attractive site for manufacturers and other businesses (Denver Post 1992). Private industry could relocate to existing buildings and use existing equipment at RFP, after necessary decontamination is complete (Boulder Daily Camera 1992). One organization working to achieve this objective is the Rocky Flats Local Impacts Initiative (RFLII). This group is comprised of representatives from local businesses and government agencies and has been formed to develop a strategy to transform future changes at RFP into economic, socioeconomic, educational, land use, environmental, and infrastructural advantages. One of this group's goals is to work with the DOE and local economic development agencies to identify and attract businesses to occupy existing buildings at RFP (RFLII 1992).

When the Atomic Energy Commission (AEC) acquired the undeveloped land surrounding the production area, it established plans to preserve the land as open space (AEC 1972). It is plausible that the buffer zone and OU7 area will be preserved as open space. The buffer zone is being considered as a potential ecological preserve or National Environmental Research Park.

> There are at least three reasons why RFP would make an exceptional environmental research area. First, the site presents an excellent sample of a shortgrass prairie/montane ecotone... Second, it also provides an almost unique opportunity to conduct environmental research in an area which abuts a major metropolitan area... Third, ...the site has an abundance of wetlands and would be an excellent outdoor laboratory for a variety of wetland related ecological research (Knight 1992).

Ecological surveys of the buffer zone, performed as part of the RFI/RI process and for compliance with the Endangered Species Act, have indicated the high quality of habitats at RFP and the documented or potential presence of several species of special concern. Additional surveys are ongoing to identify and provide for the protection of any threatened and endangered species at the site, if necessary (EG&G 1992b). Because the buffer zone has not been impacted by commercial development for many years, progressive re-establishment of native habitats has occurred. Thus the future use of this area as an ecological reserve is reasonable and consistent with DOE policy and plans (DOE 1992). This type of use is also consistent with the Jefferson County Planning Department's recommendations for the provision of large amounts of undeveloped land in the area (Jefferson County 1990). Extensive development of the area is also unlikely owing to the historical use of RFP, the potential for conversion of the buffer zone into an ecological preserve, and the steep topography in some areas.

The limited availability of water is also a factor affecting development of the RFP area, as with all of the Denver metropolitan area. The Denver Water Board controls most of the metropolitan water supply and currently provides much of the suburban area's water. The Denver Water Board, however, is under no obligation to supply water to the suburbs, making the future supply questionable (Jefferson County 1989). The amount of industrial development expected in the area surrounding RFP will also result in competition for water. In addition, existing facilities within RFP are already served by municipal water supplies from the City of Golden, increasing the likelihood that existing structures will be targeted for use by industry and business.

In summary, future land use will generally follow existing land-use patterns and will likely involve industrial/office or open-space uses.

2.0 GENERAL CONCEPTUAL MODEL FOR OU7

2.1 Conceptual Site Model

This section discusses the potential release and transport of chemicals from OU7 and exposure pathways to receptor populations as identified in the Exposure Assessment Technical Memorandum (DOE 1993).

An exposure pathway is a specific environmental route by which an individual may potentially be exposed to chemical constituents present on, or originating from, a site. An exposure pathway includes five necessary elements:

- Source of chemicals
- Mechanism of chemical release
- Environmental transport medium
- Exposure point
- Human intake route

All five elements must be present for an exposure pathway to be complete. An incomplete pathway means that no human exposure can occur. Only potentially complete and relevant pathways for the Phase I investigation will be addressed in the HHRA for OU7. An exposure pathway is considered to be potentially complete and relevant if there are potential chemical release and transport mechanisms and receptors for that pathway.

Chemical Release Sources and Transport Media

The Phase I HHRA will evaluate landfill solid waste and potentially contaminated soil as the primary sources of chemical release at OU7. Environmental media that may transport chemicals of concern from OU7 to exposure points are described below in the conceptual site model.

Potentially Exposed Receptor Populations

Potentially exposed receptor populations selected for quantitative assessment in the baseline HHRA are identified below:

- Current onsite worker
- Current offsite resident
- Hypothetical future onsite worker
- Hypothetical future onsite ecological researcher
- Hypothetical future onsite resident

The current offsite resident is evaluated under current land-use conditions. The future land use scenarios assume no action takes place at OU7 and estimate exposure for future receptor populations under this condition.

Exposure Points

An exposure point is a specific location where human receptors may come in contact with site-related chemicals. Exposure points are selected so that reasonable maximum exposures will be quantitatively evaluated. Evaluation of receptor risks at these exposure points will bound the risks for receptors at other exposure points not selected for quantitative evaluation. The following exposure points were selected based on reasonable maximum estimates of risk. The exposure point locations are shown in Figure 2-1.

Current Scenario

- Onsite worker. Present landfill worker within the boundary of OU7.

- Residential receptor. Nearest residence to RFP (located at the southeastern corner of the RFP property boundary) and nearest residence in the predominant wind direction.

Future Scenario

- Occupational receptor. Hypothetical onsite worker within the boundary of OU7.
- Ecological researcher. Hypothetical onsite ecological researcher within the boundary of OU7.
- Residential receptor. Hypothetical onsite resident within the boundary of OU7.

Exposure pathways to be quantitatively evaluated in the HHRA are identified in the Conceptual Site Model (CSM) (Figure 2-2). As noted in the Exposure Assessment Technical Memorandum, the nature and extent of contamination in surface water and groundwater will not be investigated until the Phase II RFI/RI. Therefore, this Technical Memorandum addresses only direct and upward exposure pathways. Potential downward pathways are shown in the CSM in order to put the current scope of analysis in context with the overall remediation.

The CSM is a schematic representation of the chemical source areas, chemical release mechanisms, environmental transport media, potential human intake routes, and potential human receptors. The purpose of the CSM is to provide a framework for problem definition, identify exposure pathways that may result in human health risks, indicate data gaps, and aid in identifying appropriate remediation measures. Chemical release mechanisms, environmental transport media, and potential human intake routes to the contaminated site soil were identified for each potentially exposed receptor.

In the CSM, potentially complete and relatively significant exposure pathways are designated by an "S". Potentially complete and relatively insignificant exposure pathways are designated by an "I". Both potentially complete and relatively significant exposure pathways and relatively insignificant exposure pathways will be quantitatively addressed in the risk assessment. Quantitatively addressing potentially complete and relatively insignificant exposure pathways will provide for the risk estimates that do not underestimate actual risks.

A summary of potentially complete exposure pathways that will be quantitatively evaluated in the baseline human health risk assessment is provided in Table 2-1. Exposure pathways that will require fate and transport include soil gas and air as transport media to exposure points.

Primary release mechanisms involving volatilization and wind suspension are illustrated in Figure 2-3. Volatile organic compounds (VOCs) may be transported through the vadose zone from underlying soils and landfill waste and will be subsequently entrapped within a hypothetical building or residence located on top of OU7 or released to the ambient (outdoor) air. Chemicals in surface soils may be transported via fugitive dust emissions from OU7 to onsite (inhalation of particulates by the hypothetical future onsite resident, worker, or ecological researcher) and offsite exposure points (inhalation of particulates by current residents). Fugitive dust emissions from OU7 may also result in the deposition of chemicals (in airborne particulates) on surface soils and plants. Potential chemical intake and corresponding risks associated with these media will also be evaluated. Primary release mechanisms involving vegetable/plant uptake and direct contact are illustrated in Figure 2-4 and result in exposures to hypothetical future onsite receptors (onsite resident, worker, or ecological researcher).

Table 2-1 - Rocky Flats Plant OU7 Potentially Complete Exposure Pathways to be Quantitatively Evaluated

Potentially Exposed Receptor	Scenario	Potentially Complete Exposure Pathways
Onsite worker	Current	Inhalation of airborne particulates Inhalation of outdoor VOCs Incidental soil ingestion Direct dermal contact with surface soil Groundshine (direct contact)
Offsite resident	Current	Inhalation of airborne particulates Inhalation of outdoor VOCs Soil ingestion (following deposition of particulates) Dermal contact with surface soil (following deposition of particulates) Ingestion of vegetables (following deposition of particulates)
Hypothetical onsite worker	Future	Inhalation of indoor and outdoor VOCs Inhalation of airborne particulates Incidental soil ingestion Dermal contact with soil Groundshine (direct contact)
Hypothetical onsite ecological researcher	Future	Inhalation of particulates Inhalation of outdoor VOCs Incidental soil ingestion Direct dermal contact with surface soil Groundshine (direct contact)
Hypothetical onsite resident	Future	Inhalation of airborne particulates Inhalation of indoor and outdoor VOCs Ingestion of vegetables (surface deposition of particulates and root uptake) Incidental soil ingestion Direct dermal contact with surface soil Groundshine (direct contact)

3.0 FATE AND TRANSPORT MODEL DESCRIPTIONS AND SELECTION

This section specifies the models to be used in characterizing and predicting exposure point concentrations at specific receptor locations for the OU7 risk assessment. The considerations for model selection and the basis for selecting the chosen models are also discussed.

The term "model" refers to computer codes or a set of equations that can be used to mathematically represent site conditions and simulate media behavior (e.g., gas generation and flow) and contaminant fate and transport in the model domain. The models will incorporate site-specific data to allow simulation of site-specific conditions and behavior. The combination of a computer code and the necessary site-specific data will be referred to as a "site-specific model."

3.1 General Considerations for Model Selection

According to Anderson and Woessner (1992) and EPA (1986), the following general issues should be considered when selecting models for simulating conditions at a site: (1) the objectives of the project, (2) the physical and chemical conditions or meteorological and topographical complexities of the site, (3) the resources and requirements for implementing the models, (4) the level of detail and accurancy of supporting data, and (5) the presentation of modeling design and results.

The OU7 modeling objectives (Issue No. 1) are to simulate the transport of contaminants of concern for risk assessment purposes and to support the evaluation of remedial alternatives for the Corrective Measures Study/Feasibility Study. The physical and chemical conditions of the site (Issue No. 2) have been and are continuing to be characterized as part of the ongoing RFI/RI process. Models should also be capable of accurately representing the transport characteristics, including the meteorological and topographical conditions or the variability of media properties at the site as defined by the RFI/RI. Requirements for implementing the models (Issue No. 3) include the following: (a) the availability of the model, (b) the degree and nature of documentation, (c) the extent of peer review of the model, (d) the difficulity of the application and associated level of expertise and work effort required and (e) the nature of model verification and testing (model verification is the process of verifying that the model results are numerically correct and involves an independent check of the calculations performed by the model). A model that requires detailed, precise input data (Issue No. 4) should not be used when such data are limited; however, assuming detailed data are available, the greater the detail that the model considers spatial and temporal variations, the greater the ability to evaluate impacts and control strategies. Clear presentation of modeling design and results (Issue No. 5) is also essential for effective communication of the modeling effort and permits modifications to the conceptual site model or changes in model parameters, as necessary.

Based on the issues described above, a set of criteria was developed for selecting the models to be used at OU7. The general criteria are as follows:

1) The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.
2) The selected models should be able to satisfy the objectives of the study.
3) The selected models should be verified using published equations and solutions.
4) The selected models should be complete, well-documented, and preferably available in the public domain.
5) The selected models should be practical, efficient, and cost-effective in terms of actual application, presentation, and resolution of uncertainty.

These five criteria were used as the basis for selecting gas volatilization and air dispersion/transport models to be used for OU7. The following sections discuss the selected models relative to their ability to satisfy the identified selection criteria.

3.2 Present Landfill (IHSS 114) Gas Generation and Transport Model

The factors affecting landfill-gas generation rates (refuse composition and age, pH, moisture content, temperature, and quantity and quality of nutrients) and transport mechanisms (diffusion, convection, and displacement) have been evaluated by extensive research. The principal gases (by volume) generated by landfills are methane and carbon dioxide. Landfill gas consists of approximately 50 percent, by volume, of these two gases. These gases are produced by the anaerobic microbial degradation of organic matter within the landfill. Empirical evidence indicates that, in general, a landfill's gas generation rate reaches a peak a few years after final emplacement of waste and then decreases exponentially as the fraction of organic matter in the landfill declines.

Research by Thibodeaux (1981) indicates that the migration and subsequent release of vapors to the atmosphere is dominantly controlled by the upward convection of gas generated during this microbial degradation of refuse. Convective, or pressure-driven, migration of landfill-generated gas is usually so dominant that gas-phase diffusion and displacement processes become insignificant (Thibodeaux 1981 and EPA 1991a). Landfill gases (i.e., methane and carbon dioxide) generated by methanogens act as a stripping (transport) gas for nonmethane organic compounds (NMOCs) that may be present at trace concentrations within the landfill (EPA 1991a).

3.2.1 Introduction to Model

The LANDFIL2 model, recently published by the EPA (EPA 1991b), will be used to simulate internal gas generation by landfill wastes within IHSS 114 and subsequent pressure-driven transport of gases. The model will consider gas transport through an overlying permeable soil cover to either the ground surface or to just beneath a hypothetical onsite building. Modeling of landfill-generated gas transport through the floor of an onsite building is discussed below. The air transport/dispersion model that will be used to estimate airborne gas concentrations at the ground surface is discussed in Section 3.4. These activities will support and provide input to a Human Health Risk Assessment.

The LANDFIL2 model is based on the Scholl Canyon Gas Generation Model used by the EPA to develop regulations for landfill air emissions in accordance with Sections 111(b) and 111(d) of the Clean Air Act (CAA) (42 U.S.C. 1857 et seq). The Scholl Canyon Gas Generation Model uses a first-order decay equation that incorporates site-specific characteristics for estimating the time-dependant, internal, gas generation rate in a landfill. In the absence of site-specific data, the program provides reasonable default values taken from the soon-to-be proposed (EPA 1991b) New Source Performance Standard and Emission Guidelines for Municipal Solid Waste Landfill Air Emissions.

The Scholl Canyon model assumes that the gas production rate is at its peak upon initial waste placement, after a negligible lag time during which anaerobic conditions are established in the landfill. However, if desired, the lag time during which anaerobic conditions are established can be incorporated into the Scholl Canyon model. Typical lag times range from 200 days to several years depending on the landfill conditions (Pohland 1986). The gas production rate is then assumed to decrease exponentially (first order decay) as the organic fraction of the landfill refuse decreases. The Scholl Canyon model can be refined further by dividing the landfill into smaller submasses to account for different ages of the refuse accumulated over time. As suggested by the EPA (1991b), a convenient submass for computational purposes is the amount of refuse accumulated in one year. The total methane generation from the entire landfill is the sum of each submass' contribution.

Landfill gas also contains trace levels of NMOC. Once the LANDFIL2 model estimates the gas generation flowrate, the NMOC emission rate is calculated using either site-specific NMOC concentrations or default NMOC concentrations in the model. Default NMOC concentrations in LANDFIL2 are based on emission test reports from industry, state, and local regulatory agencies including the South Coast Air Quality Management District (SCAQMD).

Darcy's law, modified for pressure-dependent gas flow across a permable structure wall, will be used to estimate the volumetric flow rate of landfill emissions through the floor of an onsite building into the building confines. This volumetric flow rate is estimated by:

$$Q_{vol} = -kv\ A/v\ (dP/dZ)$$

where Q_{vol} = volumetric flow rate induced by landfill emissions and ambient air
kv = intrinsic permeability of building material
A = area of the building floor
v = viscosity of the gas
dP = pressure differential across floor of structure
dZ = thickness of floor

3.2.2 Model Selection Criteria Evaluation

The LANDFIL2 model was selected because it best satisfies the selection criteria defined in Section 3.1.

Selection Criterion 1 -- The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

The LANDFIL2 model is capable of representing key landfill gas generation and transport processes. The model, based on the Scholl Canyon Gas Generation model, uses a first-order decay equation that incorporates site-specific characteristics for estimating the time-dependant, internal, gas generation rate in a landfill. The number of years that the landfill was in operation and the number of years since closure are included in the LANDFIL2 model. Therefore, the model is capable of simulating observed changes in the gas generation rate following closure.

Upward convection of landfill-generated gases and associated nonmethane organic compounds is the key gas transport process in the LANDFIL2 model. In addition, the LANDFIL2 model allows input of site-specific NMOC concentrations that will be obtained during implementation of the Phase I RFI/RI for OU7. Therefore, estimated surface emissions are expected to sufficiently represent generation and transport of methane, carbon dioxide, and NMOCs from the landfilled wastes.

Selection Criterion 2 -- The selected models should be able to satisfy the objectives of the study.

The LANDFIL2 model satisfies the objectives of the study by predicting the ground surface emission rates of landfill-generated gases and associated NMOCs. The resulting emission rates can then be input into a modified Darcy's equation or an air-dispersion model to estimate the gas concentrations at exposure points. These estimates can be made for both the onsite and offsite receptors considered in the risk assessment exposure scenarios.

The emission estimates derived from LANDFIL2 are directly proportional to air contaminant concentrations and can be used to evaluate potential remediation strategies. For example, the effectiveness of a remedial alternative that exposes a source of landfill gas to air exposure routes can be evaluated.

Selection Criteria 3 and 4 -- The selected models should be verified using published equations and solutions. The selected models should be complete, well-documented, and preferably in the public domain.

The LANDFIL2 model for generation and transport of landfill gases is used by the EPA to develop landfill air emissions regulations that comply with Sections 111(b) and 111(d) of the Clean Air Act (CAA) (42 U.S. 1857 et seq). The LANDFIL2 model is based on published equations and the Scholl Canyon Gas Generation Model. The Scholl Canyon model has been subject to extensive validation based on data from over 1,000 landfills in the United States (EPA 1991b). This document also presents a detailed discusstion of the assumptions, capabilities, and application of the LANDFIL2 model.

Selection Criterion 5 -- The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

Although several other models are available for estimating the gas generation rate from a landfill, the Scholl Canyon model "is the most simplistic model... and yields comparable results to the other models, if comparable input values are used " (EPA 1991a and b). Since this model is public domain, there are no procurement or licensing costs for its use.

3.3 Soil Gas Transport Model

The LANDFIL2 model discussed in Section 3.2 will estimate the pressure-driven emission rates for landfill gases. Emissions of volatile gases can also occur by diffusive transport of gases derived from soil contaminants. For example, at IHSS 203, where no gas-generating landfill refuse is present at the subsurface, gas transport may occur by diffusion, not by convection or pressure-driven transport. Therefore, a diffusion model for soil gas transport maybe required to estimate volatile emission rates at IHSS 203 should contamination be identified.

VOCs may be transported through the vadose zone from underlying soils and subsequently entrapped within a hypothetical building or residence located on IHSS 203 or other areas where soil contamination may be identified. Potential chemical intakes resulting from soil gas transport must be evaluated. The diffusive transport of gases originating from contaminated soils is controlled by the physical properties of the soil cover (thickness, porosity, intrinsic permeability), and the chemical characteristics of the compounds present (partition coefficients, vapor diffusion coefficients).

3.3.1 Introduction to Model

Soil-gas transport modeling will be performed to simulate the diffusion of VOCs from underlying soil gas to a level just beneath a hypothetical onsite building. Soil gas migration through the floor of an onsite building will be estimated using the modified Darcy's equation described in Section 3.2.1. An air transport and dispersion model, discussed in Section 3.4, will then be used to estimate airborne VOC concentrations within the building. These activities will support and provide input to a HHRA.

Estimates of volatile releases will be provided by utilization of the Shen Model, modified by Farino et al. (1983), from Volume II of the Air Pathway Analysis series published by the EPA (1990). This model is also referred to as the SEAM model, since it is also documented in the Superfund Exposure Assessment Manual (SEAM) (EPA 1988a). This equation is designed for estimating volatilization from underlying soil and groundwater contamination and the subsequent diffusion of organic vapors to the surface. This equation has been applied in numerous site investigations and has been validated enough to warrant inclusion in published EPA documents.

The equation used to estimate the steady-state VOC emission rate is as follows:

$$E_i = (AD_i/L)(P_t^{4/3})(C_i)(M_i)$$

where
- E_i = emission rate of the contaminant, i, (g/sec)
- A = surface area (cm^2)
- D_i = vapor diffusion coefficient in air (cm^2/sec)
- L = surface cap thickness (cm)
- P_t = total porosity of the soil cap (cm^3/cm^3)
- C_i = saturated vapor concentration of contaminant, i, in the vapor space beneath the surface soil cap (g/cm^3)
- M_i = mole fraction of contaminant, i, in the waste

3.3.2 Model Selection Criteria Evaluation

The SEAM model was selected because it best satisfies the selection criteria defined in Section 3.1.

Selection Criterion 1 -- The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

The SEAM model is capable of representing key contaminant processes in estimating soil gas transport. The key processes in the SEAM model include treatment of soil gas diffusion to the surface as a result of underlying soil and groundwater contamination. The model allows calculation of volatilization of specific components of a complete waste mixture by assuming that Raoult's Law is applicable. A layer of relatively clean and dry soil is assumed to exist between the soil surface and the primary area of underlying soil contamination. The SEAM model assumes that surface VOC emissions are steady-state and do not decay with time. This assumption is consistent with observations at other sites that underlying areas of soil contamination produce surface VOC emissions at a steady rate for an extended period of time.

Examination of onsite data suggests that volatilization as a result of soil gas transport will primarily originate from underlying soil contamination areas closest to the ground surface. Contributions of contaminants from deeper soil and groundwater will be relatively insignificant. Estimated surface VOC emissions are thus expected to sufficiently represent volatilization of soil and groundwater contaminants from all underlying areas.

Selection Criterion 2 -- The selected models should be able to satisfy the objectives of the study.

The SEAM model estimates surface volatilization from underlying soil gas with consideration of physical and chemical mechanisms. The resulting emission estimates can then be applied to the estimation of exposure point concentrations for future onsite workers.

Emissions estimates, derived from the SEAM model, are directly proportional to air contaminant concentration and can be used to evaluate of potential remediation strategies. In addition, the effectiveness of potential remediation strategies can be related to underlying soil concentrations since this soil gas transport model estimates VOC emissions in direct proportion to underlying soil will not be used in landfill concentrations.

Selection Criteria 3 and 4 -- The selected models should be verified using published equations and solutions. The selected models should be complete, well-documented, and preferably in the public domain.

The SEAM model for soil gas transport is widely accepted and well documented in EPA literature for use in baseline, remedial, and post-remedial scenarios. The SEAM model has refined the widely used Farmer model, which was one of the first models developed and used to predict VOC emissions from covered landfills. The soil gas transport models appearing in the air pathway analysis series have been subject to extensive validation.

Selection Criterion 5 -- The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

This soil gas transport model thoroughly documents the proper use of input parameters and demonstrates their use through simulated soil gas transport scenarios. Thus, this model can be easily placed into a spreadsheet format to handle multiple VOCs. Since this model is public domain, there are no procurement or licensing costs for its use.

3.4 Air Transport and Dispersion Models

Air dispersion models simulate the transport of emissions estimated from the landfill gas and soil gas transport models and wind suspended particulate matter to specific exposure points. Transport scenarios to be evaluated include:

- The transport of vapor into a building or residence located on the surface of OU7
- The transport of vapor or particulate matter to onsite receptors (e.g., hypothetical future worker) both as air contaminant concentrations and particulate deposition values
- The transport of vapor or particulate matter to offsite receptors (e.g., current offsite resident) both as air contaminant concentrations and particulate deposition values

The air contaminant concentration and deposition values calculated by the air transport model will support and provide input the HHRA. Calculation of vapor concentration within structures will be performed using conventional box model methodologies by assigning an appropriate fixed volume and exchange rate. Selection of a model for the transport of vapor or particulate matter for other exposure scenarios is discussed below.

3.4.1 Introduction to Model

The Fugitive Dust Model (FDM) (EPA 1988b) will be used to evaluate air transport and dispersion. FDM is a computerized air quality model specifically designed for computing concentration and deposition impacts from fugitive dust sources. The sources may be point, line, or area sources. The model has not been designed to compute the impacts of buoyant point sources, thus it contains no plume rise algorithm. The model is generally based on the Gaussian plume formulation for computing airborne concentrations; however, it has been adapted to incorporate a gradient transfer deposition algorithm. Emissions for each source may be broken into 20 particle size classes and each particle size class has a gravitational settling velocity and a deposition velocity specified for it.

The model is designed to work with pre-processed meteorological data or with card-images of meteorological data in either hourly or STability ARray (STAR) format. The STAR data specifies the frequencty of each combination of wind direction, speed class, and atmospheric stability category. Three emission source types are modeled. The line source algorithm is based on the CALINES line source routine. Area sources are modeled as a series of line sources perpendicular to the wind direction.

3.4.2 Model Selection Criteria Evaluation

FDM was selected as the most appropriate model to estimate transport and dispersion of airborne contaminants to onsite and offsite receptors. This model is believed to best satisfy the selection criteria presented in Section 3.1. FDM will be used to model transport of airborne vapor and particulate matter, both as air contaminant concentrations and as particulate deposition values. A discussion of how the air transport model meets each of the selection criteria is presented below.

Selection Criterion 1 - The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.

The FDM air model is capable of representing key contaminant processes in estimating air transport and dispersion of air emissions originating from OU7. OU7 emissions are primarily ground-level area sources. FDM has been demonstrated (EPA 1988b) to provide superior airborne concentration predictions for this emission source category. Additionally, FDM incorporates an advanced deposition algorithm that is applicable to wind suspended particulate sources from OU7. While the model does not have plume rise algorithms for point sources, elevated point sources are not primary emission sources for OU7.

FDM uses accepted Gaussian plume transport and dispersion algorithms with a gradient-transfer deposition and settling algorithm to simulate air contaminant concentration and deposition values from non-point sources at distances corresponding to either onsite or offsite receptors.

FDM was specifically developed for fugitive dust modeling applications (especially wind erosion). FDM has the capability of assessing up to 100 area sources, 200 receptor points, and 20 particle size classes. FDM is unique in that it can assess rectangularly shaped area sources, not just square or circular. Additionally, the area sources can be oriented at any angle to north. FDM can also utilize constant as well as variable emission rates. For vapor calculations, FDM reduces to standard Gaussian vapor dispersion equations by setting the settling and deposition functions to zero. FDM also has short (1-, 3-, 8-, and 24-hour) and long (annual) term averaging period modeling capabilities and uses meteorological data in either hourly or STability ARray (STAR) formats.

When using AP-42 (EPA 1985) emission models for fugitive particulate emission estimation, the FDM model is not required to apply correction factors to account for varying types of land surfaces. However, the FDM will allow for direct computation of the contaminant emission rate as a function of the wind speed or allow the user to input a constant emission rate. In this way, the model can assess short-term and long-term impacts.

The FDM model uses a convergent integration of line sources methodology in its calculation of area source concentrations. A default five-line integration is initially performed to estimate receptor airborne concentrations. Subsequent calculations are performed, with the area source further divided into line sources (a maximum of 901 lines), until airborne concentration results are less than one percent different at all receptors from the previous iteration. This procedure insures accuracy for receptor concentrations very close to a source or within an area source. Consequently, the model allows for the evaluation of both onsite and offsite exposure points.

Selection Criterion 2 - The selected models should be able to satisfy the objectives of the study.

Output from the FDM model either as air contaminant concentrations or as deposition values at the designated exposure points will provide input for the assessment of health risks. The ability of the model to simulate the transport and dispersion of vapor and particulate forms supports the objective of the modeling effort.

The multiple compounds potentially identified as Contaminants of Concern (COCs) are anticipated to be easily handled by the selected air dispersion model through a multiplicative factor (the ratio of a specific compound source term to a unit emission rate) that is multiplied by the estimated ambient impacts from a unit emission rate (i.e., because of the linear relationship of air concentration to input emission rate). In addition, FDM models can be used to evaluate the effectiveness of potential remediation strategies by simply varying the source term as a function of the remediation strategy being examined.

Selection Criterion 3 and 4 - The selected models should be verified using published equations and solutions. The selected models should be complete and well documented and preferably available in the public domain.

The FDM model utilizes accepted Gaussian dispersion methodologies and an advanced deposition algorithm. FDM is accepted by EPA for air quality modeling and has been validated as documented in the user guide for the model (EPA 1988b).

Selection Criterion 5 - The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

The FDM model is within the public domain and is readily available. Consequently, it does not require special procurement or licensing costs and its use is well-documented. Additionally, the model is designed to execute on PC-compatible computers and support for its use is readily available.

3.5 Summary of Parameter Values

This section presents a summary of the data currently available to estimate model parameter values for landfill gas emission, soil gas transport, and air transport and dispersion modeling. Where available, site-specific data collected during the Phase I and II RFI/RI investigations or earlier studies will be used. If site-specific data are not available, appropriate near-site data in published literature values will be used in the modeling activities. At present, only a portion of the Phase II RFI/RI soil and groundwater data are available. Additional site-specific data from the Phase II RFI/RI will be utilized once those data become available.

Tables 3-1, 3-2, and 3-3 present a summary of data currently available to estimate model parameters. The available data were compiled based on a review of previous investigations and the data currently available from the Phase I RFI/RI, or general literature. In the case of chemical parameter values, development of the list of COCs has not been completed at this time. Therefore, it is not possible to summarize chemical parameter data for each of the COCs at this time. Chemical parameter data will be compiled following EPA approval of the COC technical memorandum.

The data presented in Tables 3-1, 3-2, and 3-3 are preliminary and, in some cases, are not site-specific. The data values or ranges of values are not intended to be fixed. The ranges are presented to convey what is currently known of the variability in parameter values that may be used in the models.

Table 3-1 - Parameter Values for Landfill Gas Emission Modeling

Parameter	Units	Range of Values	Source
Surface Area of IHSS	m^2	1.56×10^5	Phase I RFI/RI Work Plan for OU7
Potential Methans Generation Capacity of landfill material	m^3/Mg	6.2 - 270.1	(EPA, 1991 a and b)
Methane Generation Rate Constant	1/yr	0.003 - 0.21	(EPA, 1991 a and b)
Average Annual Waste Acceptance Rate during Active Life	Mg/yr	7000 - 15,000	Phase I RFI/RI Workplan (EG&G, 1991b)
Time since landfill closure/emplacement of interim soil cover	yr	1992	Phase I RFI/RI Work Plan (EG&G, 1991b)
Time of inital refuse placement	yr	1968	Phase I RFI/RI Work Plan (EG&G, 1991b)

Table 3-2 - Parameter Values for Soil Gas Transport Modeling at OU7

Parameter	Units	Range of Values [a]	Source
Surface Area of IHSS 203 [(b)]	m^2	2090	Preliminary Phase I RFI/RI field data
Surface Soil Cover Thickness	m	1-3	Personal communications with EG&G Waste Operations personnel and data obtained during Phase I RFI/RI
Soil Cover Air-filled Porosity	%	25-35	Based on RFP OU-specific and sitewide data from RFEDS database
Vapor Diffisuion Coeff. in Air	cm^2/sec	10^{-2}-10^{-1}	Compound-specific; SEAM or Lyman
Thickness of contaminated soil	m	0.5 - 1	Based on OU7 Phase I RFI/RI data
Weight fraction of contaminant in soil	g/g	[b]	Based on OU7 Phase I RFI/RI data
Intrinsic permeability of soil	cm^2	10^{-9}-10^{-7}	Based on RFP OU-specific and sitewide data

[a] Range of values may be refined with OU7 site-specific Phase I results when available.
[b] The presence or absence of contamination in soil at IHSS 203 or other areas within OU7 is not known at the this time and will be determined during the Phase I RFI/RI.

Table 3-3 - Parameter Values for Air Transport and Dispersion Modeling

Parameter	Units	Range of Values	Source
Joint frequency distribution of stability class, wind speed and direction	Unit-less	fraction of one; total sum of all entries is one	RFP Site Environmental Report for 1990
Mean annual morning and afternoon mixing heights	m	250-4000	Data for Denver, Colorado from Holzwork (1972)
Particle size	μm	1-80	RFP OU-specific (Phase I RFI/RI) and sitewide data from RFEDS database
Particle size distribution	Unit-less	fraction of one; total sum of all entries is one	RFP OU-specific (Phase I RFI/RI) and sitewide data from RFEDS database
Contaminated area (surface dimensions)	m^2	10^1 - 10^3	OU7 boundaries and IHSS dimensions
Ground Coverage (unvegetated area) observations	%	0-100	Aerial photos; onsite
Receptor locations, elevation above source, distance from source	m	1-10^3	Scaled maps of area of study
Surface roughness	cm	1-100	Site observations correlated with documented criteria on assigning appropriate surface roughness value

4.0 SUMMARY

In order to model the fate and transport of contaminants at OU7 to specific exposure point locations for the HHRA, several models have been evaluated for application to modeling landfill gas emissions, soil gas transport, and airborne transport of wind suspended particulates and gases. Model selection was based on the following five criteria:

1) The selected models should be able to incorporate key processes and accurately represent conditions known to occur at the site.
2) The selected models should be able to satisfy the objectives of the study.
3) The selected models should be verified using published equations and solutions.
4) The selected models should be complete, well-documented, and preferably available in the public domain.
5) The selected models should be practical and cost-effective in terms of actual application as well as resolution of uncertainty.

The following models were selected to meet the requirements of the modeling study:

- The LANDFIL2 model for landfill gas transport.

- The SEAM model for soil gas transport.

- FDM for onsite and offsite ambient air contaminant fate and transport of OU7 source air emissions.

Data currently available for use as input for the modeling activities were evaluated. Tables 3-1, 3-2, and 3-3 summarize the data currently available to estimate model parameters. Additional data from the Phase II RFI/RI may also be used in the modeling effort once those data become available.

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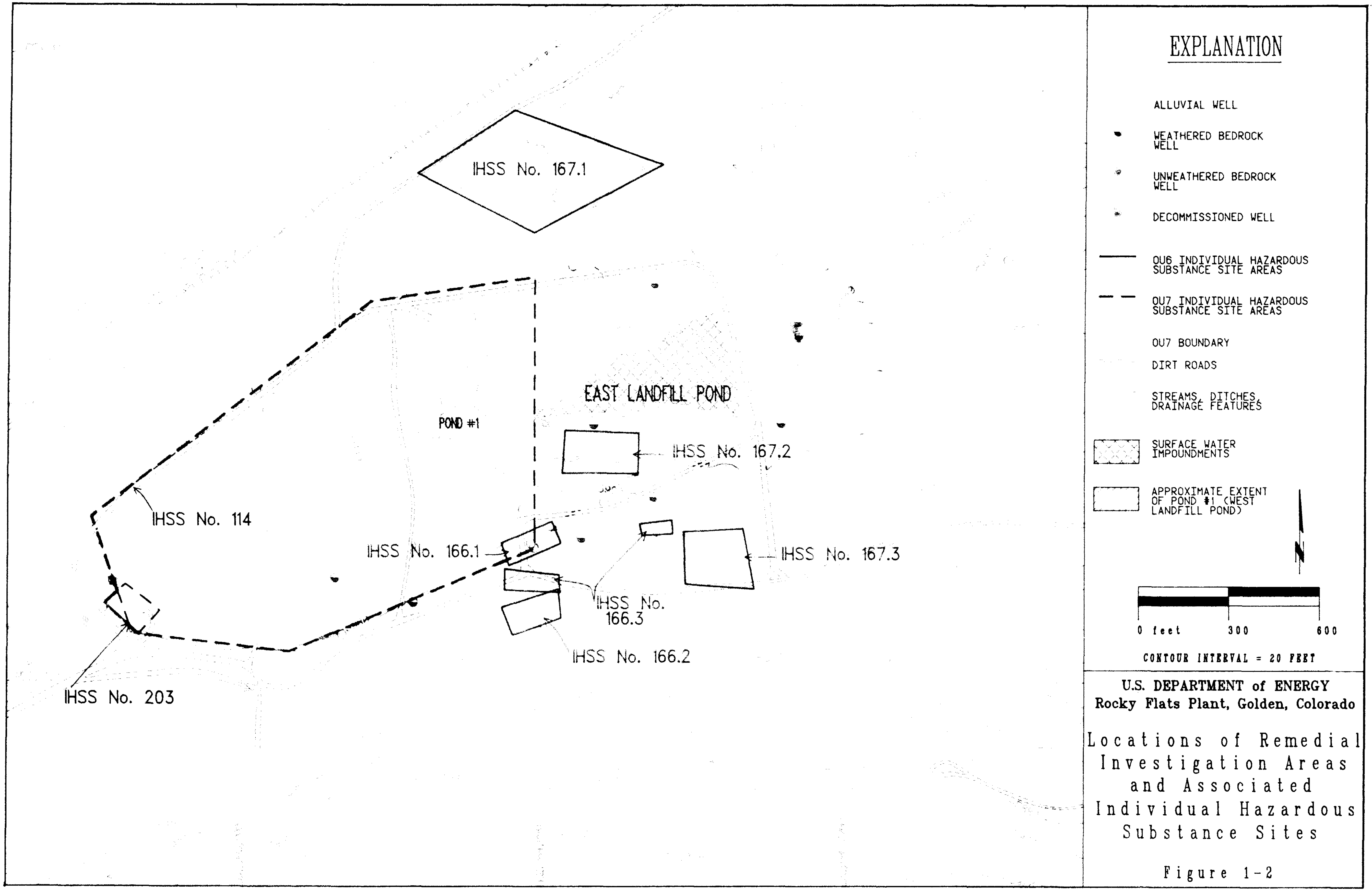

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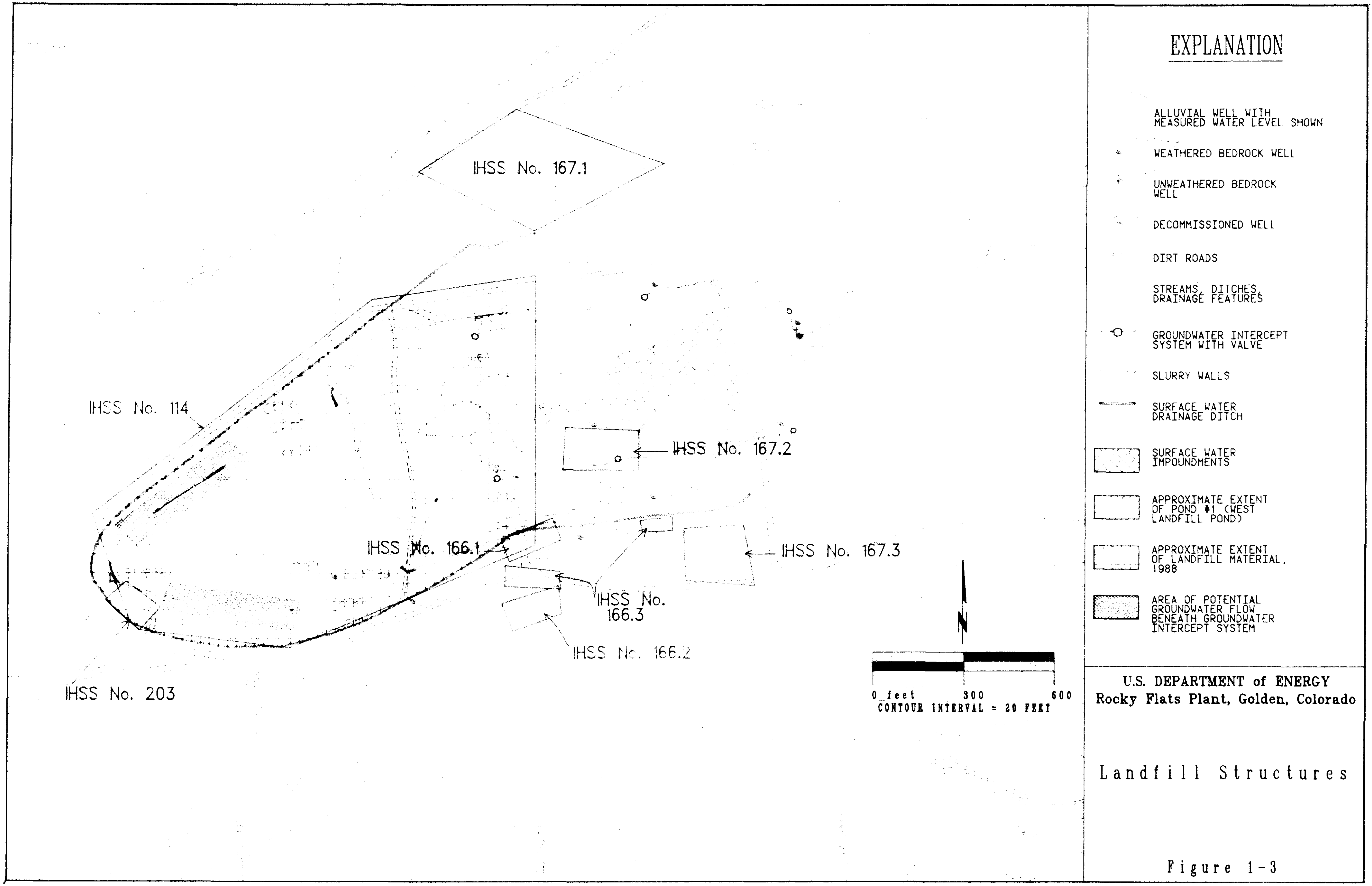
Rocky Flats Plant, Golden, Colorado

Locations of Remedial Investigation Areas and Associated Individual Hazardous Substance Sites

Figure 1-2



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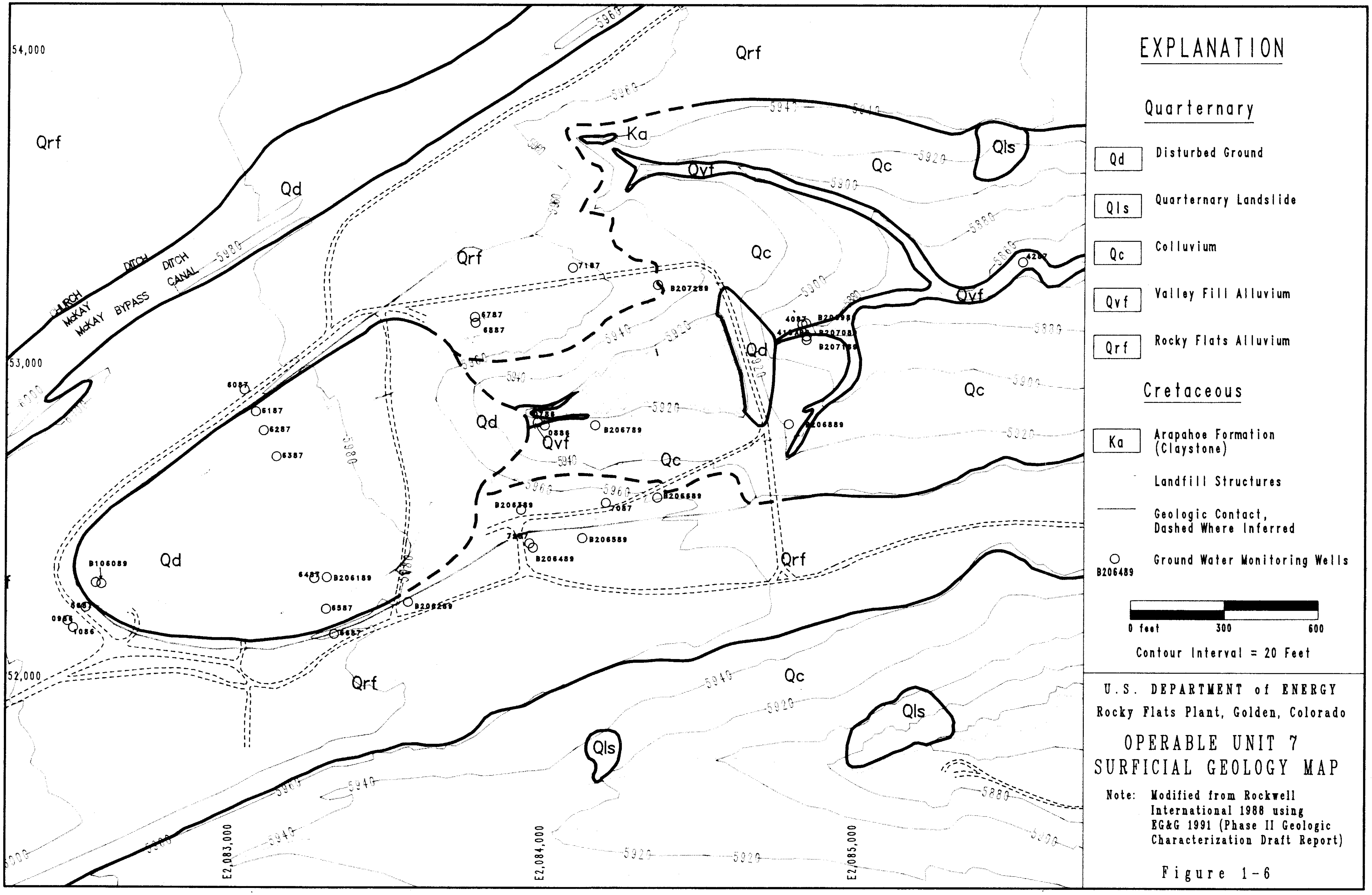
Landfill Structures

Figure 1-3


EXPLANATION
Quarternary
Qd Disturbed Ground
Qls Quarternary Landslide
Qc Colluvium
Qvf Valley Fill Alluvium
Qrf Rocky Flats Alluvium
Cretaceous
Ka Arapahoe Formation (Claystone)
Landfill Structures
Geologic Contact, Dashed Where Inferred
Ground Water Monitoring Wells
B206489
0 feet 300 600
Contour Interval = 20 Feet
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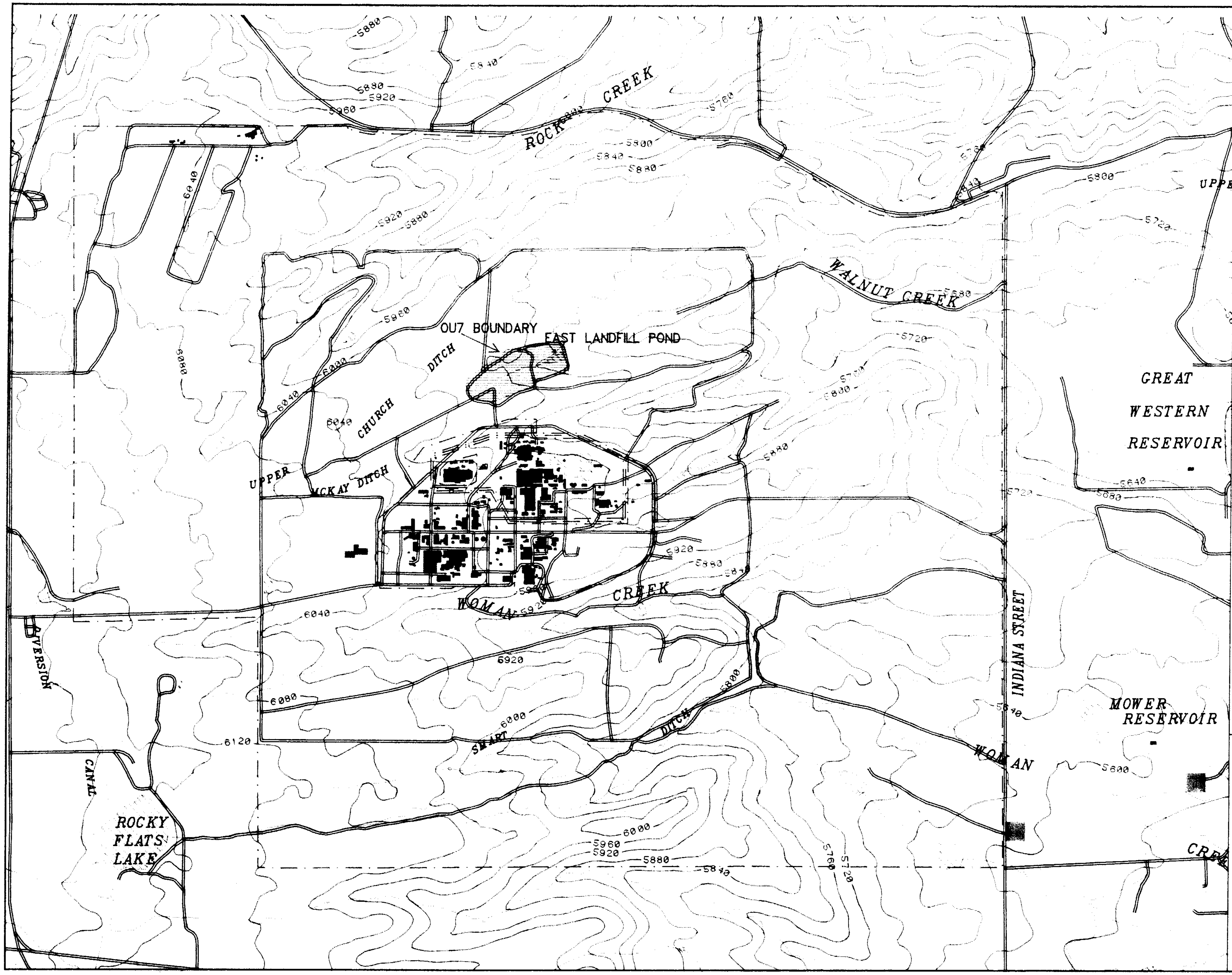
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT 7
SURFICIAL GEOLOGY MAP
Note: Modified from Rockwell International 1988 using EG&G 1991 (Phase II Geologic Characterization Draft Report)
Figure 1-6
McKAY BYPASS CANAL
CHURCH McKAY DITCH
DITCH
54,000
53,000
52,000
E2,083,000
E2,084,000
E2,085,000



EXPLANATION

EXPOSURE POINT FOR CURRENT RESIDENTS

ASSUMED EXPOSURE AREA FOR:
- CURRENT WORKER
- FUTURE RESIDENT
- FUTURE WORKER
- FUTURE ECOLOGICAL RESEARCHER

0 FEET 2200 4400

Contour interval = 40 feet

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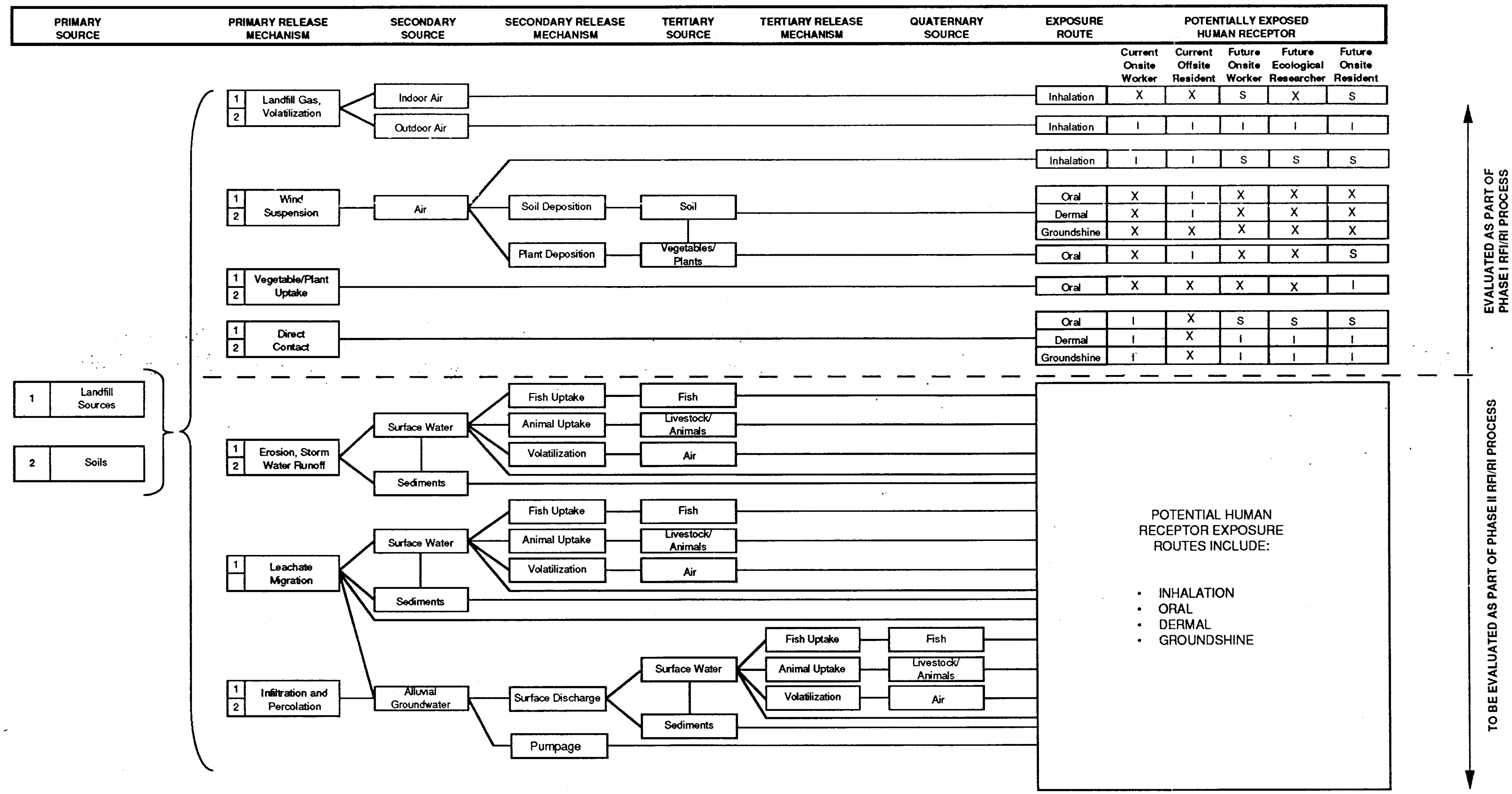
Receptor Locations

Figure 2-1



Legend

S Significant Potential Exposure Pathway (Conceivable and Relatively More Important)
I Insignificant Potential Exposure Pathway (Conceivable, Though Not As Important)
X Negligible and/or Incomplete Exposure Pathway (Unlikely to Occur)

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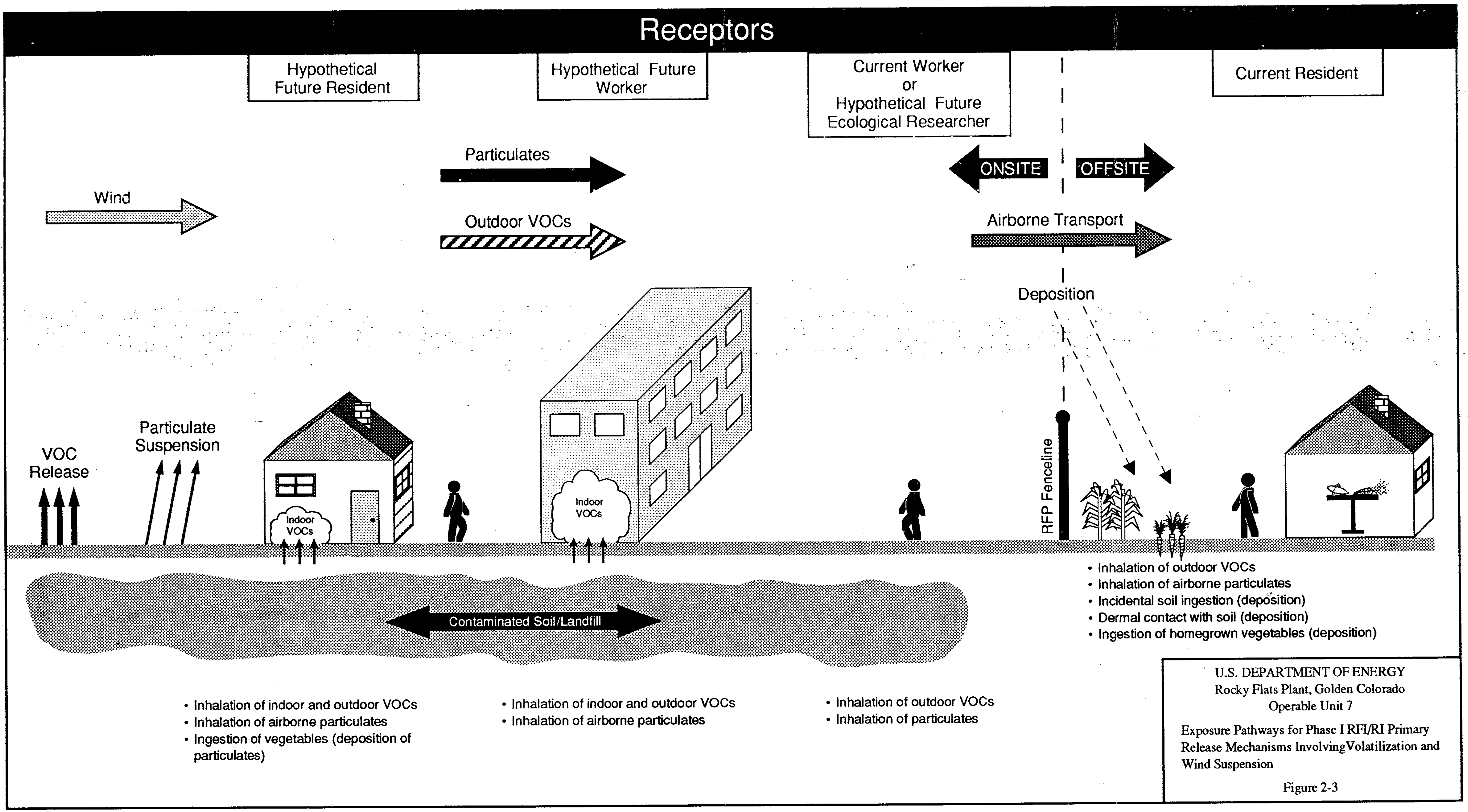
Rocky Flats Plant, Golden, Colorado
OPERABLE UNIT 7
PHASE I RFI/RI EXPOSURE ASSESSMENT
Figure 2-2 Conceptual Site Model

M65W\WM\EXPOSURE PATHWAYS.MDW/1/14/93



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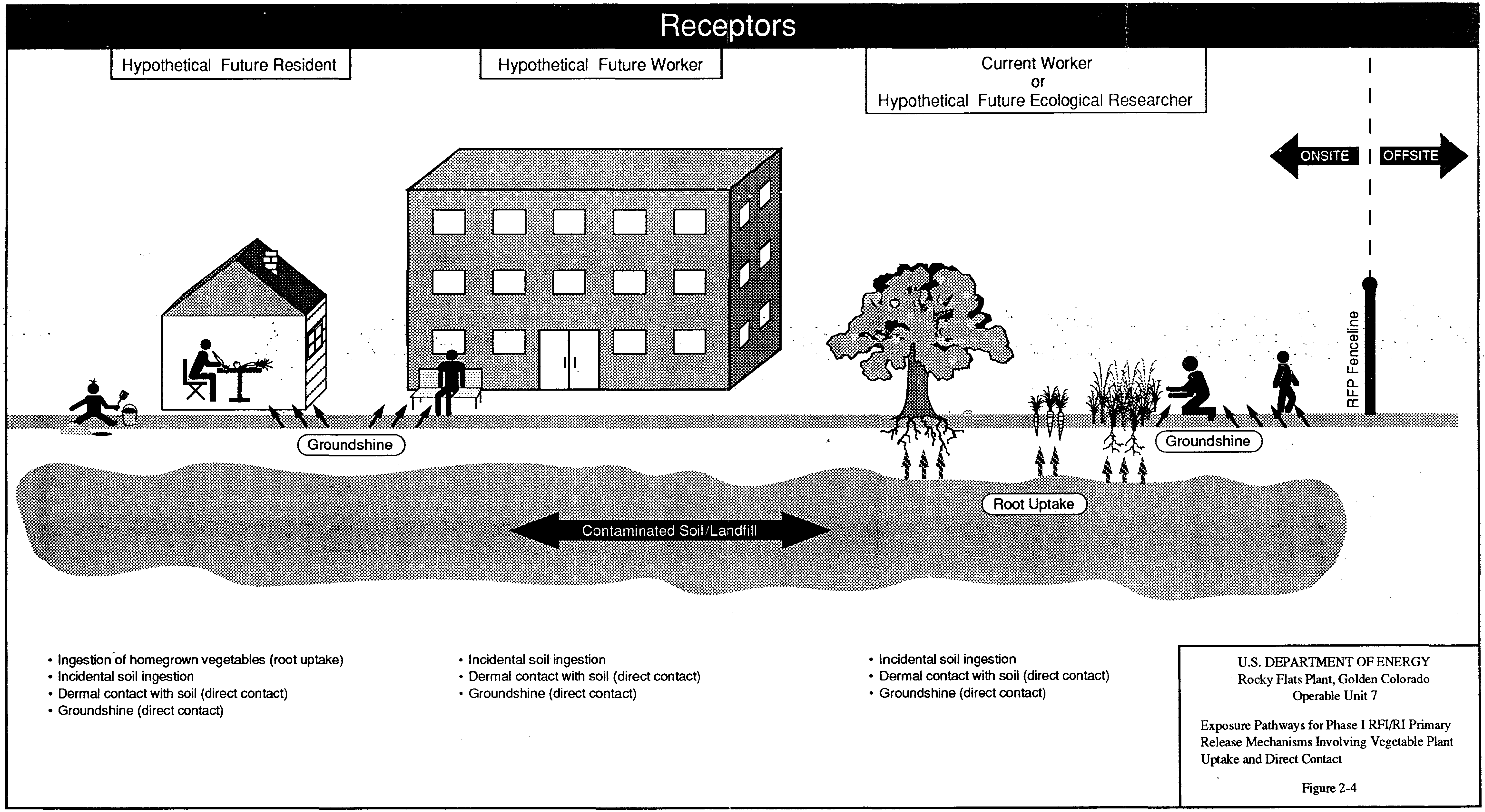
Rocky Flats Plant, Golden Colorado
Operable Unit 7

Exposure Pathways for Phase I RFI/RI Primary Release Mechanisms Involving Volatilization and Wind Suspension

Figure 2-3



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Rocky Flats Plant, Golden Colorado
Operable Unit 7

Exposure Pathways for Phase I RFI/RI Primary Release Mechanisms Involving Vegetable Plant Uptake and Direct Contact

Figure 2-4