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Preliminary Site Characterization Report Rulison Site, Colorado

August 1996

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PRELIMINARY SITE CHARACTERIZATION REPORT RULISON SITE, COLORADO

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August 1996

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Abstract

This report is a summary of environmental information gathered during a review of the documents pertaining to Project Rulison and interviews with personnel who worked on the project. Project Rulison was part of Operation Plowshare (a program designed to explore peaceful uses for nuclear devices). The project consisted of detonating a 43-kiloton nuclear device on September 10, 1969, in western Colorado to stimulate natural gas production. Following the detonation, a reentry well was drilled and several gas production tests were conducted. The reentry well was shut-in after the last gas production test and was held in standby condition until the general cleanup was undertaken in 1972. A final cleanup was conducted after the emplacement and testing wells were plugged in 1976. However, some surface radiologic contamination resulted from decontamination of the drilling equipment and fallout from the gas flaring during drilling operations. With the exception of the drilling effluent pond, all surface contamination at the Rulison Site was removed during the cleanup operations. All mudpits and other excavations were backfilled, and both upper and lower drilling pads were leveled and dressed.

This report provides information regarding known or suspected areas of contamination, previous cleanup activities, analytical results, a review of the regulatory status, the site's physical environment, and future recommendations for Project Rulison. Based on this research, several potential areas of contamination have been identified. These include the drilling effluent pond and mudpits used during drilling operations. In addition, contamination could migrate in the gas horizon.

The drilling effluent pond at the Rulison Site was used to store nonradioactive drilling mud during the drilling of the emplacement hole for the nuclear device. In 1994 and 1995, three pond-sediment sampling events were conducted to evaluate the nature of this residual drilling fluid. The sampling indicated the presence of up to seven percent, by weight, of diesel fuel and the presence of chromium. The diesel fuel contained total petroleum hydrocarbon compounds in addition to benzene, toluene, ethylbenzene, and xylene. Prior to the detonation of the nuclear device, the sumps remaining from drilling the emplacement hole (with the exception of the drilling effluent pond previously mentioned) were cleaned and filled with earth.

Two natural gas production wells are located within 5 kilometers (3 miles) of the Rulison Site. Both wells are currently shut-in because current (1995) low gas prices make production uneconomical. If contamination enters the gas horizons, it should appear in the water or gas from

one or both of these wells. Tritium is the most likely contaminant to be found in the natural gas or groundwater from the production wells because it is the most mobile of the radionuclides produced by detonation of the nuclear device.

Based on information provided in this report, the following tasks should be completed to close the remaining information gaps for Project Rulison:

- Complete the human health baseline risk assessment
- Collect gas/water samples from the gas wells closest to the shot cavity
- Characterize the mudpit located by the reentry (RE-X) well
- Continue the Long-Term Hydrologic Monitoring Program
- Develop action plan in the event contamination is found.

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List of Acronyms and Abbreviations

AEC	U.S. Atomic Energy Commission
amsl	Above mean sea level
BLM	U.S. Bureau of Land Management
BMI	Battelle Memorial Institute
°C	Degree(s) Celsius
CDNR	State of Colorado Department of National Resources
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CG	Contaminant guideline
Ci	Curie(s)
cm	Centimeter(s)
cm^2	Square centimeter(s)
cm^3	Cubic centimeter(s)
DOE	U.S. Department of Energy
DOE/NV	DOE/Nevada Operations Office
dpm	Disintegration(s) per minute
DRI	Desert Research Institute
ERDA	U.S. Energy Research and Development Administration
EPA	Environmental Protection Agency
°F	Degree(s) Fahrenheit
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
ft	Foot (feet)
gpd	Gallon(s) per day
HRS	Hazard Ranking System
in.	Inch(es)
IT	IT Corporation
K_d	Distribution coefficient
km	Kilometer(s)
LTHMP	Long-Term Hydrologic Monitoring Program
μd	Microdarcy(ies)
m	Meter(s)
m^2	Square meter(s)

m^3	Cubic meter(s)
μCi/mL	MicroCurie(s) per milliliter
MCF	Million cubic feet
mi	Mile(s)
mg	Milligram(s)
mL	Milliliter(s)
mrad	Millirad(s)
NEPA	National Environmental Policy Act
pCi/mL	PicoCurie(s) per milliliter
pCi/g	PicoCurie(s) per gram
pCi/L	PicoCurie(s) per liter
μR/h	Microroentgen(s) per hour
R-E	Emplacement well
R-EX	Reentry well
SGZ	Surface ground zero
SCS	Soil Conservation Service
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USPHS	U.S. Public Health Service

1.0 Introduction

1.1 Site Location

The Rulison Site is located in Section 25, Township 7 South, Range 95 West (6th Principal Meridian), Garfield County, Colorado, approximately 19 kilometers (km) (12 miles [mi]) southwest of Rifle, Colorado, and approximately 65 km (40 mi) northeast of Grand Junction, Colorado (Figure 1-1). The site can be accessed by traveling west on I-70 from Rifle, 22 km (14 mi) to the town of Parachute. Then proceeding south from Parachute, up the Battlement Creek Valley, approximately 13 km (8 mi) to surface ground zero (SGZ).

1.2 Objective

The objective of this preliminary site characterization report is to summarize the information gathered during the recent literature search and interview process. The documents that have been reviewed were gathered from the U.S. Department of Energy (DOE) resource centers and Central Files and ranged from field personnel daily logs to issued reports dated from the projects' origination to current data from field activities. The personnel who were interviewed included local residents and retired or current DOE and contractor employees who were present during the testing. Information gathered from these sources has been evaluated to provide a clear picture of the site, including physical characteristics, testing, cleanups, and potential contaminated areas. This preliminary site characterization report will be used to identify potential DOE liabilities, formulate baseline risk assessments, and develop field work plans which will be implemented during the Phase II-Field Site Characterization process.

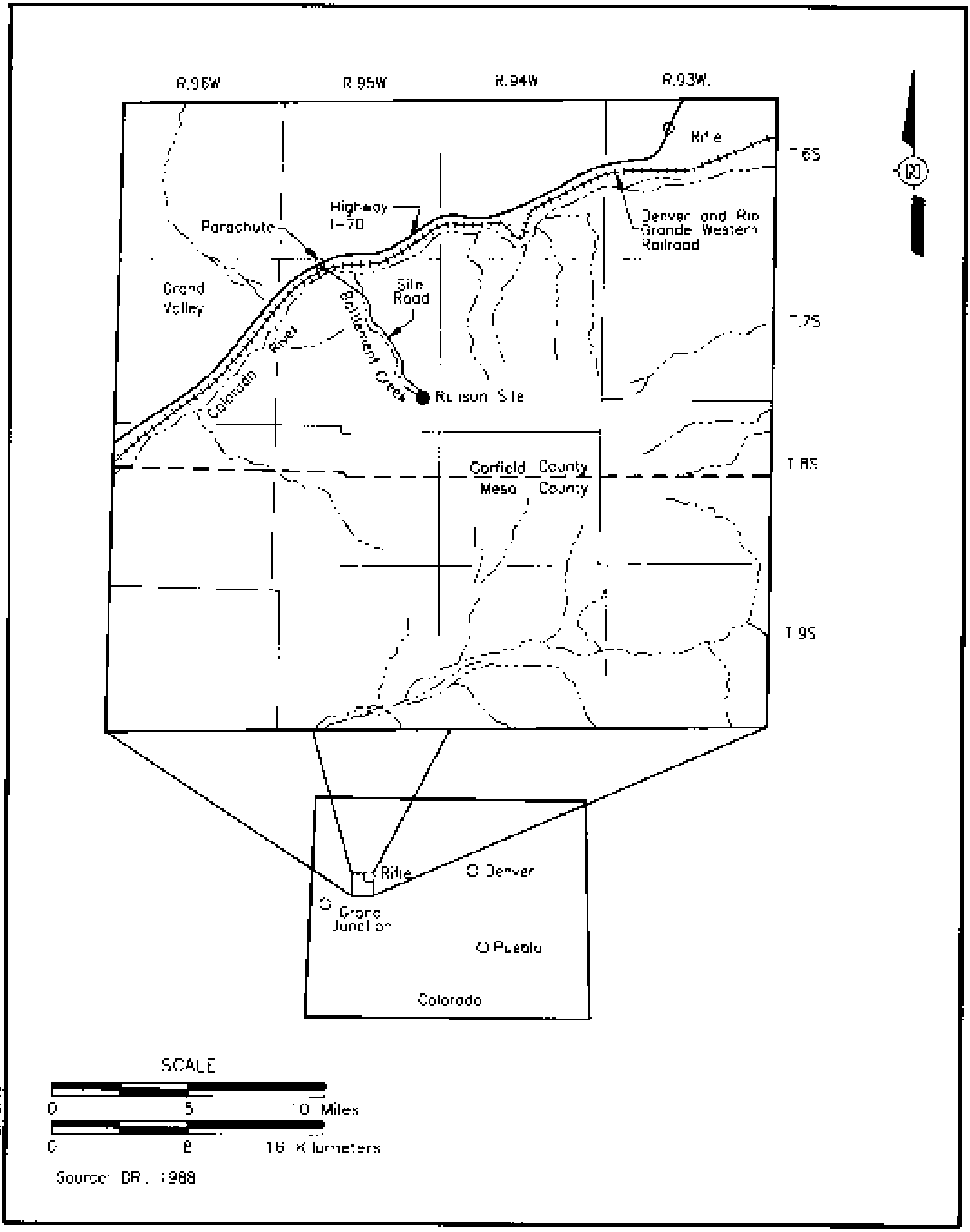

Figure 1-1
Rulison Site Location Map, Garfield County, Colorado

2.0 Rulison Site History

2.1 Overview

The Rulison Project was the second of three joint government/industry, gas-production stimulation experiments conducted under the Plowshare Program, a project designed to develop peaceful uses of nuclear explosions. Project Rulison was a joint project between the U.S. Atomic Energy Commission (AEC) (currently known as the U.S. Department of Energy) and the Austral Oil Company. Under this program, the feasibility of stimulating natural gas production in low-permeability, gas-producing geologic formations with underground nuclear explosions was studied. On September 10, 1969, a 43-kiloton nuclear device was detonated at a depth of 2,568 meters (m) (8,426 feet [ft]) below the ground surface. Redrilling of the former pre-shot exploratory hole which was then converted into the reentry well (R-EX), designed for conducting production testing of the stimulated zone, was located 300 ft southeast of the emplacement well (R-E) and was completed in October 1970.

Production testing and data evaluation took place over a seven month period between October 1970 and April 1971, and included four separate flow periods. Approximately 12.0 million stock cubic m (455 million stock cubic ft) of natural gas were produced. The well was shut-in after the last test and left in a standby condition until a general cleanup was undertaken in 1972. Cleanup activities were conducted at the site from July 10 through July 25, 1972, to remove all extraneous materials and equipment not required for gas production. A final cleanup was conducted after the emplacement and testing wells were plugged in 1976. Neither the Austral Oil Company nor the U.S. Energy Research and Development Administration (ERDA) developed any plans to commercially produce the available natural gas. Accordingly, during the period of September 1, 1976, through October 12, 1976, the R-E and R-EX wells were plugged and abandoned, and the equipment that remained after the 1972 general cleanup was decontaminated as necessary and removed from the site (Eberline, 1977, p. 2). Some surface radiologic contamination resulted from decontamination of drilling equipment and fallout from the gas flaring (DRI, 1988, p. 3.6.18); however, except for the drilling effluent pond, all surface contamination was removed during site clean-up operations.

2.2 Facility Description

2.2.1 Known or Suspected Areas of Contamination

Based on the review of available documentation and field sampling activities, several known or suspected areas of subsurface contamination are present. These include the drilling effluent pond and the mudpits used during drilling operations. In addition, contamination may be present in natural gas or water produced from nearby gas wells. Each of these locations is discussed below.

2.2.1.1 Drilling Effluent Pond

The effluent pond at the Rulison Site was used to store nonradioactive drilling mud during the boring of the emplacement hole for the nuclear device (Well R-E). The drilling fluids consisted of a bentonitic drilling mud with additives (such as diesel fuel and chrome lignosulfonate) to improve drilling characteristics. Most of the drilling mud was removed from the pond when the site was cleaned up and decommissioned in 1972; however, some residual fluid was left in the pond. In 1994 and 1995, three pond-sediment sampling events were conducted to evaluate the nature of this residual drilling fluid. The sampling indicated the presence of up to 7 percent, by weight, of diesel fuel as well as the presence of chromium. The diesel fuel contains total petroleum hydrocarbon compounds in addition to benzene, toluene, ethylbenzene, and xylene.

The DOE/Nevada Operations Office (DOE/NV) Nevada Environmental Restoration Project has undertaken a voluntary removal action to clean up the contaminated pond sediments, following which the pond will be restored to support an aquatic ecosystem. It is expected that pond restoration will be completed during the summer of 1996.

2.2.1.2 Mudpits

A pre-shot bioenvironmental survey of the area around the Rulison Site was made early in 1969 by Battelle Memorial Institute (BMI) (AEC, 1973b, p. 50). The objectives were to characterize the ecological setting of the project site and to identify any potential adverse consequences, as a result of prior project activities, which might require preventive or remedial action.

The only significant bioenvironmental hazard identified during the pre-shot survey was the possible danger of pollution of Battlement Creek by drilling wastes or other contaminants resulting from drilling operations. Sump ponds used in drilling the R-EX and the R-E wells were located very close to the channel of the East Fork of Battlement Creek (Figure 2-1).

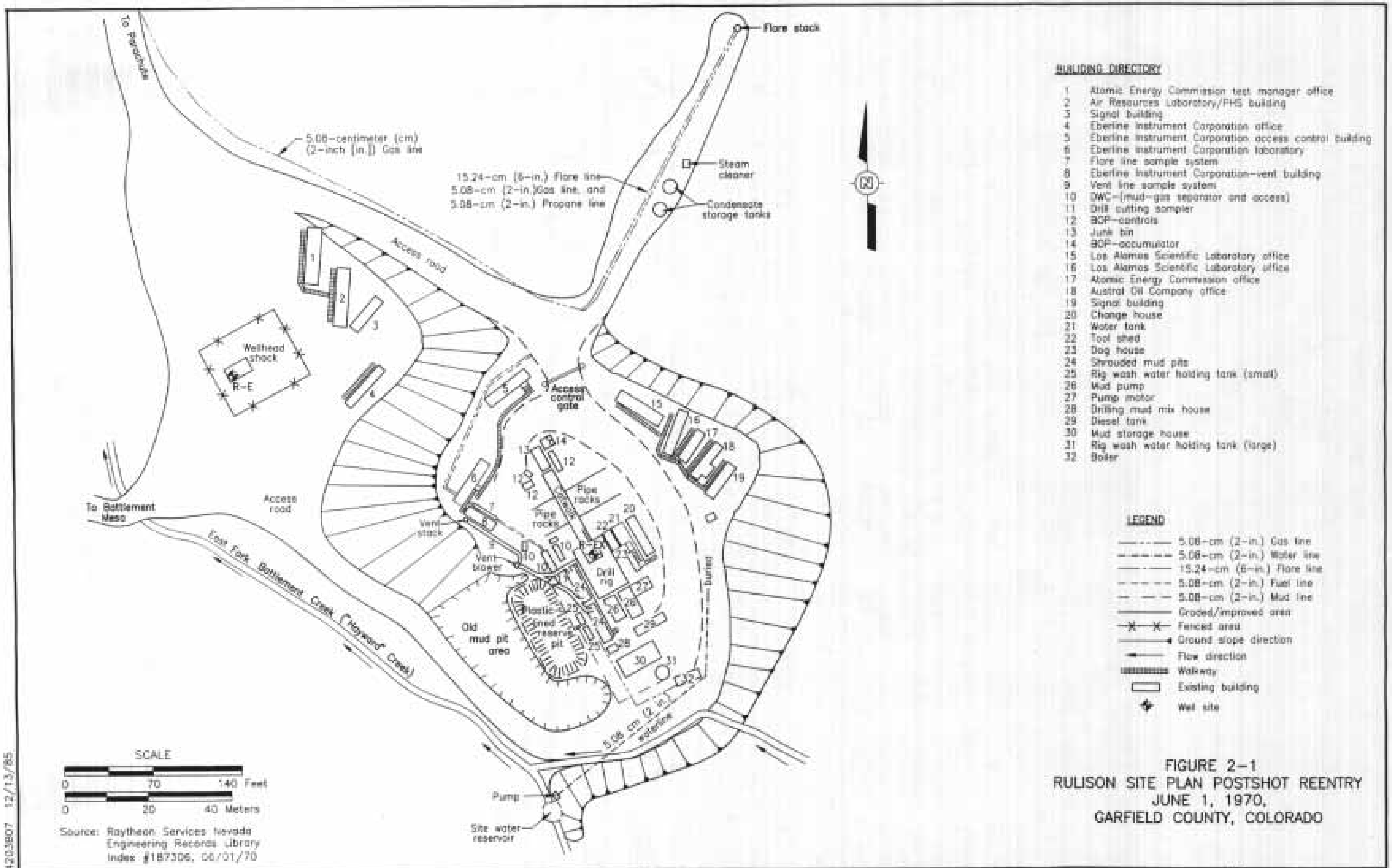

FIGURE 2–1
RULISON SITE PLAN POSTSHOT REENTRY
JUNE 1, 1970,
GARFIELD COUNTY, COLORADO

A sump failure occurred during the drilling of the pre-shot exploratory hole (Well R-EX) in December 1967, which killed fish in the stream below the site and temporarily contaminated the domestic and stock water supplies of some of the Morrisania Mesa residents. The pre-shot bioenvironmental survey report recommended that adequate precautions be taken to prevent any further pollution of the Battlement Creek watershed during the final site preparation and detonation phase. A water sampling plan for evaluating the effectiveness of these precautionary measures was also outlined. Results of a pre- and postshot stream water sampling program carried out by the Colorado Department of Health (Appendices B, C, and D) indicated these precautions were successful. In addition, springs and wells in the vicinity of the Rulison Site were sampled by the U.S. Geological Survey (USGS) (Figure 2-2) both before and after the detonation. While an increase in flow from springs and flow in Battlement Creek was observed immediately following the shot, the flow in all cases returned to pre-shot levels within a short time.

During a visit to the site between June 15 and 17, 1970, BMI and AEC personnel reported that oil and water had been running into Battlement Creek from one of the old mud sumps located next to the creek (Mason, 1970). Close examination of this area showed that most of the water was from snow buried at the time the mudpit was constructed. Two samples of water coming from the old sump were taken and submitted to the U.S. Public Health Service (USPHS) for analysis, and both samples contained elevated levels of hydrocarbons. Although the levels of hydrocarbons were an order of magnitude higher than the USPHS Drinking Water Standards, this was not considered a problem at the time because of the dilution factor when the stream flowed into Battlement Creek.

Prior to the detonation, the sumps remaining from drilling of the emplacement hole, with the exception of the drilling effluent pond previously mentioned, were cleaned and filled with earth (AEC, 1973b, p. 50). During site decommissioning in 1976, all mudpits and other excavations were backfilled and both the upper and lower drilling pads were leveled and dressed (ERDA, 1977, p. 5).

2.2.1.3 Natural Gas Wells

Two natural gas production wells are located near the Rulison Site (Section 5.5.4). These wells are the Federal 28-95, located 4.3 km (2.7 mi) west and the Federal 14-95 located 4.3 km (2.7 mi) to the northwest of SGZ (Figure 2-2). These wells have changed possession several

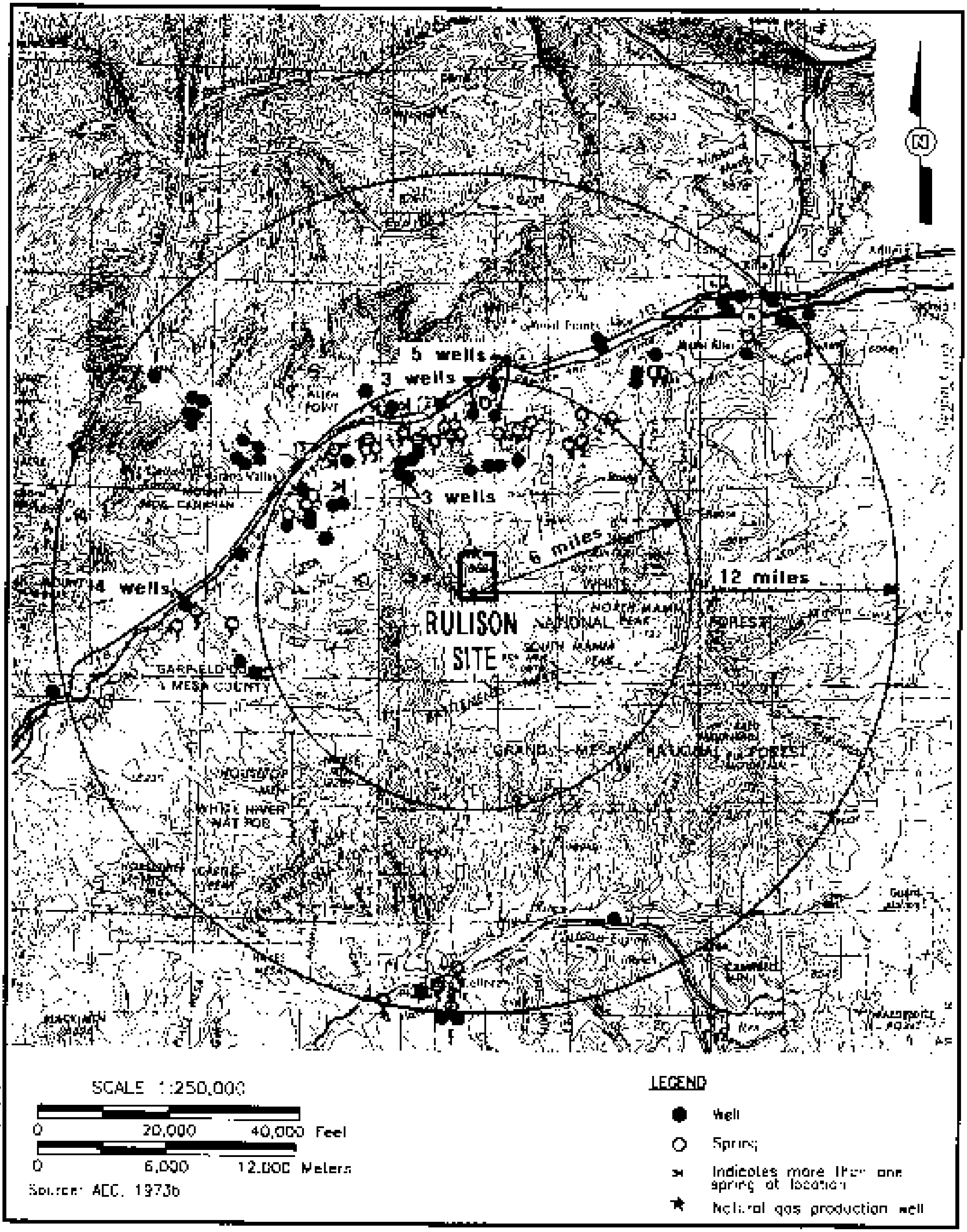

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Figure 2-2
Water Wells and Springs in the Vicinity of Project Rulison, Garfield and Mesa Counties, Colorado

times since they were initially completed and have produced gas and minor amounts of water on an intermittent basis. Both wells are currently shut-in because of low gas prices.

If any contamination enters the gas horizons, it would be expected to appear in the water or gas from these wells. Since natural gas production from the Mesaverde Group is primarily from fractures, and the dominant fracture strike in the Rulison area is northwest-southeast, then contaminated natural gas or groundwater may be drawn by well production activity or by natural gradients toward these production wells, principally the Federal 14-95. The highly anisotropic nature of the fracturing in the Mesaverde limits the potential for contaminated gas or groundwater production from wells that are or may be located in other directions from the Rulison Site.

Tritium is the contaminant most likely to be found in the natural gas or groundwater from the production wells because it is the most mobile of the radionuclides produced by the nuclear device. The amount of tritium and other radionuclides produced by the explosion of the nuclear device is still classified information.

2.2.2 Previous Cleanup

The decontamination effort at the Rulison Site was divided into two operations: the general (initial) cleanup in 1972 and the final cleanup in 1976 (Eberline, 1977). The total amount of tritium shipped from the Rulison Site as a result of both cleanup operations was estimated to be 0.781 curies (Ci). No other radionuclides were reported in either cleanup, and no burial of radioactive solids occurred at the Rulison Site. All on-site equipment was removed during the final cleanup with the exceptions of the R-E wellhead, a power pole with a fuse box, a telephone line, a concrete slab, and a small monument over the emplacement well stating drilling restrictions at the site (DRI, 1988, p. 3.6.5).

2.2.2.1 Initial Cleanup Effort (July 10 through 25, 1972)

Prior to the initial cleanup, the site was in standby condition with all surface equipment intact (Figure 2-3). During this cleanup, all items of equipment and material that were not required for production testing were removed from the site. Following the cleanup, soil, water, and vegetation sampling was conducted which is further discussed in Section 2.2.2.4.2. A release log was maintained to describe each item and to record its radiological condition if it were to be released for unrestricted use. There were 504 uncontaminated and decontaminated items logged and released, and those items that could not be economically decontaminated were included in

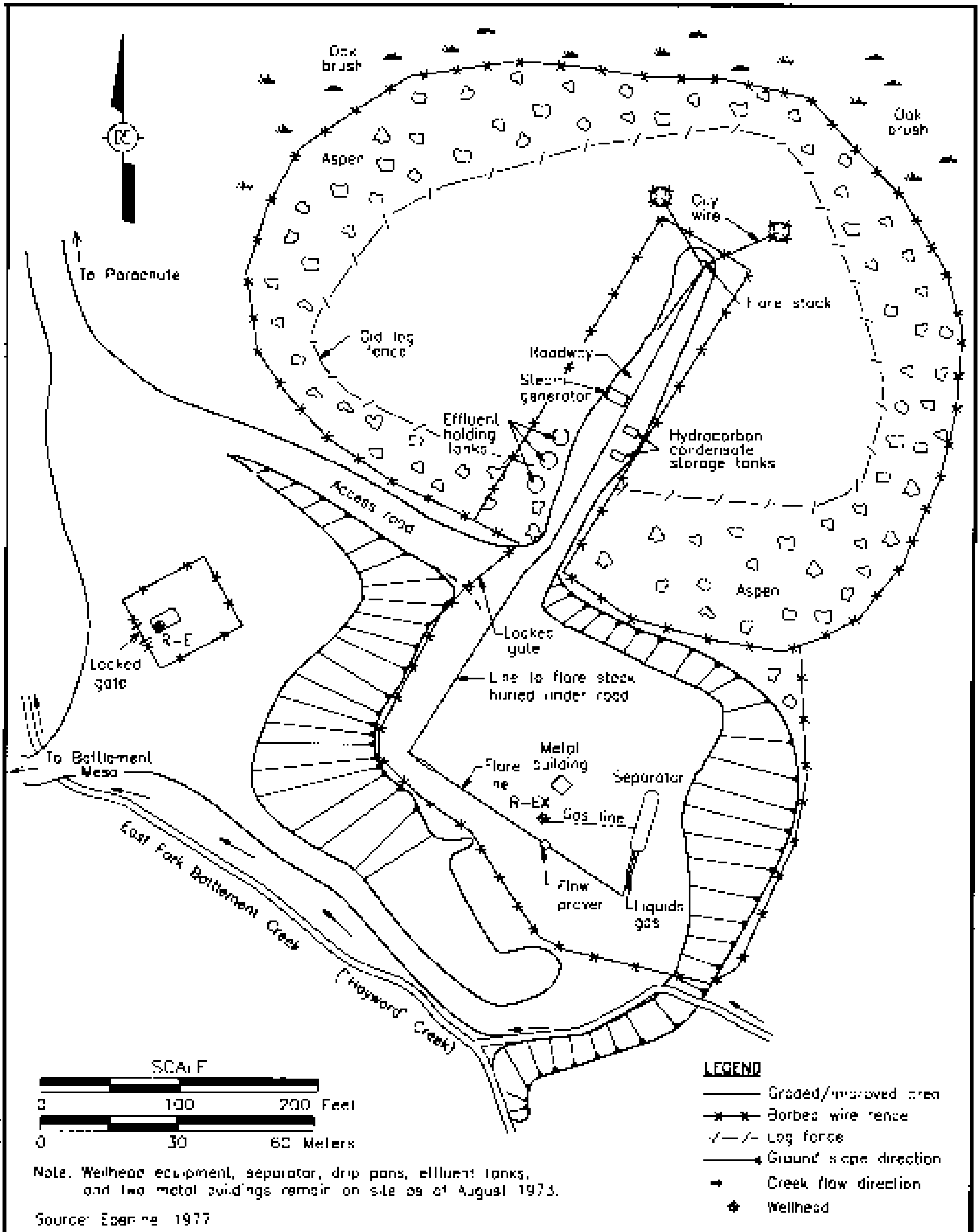


Figure 2-3
Rullson Site at Completion of Flare Testing, April 1971, Garfield County, Colorado

the material shipped to Beatty, Nevada, for burial at the Nuclear Engineering Company facility, now known as U.S. Ecology. Decontamination operations were conducted in a large, sheet-metal pan using saturated steam and Steamzall®. The guideline limits for release of material were 1,000 counts per minute beta-gamma removable from any 100 square centimeters (cm^2), and a total of 0.4 millirad (mrad)/hour at 1 centimeter (cm) from the surface, through not more than a 7 milligram (mg)/cm^2 absorber. In practice, the actual removable contamination for released items in each case was not above background (0.02 mrad/hour) of the site area. Items of equipment and materials found to be clean, or that had been decontaminated, were removed to the Austral storage yard at Rifle, Colorado. Items in this category included the flare stack and the sections of 2-inch (in.) and 6-in. pipe that ran between the north gate and the separator.

On July 20, 1972, 11.36 cubic meters (m^3) (3,000 gallons) of decontamination fluid containing 0.69 Ci of tritium were shipped by tank truck to the waste facility at Beatty, Nevada. On July 22, 1972, thirty-two packages of contaminated solid waste and six 55-gallon steel drums of solidified liquid waste, both containing an estimated 0.073 Ci of tritium, were also shipped.

Upon completion of the 1972 cleanup, the following equipment was left on site (Figure 2-4):

- The high-pressure wellhead and pressure measuring equipment and instruments at the R-E well remained. The wellhead was protected by a metal shed surrounded by a 6-ft high cyclone and barbed wire fence with a locked gate.

- The wellhead valves (Christmas tree), separator, and connecting piping at the R-EX well were left configured for future gas production. One drip pan was in place around the wellhead, and another was under the separator.

- A tool and instrument shed in the vicinity of the R-EX well was left.

- A large decontamination pan (old pipe rack pan) was left.

- Three 210-barrel water holding tanks and two 500-gallon hydrocarbon distillate tanks, all internally contaminated stayed. The water tanks contained a few inches of contaminated sludge solidified with bentonite. The hydrocarbon tanks were drained completely dry.

- Telephone facilities and electric power on boards and poles remained.

- The area was fenced with barbed wire and posted.

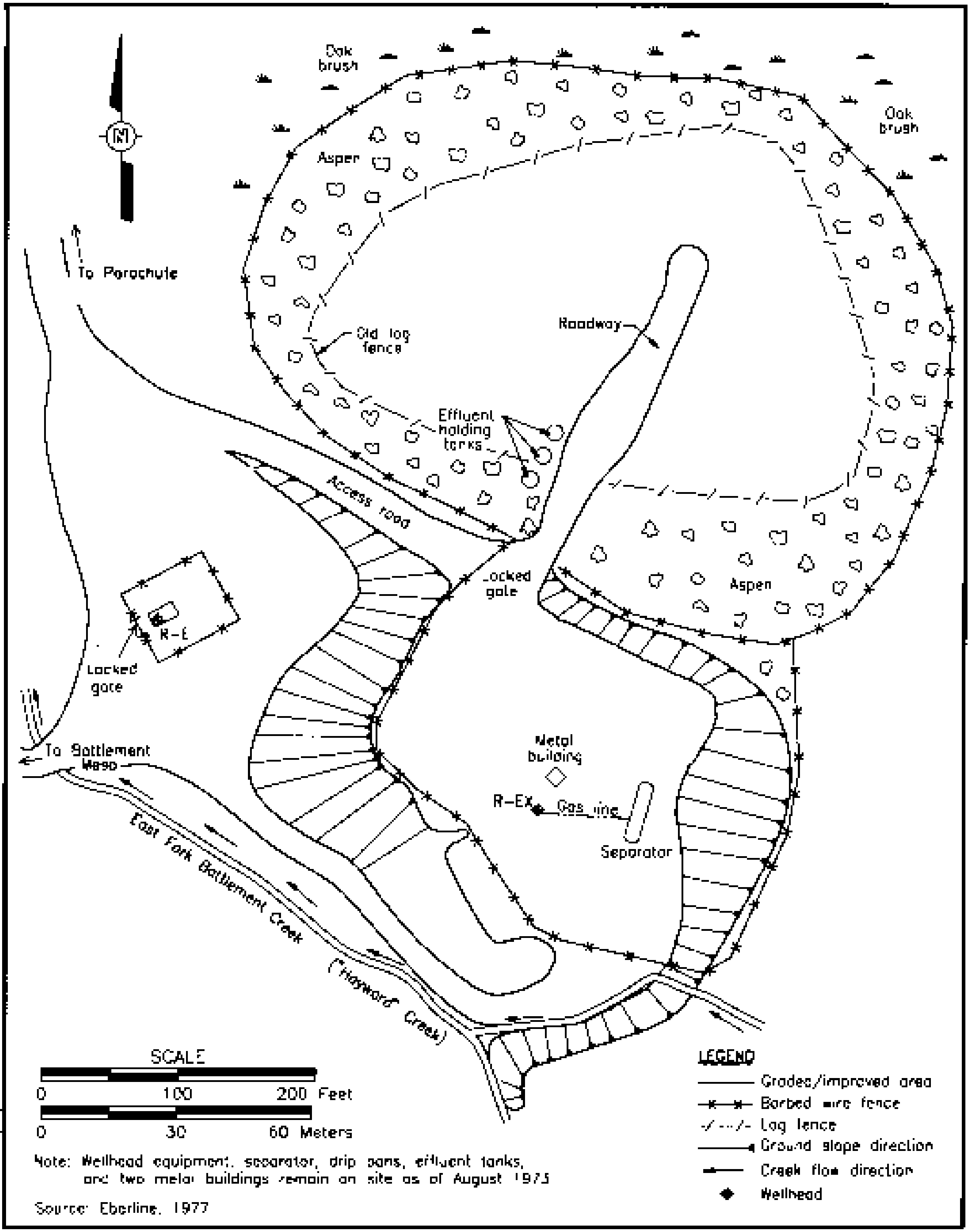


Figure 2-4
Rulison Site at Completion of the General Site Cleanup Effort, July 1972, Garfield County, Colorado

Some of the above items were, or were presumed to be, contaminated internally. Items contaminated internally with tritium were appropriately labeled. None of these items was externally contaminated.

2.2.2.2 Final Cleanup Effort (September 1 through October 12, 1976)

The R-E and R-EX wells were plugged and abandoned during the final cleanup. Concurrently, the surface equipment (itemized in the general cleanup) was dismantled, decontaminated, documented in the release log, and removed from the site. The primary method of decontamination was by cleaning in a large, sheet-metal pan using saturated steam and Steamzall® or detergent. The only contaminant of concern was tritium. The guideline limit for release to unrestricted use was 5,000 disintegrations per minute (dpm)/100 cm^2 total activity and 1,000 dpm/100 cm^2 removable activity (ERDA, 1976). The release log listed 126 items for unrestricted use. No item was above the ambient area background when surveyed at approximately 1 cm with an HP-210 beta-gamma probe having less than a 7 mg/cm^2 absorber. Removable contamination as determined by swipe sampling was in no case more than a small fraction of the guideline (ERDA, 1977, p. 3).

On October 4, 1976, 0.166 Ci of tritium in waste water and drilling mud were pumped into the Mesaverde formation of the R-E well at a depth of approximately 1,615 to 1,768 m (5,300 to 5,800 ft) for disposal. The potable aquifers above this depth were cemented off during well drilling and casing installation.

Items having inaccessible surfaces (i.e., pipes) were initially flushed with steam and cleaning solutions until flush liquids were below detection sensitivity for tritium. Following a drying period, an appropriate amount (not to exceed 1 liter) of distilled water was placed in contact with the portion of the surface to be tested. A one cubic centimeter (cm^3) aliquot of this water was collected and analyzed for tritium. If the concentration exceeded 5,000 dpm/milliliter (mL), the item was considered unfit for unconditional release. None of the decontaminated items exceeded this limit. The R-E wellhead equipment and metal shed were not contaminated and were released after the survey.

The R-EX wellhead, separator, and connecting pipeline were internally contaminated. The wellhead was disassembled so that the internal surfaces were accessible for steam cleaning. The pipeline was cut into manageable lengths which were cleaned internally with a steam lance. The separator was moved onto the decontamination pan where its pressure tanks were cut open with an acetylene torch so that internal surfaces were accessible for steam cleaning. The wellhead drip pan, the separator drip pan, and the tool shed were not contaminated.

The three water holding tanks were moved onto the decontamination pan. The heater of each was removed for decontamination and to obtain a large access port to the tank. Thirty 55-gallon steel drums of solidified sludge were mucked from the bottom of these tanks through the heater openings. The heaters and internal surfaces of the tanks were decontaminated with de-tar solvent, saturated steam, Steamzall®, and detergent. The two hydrocarbon tanks had been transferred to Project Rio Blanco, and they were not included in the Rulison cleanup.

On October 8, 1976, as a result of the final cleanup, sixty-eight 55-gallon steel drums of contaminated soil and other solid waste containing a total of 0.018 Ci of tritium were shipped to Beatty, Nevada, for burial at the Nuclear Engineering Company facility. This waste originated from mucking the tanks, soil removal of known spill areas, and from decontamination activities associated with drillback and flaring operations. The total amount of tritium shipped for burial from the Rulison Site as a result of both the general and final cleanup operations was estimated to be 0.781 Ci. No other radionuclide was involved in either cleanup.

2.2.2.3 Plugging and Abandonment Operations

The R-E and R-EX wells were plugged concurrently with the final cleanup work. The R-EX well was plugged first and the R-E well second. Both procedures required the use of a work-over drilling rig with routine support activities. Radiological monitoring support was provided to assure safety of personnel and containment of any radioactive material coming from downhole.

2.2.2.3.1 R-EX Well

This well was originally the pre-shot exploratory hole used to perform pre-shot gas-production tests, conducting geological and hydrological studies, and other studies for technical and safety confirmation. This well was also used for reentry and production testing (ERDA, 1976, p. 5). It was plugged pursuant to the plan (ERDA, 1976) (Figure 2-5). An unexpected return to the surface of 300 barrels of drilling mud and water contaminated with low levels of tritium was a potential source of contamination. However, this return was totally contained in tanks and was later disposed of, along with other liquids, as previously noted.

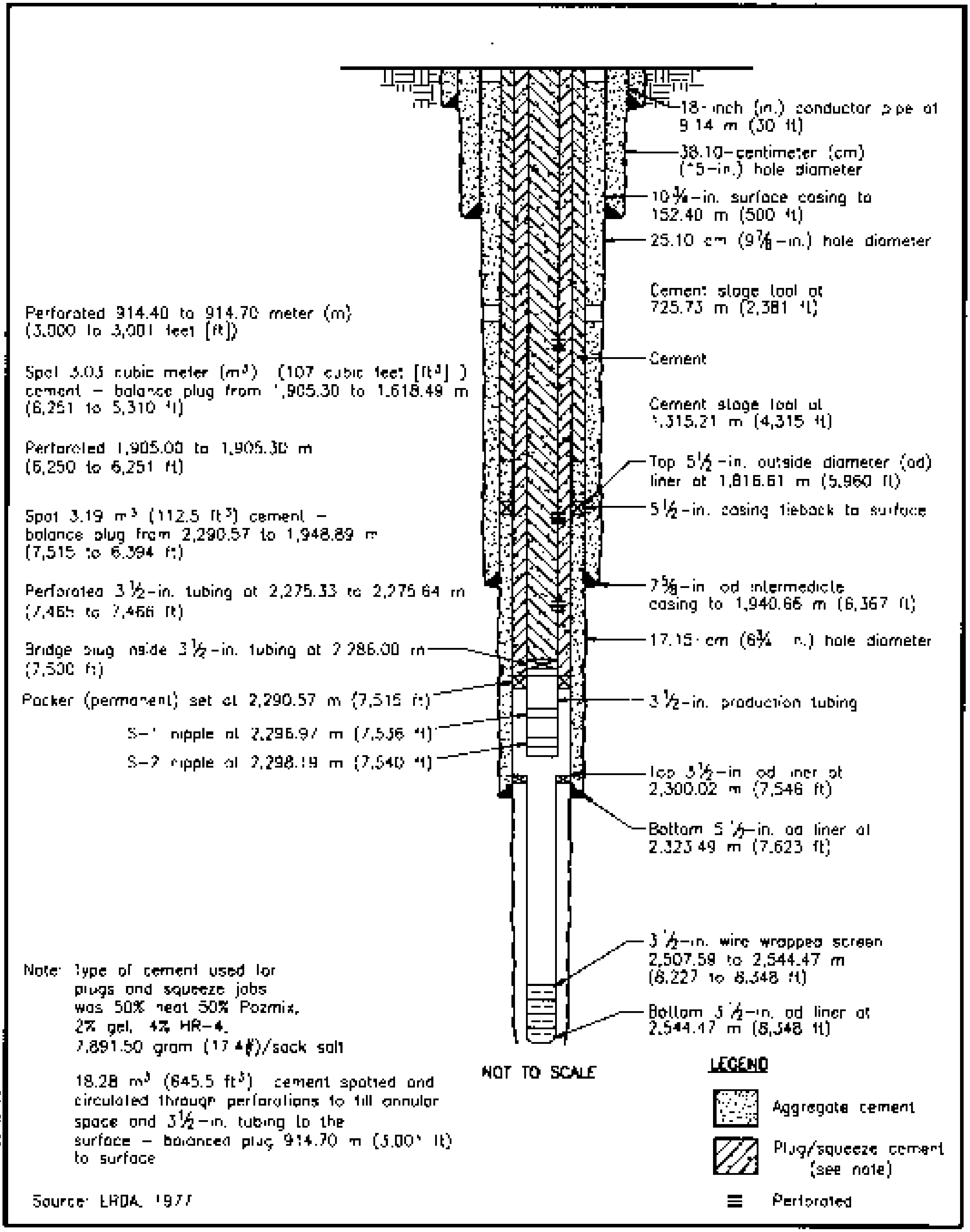


Figure 2-5
Project Rulison Exploratory - Reentry Well (R-EX) "As Built" Plugging Condition, July 1972, Garfield County, Colorado

2.2.2.3.2 R-E Well

The R-E Well contained stemming gravel and the nuclear device emplacement and detonation cable. There were several physical problems related to the washing out of stemming material and the removal of the cable (Figure 2-6). The original plan (ERDA, 1976) was modified by both regulatory decisions and practical demands. During the destemming operation, the return line of the wash-down fluid recirculating system was continuously monitored for gamma radiation with a 2-in. x 2-in. sodium iodide detector equipped with an alarm and recorder. A sample of the return fluid was collected at least every 36.58 m (120 ft) of depth and analyzed for tritium by liquid scintillation. Several samples of returned stemming material were analyzed for radioactive particulate contamination using pulse-height analysis. No radioactive contaminant above natural background was detected, and the well was satisfactorily plugged without a radiological incident.

2.2.2.4 Environmental Sampling and Survey Programs

Three environmental sampling programs were conducted. The first program was conducted after completion of production testing in 1971 and consisted of collecting soil samples from around the flare stack in a radial pattern. The second program was conducted in conjunction with the 1972 general cleanup. It included soil, vegetation, and water on and around the R-EX area, including more samples around the flare stack. The third program was part of the final cleanup in 1976 which was involved with well plugging and abandonment. It included extensive soil sampling in areas of known or potential contamination based on the results of prior sampling and operating experience. This program also included sampling the creek above and below the site as well as spring water at the site.

The three sampling programs adequately delineated the extent of soil and water contamination in the site area after completion of plugging procedures on the R-E and R-EX wells. The only radioactive nuclide in the environment of the site, other than those naturally occurring or resulting from worldwide fallout, was tritium. The final survey of tritium concentration did not exceed the guideline limit of 3×10^{-2} microCuries per milliliter (µCi/mL) (3×10^{4} picoCuries per milliliter [pCi/mL]) of soil moisture (ERDA, 1976).

After the final cleanup was completed, a survey of the site was made at 1-cm distance on a 15.24-m (50-ft grid) by 3.05-m ([10-ft] grid over areas of known spills) using an HP-210 beta-gamma probe having less than a 7 mg/cm^2 absorber. No reading was obtained greater than the ambient background (0.02 mrad/hour) of the area.

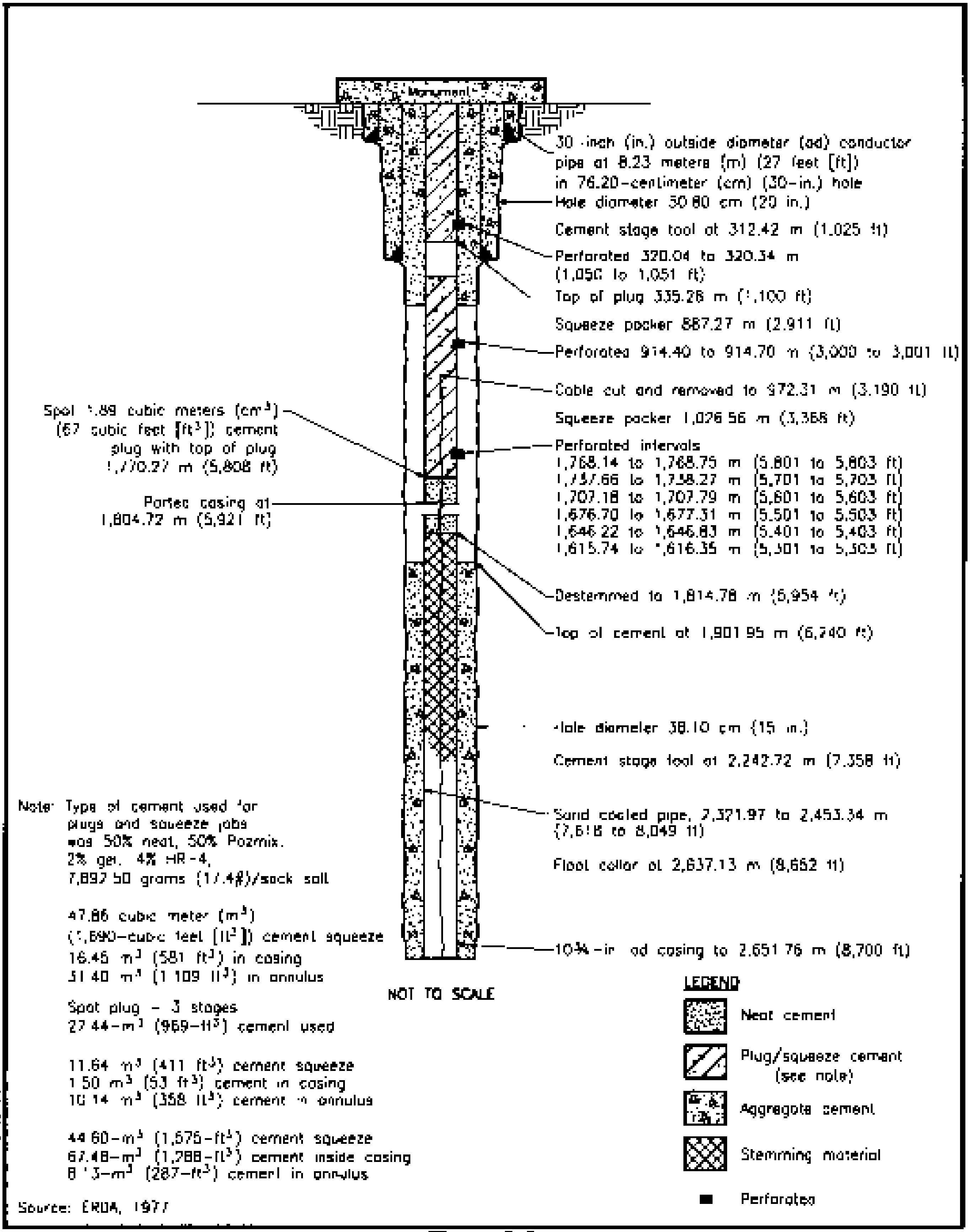


Figure 2-6

Project Rulison, Emplacement Hole (R-E) "As Built" Plugging Condition, July 1972, Garfield County, Colorado

2.2.2.4.1 First Sampling Program

This first sampling program was conducted in April 1971 when the site was placed on standby after completion of production tests. A total of 133 soil samples was taken at 70 sampling points around the flare stack. All samples were well below the guidelines for tritium in soil moisture. Figures 2-7 and 2-8 show the locations of each sampling point by azimuth and distance from the flare stack and the tritium concentration in soil moisture per milliliter and per gram at the indicated sample depths. Table 2-1 provides the same information in tabular form.

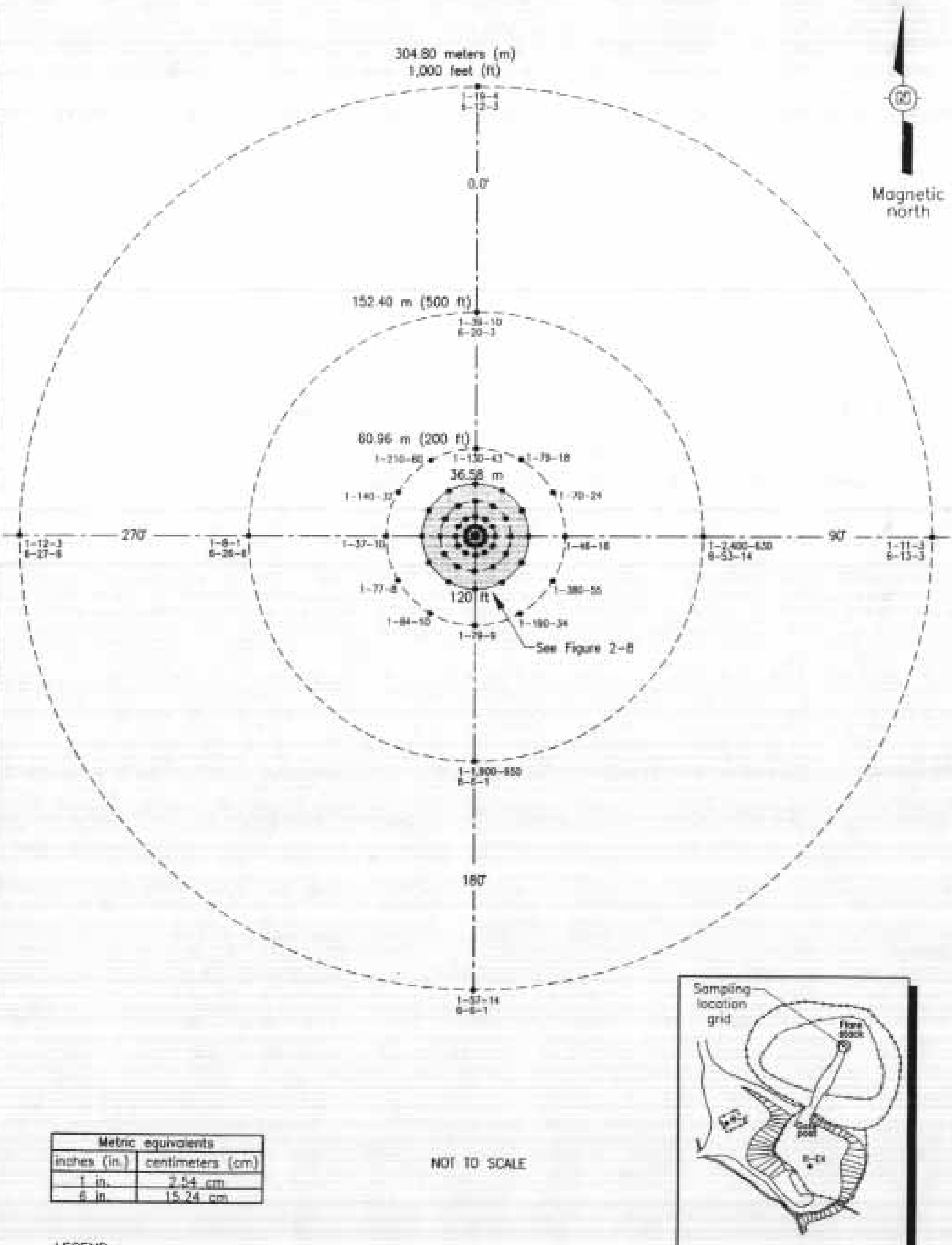
2.2.2.4.2 Second Sampling Program

This program was part of the general cleanup conducted in July 1972. It included the sampling of soil, vegetation and water.

Soil Sampling

A square grid of soil sampling points was laid out on magnetic cardinal headings using the site entrance gate post as the zero and primary reference point. Ten- and twenty-foot squares were used, depending on the area use history and on the probability of soil contamination. Squares were sometimes distorted to sample points of special interest such as storage tanks, pipeline runs, the separator, and drip pan areas or to avoid obstructions such as cement pads. While the flare stack was located on the square grid system, the area around it was sampled on a radial grid referenced to the stack. This radial grid was used because contaminated fallout originated from the stack as a center and because a radial sampling grid was used previously during postflare operations, making a comparison more meaningful. A total of 192 sampling points was located (see Figures 2-9 and 2-10). Most of these points were sampled at 2.54-cm and 30.48-cm (1- and 12-in.) depths. Fourteen points were sampled at 2.54-cm, 30.48-cm, 60.96-cm, and 121.92-cm (1-, 12-, 24-, and 48-in.) depths. Two points were sampled at multiple depths to 2.44 m and 3.35 m (96 and 132 in.), respectively, and a few were sampled at other selected depths. A total of 426 soil samples was collected for tritium analysis.

The depth increment for soil samples taken was 2.54 cm (1 in.) (i.e., the 2.54-cm sample was from the surface to 2.54 cm, and the 30.48-cm [12-in.] sample was from 27.94 to 30.48 cm [11 to 12 in.], etc.). Soil samples were collected in standard 454-gram (16-ounce) cottage cheese containers that held 61 to 68.6 cm^3 (24 to 27 cubic in.) of sample. At undisturbed and uncompacted sampling locations, an earth auger was used to bore holes up to 1.22-m (4-ft) deep. For sampling at greater depths, and at disturbed and compacted locations, a powered backhoe was used to dig required holes. After these holes were cleaned out, samples were taken from



Metric equivalents	
inches (in.)	centimeters (cm)
1 in.	2.54 cm
6 in.	15.24 cm

LEGEND

■ Flare stack

ND Nondetectable

^3H Tritium

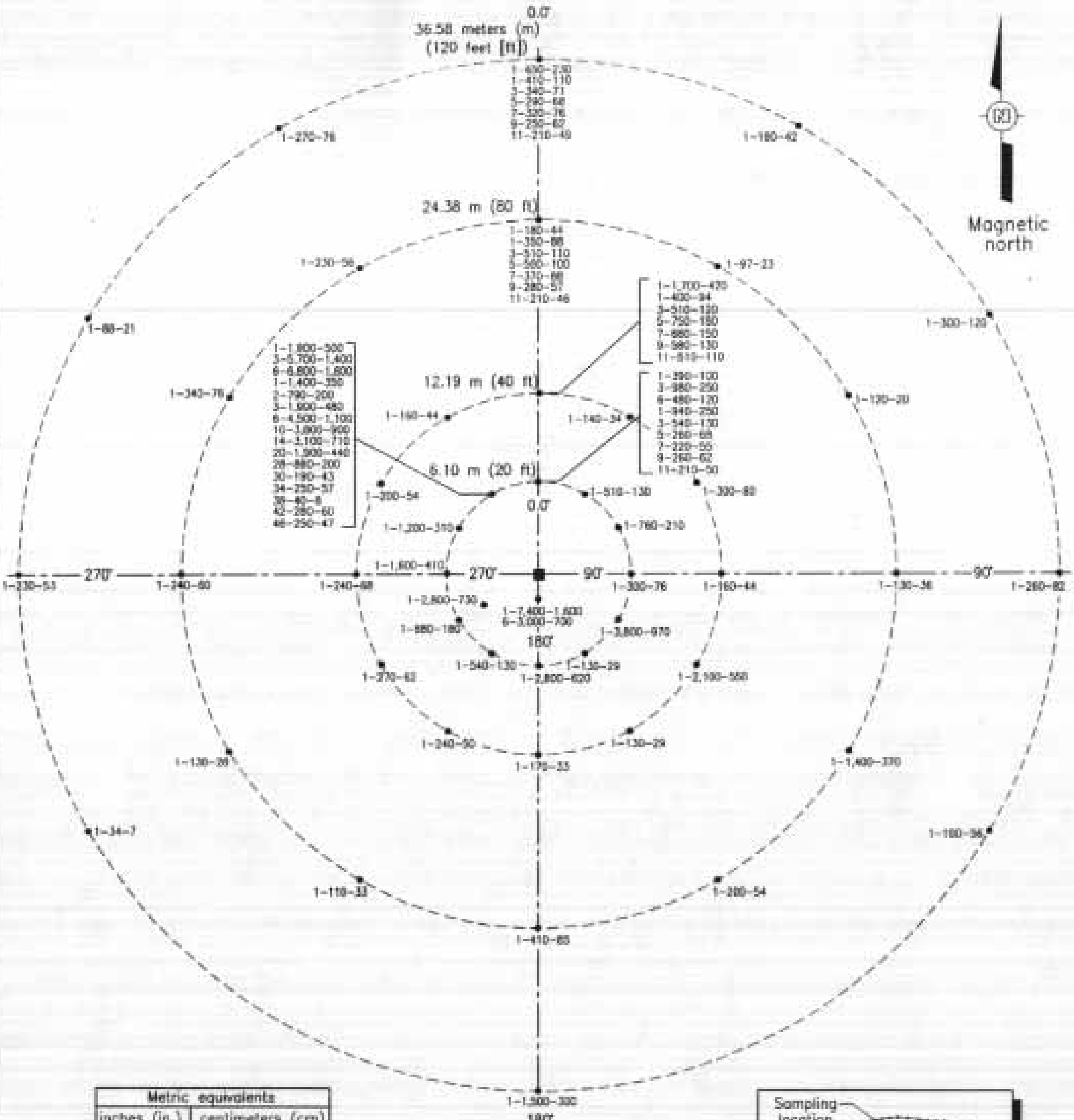
• Sample location

1-11-48
- Picocurie/gram ^3H
- Picocurie/milliliter ^3H in soil moisture
- Depth in inches

Source: Rulison Radiation Contamination Clearance Report, 1977

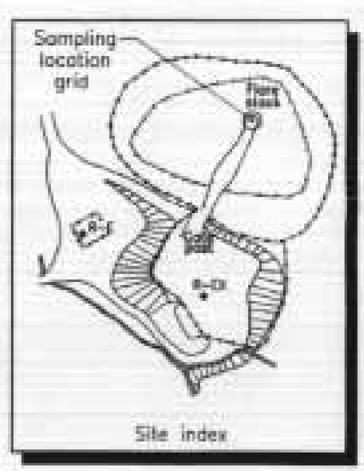
FIGURE 2-7
PROJECT RULISON SOIL SAMPLE LOCATIONS TAKEN AFTER COMPLETION OF PRODUCTION TESTING, APRIL 1971, GARFIELD COUNTY, COLORADO

4203801 10/12/95



Metric equivalents	
inches (in.)	centimeters (cm)
1 in.	2.54 cm
2 in.	5.08 cm
3 in.	7.62 cm
5 in.	12.70 cm
6 in.	15.24 cm
7 in.	17.78 cm
9 in.	22.86 cm
10 in.	25.40 cm
11 in.	27.94 cm
14 in.	35.56 cm
20 in.	50.80 cm
28 in.	71.12 cm
30 in.	76.20 cm
34 in.	86.36 cm
38 in.	96.52 cm
42 in.	106.68 cm
46 in.	116.84 cm

NOT TO SCALE



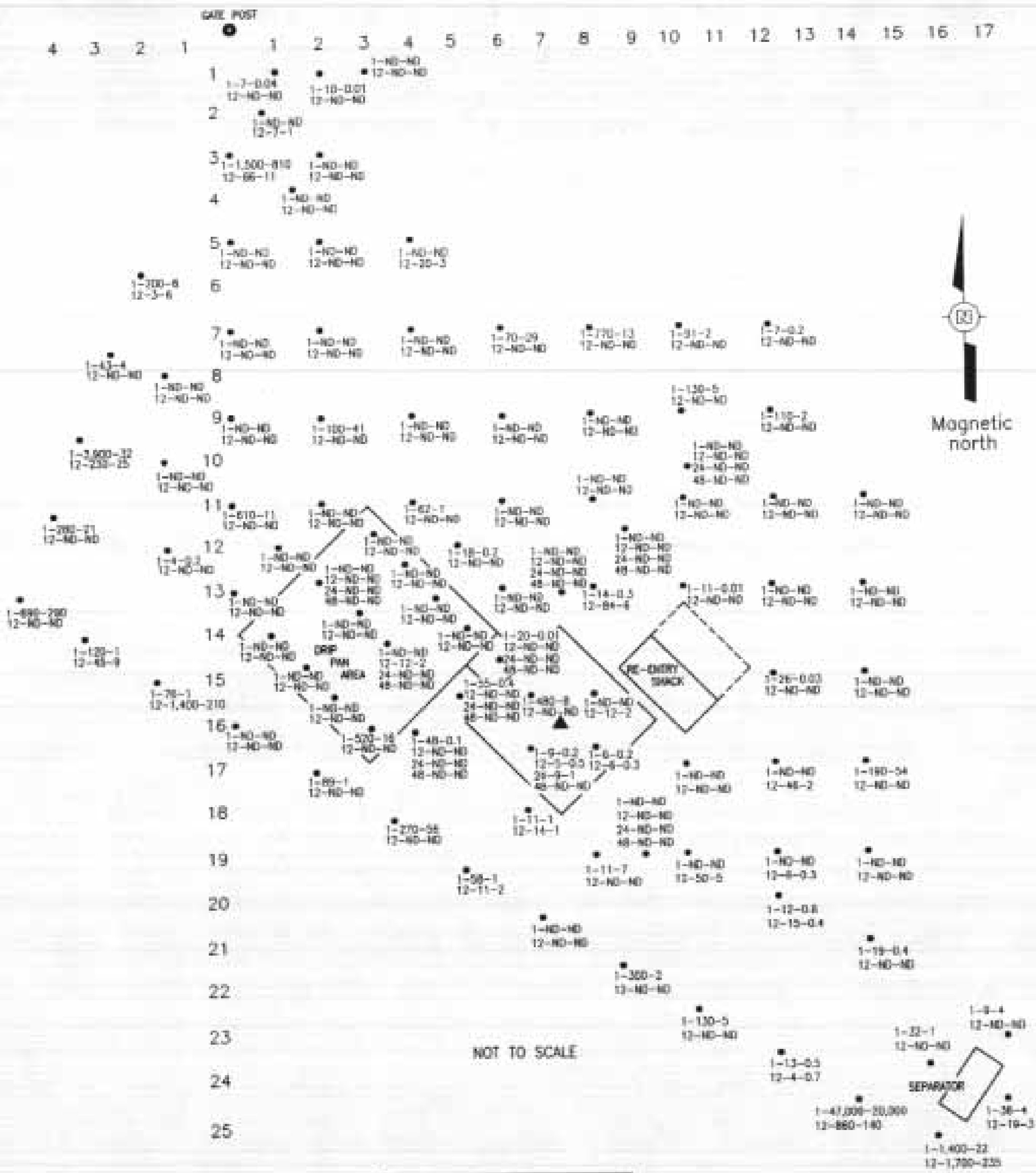
LEGEND

■ Flare stack
ND Nondetectable
^3H Tritium
• Sample location

1-11-48
└ Picocurie/gram ^3H
└ Picocurie/milliliter ^3H in soil moisture
└ Depth in inches

Source: Rulison Radiation Contamination Clearance Report, 1977

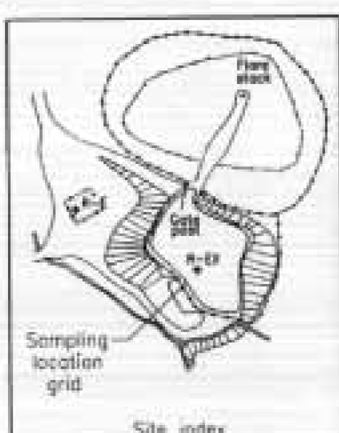
FIGURE 2-8
PROJECT RULISON SOIL SAMPLE LOCATIONS TAKEN AFTER COMPLETION OF PRODUCTION TESTING, APRIL 1971, GARFIELD COUNTY, COLORADO



WELLHEAD LOCATION

107° 56' 53" W longitude
39° 24' 21" N latitude

Metric equivalents	
inches (in.)	centimeters (cm)
1 in.	2.54 cm
12 in.	30.48 cm
24 in.	60.96 cm
48 in.	121.92 cm



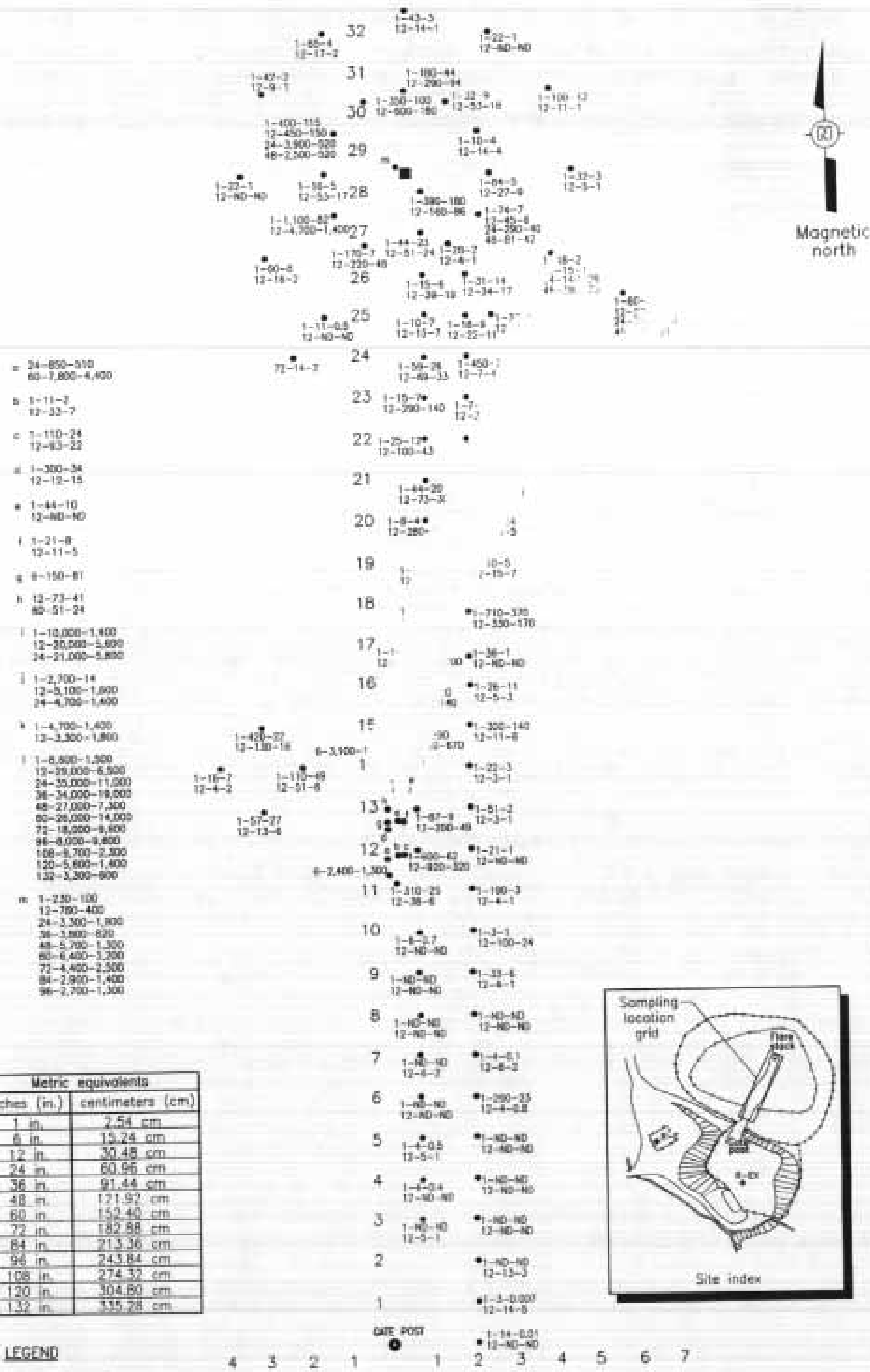
LEGEND

- Building
- ▲ Re-entry wellhead
- ND Nondetectable
- ^3H Tritium
- • Sample location

1-11-48
- ← Picocurie/gram ^3H
- Picocurie/milliliter ^3H in soil moisture
- Depth in inches

Note: Grid represents 3.05-meter (10-foot) intervals
Source: Rulison Radiation Contamination Clearance Report, 1977

FIGURE 2-9
PROJECT RULISON SOIL SAMPLE LOCATIONS TAKEN AT TIME OF SITE CLEANUP, JULY 1972, GARFIELD COUNTY, COLORADO



Metric equivalents	
inches (in.)	centimeters (cm)
1 in.	2.54 cm
6 in.	15.24 cm
12 in.	30.48 cm
24 in.	60.96 cm
36 in.	91.44 cm
48 in.	121.92 cm
60 in.	152.40 cm
72 in.	182.88 cm
84 in.	213.36 cm
96 in.	243.84 cm
108 in.	274.32 cm
120 in.	304.80 cm
132 in.	335.28 cm

LEGEND

- ■ Flare Stack
- ND Nondetectable
- ^3H Tritium
- • Sample location

1-11-48
- Picocurie/gram ^3H
- Picocurie/milliliter ^3H in soil moisture
- Depth in inches

Note: Grid represents 3.05-meter (10-foot) intervals

Source: Rulison Radiation Contamination Clearance Report, 1977

FIGURE 2-10
PROJECT RULISON SOIL SAMPLE LOCATIONS TAKEN AT TIME OF SITE CLEANUP, JULY 1972, GARFIELD COUNTY, COLORADO

Table 2-1
Tritium in Rulison Soil Moisture Postproduction Test - April 23, 1971
(Page 1 of 4)

Grid Coordinates[a] degrees, meters (feet)	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
000°, 6.10 (20)	2.54 (1)	390	100
000°, 6.10 (20)	7.62 (3)	980	250
000°, 6.10 (20)	15.24 (6)	480	120
000°, 6.10 (20)	0 to 5.08 (0 to 2)	940	250
000°, 6.10 (20)	5.08 to 10.16 (2 to 4)	540	130
000°, 6.10 (20)	10.16 to 15.24 (4 to 6)	260	68
000°, 6.10 (20)	15.24 to 20.32 (6 to 8)	220	55
000°, 6.10 (20)	20.32 to 25.40 (8 to 10)	260	62
000°, 6.10 (20)	25.40 to 30.48 (10 to 12)	210	50
000°, 12.19 (40)	2.54 (1)	1,700	420
000°, 12.19 (40)	0 to 5.08 (0 to 2)	400	94
000°, 12.19 (40)	5.08 to 10.16 (2 to 4)	510	120
000°, 12.19 (40)	10.16 to 15.24 (4 to 6)	750	180
000°, 12.19 (40)	15.24 to 20.32 (6 to 8)	660	150
000°, 12.19 (40)	20.32 to 25.40 (8 to 10)	580	130
000°, 12.19 (40)	25.40 to 30.48 (10 to 12)	510	110
000°, 24.38 (80)	2.54 (1)	180	44
000°, 24.38 (80)	0 to 5.08 (0 to 2)	350	88
000°, 24.38 (80)	5.08 to 10.16 (2 to 4)	510	110
000°, 24.38 (80)	10.16 to 15.24 (4 to 6)	500	100
000°, 24.38 (80)	15.24 to 20.32 (6 to 8)	370	88
000°, 24.38 (80)	20.32 to 25.40 (8 to 10)	280	57
000°, 24.38 (80)	25.40 to 30.48 (10 to 12)	210	46
000°, 36.58 (120)	2.54 (1)	650	230
000°, 36.58 (120)	0 to 5.08 (0 to 2)	410	110
000°, 36.58 (120)	5.08 to 10.16 (2 to 4)	340	71
000°, 36.58 (120)	10.16 to 15.24 (4 to 6)	290	68
000°, 36.58 (120)	15.24 to 20.32 (6 to 8)	320	76
000°, 36.58 (120)	20.32 to 25.40 (8 to 10)	250	62
000°, 36.58 (120)	25.40 to 30.48 (10 to 12)	210	49
000°, 60.96 (200)	2.54 (1)	130	43
000°, 152.40 (500)	2.54 (1)	39	9.8
000°, 152.40 (500)	15.24 (6)	20	3.4
000°, 304.80 (1,000)	2.54 (1)	19	4.1
000°, 304.80 (1,000)	15.24 (6)	12	2.7
030°, 6.10 (20)	2.54 (1)	510	130
030°, 12.19 (40)	2.54 (1)	140	34
030°, 60.96 (200)	2.54 (1)	79	18
030°, 24.38 (80)	2.54 (1)	97	23

Refer to footnotes at end of table.

Table 2-1
Tritium in Rulison Soil Moisture Postproduction Test - April 23, 1971
(Page 2 of 4)

Grid Coordinates[a] degrees, meters (feet)	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
030°, 36.58 (120)	2.54 (1)	180	42
060°, 6.10 (20)	2.54 (1)	760	210
060°, 24.38 (80)	2.54 (1)	120	20
060°, 36.58 (120)	2.54 (1)	300	120
060°, 60.96 (200)	2.54 (1)	70	24
090°, 6.10 (20)	2.54 (1)	300	76
090°, 12.19 (40)	2.54 (1)	160	44
090°, 24.38 (80)	2.54 (1)	130	36
090°, 36.58 (120)	2.54 (1)	260	82
090°, 60.96 (200)	2.54 (1)	46	16
090°, 152.40 (500)	2.54 (1)	2,400	630
090°, 152.40 (500)	15.24 (6)	53	14
090°, 304.80 (1,000)	2.54 (1)	11	3.2
090°, 304.80 (1,000)	15.24 (6)	13	3.3
120°, 6.10 (20)	2.54 (1)	3,800	970
120°, 12.19 (40)	2.54 (1)	2,100	550
120°, 24.38 (80)	2.54 (1)	1,400	370
120°, 36.58 (120)	2.54 (1)	190	56
120°, 60.96 (200)	2.54 (1)	380	55
150°, 6.10 (20)	2.54 (1)	130	29
150°, 12.19 (40)	2.54 (1)	710	160
150°, 24.38 (80)	2.54 (1)	200	54
150°, 36.58 (120)	0 to 2.54 (0 to 1)	210	65
150°, 36.58 (120)	2.54 to 5.08 (1 to 2)	180	53
150°, 36.58 (120)	5.08 to 10.16 (2 to 4)	220	62
150°, 36.58 (120)	10.16 to 20.32 (4 to 8)	290	87
150°, 36.58 (120)	20.32 to 30.48 (8 to 12)	420	110
150°, 36.58 (120)	30.48 to 40.64 (12 to 16)	340	84
150°, 36.58 (120)	40.64 to 50.80 (16 to 20)	130	25
150°, 36.58 (120)	50.80 to 60.96 (20 to 24)	79	16
150°, 36.58 (120)	60.96 to 71.12 (24 to 28)	75	15
150°, 36.58 (120)	71.12 to 81.28 (28 to 32)	110	19
150°, 36.58 (120)	81.28 to 91.44 (32 to 36)	110	22
150°, 36.58 (120)	91.44 to 101.60 (36 to 40)	87	19
150°,36.58 (120)	101.60 to 111.76 (40 to 44)	62	14
150°, 36.58 (120)	111.76 to 121.92 (44 to 48)	59	13
150°, 60.96 (200)	2.54 (1)	190	34
180°, 1.52 (5)	2.54 (1)	7,400	1600
180°, 1.52 (5)	15.24 (6)	3,000	700

Refer to footnotes at end of table.

Table 2-1
Tritium in Rulison Soil Moisture Postproduction Test - April 23, 1971
(Page 3 of 4)

Grid Coordinates[a] degrees, meters (feet)	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
180°, 6.10 (20)	2.54 (1)	2,800	620
180°, 12.19 (40)	2.54 (1)	170	33
180°, 24.38 (80)	2.54 (1)	410	85
180°, 36.58 (120)	2.54 (1)	1,500	300
180°, 60.96 (200)	2.54 (1)	79	8.7
180°, 152.40 (500)	2.54 (1)	1,900	650
180°, 152.40 (500)	15.24 (6)	6	1.1
180°, 304.80 (1,000)	2.54 (1)	57	14
180°, 304.80 (1,000)	15.24 (6)	6	1.2
240°, 4.27 (14)	2.54 (1)	2,800	730
240°, 6.10 (20)	2.54 (1)	680	180
240°, 12.19 (40)	2.54 (1)	270	62
240°, 24.38 (80)	2.54 (1)	130	28
240°, 36.58 (120)	2.54 (1)	34	7
240°, 60.96 (200)	2.54 (1)	77	8.1
270°, 6.10 (20)	2.54 (1)	1,600	410
270°, 12.19 (40)	2.54 (1)	240	68
270°, 24.38 (80)	2.54 (1)	240	60
270°, 36.58 (120)	2.54 (1)	230	53
270°, 60.96 (200)	2.54 (1)	37	10
270°, 152.40 (500)	2.54 (1)	8	1.2
270°, 152.40 (500)	15.24 (6)	26	5.8
270°, 304.80 (1,000)	2.54 (1)	12	2.6
270°, 304.80 (1,000)	15.24 (6)	27	5.6
300°, 6.10 (20)	2.54 (1)	1,200	310
300°, 12.19 (40)	2.54 (1)	200	54
300°, 24.38 (80)	2.54 (1)	340	76
300°, 36.58 (120)	2.54 (1)	88	21
300°, 60.96 (200)	2.54 (1)	140	32
330°, 6.10 (20)	2.54 (1)	1,900	500
330°, 6.10 (20)	7.62 (3)	5,700	1400
330°, 6.10 (20)	15.24 (6)	6,800	1600
330°, 6.10 (20)	2.54 (1)	1,400	350
330°, 6.10 (20)	5.08 (2)	790	200
330°, 6.10 (20)	5.08 to 10.16 (2 to 4)	1,900	480
330°, 6.10 (20)	10.16 to 20.32 (4 to 8)	4,500	1100
330°, 6.10 (20)	20.32 to 30.48 (8 to 12)	3,800	900
330°, 6.10 (20)	30.48 to 40.64 (12 to 16)	3,100	710
330°, 6.10 (20)	40.64 to 60.96 (16 to 24)	1,900	440

Refer to footnotes at end of table.

Table 2-1
Tritium in Rulison Soil Moisture Postproduction Test - April 23, 1971
(Page 4 of 4)

Grid Coordinates[a] degrees, meters (feet)	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
330°, 6.10 (20)	60.96 to 71.12 (24 to 28)	860	200
330°, 6.10 (20)	71.12 to 81.28 (28 to 32)	190	43
330°, 6.10 (20)	81.28 to 91.44 (32 to 36)	250	57
330°, 6.10 (20)	91.44 to 101.60 (36 to 40)	40	8.1
330°, 6.10 (20)	101.60 to 111.76 (40 to 44)	280	60
330°, 6.10 (20)	111.76 to 121.92 (44 to 48)	250	47
330°, 12.19 (40)	2.54 (1)	160	44
330°, 24.38 (80)	2.54 (1)	230	56

Source: Eberline, 1977

[a]Radial coordinates are in degrees and meters (feet) referenced to flare stack.

[b]Sampling depth increments, when not otherwise indicated, are 2.54 cm (i.e., 2.54 cm is from 0 to 2.54 cm, 15.24 cm is from 12.70 to 15.24 cm, etc.) (1" [i.e., 1" is from 0 to 1", 6" is from 5" to 6", etc.]).

[c]Picocurie per milliliter

[d]Picocurie per gram

their side walls at measured depths. Access to sampling points under waste water storage tanks was attained by drilling horizontally under each tank from a trench at its perimeter. Access to sampling points under drip pans was attained by cutting through the pan or by moving it to one side.

Each sample was weighed wet, as collected, and was then dried in an electric oven for 15 hours at 180 degrees centigrade. After drying, the sample was again weighed. Wet and dry weights were recorded for each sample, and the percentages of moisture were calculated. Where possible, a 5-mL aliquot of soil moisture was distilled from each sample. The aliquots were analyzed by liquid scintillation for tritium concentration in pCi/mL. From this, the concentration in picoCuries per gram (pCi/g) was calculated. Results of these analyses are shown in Table 2-2.

Since no soil samples contained tritium above the concentration criterion of 3×10^4 pCi/g, no soil was removed from the area.

Eight randomly located soil samples were collected for pulse height analysis by gamma spectrometry. No radioisotopes other than those naturally occurring were detected.

Vegetation Sampling

A vegetation sample was taken at each cardinal point on a 152-m, a 305-m (500-ft, and a 1,000-ft) arc around the flare stack. Additional vegetation samples were collected at site grid point N-14, W-2, and stack grid points 030º, 5' and 120º, 40'. These samples were collected because of a leak from a water tank and a close proximity to the flare stack. This was the area of highest concentration as indicated by the post-flare sampling.

Vegetation samples were analyzed at Eberline Instrument Corporation's facilities in Albuquerque after the cleanup operation. Each sample was weighed wet and dry, and an aliquot of moisture was distilled from the sample. An aliquot of dry sample was oxidized and condensed to obtain the bound tritium. The results of these analyses are shown in Table 2-3.

Water Sampling

Prior to completion of the cleanup, water samples were taken from each of two local springs at the site. One was located just off the southeast corner of the R-EX well pad, the other was on the upper side of the road about 274 m (300 yards) downhill from the pad. Both samples were analyzed by liquid scintillation, and no tritium was detected.

Table 2-2
Tritium in Rulison Soil Moisture - July 1972
(Page 1 of 9)

Grid Coordinates[a]	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
N-0, E-2	2.54 (1)	14	0.01
N-0, E-2	30.48 (12)	(5) ND	ND
N-1, E-2	2.54 (1)	3.2	0.007
N-1, E-2	30.48 (12)	14	5.2
N-2, E-2	2.54 (1)	ND	ND
N-2, E-2	30.48 (12)	13	2.9
N-3, E-.7	2.54 (1)	ND	ND
N-3, E-.7	30.48 (12)	5.2	1.1
N-3, E-2	2.54 (1)	ND	ND
N-3, E-2	30.48 (12)	ND	ND
N-4, E-.7	2.54 (1)	3.8	0.4
N-4, E-.27	30.48 (12)	ND	ND
N-4, E-2	2.54 (1)	ND	ND
N-4, E-2	30.48 (12)	ND	ND
N-5, E-.7	2.54 (1)	4.3	0.5
N-5, E-.7	30.48 (12)	4.9	0.95
N-5, E-2	2.54 (1)	ND	ND
N-5, E-2	30.48 (12)	ND	ND
N-6, E-.7	2.54 (1)	ND	ND
N-6, E-2	2.54 (1)	290	23
N-6, E-2	30.48 (12)	4	0.8
N-7, E-.7	2.54 (1)	ND	ND
N-7, E-.7	30.48 (12)	5.9	2
N-7, E-2	2.54 (1)	3.9	0.1
N-7, E-2	30.48 (12)	8.3	1.8
N-8, E-.7	2.54 (1)	ND	ND
N-8, E-.7	30.48 (12)	ND	ND
N-8, E-2	2.54 (1)	ND	ND
N-8, E-2	30.48 (12)	ND	ND
N-9, E-.7	2.54 (1)	ND	ND
N-9, E-.7	30.48 (12)	ND	ND
N-9, E-2	2.54 (1)	33	5.8
N-9, E-2	30.48 (12)	4.2	0.9
N-10, E-.7	2.54 (1)	6.1	0.68
N-10, E-.7	30.48 (12)	ND	ND
N-10, E-2	2.54 (1)	2.8	0.08
N-10, E-2	30.48 (12)	100	24
N-11, E-2	2.54 (1)	190	2.8
N-11, E-2	30.48 (12)	4.1	0.9
N-11.2, E-.2	2.54 (1)	310	25
N-11.2, E-.2	30.48 (12)	38	6
N-11.4, E-0	15.24 (6)	2,400	1,300
N-11.8, E-0	60.96 (24)	850	510
N-11.8, E-0	152.40 (60)	7,800	4,400
N-11.9, E-2.8	2.54 (1)	11	2.3
N-11.9, E-2.8	30.48 (12)	33	6.9
N-11.9, E-3.3	2.54 (1)	110	24
N-11.9, E-3.3	30.48 (12)	93	22
N-12, E-.7	2.54 (1)	600	62
N-12, E-.7	30.48 (12)	920	320
N-12, E-2	2.54 (1)	21	1

Refer to footnotes at end of table.

Table 2-2
Tritium in Rulison Soil Moisture - July 1972
(Page 2 of 9)

Grid Coordinates[a]	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
N-12, E-2	30.48 (12)	ND	ND
N-12.5, E-0	2.54 (1)	300	34
N-12.5, E-0	30.48 (12)	120	15
N-12.7, E-0	15.24 (6)	150	81
N-12.7, E-2.8	2.54 (1)	44	10
N-12.7, E-2.8	30.48 (12)	ND	ND
N-12.7, E-3.3	2.54 (1)	21	8.3
N-12.7, E-3.3	30.48 (12)	11	4.7
N-13, E-0	30.48 (12)	73	41
N-13, E-0	152.40 (60)	51	24
N-13, E-.7	2.54 (1)	87	9.3
N-13, E-.7	30.48 (12)	200	49
N-13, E-2	2.54 (1)	51	2.4
N-13, E-2	30.48 (12)	2.9	0.6
N-13, W-3	2.54 (1)	57	27
N-13, W-3	30.48 (12)	13	6.2
N-13.7, E-.1	2.54 (1)	10,000	1,400
N-13.7, E-.1	30.48 (12)	20,000	5,600
N-13.7, E-.1	60.96 (24)	21,000	5,800
N-13.7, E-.6	2.54 (1)	2,700	150
N-13.7, E-.6	30.48 (12)	5,100	1,600
N-13.7, E-.6	60.96 (24)	4,700	1,400
N-14, E-0	2.54 (1)	4,700	1,400
N-14, E-0	30.48 (12)	3,300	1,800
N-14, E-2	2.54 (1)	22	0.3
N-14, E-2	30.48 (12)	3.3	0.7
N-14.2, E-.7	2.54 (1)	8,600	1,500
N-14.2, E-.7	30.48 (12)	29,000	6,500
N-14.2, E-.7	60.96 (24)	35,000	11,000
N-14.2, E-.7	91.44 (36)	34,000	19,000
N-14.2, E-.7	121.92 (48)	27,000	7,300
N-14.2, E-.7	152.40 (60)	26,000	14,000
N-14.2, E-.7	182.88 (72)	18,000	9,600
N-14.2, E-.7	243.84 (96)	8,000	4,500
N-14.2, E-.7	274.32 (108)	9,700	2,300
N-14.2, E-.7	304.80 (120)	5,600	1,400
N-14.2, E-.7	335.28 (132)	3,300	600
N-14, W-2	2.54 (1)	110	49
N-14, W-2	30.48 (12)	51	7.7
N-14, W-4	2.54 (1)	16	7.3
N-14, W-4	30.48 (12)	4.4	2.1
N-14.2, E-0	15.24 (6)	3,100	1,700
N-15, E-1	2.54 (1)	650	290
N-15, E-1	30.48 (12)	1,400	670
N-15, E-2	2.54 (1)	300	140
N-15, E-2	30.48 (12)	11	6
N-15, W-3	2.54 (1)	420	22
N-15, W-3	30.48 (12)	130	16
N-16, E-1	2.54 (1)	270	120
N-16, E-1	30.48 (12)	260	140
N-16, E-2	2.54 (1)	26	11

Refer to footnotes at end of table.

Table 2-2
Tritium in Rulison Soil Moisture - July 1972
(Page 3 of 9)

Grid Coordinates[a]	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
N-16, E-2	30.48 (12)	5.3	2.6
N-17, E-1	2.54 (1)	160	75
N-17, E-1	30.48 (12)	17,000	6,000
N-16.7, E-2	2.54 (1)	36	0.9
N-16.7, E-2	30.48 (12)	ND	ND
N-17.8, E-2	2.54 (1)	710	370
N-17.8, E-2	30.48 (12)	330	170
N-18, E-1	2.54 (1)	11	5.3
N-18, E-1	30.48 (12)	80	41
N-19, E-1	2.54 (1)	25	12
N-19, E-1	30.48 (12)	22	11
N-19, E-2	2.54 (1)	10	4.5
N-19, E-2	30.48 (12)	15	7.1
N-20, E-1	2.54 (1)	8.4	3.9
N-20, E-1	30.48 (12)	280	130
N-20, E-2	2.54 (1)	71	34
N-20, E-2	30.48 (12)	10	4.6
N-21, E-1	2.54 (1)	44	20
N-21, E-1	30.48 (12)	73	30
N-21, E-2	2.54 (1)	56	25
N-21, E-2	30.48 (12)	ND	ND
N-22, E-1	2.54 (1)	25	12
N-22, E-1	30.48 (12)	100	43
N-22, E-2	2.54 (1)	8.4	3.9
N-22, E-2	30.48 (12)	23	12
N-23, E-1	2.54 (1)	15	6.8
N-23, E-1	30.48 (12)	290	140
N-23, E-2	2.54 (1)	6.6	3.2
N-23, E-2	30.48 (12)	3.4	1.7
N-24, E-1	2.54 (1)	59	26
N-24, E-1	30.48 (12)	69	33
N-24, E-2	2.54 (1)	450	220
N-24, E-2	30.48 (12)	6.9	3.6
N-24, W-2	182.88 (72)	14	2.1
N-25, E-1	2.54 (1)	16	7.1
N-25, E-1	30.48 (12)	15	7.3
N-25, E-2	2.54 (1)	18	8.7
N-25, E-2	30.48 (12)	22	11
N-26, E-1	2.54 (1)	15	6.4
N-26, E-1	30.48 (12)	39	19
N-26, E-2	2.54 (1)	31	14
N-26, E-2	30.48 (12)	34	17
N-27, E-1	2.54 (1)	44	23
N-27, E-1	30.48 (12)	51	24
N-28, E-1	2.54 (1)	390	180
N-28, E-1	30.48 (12)	160	86
000°, 6.10 (20)	2.54 (1)	180	44
000°, 6.10 (20)	30.48 (12)	290	94
000°, 12.19 (40)	2.54 (1)	43	3.2

Refer to footnotes at end of table.

Table 2-2
Tritium in Rulison Soil Moisture - July 1972
(Page 4 of 9)

Grid Coordinates[a]	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
000°, 12.19 (40)	30.48 (12)	14	1.1
030°, 6.10 (20)	2.54 (1)	32	8.5
030°, 6.10 (20)	30.48 (12)	53	18
030°, 12.19 (40)	2.54 (1)	22	1.1
030°, 12.19 (40)	30.48 (12)	ND	ND
060°, 6.10 (20)	2.54 (1)	10	3.5
060°, 6.10 (20)	30.48 (12)	14	4.3
060°, 12.19 (40)	2.54 (1)	100	12
060°, 12.19 (40)	30.48 (12)	11	0.75
090°, 6.10 (20)	2.54 (1)	84	4.9
090°, 6.10 (20)	30.48 (12)	27	8.6
090°, 12.19 (40)	2.54 (1)	32	3
090°, 12.19 (40)	30.48 (12)	4.8	0.55
120°, 6.10 (20)	2.54 (1)	74	7.3
120°, 6.10 (20)	30.48 (12)	45	6
120°, 6.10 (20)	60.96 (24)	290	40
120°, 6.10 (20)	121.92 (48)	81	42
120°, 12.19 (40)	2.54 (1)	18	2
120°, 12.19 (40)	30.48 (12)	15	1.4
120°, 12.19 (40)	60.96 (24)	140	28
120°, 12.19 (40)	121.92 (48)	380	73
120°, 18.29 (60)	2.54 (1)	60	8.4
120°, 18.29 (60)	30.48 (12)	27	3.6
120°, 18.29 (60)	60.96 (24)	290	160
120°, 18.29 (60)	121.92 (48)	290	61
150°, 6.10 (20)	2.54 (1)	28	2.3
150°, 6.10 (20)	30.48 (12)	3.6	0.6
150°, 12.19 (40)	2.54 (1)	37	5.4
150°, 12.19 (40)	30.48 (12)	21	3.1
210°, 6.10 (20)	2.54 (1)	170	7.1
210°, 6.10 (20)	30.48 (12)	220	48
210°, 12.19 (40)	2.54 (1)	11	0.46
210°, 12.19 (40)	30.48 (12)	ND	ND
240°, 6.10 (20)	2.54 (1)	1,100	82
240°, 6.10 (20)	30.48 (12)	4,700	1,400
240°, 12.19 (40)	2.54 (1)	60	7.6
240°, 12.19 (40)	30.48 (12)	16	2
270°, 6.10 (20)	2.54 (1)	16	5.3
270°, 6.10 (20)	30.48 (12)	53	17
270°, 12.19 (40)	2.54 (1)	22	0.93
270°, 12.19 (40)	30.48 (12)	ND	ND
300°, 0.91 (3)	2.54 (1)	230	100
300°, 0.91 (3)	30.48 (12)	780	400

Refer to footnotes at end of table.

Table 2-2
Tritium in Rulison Soil Moisture - July 1972
(Page 5 of 9)

Grid Coordinates[a]	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
300°, 0.91 (3)	60.96 (24)	3,300	1,900
300°, 0.91 (3)	91.44 (36)	3,800	820
300°, 0.91 (3)	121.92 (48)	5,700	1,300
300°, 0.91 (3)	152.40 (60)	6,400	3,200
300°, 0.91 (3)	182.88 (72)	4,400	2,500
300°, 0.91 (3)	213.36 (84)	2,900	1,400
300°, 0.91 (3)	243.84 (96)	2,700	1,300
300°, 6.10 (20)	2.54 (1)	400	115
300°, 6.10 (20)	30.48 (12)	450	150
300°, 6.10 (20)	60.96 (24)	3,900	520
300°, 6.10 (20)	121.92 (48)	2,500	520
300°, 12.19 (40)	2.54 (1)	42	2.1
300°, 12.19 (40)	30.48 (12)	8.6	1.2
330°, 6.10 (20)	2.54 (1)	350	100
330°, 6.10 (20)	30.48 (12)	600	180
330°, 12.19 (40)	2.54 (1)	65	4.1
330°, 12.19 (40)	30.48 (12)	17	1.5
S-1, E-1	2.54 (1)	6.5	0.04
S-1, E-1	30.48 (12)	ND	ND
S-1, E-2	2.54 (1)	10	0.006
S-1, E-2	30.48 (12)	ND	ND
S-1, E-3	2.54 (1)	ND	ND
S-1, E-3	30.48 (12)	ND	ND
S-2, W-.7	2.54 (1)	ND	ND
S-2, W-.7	30.48 (12)	7.3	1.2
S-3, E-0	2.54 (1)	1,500	810
S-3, E-0	30.48 (12)	66	11
S-3, E-2	2.54 (1)	ND	ND
S-3, E-2	30.48 (12)	ND	ND
S-3.8, E-1.4	2.54 (1)	ND	ND
S-3.8, E-1.4	30.48 (12)	ND	ND
S-5, E-0	2.54 (1)	ND	ND
S-5, E-0	30.48 (12)	ND	ND
S-5, E-2	2.54 (1)	ND	ND
S-5, E-2	30.48 (12)	ND	ND
S-5, E-4	2.54 (1)	ND	ND
S-5, E-4	30.48 (12)	20	3.4
S-5.7, W-2	2.54 (1)	200	7.5
S-5.7, W-2	30.48 (12)	2.9	0.56
S-7, E-0	2.54 (1)	ND	ND
S-7, E-0	30.48 (12)	ND	ND
S-7, E-2	2.54 (1)	ND	ND
S-7, E-2	30.48 (12)	ND	ND
S-7, E-4	2.54 (1)	ND	ND
S-7, E-4	30.48 (12)	ND	ND
S-7, E-6	2.54 (1)	70	29
S-7, E-6	30.48 (12)	ND	ND

Refer to footnotes at end of table.

Table 2-2
Tritium in Rulison Soil Moisture - July 1972
(Page 6 of 9)

Grid Coordinates[a]	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
S-7, E-8	2.54 (1)	770	13
S-7, E-8	30.48 (12)	ND	ND
S-7, E-10	2.54 (1)	91	2.3
S-7, E-10	30.48 (12)	ND	ND
S-7, E-12	2.54 (1)	6.7	0.17
S-7, E-12	30.48 (12)	ND	ND
S-7.5, W-2.7	2.54 (1)	43	0.37
S-7.5, W-2.7	30.48 (12)	ND	ND
S-8, W-1.5	2.54 (1)	ND	ND
S-8, W-1.5	30.48 (12)	ND	ND
S-9, E-0	2.54 (1)	ND	ND
S-9, E-0	30.48 (12)	ND	ND
S-9, E-2	2.54 (1)	100	41
S-9, E-2	30.48 (12)	ND	ND
S-9, E-4	2.54 (1)	ND	ND
S-9, E-4	30.48 (12)	ND	ND
S-9, E-6	2.54 (1)	ND	ND
S-9, E-6	30.48 (12)	ND	ND
S-9, E-8	2.54 (1)	ND	ND
S-9, E-8	30.48 (12)	ND	ND
S-9, E-10	2.54 (1)	130	4.5
S-9, E-10	30.48 (12)	ND	ND
S-9, E-12	2.54 (1)	110	2.1
S-9, E-12	30.48 (12)	ND	ND
S-9.4, W-3.4	2.54 (1)	3,900	32
S-9.4, W-3.4	30.48 (12)	230	25
S-10, W-1.5	2.54 (1)	ND	ND
S-10, W-1.5	30.48 (12)	ND	ND
S-10.3, E-10.1	2.54 (1)	ND	ND
S-10.3, E-10.1	30.48 (12)	ND	ND
S-10.3, E-10.1	60.96 (24)	ND	ND
S-10.3, E-10.1	121.92 (48)	ND	ND
S-11, E-0	2.54 (1)	610	11
S-11, E-0	30.48 (12)	ND	ND
S-11, E-2	2.54 (1)	ND	ND
S-11, E-2	30.48 (12)	ND	ND
S-11, E-4	2.54 (1)	62	0.98
S-11, E-4	30.48 (12)	ND	ND
S-11, E-6	2.54 (1)	ND	ND
S-11, E-6	30.48 (12)	ND	ND
S-11, E-8	2.54 (1)	ND	ND
S-11, E-8	30.48 (12)	ND	ND
S-11, E-10	2.54 (1)	ND	ND
S-11, E-10	30.48 (12)	ND	ND
S-11, E-12	2.54 (1)	ND	ND
S-11, E-12	30.48 (12)	ND	ND
S-11, E-14	2.54 (1)	ND	ND
S-11, E-14	30.48 (12)	ND	ND
S-11.2, W-4	2.54 (1)	280	21
S-11.2, W-4	30.48 (12)	ND	ND
S-11.7, E-3.1	2.54 (1)	ND	ND

Refer to footnotes at end of table.

Table 2-2
Tritium in Rulison Soil Moisture - July 1972
(Page 7 of 9)

Grid Coordinates[a]	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
S-11.7, E-3.1	30.48 (12)	ND	ND
S-11.7, E-8.7	2.54 (1)	ND	ND
S-11.7, E-8.7	30.48 (12)	ND	ND
S-11.7, E-8.7	60.96 (24)	ND	ND
S-11.7, E-8.7	121.92 (48)	ND	ND
S-12, E-1	2.54 (1)	ND	ND
S-12, E-1	30.48 (12)	ND	ND
S-12, E-5	2.54 (1)	18	0.2
S-12, E-5	30.48 (12)	ND	ND
S-12, W-1.5	2.54 (1)	3.8	0.2
S-12, W-1.5	30.48 (12)	ND	ND
S-12.4, E-3.8	2.54 (1)	ND	ND
S-12.4, E-3.8	30.48 (12)	ND	ND
S-12.8, E-1.9	2.54 (1)	ND	ND
S-12.8, E-1.9	30.48 (12)	ND	ND
S-12.8, E-1.9	60.96 (24)	ND	ND
S-12.8, E-1.9	121.92 (48)	ND	ND
S-13, E-0	2.54 (1)	ND	ND
S-13, E-0	30.48 (12)	ND	ND
S-13, E-6	2.54 (1)	ND	ND
S-13, E-6	30.48 (12)	ND	ND
S-13, E-8	2.54 (1)	14	0.32
S-13, E-8	30.48 (12)	84	6.3
S-13, E-10	2.54 (1)	1	0.01
S-13, E-10	30.48 (12)	ND	ND
S-13, E-12	2.54 (1)	ND	ND
S-13, E-12	30.48 (12)	ND	ND
S-13, E-14	2.54 (1)	ND	ND
S-13, E-14	30.48 (12)	ND	ND
S-13.1, E-7.3	2.54 (1)	ND	ND
S-13.1, E-7.3	30.48 (12)	ND	ND
S-13.1, E-7.3	60.96 (24)	ND	ND
S-13.1, E-7.3	121.92 (48)	ND	ND
S-13.1, W-4.8	2.54 (1)	690	290
S-13.1, W-4.8	30.48 (12)	ND	ND
S-13.2, E-4.5	2.54 (1)	ND	ND
S-13.2, E-4.5	30.48 (12)	ND	ND
S-13.5, E-2.8	2.54 (1)	ND	ND
S-13.5, E-2.8	30.48 (12)	ND	ND
S-13.9, E-5.2	2.54 (1)	ND	ND
S-13.9, E-5.2	30.48 (12)	ND	ND
S-14, E-.8	2.54 (1)	ND	ND
S-14, E-.8	30.48 (12)	ND	ND
S-14, W-3.4	2.54 (1)	120	1.1
S-14, W-3.4	30.48 (12)	45	8.5
S-14.2, E-3.4	2.54 (1)	ND	ND
S-14.2, E-3.4	30.48 (12)	12	1.6
S-14.2, E-3.4	60.96 (24)	ND	ND
S-14.2, E-3.4	121.92 (48)	ND	ND
S-14.6, E-5.9	2.54 (1)	20	0.1
S-14.6, E-5.9	30.48 (12)	ND	ND

Refer to footnotes at end of table.

Table 2-2
Tritium in Rulison Soil Moisture - July 1972
(Page 8 of 9)

Grid Coordinates[a]	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
S-14.6, E-5.9	60.96 (24)	ND	ND
S-14.6, E-5.9	121.92 (48)	ND	ND
S-14.7, E-1.6	2.54 (1)	ND	ND
S-14.7, E-1.6	30.48 (12)	ND	ND
S-15, E-12	2.54 (1)	26	0.03
S-15, E-12	30.48 (12)	ND	ND
S-15, E-14	2.54 (1)	ND	ND
S-15, E-14	30.48 (12)	ND	ND
S-15, W-1.8	2.54 (1)	76	1.4
S-15, W-1.8	30.48 (12)	1,400	210
S-15.4, E-2.2	2.54 (1)	ND	ND
S-15.4, E-2.2	30.48 (12)	ND	ND
S-15.4, E-5	2.54 (1)	55	0.4
S-15.4, E-5	30.48 (12)	ND	ND
S-15.4, E-5	60.96 (24)	ND	ND
S-15.4, E-5	121.92 (48)	ND	ND
S-15.4, E-6.6	2.54 (1)	480	7.6
S-15.4, E-6.6	30.48 (12)	ND	ND
S-15.4, E-8	2.54 (1)	ND	ND
S-15.4, E-8	30.48 (12)	12	2.1
S-16, E-0	2.54 (1)	ND	ND
S-16, E-0	30.48 (12)	ND	ND
S-16.1, E-3	2.54 (1)	520	16
S-16.1, E-3	30.48 (12)	ND	ND
S-16.2, E-4	2.54 (1)	48	1.3
S-16.2, E-4	30.48 (12)	ND	ND
S-16.2, E-4	60.96 (24)	ND	ND
S-16.2, E-4	121.92 (48)	ND	ND
S-16.6, E-6.6	2.54 (1)	8.5	0.2
S-16.6, E-6.6	30.48 (12)	5.3	0.5
S-16.6, E-6.6	60.96 (24)	8.9	0.9
S-16.6, E-6.6	121.92 (48)	ND	ND
S-16.6, E-8	2.54 (1)	5.9	0.24
S-16.6, E-8	30.48 (12)	5.7	0.3
S-17, E-10	2.54 (1)	ND	ND
S-17, E-10	30.48 (12)	ND	ND
S-17, E-12	2.54 (1)	ND	ND
S-17, E-12	30.48 (12)	46	2.4
S-17, E-14	2.54 (1)	190	54
S-17, E-14	30.48 (12)	ND	ND
S-17.1, E-1.8	2.54 (1)	89	1.2
S-17.1, E-1.8	30.48 (12)	ND	ND
S-18, E-6.5	2.54 (1)	11	0.1
S-18, E-6.5	30.48 (12)	14	1.3
S-18.2, E-3.5	2.54 (1)	270	56
S-18.2, E-3.5	30.48 (12)	ND	ND
S-19, E-8	2.54 (1)	11	0.67
S-19, E-8	30.48 (12)	ND	ND
S-19, E-9	2.54 (1)	ND	ND
S-19, E-9	30.48 (12)	ND	ND
S-19, E-9	60.96 (24)	ND	ND

Refer to footnotes at end of table.

Table 2-2
Tritium in Rulison Soil Moisture - July 1972
(Page 9 of 9)

Grid Coordinates[a]	Sampling Depth[b] centimeters (inches)	pCi/ml[c]	pCi/g[d] (soil)
S-19, E-9	121.92 (48)	ND	ND
S-19, E-10	2.54 (1)	ND	ND
S-19, E-10	30.48 (12)	50	4.9
S-19, E-12	2.54 (1)	ND	ND
S-19, E-12	30.48 (12)	5.8	0.28
S-19, E-14	2.54 (1)	ND	ND
S-19, E-14	30.48 (12)	ND	ND
S-19.3, E-5.1	2.54 (1)	58	1.4
S-19.3, E-5.1	30.48 (12)	11	2.3
S-20, E-12	2.54 (1)	12	0.56
S-20, E-12	30.48 (12)	15	0.39
S-20.4, E-6.8	2.54 (1)	ND	ND
S-20.4, E-6.8	30.48 (12)	ND	ND
S-21, E-14	2.54 (1)	19	0.43
S-21, E-14	30.48 (12)	ND	ND
S-21.5, E-8.5	2.54 (1)	300	2.2
S-21.5, E-8.5	30.48 (12)	ND	ND
S-22.5, E-10.2	2.54 (1)	130	0.52
S-22.5, E-10.2	30.48 (12)	ND	ND
S-23.2, E-17	2.54 (1)	9.4	4.1
S-23.2, E-17	30.48 (12)	ND	ND
S-23.5, E-12	2.54 (1)	13	0.54
S-23.5, E-12	30.48 (12)	4.1	0.71
S-23.5, E-12	2.54 (1)	32	1.2
S-23.8, E-15.3	30.48 (12)	ND	ND
S-24.6, E-13.7	2.54 (1)	47,000	20,000
S-24.6, E-13.7	30.48 (12)	860	140
S-24.6, E-17	2.54 (1)	36	0.39
S-24.6, E-17	30.48 (12)	19	3.2
S-25.4, E-15.4	2.54 (1)	1,400	22
S-25.4, E-15.4	30.48 (12)	1,700	235

Source: Eberline, 1977

[a]Cardinal coordinates referenced to entrance gate post scale; 1 unit equals 3.05 meters (10 feet). Radial coordinates are in degrees and meters (feet) referenced to flare stack.

[b]Sampling depth increments are 2.54 cm (i.e., 2.54 cm is from 0 to 2.54 cm, 30.48 is from 27.94 to 30.48 cm, etc.) (1" [i.e., 1" is from 0 to 1", 12" is from 11" to 12", etc.]).

[c]Picocurie per milliliter

[d]Picocurie per gram

Table 2-3
Tritium in Vegetation - July 1972

Grid Coordinates[a] degrees, meters (feet)	Dry/Wet Ratio	Unbound[b]		Bound[c]		Total
		pCi/ml[d] (H2O)[e]	pCi/g[f] (wet)	pCi/ml (H_2O) (water from oxidation)	pCi/g (wet)	pCi/g (wet)
000°, 152.40 (500)	0.38	7	4.3	<31	<1.7	≈ 4.3
000°, 304.80 (1,000)	0.42	7.2	2.8	<8.3	<1.4	≈ 2.8
090°, 152.40 (500)	0.23	4.5	3.5	<32	<1.5	≈ 3.5
090°, 304.80 (1,000)	0.30	8.1	5.7	<33	<1.1	≈ 5.7
180°, 152.40 (500)	0.22	75	58	<16	<0.9	≈ 58
180°, 304.80 (1,000)	0.25	7.1	5.3	<11	<0.8	≈ 5.3
270°, 152.40 (500)	0.19	5.5	4.5	<28	<0.8	≈ 4.5
270°, 304.80 (1,000)	0.25	7.5	5.6	<14	<1.0	≈ 5.6
030°, 1.52 (5)	0.13	170	150	190	5.3	160
120°, 12.19 (40)	0.27	64	47	97	3.6	51
*N-14, W-2	0.22	150	120	41	2.3	120

Source: Eberline, 1977

*West of tank 3, referenced to entrance gate post.

[a]Coordinates are in degrees and meters (feet) referenced to flare stack.

[b]Unbound; tritium in water that was removable by drying the sample in an electric oven for 16 hours.

[c]Bound; tritium converted to water form by oxidizing the dried sample.

[d]Picocurie per milliliter

[e]Water

[f]Picocurie per gram

A Hydrologic Program Advisory Group reviewed the hydrologic monitoring program proposed for the Rulison Site at a meeting in December 1971. They found the program adequate and recommended its immediate initiation. The U.S. Environmental Protection Agency (EPA), Las Vegas, Nevada, has been conducting the monitoring program since that time (ERDA, 1977, p. 33). Sampling locations are presented on Figure 2-11. Analytical results, to date, are given in Appendix A. Results of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Preliminary Assessment prepared by Desert Research Institute (DRI) for the Rulison Site in 1988 recommended that the hydrologic monitoring program be continued and periodically updated as new monitoring wells and hydrologic data become available (p. 3.6.21).

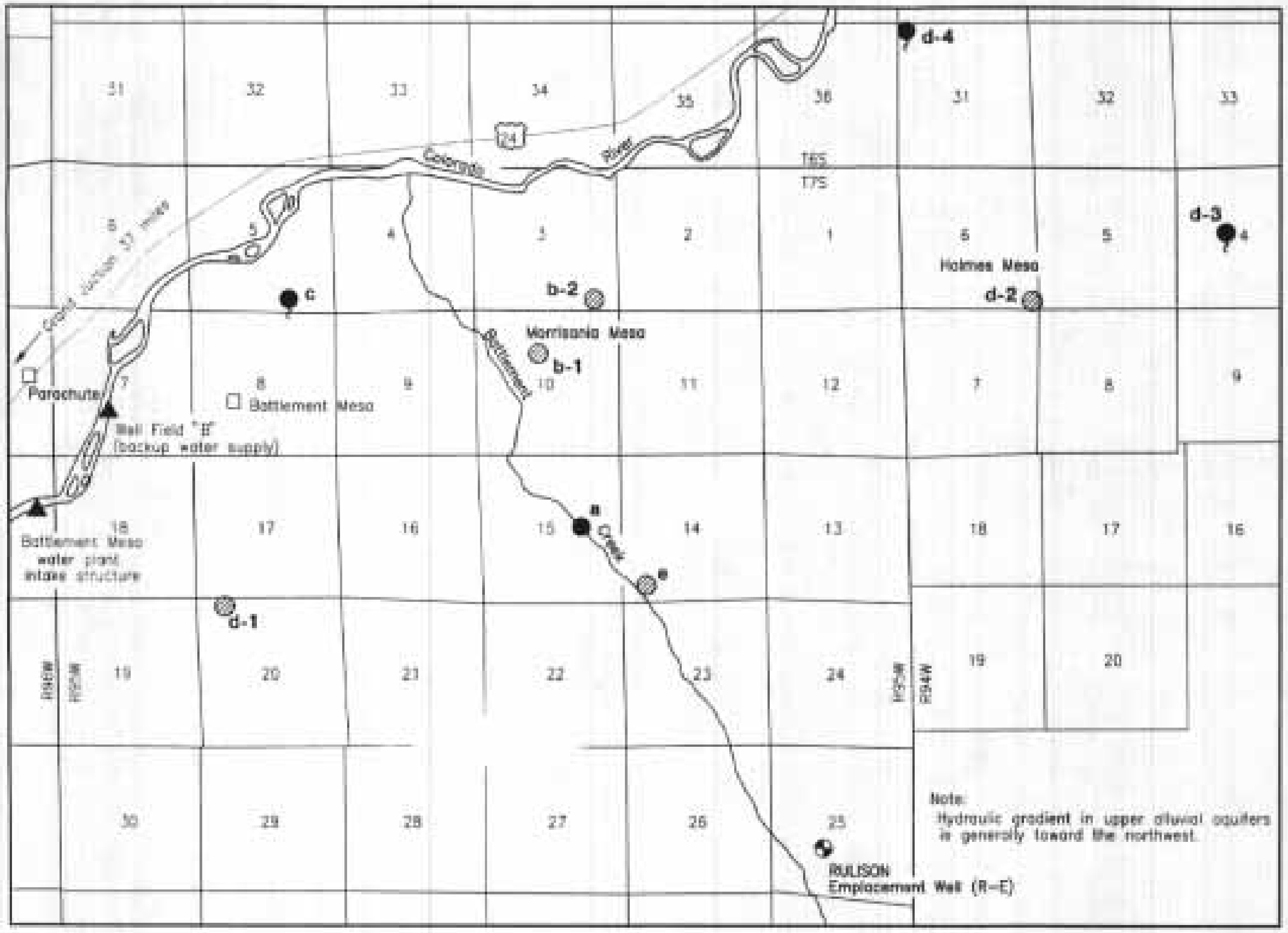
Unless otherwise specified, all samples collected for the hydrologic monitoring program are analyzed for tritium. All samples are also analyzed for gross alpha and gross beta radioactivity and are given a gamma spectral scan. Gross chemistry analyses, comparable to the USGS chemical water quality analyses, will be performed on all samples collected on the initial sample run. Based on the results of those analyses, suspect samples will be analyzed for appropriate, naturally occurring, and man-made isotopes. Splits of each collected sample will be retained by EPA for this purpose until it is demonstrated that the need to retain them does not exist. Each water source is sampled once a year, preferably in the early spring, weather permitting.

2.2.2.4.3 Third Sampling Program

The third sampling program occurred during September 1 to October 12, 1976, and was associated with the plugging of the emplacement and production wells and abandonment of the Rulison Site. It was designed to consider the history of the site and then to complete all requirements for radiation contamination clearance. It primarily consisted of sampling soil at the following locations:

- At two locations that exceeded the current guideline for tritium in the 1972 cleanup
- At the location of a known spill which occurred during the final cleanup
- In the vicinity of decontamination work
- Around the R-E wellhead location

In addition, the creek was sampled above and below the site, and the same two springs (one on the site, one about 274 m [300 yards] down the road) were sampled.



SAMPLING POINTS

a. Battlement Creek at the nearest down gradient accessible location in T7S, R95W, Sec. 15 SE 1/4 NE 1/4.

b. Two private wells in alluvium on Morrisonia Mesa.

Locations:

(1) T7S, R95W, Sec. 10 NE 1/4 SE 1/4 NW 1/4 (Lee Hayward Ranch).

(2) T7S, R95W, Sec. 3 SW 1/4 SE 1/4 SE 1/4 (Glen Schwab Ranch).

c. Water supply springs for Parachute located at T7S, R95W, Sec. 5 SE 1/4 SW 1/4 SE 1/4.

d. Two springs and two wells located in the vicinity of surface ground zero:

(1) Well: T7S, R95W, Sec. 20 NE 1/4 NW 1/4 NW 1/4 (Albert Gardner Ranch).

(2) Well: T7S, R95W, Sec. 6 NE 1/4 SE 1/4 SE 1/4 (Felix Sefcovic Ranch).

(3) Spring: T7S, R94W, Sec. 4 SW 1/4 SE 1/4 NW 1/4 (Bernklau Ranch).

(4) Spring T6S. R94W, Sec. 31 NW 1/4 NW 1/4 NW 1/4 (Potter Ranch).

e. The Austral Oil Co. well located at T7S, R95W, Sec. 14 SW 1/4 SW 1/4

SCALE

0 5,000 10,000 Feet

0 1,500 3,000 Meters

Source: Project Rulison Well Plugging and Site Abandonment Final Report, 1977.

LEGEND

- Well location sampled
- Spring location sampled
- Creek location sampled
- Town
- Well at surface ground zero
- Municipal water supply intake

FIGURE 2-11
PROJECT RULISON, LONG-TERM HYDROLOGIC MONITORING PROGRAM SAMPLING DATA POINTS, DECEMBER 1971, GARFIELD COUNTY, COLORADO

4203B06 08/21/96

Sampling Point N-14.2, E-.7 (Refer to Figure 2-10)

In July 1972, the samples taken at 61- and 91.4-cm (24- and 36-in.) depths contained concentrations of tritium at 35,000 and 34,000 pCi/mL, respectively, in soil moisture. The guideline was 30,000 pCi/mL (ERDA, 1976). This contamination was the result of a known spill from a valve that froze and broke during the 1971 to 1972 winter. This sampling point and the area adjacent to the spill were sampled thoroughly. Results of analyses showed that intervening time and weather had reduced contamination to negligible levels. The sample locations and results of analyses are shown on Figure 2-12 and in Table 2-4.

Sampling Point S-24.6, E-13.7 (Refer to Figure 2-9)

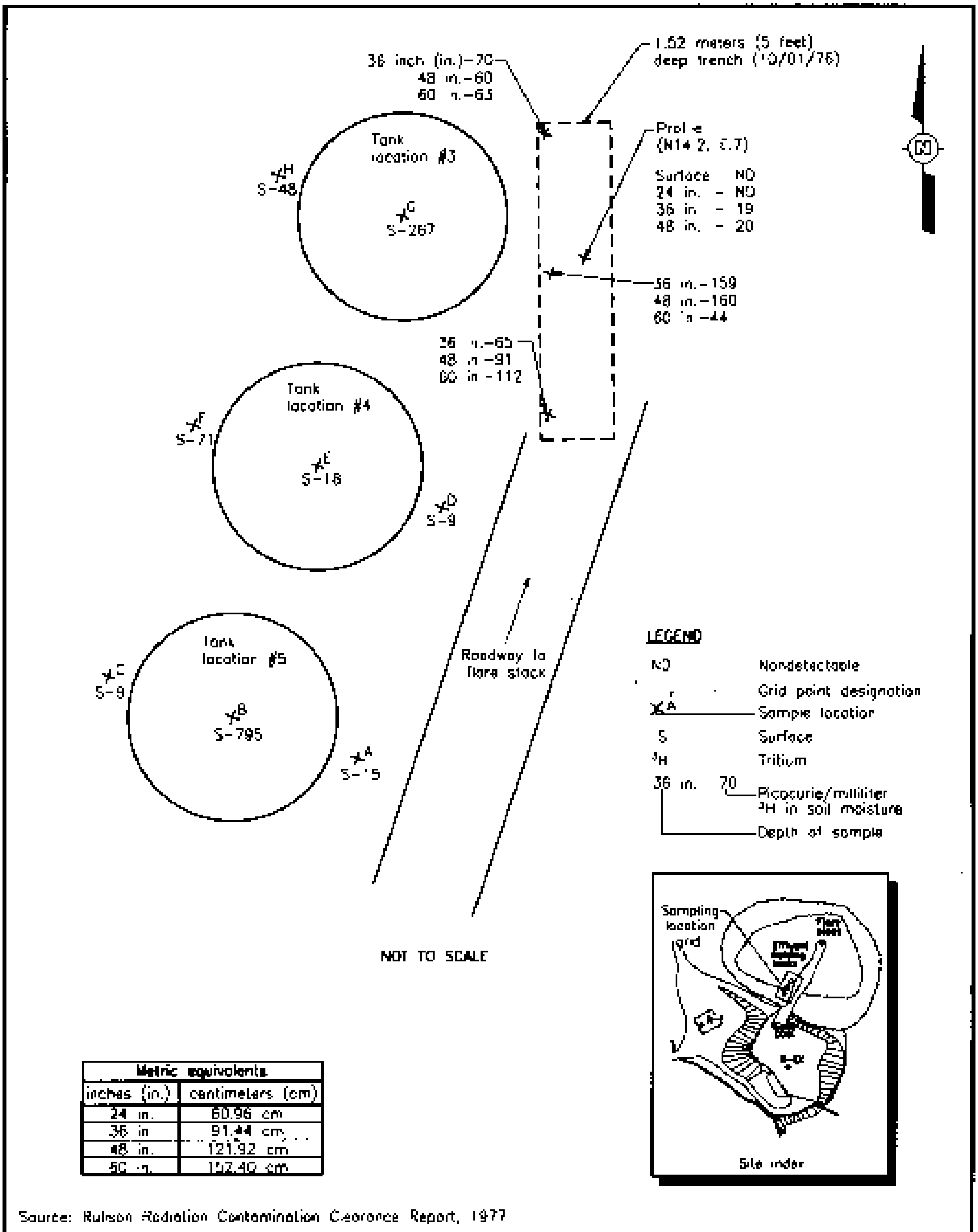
The surface sample taken at this point in July 1972 contained 47,000 pCi/mL tritium in soil moisture. This was the result of a spill that occurred during production test operations. This point and the adjacent area, including the separator location, were sampled. Results of analyses showed that soil contamination at this location is now negligible. The sample locations and results of analyses are shown on Figure 2-13 and in Table 2-5.

Accidental Spill Area

On September 1, 1976, the separator was being moved onto the decontamination pan. It was dropped about half onto the pan, and liquid spilled from the separator onto the pan and onto the soil southwest of the pan. An estimated 60 gallons spilled on the soil. The tritium concentration in the separator liquid was about 230,000 pCi/mL. Soil visibly moistened by the liquid was picked up, mixed with diatomaceous earth for additional drying, and was contained in plastic-lined, 55-gallon steel drums. Preliminary samples were taken, and more soil was picked up as indicated. Figure 2-14 shows a sketch of the spill area after 15 drums of soil were removed.

On September 16, 1976, the area was divided into a 1.5-m (5-ft) grid locating 42 sampling points, and a surface sample was taken at each point. Figure 2-15 shows that the contaminated area was delineated and that the decontamination effort had been very effective. All points sampled were less than the guideline; the highest concentration detected was 13,078 pCi/mL tritium in soil moisture.

On September 21, 1976, five more drums of soil were removed from the area of highest concentration as indicated by the contour boundary line on Figure 2-16. Samples were taken the length and direction of the removed soil as shown also on Figure 2-16.



Metric equivalents	
inches (in.)	centimeters (cm)
24 in.	60.96 cm
36 in.	91.44 cm
48 in.	121.92 cm
60 in.	152.40 cm

Source: Rulison Radiation Contamination Clearance Report, 1977

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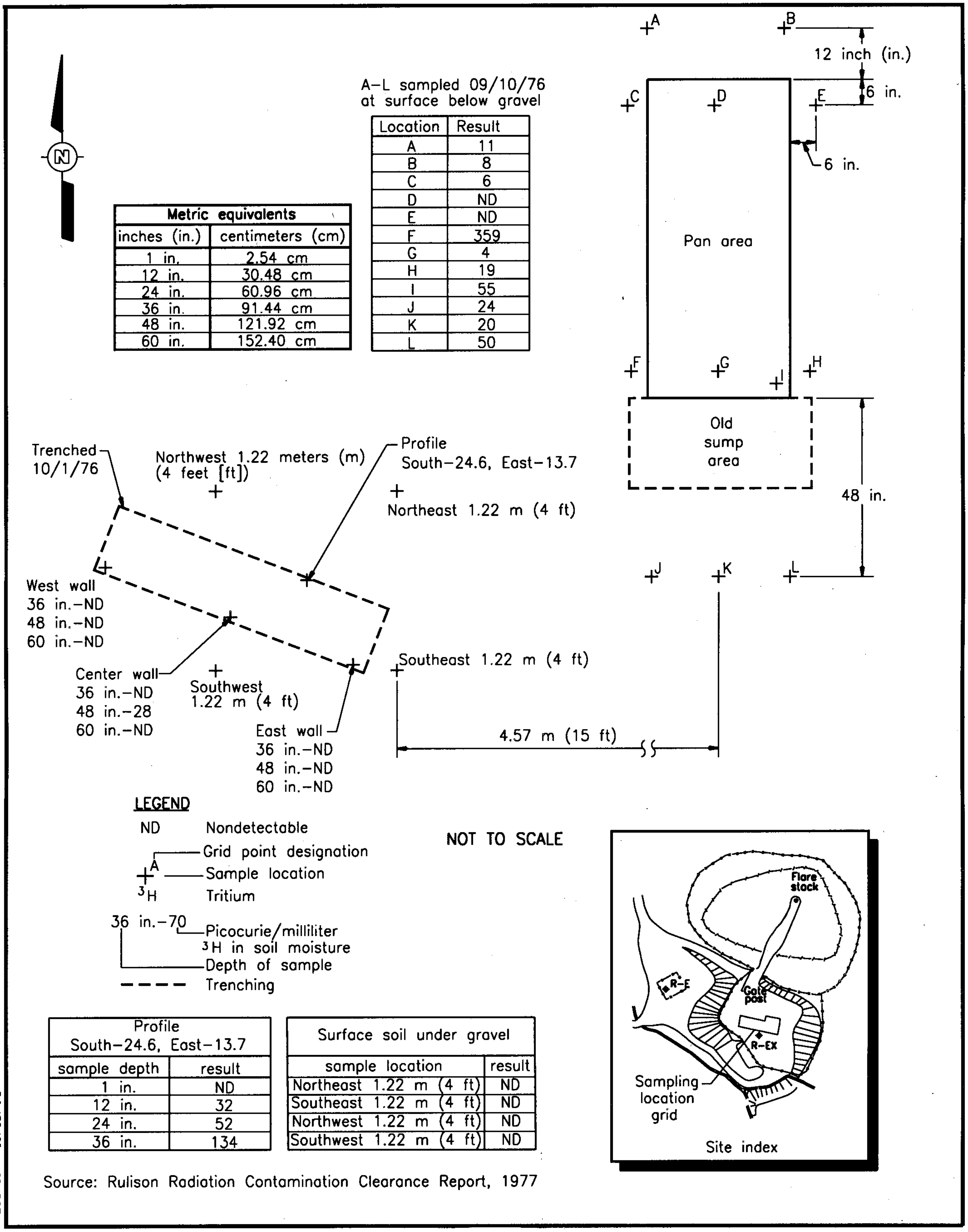
Figure 2-12
Soil Sampling, Rulison Tank Area, October 1976, Garfield County, Colorado



Metric equivalents	
inches (in.)	centimeters (cm)
1 in.	2.54 cm
12 in.	30.48 cm
24 in.	60.96 cm
36 in.	91.44 cm
48 in.	121.92 cm
60 in.	152.40 cm

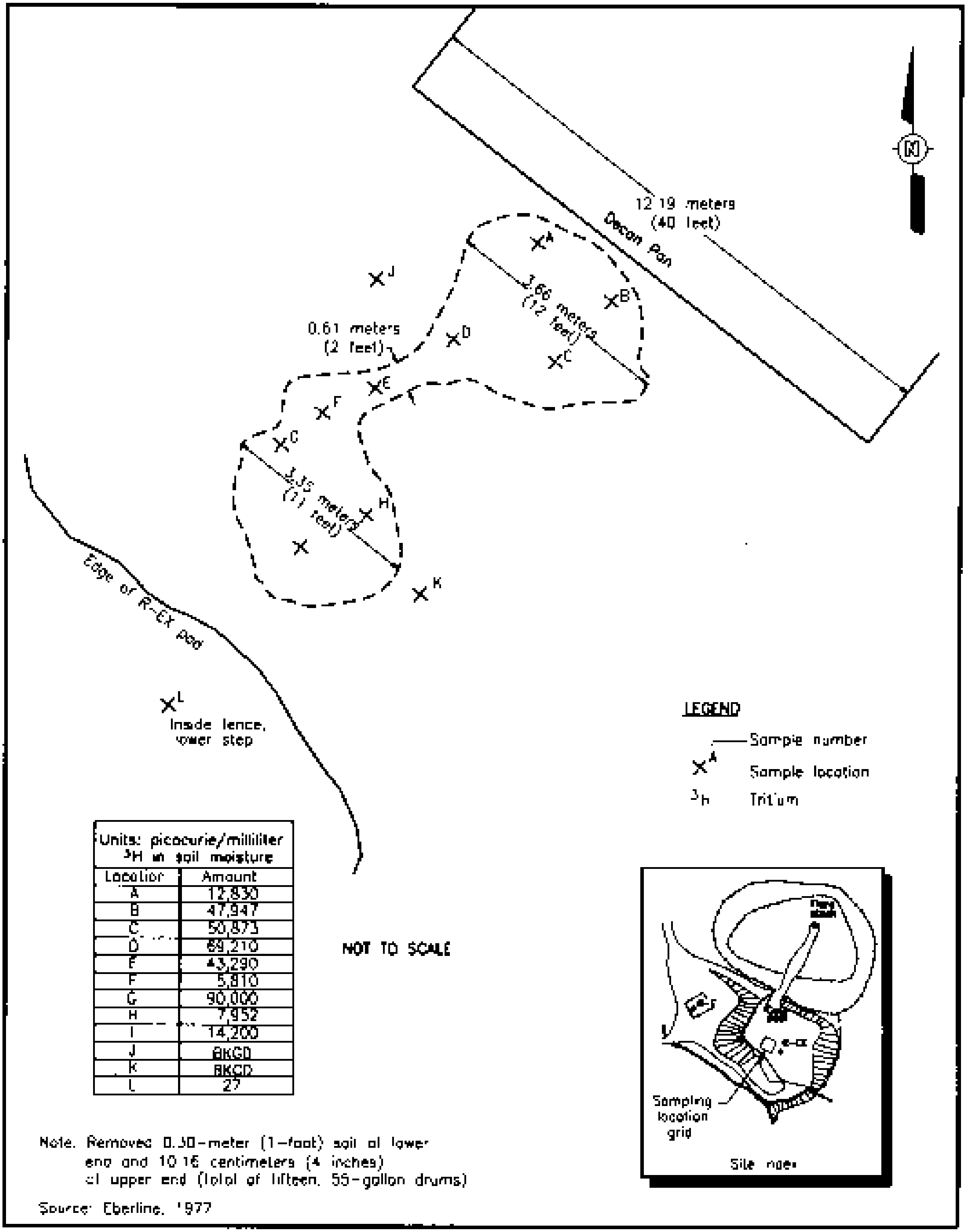
Location	Result
A	11
B	8
C	6
D	ND
E	ND
F	359
G	4
H	19
I	55
J	24
K	20
L	50

Profile South–24.6, East–13.7	
sample depth	result
1 in.	ND
12 in.	32
24 in.	52
36 in.	134

Surface soil under gravel	
sample location	result
Northeast 1.22 m (4 ft)	ND
Southeast 1.22 m (4 ft)	ND
Northwest 1.22 m (4 ft)	ND
Southwest 1.22 m (4 ft)	ND

Source: Rulison Radiation Contamination Clearance Report, 1977

Figure 2-13
Soil Sampling, Rulison Separator Pan Area (previous pipe spill), September 30, 1976, Garfield County, Colorado



Units: picocurie/milliliter ^3H in soil moisture	
Location	Amount
A	12,830
B	47,947
C	50,873
D	69,210
E	43,290
F	5,810
G	90,000
H	7,952
I	14,200
J	BKGD
K	BKGD
L	27

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Figure 2-14
Surface Soil Sampling, Rulison Separator Spill, September 1, 1976, Garfield County, Colorado

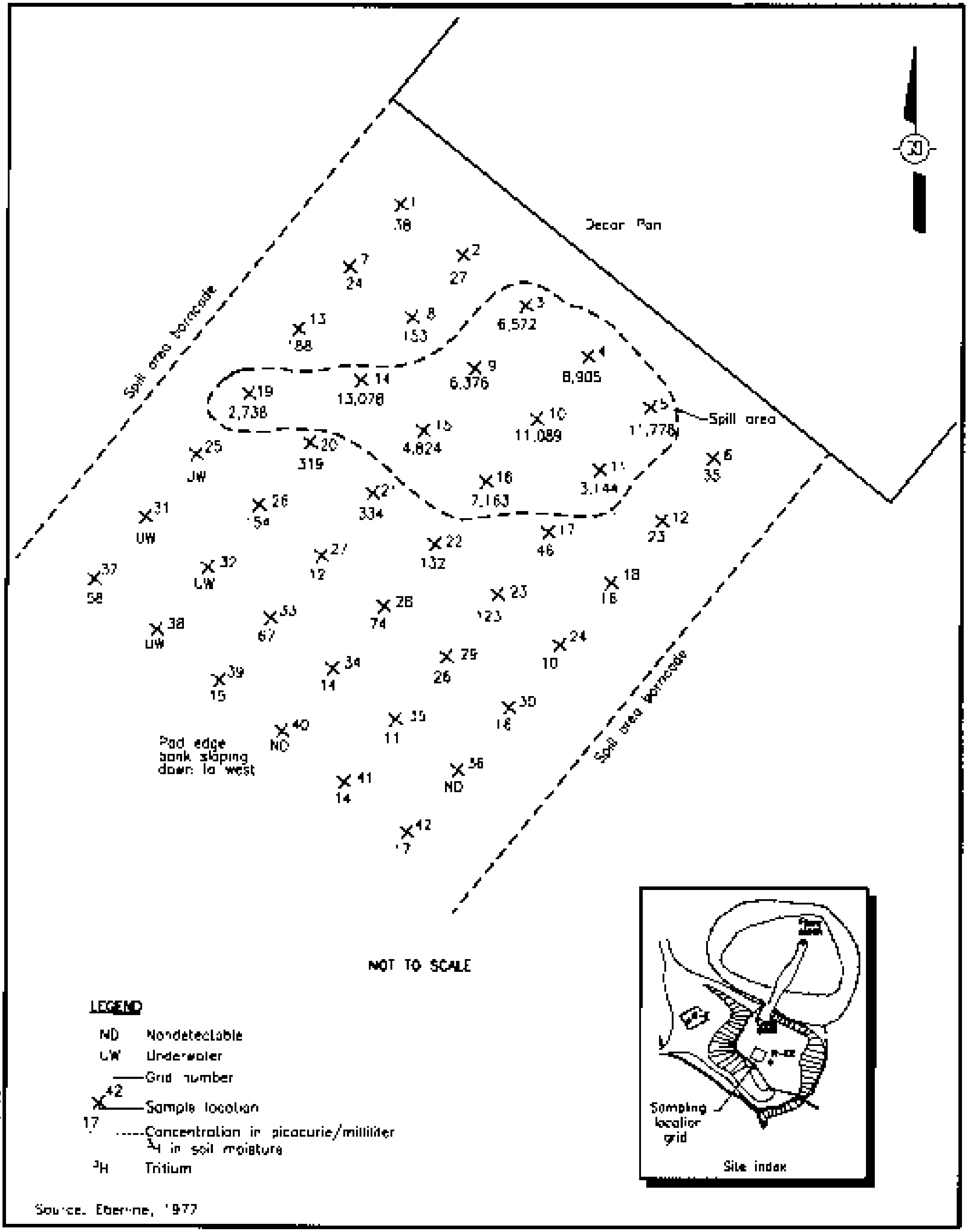
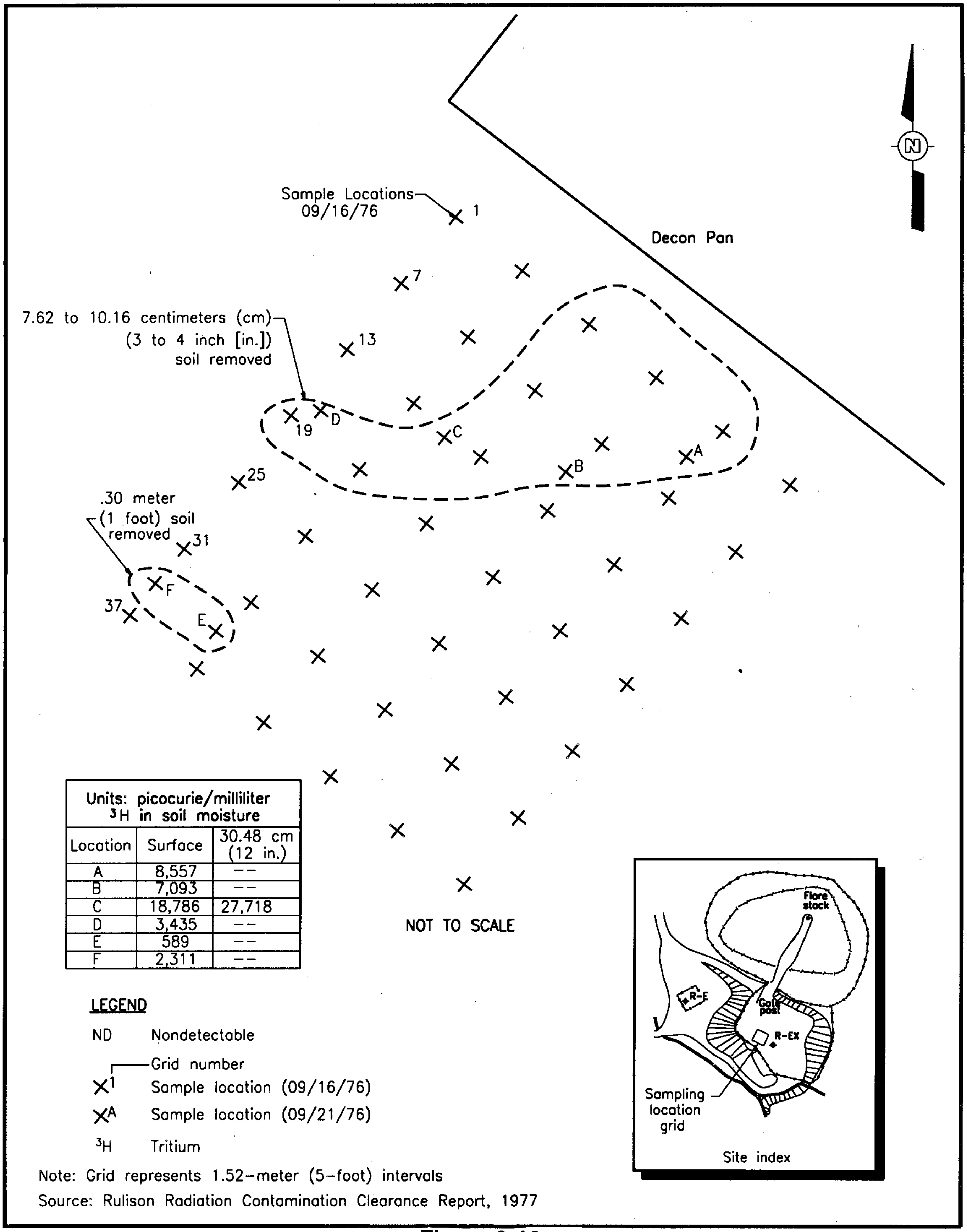


Figure 2-15
Surface Soil Sampling, Rulison Separator Spill Survey after 15 Drum Soil Removal, September 16, 1976, Garfield County, Colorado



Units: picocurie/milliliter ^3H in soil moisture		
Location	Surface	30.48 cm (12 in.)
A	8,557	--
B	7,093	--
C	18,786	27,718
D	3,435	--
E	589	--
F	2,311	--

Figure 2-16
Soil Sampling, Rulison Separator Spill after Removal of Five Additional Drums of Soil, September 21, 1976, Garfield County, Colorado

Table 2-4
Tritium in Soil at Sampling Point N-14.2, E-.7 - October 1976

Sample Identification	Sampling Depth centimeters (inches)	pCi/ml[a] in Soil Moisture
Location A	Surface	15
Location B	Surface	795
Location C	Surface	9
Location D	Surface	9
Location E	Surface	18
Location F	Surface	71
Location G	Surface	267
Location H	Surface	48
N-14.2, E-.7	Surface	ND
N-14.2, E-.7	60.96 (24)	ND
N-14.2, E-.7	91.44 (36)	19
N-14.2, E-.7	121.92 (48)	20
Trench, South End	91.44 (36)	65
Trench, South End	121.92 (48)	91
Trench, South End	152.40 (60)	112
Trench, Mid-Point	91.44 (36)	159
Trench, Mid-Point	121.92 (48)	160
Trench, Mid-Point	152.40 (60)	44
Trench, North End	91.44 (36)	70
Trench, North End	121.92 (48)	60
Trench, North End	152.40 (60)	63

Source: Eberline, 1977

[a]Picocurie per milliliter

Table 2-5
Tritium in Soil at Sampling Point S-24.6, E-13.7 - October 1976

Sample Identification	Sampling Depth centimeters (inches)	pCi/ml[a] in Soil Moisture
Location A	Surface	11
Location B	Surface	8
Location C	Surface	6
Location D	Surface	ND
Location E	Surface	ND
Location F	Surface	359
Location G	Surface	4
Location H	Surface	19
Location I	Surface	55
Location J	Surface	24
Location K	Surface	20
Location L	Surface	50
S-24.6, E-13.7	2.54 (1)	ND
S-24.6, E-13.7	30.48 (12)	32
S-24.6, E-13.7	60.96 (24)	52
S-24.6, E-13.7	91.44 (36)	134
S-24.6, E-13.7 (NE 1.22 m [4 ft])	Surface	ND
S-24.6, E-13.7 (SE 1.22 m [4 ft])	Surface	ND
S-24.6, E-13.7 (SW 1.22 m [4 ft])	Surface	ND
S-24.6, E-13.7 (NW 1.22 m [4 ft])	Surface	ND
Trench Wall, East End	91.44 (36)	ND
Trench Wall, East End	121.92 (48)	ND
Trench Wall, East End	152.40 (60)	ND
Trench Wall, Center	91.44 (36)	ND
Trench Wall, Center	121.92 (48)	28
Trench Wall, Center	152.40 (60)	ND
Trench Wall, West End	91.44 (36)	ND
Trench Wall, West End	121.92 (48)	ND
Trench Wall, West End	152.40 (60)	ND

Source: Eberline, 1977

[a]Picocurie per milliliter

On September 23, 1976, a transect of sampling holes was dug as shown on Figure 2-17 to determine a vertical profile of concentrations across the spill area. Results of these samples are indicated on the figure.

On October 1, 1976, a final comprehensive sampling of the spill area was made. Three ditches were dug with a backhoe across the area of interest to a depth of 152 cm (60 in.). The side walls of each ditch were sampled at four locations at depths of 30, 61, 91, 122, and 152 cm (12, 24, 36, 48 and 60 in.). Figure 2-18 shows the locations and results of these samples. Table 2-6 tabulates the same results. The figure and table indicate that the spill area had been successfully decontaminated.

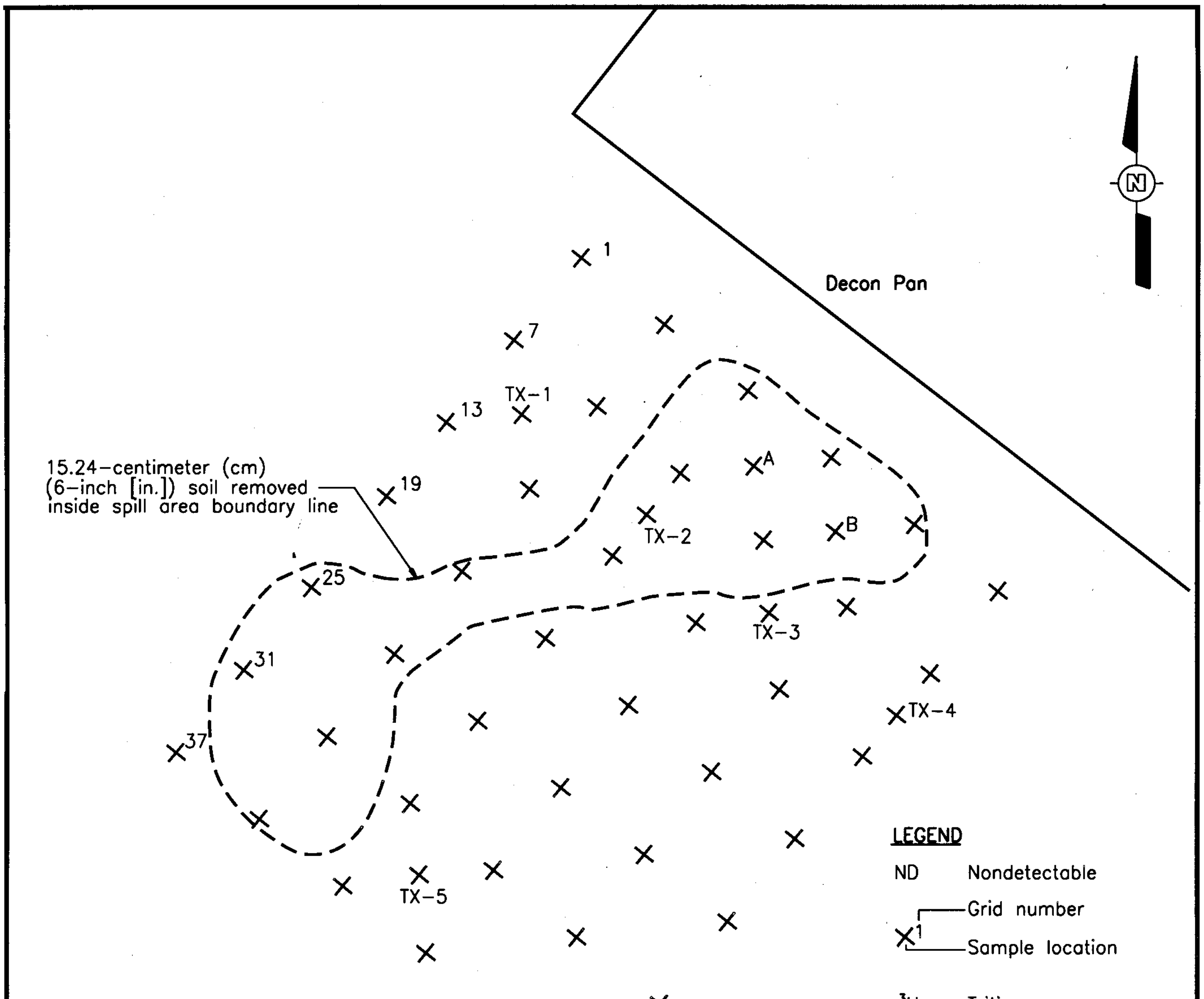
On October 4, 1976, 0.166 Ci of tritium in waste water and drilling mud were pumped into the Mesaverde formation at a depth of approximately 1,615 to 1,768 m (5,300 to 5,800 ft) for disposal. It should be noted that the potable aquifers above this depth were previously cemented off during emplacement drilling.

Decontamination Work Area

The decontamination work area included the area around and under the decontamination pan as well as the adjacent area used to convert low-level, tritiated water into steam for disposal. After work in the area was completed, the soil was sampled at 25 points on the surface and at a 30-cm (12-in.) depth, giving a total of 50 samples. Results of sample analyses and the locations are shown on Figure 2-19. The results are also tabulated on Table 2-7. Note that all concentrations of tritium in soil moisture were negligible except for two locations where the highest of four samples was 10,953 pCi/mL, still well below the guideline. This anomaly is explained by the fact that a small hole was punched through the pan at that location. A small amount of the decontaminated liquid leaked to the soil before the hole could be repaired.

R-E Wellhead Area

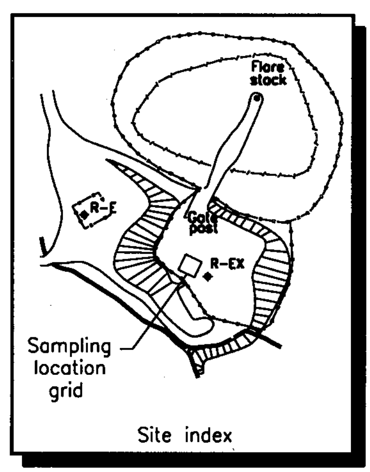
No contamination had ever been detected in the recirculating fluid during the destemming operation, nor were the wellhead or workover rig contaminated, therefore, there was little or no potential for soil contamination around the wellhead. However, since this area had not been previously sampled, soil samples were taken from the surface and from a 30-cm (12-in.) depth at the four corners, 0.3048 m (1 ft) from the cement cellar, giving a total of eight samples. Locations and analytical results are shown on Figure 2-20, and the results are tabulated in Table 2-8. Concentrations of tritium in soil moisture were negligible, as expected.



Metric equivalents	
inches (in.)	centimeters (cm)
12 in.	30.48 cm
18 in.	45.72 cm
24 in.	60.96 cm

NOT TO SCALE

Units: picocurie/milliliter ^{3}H in soil moisture				
Location	Surface	12 in.	18 in.	24 in.
A	2,716			
B	5,172			
TX-1	96	ND	ND	15
TX-2	446	33	27	21
TX-3	85.7	ND	ND	ND
TX-4	21.7	22.2	ND	ND
TX-5	ND	ND	ND	ND



Note: Grid represents 1.52-meter (5-foot) intervals

Source: Rulison Radiation Contamination Clearance Report, 1977

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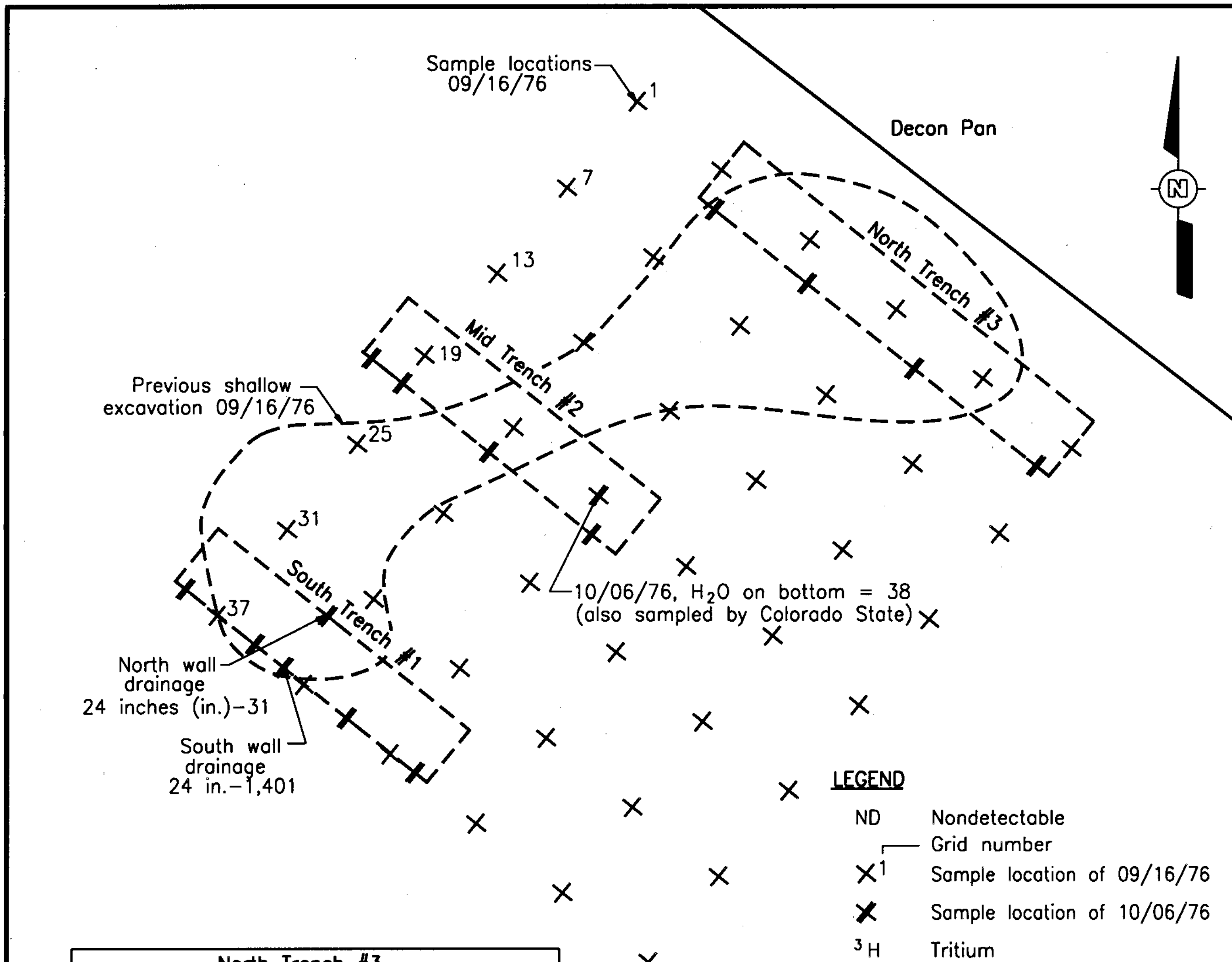
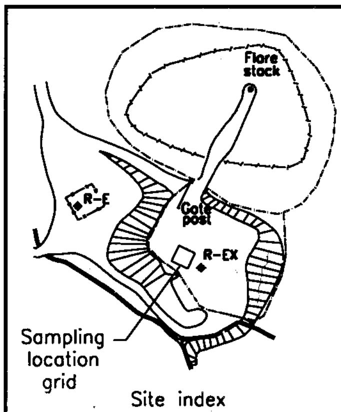
Figure 2-17
Soil Sampling, Rulison Separator Spill, September 23, 1976, Garfield County, Colorado



North Trench #3 Units: picocurie/milliliter ^3H in soil moisture					
Sample location	12 in.	24 in.	36 in.	48 in.	60 in.
West wall	55	8	10	ND	ND
Southwest wall	10	ND	ND	51	ND
Southeast wall	11	32	112	50	33
East wall	ND	ND	ND	ND	ND

Metric equivalents	
inches (in.)	centimeters (cm)
12 in.	30.48 cm
24 in.	60.96 cm
36 in.	91.44 cm
48 in.	121.92 cm
60 in.	152.40 cm

Mid Trench #2 Units: picocurie/milliliter ^3H in soil moisture						
Sample location	Surface	12 in.	24 in.	36 in.	48 in.	60 in.
West end	18	298	454	282	325	--
West wall	--	610	1,175	1,288	1,171	10
Center	--	38	21	9	ND	ND
East wall	--	ND	ND	ND	ND	ND



South Trench #1 Units: picocurie/milliliter ^3H in soil moisture					
Sample location	12 in.	24 in.	36 in.	48 in.	60 in.
West wall	48	9	24	10	37
Southwest wall	ND	ND	ND	ND	ND
Southeast wall	ND	ND	116	124	ND
East wall	ND	ND	ND	ND	ND

Source: Rulison Radiation Contamination Clearance Report, 1977

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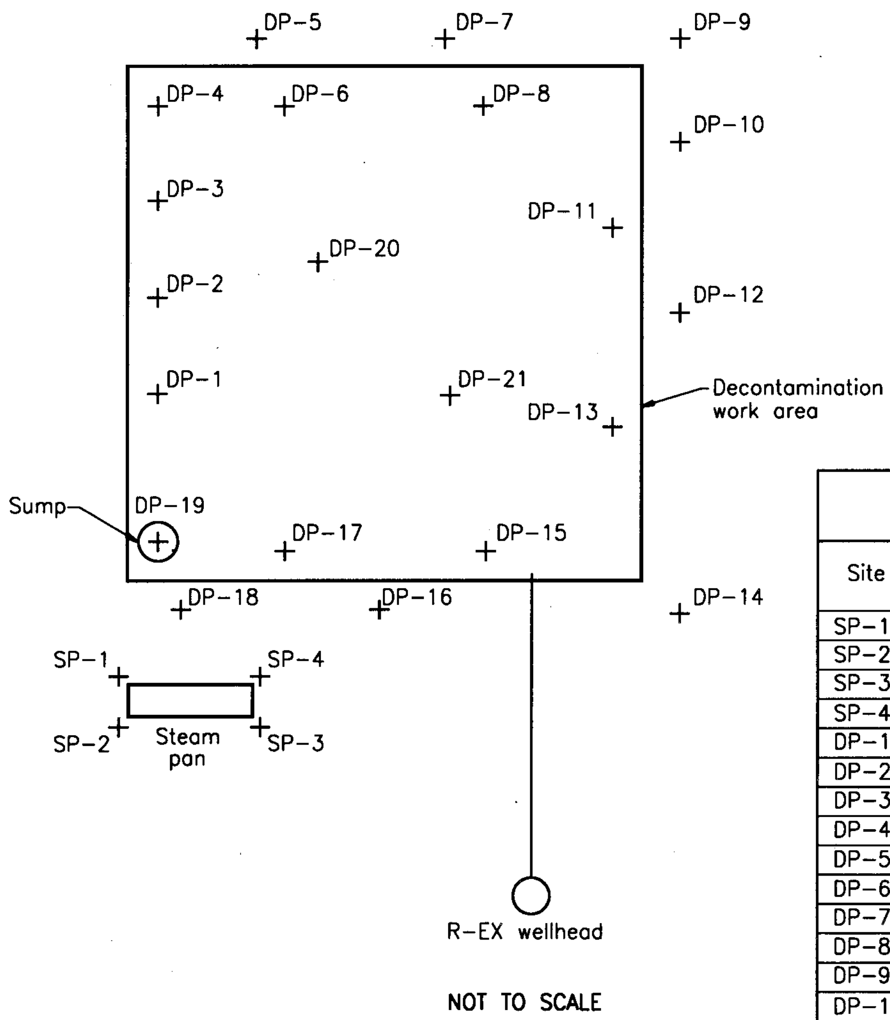
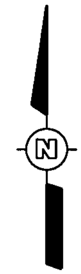
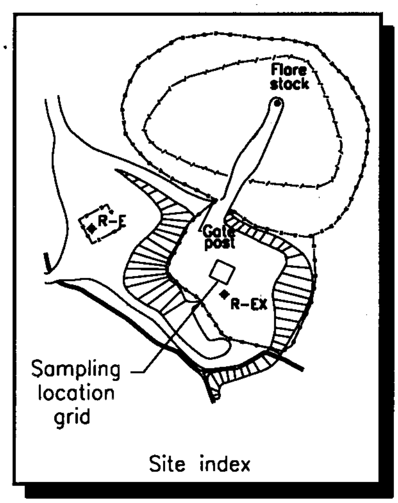
Figure 2-18
Rulison Separator Spill (Trenches), October 1, 1976, Garfield County, Colorado





Units: picocurie/milliliter ^{3}H in soil moisture		
Site	Surface	30.48 centimeters (12 inches)
SP-1	73	24.4
SP-2	24.3	7.1
SP-3	10.3	5.4
SP-4	17.8	1.6
DP-1	5,202	6,288
DP-2	10,953	1,628
DP-3	64.9	2.9
DP-4	12.8	4.4
DP-5	16.1	5.5
DP-6	56.7	ND
DP-7	14.8	2.8
DP-8	4.9	ND
DP-9	ND	ND
DP-10	5.9	ND
DP-11	6.0	3.7
DP-12	10.9	3.5
DP-13	8.2	2.8
DP-14	ND	ND
DP-15	4.5	5.8
DP-16	12.1	2.3
DP-17	25.4	9.5
DP-18	35.3	93
DP-19	35.7	31.1
DP-20	54	4.5
DP-21	17.1	4.4



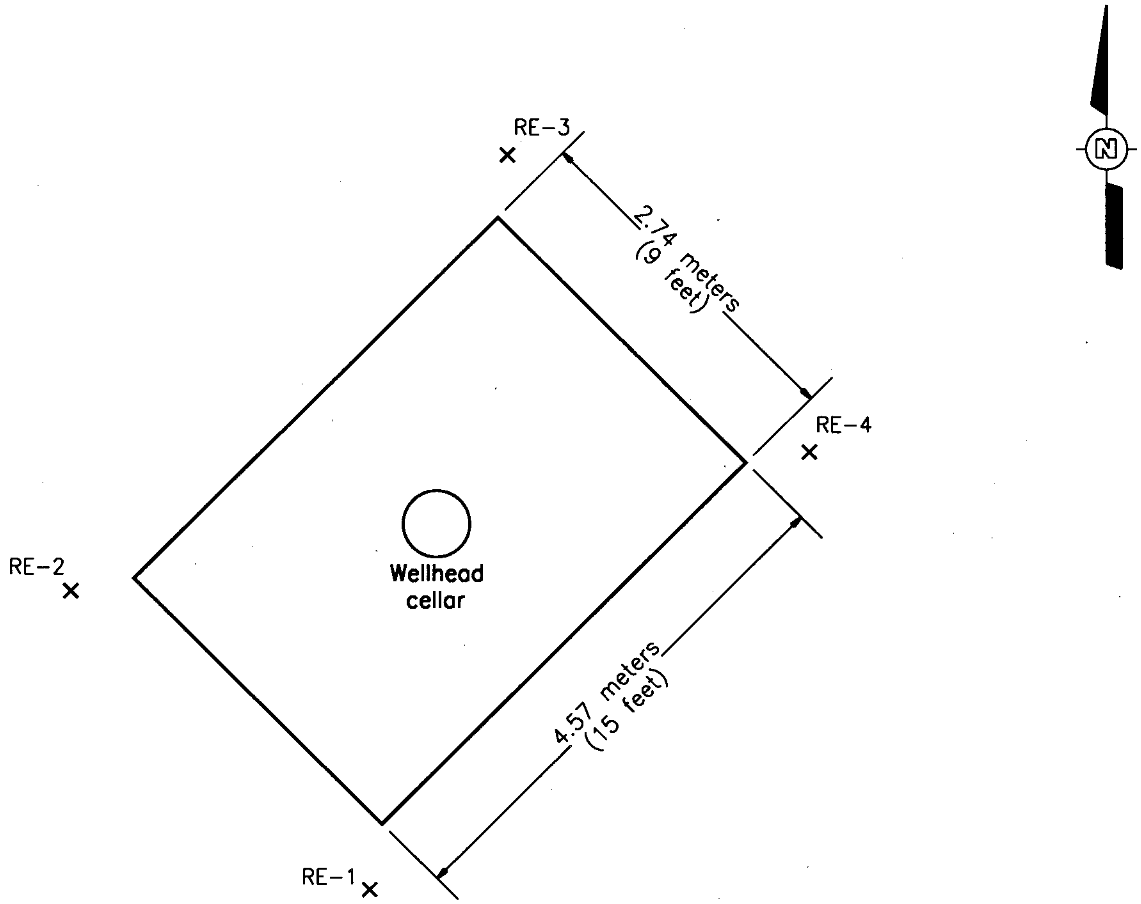
LEGEND

DP-1	Decon Pan
SP-1	Steam Pan
ND	Nondetectable
+	Sample location
^{3}H	Tritium

Source: Rulison Radiation Contamination Clearance Report, 1977

4203A09 10/13/95

Figure 2-19
Soil Sampling, Rulison R-EX Decon Pan Area, October 7, 1976, Garfield County, Colorado



NOT TO SCALE

LEGEND

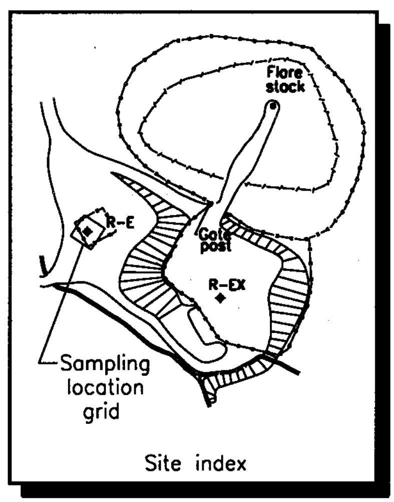
ND Nondetectable

RE-1 Sample number

+ Sample location

^3H Tritium

Units: picocurie/milliliter ^3H in soil moisture		
Site	Surface	30.48 centimeters (12 inches)
RE-1	4.9	ND
RE-2	5.7	ND
RE-3	6.7	4.4
RE-4	ND	ND



Source: Rulison Radiation Contamination Clearance Report, 1977

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Figure 2-20
Soil Sampling, Rulison R-E Wellhead Cellar Area, October 7, 1976, Garfield County, Colorado

Table 2-6
Tritium in Soil at Spill Area after Decontamination - October 1976
(Page 1 of 2)

Sample Identification	Sampling Depth centimeters (inches)	pCi/ml[a] in Soil Moisture
South Trench #1, East Wall	30.48 (12)	ND
South Trench #1, East Wall	60.96 (24)	ND
South Trench #1, East Wall	91.44 (36)	ND
South Trench #1, East Wall	121.92 (48)	ND
South Trench #1, East Wall	152.40 (60)	ND
South Trench #1, S.E. Wall	30.48 (12)	ND
South Trench #1, S.E. Wall	60.96 (24)	ND
South Trench #1, S.E. Wall	91.44 (36)	116
South Trench #1, S.E. Wall	121.92 (48)	124
South Trench #1, S.E. Wall	152.40 (60)	ND
South Trench #1, S. Drain Area	60.96 (24)	1,401
South Trench #1, S.W. Wall	30.48 (12)	ND
South Trench #1, S.W. Wall	60.96 (24)	ND
South Trench #1, S.W. Wall	91.44 (36)	ND
South Trench #1, S.W. Wall	121.92 (48)	ND
South Trench #1, S.W. Wall	152.40 (60)	ND
South Trench #1, West Wall	30.48 (12)	48
South Trench #1, West Wall	60.96 (24)	9
South Trench #1, West Wall	91.44 (36)	24
South Trench #1, West Wall	121.92 (48)	10
South Trench #1, West Wall	152.40 (60)	37
Mid Trench #2, East Wall	30.48 (12)	ND
Mid Trench #2, East Wall	60.96 (24)	ND
Mid Trench #2, East Wall	91.44 (36)	ND
Mid Trench #2, East Wall	121.92 (48)	ND
Mid Trench #2, East Wall	152.40 (60)	ND
Mid Trench #2, Center	30.48 (12)	38
Mid Trench #2, Center	60.96 (24)	21
Mid Trench #2, Center	91.44 (36)	9
Mid Trench #2, Center	121.92 (48)	ND
Mid Trench #2, Center	152.40 (60)	ND
Mid Trench #2, West Wall	30.48 (12)	610
Mid Trench #2, West Wall	60.96 (24)	1,175
Mid Trench #2, West Wall	91.44 (36)	1,288
Mid Trench #2, West Wall	121.92 (48)	1,171
Mid Trench #2, West Wall	152.40 (60)	10
Mid Trench #2, West End	Surface	18
Mid Trench #2, West End	30.48 (12)	298
Mid Trench #2, West End	60.96 (24)	454
Mid Trench #2, West End	91.44 (36)	282
Mid Trench #2, West End	121.92 (48)	352

Refer to footnotes at end of table

Table 2-6
Tritium in Soil at Spill Area after Decontamination - October 1976
(Page 2 of 2)

Sample Identification	Sampling Depth centimeters (inches)	pCi/ml[a] in Soil Moisture
North Trench #3, East Wall	30.48 (12)	ND
North Trench #3, East Wall	60.96 (24)	ND
North Trench #3, East Wall	91.44 (36)	ND
North Trench #3, East Wall	121.92 (48)	ND
North Trench #3, East Wall	152.40 (60)	ND
North Trench #3, S.E. Wall	30.48 (12)	11
North Trench #3, S.E. Wall	60.96 (24)	23
North Trench #3, S.E. Wall	91.44 (36)	112
North Trench #3, S.E. Wall	121.92 (48)	50
North Trench #3, S.E. Wall	152.40 (60)	33
North Trench #3, S.W. Wall	30.48 (12)	10
North Trench #3, S.W. Wall	60.96 (24)	ND
North Trench #3, S.W. Wall	91.44 (36)	ND
North Trench #3, S.W. Wall	121.92 (48)	51
North Trench #3, S.W. Wall	152.40 (60)	ND
North Trench #3, West Wall	30.48 (12)	55
North Trench #3, West Wall	60.96 (24)	8
North Trench #3, West Wall	91.44 (36)	10
North Trench #3, West Wall	121.92 (48)	ND
North Trench #3, West Wall	152.40 (60)	ND

Source: Eberline, 1977

[a]Picocurie per milliliter

Table 2-7
Tritium in Decontamination Work Area Soil
(Page 1 of 2)

Sample Identification	Sampling Depth centimeters (inches)	pCi/ml[a] in Soil Moisture
DP-1	Surface	5,202
DP-1	30.48 (12)	6,288
DP-2	Surface	10,953
DP-2	30.48 (12)	1,628
DP-3	Surface	64.9
DP-3	30.48 (12)	2.9
DP-4	Surface	12.8
DP-4	30.48 (12)	4.4
DP-5	Surface	16.1
DP-5	30.48 (12)	5.5
DP-6	Surface	56.7
DP-6	30.48 (12)	ND
DP-7	Surface	14.8
DP-7	30.48 (12)	2.8
DP-8	Surface	4.9
DP-8	30.48 (12)	ND
DP-9	Surface	ND
DP-9	30.48 (12)	ND
DP-10	Surface	5.9
DP-10	30.48 (12)	ND
DP-11	Surface	6
DP-11	30.48 (12)	3.7
DP-12	Surface	10.9
DP-12	30.48 (12)	3.5
DP-13	Surface	8.2
DP-13	30.48 (12)	2.8
DP-14	Surface	ND
DP-14	30.48 (12)	ND
DP-15	Surface	4.5
DP-15	30.48 (12)	5.8
DP-16	Surface	12.1
DP-16	30.48 (12)	2.3
DP-17	Surface	25.4
DP-17	30.48 (12)	9.5
DP-18	Surface	35.3
DP-18	30.48 (12)	93
DP-19	Surface	35.7
DP-19	30.48 (12)	31.1
DP-20	Surface	54
DP-20	30.48 (12)	4.5
DP-21	Surface	17.1

Refer to footnotes at end of table

Table 2-7
Tritium in Decontamination Work Area Soil
(Page 2 of 2)

Sample Identification	Sampling Depth centimeters (inches)	pCi/ml[a] in Soil Moisture
DP-21	30.48 (12)	4.4
SP-1	Surface	73
SP-1	30.48 (12)	24.4
SP-2	Surface	24.3
SP-2	30.48 (12)	7.1
SP-3	Surface	10.3
SP-3	30.48 (12)	5.4
SP-4	Surface	17.8
SP-4	30.48 (12)	1.6

Source: Eberline, 1977

[a]Picocurie per milliliter

Table 2-8
Tritium in Soil at R-E Wellhead - October 1976

Sample Identification	Sampling Depth centimeters (inches)	pCi/ml[a] in Soil Moisture
RE-1	Surface	4.9
RE-1	30.48 (12)	ND
RE-2	Surface	5.7
RE-2	30.48 (12)	ND
RE-3	Surface	6.7
RE-3	30.48 (12)	4.4
RE-4	Surface	ND
RE-4	30.48 (12)	ND

Source: Eberline, 1977

[a]Picocurie per milliliter

Surface Water

Surface water was sampled at the four locations mentioned: the creek above and below the site, the spring on the site, and the spring down the road from the site. Tritium was not detected at a detection sensitivity of 2 pCi/mL.

2.2.2.4.4 Aerial Radiological Survey

An aerial radiological survey was conducted over the Project Rulison Site, 64 km (40 mi) northeast of Grand Junction, Colorado, from July 6 through July 12, 1993. Parallel lines were flown at intervals of 76 m (250 ft) over a 17-km^2 (6.5-mi^2) area at a 61-m (200-ft) altitude surrounding Battlement Creek Valley. The gamma energy spectra obtained were reduced to an exposure rate contour map overlaid on a high altitude aerial photograph of the area. The terrestrial exposure rate varied from 3.5 to 12.5 microroentgens per hour (μR/hr) (excluding cosmic) at 1 m (3 ft) above ground level. No anomalous or man-made isotopes were found (EG&G, 1995, p. ii).

2.2.2.5 Sampling Summary

A review of the history of operations at the Rulison Site, the analytical results of sampling programs, and the results of the detailed radiological survey identified the extent of radioactive contamination on the property. The only nuclide of concern was tritium in surface soil moisture. A reasonable and conscientious effort was made to reduce contamination to an amount as low as practicable. Tritium concentrations, where detected, were in most cases negligible and well below the guideline (ERDA, 1976). There is no reason the Rulison Site should change from unrestricted use, subject to applicable subsurface drilling restrictions as stated in *Project Rulison Well Plugging and Site Abandonment Plan*, NVO-174 (Rev. 1) and *Project Rulison Well Plugging and Site Abandonment Final Report*, NVO-187 (ERDA, 1976, p. 16; ERDA, 1977, p. 20).

3.0 Review of Regulatory Status

3.1 Federal Regulatory Overview

In May 1976, an environmental impact assessment of the Rulison Site was prepared in accordance with the requirements of Title 10 *Code of Federal Regulations* (CFR), Part 11, dated February 16, 1974, which detailed the procedures to be followed for ERDA implementation of the *National Environmental Policy Act of 1969* (ERDA, 1976). The purpose of this assessment was to present a brief description of proposed activities for the Rulison well plugging and site abandonment cleanup and an evaluation of whether an environmental impact statement needed to be prepared.

It was determined from the assessment that the requested action did not constitute a major federal action which significantly affecting the environment, in the sense of the *National Environmental Policy Act (NEPA), Section 102(2)(c)*. At that time, it was determined that no adverse effects to the environment had occurred (ERDA, 1976, p. 18).

In May 1986, Reynolds Electrical & Engineering Company, Inc., conducted a Hazardous Waste Installation Assessment in which three "operational areas" were sampled, and a report was produced. The descriptive name and actual location of these areas is shown on Figure 3-1. No hazardous materials were detected in any of the samples collected at the Rulison Site (Fauver, 1986, p. 30). The objective of the Hazardous Waste Installation Assessment Project was to identify and evaluate inactive sites at DOE/NV installations where hazardous substances may have been released into the environment. These "Installation Assessments" were the first phase of the DOE/NV effort to satisfy DOE Order 5480/14, which required that federal facilities comply with the CERCLA.

A CERCLA Preliminary Assessment was prepared by the DRI for the Rulison Site in 1988. The *CERCLA/Superfund Amendments and Reauthorization Act* provides that all EPA regulations and criteria pertaining to inactive hazardous waste sites are applicable to U.S. Government facilities. Included among the provisions of these acts are requirements for a preliminary assessment of each facility and an evaluation based on the same Hazard Ranking System (HRS) that is applied to nonfederal facilities.

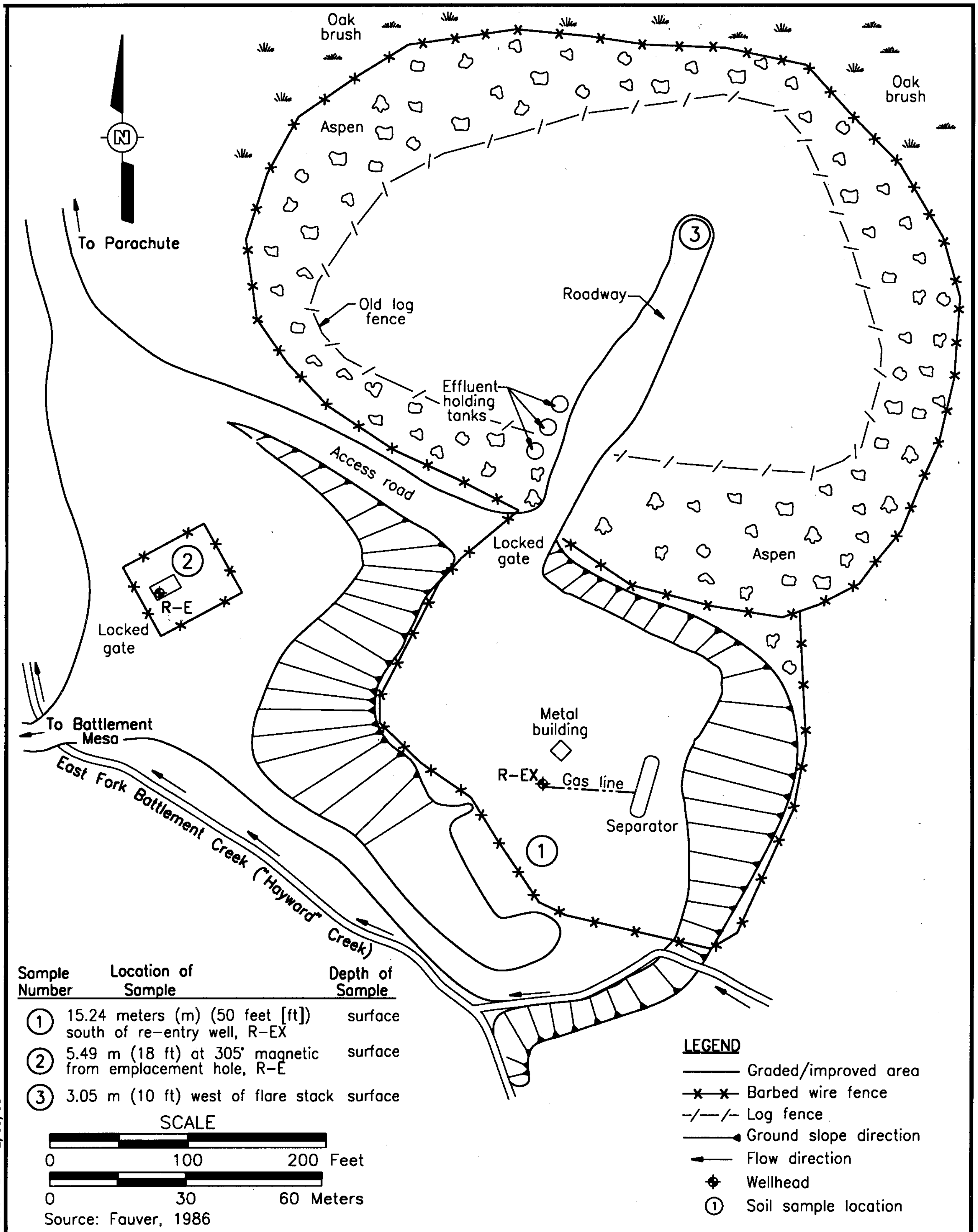

Figure 3-1
Soil Sampling, Potential Hazardous Waste Release Sites at the Rulison Test Site, September 1976, Garfield County, Colorado

The 1988 preliminary assessment concluded that radiation was released to the environment during Project Rulison production testing. The R-E and R-EX wells were plugged to prevent the escape of radiation, and the explosive device was detonated 2,568 m (8,426 ft) below ground surface in the Mesa Verde formation. Given the extremely low permeability of this formation, radionuclide migration should be very limited; however, surface and subsurface water quality monitoring is still being conducted near the Rulison Site. A preliminary HRS score for Project Rulison was calculated to be 15.12, well below the score of 28.5 which is required for a site to be placed on the National Priorities List. The only contributing score was from the air route due to the release of radioactivity during gas production testing. An extensive on- and off-site radiation surveillance effort failed to detect any radioactivity other than tritium and krypton in the environment. Typically, the concentrations of these isotopes in the air were around one 10-millionth of their concentration in the gas (DOE, 1984). Because the emplacement and re-entry holes have been plugged, it is unlikely that further air releases will occur.

DOE Order 5440.1E, implementing NEPA, requires that the presence of environmentally sensitive resources such as cultural resources, sensitive species, wetlands, and floodplains be determined so that the appropriate level of NEPA documentation can be established and adequate mitigation measures implemented. IT Corporation (IT) prepared several reports documenting the surveys conducted for these environmentally sensitive resources (IT, 1993a; IT, 1993b; IT, 1993c).

3.2 State Regulatory Overview

3.2.1 Property of Historic, Archaeological, or Architectural Significance

The Colorado Office of Archaeology and Historic Preservation instituted a file search on December 22, 1992, and IT conducted a Class II Cultural Resources Field Survey on July 1, 1993 (IT, 1993a). The purpose of the investigation was to comply with federal mandates pertaining to the historic preservation of cultural resources, including Section 106 of the *National Historic Preservation Act*, as implemented by the Advisory Council on Historic Preservation, *(Title 36 CFR Part 800; the Archaeological and Historic Preservation Act), Executive Order 11593*, and the *American Indian Religious Freedom Act*. The DOE regulations contained in *Title 10 CFR Part 1021* also require compliance with historic preservation mandates. The Project Rulison survey was conducted on private lands under the auspices of State of Colorado Archaeological Permit No. 93-48, the survey was conducted to evaluate the potential impacts that could occur as a result of performing site characterization or possible remedial activities at the Rulison Site.

The survey resulted in one historic, isolated find consisting of a cast iron stove and one historic monument, the Rulison Site SGZ. The Rulison Site SGZ monument (5GF1656) should be considered eligible for nomination to the National Register of Historic Places along with three other similar sites in Colorado and New Mexico. The monument inscription at SGZ reads:

> *No excavation, drilling, and/or removal of subsurface materials to a depth of 12,450 ft is permitted within Lot 11, NE 1/4 SW 1/4 of Section 25, Township 7 South, Range 95 West, 6th Principal Meridian, Garfield County, Colorado, without U.S. Government permission. U.S. Atomic Energy Commission and the Department of the Interior (AEC, 1973a).*

Based on the field survey results, it was determined that project field activities could proceed. However, if any cultural material were to be uncovered during any field activities, it is recommended that a qualified archaeologist be called in to assess the find. The U.S. Bureau of Land Management (BLM), the Glenwood Springs Resource Area archaeologist, and the Office of Archaeology and Historic Preservation should also be notified under those circumstances.

3.2.2 Special Sources of Water

No water sources within this area are vital to the region. The East Fork of Battlement Creek is used, in part, to irrigate land downstream from the Rulison Site (USGS, 1970, p. 7). Groundwater resources around the Rulison Site occur in surficial deposits such as fan gravel and terraces. These deposits are reportedly “the only sources of usable groundwater near the Rulison Site” (USGS, 1970. p. 9). Available records do not indicate the existence of a sole-source aquifer or a well-head protection area at this site. Refer to Figure 2-1 which shows the wells in the vicinity of the Rulison Site.

4.0 Surrounding Land Use

The Rulison Site is located a few miles outside of the White River National Forest and approximately nine miles north of the Grand Mesa National Forest. No areas within the Rulison Site are federal or state property (BLM, 1980 and 1986; USGS, 1987). Surface ground zero is located on the approximately 16-hectare (40-acre) lot owned by Mr. Cary Weldon; however, the U.S. Government retains control of the subsurface rights. The former drilling effluent pond is on land jointly owned by Ms. Cristy Koeneke and Mr. Craig Hayward. The surrounding land is also privately owned. A map showing current ownership is included as Figure 4-1.

The surrounding land is currently used for recreational purposes (e.g., hunting and fishing) and cattle grazing. During the summer months, a residence located approximately 427 m (1,400 ft) from the former drilling effluent pond is occupied. Future use of this land is likely to also include recreational and grazing applications.

The closest population center to the Rulison Site is the town of Parachute, which is located approximately 12 km (8 mi) north of the site and has a recorded population of 660 (Rand McNally, 1993).

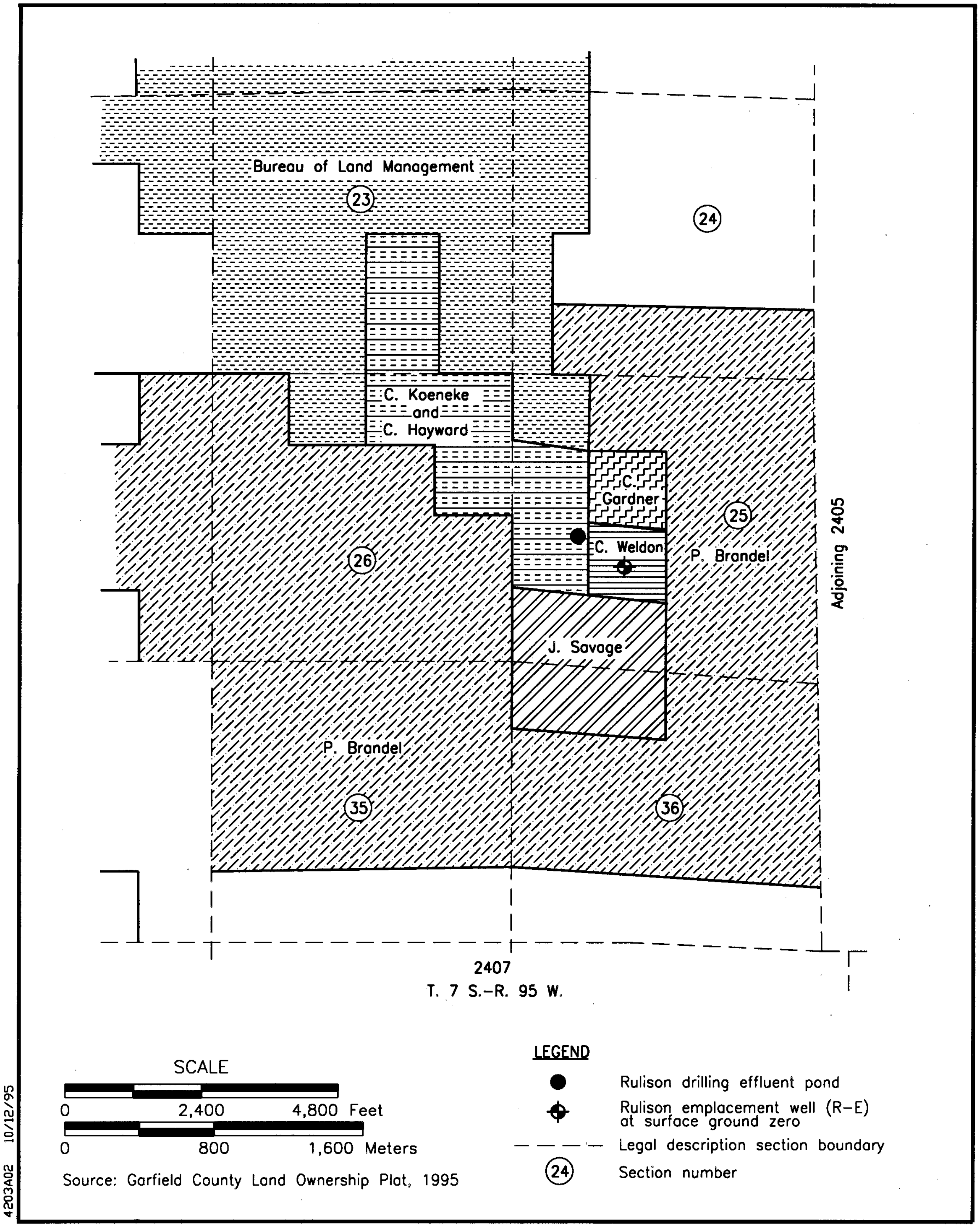

Figure 4-1
Project Rulison, Garfield County, Land Ownership Map

5.0 Physical Environment

5.1 Meteorology

West-central Colorado is generally classified as semiarid, with low precipitation and relative humidity, warm summer temperatures, and abundant sunshine (Marlatt, 1973). Winds are generally from the west, but fail to carry much moisture from the Pacific Ocean past mountain barriers. The average annual precipitation for the Rulison Site is 50 cm (20 in.) and the temperature ranges from -10 degrees Fahrenheit (°F) to +98°F (-23 degrees Celsius [°C] to +37°C). Annual precipitation ranges from 25 cm (10 in.) at elevations of 1,524 m (5,000 ft) above mean sea level (amsl) to 64 cm (25 in.) at 2,439 m (8,000 ft) amsl. Winter snowfall may exceed 256 cm (100 in.) on plateau tops (Marlatt, 1973). The length of the growing season at Parachute is 150 days (Brooks et al., 1933). Movement of air away from the Rulison Site is controlled by the valley drainage winds and daily up-slope winds in both the Battlement Creek Valley and the Colorado River Valley. The regional gradient wind generally blows east-northeast, above the topographical features (DOE, 1984, p. 3).

The evaporative demand on the north slope of Battlement Mesa is fairly low compared to that of the area north of the Colorado River (Marlatt, 1973). Moisture has a chance to soak into the volcanic soils; thus, the vegetative community is well developed. This enables the community to support a variety of faunal species.

5.2 Biota

5.2.1 Sensitive Species Survey

The Rulison Site has the potential for supporting a large number of wildlife species. Uplands, wetlands, and surface water bodies offer numerous resources for the organisms that use the site. Food resources for deer, rodents, birds, and canids are abundant. Acorns from the Gambel oak and seeds from the conifers provide mast for herbivores which, in turn, are prey for the carnivores. The beavers on the site feed primarily on aspen. Cover required for all wildlife species is abundant and varied.

A Level I reconnaissance survey for sensitive species was conducted at the Rulison Site in June 1993 (IT, 1993b). For this survey, sensitive species included both federal- and state-listed threatened and endangered species and candidate species. Tables 5-1 through 5-3 list the various species found on the Rulison Site during this survey.

In addition, suitable habitat and food resources for several endangered and candidate bird species were identified; however, none of these species were observed during the site reconnaissance. The tiger salamander *(Ambystoma tigrinium)*, which is a State listed species, was observed in the drilling effluent pond. However, communication with the Colorado Division of Wildlife indicated that the tiger salamander is not a species of special concern in that area (Nessler, 1995).

5.2.2 Vegetation

The habitats present at the Rulison Site are a combination of Rocky Mountain Montane and Subalpine forest (Whitney, 1992). At lower elevations (2,290 to 2,440 m [7,500 to 8,000 ft]), the dominant montane vegetation consists of quaking aspen (*Populus tremuloides*), Colorado blue spruce (*Pecea pungens*), willow (*Salix spp.*), lodgepole pine (*Pinus contorta*), Gambel oak (*Quercus gambelii*), Douglas fir (*Pseudotsuga menziesii*), mountain mahogany (*Cercocarpus montenus*), service berry (*Amelanchier alnifolia*), and mixed mountain shrubs and grasses. The plant species are suitable for grazing of cattle and horses. At elevations greater than 2,440 m (8,000 ft), subalpine species such as sub-alpine fir (*Abies lasiocarpa*) and Engelmann spruce (*Picea engelmannii*) become more prevalent in the vegetation.

5.3 Topography

The site is located on the north slope of Battlement Mesa, on the upper reaches of Battlement Creek, at an elevation of approximately 2,500 m (8,200 ft) (Figure 5-1). The valley is open to the north-northwest and is bounded on the remaining three sides by steep mountain slopes, which rise to elevations above 2,927 m (9,600 ft).

Table 5-1
List of Reptile and Amphibian Species Observed during the Sensitive Species Survey of the Rulison Site, Colorado, June 1993

Scientific Name	Common Name
Amphibians	
Family: Ambystomatidae *Ambystoma tigrinum*	Tiger Salamander
Reptiles	
Family: Colubridae *Opheodrys vernacis*	Smooth Green Snake

Table 5-2
List of Bird Species Observed during the Sensitive Species Survey of the Rulison Site, Colorado, June 1993

Scientific	Common Name
Family: Accipitridae *Aquila chrysaetos*	Golden Eagle
Family: Scolopacidae *Calidris minutilla*	Least Sandpiper
Family: Columbidae *Zenaida macroura*	Morning Dove
Family: Trochilidae *Selasphorus platycercus*	Broad-Tailed Hummingbird
Family: Picidae *Sphyrapicus varius* *Colaptes auratus*	Yellow-Bellied Sapsucker Northern Flicker
Family: Hirundinidae *Tachycineta bicolor*	Violet-Green Swallow
Family: Corvidae *Corvus corax*	Common Raven
Family: Paridae *Parus atricapillus*	Black-Capped Chickadee
Family: Troglodytidae *Troglodytes aedon*	House Wren
Family: Muscicapidae *Regulus calendula* *Catharus guttatus* *Turdus migratorius*	Ruby-Crowned Kinglet Hermit Thrush American Robin
Family: Emberizidae Subfamily: Parulinae *Vermivora virginae* *Dendorica petechia* *Dendrocia coronata* *Oporornis tolmiei*	Virginia’s Warbler Yellow Warbler Yellow-Rumped Warbler [Audubon’s form] MacGillivray's Warbler
Subfamily: Emberizinae *Amophila ruficeps* *Pooecetes gramineus*	Rufous-Crowned Sparrow Vesper Sparrow
Family: Passeridae *Passer domesticus*	House Sparrow

Table 5-3
List of Mammal Species Observed during the Sensitive Species Survey of the Rulison Site, Colorado, June 1993

Scientific Name	Common Name
Family: Leporidae *Sylvilagus nuttalli*	Mountain Cottontail
Family: Sciuridae *Eutamias minimus* *Marmota flaviventris* *Citellus lateralis*	Least Chipmunk Yellow-Bellied Marmot Golden-Mantled Ground Squirrel
Family: Castoridae *Castor canadensis*	Beaver
Family: Procyonidae *Procyon lotor*	Raccoon
Family: Canidae *Canis familiaris* *Canis latrans*	Domestic Dog Coyote
Family: Cervidae *Odocoileus hemionus*	Mule Deer

5.4 Soils

The Rifle Area, Colorado, Soil Survey (USDA, 1980) indicates two soil types within the 161,880-square meters (m^2) (40-acre) site. These include Bucklon-Inchau association loams and Cochetopa loam (Figure 5-2). The character of these soils was confirmed by field analysis of numerous soil borings during the wetlands and floodplain investigation performed in June 1993 (IT, 1993c, p. 4-4). Neither of these soil types constitutes prime agricultural land (Carlson, 1993, personal communication).

Numerous soil borings were taken and field-analyzed during the wetlands delineation. Hydric soils were identified in areas identified as wetlands. These results correspond with the U.S. Department of Agriculture, Soil Conservation Service soils mapping of the Rifle Area.

Bucklon soils make up approximately 55 percent of the map unit and are found on the more steep, convex parts of the landscape. It is a shallow and well-drained soil. Permeability of the Bucklon soil is slow above bedrock. The available water capacity is very low. Effective rooting depth is about 0.25 to 0.51 m (10 to 20 in.). Surface runoff is medium, and the erosion hazard is severe.

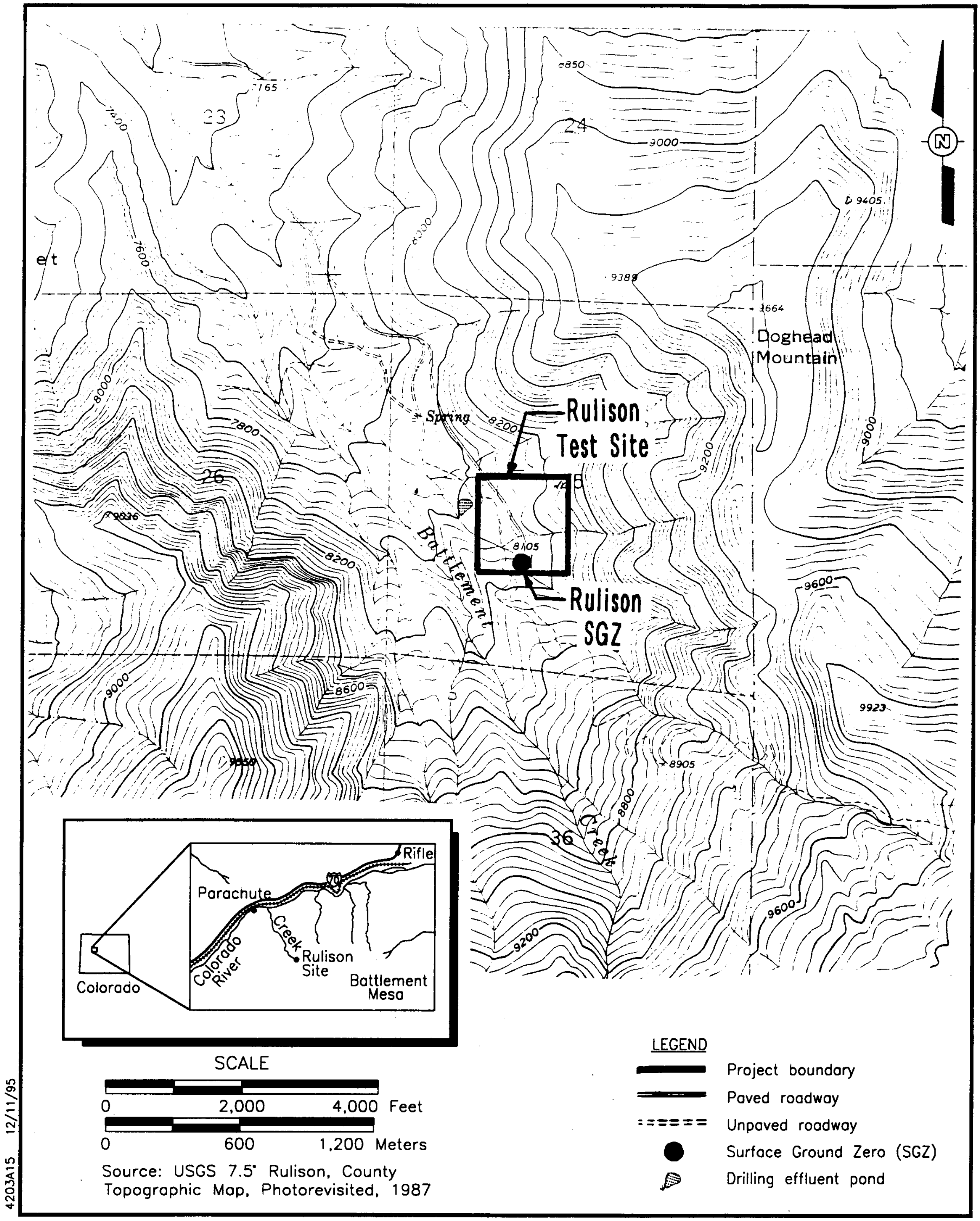

Figure 5-1
Topographic Map of Garfield County, Colorado, Project Rulison

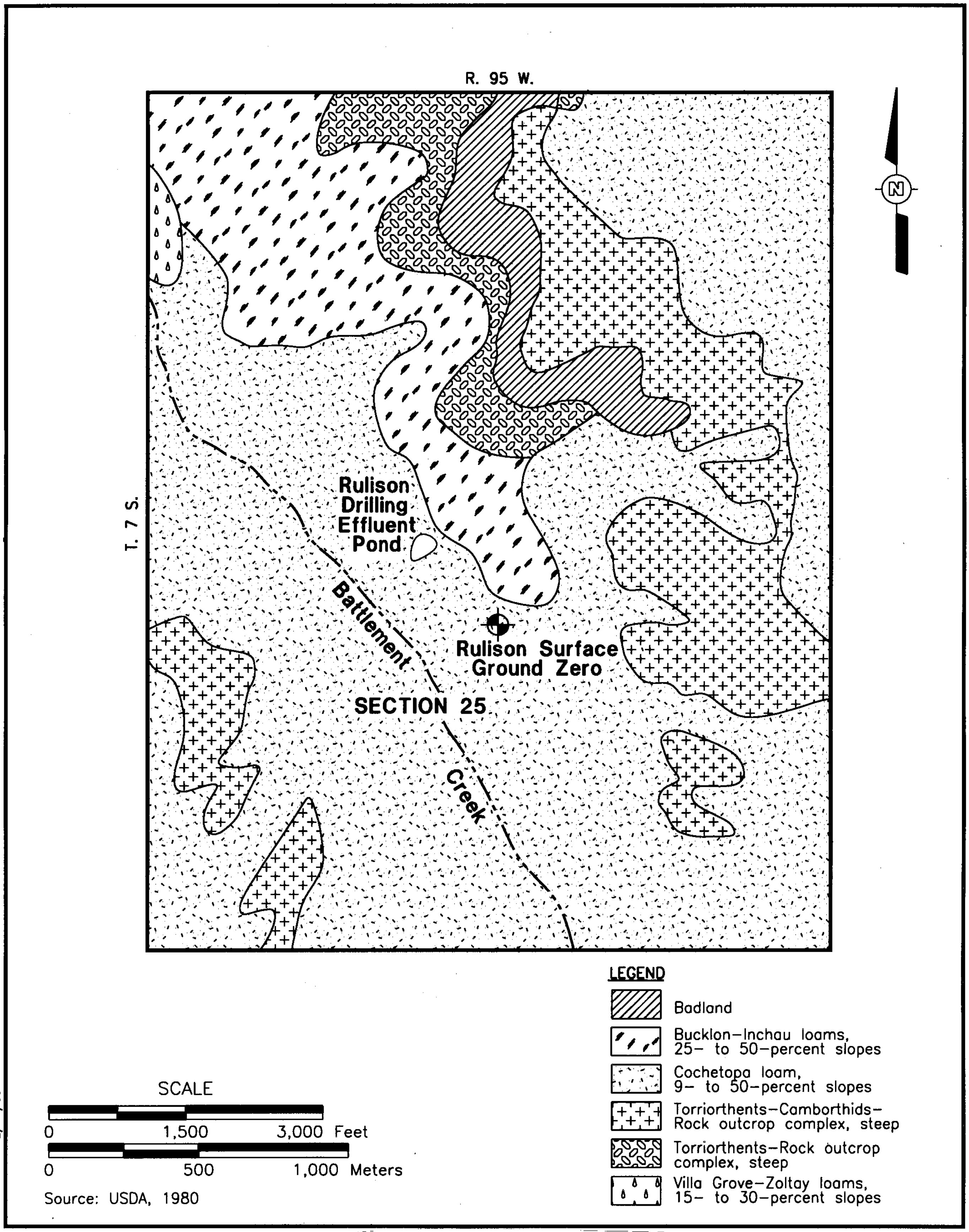

Figure 5-2
U.S. Department of Agriculture Soil Conservation Service Soils Map, Rifle Area, Colorado, Rulison Project

Inchau soils make up approximately 35 percent of the map unit and occur on the slightly concave parts of the landscape. It is a moderately-deep and well-drained soil. Permeability of Inchau soil is moderate above bedrock, and available water capacity is moderate.

Cochetopa loam is a deep, well-drained soil, and is found on rolling to steep mountainsides and alluvial fans. Elevation ranges from 2,134 to 2,896 m (7,000 to 9,500 ft). This soil is formed in basaltic alluvium. Permeability is slow, and available water capacity is high. Effective rooting depth is 1.5 m (60 in.) or more. Surface runoff is slow, and the erosion hazard is severe. High clay content in the soil causes low soil strength and high potential for soil slumping. The subsoil, below a depth of approximately 0.2 m (24 in.), consists of stony clay with a low permeability. The Rulison SGZ was constructed in the Cochetopa loam.

5.5 Geology

5.5.1 General Description

The Rulison Site is located within the Piceance Creek Basin. This northwest-southeast trending, structurally downwarped basin, is delineated primarily by the distribution of the Mesaverde Formation. The basin was structurally deformed by northeast-directed, Laramide-aged, shortening and reactivated, high angle basement structures (CER, 1989; Dickenson and Snyder, 1978). The present basin axis (a synformal fold axis) is oriented approximately northwest-southeast (Figures 5-3 and 5-4). This present axis is approximately the same as the paleo-depositional axis of the Mesaverde Formation. The Rulison Site is located on the southwest limb of the downwarp where the dip of the Mesaverde is about 2 to 3 degrees to the northeast.

5.5.2 Surficial Geology

The surficial geology at the Rulison Site consists of Quaternary deposits comprised of talus accumulations, mud flows, fan and pediment gravel, and the alluvium of Battlement Creek and the Colorado River. These deposits range from 6 to 12 m (20 to 40 ft) in thickness, but locally may be more than 30-m (100-ft) thick. Groundwater occurs in many of these deposits (Voegeli et al., 1970).

Two soil-mapping units have been identified within the 161,880 m^2 (40 acres) surrounding the effluent-pond location. These are the Bucklon-Inchau loams and Cochetopa loam described in Section 5.4 (refer to Figure 5-2). The drilling-effluent pond was constructed in the Cochetopa loam.

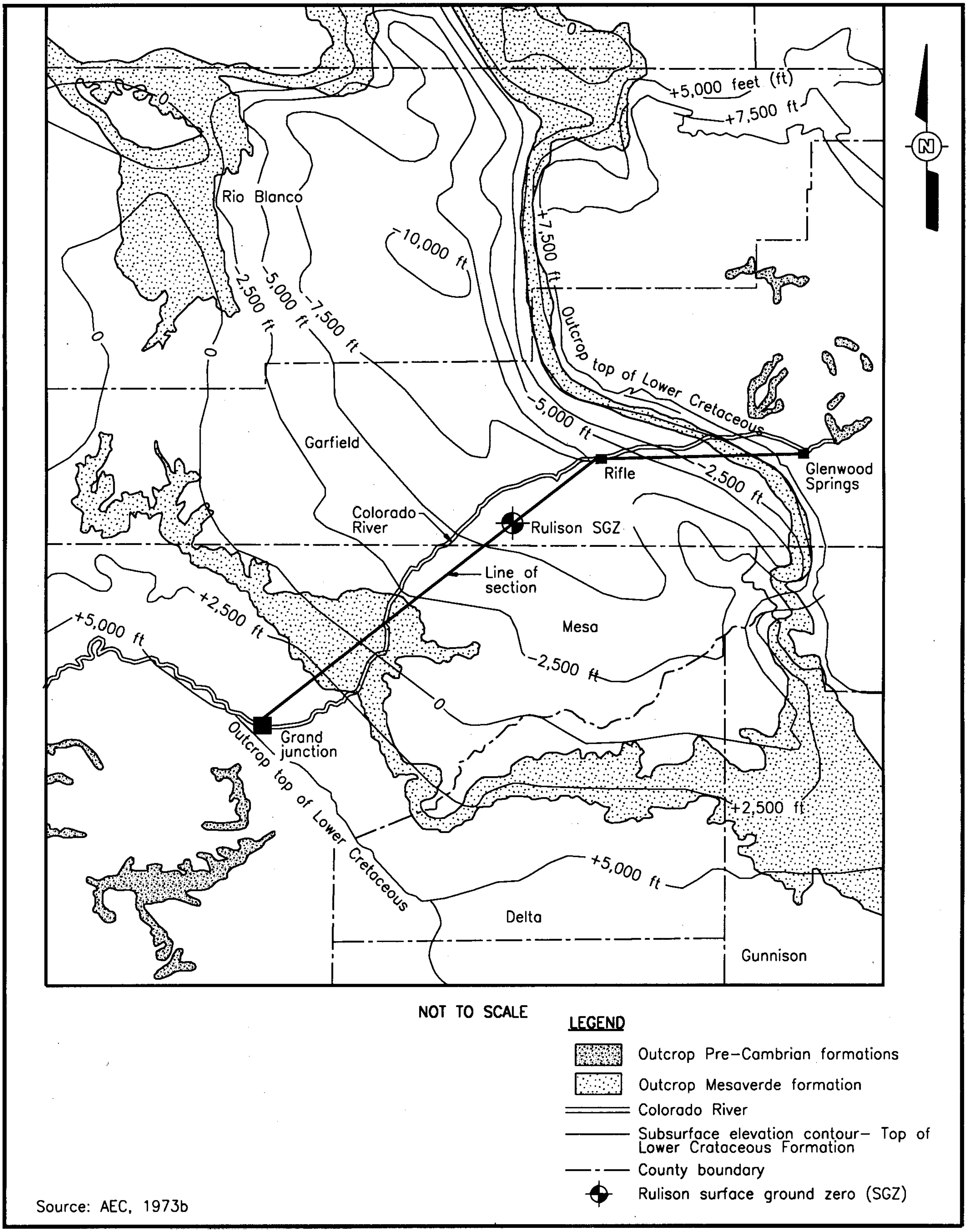

Figure 5-3
Rulison Site, Piceance Creek Basin - Regional Map and Structural Interpretation, Garfield and Mesa Counties, Colorado

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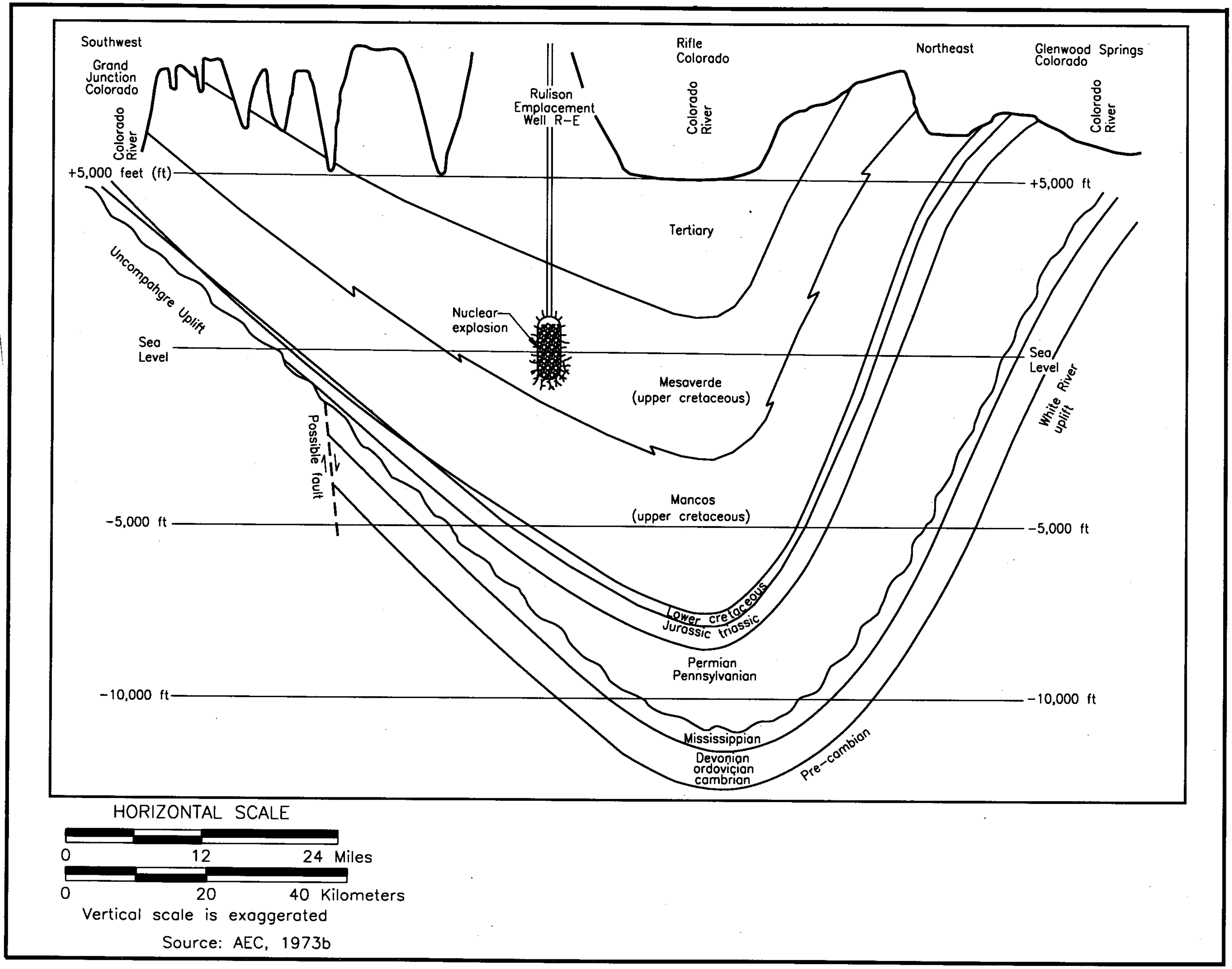

Figure 5-4
Rulison Site Piceance Creek Basin Schematic Cross Section, Garfield and Mesa Counties, Colorado

5.5.3 Subsurface Stratigraphy

The Piceance Basin contains Precambrian through Holocene stratigraphy. However, because the R-E well only encountered rocks as old as the lower Cretaceous (Mancos Shale), this section will only describe the stratigraphy from the Mancos Shale and above (Figures 5-5 and 5-6).

5.5.3.1 Mancos Shale

The lower Cretaceous Mancos Shale is a marine shale with sparse lenses of sand. Towards the upper half of the Mancos Shale, a transition to a regressive sequence begins that intertongues the shales with the upper Cretaceous Iles Formation within the Mesaverde Group. Overlying the Iles Formation (290 m [900 ft]) the regressive transition continues up into the Williams Fork Formation (1,067 m [3,500 ft]) which includes the Tertiary Ohio Creek member (15 m [50 ft]) (Lorenz and Rutledge, 1985). The Tertiary units continue with the Fort Union (152 m [500 ft]), Wasatch (1,188 m [3,900 ft]) and Green River Formations (518 m [2,100 ft]). Quaternary basalt flows, locally found in the Rulison area, and alluvial deposits (Pleistocene and recent) unconformably rest on all units.

5.5.3.2 Mesaverde Group

At Rulison, the Mesaverde Group is divided into two Formations: the Iles and Williams Fork (Figure 5-7). The Mesaverde represents a regressive phase from near-shore, deltaic marine (Isles Formation) to non-marine coastal plain, to paludal and meandering river plain, to fluvial environments (Williams Fork) (Lorenz, 1983; Lorenz, 1985; Johnson et al., 1987).

The Isles Formation is characterized by three sand members: the Cocoran and Cozzette intertongued with the Mancos Shale, and the Rollins, a blanket sand that underlies the Cameo-Fairfield Coal of the Williams Fork Formation. The Isles Formation represents a deltaic, shallow-marine sequence (Lorenz, 1983).

Within the Piceance Basin, the thickest sections of the Williams Fork Formation are coincident with the basin axis. The fluvial sand bodies throughout the Williams Fork are laterally extensive and heterogeneous. This suggests that the basin was subsiding during deposition (CER, 1989). In the vicinity of the Rulison Site, the basin axis is oriented east-southeast from which the fluvial paleocurrent directions in the upper Mesaverde can be inferred. Sand-body shapes in the fluvial sequences appear lenticular in cross-section; they are likely longer than the cross-section in the

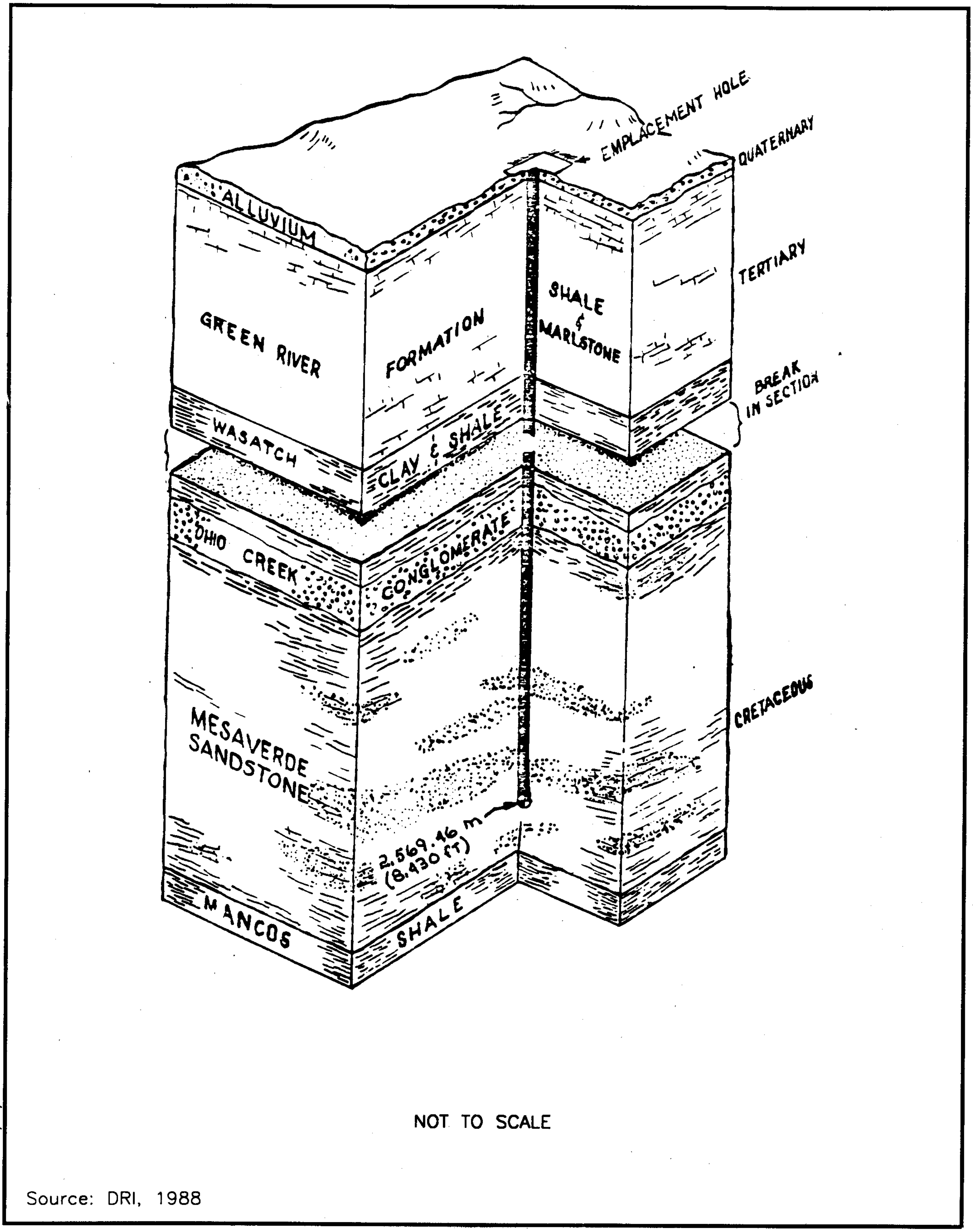

Figure 5-5
Project Rulison Generalized Geologic Cross Section, Garfield County, Colorado

SYSTEM AND PERIOD			FORMATIONS	STRATIGRAPHIC COLUMN	GENERAL LITHOLOGY	APPROXIMATE THICKNESS meters (m) feet (ft)
Holocene			"Recent"		Low terrace, floodplane, and alluvial deposits	30.48 m(100 ft)
Quaternary			"Pleistocene"		Terrace and fan sand and gravel, pediment gravel, colluvium, mudflow, and solifluction deposits	60.96 m (200 ft)
Tertiary			Unnamed		Basalt flows underlain by variegated claystones and gravel	304.80 m (1,000 ft)
Tertiary			Green River		Oil shales, marlstones, and sandstones (dark color)	640.08 m (2,100 ft)
Tertiary			Wasatch		Bright colored clays and shale with with minor sandstone	1,188.72 m (3,900 ft)
Tertiary			Fort Union		Brown-gray shale and coal	152.40 m (500 ft)
Tertiary		Mesaverde	Ohio Creek		Sandstone and conglomerate	15.24 m (50 ft)
Cretaceous	Upper	Mesaverde	Williams Fork		Shale - sandstone	1,066.80 m (3,500 ft)
Cretaceous	Upper	Mesaverde	Isles		Shale - sandstone	274.32 m (900 ft)
Cretaceous	Lower		Mancos		Gray shale	518.16 m (1,700 ft)
Cretaceous	Lower		Naturita		Shale - sandstone	182.88 m (600 ft)
Cretaceous	Lower		Dakota Cedar Mountain		Sandstone	60.96 m (200 ft)

NOT TO SCALE

Source: AEC, 1973b

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Figure 5-6
Rulison Site Stratigraphic Column, Garfield County, Colorado

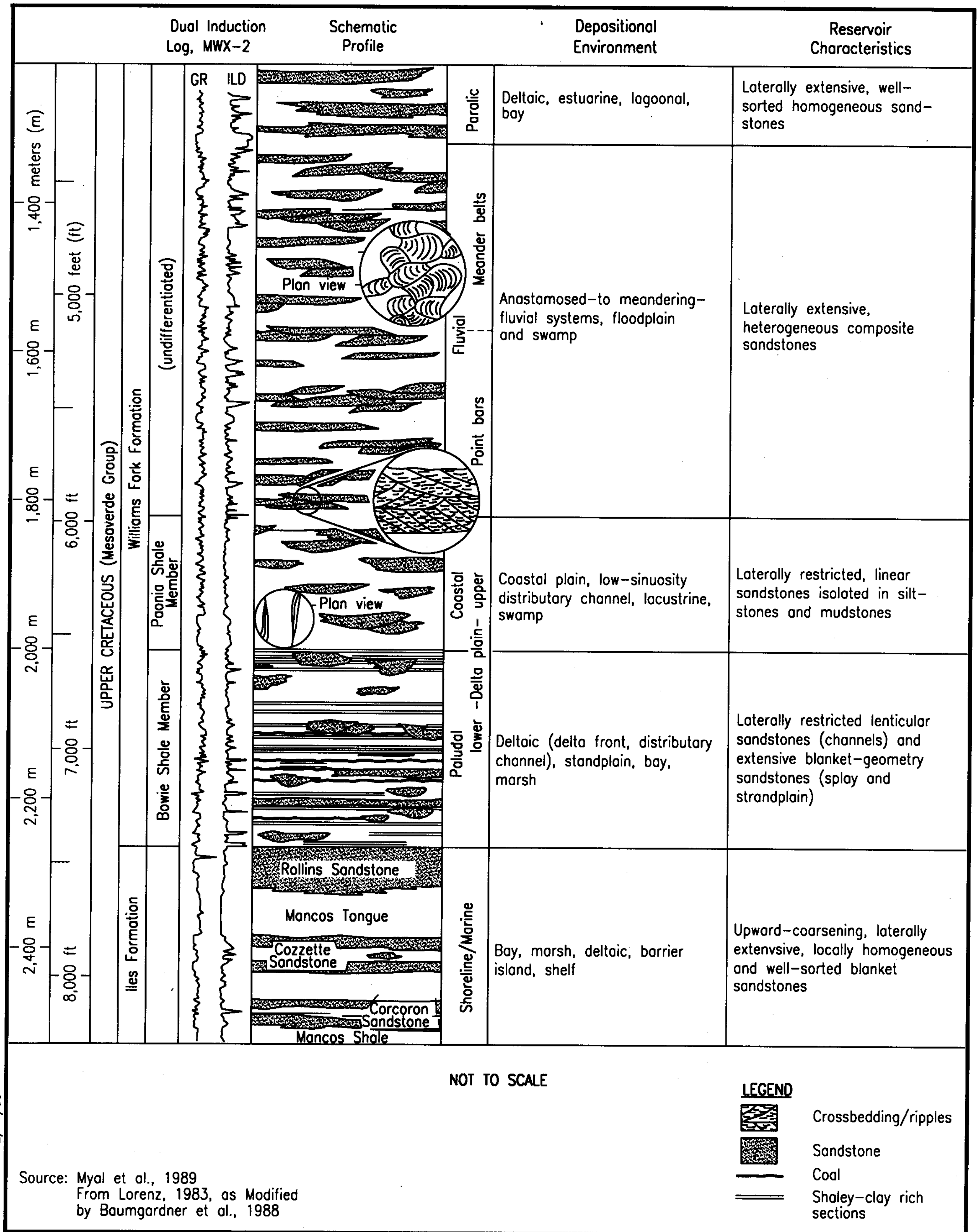


Figure 5-7
Correlation of Paleoenvironmental Depositional Units at the Multi-Well Experiment Site with Regional Stratigraphic Nomenclature, Garfield County, Colorado

paleocurrent direction parallel to the basin axis. As the basin continued to subside throughout the Tertiary, the axis of the basin became the deepest zone of the burial (Figure 5-8). This resulted in high compaction and reduced porosity and permeability.

5.5.3.3 Tertiary Stratigraphy

The Tertiary Wasatch and Green River Formations (refer to Figure 5-6) are mostly interbedded shale, marlstone, limestone, and sandstone. Combined, the two formations are over 1,700-m (5,600-ft) thick.

The Wasatch Formation consists of brightly colored clay and shale, but sandstone lenses are common. Locally, minor amounts of conglomerate, pebbly sandstone, limestone, coal, and black cabonaceous shale occur in the formation. The formation is approximately 1,188-m (3,900-ft) thick at the Rulison Site. The Wasatch is not a source of groundwater in the Rulison area.

In and near the Rulison Site, the Green River Formation contains fours members. In ascending order they are: Douglas Creek, Garden Gulch, Parachute Creek, and Evacuation Creek. At the Rulison Site, the Green River Formation is about 518-m (1,700-ft) thick. The most notable unit of the upper Green River, the Parachute Creek member, is an oil shale. This formation is composed of mostly shale and marlstone with minor amounts of sandstone, siltstone, and limestone. Sandy zones in the lower part of the formation may be capable of yielding minor quantities of groundwater at some location in the area (Coffin et al., 1968; Voegeli et al., 1970).

5.5.4 Natural Gas Production in the Rulison Area

In the Southern Piceance Basin, natural gas is found in sandstones of both the Wasatch and Mesaverde Formations and in coals of the Mesaverde. The Rulison Site is on the outskirts of the Rulison and Grand Valley gas fields, centered along the Colorado River, which produces gas from both formations.

The closest commercial production wells to the Rulison Site are the Federal 28-95 located 4.3 km (2.7 mi) west and the Federal 14-95 located 4.34 km (2.7 mi) to the northwest. The wells are currently operated by Riata Energy, Inc. and Bonneville Fuels Corporation and were drilled in 1961 and 1962, respectively. Both wells produce gas from the Mesaverde Formation. Federal 14-95 had produced a total of 2.12 million m^3 (75 million cubic feet [MCF]) by 1988, and the Federal 28-95 39.83 million m^3 (375 MCF) by 1993. Both wells produced up to 1993 and are now presently shut in because of the declining gas market.

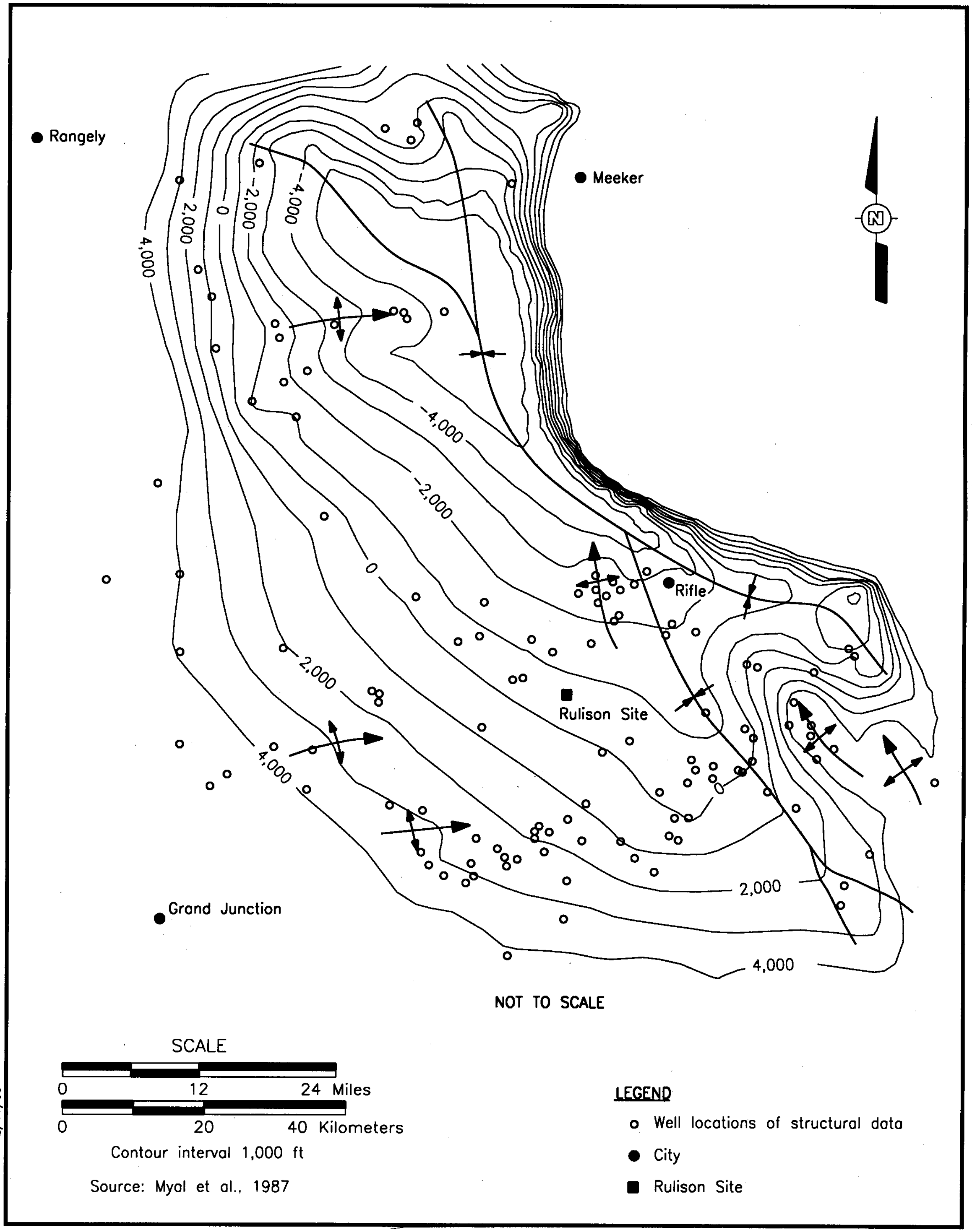


Figure 5-8
Structure Contour Map of the Top of Marine Intervals (Rollins-Trout Creek) of the Piceance Basin, Colorado

The Mesaverde Formation contains a tremendous gas resource throughout the Piceance Basin. However, because of its very low permeability, commercial development of the resource is often marginally economical. For this reason, the Rulison area has been the center of government- and institution-sponsored research to better understand Mesaverde production characteristics and enhancement potential. The Rulison test in 1969 in the Hayward 25-95 well was the first experiment to attempt to stimulate production of gas by fracturing the formation with a nuclear device.

5.5.5 Gas Reservoir Characteristics

The Mesaverde can be a prolific gas producer; however, it is often found to be “tight”, having low porosity (<10%) and low permeability (<0.05 millidarcies) (CER, 1992). The highest production from the Mesaverde is limited to zones where natural, open fractures are encountered. When fractures are not encountered, fractures are artificially induced using hydraulic pressure (Hydrofracs). The enhanced or new fractures are then propped open using sands or other compounds. Artificially stimulated wells do not perform as well as wells that encounter natural open fractures (CER, 1989).

Based upon intensive analysis of the core, high resolution geophysical logging methods, and well interference tests, one dominant fracture set is present within the Mesaverde Group. These open fractures strike northwest-southeast parallel to the local basin axis (Figure 5-9). Wells that intersect these fractures show the highest rates of gas production (CER, 1989). Fracture development by artificial means tends to develop parallel to the dominant fracture set.

Gas produced from the Mesaverde is usually dry. However, water content within the reservoirs is variable, and water can be produced from the formation along with the gas.

5.6 Surface Water

5.6.1 Streams, Springs, and Seeps

There are three major surface water features at the Rulison Site. First, Battlement Creek is a rushing mountain stream that flows through the southwest corner of the site. Battlement Creek is principally fed by snow melt, shallow groundwater, and springs, and its flow is regulated upstream (south) of the site by Battlement Reservoir. Second, a smaller, spring-fed tributary of Battlement Creek flows across the site east of Battlement Creek. Third, an artificially created

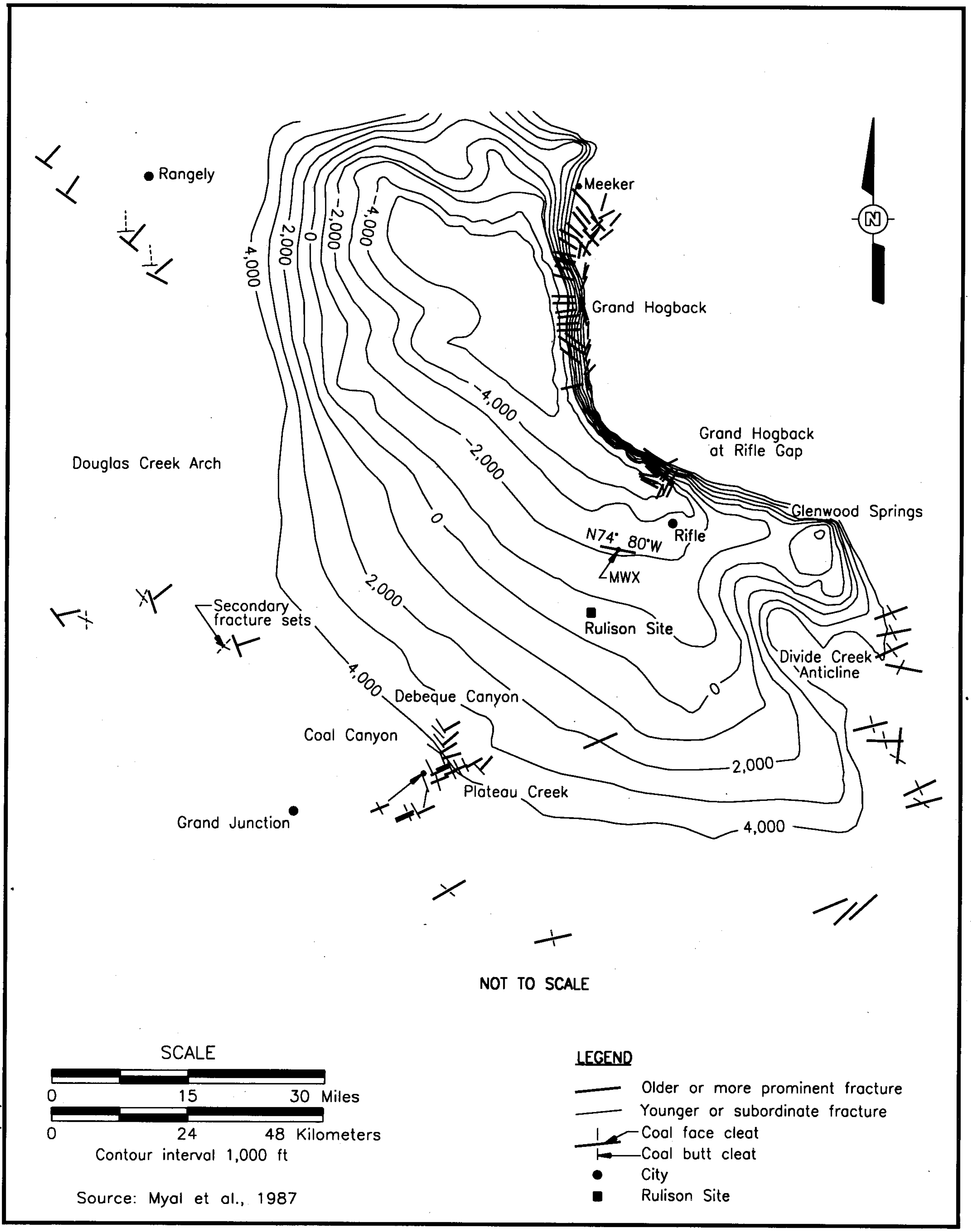


Figure 5-9
Compilation Map of the Fracture Orientation, Piceance Basin, Colorado

drilling effluent pond is located at the center of the site. This pond was built to store drilling mud as part of emplacement hole drilling for the nuclear device.

Battlement Creek and its tributaries provide the main control over surface waters at the Rulison Site. The creek and the tributaries flow in a generally northwesterly direction toward the Colorado River.

An unnamed tributary (locally known as “Hayward” Creek) transects the Rulison Site and is adjacent to the effluent pond. Approximately 30 m (100 ft) below the effluent pond, this tributary flows into a series of beaver ponds (Figure 5-10). This stream is impounded by the beaver dams, creating a marshy, wetland complex through the middle of the site. Because of the topographic slope of the area, Battlement Creek and its tributaries are generally confined to relatively narrow stream channels except for the beaver pond area where the tributary channel widens because of the slower flow resulting from a more shallow stream gradient.

Additionally, several springs exist near the Rulison Site and the drilling effluent pond. The current source of water for the pond is from snow melt, groundwater, and a spring located approximately 300 m (915 ft) southeast of the pond, which replenishes the pond by surface flow via an inlet in the eastern berm. The pond also has an overflow in the western berm although the water level is seldom high enough for overflow to occur.

The Rulison drilling effluent pond is triangular in shape and covers approximately 1 acre. It is approximately 6-m (20-ft) deep (from top of the berm to pond bottom) and is located approximately 400 m (1,300 ft) north-northwest of SGZ. The pond originally was used for containment of surplus drilling fluids during the emplacement hole drilling operations. The pond is equipped with a spillway on the downslope side, 1.8 m (6 ft) below the crest. The present owner of the property, Lee Hayward, son of Claude V. Hayward, has retained the pond for his own use (AEC, 1973a, p. 5) and has converted the pond to a fresh-water trout pond. The pond is fenced to prevent access by wildlife and livestock. Because the effluent pond is an artificial impoundment that does not have the vegetative characteristics of a natural wetland, it has not been designated as a “wetland” (IT, 1993c, p. 4-1).

5.6.2 Wetlands

A wetlands, vegetation, and floodplains survey was conducted during June 1993 (IT, 1993c). An initial wetlands and floodplains determination for the Rulison Site was made using information

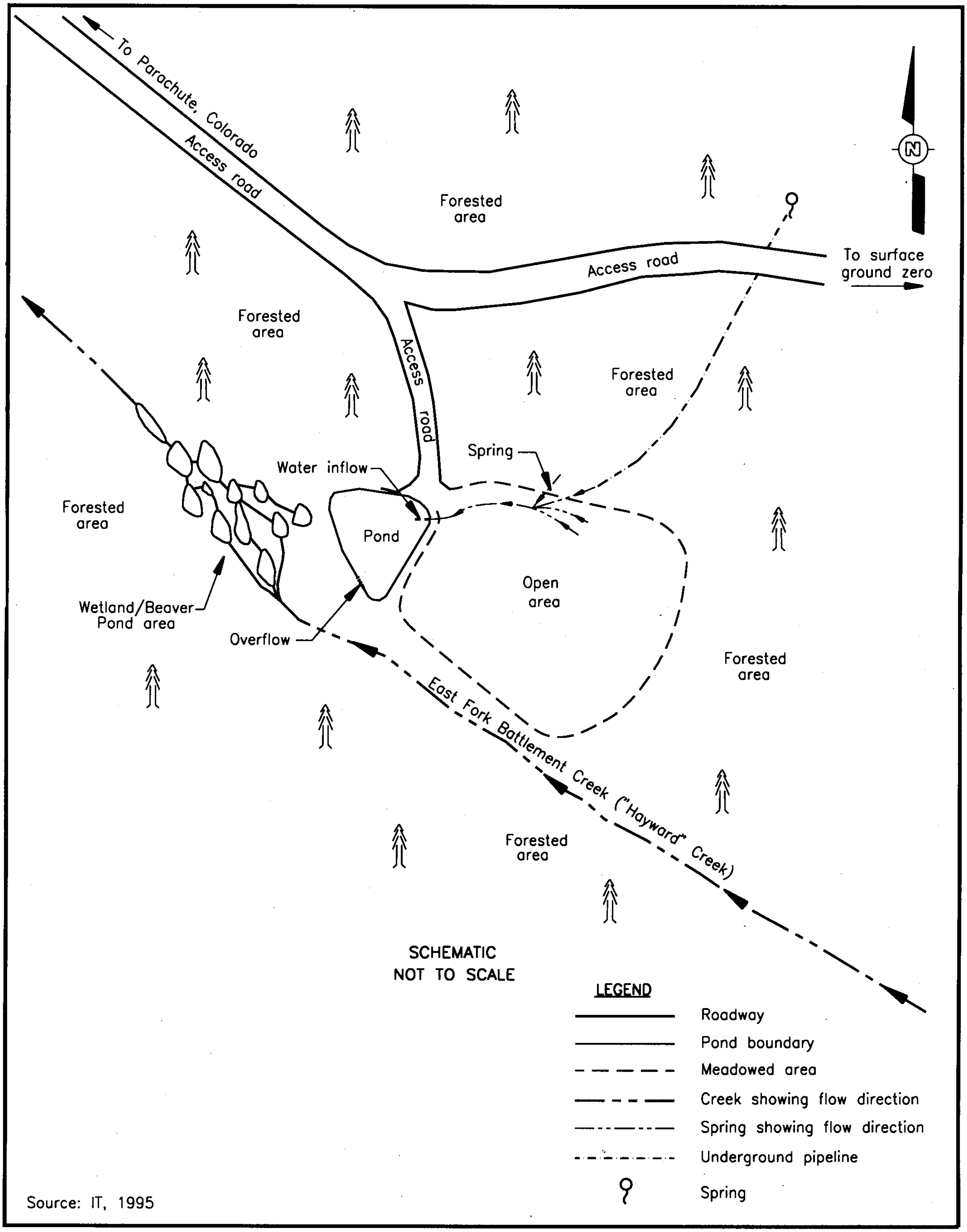


Figure 5-10
General Site Layout Diagram, Rulison Drilling Effluent Pond, January 1995

from aerial photographs; a USGS topographic map (7.5 minute Rulison quadrangle); a Rifle Area, Colorado, Soil Survey (1980) map; and Flood Insurance Rate Maps (FIRM) for Garfield County, Colorado, in conjunction with field surveys.

Floodplains and wetlands were delineated using the methods outlined in the Corps of Engineers *Wetlands Delineation Manual* (U.S. Army Corps of Engineers, 1987), and the procedures outlined in *Title 10 CFR Part 1022, "Compliance with Floodplains in Wetlands Environmental Review Requirements."*

A list of dominant plant species found in upland and wetland communities at the Rulison Site is presented in Table 5-4.

The wetlands on the site are either associated with Battlement Creek or its tributary which transects the site. Battlement Creek flows within a narrow, well defined path. The high flow rate of Battlement Creek has scoured the channel, leaving a very rocky substrate supporting limited, if any, vegetation within the channel. However, the wooded slopes adjacent to the Creek contain a dense canopy of blue and Englermann spruce intermixed with quaking aspen. The understory contains mountain maple, water birch, and mountain alder.

The tributary to Battlement Creek, which transects the site, has a similar wetland community. These wetlands are due to adjacent springs feeding the tributary and beaver disturbance in the center of the site. The two most common species in this area are the quaking aspen and mountain maple in the canopy, with serviceberry and grasses in the understory and ground cover. Often, the aspen form pure stands. In the center of the site, beaver have removed the canopy layer and formed numerous ponds on several terraces. Associated with the terraces are saplings of quaking aspen with adult spruces intermixed. Sandbar willow is also common, recolonizing the wetter areas with common choke cherry sprouting in the drier areas. Numerous emergent species, such as grasses and sedges, were also observed colonizing the disturbed areas and on the beaver dams.

The center of the site also contains the man-made drilling effluent pond. This drilling effluent pond was created during the original testing activity on the site and is contained within an earthen berm that has little hydrophytic and no aquatic vegetation.

Table 5-4
List of Dominant Plant Species - Rulison Site Wetland Survey
June 25 - 30, 1993

Scientific Name[b]	Common Name	Indicator Status[a] Regional	National
Osmundaceae *Osmunda cinnamomea*	Cinnamon Fern	NL	FACW
Gramineae *Gramineae spp.*	Grasses	NIS	
Salicaceae *Salix exigua* *Populus tremuloides*	Sandbar Willow Quaking Aspen	OBL FAC	FACW, OBL FACU, FAC
Betulaceae *Betula occidentalis* *Alnus tenuifolia*	Water Birch Mountain Alder	FACW FACW	FAC, FACW FAC, FACW
Cyperaceae *Carex spp.*	Sedge	NIS	FACW, OBL
Juncaceae *Juncus effusus*	Soft Rush	OBL	FACW, OBL
Fagaceae *Quercus gambelii*	Gamble Oak	NL	UPL
Rosaceae *Prunus virginiana* *Amelanchier alnifolia* *Cowania mexicana* *Purshia tridentata*	Common Chokecherry Western Serviceberry Cliffrose Antelope Brush	FACU FACU UPL UPL	FACU, FAC UPL, FAC UPL UPL
Aceraceae *Acer glabrum*	Rocky Mountain Maple	FAC	FACU, FAC
Cornaceae *Cornus stolonifera*	Red-Osier Dogwood	FACW	FAC, FACW
Pinaceae *Picea engelmannii* *Picea pungens* *Pinus edulis*	Engelmann Spruce Blue Spruce Colorado Pinyon	FACU FAC UPL	FAC, FACU FAC UPL
Typhaceae *Typha latifolia*	Broad-Leaf Cattail	OBL	OBL
Balsaminaceae *Impatiens capensis*	Jewelweed	FACW	FACW
Urticaceae *Urtica dioica*	Stinging Nettle	FAC	FACU, FACW

Source: IT, 1993c

[a]Indicator status derived from the U.S. Fish and Wildlife Service's National List of Plant Species that occur in Wetlands: 1988 National Summary (Reed, 1988).
[b]Nomenclature conforms to that of *Grays Manual of Botany* (Fernald, 1950).

OBL = Obligate wetland plants that occur almost always in wetlands (>99%)
FACW = Facultative wetland plants that usually occur in wetlands (67-99%)
FAC = Facultative plants that are equally likely to occur in wetlands or nonwetlands (34-66%)
FACU = Facultative upland plants that usually occur in nonwetlands (1-33%)
UPL = Obligate upland plants that occur almost always in nonwetlands (>99%)
NL = Species not listed
NIS = Not identified to species

Interviews with personnel who were present when the drilling effluent pond was constructed indicated that the pond may have been built on a spring or the pond may have been built below the local water table. Verbal reports by personnel who were present when the site was decommissioned indicate that groundwater entered the pond faster than it could be removed. In addition, the local surface expression of groundwater (springs) proximal to the Rulison Site indicates that the depth to groundwater may be less than expected based on regional information.

Finally, the pond-water level has remained stable after 26 years with only seasonal elevation changes observed, indicating that recharge to the pond and discharge from the pond have reached equilibrium with the local groundwater environment. The water level in the pond ranges from approximately 1 to 3 m (3 to 10 ft) below the pond berm.

Based on this evidence and an inspection of the site hydrology (conducted on April 19 and 20, 1995), groundwater at the effluent pond is expected to be at a relatively shallow depth, following the natural topographic slope. At the south end of the pond, the water surface is anticipated to be equivalent to the groundwater surface. At the north end, the hydraulically down gradient end of the pond, the water surface is anticipated to be above the groundwater surface because of the damming action of the pond berm.

5.6.3 Floodplains

No flood plains or flood-prone areas have been identified at the Rulison Site based on review of the FIRM Index Map (FEMA, 1986) for Garfield County, Colorado, although a more detailed map has not been published.

5.7 Hydrogeology

5.7.1 Occurrence of Groundwater

The groundwater resources in the Rulison area are confined primarily to alluvium and surficial deposits (e.g., floodplain deposits and terrace and fan gravel). Essentially all the wells and most of the springs in the area derive their water from these shallow sources. Water in the alluvium occurs under both water-table and artesian conditions (Coffin et al., 1968, p. 8). Most of the springs are located along the contact of different strata within the surficial deposits. The underlying shale bedrock formations generally have low permeability and yield little or no water (Voegeli et al., 1970, p. 9).

Marine and nonmarine sedimentary rocks, approximately 5,486.40 m (18,000 ft) thick, underlie the Rulison Site. The emplacement (R-E) and exploratory (R-EX) holes, see Figure 5-11 (ERDA, 1977, p. 3), penetrated the following formations, in descending order:

- Quaternary alluvium is as much as 42.67 m (140 ft) thick;
- Green River Formation composed chiefly of shale and marlstone is about 518.16 m (1,700 ft) thick;
- Wasatch Formation consisting principally of clay and shale with sandstone lenses is about 1,188.72 m (3,900 ft) thick;
- An unnamed unit of Paleocene age consisting of sandstone, shale, and a few thin beds of coal is about 152.40 m (500 ft) thick;
- Ohio Creek Conglomerate is about 11.28 m (37 ft) thick;
- Mesaverde Formation consisting mainly of sandstone and interbedded shale is about 762 m (2,500 ft) thick (Nork and Fenske, 1970, p. 5; Voegeli et al., 1970, pp. 5-7).

The Mesaverde Formation is of particular interest because the nuclear device was detonated within this group at a depth of 2,568.24 m (8,426 ft) in hole R-E (Voegeli, 1969, p. 4; Voegeli et al., 1970, p. 5; ERDA, 1977).

A small amount of water was found in an upper Mesaverde sandstone lens during the drilling of hole R-EX. Later tests of this zone and other zones thought to contain water in the Mesaverde yielded no significant groundwater. Several deep drill holes in the Ohio Creek Conglomerate above the Mesaverde Group in the Rulison gas field have produced water; hole R-EX produced no water from the Ohio Creek Conglomerate. The Wasatch Formation contains some sandy zones in the middle and the upper parts of the formation; however, these zones produced no water in hole R-EX. The lower Green River Formation, about 1,524 m (5,000 ft) above the detonation, has some sandy zones that produced water in sufficient quantities (none exceeding 0.73 m^3/day [4 gallons per minute]) to make air drilling difficult (Voegeli, 1969, p. 7; Voegeli et al., 1970, p. 15; DOE, 1984, p. 10).

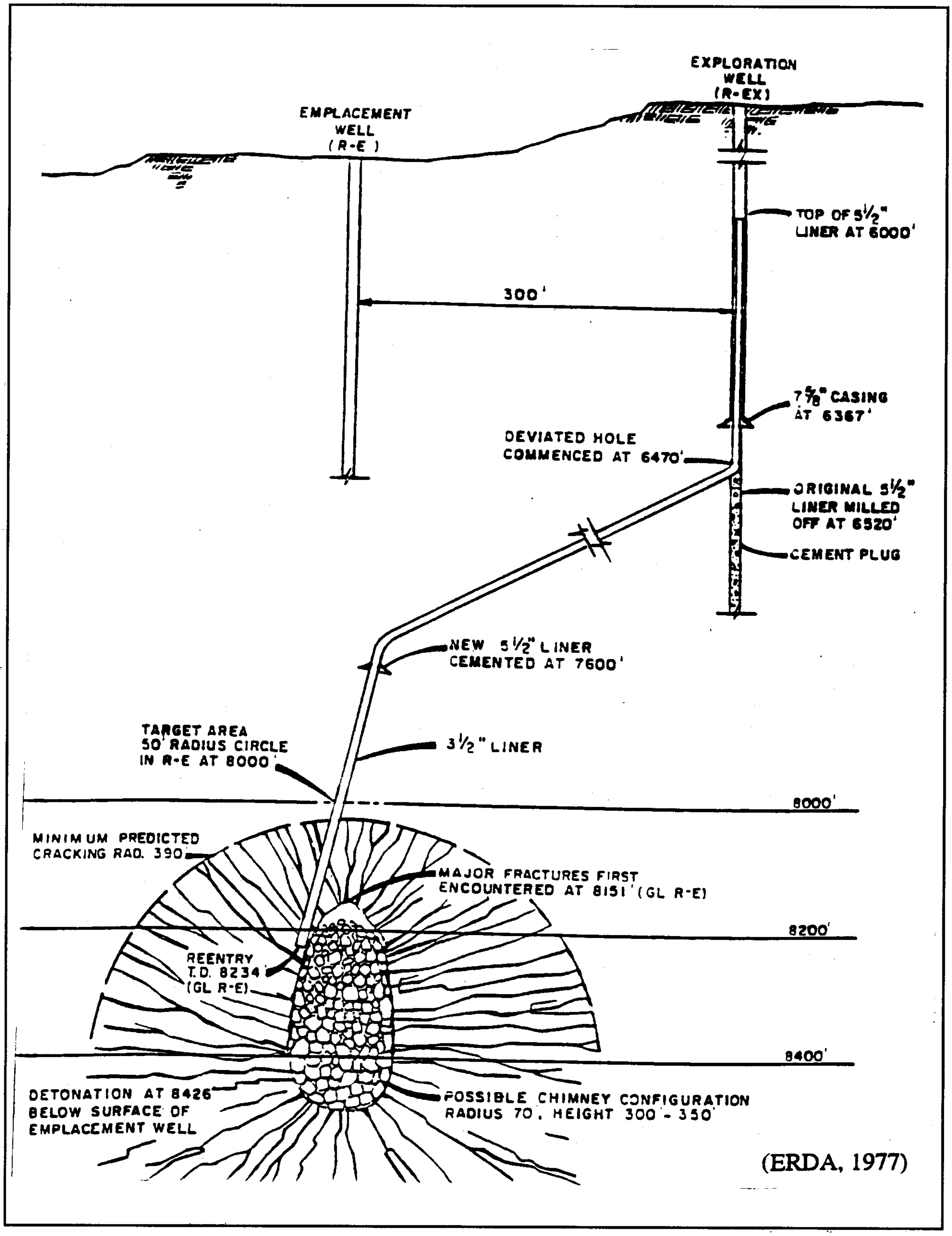


Figure 5-11
Project Rulison Emplacement and Reentry Well Configuration

The Quaternary alluvial deposits are of particular importance since they provide most of the area's groundwater resources. The deposits include mudflows, talus accumulations, fan and pediment gravel, slump blocks, and the alluvium of Battlement Creek and the Colorado River. The regional water table ranges from 1.83 to 48.77 m (6 to 160 ft) below the land surface (Voegeli et al., 1970, pp. 25-28). The direction of groundwater flow in the alluvial deposits is expected to be northward, consistent with topographic slope. Rocks below the alluvium dip two degrees or less to the north and groundwater flow is expected to be northward also (Nork, 1969, p. 4; Voegeli et al., 1970, pp. 25-28; Nork and Fenske, 1970, p. 7).

5.7.1.1 Hydraulic Characteristics

Results of hydraulic tests in hole R-EX, shown in Table 5-5 (Voegeli et al., 1970, p. 19), indicate that samples consist primarily of drilling fluid rather than formation water. This suggests that the permeability of the formation is so low that little or no water movement occurs in the zones tested (Voegeli et al., 1970, p. 23). Although no fluid was recovered on any of the swab tests performed during the drill-stem tests, the complete absence of formation water cannot be ruled out as attested to by regular variations in other ions such as carbonate, sulfate, chloride, and sodium. The tritium content of the fluid indicates that it was derived from or contaminated by a surface source rather than from formation water (Voegeli, 1969, p. 14; Voegeli et al., 1970, p. 20).

Hydrologic tests were performed only in the Ohio Creek and Mesaverde rocks encountered in drill hole R-EX. Preshot permeability for the Mesaverde Formation was first estimated at 0.5 microdarcys (μd) and then at 0.01 μd, while postshot production data and reservoir simulation studies indicated that actual matrix permeability was approximately 0.001 to 0.04 μd (Stosur, 1977, p. 709). Additional porosities and permeabilities for deep rocks in the Rulison gas field are presented in DOE's Multi-Well Experiment reports (Sattler, 1984; Hart et al., 1984; CER, 1984; and Hart et al., 1987). Extensive pressure drawdown and build-up data for R-EX are reported by Austral and CER (1969, pp. I-1-IX-3).

Pressures recorded by the USGS during the testing of all water-bearing zones below the unnamed Paleocene unit indicate steep pressure build-up curves as a function of time, but yielded low fluid recoveries. This could indicate fracture dominated permeability. The presence of linear features on the land surface supports this theory. If there is fracture flow, lateral flow rates could be much higher than those previously predicted. The most permeable interval tested was from 2,193.34 to 2,193.95 m (7,196 to 7,198 ft). The shut in pressure for this interval was 2,875

Table 5-5
Summary of Hydraulic Tests, Hole R-EX
(Voegeli et al., 1970)

Geologic Formation	Depth of Zone Tested Below Land Surface (feet)	Date Tested	Casing Size (inches)	Perforations	Type of Test Tool	Fluid Entry During Time Tool was Open	Bottomhole Temperature (°F)	Remarks
Ohio Creek Formation	6,129 to 6,149	1-15-68	7⅝	⅜ in. to ½ in. 4 per ft	M.F.E.[1]	Pressure charts indicated no fluid entry.	151	Recovered about 15 gallons of drilling mud from top of test tool.
Mesaverde Group	7,066 to 7,080	4-8-68	5½	⅜ in. to ½ in. 2 per ft	F.A.S.T.[2]	Pressure charts indicated no fluid entry.	196	Swabbed to 7,004 ft below land surface. No fluid recovered. Recovered about 10 gallons of fluid from top of test tool.[3]
Mesaverde Group	7,196 to 7,198	4-5&6-68	5½	⅜ in. to ½ in. 2 per ft	F.A.S.T.[2]	Pressure charts indicated no fluid entry.	195	Swabbed to 7,134 ft below land surface. No fluid recovered. Recovered about 240 gallons of fluid from top of test tool.[3]
Mesaverde Group	7,312 to 7,320	4-4&5-68	5½	⅜ in. to ½ in. 2 per ft	F.A.S.T.[2]	Pressure charts indicated no fluid entry.	196	Swabbed to 7,250 ft below land surface. No fluid recovered. Recovered about 15 gallons of fluid from top of test tool.[3]
Mesaverde Group	7,598 to 7,604	4-3&4-68	5½	⅜ in. to ½ in. 2 per ft	F.A.S.T.[2]	Pressure charts indicated no fluid entry.	197	Swabbed to 7,544 ft below land surface. No fluid recovered. Recovered about 20 gallons of fluid from top of test tool.[3]
Mesaverde Group	8,014 to 8,018	3-28-68	5½	⅜ in. to ½ in. 2 per ft	F.A.S.T.[2]	Pressure charts indicated no fluid entry.	199	Swabbed to 7,929 ft below land surface. No fluid recovered. Recovered about 30 gallons of fluid from top of test tool.[3]

[1] Johnston Testers Multi-Flow Evaluator.
[2] Johnston Testers Fracturing Acidizing Squeezing Tool.
[3] Fluid likely to have entered the tubing after the packer was pulled loose.

pounds per square inch, which is adequate to support a column of water 2,020.82 m (6,630 ft) high or 172.52 m (566 ft) below land surface (Voegeli et al., 1970; Nork and Fenske, 1970, p. 6).

Little information was obtained about the hydraulic properties of the rocks above 1,828.80 m (6,000 ft) (Nork, 1969, p. 4; Nork and Fenske, 1970, p. 5). However, water-bearing characteristics for the same geologic formations in the shallow groundwater aquifer system slightly north (< 48.27 km [< 30 mi]) of the Rulison Site, presented in Table 5-6 (Coffin et al., 1968, p. 3), are assumed to be representative of the water-bearing characteristics for the alluvium and Green River Formation in the Rulison area.

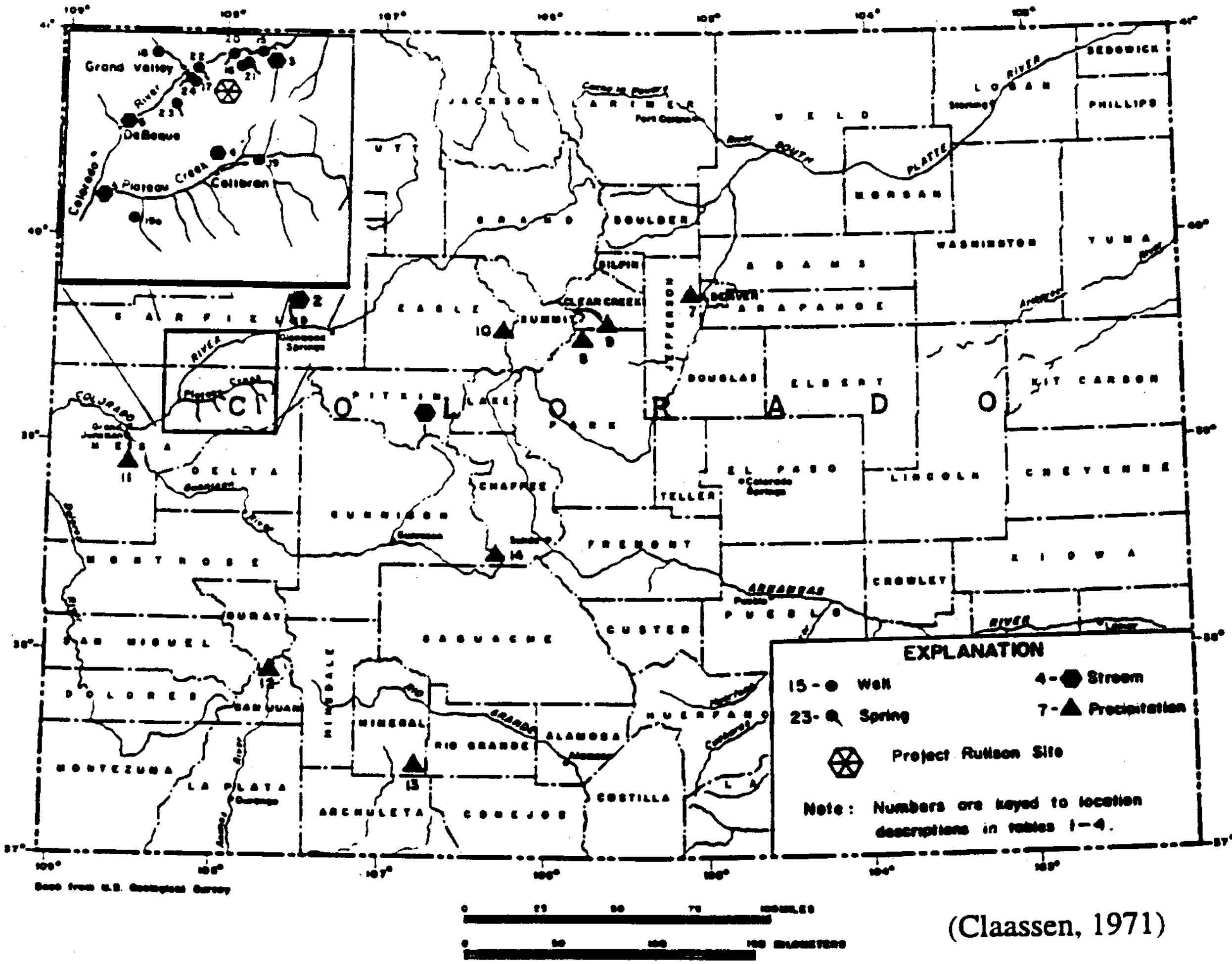
The transmissibility of the alluvial fill differs from place to place. In places where the alluvium is mainly sand and gravel, transmissibility may be as much as 1,242.08 m^2/day (100,000 gallons per day [gpd]/ft). In places where the alluvium contains clay beds, the transmissibility may be as low as 248.42 m^2/day (20,000 gpd/ft). The average coefficient of storage probably averages about 0.20 (Coffin et al., 1968, p. 17). Thus, well yields depend largely on the lithology of the alluvium at the well, and the location of the well with respect to local hydrologic boundaries.

Specific conductance of the water decreased from about 12,000 to 10,000 microhoms, which may indicate a layering of the water and subsequent mixing when pumped (Coffin et al., 1968, p. 17).

Results of pumping and recovery tests in the Green River Formation indicate a range of transmissibility from 12.42 to 24.84 m^2/day (1,000 to 2,000 gpd/ft) (Coffin et al., 1968, pp. 17-18) and a storage coefficient of 1×10^{-5} (Coffin et al., 1968, p. 21).

5.7.2 Regional Hydrochemistry

A pre-shot inventory of wells and springs in the Rulison area was conducted by the USGS between March 20 and May 25, 1969, to document the condition of wells and springs and to collect water samples for chemical and radiochemical analysis. All known wells within a 9.65-km (6-mi) radius of the Rulison emplacement hole, as well as selected wells and springs within a 16.09- to 32.18-km (10- to 20-mi) radius, are given in Appendix B (Hurr et al., 1969, pp. 3-9; Voegeli et al., 1970, pp. 25-31). Figure 5-12 shows the location of the water-sampling points in the network (Claassen, 1971, p. 3). Detailed location descriptions of sampling sites are presented in Voegeli et al. (1970, pp. 35-37).



(Claassen, 1971)

Figure 5-12
Location of the U.S. Geological Survey Water-Sampling Points, Project Rulison

Table 5-6
Summary of the Water-Bearing Characteristics of the Geologic Formation
(Coffin et al., 1968)

System	Series	Geologic unit		Thickness (feet)	Physical character	Water quality	Hydrologic character	Water supply
Quaternary	Recent and Pleistocene	Alluvium		0-140	Sand, gravel, and clay partly fill major valleys as much as 140 feet; generally less than one-half mile wide. Beds of clay may be as thick as 70 feet; generally thickest near the center of valleys. Sand and gravel contain stringers of clay near mouths of small tributaries to major streams.	Near the headwaters of the major streams, dissolved-solids concentrations range from 250 to 700 ppm. The water is generally a calcium magnesium bicarbonate type. In most of the area, dissolved solids range from 700 to as much as 25,000 ppm. Above 3,000 ppm the water is generally a sodium bicarbonate type.	Water is under artesian pressure where sand and gravel are overlain by beds of clay. Well yields will decrease with time because valleys are narrow and the valley walls act as relatively impermeable boundaries. Calculated coefficients of transmissibility range from 20,000 to 150,000 gpd per ft. The coefficient of storage averages 0.20.	Reported yields as much as 1,500 gpm.
Tertiary	Eocene	Green River Formation	Evacuation Creek Member	0-1,250	Intertonguing and gradational beds of sandstone, siltstone, and marlstone; contains pyroclastic rocks and a few conglomerate lenses. Forms surface rock over most of the area; thins appreciably westward.	Water ranges from 250 to 1,800 ppm dissolved solids. It is a mixed type water with no dominant cation or anion.	Beds of sandstone are predominantly fine grained and are poorly permeable. Water moves primarily through fractures. The part of the member higher than valley floors is mostly drained.	Reported to yield as much as 100 gpm. Member has not been thoroughly tested, and larger yields may be possible.
			Parachute Creek Member	500-1,800	Kerogenaceous dolomitic marlstone (oil shale) and shale; contains thin pyroclastic beds; fractured to depths of at least 1,800 feet. Abundant saline minerals in deeper part of the basin.	Water ranges in dissolved-solids content from 250 to about 63,000 ppm. Below 500 ppm, calcium is dominant cation; above 500 ppm, sodium is generally dominant. Bicarbonate is generally the dominant anion regardless of concentration. Fluoride ranges from 0.0 to 54 ppm.	Oil shale is relatively impermeable. Water moves through the fractures. Calculated coefficients of transmissibility range from 1,000 to 2,000 gpd per ft; storage coefficient is about 0.00001.	Estimated potential yields as much as 500 gpm.
			Garden Gulch Member	0-900	Papery and flaky marlstone and shale; contains some beds of oil shale and, locally, thin beds of sandstone.	One water analysis indicates dissolved-solids concentration of 12,000 ppm.	Relatively impermeable and probably contains few fractures.	Not known to yield water to wells.
			Douglas Creek Member	0-800	Sandstone, shale, and limestone; contains oolites and ostracods. Throughout most of the area the member is deeply buried. Sandstone forms prominent cliffs along the basin margin on the south and west; thins toward the deeper part of the basin where the member seems to grade into a finer grained facies.	The few analyses available indicate that dissolved-solids content ranges from 3,000 to 12,000 ppm. The type is either sodium bicarbonate or sodium chloride.	Relatively low permeability and probably little fractured.	Maximum yield is unknown, but probably less than 50 gpm.
			Anvil Points Member	0-1,870	Shale, sandstone, and marlstone grade within a short distance westward into the Douglas Creek, Garden Gulch, and lower part of the Parachute Creek Members. Beds of sandstone are fine grained.	Water is generally of a magnesium sulfate type and may range in dissolved-solids content from about 1,200 to 1,800 ppm.	Beds of sandstone are poorly permeable.	A few wells tapping beds of sandstone yield less than 10 gpm; maximum potential yield is unknown. Springs yielding less than 100 gpm issue from fractures.
		Wasatch Formation		300-5,000	Clay, shale, lenticular sandstone; locally, beds of conglomerate and limestone. Beds of clay and shale are the main constituents of the formation. Contains gypsum.	Gypsum contributes sulfate to both surface-water and ground-water supplies.	Beds of clay and shale are relatively impermeable. Beds of sandstone are poorly permeable.	Not known to yield water to wells.

The results of chemical analyses of groundwater (Hurr et al., 1969, pp. 12-13; Larson and Beetem, 1970, pp. 14-15; Voegeli et al., 1970, pp. 32-33) and surface water samples (Larson and Beetem, 1970, p. 8; Voegeli et al., 1970, p. 37) are given in Appendix C. The results of radiochemical analyses of spring and well samples collected during re-entry drilling at the Rulison Site (Voegeli and Claassen, 1971a, pp. 13-14; Voegeli and Claassen, 1971b, pp. 7-8), as well as radiochemical data obtained from stream samples in the Rulison area (Voegeli and Claassen, 1971a, p. 12; Voegeli and Claassen, 1971b, p. 6; Claassen and Voegeli, 1971, p. 4; Claassen, 1971, p. 4), are presented in Appendix D.

Tritium results are given in Appendix A (DOE, 1984, p. 24). Background levels of tritium in surface waters averaged 910 +/- 570 picoCuries per liter (pCi/L), well water samples averaged 640 +/- 450 pCi/L, and spring water samples averaged 770 +/- 770 pCi/L. Water samples collected during flaring ranged from less than 400 to 1,600 pCi/L (Boysen, 1976, p. 31). Numerous analytical results of water samples, as well as environmental and biological samples, collected from the Rulison area are given in Boysen, (1976). Atmospheric levels of radiation, as well as radiation exposures to off-site populations, are reported by the EPA (1974).

Prior to the completion of site cleanup, water samples were collected from two springs at the site, one located just off the southeast corner of the R-EX well pad and the other on the upper side of the road about 274.32 m (300 yards) downhill from the pad. No radioisotopes other than those naturally occurring were detected (AEC, 1973, p. 12; Eberline, 1977, p. 5). Decontamination of drilling equipment and radioactive fallout from gas flaring operations are also possible sources of shallow aquifer contamination. Extensive soil sampling at the site was done to access surface contamination resulting from radioactive fallout during gas flaring. Contaminated soil was removed from the site and transported to a suitable disposal site (Eberline, 1977).

Source term concentrations were estimated by assuming that the radionuclides are completely and uniformly mixed with a quantity of water equivalent to the volume of the cavity void space anticipated to be formed by the detonation. Predictions of cavity dimensions are given in Table 5-7 (AEC, 1969, p. 1; Nork and Fenske, 1970, p. 8). The cavity volume is calculated to be about 56,640 to 141,600 m^3 (2×10^6 to 5×10^6 cubic feet). In this water volume, tritium concentration would be about 6×10^{-3} microCuries per milliliter (μCi/mL) to 2×10^{-1} μCi/mL (Nork, 1969, p. 5); strontium-90 concentration would be about 4×10^{-2} μCi/mL to 1×10^{-1} μCi/mL (Nork and Fenske, 1970, p. 11). From the post-shot drilling data, it was estimated that the rubble-filled chimney was approximately 106.68 m (350 ft) in height. This is greater than the

Table 5-7
Physical Explosion Effects

	Maximum	Mean	Minimum	Units
Cavity Radius	108	90	72	feet
Cracking Radius	580	485	390	feet
Chimney Height	451	376	301	feet
Cavity Volume (or Chimney Void Space)	5.28×10^6	3.05×10^6	1.56×10^6	cubic feet
Chimney Volume	16.5×10^6	9.57×10^6	4.90×10^6	cubic feet

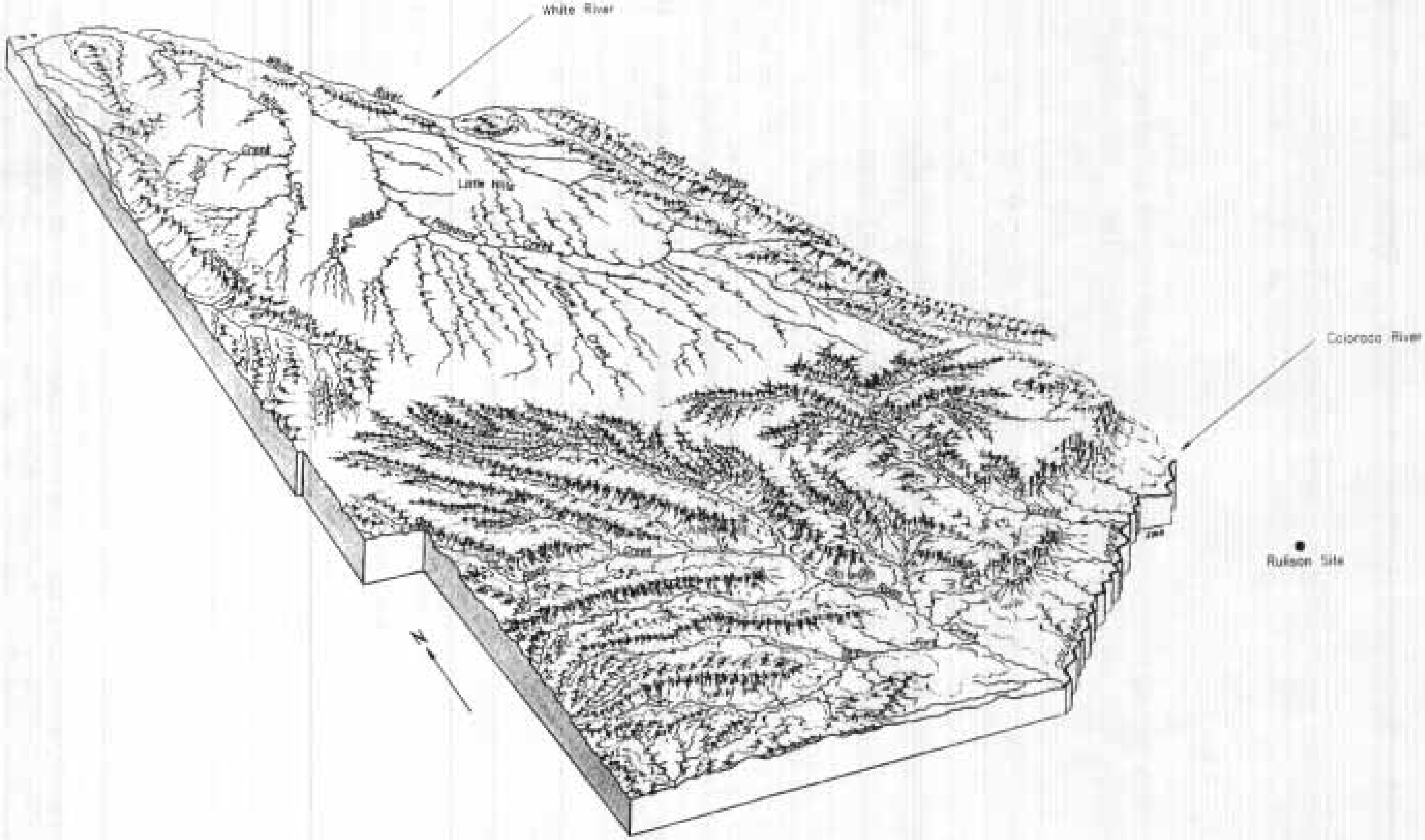
Source: Nork and Fenske, 1970

minimum 91.74 m (301 ft) that was predicted, but comparable with the associated cavity radii dimensions determined from well test data (Reynolds, 1971, p. 1).

5.7.3 Regional Flow System

The Rulison Site is on the southwest limb of the Piceance Creek basin, a large northwest- trending structural downwarp in northwestern Colorado (Figure 5-13). The northern part of the Piceance Creek basin drains to the White River; the southern part of the basin drains to the Colorado River. The Rulison Site drains northward to the Colorado River (Voegeli, 1969, p. 4; Voegeli et al., 1970, p. 4).

The principal surface hydrologic feature of the Rulison Site is Battlement Creek, a stream that discharges to the Colorado River at Parachute, Colorado. Battlement Creek carries most of the runoff to the river, while some runoff is diverted for irrigation use and some infiltrates the stream alluvium and terrace deposits. The underflow in the alluvium appears as springs in several places downstream from the Rulison Site (Voegeli, 1969, p. 7; Voegeli et al., 1970, p. 7). Ranchers on Morrisania Mesa obtain water for their domestic and livestock usage from shallow wells in alluvium and terrace deposits or from cisterns and ponds which obtain their water from Battlement Creek and other small streams and springs (Voegeli, 1969, p. 10; Voegeli et al., 1970, p. 5). Municipal groundwater resources in the Rulison area are confined primarily to alluvium and surficial deposits (e.g., flood-plain deposits and terrace and fan gravel) (Voegeli, 1969, p.7).



NOT TO SCALE

FIGURE 5-13
PICEANCE CREEK BASIN
RIO BLANCO, GARFIELD, AND
MESA COUNTIES, COLORADO

Source: USGS, 1968

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5.7.4 Impact of Test on Hydrology

Studies of pre-shot and postshot hydrologic conditions indicate that the detonation had no effect on the physical, chemical, or radiochemical characteristics of wells, springs, streams, shallow aquifers, or reservoirs in or near the Rulison Site (Voegeli et al., 1970, p. 48; AEC, 1973, p. 18). The USGS also sampled springs, rivers, and wells before and after reentry drilling and after each of the three gas production tests with the same negative results (DOE, 1984, pp. 15-16).

The Rulison device was emplaced near the base of the Mesaverde Formation at a depth of 2,568 m (8,426 ft). Essentially all of the explosion-produced radionuclides were contained within the Mesaverde Formation. Any mobile water in the Mesaverde Formation which becomes contaminated with explosion nuclides, and is located below about 2,133.60 m (7,000 ft), is expected to move downward or laterally, but not upward. Above 2,133.60 m (7,000 ft), any contaminated mobile waters are expected to move laterally. Groundwater movement in this formation is estimated to be a maximum of 0.3048 m (1 ft) per day. The most probable rate is essentially negligible (Nork and Fenske, 1970, p. 2).

Six drill stem tests were run in the vicinity of the shot point. The USGS interpreted the chemical character of fluids collected from tubing after each drill stem test in exploration hole R-EX as indicating that "little mobile water occurs in the zones tested" (Voegeli, 1969, P.14). Three of these tests, 2,153.72 to 2,157.98; 2,193.34 to 2,193.95; and 2,228.70 to 2,231.14 m (7,066 to 7,080; 7,196 to 7,198; and 7,312 to 7,320 ft) below land surface resulted in pressure build-up curves that could be extrapolated to infinite time by the Van Everdingen method to estimate the virgin aquifer pressures. Table 5-8 shows the extrapolated shut-in pressures along with the post shot reservoir pressure compared to estimated hydrostatic pressures for the same depths.

The actual distribution of pressures above 7,066 feet are not well known. However, there can be no general upward or downward movement of water in this interval, and lateral flow must predominate. Below 7,066 feet pressures drop off rapidly and downward movement of water is expected to a point within or below the 7,312 to 7,320 foot interval. Since the pressure increases below this interval, a drain exists between 7,312 and about 8,442 feet where lateral flow is likely.

The three drill stem tests analyzed indicate relatively steep pressure build-up curves as a function of time but low fluid recoveries. A possible explanation of this phenomenon is that the predominant permeability belongs to a fracture system. The presence of many linears on the geologic map at the Rulison Site tends to substantiate this hypothesis. If this is the case, lateral

Table 5-8
R-EX Drill Stem Test Formation Pressures

Depth (feet)	**Estimated Shut-In Pressure** (pounds per inch)	**Estimated Hydrostatic Pressure** (pounds per inch)
7,066 - 7,080	3,050	3,050
7,196 - 7,198	2,900	3,096
7,312 - 7,320	2,250	3,150
≈ 8,442	2,950	3,640

flow of water could occur at significant velocities in terms of usual groundwater flow rates. However, since the interfracture blocks in the sandstone beds must also have some permeability, all water would also have to flow through these low permeability blocks. The average water velocity is therefore expected to be extremely low (Nork and Fenske, 1970, pp. 5-6).

If groundwater in the Mesaverde Formation is immobile, all radioactivity will reside essentially in place until artificially removed, and will eventually decay below detection levels. If the groundwater in the Mesaverde Formation is mobile, very likely the velocity of movement will be slow enough and chemical-exchange retardation high enough to prevent the transport of radionuclides in greater-than-contaminant guideline (CG) concentrations for any significant distances. Although distribution coefficient distribution coefficient (K_d) values were not determined for the Rulison Site, approximation for retardation of radionuclides may be determined using values from other locations, given in Table 5-9 (Nork, 1969, p. 7; Nork and Fenske, 1970, p. 13). Assuming a 0.31 m/day (1 ft/day) rate of flow, it is predicted that tritium would move less than 1.61 km (1 mi) before decaying to a concentration less than 1 x 10^6 pCi/L (AEC, 1973, p. 18; DOE, 1984, p. 14). Under the same conditions of movement but with consideration of retardation effects (assuming K_d = 10), strontium-90 would probably move less than 1.62 km (1 mi) before decay to below one CG (Nork, 1969, p. 8; Nork and Fenske, 1970, p. 14).

It is not clear what contaminant release scenario or scenarios were considered in the selection of Long-Term Hydrologic Monitoring Program (LTHMP) sampling sites (refer to Figure 2-11). It appears that rather than drilling a network of monitoring wells based on hydrologic data, the

Table 5-9
Distribution Coefficients of Strontium-85 and Cesium-137 for Various Materials
(Material suspended in 4 parts saturating solution for 72 hours. Minimum particle diameter is 4,000μ [Nork, 1969].)

Material	Saturating Medium	Kd (Ml/g)	
		Sr	Cs
Basalt (Amchitka)	Sea Water	1.07	6.50
Carbonate (Yucca Flat, Nevada Test Site)	Prepared Water* (Well)	0.19	13.5
Salt (Tatum Salt Dome)	Salt Saturated Water	0.19	0.02
Shaley Siltstone (Gasbuggy Site, Northern New Mexico)	GB-2 Well Water	8.32	309.
Sandstone (Gasbuggy Site, Northern New Mexico)	GB-2 Well Water	1.37	102.
Granite (Shoal Site, Nevada)	Deep Formation Water	1.7	34.3
Tuff (Rainier Mesa, Nevada Test Site)	Prepared Water* (Rainier Spring)	260.	1020.
Desert Alluvium (Hot Creek Valley, Nevada)	Deep Formation Water	50-2450	70-2640

*Water prepared to have major chemical composition similar to that of referenced water source.

LTHMP groundwater sampling program has clearly focused on local domestic supply wells and springs already in place as discussed in Section 2.2.2.4.2 Second Sampling Program, Water Sampling (Chapman and Hokett, 1991, p. 36).

The alluvial deposits are separated from the emplacement horizon by great thicknesses of low permeability formations, making transport of contaminants through the geologic media unlikely. The most probable mechanism for contaminant transport to the shallow monitoring wells from the shot point at a depth of over 2,438.40 m (8,000 ft) involves contaminant transport up the test holes. However, the presence of a low-pressure horizon at a depth of about 2,194.56 m (7,200 ft) is presumed to behave as a sump between the shot depth and near-surface aquifers. This zone will prevent vertical flow into the higher pressure zones above, diverting contaminants to lateral flow along this hydrologic drain (Voegeli et al., 1970). In addition, the boreholes were plugged. The possibility of surface contamination by fallout during gas flaring operations was addressed by monitoring during flaring and presumably no longer poses a threat (Chapman and Hokett, 1991, p. 36).

Clearly, if the borehole release scenario is verifiably impossible, there is no reason to monitor the quality of the shallow aquifer. However, given that it is the only scenario proposed that could result in contamination of local supply aquifers, the LTHMP at Rulison is evaluated on the basis that contaminant transport is only possible through the boreholes drilled for the test.

During September 1995, DOE installed two shallow wells in the alluvial aquifer directly downgradient of the emplacement shaft. These two wells will be included in the EPA's annual LTHMP. The purpose of these wells is to function as early warning detection devices (for the alluvial aquifer) in the unlikely event that upward migration has occurred via the emplacement shaft.

6.0 Recommendations

Based on the information provided in this report, the following tasks should be completed to fill the information gaps that remain on this project:

- Complete the human health baseline risk assessment
- Collect gas/water samples from the gas wells closest to the shot cavity
- Characterize the mudpit located by the RE-X well
- Continue the Long-Term Hydrologic Monitoring Program
- Develop an action plan in the event contamination is found

6.1 Complete Human Health Risk Assessment

The human health baseline risk assessment for the hydrocarbon/heavy metal contaminants is in the process of being prepared by DOE. Once it is completed it can be used to: (1) identify areas in which additional information is needed, (2) to determine the relative importance of the proposed tasks, and (3) to determine if a task is necessary.

6.2 Collect Gas/Water Samples

One of the potential pathways for contamination from the shot cavity to reach a receptor is by tritium migrating to one of the gas producing horizons. To check this, two wells have been identified from which gas/water samples should be collected and analyzed for tritium. Permission will have to be obtained from the owners of the wells and arrangements made to collect the samples when the owners can be present.

6.3 Characterize the Mudpit

During drilling of the soil borings in September 1995, drilling mud was discovered near the RE-X well. The mud was contaminated primarily with total petroleum hydrocarbons (probably diesel fuel). The Toxicity Characteristic Leaching Procedure metals analyses all came back nondetect. The vertical extent of the mud was defined but not the lateral extent. Depending on the opinion the Colorado State Department of Health takes regarding this information, additional characterization and possible cleanup may be required at this site.

6.4 Continue the Long-Term Hydrologic Monitoring Program

The Long-Term Hydrologic Monitoring Program should be continued and expanded to include the two monitoring wells installed onsite near SGZ during 1995. Sampling of another five wells emplaced to evaluate the impacts of the contaminated pond sediments will take place quarterly for two years. Analyses will include total petroleum hydrocarbons and metals. At the end of the required two-year monitoring period, if no impacts from the hydrocarbon or metals have been detected in the groundwater, the State may waive the monitoring requirement or request that these five wells be monitored on an annual basis.

6.5 Develop an Action Plan

Finally, a plan should be developed to specify what actions need to be taken in the event that contamination is found in any of the monitoring locations. At the present time, no plans exist that identify what happens in the event that radiological contamination is found in any of the sampling locations.

Implementing these recommendations will reduce the amount of money to be spent on the site by identifying exactly where it needs to be spent to fill data gaps and alleviate risks. It will also reduce DOE liability by allowing the investigations to focus on those areas that pose the greatest liability (if any).

7.0 References

AEC (for reference, see U.S. Atomic Energy Commission).

American Indian Religious Freedom Act of 1978. Public Law 95-341.

Andrews, R. and R. Righter. 1992. *Colorado Birds: A Reference to Their Distribution and Habitat*. Denver, CO: Denver Museum of Natural History.

Austral, see Austral Oil Company, Inc.

Austral Oil Company, Inc. 1972. *Project Rulison - Post-Shot Well Test Data: PNE-R-52*. Las Vegas, NV.

Austral Oil Company, Inc. and CER Geonuclear Corporation. 1969. *Project Rulison - Site Evaluation Pre-Shot R-EX Well Test Data: PNE-R-7*. Las Vegas, NV.

BLM, see U.S. Bureau of Land Management.

Baumgardner, R.W., Jr. et al. 1988. "Site Selection for GRI Cooperative Tight Gas Field Research, Volume II: Geologic Characteristics of Selected Low-Permeability Gas Sandstones." Bureau of Economic Geology Topical Report prepared for Gas Research Institute under Contract No. 5082-211-0708. Austin, TX: University of Texas.

Boysen, G.A. U.S. Environmental Protection Agency. 1976. *Off-Site Radiological Safety Program For Project Rulison Flaring, Phase III: Monitoring Operations Division, EMSL-LV-539-8*. Washington, DC: U.S. Government Printing Office.

Brooks, L.R., J.F. Duds, and D. Falck. U.S. Geological Survey. 1933. *Land Classifications of Western Colorado*. Washington, DC: U.S. Government Printing Office.

Carlson, J. U.S. Department of Agriculture. Soil Conservation Service. 1993. Personal Communication, 4 January.

CDNR, see Colorado Department of Natural Resources.

CER Corporation. 1984. *Multi-Well Experiment MWX-3 As-Built Report: SAND84-7132*. Las Vegas, NV.

CER Corporation. 1989. *Geologic and Production Characteristics of the Tight Mesaverde Group: Piceance Basin, Colorado*. Las Vegas, NV.

CER Corporation. 1992. *Results of Field Verification Tests in the Tight Mesaverde Group: Piceance Basin, Colorado*. Las Vegas, NV.

CFR, see Office fo the Federal Register.

Chapman, J.B. and S.L. Hokett. U.S. Department of Energy, Nevada Operations Office. 1991. *Evaluation of Groundwater Monitoring at Offsite Nuclear Test Areas. #45085,* Report DOE/NV/10845-07, UC-703. Las Vegas, NV: Desert Research Institute Water Resources Center Publication #45085.

Claassen, H.C. 1971. *Radiochemical Analyses of Water Samples From Selected Streams and Precipitation Collected October 23-November 9, 1970, in Conjunction with the First Production-Test Flaring of Gas from Test Well, Project Rulison: USGS-474-108.* Denver, CO: U.S. Geological Survey.

Claassen, H.C. and P.T. Voegeli, Sr. 1971. *Radiochemical Analyses of Water Samples Collected in Connection with Calibration-Test Flaring of Gas from Test Well, August 15-October 13, 1970, Project Rulison: USGS-474-107.* Denver, CO: U.S. Geological Survey.

Coffin, D.L., F.A. Welder, and R.K. Glanzman. 1971. *Geohydrology of the Piceance Creek Structural Basin Between the White and Colorado Rivers, Northwestern Colorado: USGS Atlas HA-370*. Denver, CO: U.S. Geological Survey.

Coffin, D.L., F.A. Welder, R.K. Glanzman, and X.W. Dutton. 1968. *Geohydrologic Data from the Piceance Creek Basin, between the White and Colorado Rivers, Northwestern Colorado*. Colorado Groundwater Circular No. 12. Denver, CO.

Colorado. Department of Natural Resources (CDNR). Division of Wildlife. 1993. *WILDATA and Wildlife Habitat Relationships.* Data base accessed February 5. Grand Junction, CO.

Desert Research Institute. 1988. *CERCLA Preliminary Assessment of DOE's Nevada Operations Office Nuclear Weapons Testing Areas.* Las Vegas, NV.

Dickinson, W.R. and W.S. Snyder. 1978. "Plate tectonics of the Laramide orogeny." In *Laramide folding associated with basement block faulting in the western United States,* edited by Vincent Matthews, III. Geological Society of America Memoir 151.

DOE, see U.S. Department of Energy.

Donnell, J.R. 1968. Rulison Area Geological Maps. USGS open file.

DRI, see Desert Research Institute.

Eberline Instrument Corporation. 1977. *Rulison Radiation Contamination Clearance Report*: PNE-R-68. Sante Fe, NM.

EG&G Energy Measurements. 1995. *An Aerial Radiological Survey of Project Rulison and Surrounding Area*, EGG 11265-1094. Las Vegas, NV.

EL, see U.S. Army Corps of Engineers, Environmental Laboratory.

EPA, see U.S. Environmental Protection Agency.

ERDA, see U.S. Energy Research and Development Administration.

Fauver, D.N. 1986. *Hazardous Waste Installation Assessment Report*. Las Vegas, NV: Reynolds Electrical & Engineering Co., Inc.

FEMA, see U.S. Federal Emergency Management Agency.

Hammerson, G.A. 1986. *Amphibians and Reptiles in Colorado,* Denver, CO: Colorado Division of Wildlife.

Hart, C.M., D. Engi, R.P. Fleming, and H.E. Morris. 1984. "Fracture Diagnostics Results for the Multiwell Experiment's Paludal Zone Stimulation." Paper SPE/DOE GRI 12852 presented at the SPE/DOE Unconventional Gas Recovery Symposium, Pittsburgh, PA, 13-15 May.

Historic Properties Preservation Act of 1966. Public Law 89-665, 80 Stat. 915, 16 U.S.C.A. § 470 et seq. by Public Laws 91-243, 93-54, 94-422, 94-458, 96-244, and 96-515.

Historical and Archaeological Data Preservation Act of 1974. Public Law 93-291; 88 Stat. 174; 16 U.S.C.A. § 469.

Hurr, R.T., W.W. Wilson, F.A. Welder, and R.L. Emerson. 1969. *Records of Selected Wells and Springs in the Rulison Project Area, Garfield and Mesa Counties, Colorado: USGS-474-40*. Denver, CO: U.S. Geological Survey.

IT, see IT Corporation.

IT Corporation. 1993a. *A Class III Cultural Resources Survey of the U.S. Department of Energy Rulison Gas Stimulation Test Site, Garfield County, Colorado*, DOE/NV/10972-62. Report prepared for U.S. Department of Energy, Las Vegas, NV.

IT Corporation. 1993b. *Sensitive Species Survey Results for the Rulison and Rio Blanco Sites, Colorado*, DOE/NV/10972-55. Report prepared for U.S. Department of Energy, Las Vegas, NV.

IT Corporation. 1993c. *Floodplains and Wetlands Survey Results for the Rulison and Rio Blanco Sites, Colorado*, DOE/NV/10972-59. Report prepared for U.S. Department of Energy, Las Vegas, NV.

IT Corporation. 1995. *Corrective Action Plan, Rulison Drilling Effluent Pond*. Report prepared for U.S. Department of Energy, Las Vegas, NV.

Johnson, R.C., R.A. Crovelli, C.W. Spencer, and R.F. Mast. 1987. *An Assessment of gas resources in Low-Permeability Sandstones of the Upper Cretaceous Mesaverde Group, Piceance Basin, Colorado*. U.S. Geological Survey Open-File Report 87-357.

Knutson, C.F. 1977. *Outcrop Study of Fracture Patterns and Sandstone Geometry, Eastern Uinta Basin, Utah: Study Results and Implication to Stimulation of Tight Gas 'Sands' in the Area*. Report prepared for U.S. Energy Research and Development Administration, Nevada Operations Office, NVO-655-1, Las Vegas, NV.

Kollmorgen Corporation. 1975. *Munsell Soil Color Charts*. Baltimore, MD: Macbeth Division, Kollmorgen Corporation.

Kukal, G.C., E.H. Price, R.E. Hill, and E.R. Monson. August 1992. *Results of Field Verification Tests in the Tight Mesaverde Group: Piceance Basin, Colorado*, DOE Report DOE/MC/24120. Las Vegas, NV.

Larson, J.D. and W.A. Beetem. 1970. *Chemical and Radiochemical Analyses of Water from Streams, Reservoirs, Wells, and Springs in the Project Rulison Area, Garfield and Mesa Counties, Colorado*: USGS-474-67. Denver, CO: U.S. Geological Survey.

Lorenz, J.C. 1983. *Reservoir Sedimentology of the Mesaverde Rocks at the Multi-Well Experiment Site*. Sandia National Laboratories Report, SAND83-1078. Albuquerque, NM and Livermore, CA.

Lorenz, J.C. 1985. *Tectonic and stress Histories of the Piceance Creek Basin and the MWX Site, from 75 Million Years Ago to the Present*. Sandia National Laboratories Report, SAND84-2603. Albuquerque, NM and Livermore, CA.

Marlatt, W.E. 1973. "Climate of the Piceance Creek Basin." In *An Environmental Reconnaissance of the Piceance Creek Basin, Part I, Phase I*. Boulder, CO: Thorne Ecological Institute.

Mason, B.J. Battelle Memorial Institute. 1970. Letter to Ernest Campbell, 13 July.

Myal, F.R., E.H. Price, R.E. Hill, G.C. Kukal, P.J. Abadie, and C.C. Riecken. July 1989. Geologic and Production Characteristics of the Tight Mesaverde Group: Piceance Basin, Colorado. DOE Report DOE/MC/24120-2769. Las Vegas, NV.

National Environmental Policy Act of 1969, Title 42, U.S.C.S. § 4332, Section 102(2)(c). Public Law 91-190.

Nessler, Thomas. State of Colorado, Colorado Department of Wildlife. 1995. Personal Communication, 20 April.

Nork, W.E. 1969. *Radioactivity in the Hydrologic Environment Project Rulison Final Pre-Shot Report (U)*: U.S. Atomic Energy Commission, NVO-1229-108. Las Vegas, NV.

Nork, W.E. and P.R. Fenske. 1970. *Radioactivity in Water - Project Rulison*: U.S. Atomic Energy Commission, NVO-1229-131. Las Vegas, NV.

Office of the Federal Register. National Archives and Records Administration. *Code of Federal Regulations, Executive Order 11593, "Protection and Enhancement of the Cultural Environment," 36 F.R. 8921*. Washington, DC: GPO, May 15, 1971.

Office of the Federal Register. National Archives and Records Administration. *Code of Federal Regulations, Title 10, Part 11*. Washington, DC: GPO, 1974.

Office of the Federal Register. National Archives and Records Administration. *Code of Federal Regulations, Title 10, "Energy," Part 1021, "National Environmental Policy Act Implementing Procedures."* Washington, DC: GPO, 1992.

Office of the Federal Register. National Archives and Records Administration. *Code of Federal Regulations, Title 36, "Parks, Forests, and Public Property," Part 800, "Advisory Council on Historic Preservation."* Washington, DC: GPO, 1995.

Office of the Federal Register. National Archives and Records Administration. 1992. "Compliance with Floodplain Wetlands Environmental Review Requirements," *Code of Federal Regulations, Title 10, Part 1022*. Washington, DC: U.S. Government Printing Office.

Rand McNally. *Commercial Atlas and Marketing Guide*. 1993. Chicago, IL.

Reed, P.B., Jr. U.S. Fish and Wildlife Service. 1988. "National List of Plant Species that Occur in Wetlands: National Summary," *Biological Report 88 (24)*. Washington, DC: U.S. Government Printing Office.

Reed, A.D. State Historical Society of Colorado. 1984. *West Central Colorado Prehistoric Context*. Denver, CO: Office of Archaeology and Historic Preservation.

Reynolds, Jr., M. 1971. *Project Rulison Post-Shot Investigations Summary of Re-Entry Operations*: PNE-R-45. Houston, TX: Austral Oil Company, Inc.

Reynolds, Jr., M. Austral Oil Company. 1977. *The Rulison Field Massive Hydraulic Fracturing Experiment*: NVO/0679-1. Report prepared for the U.S. Department of Energy, Las Vegas, NV.

Sattler, A.R. 1984. "The Multiwell Experiment Core Program, II.": Paper SPE/DOE GRI 12854 presented at the SPE/DOE Unconventional Gas Recovery Symposium, Pittsburgh, PA: 13-15 May.

SCS, see U.S. Department of Agriculture, Soil Conservation Service.

Stosur, J.J. 1977. "Current Status of Projects Gasbuggy, Rulison, and Rio Blanco and an Appraisal of Nuclear-Explosive Fracturing Potential for the Near Future." In *The Future Supply of Nature-made Petroleum and Gas; Technical Reports*, edited by R.F. Meyer. New York: Pergamon Press.

Thompson, J. 1992. *Fisheries Report.* Grand Junction, CO: United States Bureau of Land Management.

Thompson, J. Bureau of Land Management. 1993. Personal Communication, 1 July.

Tuttle, M.L., D.J. Ackerman, W.E. Dean, P.H. Briggs, and A.J. Bartel. 1983. *Chemical and Mineral Composition Data on Oil Shale and Retorted Oil-Shale Wastes From Rulison, Colorado*: USGS Open File Report 83-378.

U.S. Army Corps of Engineers, Environmental Laboratory. 1987. *Corps of Engineers Wetlands Delineation Manual*, Technical Report Y-87-1. Vicksburg, MS.

U.S. Atomic Energy Commission. Nevada Operations Office. December 1969a. *Project Rulison Post-Shot Plan and Evaluations*, NVO-61. Las Vegas, NV.

U.S. Atomic Energy Commission. Nevada Operations Office. 1969b. *Project Rulison Planning Directive*. Las Vegas, NV.

U.S. Atomic Energy Commission. Nevada Operations Office. September 1973a. *Rulison Site Cleanup Report*, NVO-136. Las Vegas, NV.

U.S. Atomic Energy Commission. Nevada Operations Office. April 1973b. *Project Rulison Manager's Report*, NVO-71. Las Vegas, NV.

U.S. Bureau of Land Management. June 1986. *State of Colorado Wilderness Map.* Denver, CO.

U.S. Bureau of Land Management. 1980. Recreation Management Areas--Bureau of Land Management-Colorado. Revised map. Denver, CO.

U.S. Congress. Office of Technology Assessment. October 1989. *The Containment of Underground Nuclear Explosions*. OTA-ISC-414. Washington, DC: U.S. Government Printing Office.

U.S. Department of Agriculture. Soil Conservation Service. 1980. *Soil Survey of Rifle Area, Colorado*. Washington, DC: U.S. Government Printing Office.

U.S. Department of Agriculture. Soil Conservation Service. 1983. *National Soils Handbook.* Washington, DC: U.S. Government Printing Office.

U.S. Department of Agriculture. Soil Conservation Service. 1987. *Hydric Soils of the United States*. In cooperation with the National Technical Committee for Hydric Soils. Washington, DC: U.S. Government Printing Office.

U.S. Department of Energy. Nevada Operations Office. 1984. *Long-Term Hydrologic Monitoring Program Rulison Event Site, Grand Valley, Colorado*, NVO-273. Las Vegas, NV.

U.S. Energy Research and Development Administration. 1976. *Project Rulison Well Plugging and Site Abandonment Plan,* NVO-174. Las Vegas, NV.

U.S. Energy Research and Development Administration. 1977. *Project Rulison Well Plugging and Site Abandonment Final Report*, NVO-187. Las Vegas, NV.

U.S. Environmental Protection Agency. 1974. *Off-Site Surveillance Activities of the National Environmental Research Center from July through December 1970,* NERC-LV-539-17. Las Vegas, NV.

U.S. Geological Survey. 1970. *Geohydrology--Project Rulison, Garfield County, Colorado, With a Section on Aquifer Response*, USGS-474-68. Denver, CO.

U.S. Geological Survey. 1980. Rulison, Colorado, and 1952 Rock School, Colorado, 7.5 Minute Quadrangle Maps. Denver, CO.

U.S. Geological Survey. 1987. *National Wilderness Preservation System*, map. Denver, CO.

U.S. Federal Emergency Management Agency. January 3, 1986. *Flood Insurance Rate Map, Garfield County, Colorado (Unincorporated areas), Map Index,* Community-Panel Numbers 080205 0001-1900. Washington, DC: U.S. Government Printing Office.

USDA, see U.S. Department of Agriculture.

USGS, see U.S. Geological Survey.

Voegeli, P.T., Sr. 1969. *Geology and Hydrology of the Project Rulison Exploratory Hole, Garfield County, Colorado,* USGS-474-16. Denver, CO: U.S. Geological Survey.

Voegeli, P.T., Sr., S.W. West, and E.H. Cordes. 1970. *Geohydrology - Project Rulison, Garfield County, Colorado*, USGS-474-68. Denver, CO: U.S. Geological Survey.

Voegeli, P.T., Sr., and H.C. Claassen. 1971a. *Radiochemical Analyses of Water from Selected Streams, Wells, Springs, and Precipitation Collected Prior to Reentry Drilling, Project Rulison*, USGS-474-83. Denver, CO: U.S. Geological Survey.

Voegeli, P.T., Sr., and H.C. Claassen. 1971b. *Radiochemical Analyses of Water from Selected Streams, Wells, Springs, and Precipitation Collected During Reentry Drilling, Project Rulison*, USGS-474-101. Denver, CO: U.S. Geological Survey.

Whitney, S. 1992. Western Forests, *Audobon Society Nature Guides*. New York: Alfred A. Knoff, Inc.

Yeend, W.E. 1968. *Quaternary Geology of the Grand-Battlement Mesa Area, Colorado.* USGS Open File Report.

Appendix A
Project Rulison, Long-Term Hydrologic Monitoring Program Analytical Results, 1972-1994, Garfield County, Colorado

Rulison Tritium Results in pCi/L for 1972-1982

	1972		1973		1974		1975		1976		1977		1978		1979		1980		1981		1982	
	3H	3H+	3H	3H+	3H	3H+	3H	3H+	3H	3H+	3H	3H+	3H	3H+	3H	3H+	3H	3H+	3H	3H+	3H	3H+
HAYWARD RANCH WELL	380± 230		<300		480± 13		350± 12		480± 210		440± 230		710± 350			390± 11		330± 11		360± 10		370± 8.4
SEARCY RANCH WELL (SCHWAB)	740± 240		670± 250		800± 16		380± 13		740± 270			430± 14	690± 350			440± 11		360± 11		250± 8.9		320± 8.3
GARDNER RANCH WELL	770± 240		420± 240		510± 12		510± 15		610± 270	310± 9.8	390± 230		650± 350			310± 9.8		300± 10		240± 8.8		250± 7.7
SEFCOVIC RANCH WELL							580± 15		420± 11		520± 240		880± 350			300± 10		310± 11		290± 9.5		320± 8.4
CER TEST WELL	770± 240		800± 250		610± 15		540± 16		350± 11		560± 240		580± 350			230± 8.9		240± 9.6		190± 7.7		280± 8.0
BERNKLAU RANCH WELL	250± 230		320± 240		350± 13		510± 19		350± 9.6													
GRAND VALLEY CITY SUPPLY (SPRING)	270± 230		<300		170± 11		130± 9.6		<6			56± 8.3		<20		40± 6.8		31± 6.6		46± 6.1		74± 5.8
POTTER RANCH SPRING											460± 240		680± 350			280± 9.5		230± 9.4		210± 8.2		270± 7.6
SPRING (300 YDS. N.W. OF GZ)	510± 230		740± 250		450± 13		480± 16		270± 9.3			170± 11	730± 350			180± 8.5		210± 9.2		130± 7.7		190± 7.1
BATTLEMENT CREEK (SURFACE)	860± 240		510± 240		580± 15		300± 12		250± 13			330± 13	850± 350			240± 9.1		140± 8.2		200± 8.5		190± 7.1

3H = Tritium analysis by conventional method.
3H+ = Tritium analysis by enrichment method.

(U.S. DOE, 1984)

Project Rulison, Long-Term Hydrological Monitoring Program Analytical Results, 1983-1985

	Collection Date	Conc. ± 2 Sigma Tritium (pCi/ℓ)[1]	% of Conc. Guide[2]	Collection Date	Conc. ± 2 Sigma Tritium (pCi/ℓ)	% of Conc. Guide	Collection Date	Conc. ± 2 Sigma Tritium (pCi/ℓ)	% of Conc. Guide
Grand Valley, Colorado									
City Spring	5/29/83	110 ± 6	0.6	6/20/84	3.3 ± 5.0*	< 0.02	6/20/85	-6.2 ± 7.7*	< 0.01
Albert Gardner Ranch Well	5/29/83	260 ± 7	1	6/21/84	200 ± 6	1	6/19/85	200 ± 8	1
Battlement Creek (surface)	5/30/83	200 ± 7	1	6/20/84	120 ± 5	0.6	6/19/85	130 ± 8	0.6
Spring 300 yards NW of GZ	5/30/83	-----	-----	6/20/84	130 ± 6	0.6	6/19/85	130 ± 8	0.6
CER Test Well	5/30/83	-----	-----	6/20/84	110 ± 6	0.6	6/19/85	210 ± 9	1
Rulison, Colorado									
Lee Hayward Ranch Well	5/29/83	260 ± 7	1	6/21/84	310 ± 7	2	6/20/85	280 ± 9	1
Potter Ranch Well	5/30/83	250 ± 7	1	6/21/84	160 ± 6	0.8	6/20/85	150 ± 8	0.8
Robert Searcy (G. Schwab) Ranch Well	5/29/83	170 ± 6	0.9	6/21/84	180 ± 6	0.9	6/20/85	170 ± 9	0.9
Felix Sefcovic Ranch Well	5/29/83	360 ± 8	2	6/21/84	240 ± 7	1	6/20/85	210 ± 8	1

[1]Picocurie per liter (pCi/ℓ)
[2]Established by DOE Order as 90,000 pCi/ℓ tritium.
* = Concentration is less than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.

Project Rulison, Long-Term Hydrological Monitoring Program
Analytical Results, 1986-1988

	Collection Date	Conc. ± 2 Sigma Tritium (pCi/ℓ)[1]	% of Conc. Guide[2]	Collection Date	Conc. ± 2 Sigma Tritium (pCi/ℓ)	% of Conc. Guide	Collection Date	Conc. ± 2 Sigma Tritium (pCi/ℓ)	% of Conc. Guide
Grand Valley, Colorado									
City Spring	6/15/86	28 ± 8	0.1	7/27/87	-0.13 ± 8.2*	< 0.01	6/25/88	-2 ± 16*	< 0.01
Albert Gardner Ranch Well	6/15/86	190 ± 9	1	7/27/87	170 ± 8	0.8	6/25/88	170 ± 12	0.86
Battlement Creek (surface)	6/15/86	100 ± 8	0.5	7/27/87	100 ± 8	0.5	6/25/88	140 ± 11	0.70
Spring 300 yards NW of GZ	-----	-----	-----	7/27/87	87 ± 8	0.4	6/25/88	84 ± 11	0.42
CER Test Well	6/15/86	N/A	-----	7/27/87	160 ± 9	0.8	6/25/88	160 ± 12	0.79
Rulison, Colorado									
Lee Hayward Ranch Well	6/15/86	260 ± 12	1	7/27/87	220 ± 8	1	6/25/88	250 ± 12	1.24
Potter Ranch Well	6/16/86	140 ± 8	0.7	7/27/87	120 ± 8	0.6	6/27/88	140 ± 11	0.71
Robert Searcy (G. Schwab) Ranch Well	6/15/86	90 ± 9	0.5	7/27/87	160 ± 9	0.8	6/25/88	150 ± 11	0.76
Felix Sefcovic Ranch Well	6/15/86	98 ± 8	0.5	7/27/87	170 ± 8	0.8	6/25/88	160 ± 11	0.82
	6/15/86	190 ± 8	1						

[1]Picocurie per liter (pCi/ℓ)
[2]Established by DOE Order as 90,000 pCi/ℓ tritium.
* = Concentration is less than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.

Project Rulison, Long-Term Hydrological Monitoring Program Analytical Results, 1989-1991

	Collection Date	Conc. ± 2 Sigma Tritium (pCi/ℓ)[1]	% of Conc. Guide[2]	Collection Date	Conc. ± 1 Sigma Tritium (pCi/ℓ)	% of Conc. Guide	Collection Date	Conc. ± 1 Sigma Tritium (pCi/ℓ)	% of Conc. Guide
Grand Valley, Colorado									
City Spring	6/13/89	1.1 ± 6.8*	0.01	6/19/90	9.9 ± 4.1*	0.05	6/11/91	0.78 ± 3.12*	NA
Albert Gardner Ranch Well	6/13/89	140 ± 8	0.70	6/19/90	87 ± 5.0	0.43	6/11/91	113 ± 4	0.6
Battlement Creek (surface)	6/13/89	86 ± 8	0.43	6/19/90	22 ± 2.2	0.11	6/11/91	56 ± 3	0.3
Spring 300 yards NW of GZ	6/13/89	73 ± 7	0.36	6/19/90	18 ± 2.0	0.09	6/11/91	57 ± 3	0.3
CER Test Well	6/13/89	140 ± 8	0.70	6/19/90	41 ± 2.2	0.21	6/11/91	57 ± 2.1	0.3
Rulison, Colorado									
Lee Hayward Ranch Well	6/13/89	170 ± 8	0.85	6/19/90	88 ± 2.7	0.44	6/11/91	187 ± 4	0.9
Potter Ranch Well	6/13/89	120 ± 8	0.6	6/19/90	43 ± 2.1	0.22	6/11/91	119 ± 4	0.6
Robert Searcy (G. Schwab) Ranch Well	6/13/89	89 ± 8	0.45	6/19/90	41 ± 2.8	0.21	6/11/91	63 ± 4	0.3
Felix Sefcovic Ranch Well	6/13/89	77 ± 8	0.38	6/19/90	27 ± 2.6	0.13	6/11/91	133 ± 4	0.7

[1]Picocurie per liter (pCi/ℓ)
[2]Established by DOE Order as 90,000 pCi/ℓ tritium.
* = Concentration is less than the minimum detectable concentration (MDC).
NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.

Project Rulison, Long-Term Hydrological Monitoring Program Analytical Results, 1992-1994

	Collection Date	Conc. ± 2 Sigma Tritium (pCi/ℓ)[1]	% of Conc. Guide[2]	Collection Date	Conc. ± 2 Sigma Tritium (pCi/ℓ)	% of Conc. Guide	Collection Date	Conc. ± 1 Sigma Tritium (pCi/ℓ)	% of Conc. Guide
Grand Valley, Colorado									
City Spring	6/9/92	0.43 ± 1.49*	NA	6/16/93	-1.6 ± 3.1*	NA	5/29/94	-1.2 ± 3.5*	NA
Albert Gardner Ranch Well	6/9/92	98 ± 3	0.11	6/16/93	80 ± 4.4	0.09	5/29/94	82 ± 5.1	0.09
Battlement Creek (surface)	6/9/92	63 ± 2	0.07	6/16/93	49 ± 3.8	0.05	5/29/94	48 ± 4.2	0.05
Spring 300 yards NW of GZ	6/9/92	63 ± 2	0.07	6/16/93	57 ± 4.2	0.06	5/29/94	47 ± 4.0	0.05
CER Test Well	6/9/92	48 ± 2	50.05	6/16/93	51 ± 4.2	0.06	5/29/94	84 ± 4.6	0.09
Rulison, Colorado									
Lee Hayward Ranch Well	6/9/92	160 ± 3	0.18	6/16/93	116 ± 5.2*	0.02	5/29/94	100 ± 4.6*	0.11
Potter Ranch Well	6/9/92	67 ± 2	0.07	6/16/93	1.4 ± 2.9	0.002	5/29/94	82 ± 4.6	0.09
Rothgery (Searcy) (Schwab) Ranch Well	6/9/92	78 ± 2	0.09	6/16/93	57 ± 4.1	0.06	5/29/94	71 ± 4.7	0.08
Felix Sefcovic Ranch Well	6/9/92	57 ± 2	0.06	6/16/93	100 ± 4.9*	0.11	5/29/94	87 ± 4.4	0.10

[1]Picocurie per liter (pCi/ℓ)

[2]Established by DOE Order as 90,000 pCi/ℓ tritium.

* = Concentration is less than the minimum detectable concentration (MDC).

NA = Not applicable. Percent of concentration guide is not applicable either because the tritium result is less than the MDC or because the water is known to be nonpotable.

Appendix B
Records of Selected Wells and Springs, Rulison Project Area

Records of selected wells, Rulison project area, Garfield and Mesa Counties, Colorado

(Adapted from Hurr, and others, 1969, and Larson and Beetem, 1970.)

Location number: See text for well-numbering system.
Date of inventory: Date of inventory, water-level measurement, yield measurement.
Depth of well: Measured depths are given in feet and tenths below land surface (accuracy ± 0.5 ft); reported depths are given in feet.
Altitude of land surface: Altitude, estimated from 7½-minute quadrangle topographic maps, is given in feet above mean sea level.
Depth to water: Measured depths to water are given in feet and tenths below land surface; reported depths are given in feet below land surface. A "P" indicates pumping level at time of measurement.
Method of lift and type of power: J, jet; N, none; P, piston; S, submersible; T, turbine; E, electric motor; NG, natural gas engine.
Yield: All quantities are given in gallons per minute. R, reported; E, estimated.
Use of water: D, domestic; I, irrigation; Ind, industrial; N, none; S, stock.
Well permit number: Permit on file at State Engineer's office under this number.
Remarks: DC, depth well cased; Pf, perforated casing with interval shown; OH, open hole with interval shown.

Location number	Owner or tenant	Date of inventory	Year completed	Depth of well (feet)	Casing		Altitude of land surface (feet)	Depth to water (feet)	Method of lift and power	Yield (gallons per minute)	Use of water	Temperature of water (°C)	Turbidity (milligrams per liter)	Well permit number	Remarks
					Diameter (inches)	Type									
SC 5-92-33aac	W. Jewell	10-22-69	1962	35	6	Steel	5,690	6.5	J,E	--	D,S	--	--	P12707	Inventoried postshot.
SC 6-93-15cbd	K. Johnson	3-26-69	1941	41	--	--	5,330	25	J,E	--	D	10	1	--	Outside 20-km radius.
-16bcb	Kozy Kottage Kourt	3-27-69	1954	50	6	--	5,300	20	--	60R	D	--	--	R1198	Pump would not start.
-16cdb	J. Layne	3-27-69	1963	40	7	Steel	5,310	19	J,E	20R	D,S	--	--	P18318	Pump was not working. Owner uses city water.
-16cdd	W. Wood	3-27-69	1964	24	7	Steel	5,305	8	J,E	20R	N	--	--	P20897	
-16dcc	R. Swallow	3-27-69	1964	44	7	Steel	5,315	18	--	20R	D	--	--	PF5733	
-17bbd	W. Shafto	3-26-69	1956	38	5	Steel	5,290	18	J,E	5E	D	11	<1	N28	Problems with salt and corrosion. Well cleaned out about 1 year ago.
-18adb	A. Wooley	3-26-69	1965	42	5	Steel	5,290	31	J,E	10R	N	--	--	P25185	
-18dac	Union Carbide Corp.	3-26-69	1957	30.5	96	Steel	5,270	10.6P	T,E	1,500R	Ind	15	15	--	Two 8-inch pumps in well.
-20ccc	E. Hull	3-26-69	--	300	7	Steel	5,710	80	P,E	--	D	8	4	--	
SC 6-94-23dca	C. Saulsbury	3-24-69	1966	94	--	--	5,520	--	J,E	5E	D	10	<1	--	
-26bcc	N. Mead	3-24-69	1964	75	7	Steel	5,300	30	S,E	15R	D,S	10	<1	P19365	
-26cac	H. Boor	3-24-69	1953	210	15	Steel	5,360	88.8	T,NG	650R	I	--	--	R13852	Well number 1.
-27daa	L. Dotson	3-24-69	1962	103	6	Steel	5,300	--	P,E	--	D,S	17	2	--	Owner reports motor needs replacing.
-27dda	H. Boor	3-24-69	1953	210	15	Steel	5,340	83.6	T,NG	650R	I	--	--	R13851	Well number 2.
-30cda	E. Becktell	3-20-69	1954	140	--	--	5,280	--	S,E	--	D	5	3	--	
-31bbd	G. Ems	3-20-69	1967	105	7	Steel	5,270	65	S,E	40R	D	3	<1	--	
-31bca	R. McDaniel	3-20-69	1965	130	7	Steel	5,350	110	S,E	23R	I,D,S	3	<1	--	DC, 130 feet.
-31bcd	Seventh Day Adventist	3-20-69	1962	100	7	Steel	5,360	80	S,E	20R	D	4	3	P13564	

--Records of selected wells, Rulison project area, Garfield and Mesa Counties, Colorado--Continued

Location number	Owner or tenant	Date of inventory	Year completed	Depth of well (feet)	Casing: Diameter (inches)	Casing: Type	Altitude of land surface (feet)	Depth to water (feet)	Method of lift and power	Yield (gallons per minute)	Use of water	Temperature of water (°C)	Turbidity (milligrams per liter)	Well permit number	Remarks
SC 6-94-31bdc	W. Massey	3-24-69	1967	142	6	Steel	5,380	70	S,E	8R	D	11	<1	P32393	OH, 110-142 feet.
-31dac	E. Robinson	3-20-69	1964	160	7	Steel	5,600	15	E	30R	D	10	<1	--	
-31dbb	O. Gibbs	3-21-69	1969	54.0	9	Steel	5,470	22.9	N	--	N	--	--	--	New well,no pump.
SC 6-95-28cdd	O. Mahaffey	3-20-69	1963	180	5	Steel	5,485	120	S,E	2R	D	8	2	P18113	
-34cba	do.	3-24-69	1963	88.0	7	Steel	5,220	69.5	S,E	12R	S	--	--	P18114	
-35acd	W. Arnett	3-27-69	--	12.0	(48x48)	Wood	5,140	10.7	N	--	N	--	--	--	
-36adb	C. Gardner	3-26-69	--	33	7	Steel	5,220	--	J,E	5E	D	3	12	--	
-36add	R. Smith	3-24-69	1921	86	--	--	5,280	--	J,E	--	D	7	3	--	
-36dab	L. Dix	3-20-69	--	110.0	96	Concrete	5,280	44.0	J,E	--	D	8	<1	--	
SC 6-96-29daa	Sinclair Oil Co.	3-20-69	1959	40	4	Steel	5,440	20	J,E	35R	D,S	14	<1	--	
-34bda	Union Oil Co.	3-20-69	1951	88.0	8	Steel	5,445	65.9	S,E	10	S	12	<1	--	Formerly used for irrigation. Reported to yield about 250 gpm when equipped with 4-inch turbine pump.
-34bdb	do.	3-20-69	--	85.0	4	Steel	5,425	57.9	S,E	<10R	D	7	<1	--	Casing quite rusty.
-34cad	do.	3-20-69	1963	59.0	6	Steel	5,340	39.0	S,E	5E	S	9	27	P17375	
-34cbd	do.	3-20-69	--	121.4	6	Steel	5,380	61.0	J,E	--	N	--	--	--	
-34cdb	do.	3-20-69	1963	81.9	6	Steel	5,330	68.0	J,E	10E	S	11	<1	P17376	Casing rusty but pump in good condition.
SC 7-94- 6ddd	R. Bingman, Sr.	3-22-69	1945	140	7	Steel	6,480	100	P,E	--	D,S	6	1	--	
- 7bab	F. Sefcovic	3-22-69	1954	85	6	Steel	6,460	--	P,E	3R	D,S	8	<1	--	
- 7bba	J. Lemon	3-28-69	--	--	6	Steel	--	--	--	--	N	--	--	--	Pump out of hole.
SC 7-95- 2cbc	P. Baum	3-19-69	1969	295	7	Steel	5,860	130	S,E	5E	D	6	1	PF6667(?)	
- 3dcd	H. Pfost	4- 3-69	1959	125	7	Steel	5,940	--	S,E	--	N	--	--	--	Pump set at 50 feet.
- 3ddc	C. Moore	4- 3-69	1961	150	6	Steel	5,965	70	S,E	50R	I,D	--	--	PF2713	
- 4ccc	J. Savage	3-26-69	--	122.5	5	Galv. iron	5,550	120.0	S,E	--	N	--	--	--	Pump pulled.
- 7adb	J. Lawson	5-13-69	1960	100	7	Steel	5,160	30	J,E	1R	D	16	--	P5480	DC, 63 feet.
- 7dab	M. Zediker	3-24-69	1958	12.5	36	Concrete	5,120	7.8	P,E	5E	I,D	11	<1	--	
- 9adb	J. Smith	5-20-69	1968	160	7	Steel	5,920	--	N	--	N	--	--	P28859	
-10acb	L. Hayward	4- 3-69	1958	115	5	Galv. iron	6,050	90	J,E	10R	D,S	--	--	P924	
-10acc	Sorensen	5-20-69	1966	160	7	Steel	6,100	80	N	20R	N	--	--	P28863	
-10adc1	E. Schwab	4- 3-69	1955	75	--	--	6,140	32	--	--	I,D	--	--	R6280	
-10adc2	do.	5-14-69	1954	134	6	Steel	6,140	13	S,E	50R	I,D	--	--	--	
-10adc3	do.	4- 3-69	--	--	--	--	6,140	--	S,E	--	--	--	--	--	
-10bda	L. Hayward	5-14-69	1962	143	5	Steel	5,990	43	S,E	--	D	11	--	--	
-10dcd	do.	5-20-69	--	160	7	Steel	6,300	81.0	N	--	N	--	--	P28861	
-12bad	B. Smith	3-22-69	1951	80	8	Steel	6,210	--	S,E	--	D,S	12	<1	--	

--Records of selected wells, Rulison project area, Garfield and Mesa Counties, Colorado--Continued

Location number	Owner or tenant	Date of inventory	Year com-pleted	Depth of well (feet)	Casing: Diameter (inches)	Casing: Type	Altitude of land surface (feet)	Depth to water (feet)	Method of lift and power	Yield (gallons per minute)	Use of water	Temper-ature of water (°C)	Turbid-ity (milli-grams per liter)	Well permit number	Remarks
SC 7-95-17aab	A. McLane	3-19-69	1966	230	5	Steel	5,660	100	S,E	3R	D	7	1	P28860	Pf, 170-220 feet; OH, 220-230 feet.
-17aba	D. Dupice	3-19-69	1966	240	5	Steel	5,600	160	S,E	7R	D	13	10	P28862	Pf, 160-210 feet; OH, 210-240 feet.
-18adb	R. Nordstrom	3-18-69	1949	100	7	Steel	5,380	50	S,E	8R	D	14	2	--	Owner reports water is rusty.
-18cbb	G. Rogers	5-13-69	1960	95	7	Steel	5,110	66	S,E	30E	D	12	--	P5517	
-18dad	M. Christianson	3-18-69	--	--	6	Steel	5,470	--	S,E	--	D	12	2	--	
-20bba	A. Gardner	3-26-69	1957	130	6	Steel	5,510	80	S,E	10E	D,S	12	<1	--	
SC 7-96- 1ccc	Lindauer	--	--	--	--	--	5,150	--	--	--	N	--	--	--	Tenant reports that well is no good. It was drilled in too fine and clayey material.
- 2dbb	C. Alber	3-20-69	1900	29.3	24	Rock	5,195	15.1	J,E	8R	S	--	--	N439	Motor on pump reported to have failed Dec. 1968. It has not yet been repaired.
-12bbb	B. Lindauer	3-20-69	1948	57	6	Steel	5,140	32	J,E	10E	D	16	<1	--	
-13abb	W. Gray	3-24-69	1964	50.7	7	Steel	5,080	34.4	J,E	--	D	--	--	P16995	
-13abd	J. Smith	3-24-69	1959	14.6	24	Concrete	5,060	7.2	J,E	5E	D	11	11	--	
-23cad	Mountain Corp.	3-25-69	1959	13.9	23	Oil drums	5,030	11.0	P,E	5E	D	7	1	--	
-34bac	A. DeMaestri	--	--	--	--	--	4,995	--	--	--	N	--	--	--	
-34bbc	do.	3-25-69	--	11.0	(24x24)	Concrete	4,995	8.9	J,E	5E	D	7	<1	--	
-34bcd	R. Ellis	3-25-69	1961	23.2	7	Steel	4,990	9.8	J,E	5E	D	11	12	--	
-34bdc	C. Hayward	3-25-69	1963	25.5	7	Steel	4,990	11.1	J,E	15R	D	11	37	P16997	
SC 8-96-11acc	E. Kennon	3-18-69	--	50	8	--	5,760	38	S,E	--	D,S	9	2	--	
-11bbd	L. Knox	3-18-69	1950	10	36	None	5,600	6.0	J,E	6E	D	6	3	--	
-12aac	N. Dutton	5-13-69	1949	165	6	Steel	6,100	134	P,E	2E	D,S	13	--	--	DC, 165 feet.
SC 8-97-14dad	O. Mahaffey	3-26-69	1964	107.0	5	Steel	5,020	66.7	S,E	8R	S	--	--	P19065	Outside 20-km radius.
SC 9-94-22acc	W. Nicoll	3-25-69	1965	290	9	Steel	6,980	100	S,E	5E	D,S	12	<1	P20032(?)	
-22bab	W. Severson	5-15-69	1966	110	7	Steel	6,940	--	S,E	5E	D,S	10	--	--	
SC 9-95-26baa	F. Hight	5-15-69	1951	75	5	Steel	6,320	57	J,E	--	D	15	--	--	
-34bdb	M. Campbell	3-25-69	1900	40	6	Rock	5,994	--	J,E	--	D	10	<1	--	Pump in basement of store. Well under street about 25 feet north of store.

--Records of selected wells, Rulison Project area, Garfield and Mesa Counties, Colorado--Continued

Location number	Owner or tenant	Date of inventory	Year completed	Depth of well (feet)	Casing		Altitude of land surface (feet)	Depth to water (feet)	Method of lift and power	Yield (gallons per minute)	Use of water	Temperature of water (°C)	Turbidity (milligrams per liter)	Well permit number	Remarks
					Diameter (inches)	Type									
SC 9-95-35abc	T. Young	5-20-69	1964	765	7	Steel	6,100	55	S,E	50E	D	--	--	PF6238	DC, 765 feet. Pf, 175-200 feet, 405-510 feet, and 565-765 feet.
SC 10-95- 2aab	Unknown	4- 3-69	--	35	--	--	6,240	--	--	--	N	--	--	--	Pump bad. Tenant hauling water.
- 2baa	H. Castle	4- 3-69	1964	185	5	Steel	6,245	138	J,E	12R	D	--	--	P21409	

Records of selected springs, Rulison project area, Garfield and Mesa Counties, Colorado

(Adapted from Hurr, and others, 1969, and Larson and Beetem, 1970.)

Location number: See text for spring-numbering system.
Date of inventory: Date of inventory and yield measurement.
Altitude of land surface: Altitude of point of discharge, estimated from 7½-minute quadrangle topographic maps, is given in feet above mean sea level.
Yield: R, reported; E, estimated.
Use of water: C, commercial; D, domestic; I, irrigation; M, municipal; S, stock.
Improvements: B, box; N, none; P, pipe; U, undetermined.
Temperature: Recorded to nearest 1°C.

Location number	Owner or tenant	Date of inventory	Altitude of land surface (feet)	Yield (gallons per minute)	Use of water	Improvements	Temperature (°C)	Turbidity (milligrams per liter)	Remarks
SC 6-93-18aac	A. Wooley	3-26-69	5,340	1E	C,D	B,P	6	<1	Spring went dry once or twice 6 or 7 years ago.
-20bdd	J. Todd, Sr.	3-26-69	5,400	--	D	U	4	>150	
SC 6-94-26aca	L. Farris	3-24-69	5,520	--	D	U	10	<1	
-26adc	H. Boor	3-24-69	5,500	12R	D	U	7	<1	
-31bbb	B. Potter	3-20-69	5,210	100E	I,D	B	13	<1	
-32cca	W. Wells	3-21-69	5,770	--	D	U	8	<1	
-33dbd	D. Winch	3-24-69	5,640	--	D	U	5	<1	
-34dcc	J. Smith	3-24-69	5,510	--	D	U	4	<1	
SC 6-95-36aab	W. Lemon	9- 5-69	5,200	--	D,I	N	13	--	
-36aabl	do	9- 5-69	5,200	--	D,I	N	13	--	
-36abd	do	9- 4-69	5,200	--	D,I	N	12	--	
-36abdl	do	9- 5-69	5,200	--	D,I	N	13	--	
-36cdd	G. Scarrow	3-21-69	5,480	--	D	U	5	3	
SC 7-94- 4acd	M. Bernklau	3-24-69	5,920	--	D	U	7	<1	
- 4bdc	C. Bernklau	3-22-69	6,040	--	D	U	5	<1	
- 6aba	E. Pettigrew	3-21-69	5,840	--	D	U	3	21	
- 6bba	M. Gerst	3-20-69	5,800	--	D,S	U	5	2	Supplies water to four houses.

Records of selected springs, Rulison project area, Garfield and Mesa Counties, Colorado--Continued

Location number	Owner or tenant	Date of inventory	Altitude of land surface (feet)	Yield (gallons per minute)	Use of water	Improvements	Temperature (°C)	Turbidity (milligrams per liter)	Remarks
SC 7-95- 1aba	G. Elliott	3-21-69	5,760	--	D	U	6	<1	
- 1baa	C. Clark	3-21-69	5,680	--	D	U	4	<1	
- 2add	A. Hoagland	3-26-69	5,740	--	D	U	6	<1	
- 2bcd	E. Forshee	3-21-69	5,580	--	D,S	U	4	4	
- 3bdb	G. Knight	3-26-69	5,340	150E	I	N	--	--	Contour ditch along hillside collects water from numerous springs along 1/2 - 3/4 mile of spring line.
- 4acd	do.	3-26-69	5,340	5	D	N	9	3	
- 4add	do.	3-26-69	5,340	155	I	N	9	14	Irrigates with sprinkler.
- 4dbb	do.	3-26-69	5,340	70	I	N	10	9	
- 5dcd	Town of Grand Valley	3-21-69	5,340	125	M	B	12	<1	Twenty-one separate spring boxes collect water from numerous springs along 1/2 mile of spring line.
- 8ccb	R. Eaton	3-24-69	5,300	47	D,I,S	N	9	2	Contour ditch along hillside collects water from two separate springs.
-18aad	do.	3-25-69	5,320	85	S	N	7	9	
-18bcd	C. Gardner	3-26-69	5,120	--	S	U	9	<1	

Records of selected springs, Rulison project area, Garfield and Mesa Counties, Colorado--Continued

Location number	Owner or tenant	Date of inventory	Altitude of land surface (feet)	Yield (gallons per minute)	Use of water	Improvements	Temperature (°C)	Turbidity (milligrams per liter)	Remarks
SC 7-96-33dcd	W. Hammerick	3-25-69	5,040	16	D,S	N	12	<1	
-34caa	D. Knox	3-18-69	5,080	--	D	U	10	2	
-35dcb	O. Murray	3-18-69	5,500	--	D	U	4	4	Location number is for residence.
SC 8-95-24acc	F. Wallace	9-19-69	10,200	--	--	U	7	1	Inventoried postshot.
SC 9-93-19bda	C. Bruton	9- 4-69	7,180	75E	D,S,I	B	9	--	Supplies water to two houses.
SC 9-95-26daa	City of Collbran	3-25-69	6,040	--	M	U	8	<1	
-33dba	Plateau Valley School	3-25-69	5,720	--	M	U	10	<1	
-34adb	R. Gibson	3-25-69	6,040	--	C,D	U	7	<1	Supplies a motel and the Civilian Conservation Center of the U.S. Bureau of Reclamation.
-35ddb	E. Chapman	3-25-69	6,150	--	D,S	U	2	<1	

Appendix C
Chemical Analyses of Groundwater and Surface Water, Project Rulison Area

--Chemical analyses of water from selected wells, springs, and cisterns, Rulison project area, Garfield and Mesa Counties, Colorado.
(Adapted from Burr and others, 1963, and Larson and Beetem, 1970.)

Location number: See text for hydrologic data point numbering system.

Location number	Well, spring, or cistern (W,S,C)	Date of collection	Silica (SiO2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO3)	Carbonate (CO3)	Sulfate (SO4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO3)	Phosphate (PO4)	Copper (Cu)	Zinc (Zn)	Selenium (Se)	Boron (B)	Dissolved solids (residue at 180°C)	Specific conductance (micromhos per cm at 25°C)	Hardness as CaCO3: Calcium magnesium	Hardness as CaCO3: Noncarbonate	pH	Tritium T.U.	Gross beta in picocuries per liter (as Sr90-Y90)	Gross alpha in micrograms per liter (as U equivalent)
SO5-95-3[illegible]aac	W	[illegible]	31	<0.01	[illegible]	<0.01	73	31	0.4	54	2.5	<0.01	421	[illegible]	262	30	0.9	30	<0.01	0.02	0.11	<0.01	0.30	783	1,180	385	43	7.2	<200	<6.5	17
SO6-95-13cbc	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	896	[illegible]	--	--	--	--	--	--	--	--	--	--	1,990	--	--	7.4	--	--	--
17bbc	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	750	[illegible]	--	--	--	--	--	--	--	--	--	--	2,870	--	--	7.3	--	--	--
18aac	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	530	[illegible]	--	--	--	--	--	--	--	--	--	--	2,020	--	--	7.8	--	--	--
18aaa	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	222	[illegible]	--	--	--	--	--	--	--	--	--	--	3,480	--	--	7.2	--	--	--
20bbb	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	510	[illegible]	--	--	--	--	--	--	--	--	--	--	1,020	--	--	7.8	--	--	--
21ccc	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	390	[illegible]	--	--	--	--	--	--	--	--	--	--	686	--	--	7.6	--	--	--
SO6-96-23dca	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	960	[illegible]	--	--	--	--	--	--	--	--	--	--	870	--	--	7.2	--	--	--
25aca	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	428	[illegible]	--	--	--	--	--	--	--	--	--	--	1,180	--	--	7.8	--	--	--
26aab	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	387	[illegible]	--	--	--	--	--	--	--	--	--	--	1,010	--	--	7.7	--	--	--
26bcc	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	535	[illegible]	--	--	--	--	--	--	--	--	--	--	1,180	--	--	7.5	400	6.1	6.8
27daa	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	501	[illegible]	--	--	--	--	--	--	--	--	--	--	1,180	--	--	7.4	--	--	--
31cda	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	536	[illegible]	--	--	--	--	--	--	--	--	--	--	658	--	--	8.2	--	--	--
31bbb	S	[illegible]	34	<.1	[illegible]	<.01	[illegible]	[illegible]	[illegible]	33	7.1	<.01	341	[illegible]	41	3.7	.8	4.8	<.01	.02	.01	.00	.06	398	600	247	[illegible]	7.6	<200	6.4	22
31bbc	W	[illegible]	--	--	<.01	--	--	--	--	--	--	--	418	[illegible]	--	--	--	--	--	--	--	--	--	--	707	--	--	7.6	--	--	--
31bca	[illegible]	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	411	[illegible]	--	--	--	--	--	--	--	--	--	--	759	--	--	7.4	--	--	--
31bcc	[illegible]	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	431	[illegible]	--	--	--	--	--	--	--	--	--	--	729	--	--	[illegible]	--	--	--
31bdc	[illegible]	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	446	[illegible]	--	--	--	--	--	--	--	--	--	--	783	--	--	7.5	--	--	--
31dac	[illegible]	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	357	[illegible]	--	--	--	--	--	--	--	--	--	--	656	--	--	[illegible]	--	--	--
31aaa	[illegible]	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	897	[illegible]	--	--	--	--	--	--	--	--	--	--	1,710	--	--	7.5	<200	3.2	8.0
Do.	S	[illegible]	23	<.1	[illegible]	<.01	41	14	.4	33	4.7	<.01	866	[illegible]	35	7.9	.3	41	<.01	.04	.11	<.01	.01	304	500	219	2	7.5	<200	3.6	4.8
13dbd	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	412	[illegible]	--	--	--	--	--	--	--	--	--	--	702	--	--	7.6	<200	11	51
34dcc	S	[illegible]	--	--	<.01	--	--	--	--	--	--	--	440	[illegible]	--	--	--	--	--	--	--	--	--	--	854	--	--	7.7	--	--	--
SO5-97-02cdd	W	[illegible]	80	.1	[illegible]	.04	90	42	.73	750	4.0	.08	755	[illegible]	1,160	87	.6	30	<.01	.06	.49	.05	.42	2,450	3,250	399	[illegible]	7.4	<200	8.1	34
36aab	S	6-5-64	--	--	--	--	61	23	--	--	--	--	429	[illegible]	--	--	--	--	--	--	--	--	--	425	695	322	[illegible]	8.0	<200	--	--
36aab	S	6-5-64	--	--	--	--	61	31	--	--	--	--	431	[illegible]	--	--	--	--	--	--	--	--	--	416	698	330	0	7.3	<200	--	--
36abd	S	[illegible]	--	--	--	--	61	33	--	--	--	--	440	[illegible]	--	--	--	--	--	--	--	--	--	433	725	330	[illegible]	7.5	<200	--	--
36add	S	6-5-64	--	--	--	--	77	33	--	--	--	--	434	[illegible]	--	--	--	--	--	--	--	--	--	488	718	330	[illegible]	8.2	<200	--	--
36adb	W	[illegible]	--	--	.13	--	--	--	--	--	--	--	376	[illegible]	--	--	--	--	--	--	--	--	--	--	660	--	--	7.1	--	--	--
36add	W	[illegible]	--	--	.13	--	--	--	--	--	--	--	411	[illegible]	--	--	--	--	--	--	--	--	--	--	708	--	--	7.6	--	--	--
36aac	W	[illegible]	33	<.1	[illegible]	<.01	47	33	.33	65	8.9	.03	500	[illegible]	43	7.9	.3	5.4	<.01	.03	.03	<.01	.09	307	850	349	0	7.3	<200	5.6	28
36dab	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	414	[illegible]	--	--	--	--	--	--	--	--	--	--	805	--	--	8.2	--	--	--
SO6-96-25dda	W	[illegible]	23	<.1	[illegible]	.03	130	51	1.1	90	85	.07	636	[illegible]	186	7.9	1.4	6.0	<.01	.05	.18	.01	.16	835	1,260	537	0	7.4	<200	15	33
34dda	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	617	[illegible]	--	--	--	--	--	--	--	--	--	--	1,390	--	--	7.4	--	--	--
34dcb	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	606	[illegible]	--	--	--	--	--	--	--	--	--	--	1,390	--	--	7.4	--	--	--
[illegible]caa	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	637	[illegible]	--	--	--	--	--	--	--	--	--	--	1,840	--	--	7.4	--	--	--
[illegible]cab	W	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	625	[illegible]	--	--	--	--	--	--	--	--	--	--	1,800	--	--	7.4	--	--	--
SO7-[illegible]-01aaa	[illegible]	[illegible]	--	--	<.01	--	--	--	--	--	--	--	377	[illegible]	--	--	--	--	--	--	--	--	--	--	723	--	--	7.6	--	--	--
[illegible]aab	S	[illegible]	[illegible]	<.1	[illegible]	<.01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	11	.3	14	<.01	[illegible]	[illegible]	<.01	.07	550	825	357	[illegible]	7.7	<200	[illegible]	[illegible]
[illegible]aab	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	408	[illegible]	--	--	--	--	--	--	--	--	--	--	796	--	--	7.5	--	--	--
Do.	S	[illegible]	32	<.1	[illegible]	.02	[illegible]	41	[illegible]	43	3.6	.01	431	[illegible]	[illegible]	11	.3	14	<.01	.01	<.01	<.01	.06	512	840	354	1	7.5	<200	<3.0	3.4
06aba	S	[illegible]	31	<.1	[illegible]	.02	[illegible]	[illegible]	[illegible]	[illegible]	3.4	.03	309	[illegible]	[illegible]	6.5	.3	9.0	<.01	.03	.03	<.01	.10	341	565	240	[illegible]	8.1	<200	5.1	11
06bba	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	358	[illegible]	--	--	--	--	--	--	--	--	--	--	557	--	--	8.2	--	--	--
06dda	W	[illegible]	--	--	<.01	--	--	--	--	--	--	--	324	[illegible]	--	--	--	--	--	--	--	--	--	--	545	--	--	7.7	<200	<.4	5.0
Do.	W	[illegible]	[illegible]	<.1	[illegible]	<.01	[illegible]	[illegible]	[illegible]	[illegible]	3.2	<.01	323	[illegible]	87	7.2	.2	8.1	<.01	.02	.19	<.01	<.02	356	545	264	[illegible]	7.7	<200	8.1	<6.5
07baa	W	[illegible]	--	--	<.01	--	--	--	--	--	--	--	829	[illegible]	--	--	--	--	--	--	--	--	--	--	366	--	--	7.6	--	--	--
SO7-95-01aba	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	441	[illegible]	--	--	--	--	--	--	--	--	--	--	686	--	--	7.6	--	--	--
01bba	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	679	[illegible]	--	--	--	--	--	--	--	--	--	--	1,030	--	--	7.8	--	--	--
01add	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	473	[illegible]	--	--	--	--	--	--	--	--	--	--	760	--	--	7.7	--	--	--
01bcd	S	[illegible]	[illegible]	<.1	[illegible]	<.01	90	[illegible]	[illegible]	[illegible]	8.9	<.01	863	[illegible]	[illegible]	7.2	.2	8.4	<.01	.03	.11	<.01	.02	308	500	218	[illegible]	7.6	<200	3.4	11
[illegible]cbc	W	[illegible]	[illegible]	.1	[illegible]	<.01	[illegible]	[illegible]	[illegible]	150	3.5	.05	383	[illegible]	[illegible]	1.1	.3	6.1	<.01	.05	.81	<.01	.30	587	940	200	[illegible]	7.8	<200	5.6	17
[illegible]acc	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	378	[illegible]	--	--	--	--	--	--	--	--	--	--	709	--	--	7.9	--	--	--
[illegible]add	S	[illegible]	[illegible]	<.1	[illegible]	.02	--	[illegible]	[illegible]	[illegible]	3.1	.02	401	[illegible]	17	8.9	.2	8.8	<.01	<.01	.02	<.01	.11	364	850	298	[illegible]	8.1	<200	4.0	9.1
[illegible]dbb	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	322	[illegible]	--	--	--	--	--	--	--	--	--	--	588	--	--	7.9	--	--	--
[illegible]dcc	S	[illegible]	[illegible]	<.1	[illegible]	<.01	[illegible]	[illegible]	[illegible]	[illegible]	8.0	[illegible]	383	[illegible]	[illegible]	8.5	.2	8.6	<.01	.01	.02	<.01	.04	338	560	202	[illegible]	7.7	<200	3.0	21
Do.	S	[illegible]	--	--	[illegible]	--	--	--	--	--	--	--	310	[illegible]	--	--	--	--	--	--	--	--	--	--	514	--	[illegible]	7.8	--	--	--
Do.	S	[illegible]	--	--	--	--	[illegible]	13	--	--	--	--	315	[illegible]	--	--	--	--	--	--	--	--	--	289	515	190	[illegible]	7.9	<200	--	--
Do.	[illegible]	11-19-63	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<200	--	--
07adb	W	[illegible]	--	--	<.01	--	--	--	--	--	--	--	578	[illegible]	--	--	--	--	--	--	--	--	--	--	1,470	--	--	7.3	<200	--	--
08aaa	W	[illegible]	33	<.1	[illegible]	<.01	[illegible]	[illegible]	[illegible]	115	3.3	.08	505	[illegible]	[illegible]	50	.19	<.1	<.01	.30	.05	<.01	.14	665	1,080	375	[illegible]	7.5	<200	11	22

--Chemical analyses of water from selected wells, springs, and cisterns, Rulison project area, Garfield and Mesa Counties, Colorado.--Continued
(Adapted from Hurr and others, 1969, and Larson and Beeton, 1970.)

Location number: See text for hydrologic data point numbering system.

Location number	Well, spring, or cistern (W,S,C)	Date of collection	Silica (SiO_2)	Aluminum (Al)	Iron (Fe)	Manganese (Mn)	Calcium (Ca)	Magnesium (Mg)	Strontium (Sr)	Sodium (Na)	Potassium (K)	Lithium (Li)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrate (NO_3)	Phosphate (PO_4)	Copper (Cu)	Zinc (Zn)	Selenium (Se)	Boron (B)	Dissolved solids (residue at 180°C)	Specific conductance (micromhos per cm at 25°C)	Hardness as $CaCO_3$: Calcium magnesium	Hardness as $CaCO_3$: Noncarbonate	pH	Tritium T.U.	Gross beta in picocuries per liter (as Sr90-Y90)	Gross alpha in micrograms per liter (as U equivalent)
SCT-95-6ccb	S	5-8-69	--	--	0.02	--	--	--	--	--	--	--	370	0	--	--	--	--	--	--	--	--	--	--	695	--	--	8.1	--	--	--
Do.[5]	S	5-2-69	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	<220	--	--
10ab	C	5-13-69	--	--	.22	--	27	5.5	--	--	--	--	96	18	--	--	--	--	--	--	--	--	--	--	250	94	0	9.0	--	--	--
10adc	W	5-3-69	--	--	<.01	--	31	20	--	--	--	--	268	0	--	--	--	--	--	--	--	--	--	--	480	160	0	7.8	383	--	--
Do.	W	5-13-69	--	--	2.6	--	23	7.2	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	89	--	--	--	--	--
10bda	W	5-1-69	--	--	<.01	--	--	--	--	--	--	--	427	0	--	--	--	--	--	--	--	--	--	--	710	--	--	7.8	<220	--	--
10bdb	C	10-21-69	3.9	<0.1	.13	<0.01	35	1.9	1.5	13	1.9	<0.01	--	7	11	8	0.1	0.8	<0.01	0.03	<0.01	<0.01	0.01	103	310	89	18	10.6	275	1.5	<2.0
10bdc[6]	--	10-25-69	20	<.1	.05	<.01	86	8.6	.22	11	1.7	<.01	154	0	18	.6	.1	.2	<.01	.01	<.01	<.01	.03	154	270	114	0	8.2	315	2.0	1.8
10bad	W	1-8-69	36	<.1	.03	<.01	84	8-	.--	23	2.1	.01	373	0	37	11	.1	8.0	<.01	.03	.09	<.01	.01	402	665	309	3	7.4	<220	1.5	5.5
17aab	W	5-19-69	30	.2	.13	<.01	23	2-	.--	--	4.0	.08	337	0	48	.6	.2	3.8	<.01	.03	2.6	<.01	.15	364	595	158	0	7.9	<220	6.9	18
17aba	W	5-19-69	--	--	.22	--	--	--	--	--	--	--	369	0	--	--	--	--	--	--	--	--	--	--	622	--	--	7.7	--	--	--
18aad	S	5-25-69	--	--	.06	--	--	--	--	--	--	--	404	0	--	--	--	--	--	--	--	--	--	--	1,180	--	--	8.0	--	--	--
18adb	W	5-26-69	27	.1	.02	.21	60	60	.13	173	6.1	.02	408	0	308	30	.3	7.8	<.01	.03	8.0	<.01	.15	899	1,260	398	63	7.8	<220	4.8	<.4
18bcd	S	5-26-69	27	<.1	.01	.11	82	67	1.1	177	4.3	.03	439	0	437	40	.4	4.6	<.01	.03	.08	<.01	.07	1,100	1,500	482	122	7.5	<220	4.0	20
18dad	W	5-15-69	--	--	.2	--	--	--	--	--	--	--	363	0	--	--	--	--	--	--	--	--	--	--	861	--	--	7.6	--	--	--
19cbb	W	5-13-69	--	--	<.01	--	--	--	--	--	--	--	375	0	--	--	--	--	--	--	--	--	--	--	892	--	--	7.6	150	--	--
20bba	W	5-25-69	14	<.1	.12	.02	40	20	.73	51	1.5	.02	383	0	63	4.6	.3	12	<.01	.01	.16	<.01	.05	435	730	270	0	7.6	320	<.4	9.1
SCT-96-12bbb[1]	W	5-15-69	13	.1	.12	.21	140	50	1.1	505	5.0	.1	626	0	578	12	.7	.1	<.01	.07	1.3	<.01	.15	1,490	1,870	722	105	7.4	<220	6.5	32
13abd	W	5-24-69	17	<.1	.16	.13	130	100	1.1	260	5.6	.06	851	0	657	27	.8	.4	<.01	.01	.19	<.01	.18	1,730	2,250	778	74	7.4	<220	8.7	17
23cad	W	5-25-69	14	<.1	.04	.08	110	23	.73	111	3.1	.03	313	0	178	164	.3	<.1	<.01	.14	1.2	<.01	.04	781	1,200	391	134	7.4	370	3.4	8.4
33dcd	S	5-25-69	25	<.1	.01	.21	105	62	.34	150	4.4	.02	490	0	464	16	.2	0.6	<.01	.01	.02	<.01	.88	1,140	1,500	523	121	7.4	830	5.4	20
34bba	W	5-25-69	15	<.1	.01	.15	125	38	1.1	140	5.5	.02	358	0	188	240	.3	<.1	<.01	.01	.34	<.01	.03	953	1,450	470	101	7.6	590	1.8	8.7
34bcd	W	5-25-69	--	--	.18	--	--	--	--	--	--	--	392	0	--	--	--	--	--	--	--	--	--	--	1,060	--	--	7.6	--	--	--
34bdc	W	5-25-69	--	--	.17	--	--	--	--	--	--	--	383	0	--	--	--	--	--	--	--	--	--	--	1,840	--	--	7.5	--	--	--
34caa	S	5-18-69	--	--	.06	--	--	--	--	--	--	--	349	0	--	--	--	--	--	--	--	--	--	--	1,490	--	--	7.6	--	--	--
35dcb	S	5-18-69	--	--	.03	--	--	--	--	--	--	--	402	0	--	--	--	--	--	--	--	--	--	--	1,840	--	--	8.1	<220	6.7	11
SCS-95-24acc	S	6-19-69	20	<.1	.01	<.01	8.5	2.2	.02	2.4	.9	<.01	39	0	5	.3	.1	.3	<.01	--	--	.02	.02	64	65	30	0	7.0	<220	--	--
SCS-96-11acc	W	5-18-69	27	<.1	.03	<.01	69	25	.4	33	2.9	.02	365	0	56	8.4	.2	14	<.01	.02	.07	<.01	.09	414	670	250	0	7.6	<220	2.6	4.7
11bbd	W	5-18-69	--	--	.03	--	--	--	--	--	--	--	411	0	--	--	--	--	--	--	--	--	--	--	711	--	--	7.5	--	--	--
12aac	W	5-13-69	--	--	<.01	--	--	--	--	--	--	--	304	0	--	--	--	--	--	--	--	--	--	--	782	--	--	7.8	<220	--	--
Do.	W	10-21-69	25	<.1	.01	<.01	46	41	1.1	55	3.7	.02	399	0	108	35	.4	15	<.01	.01	.47	<.01	.06	486	760	390	45	7.7	<220	5.6	18
SCS-95-19bda	S	5-14-69	--	--	--	--	120	40	--	--	--	--	537	0	--	--	--	--	--	--	--	--	--	933	1,280	484	44	7.6	<220	--	--
SCS-96-22acc	W	5-25-69	--	--	.1	--	--	--	--	--	--	--	363	0	--	--	--	--	--	--	--	--	--	--	858	--	--	7.6	<220	15	14
22baa	W	5-15-69	--	--	.2	--	--	--	--	--	--	--	443	0	--	--	--	--	--	--	--	--	--	--	675	--	--	7.6	616	--	--
SCS-95-28baa	W	5-15-69	--	--	.2	--	--	--	--	--	--	--	563	0	--	--	--	--	--	--	--	--	--	--	1,100	--	--	7.8	396	--	--
35daa	S	5-15-69	36	<.1	<.01	.01	51	85	.55	32	6.4	.01	398	0	22	8.6	.4	3.0	<.06	.01	.04	<.01	.02	381	590	343	0	7.6	600	5.9	10
Do.	S	5-20-69	--	--	--	--	75	22	--	--	--	--	442	0	--	--	--	--	--	--	--	--	--	509	652	385	0	7.7	387	--	--
35dba	S	5-25-69	--	--	<.01	--	--	--	--	--	--	--	507	0	--	--	--	--	--	--	--	--	--	--	706	--	--	7.6	--	--	--
36adb	S	5-25-69	--	--	.01	--	--	--	--	--	--	--	398	0	--	--	--	--	--	--	--	--	--	--	622	--	--	7.7	--	--	--
36adb	W	5-25-69	3-	<.1	.01	<.01	57	3-	.4-	35	14	.01	449	0	41	5.5	.2	8.5	.17	.08	.13	<.01	.06	465	700	391	0	7.5	490	24	43
35ddb	S	5-15-69	--	--	.01	--	--	--	--	--	--	--	471	0	--	--	--	--	--	--	--	--	--	--	794	--	--	7.4	--	--	--

1/ Sample taken had passed through a domestic water softener.

2/ Sample collected from tap at Bernklau home (SCS-94-35cba).

3/ Before chlorination.

4/ After chlorination.

5/ Sample collected from tap at Satterfield home (SCT-95-6ccb).

6/ Sample collected from ditch supplying Moore cistern (SCT-95-10bdb).

(Chemical analyses in milligrams per liter.)

Station name	Altitude (feet above msl)	Date	Time (mountain daylight)	Temperature (°C)	Calcium (Ca)	Magnesium (Mg)	Bicarbonate (HCO_3)	Carbonate (CO_3)	Hardness as $CaCO_3$		Dissolved solids (residue at 180°C)	Specific conductance (micromhos per cm at 25°C)	pH	Turbidity	Tritium (T.U.)[1/]
									Calcium magnesium	Noncarbonate					
Colorado River at New Castle	5,515	8-26-69	1225	19.0	71	14	161	0	235	103	534	898	7.3	6	368
Colorado River at New Castle	5,515	10-19-69	1600	8.0	--	--	--	--	--	--	--	--	--	--	<220
East Mamm Creek near Rifle	6,220	9- 2-69	1500	27.0	51	60	671	0	374	0	1,050	1,460	8.1	--	<220
Middle Mamm Creek near Rifle	6,830	8-27-69	1235	19.5	44	21	261	0	197	0	237	450	7.9	8	<220
West Mamm Creek near Rifle	7,080	8-27-69	1145	13.5	62	31	360	0	282	0	369	648	7.6	4	<220
Mamm Creek near Rifle	5,610	8-27-69	1300	27.5	51	93	588	0	510	28	1,390	1,820	7.7	50	<220
Beaver Creek near Rifle	6,685	3-24-69	--	1.0											
Beaver Creek near Rifle	6,685	9-20-69	1209	10.0	36	8.0	173	0	124	0	149	282	8.1	15	<220
Cache Creek near Rulison	5,950	8-27-69	1025	13.5	21	4.5	101	0	71	0	81	171	7.0	5	263
Battlement Reservoir near Grand Valley	10,200	9- 3-69	1000	7.0	7.1	.8	35	0	21	0	53	60	7.0	--	336
Battlement Creek near Morrisania	7,760	8-28-69	0815	9.5	10	2.5	55	0	36	0	74	96	7.1	10	229
Battlement Creek near Morrisania	7,760	9-20-69	1355	9.5	12	2.6	59	0	41	0	41	100	7.4	2	<220
Tributary of Battlement Creek near Morrisania	7,880	8-27-69	1500	17.0	36	11	200	0	135	0	147	322	7.3	<1	<220
Tributary of Battlement Creek near Morrisania	7,880	9-20-69	1400	16.5	36	11	208	0	135	0	178	338	8.0	7	<220
Battlement Creek near Grand Valley	6,630	8-27-69	1425	8.0	17	5.0	89	0	63	0	110	150	6.8	2	258
Battlement Creek near Grand Valley	6,630	9-20-69	1320	11.0	.23	7.3	126	0	88	0	104	212	8.0	2	<220
Battlement Creek near Grand Valley	6,630	10-19-69	1420	4.0	--	--	--	--	--	--	--	--	--	--	<220
Spring Creek near Grand Valley	5,080	8-27-69	1610	22.0	29	38	334	0	229	0	471	790	7.9	1	<220
Colorado River near DeBeque	4,940	8-26-69	1615	23.5	67	15	157	0	229	100	537	882	6.5	10	335
Colorado River near DeBeque	4,940	9-20-69	1515	17.0	105	16	166	0	328	192	601	1,030	8.1	10	<220
Colorado River near DeBeque	4,940	10-19-69	1200	18.0	--	--	--	--	--	--	--	--	--	--	288
Vega Reservoir near Collbran	7,906	8-26-69	1945	14.0	18	3.2	81	0	58	0	56	124	6.7	4	230
Plateau Creek near Collbran	7,130	8-27-69	0755	12.0	17	4.2	83	0	60	0	57	121	6.8	2	240
Road Gulch near Collbran	7,400	8-28-69	1110	18.5	51	10	295	0	168	0	276	475	7.9	15	<220
Buzzard Creek near Collbran	6,955	8-26-69	1830	22.0	51	25	338	0	230	0	383	565	7.8	10	430
Buzzard Creek near Collbran	6,955	9-20-69	1800	14.5	76	18	322	0	264	0	335	580	8.2	2	<220
Brush Creek near Collbran	8,183	8-26-69	1905	16.0	51	13	248	0	181	0	201	350	7.9	10	263
Hawxhurst Creek near Collbran	6,560	8-26-69	1800	19.0	51	29	430	0	247	0	370	605	7.5	2	354
Hawxhurst Creek near Collbran	6,560	9-20-69	1655	14.5	76	30	443	0	313	0	404	668	7.9	<1	250
Kimball Creek near Collbran	6,880	8-26-69	1735	17.0	67	20	433	0	250	0	384	610	7.5	<1	<220
Kimball Creek near Collbran	6,880	9-20-69	1630	12.5	105	20	481	0	345	0	425	708	7.9	2	<220
Plateau Creek near Cameo	4,836	8-28-69	0955	18.5	41	38	411	0	259	0	485	780	8.1	2	<220
Plateau Creek near Cameo	4,836	9-20-69	1545	17.0	37	35	385	0	237	0	418	712	8.1	8	<220
Plateau Creek near Cameo	4,836	10-19-69	1100	16.0	--	--	--	--	--	--	--	--	--	--	291

1/ The tritium analyses were by liquid scintillation counting and the lowest detectable concentration by this method was 220 T.U.

Appendix D
Radiochemical Analyses of Spring, Well, and Stream Waters, Rulison Project Area

Radiochemical analyses of water from selected springs in western Colorado

Owner or tenant	Sample point number[1/]	Location				Latitude N.			Longitude W.			Distance from surface ground zero, in miles (kilometers)	Date of collection	Tritium		Gross alpha		Gross beta		Remarks
		Town-ship S.	Range W.	Section	¼ section	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds			pCi/l	TU	(µg/l as U natural)	(pCi/l as U natural)	(pCi/l as Sr-90/Y-90)	(pCi/l as Cs-137)	
Mrs. Betty Potter	20	6	94	31	NW	39	29	20	107	56	12	5.7(9.2)	3-20-69	<700	<220	12	3.9	8.4	11	--
													4-10-70	<1,300	<400	18	5.9	8.8	9.1	
Carl Bernklau	21	7	94	4	NW	39	28	09	107	53	45	5.1(8.2)	10-20-69	<960	<300	10	3.4	4.6	5.8	--
													4-10-70	<960	<300	10	3.5	4.3	4.8	
Town of Grand Valley	22	7	95	5	SE	39	27	49	108	00	58	5.3(8.5)	3-21-69	<700	<220	21	6.8	3.0	3.7	Town of Grand Valley water supply.
													9-20-69	<960	<300	--	--	--	--	
													10-19-69	<960	<300	--	--	--	--	
													4-11-70	<1,300	<400	20	6.7	3.0	3.4	
Otis Murray	23	7	96	35	SE	39	23	23	108	04	28	6.8(11)	3-18-69	<700	<220	11	3.7	6.7	8.4	--
													4-11-70	<1,300	<400	45	15	19	24	
Cecil Gardner	24	7	95	18	NW	39	26	16	108	02	40	5.6(9.0)	3-26-69	<700	<220	26	8.7	4.6	5.8	--
													4-11-70	<1,300	<400	31	10	5.2	6.0	

[1/] As shown on figure 1.

(Voegeli and Claassen, 1971a)

Radiochemical analyses of water from selected springs in western Colorado

Owner or tenant	Sample point number 1/	Location				Latitude N.			Longitude W.			Distance from surface ground zero		Date of collection	Tritium		Gross alpha		Gross beta		Remarks
		Township S.	Range W.	Section	¼ Section	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds	miles	kilometers		pCi/l	TU	(μg/l as U natural)	(pCi/l as U natural)	(pCi/l as Sr-90/Y-90)	(pCi/l as Cs-137)	
Mrs. Betty Potter	20	6	94	31	NW	39	29	20	107	56	12	5.7	9.2	5-30-70	<960	<300	24	7.8	9.2	9.8	--
Carl Bernklau	21	7	94	4	NW	39	28	09	107	53	45	5.1	8.2	5-30-70	<960	<300	<6.3	<2.1	3.2	3.8	--
Town of Grand Valley	22	7	95	5	SE	39	27	49	108	00	58	5.3	8.5	5-30-70	<960	<300	7.9	2.6	3.1	3.4	Town of Grand Valley water supply.
Otis Murray	23	7	96	35	SE	39	23	23	108	04	28	6.8	11	5-30-70	<960	<300	11	3.6	5.5	6.1	--
Cecil Gardner	24	7	95	18	NW	39	26	16	108	02	40	5.6	9.0	5-30-70	<960	<300	42	14	5.0	5.6	--
Fred Wallace	25	8	95	24	NE	39	21	04	107	56	26	3.8	6.1	5-29-70	<960	<300	<.6	<.2	2.1	2.7	--

(Voegeli and Claassen, 1971b)

Radiochemical analyses of water from selected wells in western Colorado

Owner or tenant	Sample point number[1/]	Location: Town-ship S.	Location: Range W.	Location: Section	Location: ¼ section	Latitude N.: Degrees	Latitude N.: Minutes	Latitude N.: Seconds	Longitude W.: Degrees	Longitude W.: Minutes	Longitude W.: Seconds	Distance from surface ground zero, in miles (kilometers)	Date of collection	Tritium: pCi/l	Tritium: TU	Gross alpha: (µg/l as U natural)	Gross alpha: (pCi/l as U natural)	Gross beta: (pCi/l as Sr-90/ Y-90)	Gross beta: (pCi/l as Cs-137)	Remarks
orman Head	15	6	94	26	NW	39	29	50	107	51	44	7.7(12)	3-24-69	1,300	420	6.8	2.3	6.3	7.8	--
													4-10-70	1,000	310	17	5.6	7.0	7.3	
ussell Bingham, Sr.	16	7	94	6	SE	39	27	41	107	55	12	4.1(6.6)	3-22-69	<700	<220	5.0	1.7	<3.5	<4.3	--
													10-20-69	<960	<300	<4.6	<1.5	2.1	2.7	
													4-10-70	<1,300	<400	4.8	1.6	3.9	4.5	
lbert Gardner	17	7	95	20	NW	39	25	49	108	01	37	4.6(7.4)	3-26-69	960	300	9.1	3.0	<.4	.5	--
													4-11-70	<1,300	<400	17	5.6	4.1	4.4	
inclair Oil Co.	18	6	96	29	SE	39	29	31	108	07	23	11.1(17.9)	3-20-69	<700	<220	31	10	15	19	--
													4-12-70	<1,300	<400	26	8.6	15	18	
illard Nicoll	19	9	94	22	NE	39	15	49	107	52	02	10.6(17.1)	3-25-69	<700	<220	14	4.8	15	19	--
													4-11-70	<1,300	<400	34	11	6.0	7.3	

1/ As shown on figure 1.

(Voegeli and Claassen, 1971a)

Radiochemical analyses of water from selected wells in western Colorado

Owner or tenant	Sample point number[1]	Location				Latitude N.			Longitude W.			Distance from surface ground zero		Date of collection	Tritium		Gross alpha		Gross beta		Remarks
		Township S.	Range W.	Section	¼ Section	Degrees	Minutes	Seconds	Degrees	Minutes	Seconds	miles	kilometers		pCi/l	TU	(µg/l as U natural)	(pCi/l as U natural)	(pCi/l as Sr-90/Y-90)	(pCi/l as Cs-137)	
Norman Mead	15	6	94	26	NW	39	29	50	107	51	44	7.7	12	5-30-70	<960	<300	<9.1	<3.0	9.3	11	--
Russell Bingham, Sr.	16	7	94	6	SE	39	27	41	107	55	12	4.1	6.6	5-30-70	<960	<300	9.8	3.3	4.1	4.4	--
Albert Gardner	17	7	95	20	NW	39	25	49	108	01	37	4.6	7.4	5-30-70	<960	<300	13	4.3	5.7	6.4	--
Sinclair Oil Co.	18	6	96	29	SE	39	29	31	108	07	23	11.1	17.9	5-30-70	<960	<300	27	9.0	23	26	--
Willard Nicoll	19	9	94	22	NE	39	15	49	107	52	02	10.6	17.1	5-29-70	<960	<300	13	4.3	14	16	--

(Voegeli and Claassen, 1971b)

Radiochemical analyses of water from selected [illegible]

Stream	Sample point number[1/]	Location: Township S.	Location: Range W.	Location: Section	Location: ¼ section	Latitude N.: Degrees	Latitude N.: Minutes	Latitude N.: Seconds	Longitude W.: Degrees	Longitude W.: Minutes	Longitude W.: Seconds	Distance from surface ground zero, in miles (kilometers)	Date of collection	Tritium: pCi/l	Tritium: TU	Dissolved: Gross alpha (µg/l as U natural)	Dissolved: Gross alpha (pCi/l as U natural)	Dissolved: Gross beta (pCi/l as Sr-90/Y-90)	Dissolved: Gross beta (pCi/l as Cs-137)	Suspended: Solids mg/l	Suspended: Gross alpha (µg/l as U natural)	Suspended: Gross alpha (pCi/l as U natural)	Suspended: Gross beta (pCi/l as Sr-90/Y-90)	Suspended: Gross beta (pCi/l as Cs-137)	Remarks
Roaring Fork River near Aspen	1	(2/)				39	10	48	106	48	05	64(103)	4- 6-70	<960	<300	7.8	2.6	2.3	2.9	<1	<0.4	<0.1	0.6	0.6	USGS gaging station 9-0734.
Colorado River at New Castle	2	5	90	31	SW	39	34	06	107	32	26	25(40)	8-26-69	1,100	350	--	--	--	--		--	--	--	--	USGS gaging station 9-0876.
													10-19-69	1,100	350	--	--	--	--		--	--	--	--	
													4- 6-70	1,300	390	28	9.3	8.7	11	16	.9	.3	1.1	1.3	
Beaver Creek near Rifle	3	6	93	20	SE	39	30	40	107	48	03	10.6(17.1)	3-24-69	<700	<220	<2.6	<.9	2.5	3.1	--	--	--	--	--	Sample collected between settling pond and filter plant, Rifle water works.
	3	7	94	1	NE	39	28	20	107	49	55	7.6(12)	9-20-69	<960	<300	--	--	--	--		--	--	--	--	USGS gaging station 9-0925.
													4-10-70	<960	<300	6.9	2.3	3.4	4.2	39	3.6	1.2	2.9	3.3	
Kimball Creek near Collbran	4	9	95	14	NE	39	17	00	107	57	13	8.4(14)	8-26-69	<960	<300	--	--	--	--		--	--	--	--	--
													9-20-69	<960	<300	--	--	--	--		--	--	--	--	
													4-11-70	<1,300	<400	7.2	2.4	7.6	9.4	10	.5	.2	5.8	6.4	
Plateau Creek near Cameo	5	10	97	18	SW	39	11	00	108	16	10	23(37)	8-28-69	<960	<300	--	--	--	--		--	--	--	--	USGS gaging station 9-1050.
													9-20-69	<960	<300	--	--	--	--		--	--	--	--	
													10-19-69	<960	<300	--	--	--	--		--	--	--	--	
													4- 6-70	<960	<300	24	8.0	7.1	8.9	98	6.1	2.0	3.9	4.9	
Colorado River near DeBeque	6	8	97	23	SW	39	20	22	108	11	35	14(23)	8-26-69	960	300	--	--	--	--		--	--	--	--	Downstream 2.7 miles (4.3 kilometers) from USGS gaging station 9-0937.
													9-20-69	960	300	--	--	--	--		--	--	--	--	
													10-19-69	<960	<300	--	--	--	--		--	--	--	--	
													4- 6-70	1,200	380	17	5.8	7.6	9.5	14	.7	.2	1.2	1.3	

1/ As shown on figure 1.

2/ Not surveyed.

(Voegeli and Claassen, 1971a)

Radiochemical analyses of water from selected streams [illegible]

Stream	Sample point number[1]	Location: Township S.	Location: Range W.	Location: Section	Location: ¼ Section	Latitude N.: Degrees	Latitude N.: Minutes	Latitude N.: Seconds	Longitude W.: Degrees	Longitude W.: Minutes	Longitude W.: Seconds	Distance from surface ground zero: miles	Distance from surface ground zero: kilometers	Date of collection	Tritium: pCi/l	Tritium: TU	Dissolved: Gross alpha (µg/l as U natural)	Dissolved: Gross alpha (pCi/l as U natural)	Dissolved: Gross beta (pCi/l as Sr-90/Y-90)	Dissolved: Gross beta (pCi/l as Cs-137)	Suspended: Solids mg/l	Suspended: Gross alpha (µg/l as U natural)	Suspended: Gross alpha (pCi/l as U natural)	Suspended: Gross beta (pCi/l as Sr-90/Y-90)	Suspended: Gross beta pCi/l as Cs-137)	Remarks
Roaring Fork River near Aspen	1	(2/)				39	10	48	106	48	05	64	103	6- 1-70	<960	<300	2.7	0.9	4.5	5.5	30	4.1	1.4	3.3	3.8	USGS gaging station 9-0734.
														6-25-70	<960	<300	2.2	.7	3.5	4.3	6	.8	.3	1.0	1.1	
Colorado River at New Castle	2	5	90	31	SW	39	34	06	107	32	26	25	40	6- 1-70	<960	<300	3.5	1.2	4.3	5.4	100	5.7	1.9	3.8	4.6	USGS gaging station 9-0876.
														6-25-70	1,100	360	4.4	1.5	4.4	5.5	86	5.6	1.9	4.6	5.7	
Beaver Creek near Rifle	3	7	94	1	NE	39	28	20	107	49	55	7.6	12	5-30-70	<960	<300	1.1	.4	3.5	4.5	210	12	4.0	7.8	9.8	USGS gaging station 9-0925.
														6-25-70	1,000	320	1.7	.6	2.7	3.4	32	1.8	.6	1.9	2.1	
Kimball Creek near Collbran	4	9	95	14	NE	39	17	00	107	57	13	8.4	14	5-29-70	<960	<300	2.1	.7	2.1	2.6	140	9.8	3.3	5.4	6.5	--
														6-25-70	1,200	390	2.2	.7	2.7	3.4	54	4.5	1.5	2.6	3.1	
Plateau Creek near Cameo	5	10	97	18	SW	39	11	00	108	16	10	23	37	5-29-70	<960	<300	3.9	1.3	5.3	6.5	330	27	8.9	7.4	9.4	USGS gaging station 9-1050.
														6-25-70	<960	<300	12	4.0	11	14	40	1.6	.5	2.2	2.5	
Colorado River near DeBeque	6	8	97	23	SW	39	20	22	108	11	35	14	23	5-29-70	<960	<300	4.7	1.6	9.9	13	180	14	4.7	8.0	10	Downstream 2 7 miles (4.3 kilometers) from USGS gaging station 9-0937.
														6-25-70	<960	<300	3.2	1.1	6.8	8.5	78	5.6	1.9	3.8	4.7	

(Voegeli and Claassen, 1971b)

Radiochemical analyses of water from selected streams in western Colorado

Stream	Sample point number[1]	Location: Township S.	Location: Range W.	Location: Section	Location: ¼ Section	Latitude N.: Degrees	Latitude N.: Minutes	Latitude N.: Seconds	Longitude W.: Degrees	Longitude W.: Minutes	Longitude W.: Seconds	Distance from surface ground zero: miles	Distance from surface ground zero: kilometers	Date of collection	Tritium: pCi/l	Tritium: TU	Dissolved: Gross alpha (µg/l as U natural)	Dissolved: Gross alpha (pCi/l as U natural)	Dissolved: Gross beta (pCi/l as Sr-90/Y-90	Dissolved: Gross beta (pCi/l as Cs-137)	Suspended: Solids mg/l	Suspended: Gross alpha (µg/l as U natural)	Suspended: Gross alpha (pCi/l as U natural)	Suspended: Gross beta pCi/l as Sr-90/Y-90	Suspended: Gross beta pCi/l as Cs-137)	Remarks
Roaring Fork River near Aspen	1	(2/)				39	10	48	106	48	05	64	103	8-17-70	880	280										USGS gaging station 9-0734.
														9-30-70	1,100	330										
														10-10-70	740	230										
Colorado River at New Castle	2	05	90	31	SW	39	34	06	107	32	26	25	40	8-17-70	1,000	320										USGS gaging station 9-0876.
														9-30-70	1,100	330										
														10-10-70	<700	<220										
Beaver Creek near Rifle	3	07	94	01	NE	39	28	20	107	49	55	7.6	12	8-17-70	<700	<220										USGS gaging station 9-0925.
														9-30-70	910	280										
														10-10-70	<700	<220										
Kimball Creek near Collbran	4	09	95	14	NE	39	17	00	107	57	13	8.4	14	8-17-70	<700	<220										--
														9-30-70	<700	<220										
														10-11-70	<700	<220										
Plateau Creek near Cameo	5	10	97	18	SW	39	11	00	108	16	10	23	37	8-17-70	990	310	15	4.9	8.7	11	69	3.1	1.0	2.4	3.0	USGS gaging station 9-1050.
														9-30-70	1,000	320	22	7.5	6.4	8.0	18	<.5	<.2	<.9	<1.0	
														10-11-70	810	250	36	12	10	13	790	82	27	25	27	
Colorado River near DeBeque	6	08	97	23	SW	39	20	22	108	11	35	14	23	8-17-70	1,000	320	5.7	1.9	3.8	4.8	33	1.9	.6	2.0	24	Downstream 2.7 miles (4.3 kilometers) from USGS gaging station 9-0937.
														9-30-70	1,000	320	15	4.9	4.2	5.3	10	<.6	<.2	<1.3	<1.4	
														10-11-70	800	250	15	4.9	9.5	12	490	39	13	20	26	

1/ As shown on figure 1.

2/ Not surveyed.

(Claassen and Voegeli, 1971)

Radiochemical analyses of water from selected streams in western Colorado

Stream	Sample point number[1]	Location: Township S.	Location: Range W.	Location: Section	Location: ¼ Section	Latitude N.: Degrees	Latitude N.: Minutes	Latitude N.: Seconds	Longitude W.: Degrees	Longitude W.: Minutes	Longitude W.: Seconds	Distance from surface ground zero: miles	Distance from surface ground zero: kilometers	Date of collection	Tritium: pCi/l	Tritium: TU	Dissolved Gross alpha (µg/l as U natural)	Dissolved Gross alpha (pCi/l as U natural)	Dissolved Gross beta (pCi/l as Sr-90/Y-90)	Dissolved Gross beta (pCi/l as Cs-137)	Suspended Solids mg/l	Suspended Gross alpha (µg/l as U natural)	Suspended Gross alpha (pCi/l as U natural)	Suspended Gross beta (pCi/l as Sr-90/Y-90)	Suspended Gross beta (pCi/l as Cs-137)	Remarks
Roaring Fork River near Aspen	1	([2])				39	10	48	106	48	05	64	103	10-23-70	1,000	320										USGS gaging station 9-0734.
														11- 4-70	990	310										
Colorado River at New Castle	2	05	90	31	SW	39	34	06	107	32	26	25	40	10-23-70	1,000	330										USGS gaging station 9-0876.
														[3] 11- 4-70	--	--	--	--	--	--	--	--	--	--	--	
														11- 9-70	860	270										
Beaver Creek near Rifle	3	07	94	01	NE	39	28	20	107	49	55	7.6	12	10-23-70	880	280										USGS gaging station 9-0925
														[3] 11- 5-70	--	--	--	--	--	--	--	--	--	--	--	
														11- 9-70	<700	<220										
Kimball Creek near Collbran	4	09	95	14	NE	39	17	00	107	57	13	8.4	14	10-24-70	<700	<220										--
														[3] 11- 5-70	--	--	--	--	--	--	--	--	--	--	--	
														11- 9-70	<700	<220										
Plateau Creek near Cameo	5	10	97	18	SW	39	11	00	108	16	10	23	37	10-24-70	940	290	26	8.6	10	13	62	1.2	0.4	4.2	4.8	USGS gaging station 9-1050
														11- 5-70	990	310	20	6.7	25	32	37	.9	.3	1.6	1.9	
Colorado River near DeBeque	6	08	97	23	SW	39	20	22	108	11	35	14	23	10-23-70	900	280	24	8.0	6.6	8.1	16	2.6	.9	4.3	4.6	Downstream 2.7 miles (4.3 kilometers) from USGS gaging station 9-0937.
														[3] 11- 5-70	--	--	--	--	--	--	--	--	--	--	--	
														11- 9-70	900	280	11	3.5	62	78	8	2.2	.7	2.5	2.7	

[1] As shown on figure 1.

[2] Not surveyed.

[3] Samples for tritium, gross alpha, and gross beta collected and stored.

(Claassen, 1971, p. 4)