HYDROLOGY OF A NUCLEAR-PROCESSING PLANT SITE, ROCKY FLATS, JEFFERSON COUNTY, COLORADO

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[Plates are in pocket]

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CONVERSION TABLE

English units in this report may be expressed as metric units by use of the following conversion factors:

To convert English units	Multiply by	To obtain metric units
inches (in)	25.4	millimetres (mm)
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
feet per mile (ft/mi)	.1894	metres per kilometres (m/km)
cubic feet (ft^3)	.02832	cubic metres (m^3)
acres	.4047	hectares (ha)
square miles (mi^2)	2.590	square kilometres (km^2)
gallons (gal)	3.785	litres (ℓ)
million gallons (Mgal)	3.785	million litres (Mℓ)
acre-feet (acre-ft)	.001233	cubic hectometres (hm^3)
tons (short)	.9072	tonnes (t)
feet per day (ft/d)	.3048	metres per day (m/d)
cubic feet per second (ft^3/s)	.02832	cubic metres per second (m^3/s)

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ABSTRACT

Accidental releases of contaminants resulting from the operation of the U.S. Energy Research and Development Administration's nuclear-processing and recovery plant located on Rocky Flats will move at different rates through different parts of the hydrologic system. Rates of movement are dependent upon the magnitude of the accidental release and the hydrologic conditions at the time of the release. For example, during wet periods, a contaminant resulting from a 5,000-gallon (19,000-litre) release on the land surface would enter the ground-water system in about 2 to 12 hours. Ground-water flow in the Rocky Flats Alluvium might move the contaminant eastward at a rate of about 3 to 11 feet (0.9 to 3.4 metres) per day, if it remains dissolved. Maximum time to a point of discharge would be about 3 years; minimum time could be a few days. A contaminant entering a stream would then move at a rate of about 60 feet (18 metres) per minute under pool-and-riffle conditions. The rate of movement might be about 420 feet (128 metres) per minute under open-channel-flow conditions following intense thunderstorms.

INTRODUCTION

Purpose

The U.S. Energy Research and Development Administration, formerly the U.S. Atomic Energy Commission, administers the operation of a nuclear processing and recovery plant, known as the Rocky Flats Plant, in Jefferson County, 16 mi (26 km) northwest of Denver, Colo. (fig. 1). To assess the potential impact of plant operations on the hydrologic environment, the U.S. Geological Survey on behalf of the the U.S. Atomic Energy Commission began a study in 1972 of the surface-water and ground-water hydrology of the plant area and vicinity, to determine how contaminants would be distributed spatially and temporally as they move through the hydrologic system.

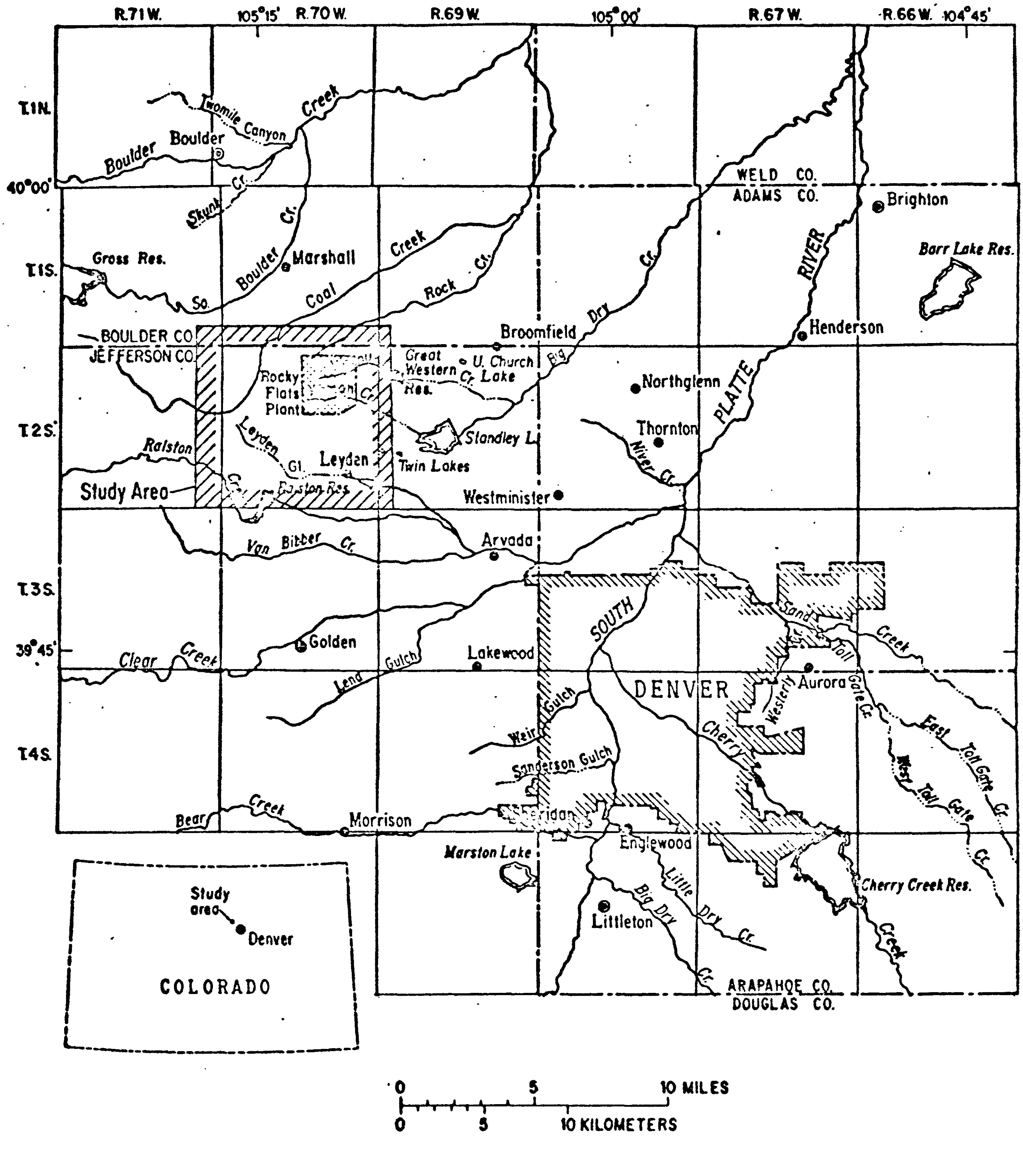


Figure 1. – Index map showing location of the Rocky Flats Plant and study area.

Methods of Investigation

Aspects of the hydrology of the area have been reported by M. R. Mudge and R. F. Brown (written commun., 1952), and in reports by John A. Blume & Associates (1972) and Engineering-Science, Inc. (1974). However, the previous studies were not sufficiently detailed to permit a definition of hydrologic or hydrogeologic relationships. Therefore, additional investigations, including geologic mapping, test drilling, surface and borehole geophysical measurements, collection of additional well data and water-level measurements, and installation of three stream-gaging stations and a stream-sediment sampler, were necessary. Two of the gaging stations were equipped with recording rain gages. Data resulting from these field studies were incorporated with the existing data for interpretation.

The geologic map (pl. 1) was modified from reports and maps by Spencer (1961), Malde (1955), Wells (1967), Van Horn (1972), and Sheridan, Maxwell, and Albee (1967). Geological mapping by Chase and McConaghy (1972) and Van Horn (1957), and faulting shown by Weimer (1973), and Gude and McKeown (1953) also were considered.

Acknowledgments

Many people assisted in the collection and interpretation of data for this study. Their help is greatly appreciated. Special recognition is due to C. T. Illsley, an engineer with Rockwell International, the commercial operators of the Rocky Flats Plant, for his continued assistance and cooperation in making available, tabulating, and analyzing plant-related data.

GEOLOGIC SETTING

The geologic framework of the study area directly affects the movement and quality of ground water and surface water. Therefore, a knowledge of the geology is needed to understand the hydrology of the Rocky Flats study area. A brief description of the stratigraphy and structural geology of the study area is included. A more detailed description is provided at the end of this report in the section entitled Supplemental Information.

Stratigraphy

The rocks in the study area range in age from Precambrian to Holocene. The oldest rocks are the Precambrian gneisses, schists, and quartzites that form the core of the Front Range west of the area. Beneath the area the Precambrian rocks are at a depth of about 12,000 ft (3,700 m). Stratigraphically above these rocks are sedimentary bedrock formations which range in age from Pennsylvanian to Late Cretaceous, and surficial deposits which range in age from Pleistocene to Holocene. The surficial deposits rest uncomformably on the eroded surface of the folded and faulted bedrock formations.

The top of the Pierre Shale of Cretaceous age is considered by the author to be the base of the hydrologic system which could be affected by operations at the Rocky Flats Plant. Therefore, stratigraphic descriptions will be limited to those formations which are younger than the Pierre Shale.

Bedrock Formations

Three bedrock formations are important to the hydrology of the study site. In ascending order, the three formations are the Fox Hills Sandstone, Laramie Formation, and Arapahoe Formation of Cretaceous age. The geologic units and their stratigraphic relationships are shown on plate 1.

The Fox Hills Sandstone, about 40 to 90 ft (12 to 27 m) thick, consists of sandy shale grading stratigraphically upward into a massive sandstone. The Fox Hills Sandstone is conformably overlain by the Laramie Formation.

The Laramie Formation is divisible into two units; a lower sandstone unit and an upper shale unit. The lower sandstone unit consists of 150 to 320 ft (46 to 98 m) of interbedded sandstone and claystone. The lower sandstone unit together with the Fox Hills Sandstone is collectively referred to as the Laramie-Fox Hills aquifer. The upper shale unit of the Laramie Formation is a 450- to 630-ft (137- to 192-m) thickness of claystone. The Laramie Formation is conformably overlain by the Arapahoe Formation.

The Arapahoe Formation is a continental deposit of lenticular sands interbedded with clay. Maximum thickness of the formation in the study area is about 270 ft (82 m). The lower one-half of the formation contains more sand beds than the upper one-half. The Arapahoe Formation is the uppermost bedrock formation and is either exposed at land surface or covered unconformably by unconsolidated surficial deposits.

Surficial Deposits

Surficial deposits within the study area are generally less than 50 ft (15 m) thick and consist of terrace alluvium, colluvium, and valley fill. There are several levels of terraces cut in the alluvium that were formed by stream erosion. The oldest terraces are topographically highest. As the streams eroded their channels, new terraces were formed. Consequently, the youngest terraces are topographically lower than the older terraces. Erosion has formed deposits of colluvium (not shown on pl. 1) on the sides and at the base of steep slopes in the stream valleys. The valley bottoms consist of valley-fill deposits from sedimentation by streams.

All of the surficial deposits consist of clay, silt, sand, gravel, cobbles, and frequently boulders. The source of these deposits is primarily the Precambrian quartzite from the mountains to the west, but also includes the sedimentary bedrock and older surficial deposits.

The oldest surficial deposit in the study area is the pre-Rocky Flats Alluvium, which caps some hills and terrace remnants along the western edge of the area (pl. 1). Next youngest is the Rocky Flats Alluvium which dominates the topography and hydrology of the entire study area. The Rocky Flats Alluvium is a broad, planar deposit which in this area is an alluvial fan deposited downslope from the mouth of Coal Creek Canyon. Contact springs commonly issue from the base of the Rocky Flats Alluvium. The next youngest formations are the Verdos and Slocum Alluviums. These formations are of little hydrologic importance, except south of Leyden where contact springs at the base of the Verdos Alluvium have provided a municipal water supply for Leyden. The alluvial deposits are shown on plate 1.

Structure

The general geologic structure of the area is reflected in the north-striking beds dipping to the east or southeast. In the western part of the area the beds are nearly vertical to overturned. In the eastern part, the strike swings to the northeast and the dip of the beds is less than 1¼ degrees to the southeast. An east-west geologic section through the study area is shown on plate 1.

The Golden fault (pl. 1) stretches northwest across the study area. The fault is a medium- to high-angle, west-dipping, reverse fault which displaces the Verdos Alluvium in the southern part of the area (pl. 1). A branch of the Golden fault trends to the northwest and joins at the mouth of Coal Creek Canyon with the Livingston shear zone shown on plate 1. In the northern part of the study area faulting is high-angle and normal, trending in a northeastern direction. Observations during the current study indicate that the Eggleston fault extends into the study area.

HYDROLOGY

Surface Water

The surface-water system in the study area supplies water to two reservoirs used for municipal water supply and recharges aquifers used for domestic water supply. Consequently, the accidental release of a contaminant into the surface-water system could affect surface- and ground-water quality. The following sections describe the relationships between surface and ground water.

General Description

Six streams, all ephemeral, are included in the study area. Of these, Walnut Creek, South Walnut Creek, and Woman Creek are the most important because they drain the Rocky Flats Plant site. The drainage basins of Walnut, South Walnut, and Woman Creeks are shown on plate 2. The other three streams in the study area are Coal Creek, Rock Creek, and Leyden Gulch.

Walnut Creek and South Walnut Creek head in the study area and flow eastward. South Walnut Creek is tributary to Walnut Creek which flows into Great Western Reservoir as shown schematically on figure 2. Great Western Reservoir supplies water to the city of Broomfield (fig. 1).

Woman Creek heads in the study area, draining the south side of Rocky Flats Plant, and flows eastward into Standley Lake (pl. 2 and fig. 2). Standley Lake provides irrigation storage and the municipal water supply for the city of Westminster (fig. 1).

Coal Creek and Rock Creek (pl. 2 and fig. 2) flow northward out of the study area and Leyden Gulch is tributary to Leyden Lake (fig. 2). Coal and Rock Creeks drain the northern part and Leyden Gulch drains the southern part of the study area.

Six ditches convey water through the study area (fig. 2). The South Boulder Diversion Canal carries water southward from South Boulder Creek (north of the study area) to Ralston Reservoir, which supplies water to the city of Denver. The water supply for the Rocky Flats Plant is obtained from South Boulder Diversion Canal and Ralston Reservoir. The Last Chance, Church, McKay, and Kinnear Ditch and Reservoir Co. Ditches divert water from Coal Creek. The Last Chance Ditch delivers water to Rocky Flats Lake and Twin Lakes. Outflow from Rocky Flats Lake is transported out of the area by Smart Ditch. The Church Ditch supplies water to Upper Church Lake and Great Western Reservoir, McKay Ditch supplies water to Great Western Reservoir, and Kinnear Ditch and Reservoir Co. Ditch supply water to Standley Lake.

Precipitation

Precipitation, principally from rainfall and to a lesser extent snowmelt, produces surface runoff in the study area. The duration, amount, and areal distribution of precipitation are required to develop rainfall-runoff relations and to compute rates of contaminant movement. The locations of the rainfall gages in the study area are shown on plate 2. Graphs of cumulative precipitation during 15-minute increments for selected storms on Walnut Creek and Woman Creek basins are shown on plate 3. The length of the curves indicates the duration of the storm, or series of storms; the height of the curves shows the cumulative rainfall; and the slope of the curves indicates the rainfall intensity with the restriction that rates are measured in increments of 15 minutes. The maximum rainfall intensity for the storms shown on plate 3 was approximately 0.6 inch (15.2 mm) per hour during May 6, 1973. Rainfall intensities for the other storms range from less than 0.1 inch (2.5 mm) per hour to about 0.5 inch (12.7 mm) per hour.

Daily precipitation totals for the Woman Creek, Walnut Creek, and Rocky Flats precipitation stations are presented in the section entitled Supplemental Information at the back of the report. Data for the Rocky Flats station are not given for periods when the other two stations were closed for the winter.

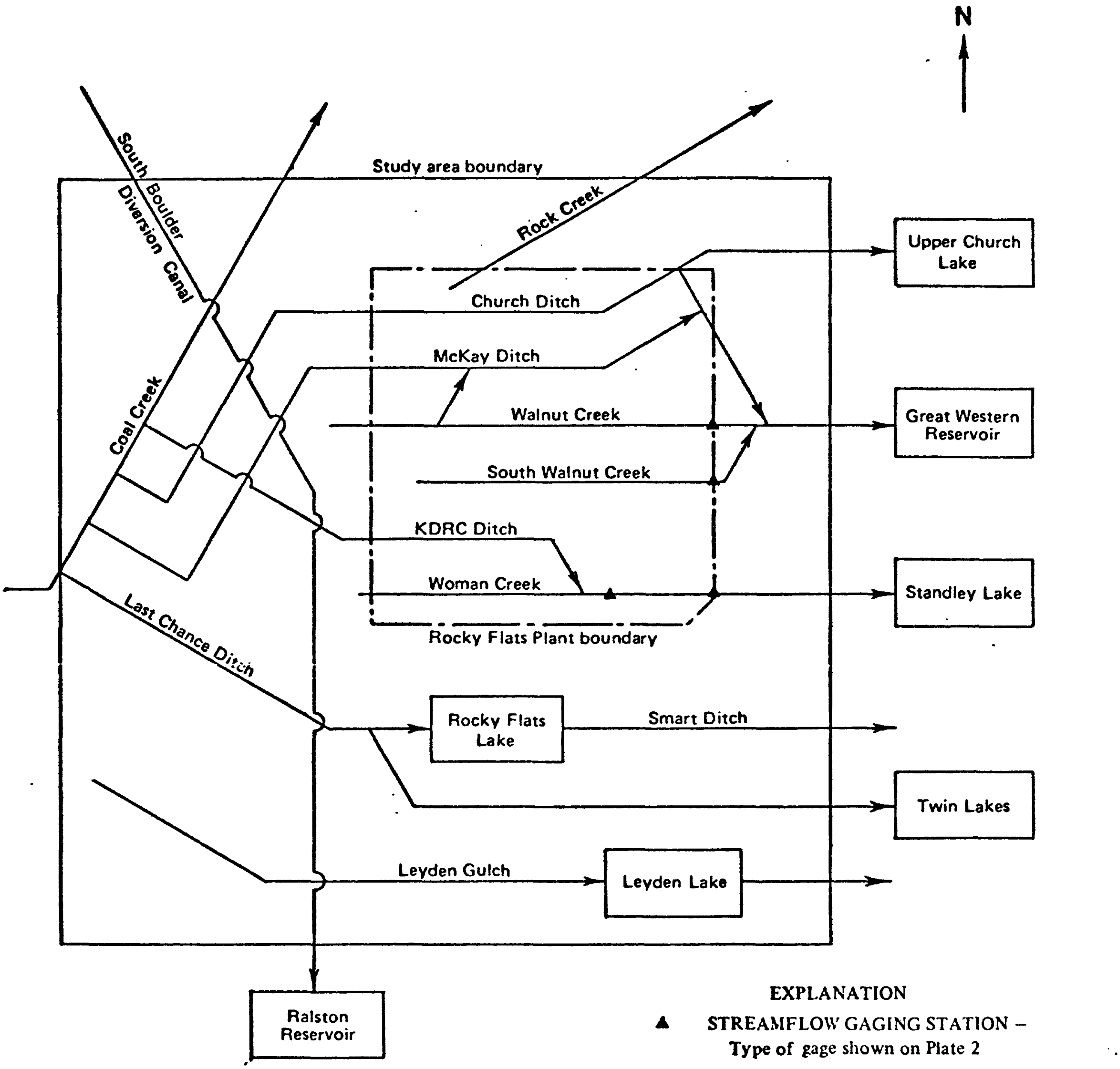


Figure 2. – Schematic diagram of surface-water system.

The period of record for rainfall at the Walnut and Woman Creek stations is insufficient for a frequency analysis of rainfall. However, a report by the Denver Regional Council of Governments (1972) contains rainfall-recurrence interval data by township for the metropolitan area. A plot of data (fig. 3) from the above report for T. 2 S., R. 70 W., the township in which the Rocky Flats Plant is located, shows the relationship between rainfall and recurrence interval.

Streamflow

The water that moves through stream and man-made channels in the study area results from direct surface runoff following periods of rainfall and snowmelt, baseflow supplied by seeps and springs, and diversions and wastewater from various man-related activities. The network of streams and channels is a potential transmission system for contaminants derived from the study area. A knowledge of both volume and rate of movement of water through the surface-water system is required in order to evaluate effects of possible contaminant releases on downstream areas.

Stream-gaging stations were established in 1972 on Walnut Creek, South Walnut Creek, and Woman Creek to measure outflow from the plant area. The streamflow records also provided data for deriving rainfall-runoff relations and for estimating rate of water movement through the network of streams. Daily streamflow for each of the three gaging stations is given in the section entitled Supplemental Information at the back of the report. Basin boundaries and subdivisions of each basin are shown on plate 2. Physical characteristics for the total and subdivided parts of the three basins are listed in table 1.

A complex network of canals, ditches, and reservoirs exists in and near the study area and it affects the rate of movement of water through the stream system. The general relationship between each of the gaged streams and the canals, ditches, and reservoirs is discussed below followed by discussions of on-channel reservoirs and a generalized water budget for Great Western Reservoir.

Walnut Creek.--Until September 1974, Walnut Creek drained an area of 1.24 mi^2 (3.21 km^2) above the gaging station. The natural streamflow was augmented by diversions from Coal Creek through Church and McKay Ditches. A new ditch was constructed in September 1974 from the SW¼NW¼ sec. 10, T. 2 S., R. 70 W., to the center of sec. 2, T. 2 S., R. 70 W., where it joined a small tributary to Walnut Creek that enters downstream from the gaging station. In effect, this ditch intercepts all of the flow from subbasins IC and ID (pl. 2) including the Coal Creek diversions and diverts the flow around the gaging station. The remaining part of the basin, subbasins IA and IB, has a combined drainage area of 0.84 mi^2 (2.18 km^2). Three on-channel reservoirs presently regulate flow at the gaging station. Two of these on-channel reservoirs were constructed during 1974, the other was constructed prior to 1972.

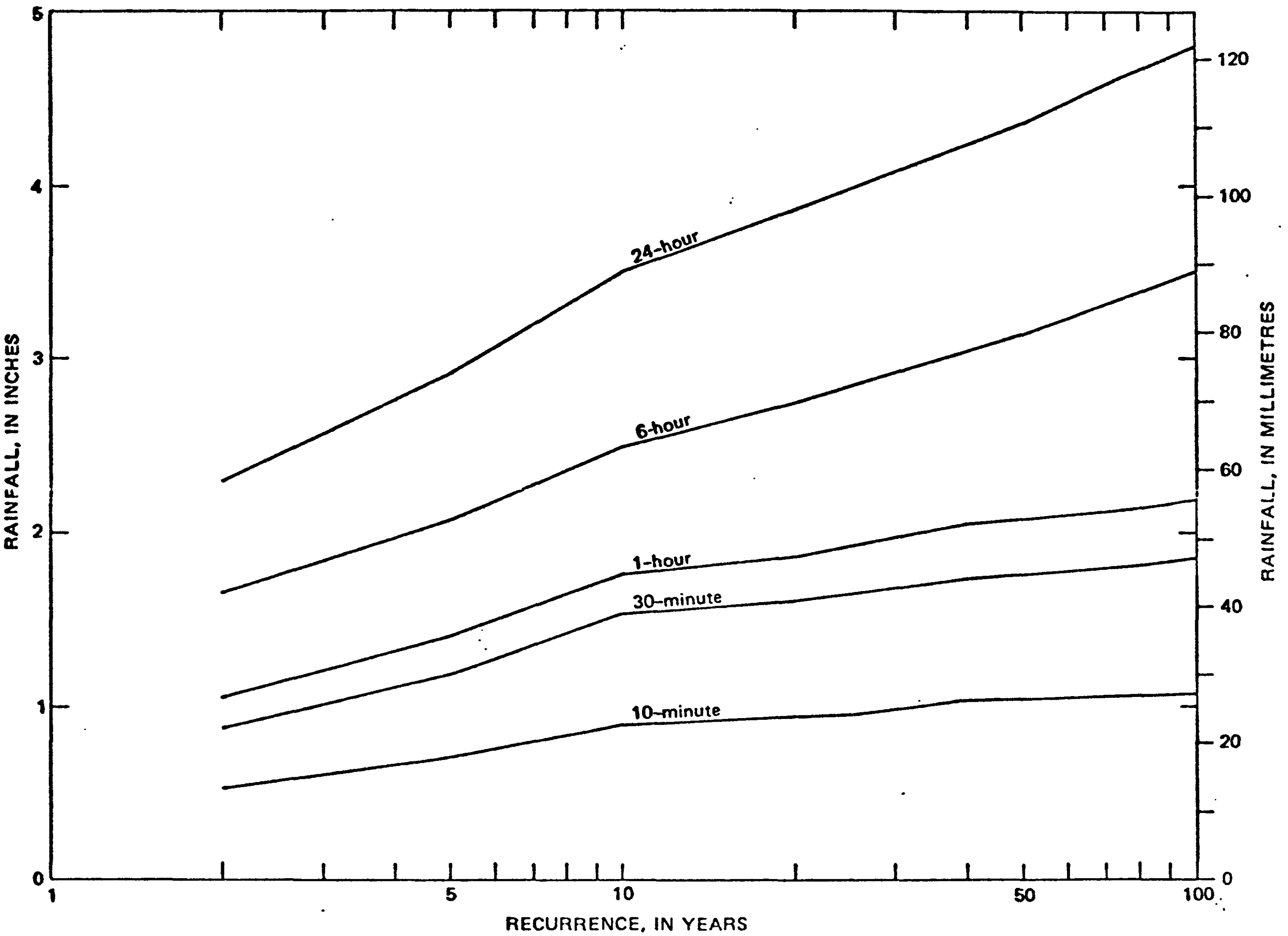


Figure 3. – Rainfall-recurrence relationship for selected durations in T. 2 S., R. 70 W.

Table 1.--*Subbasin characteristics for the drainage basins of Walnut, South Walnut, and Woman Creeks*

Drainage basin	Subbasin identifier[1]	Area, in square miles	Length, in feet	Slope, in feet per mile	Mean altitude, in feet	Remarks
Walnut Creek (total area, 1.24 square miles)	IA	0.57	8,400	171	5,920	Drains north side of plant area; has three on-channel retention reservoirs.
	IB	0.27	6,000	110	6,095	Mostly overland flow into flood-control cutoff ditch.
	IC	0.15	6,000	125	6,145	Flow routed into McKay Ditch extension around plant.
	ID	0.25	10,800	145	6,335	Largely overland flow. Channel flow affected by conveyance of diversions from Coal Creek.
South Walnut Creek (total area, 0.46 square miles)	IIA	0.21	7,200	170	5,930	Drains north-central part of plant area. Flow affected by four on-channel retention reservoirs and discharge of sanitary-sewer effluent.
	IIB	0.25	9,000	75	5,995	Drains south-central part of plant area into drainage ditch which bypasses retention reservoirs.
Woman Creek (total area, 2.10 square miles)	IIIA	0.33	4,000	130	5,875	One on-channel retention reservoir.
	IIIB	1.21	11,600	155	6,050	Drains some of southern part of plant area. Flow affected by filter plant backwash, clay pit dewatering, and leakage from South Boulder Diversion Canal.
	IIIC	0.56	9,200	160	6,340	Largely overland flow. Channel flow affected by conveyance of diversions from Coal Creek.

[1]See plate 2 for location of subbasins.

South Walnut Creek.--The total drainage area of South Walnut Creek above the gaging station is 0.46 mi^2 (1.19 km^2). Subbasin IIA drains the north-central part of the plant area and has a drainage area of 0.21 mi^2 (0.54 km^2). This subbasin has four on-channel retention reservoirs.

Prior to late 1974, the effluent from the plant's sanitary sewage disposal system was discharged into South Walnut Creek. This discharge, which averaged 6.8 Mgal (25.7 Mℓ) per month during 1971-73 (table 2), resulted in continuous flow in South Walnut Creek and Walnut Creek below the mouth of South Walnut Creek. Since late 1974 the practice has been to try to keep all process wastewater on the plant site, and discharge it by evaporation.

Table 2.--*Monthly raw water feed and sanitary-sewer effluent, Rocky Flats Plant, 1971-73*[1]
[Values are in millions of gallons]

	Raw water feed			Sanitary sewer effluent		
Month	1971	1972	1973	1971	1972	1973
Jan.	11.58	11.63	12.23	7.47	6.56	5.96
Feb.	13.31	12.72	12.05	6.38	6.84	5.41
Mar.	14.51	16.30	9.94	6.99	6.62	6.23
Apr.	11.45	14.05	10.69	7.43	6.95	7.39
May	15.51	18.50	16.00	7.90	6.82	7.05
June	24.44	16.98	14.85	7.35	6.98	5.34
July	7.76	15.78	12.72	7.55	6.59	5.33
Aug.	32.51	21.12	11.99	7.51	6.91	4.91
Sept.	20.60	15.07	11.52	8.44	6.37	4.68
Oct.	13.97	10.86	-----	6.68	6.92	5.50
Nov.	14.03	12.19	-----	6.55	6.47	5.10
Dec.	14.36	10.39	-----	6.80	6.60	5.48
Total	194.03	175.59	[2]111.99	87.05	80.63	68.38

[1]Data supplied by operators of Rocky Flats Plant.
[2]Part year total.

Woman Creek.--Prior to July 1973, the area south of the plant drained by Woman Creek above the gaging station was 2.10 mi^2 (5.44 km^2). In July 1973, the gaging station was moved upstream from the on-channel retention reservoir to a site where the total drainage area was 1.77 mi^2 (4.58 km^2). The natural flow of Woman Creek is augmented by diversions from Coal Creek through Kinnear Ditch, this flow is conveyed downstream to Standley Lake. Other sources of flow augmentation are leakage and spillage from South Boulder Diversion Canal, and seasonal pumpage to dewater a clay pit. Prior to June 1975, backwash from the plant's water-supply filter system was also discharged into Woman Creek.

On-channel reservoirs.--The on-channel reservoirs were surveyed in the spring of 1972 to determine the area and volume (table 3) of the operating pools. Most of the dams have been raised since 1972, and the area-volume relationship extended. Two additional reservoirs were constructed in 1974 on Walnut Creek for which no data are presented. The effect of the reservoirs on the daily flows of Woman Creek, Walnut Creek, and South Walnut Creek was small before the practice began of storing some plant outflow on the plant site. The reservoirs were usually full so that inflow and outflow were nearly equal. The most significant effect was the timing and height of peak flows resulting from storms.

Table 3.--*Area and volume of selected on-channel reservoirs, Rocky Flats Plant, spring 1972*

Name	Drainage	Area, in acres	Volume, in acre-feet
A-1	Walnut Creek-------------	1.13	6.23
B-1	South Walnut Creek-------	.30	.57
B-2	-----do------------------	.58	1.95
B-3	-----do------------------	.53	1.90
B-4	-----do------------------	.42	1.78
C-1	Woman Creek--------------	.80	1.80

Water Budget--Great Western Reservoir.--The municipal water supply for the city of Broomfield is stored in Great Western Reservoir. An estimated 95 percent of the municipal supply was diverted from Clear Creek and the remaining percentage equally divided between diversions from Coal Creek and effluent from the Rocky Flats Plant (Vern Chaney, oral commun., 1972). A water budget of annual reservoir operation (table 4) provides an estimate of net unmeasured inflow to the reservoir. Net inflow is actual inflow minus reservoir evaporation and seepage. An estimate of average annual evaporation is 300 to 400 acre-ft (0.37 to 0.49 hm^3) per year based on data extrapolated from Ralston Reservoir (D. B. Adams, oral commun., 1975). There are no measurements of seepage outflow; however, seepage is estimated to be 50 acre-ft (0.06 hm^3) per year. In 1973, through the end of September, the observed net inflow to Great Western Reservoir was 1,080 acre-ft (1.33 hm^3). Assuming average annual values of evaporation (400 acre-ft or 0.49 hm^3) and seepage loss (50 acre-ft or 0.06 hm^3) the actual inflow would have been about 1,530 acre-ft (1.89 hm^3). The measured total flow of Walnut Creek and South Walnut Creek was about 870 acre-ft (1.07 hm^3). The difference is due primarily to runoff below these gaging stations following a single storm on May 5-6, 1973, in which the 24-hour precipitation was about 2.5 in (64 mm).

Table 4.--*Annual reservoir operations for Great Western Reservoir*
[Data provided by courtesy of G. E. Wilson, city of Broomfield; units are acre-feet]

Year	Inflow from Clear Creek	Raw water withdrawal	Change in storage		Net inflow from Walnut Creek
			Calculated	Observed	
1970	1,645	1,696	-51	+300	351
1971	1,154	2,003	849	-390	459
1972	1,325	2,376	-1,051	-260	791
1973[1]	1,679	1,864	-185	+895	1,080

[1]Through September 27.

Relation of Runoff to Rainfall--Volume and Timing

The volume and timing of surface runoff depends on the volume and rate of rainfall or snowmelt, soil-moisture content, infiltration rate, nature of vegetation cover, and slope of the land surface. Streamflow and rainfall data for the study area were used to develop rainfall-runoff relations and to estimate travel times for movement through the streams. The rainfall-runoff relations and travel-time data can be used to determine the rate at which an accidentally released contaminant resulting from plant operations might be transported from the plant site.

The rainfall-runoff relation for Woman Creek basin (fig. 4) was developed by examining the rainfall and streamflow records and plotting the storm rainfall against the volume of surface runoff attributable to the storm. The runoff averages about 1.4 percent of the rainfall, assuming equal rainfall distribution over the entire basin. This small volume of storm runoff indicates a high infiltration rate for the soil cover in the basin. This point is discussed in more detail later in the report. Another factor contributing to the small volume of runoff is that most of the records that were used to develop the relations shown on figure 4 resulted from frontal storms with long rainfall durations. The rainfall intensity during this type of storm seldom exceeds the potential infiltration rate of the soil; thus, little surface runoff is generated. The runoff from intense summer thunderstorms would be much greater because of the high rainfall intensities associated with this type of storm. Because of insufficient data, a quantitative relationship between thunderstorm rainfall and runoff could not be derived.

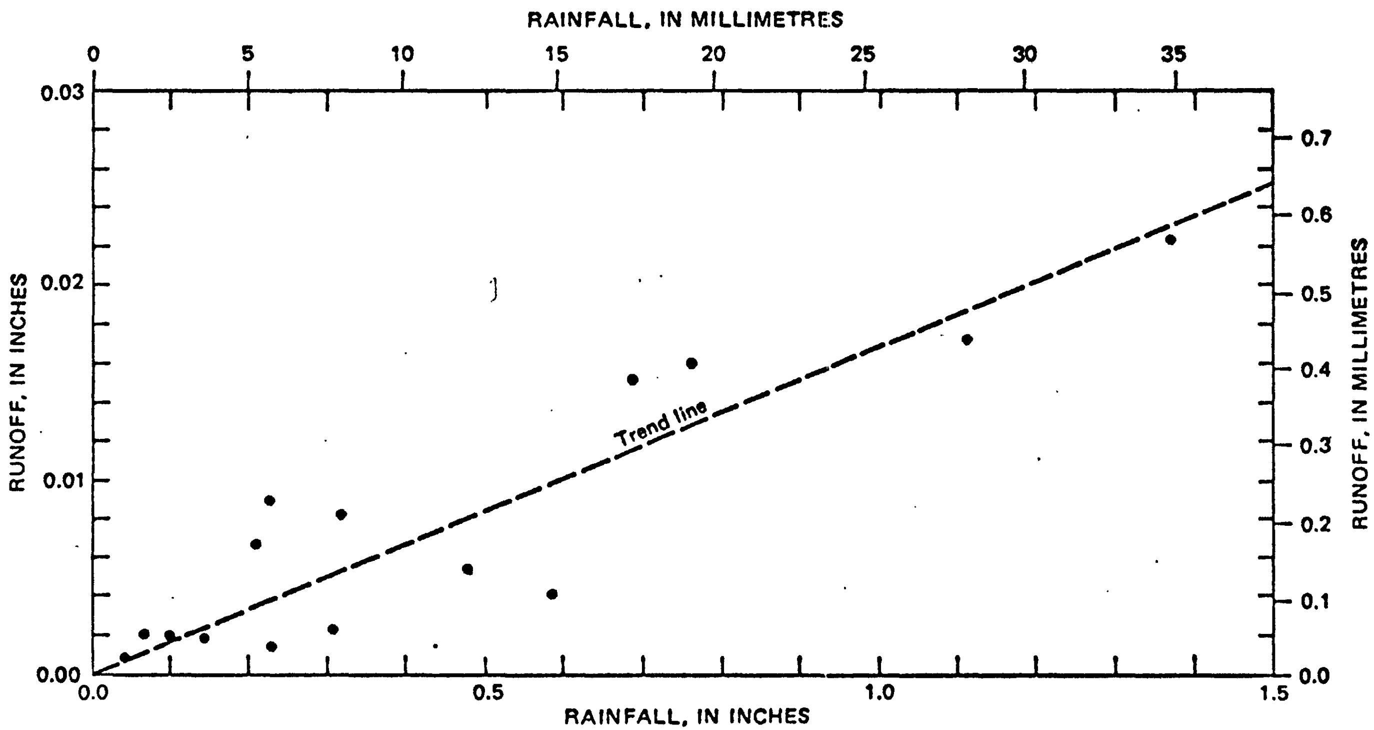


Figure 4. – Rainfall-runoff relation for Woman Creek basin at gaging station 06720690 Woman Creek near Plainview, Colo.

The rainfall and runoff data for Woman Creek basin were also used to compute time lag for the basin. These data indicate that the time lag between the centroid of rainfall and the centroid of the runoff hydrograph may be as long as 8 hours for small-volume, low-intensity rainstorms and about 3.5 hours for storms with larger volumes and higher intensities (fig. 5). Another measure of the travel time of water in Woman Creek was made by timing the movement of releases from South Boulder Diversion canal. The travel time required for releases to reach various points along the channel is listed in table 5. The relation between time of arrival of peak flow after releases and the rate of flow measured at the gaging station is shown on figure 6. Although the above estimates of travel times generally agree, the computed times are based on very small stream rises and the information is not readily transferable to other reaches in the study area.

To provide a more meaningful measure of rate of movement through the surface-water system, a procedure was developed based on the time of rise of runoff hydrographs. The rainfall-runoff data for the study area include no data for intense thunderstorms; however, such data are available for several basins in the Denver area. These data were examined and an average time of rise of the hydrograph was computed for each basin. Next, the main-channel length from the gage site to the basin divide was measured and this value was divided into the average time of rise of the hydrograph. This value, herein called the travel-time coefficient, represents the time, in minutes, required to move 1 ft (0.3 m) along a straight line toward the gage site. The travel-time coefficient computed from the above-mentioned data is 0.0024 minute per foot.

The following assumptions were made in developing the procedure:

1. Travel time in the vicinity of the study area is a linear function of distance measured along a straight line between the points of interest.

2. Rainfall excess is uniformly distributed over the basin and runoff begins at the same time at all points in the basin.

3. The time of first discernible rise of the hydrograph indicates beginning of runoff.

4. The time between first discernible rise and peak of the hydrograph represents travel time for the maximum length of channel upstream from the gage.

5. Streambed slopes, overland-flow slopes, and channel roughness in the study area are generally uniform; thus, results of travel-time computations are transferable.

The first four assumptions are generally supported by unit-hydrograph theory for simple stream systems while the fifth assumption implies homogeneity of physical basin characteristics--an intuitively acceptable assumption.

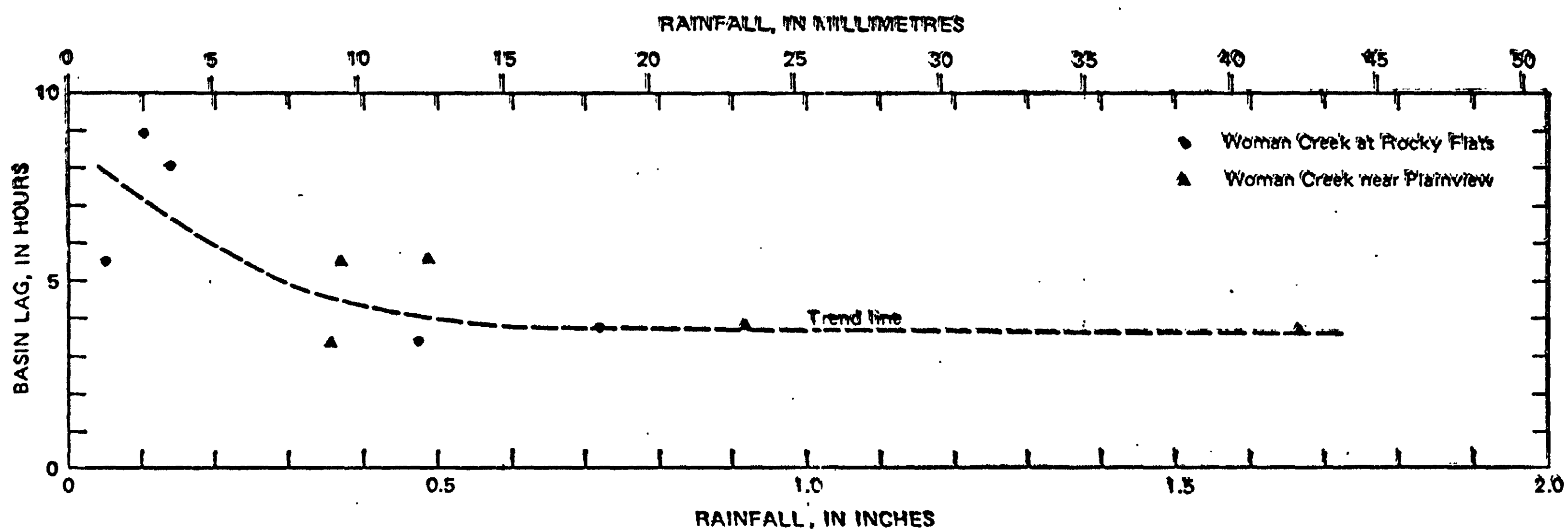


Figure 5. – Relation between rainfall and time lag for runoff accumulation in Woman Creek basin.

Table 5.--*Results of time-of-travel studies on Woman Creek*

Date 1974	Point of observation: Description	Point of observation: Distance below South Boulder Diversion Canal, in feet	Release: Discharge, in cubic feet per second	Release: Duration, in minutes	Travel time: First rise: Hours	Travel time: First rise: Minutes	Travel time: Peak: Hours	Travel time: Peak: Minutes	Discharge, in cubic feet per second: Peak flow due to release	Discharge, in cubic feet per second: Total flow
Aug. 27	Gaging station 06720690	11,600	----	30	3	50	4	12	0.28	0.54
Sept. 3	Gaging station 06720690	11,600	4.0	45	3	20	3	45	.86	1.12
	Outlet reservoir C-1	13,200			4	10	4	35	----	----
	100 feet below gaging station 06720700	15,700			5	55	6	25	.20	.28
Sept. 5	Gaging station 06720690	11,600	11.7	60	2	27	2	45	4.50	4.72
	Outlet reservoir C-1	13,200			±3		-----		----	----
	100 feet below gaging station 06720700	15,700			4	20	5		.13	.33

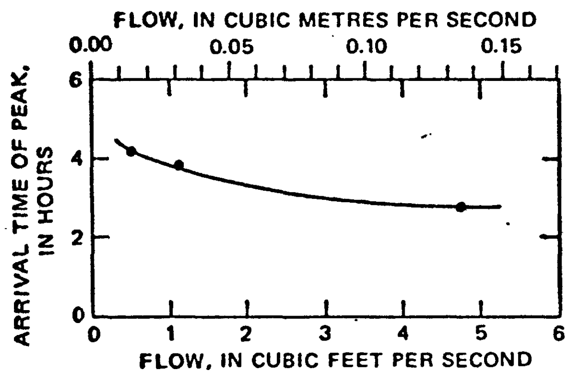


Figure 6. – Time-of-travel relations on Woman Creek.

Application of the travel-time coefficient requires a straight-line measurement of distance between the point of potential contaminant release and the downstream point of interest. This distance is then multiplied by the travel-time coefficient of 0.0024 minute per foot to obtain the travel time, in minutes, between the two points. The travel time computed by this procedure would represent the minimum time of travel following intense thunderstorms because of the use of straight-line distances and because of the possible delaying effects of on-channel reservoirs.

Quantitative rainfall-runoff relations could not be developed for Walnut Creek because of numerous water-management changes made at the Rocky Flats Plant during the course of the investigation. The changes were previously discussed. Because of the similar physical characteristics of the basins, Walnut Creek probably has runoff characteristics similar to Woman Creek.

Surface-runoff characteristics of South Walnut Creek probably are highly variable, depending primarily on storm location over the basin. Runoff from a storm centered over the southern part of the basin would have a short time lag--probably much less than 1 hour. Conversely, a storm over the northern part of the basin would produce runoff with a time lag ranging from less than an hour to several days, depending on the influence of the four on-channel reservoirs and on the intensity and duration of the storm. The relation between time of arrival of peak flow of South Walnut Creek and the rate of flow measured at the gaging station is shown on figure 6.

Ground Water

Ground water occurs in the Rocky Flats Alluvium, valley fill, Arapahoe Formation, and Laramie-Fox Hills aquifer. Recharge is from rainfall, snowmelt, and percolation from streams, ditches, and reservoirs. Discharge is by seeps, springs, base flow to the streams, and evapotranspiration. Ground water also leaves the area as subsurface flow.

Rocky Flats Alluvium

Ground water in the Rocky Flats Alluvium is recharged by infiltration of water from rain, snowmelt, and surface-water sources. The infiltration rate is high. Moreland and Moreland (1975, table 5) reported that infiltration rates in the top 5 ft (1.5 m) of soil developed on the Rocky Flats Alluvium range from 0.2 to 6.0 in (5 to 150 mm) per hour. Branson, Miller, and McQueen (1964, table 2) reported infiltration rates for stony soil on the Rocky Flats Alluvium range from 3.90 to 7.35 in (99 to 187 mm) per hour.

Water that infiltrates into the soil increases the moisture content of the soil profile. If the soil-moisture content is less than field capacity, the water will be stored in the unsaturated zone, and discharged to the atmosphere by evapotranspiration. If soil-moisture content exceeds field capacity, the water will move downward and recharge the saturated zone.

The water table in the Rocky Flats Alluvium rises in response to recharge during the spring and declines when recharge ceases during the remainder of the year. The annual cycle of water-table fluctuation is illustrated on figure 7, which is the hydrograph from well DP 1-66. Well DP 1-66 is shown on figure 8. The hydrograph shows that, overall, the water table declined from April 1974 to March 1975. Recharge caused the water table to rise from March to June 1975, after which the water table began to decline. Recharge from precipitation caused the rise in water level in October and November. A few of the numerous sharp peaks on the hydrograph were caused by natural recharge, but most are due to recharge from irrigation of a small plot of trees near well DP 1-66.

Water-level changes caused by irrigation indicate that the effective porosity of the alluvium near well DP 1-66 is about 0.10. Water levels in well DP 1-66 respond to irrigation within 2 to 4 hours when the water level is 10 to 20 ft (3 to 6 m) below land surface. Thus, water percolates through the alluvium at about 5 ft (1.5 m) per hour. If the infiltration rate is 0.5 ft (0.15 m) per hour, then the effective porosity of the alluvium is 0.10.

Variations in the water table at the Rocky Flats Plant were determined by measuring seasonal changes in water levels in 13 observation wells during a 3-year period. The hydrographs for these wells are shown on figure 8. The location of the wells is shown on figure 9. A comparison of the two hydrographs for observation well DP 1-66 (figs. 7 and 8) indicates that seasonal measurements do not provide a complete record of water-level fluctuations. However, seasonal measurements do provide a means of comparing and analyzing hydrologic conditions. All of the hydrographs on figure 8, except those for observation wells DP 3-66 and 4-71, show a similar pattern of fluctuation. This similarity indicates that the wells are in the same aquifer and respond to the same hydrologic stimuli. Observation wells DP 3-66 and 4-71 probably penetrate a different aquifer.

The water levels on figure 8 were compared with geologic contacts from lithologic logs of the observation wells and nearby test holes. Although the hydrographs are similar, some of the water levels are below the base of the Rocky Flats Alluvium. This indicates that the underlying bedrock is hydraulically connected to the Rocky Flats Alluvium.

Ground water in the Rocky Flats Alluvium flows generally eastward; movement is largely controlled by the topography of the bedrock. The configuration of the bedrock surface beneath the alluvium, determined from well logs and test pits, is shown on figure 10. The shape of the water table and the direction of ground-water movement are shown on figure 11. The direction of flow is perpendicular to the water-table contours. The hydraulic conductivity of the alluvium is estimated to be about 35 ft/d (3.3 m/d). From the water-table map (fig. 11), the hydraulic gradient ranges from 0.02 to 0.05. Assuming an effective porosity of 0.10, the pore velocity ranges from 7 to 18 ft/d (2.1 to 5.5 m/d).

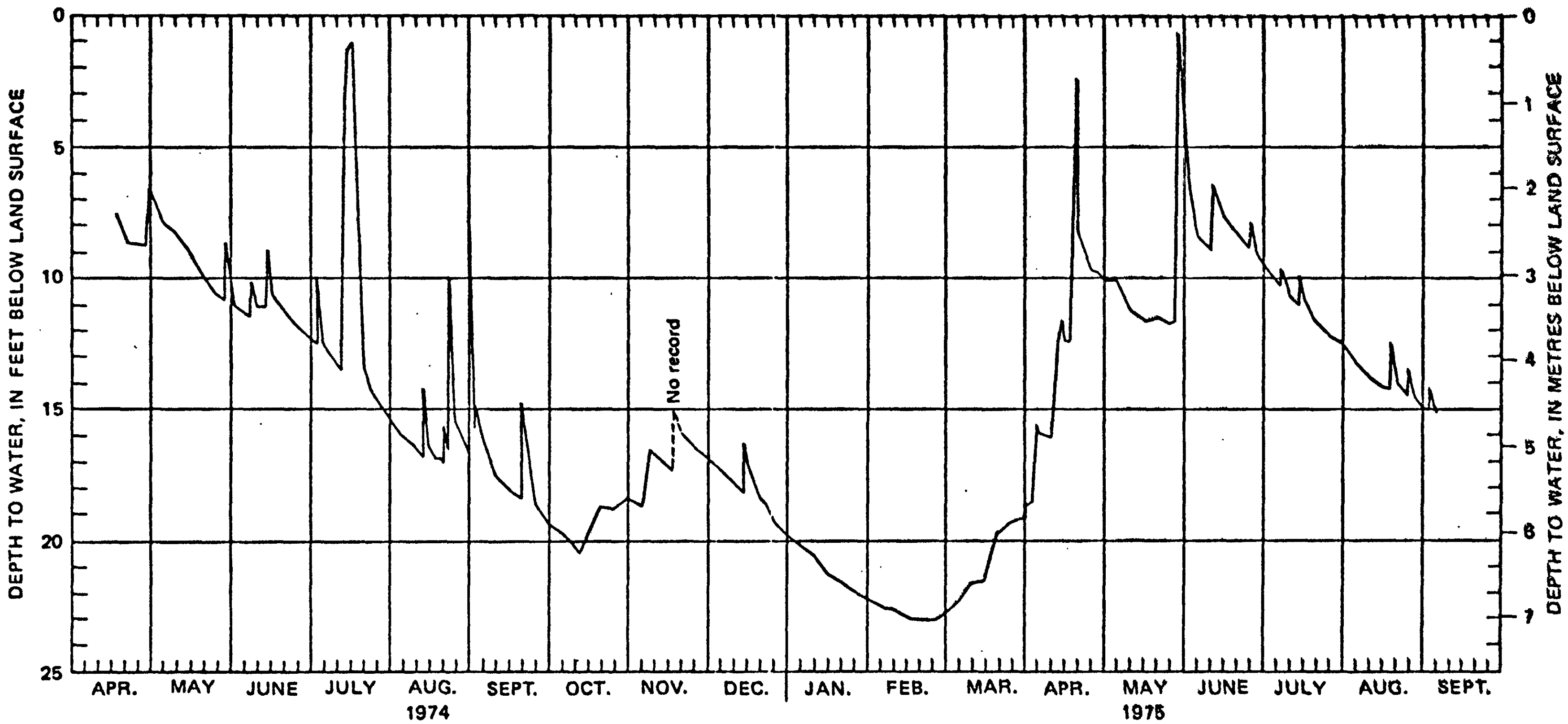


Figure 7. — Hydrograph of water levels in observation well DP1-66, Rocky Flats Plant.

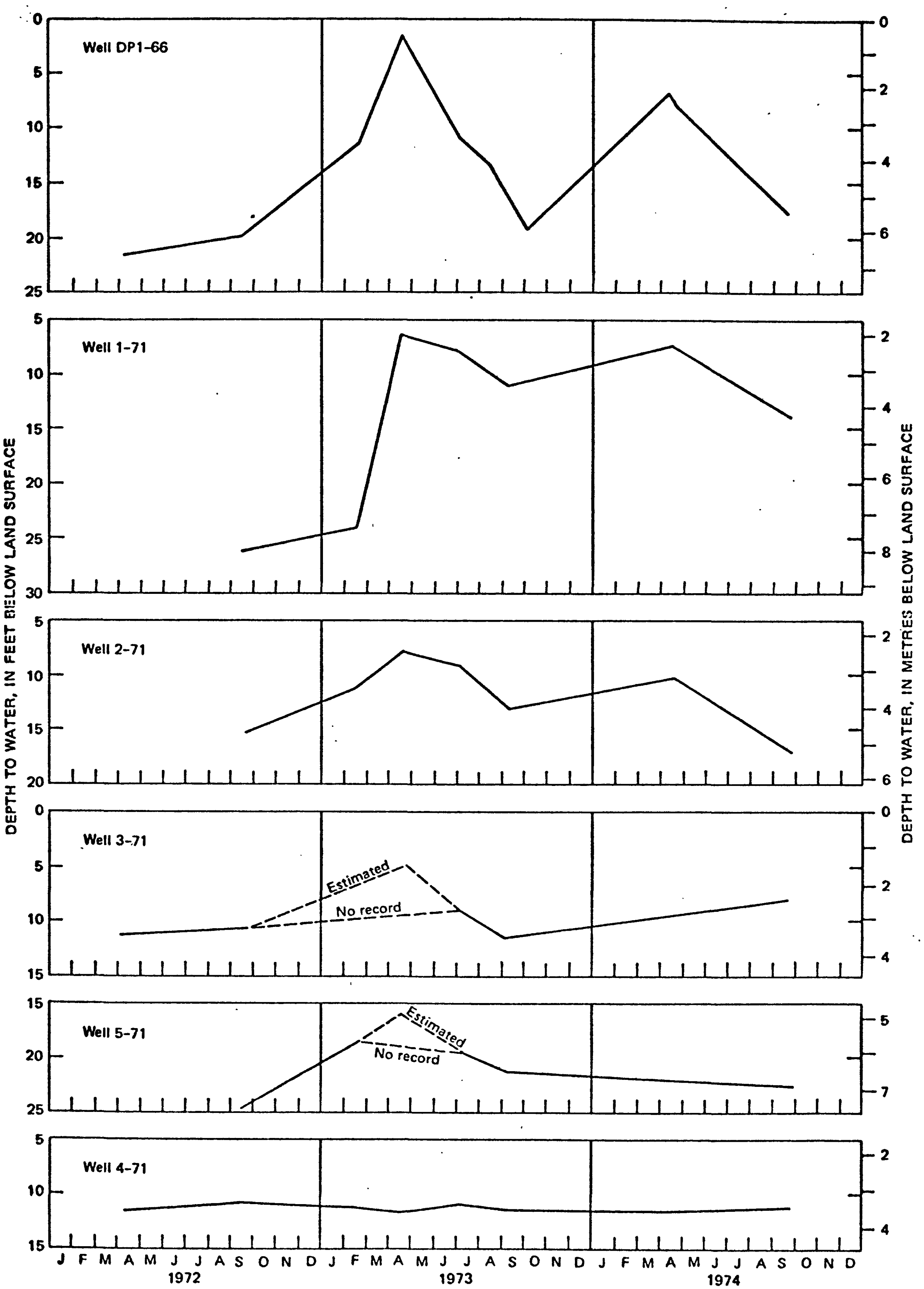


Figure 8. – Hydrographs of water levels in selected observation wells, Rocky Flats Plant.

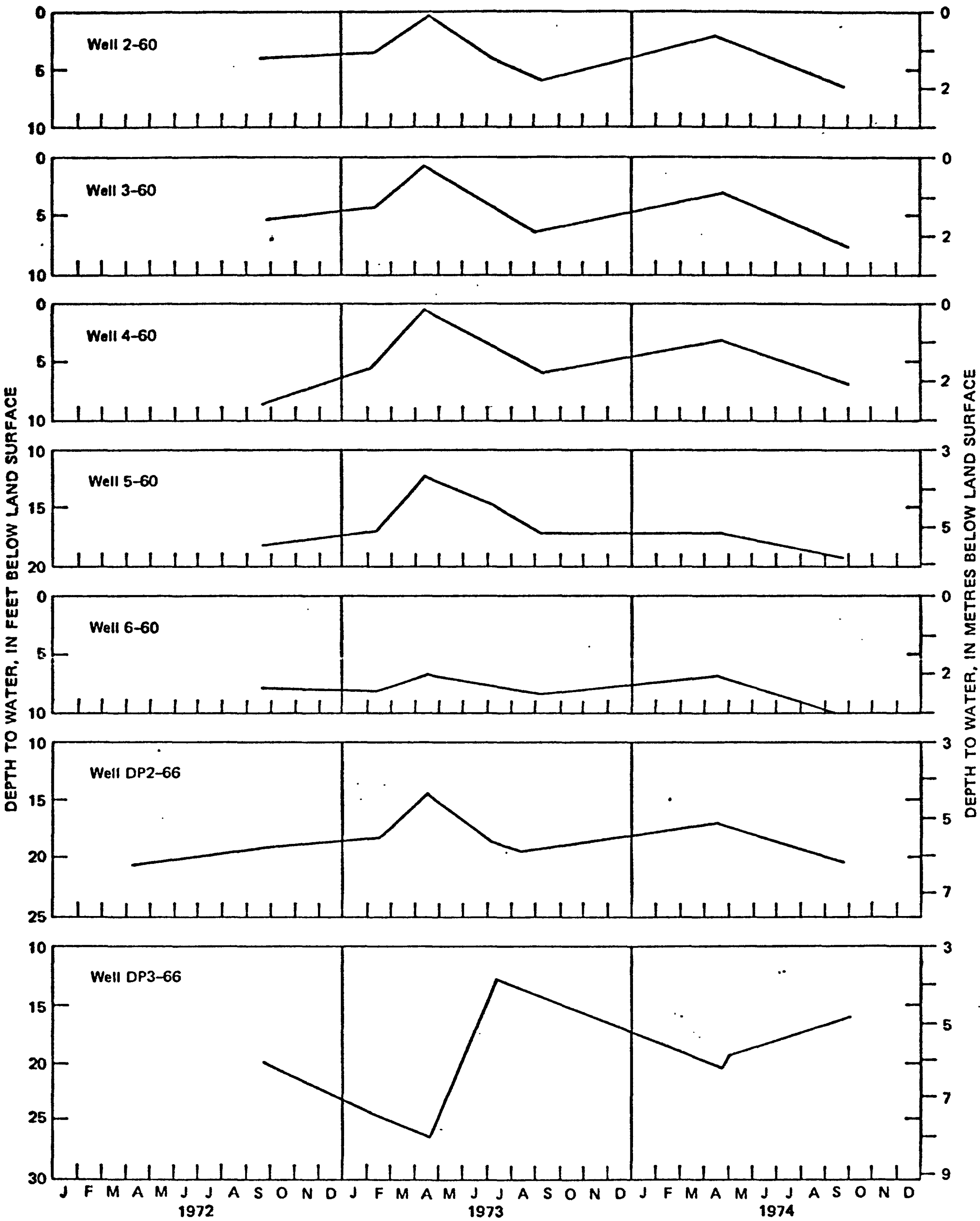


Figure 8. – Hydrographs of water levels in selected observation wells, Rocky Flats Plant, – Continued.

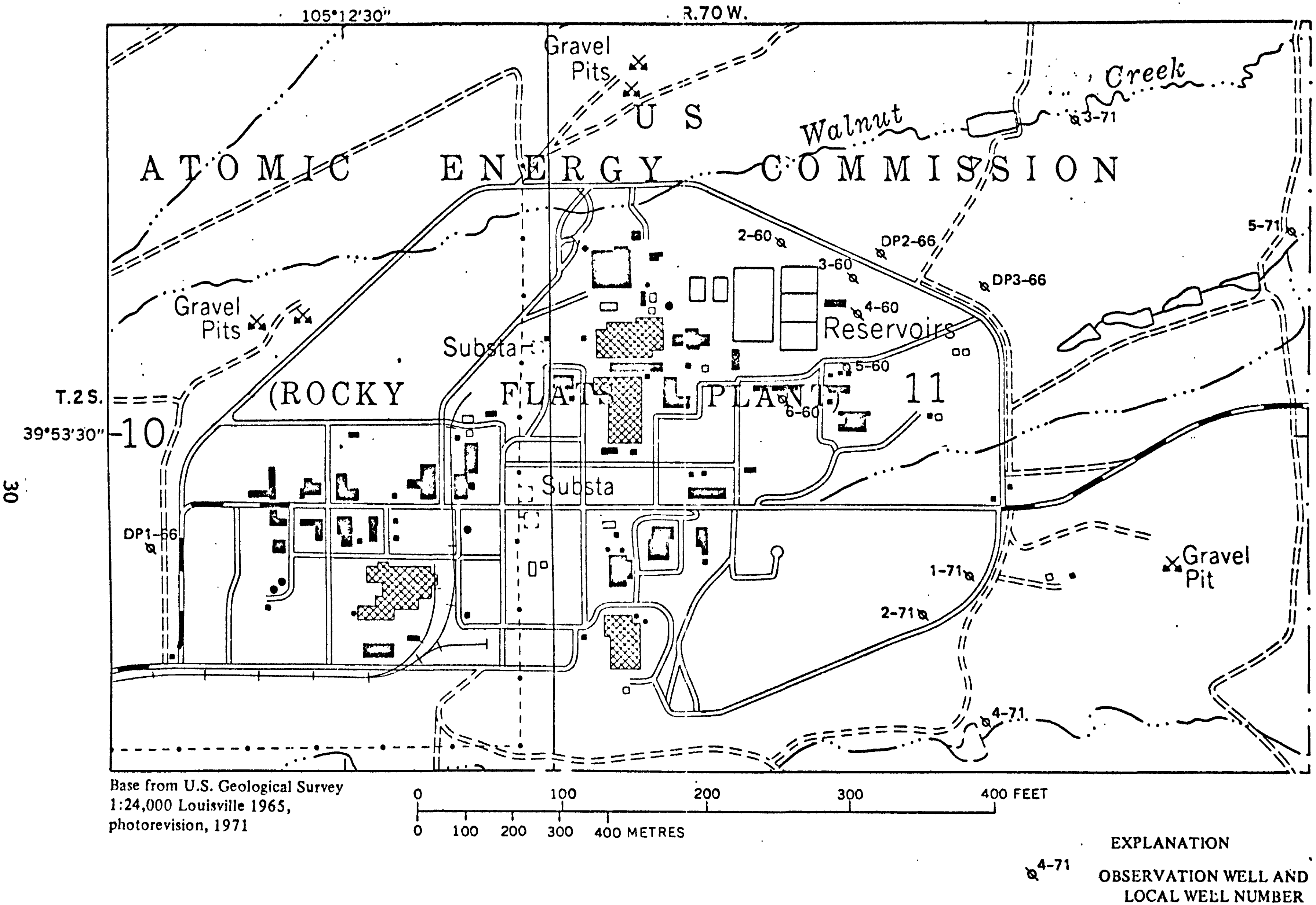


Figure 9. – Location of selected observation wells, Rocky Flats Plant.

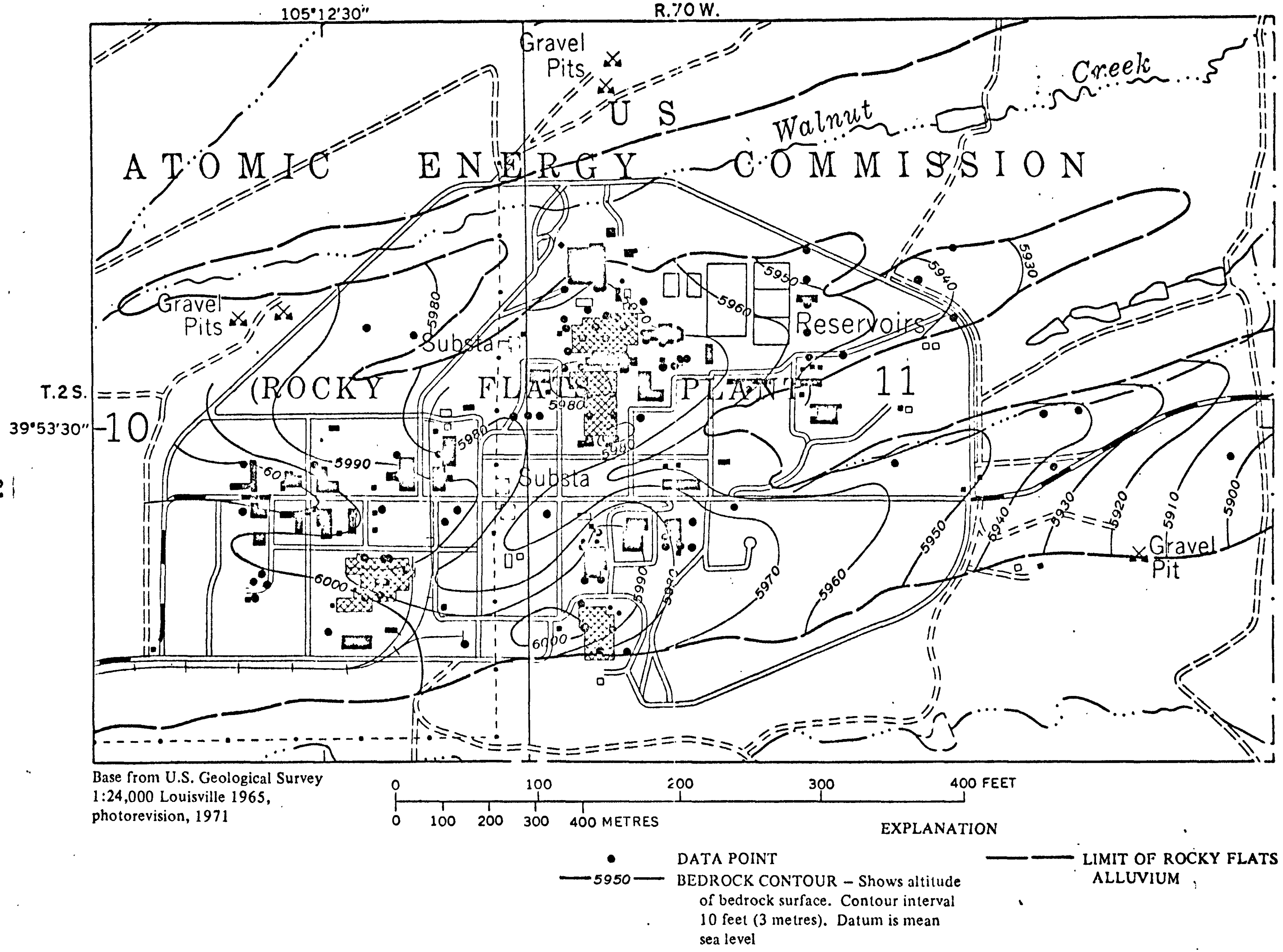


Figure 10. – Configuration of the bedrock beneath the Rocky Flats Alluvium, Rocky Flats Plant.

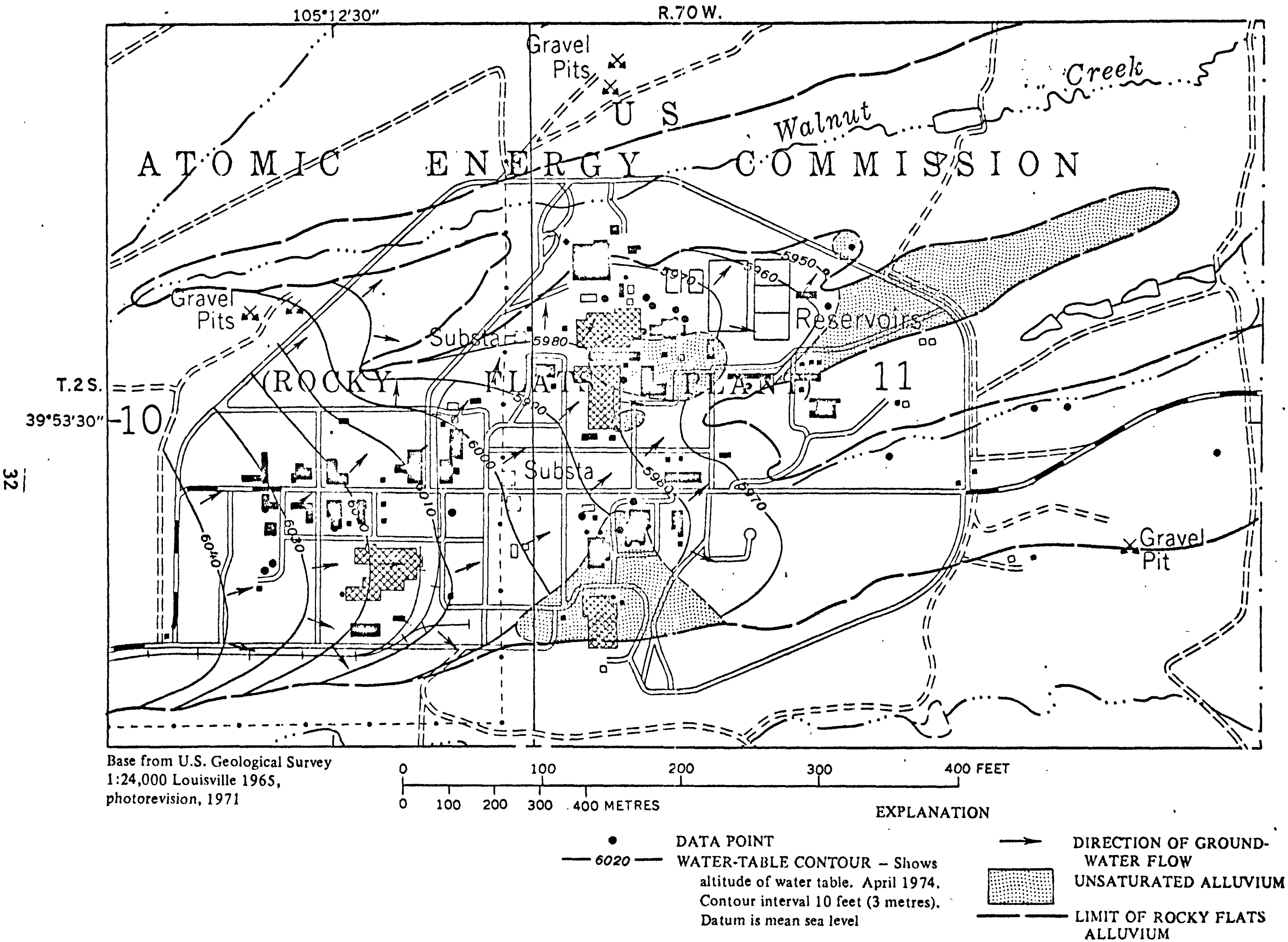


Figure 11. – Configuration of the water table and direction of ground-water flow in the Rocky Flats Alluvium, Rocky Flats Plant.

The thickness of the saturated alluvium at the Rocky Flats Plant is shown on figure 12. Ground-water flow in the area is controlled by buried channels in the bedrock where the alluvium is thickest. Areas where the water table is below the base of the alluvium are outside the line showing the boundary of saturated alluvium (fig. 11). The boundary moves as the water table varies in response to seasonal changes in recharge.

Seeps and springs, supplied by ground water in the alluvium, issue from the alluvium-bedrock contact along the sides of valleys in the study area. Frequently, the location of seeps are marked by changes in the indigenous vegetation. Various types of grasses, which have a high demand for water and wilt quickly when the supply is restricted, are found at springs and seeps. During spring and early summer when ground-water discharge is greatest, the grasses are lush and vigorous, in contrast to the semiarid vegetation of adjacent areas. Later in the season, as the ground-water discharge decreases, the grasses wilt and turn yellow, while the semiarid vegetation continues to thrive because of greater tolerance to water deficiency. Seepage that is not evapotranspired by the plants either contributes to the baseflow of the streams or recharges the valley-fill alluvium.

Valley-fill alluvium

Ground water in the valley-fill alluvium is recharged by precipitation, percolation from streams during periods of surface-water runoff, and by seeps and springs discharging from the Rocky Flats Alluvium. Discharge from the valley-fill alluvium is by evapotranspiration and seepage into other geologic formations and streams. The direction of ground-water flow generally is along the course of the stream. During periods of high surface-water flow, water is lost to bank storage in the alluvium and returns to the stream after runoff subsides.

The valley-fill alluvium is usually better sorted than the Rocky Flats Alluvium and, therefore, is more permeable. Pore velocity is estimated to range from 15 to 25 ft/d (4.6 to 7.6 m/d), depending on the hydraulic gradient. The deposits in the stream channel are usually very coarse and very permeable. Pore velocities in the channel deposits may be several hundred feet per day.

The movement of ground water to and from the valley-fill alluvium varies along the length of the valleys. In the upper reaches of the valleys where the valley fill is underlain by the Rocky Flats Alluvium, water moves from the valley-fill alluvium to the Rocky Flats Alluvium. Ground-water discharge to streams does not occur in the upper reaches of the valleys. Downstream, where the valley bottom is below the base of the Rocky Flats Alluvium, water moves from the Rocky Flats Alluvium to the valley fill; ground water flows from the valley-fill aquifers to the streams. Where the valleys have been cut into bedrock, water moves from the streams into the valley fill and then recharges the underlying bedrock formation.

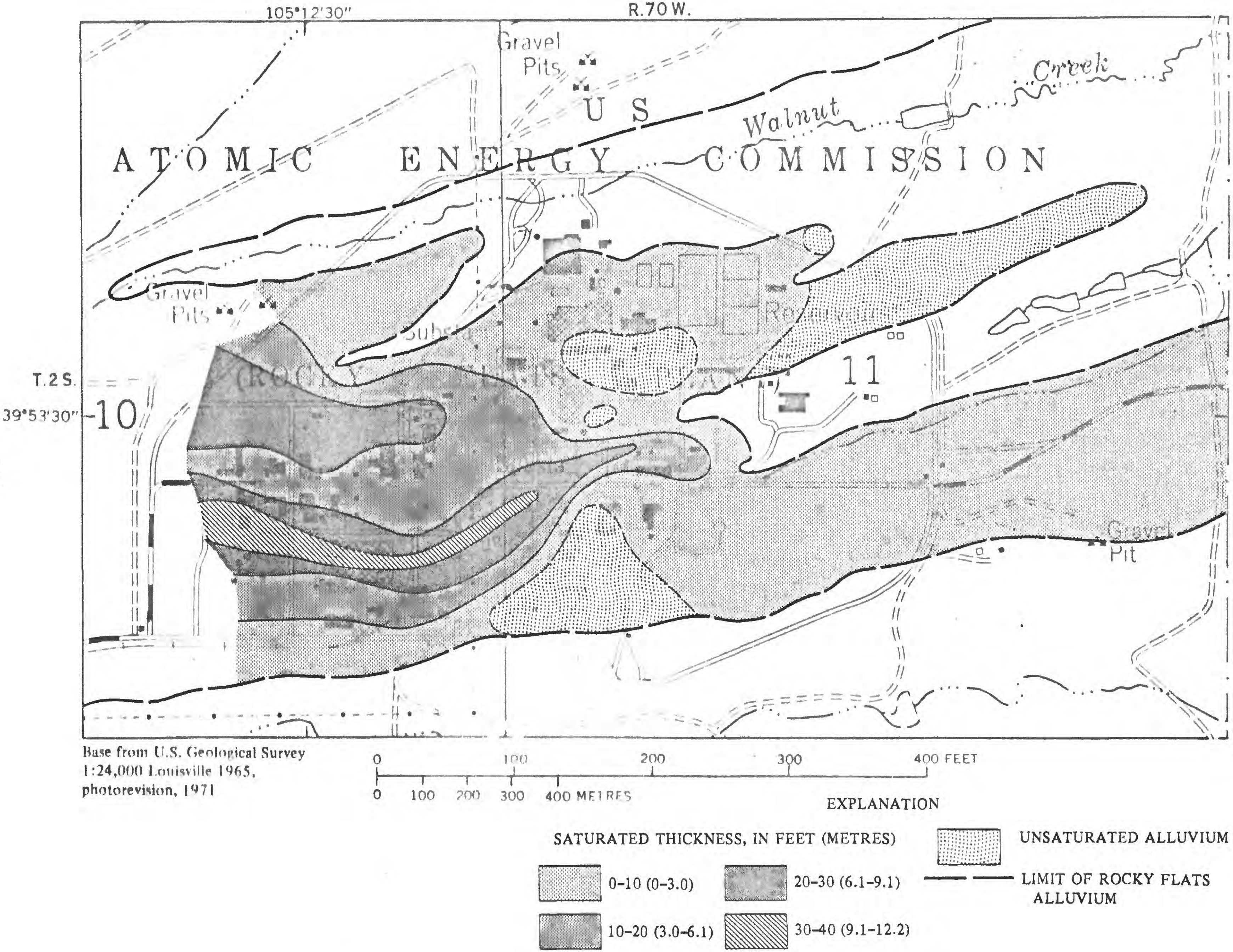


Figure 12. – Saturated thickness of the Rocky Flats Alluvium, Rocky Flats Plant.

Ground-water discharge by evapotranspiration occurs throughout the valleys. From July to September 1974 streamflow in Woman Creek was observed to fluctuate diurnally; the range was 0.25 to 0.50 ft^3/s (0.007 to 0.014 m^3/s). The fluctuations were caused by diurnal changes in evapotranspiration. Downstream from the point of observation, Woman Creek ceased to flow entirely because of streamflow losses to the valley-fill alluvium and the subsequent evapotranspiration and recharge to the bedrock formation.

Arapahoe Formation

The Arapahoe Formation is recharged by leakage from streams and ground-water movement from the overlying alluvial deposits. The main recharge area is under the Rocky Flats Alluvium, west of the plant area, although some recharge from the valley fill occurs along the stream valleys north and south of the Rocky Flats Plant. Recharge is greatest during the spring and early summer when rainfall and streamflow are the greatest and water levels in the Rocky Flats Alluvium are highest. The effect of recharge to the Arapahoe Formation aquifer is shown by the hydrograph of well DP 3-66 (fig. 13). Irregularities in the hydrograph occurred in May 1974 and May 1975. The irregularities were caused when water-quality samples were obtained. The response of the well to sampling indicates that the well has poor hydraulic connection with the aquifer. However, the annual cycle of water-level rise and decline in response to changes in recharge is similar to the fluctuations discussed in relation to well DP 1-66. The response of the water level in well DP 3-66 (fig. 13) to recharge during the spring of 1975 is about 2 months later than that for well DP 1-66 (fig. 7). The time difference between the two responses is due to the differences in aquifer characteristics and increased distance from the recharge area at well DP 3-66.

Ground-water movement in the Arapahoe Formation is downdip to the east. Hydraulic conductivity is estimated to be about 0.3 to 0.4 ft/d (0.09 to 0.12 m/d) (Wilson, 1965) and the hydraulic gradient is about 0.03. Assuming an effective porosity of 0.10 to 0.15, the pore velocity is about 0.1 ft/d (0.03 m/d). Although there are a few seeps along the sides of some valleys where the Arapahoe Formation crops out, most of the ground water flows eastward, out of the study area.

The effect of faulting on ground-water movement in the Arapahoe Formation is not known. The Eggleston Fault extends into the study area from the north (pl. 1). Drag along the fault plane could reduce permeability and impede the movement of ground water through the Arapahoe Formation to the northeast.

Laramie-Fox Hills aquifer

The lower sandstone unit of the Laramie Formation and the Fox Hills Sandstone are collectively called the Laramie-Fox Hills aquifer. The steeply dipping beds of the aquifer crop out west of the Rocky Flats Plant and quickly flatten toward the east. Recharge to the aquifer occurs along the rather limited outcrop area exposed to surface-water flow and leakage from overlying alluvium.

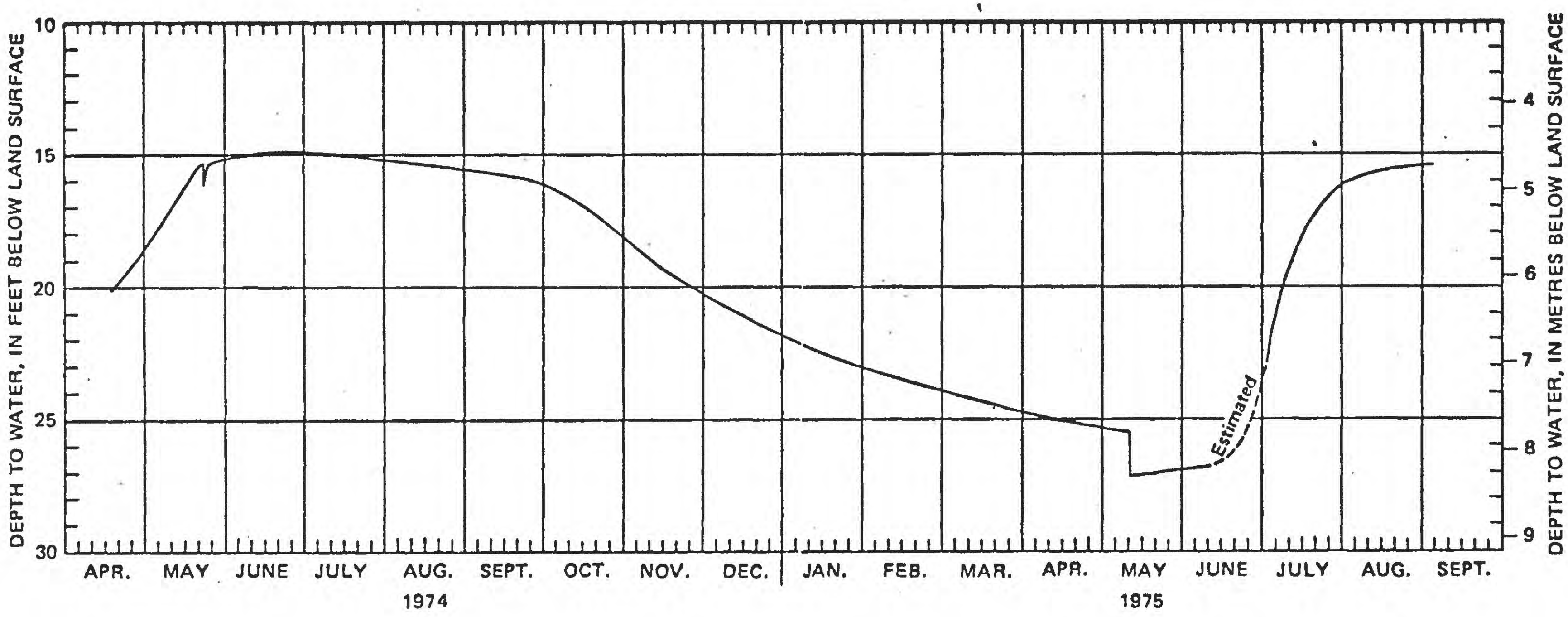


Figure 13. – Hydrograph of water levels in observation well DP3-66, Rocky Flats Plant.

Within the study area ground-water movement is to the east or southeast. North of the study area, near Marshall (fig. 1), faulting has disrupted the Laramie-Fox Hills aquifer to such an extent that regional patterns of flow are greatly altered. In the southern part of the study area, in the vicinity of Leyden (fig. 1), regional flow patterns are disrupted by the underground gas-storage operations of the Public Service Co. of Colorado.

The Laramie-Fox Hills aquifer and the Arapahoe Formation aquifer are separated by several hundred feet of relatively impermeable shale (the upper unit of the Laramie Formation). Consequently, there is little, if any, hydraulic connection between the two aquifers. Furthermore, the recharge area for the Laramie-Fox Hills aquifer is considerably west of Rocky Flats Plant. Therefore, plant operations, as currently practiced, should have little or no effect on the Laramie-Fox Hills aquifer.

MATERIAL MOVEMENT IN THE HYDROLOGIC SYSTEM

Infiltrating Ground Water

The distribution of chemical constituents that enter the hydrologic environment will be controlled largely by the existing hydrogeologic conditions. Infiltration from rainfall carries soluble constituents downward in the soil. Particulate matter probably can not travel more than a few inches into the soil zone because of the clogging of pores in the soil.

Dissolved constituents that enter the soil may sorb on clay particles, undergo ion exchange, precipitate when evaporation of the soil moisture occurs, precipitate by chemical reaction, or move to the saturated zone. The sorption-desorption process and ion exchange by elution will not only cause the rate of solute transport to be different than the rate of water movement, but also cause differential movement of the constituents, depending on their relative participation in the chemical reactions and physical processes. If sorption is high, some chemical constituents may be effectively trapped in the upper part of the soil zone. Precipitates deposited by evaporation may be remobilized by penetration of subsequent infiltration. Ultimately, soluble precipitates may be moved into the saturated zone. The total travel time to move material through the soil to the saturated zone could range from hours to months, depending on local precipitation, infiltration conditions, soil type, and the chemical reactions and physical processes that occur. Precipitates deposited by chemical reaction, in most cases, probably will not be mobilized by subsequent infiltration from rainfall. The chemical environment that caused precipitation probably would not be changed by the additional infiltration. Infiltration by water of greatly different chemical characteristics, however, could change the chemical environment enough to allow resolution and subsequent migration.

Dissolved constituents in the saturated zone are subject to the same processes just described for the unsaturated zone, except that the concentration of dissolved material would be lower. Movement of dissolved constituents in the saturated zone generally follows ground-water flow, although dispersion can be important. Diffusion has minimal effect on the transport of dissolved constituents in the alluvial deposits of the study area.

Runoff and Streamflow

Runoff from precipitation may transport both dissolved constituents and particulate matter into the streams where the rate of transport will be controlled by flow velocity and channel characteristics. Dissolved constituents and particles small enough to be transported in suspension will move at about the same velocity as the streamflow, although there will be some dispersion effects. Coarse particles that are moved as bedload will move much slower than the water. Large particles will be deposited in the streambed as streamflow recedes, and not moved again until the next high flow. In some instances, particles--even small particles--will not be remobilized by a flow velocity that previously transported them, because the flow must exceed some threshold value in order to scour the particles off the channel bottom.

Overall, the time required for dissolved and suspended material to travel a given distance along a stream is longer than the time required for water to travel the same distance. This is due to the riffle-and-pool nature of the streams, and is particularly the case during low flow. Water entering a pool will raise the level, almost immediately causing the flow out of the pool to increase. Molecules of water, however, must traverse the length of the pool. This type of delay was observed on Woman Creek during the summer of 1973. A clay pit adjacent to the stream was being dewatered with a pump which discharged turbid water into the stream. The pump was usually started early in the morning. The increased streamflow caused by this discharge reached the Woman Creek gage 1.75 mi (2.8 km) downstream about 1 p.m. The turbid water, however, did not arrive at the gage until about 4 p.m.--a delay of 3 hours.

Erosion, Sedimentation, and Landslides

The rate of erosion and transport of soil and rock generally is rather low. The highest rate occurs in April, May, and June, when streamflow is greatest. Instantaneous point samples of suspended-sediment concentration on Woman Creek (fig. 14) indicate highest suspended-sediment concentration occurs during periods of high flow. Maximum suspended-sediment discharge during high flow is estimated to be about 75 to 100 tons (68 to 90 t) per day. Using a specific volume of 15 ft^3 (0.42 m^3) per ton, the suspended-sediment load indicates a maximum removal during high flow of from 0.006 to 0.008 mm of sediment per day from the land-surface area of the drainage basin.

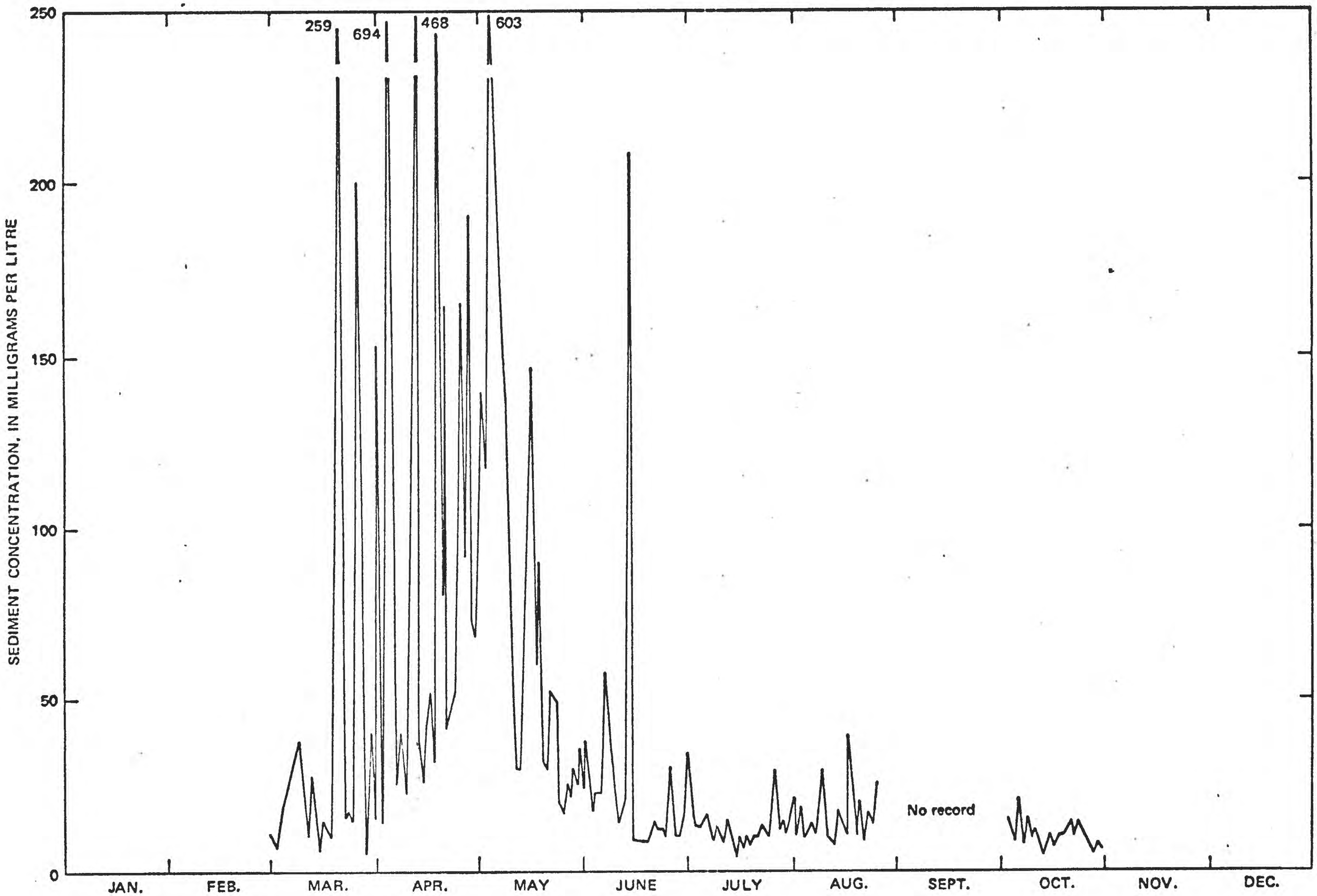


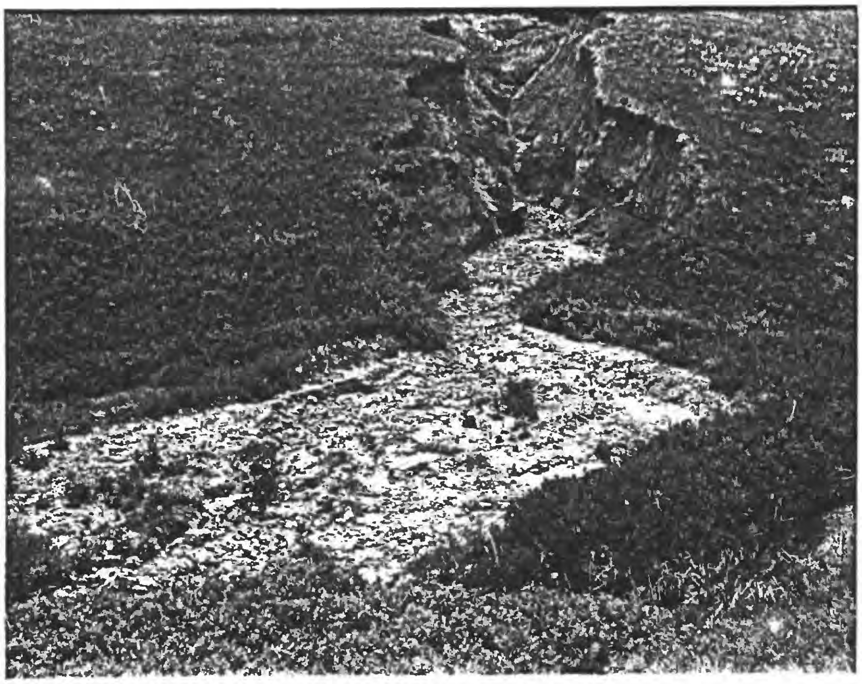
Figure 14. – Suspended-sediment concentration of instantaneous point samples collected at gaging station 06720690 Woman Creek near Plainview, Colo., 1973.

Because some of the suspended-sediment load during high flow is contributed by diversions from Coal Creek, the actual rate of erosion from Rocky Flats Plant is less. However, because erosion is not uniform over the area, localized erosion may be much larger. The annual rate of sediment removal from the land surface, however, is smaller, because the periods of high flow occur during a small percentage of time.

The severest erosion observed in the plant area was along the storm ditch that discharges into South Walnut Creek. This ditch drains an area of 0.25 mi^2 or 0.65 km^2 (table 1) which has a high percentage of impervious cover. The discharge of the ditch drops in two steps from the surface of the Rocky Flats Alluvium to the channel of South Walnut Creek. The first step drops the discharge from the storm ditch to a lower ditch that runs along the south side of South Walnut Creek. The drop between the two ditches crosses the lower part of the Rocky Flats Alluvium and the upper part of the underlying Arapahoe Formation. Erosion in the first drop has produced the gully shown in figure 15*A*. The depth of the gully pictured is about 7 ft (2.1 m). Flow is conveyed for about 700 ft (210 m) in the lower ditch where the second step begins that drops the discharge into the creek. The gully produced by erosion of the Arapahoe Formation in the second drop is shown in figure 15*B*. The depth of the gully shown is about 15 to 20 ft (4.6 to 6.1 m). The streambed of South Walnut Creek crosses the area photographed from right to left and is hidden by the left bank in the foreground. The gaging station, South Walnut Creek at or near Rocky Flats, is about 200 ft (61 m) downstream. During the rainstorm of May 5-6, 1973, discharge through this gully and down South Walnut Creek moved enough sediment--sand, gravel, and cobbles--to completely bury the 30-in (760-mm) flume at the gaging station. Sediment and other material collected in the flume and diverted the flow around both sides of the flume. The condition of the gage on the afternoon of May 6, 1973, is shown in figure 16. The gravel bar in the center of the stream, created by plugging of the flume, was the location of the main channel before the storm.

Sediment transported by Walnut Creek and its tributaries accumulates in Great Western Reservoir. A survey and determination of the stage-capacity relation for the reservoir made in October 1953 defined zero capacity at zero stage (altitude, 5,844 ft or 1,781.3 m above mean sea level). A resurvey in September 1973 by the U.S. Geological Survey showed that sediment accumulation had raised the stage height of zero capacity to 17.5 ft or 5.3 m (altitude, 5,861.5 ft or 1,786.6 m above mean sea level). Although a direct measure of the volume of sediment accumulated during the 21-year period could not be made because of discrepancies in the initial capacity data, it is estimated that 200 to 300 acre-ft (0.25 to 0.37 hm^3) of sediment accumulated in the reservoir. This volume of sediment indicates an average removal rate of about 0.003 mm of sediment per day from the drainage basin over the 21-year period. The Walnut Creek sediment load per unit area is quite similar to the observed sediment load of Woman Creek.

A. Gullying across lower part of Rocky Flats Alluvium and the upper part of the underlying Arapahoe Formation.



B. Gullying in the sandstone and clays of the Arapahoe Formation.

Figure 15.--Views of gully erosion on the storm ditch along South Walnut Creek.

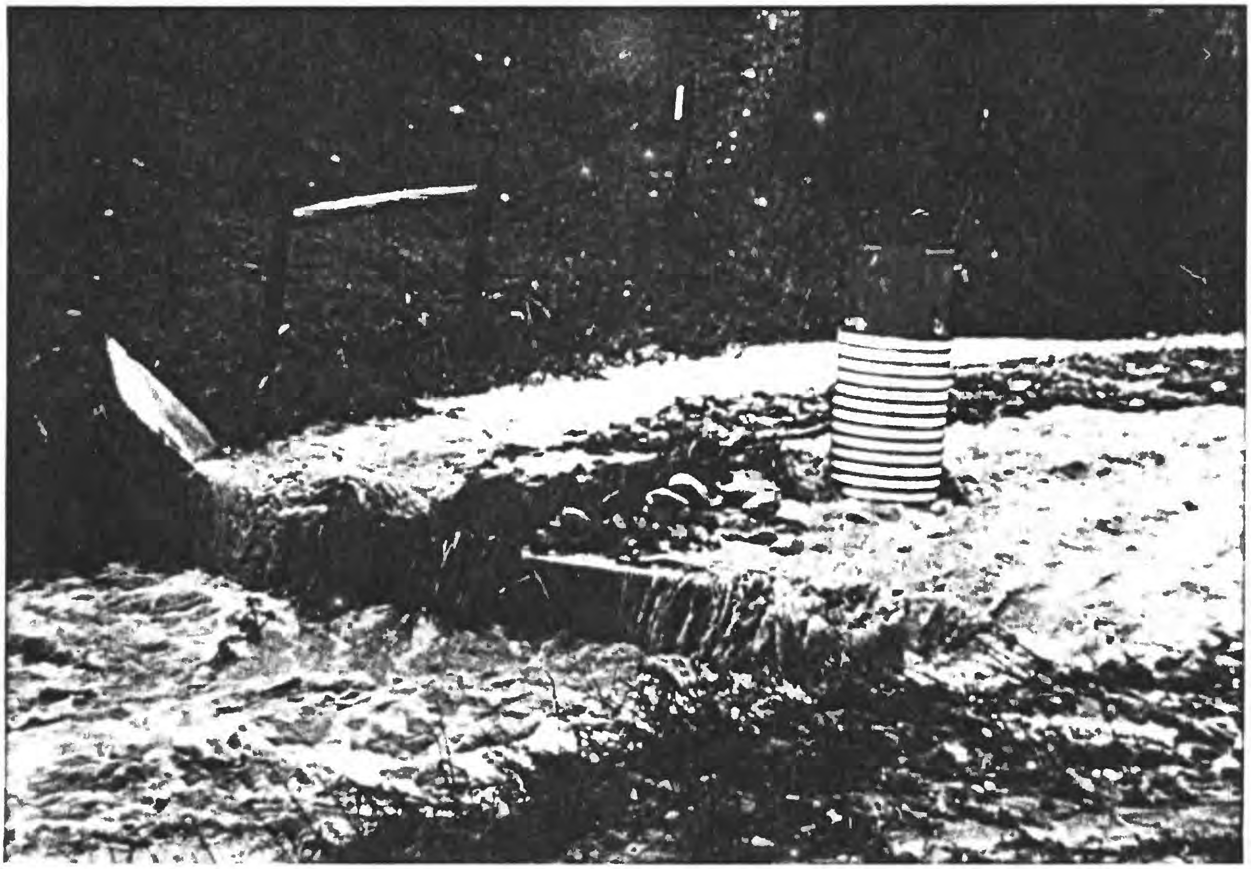


Figure 16.--View of gaging station 06720790 South Walnut Creek at Rocky Flats Plant during the rainstorm of May 5-6, 1973.

Landslides are another form of material transport which is prevalent throughout the study area. Landslides that occur on the sides of the valleys are caused by hydration and lubrication of the bedrock clay. The predominant clay mineral in the Arapahoe Formation is montmorillonite, which shrinks or swells depending on the availability of water. Although most of the landslides appear to be old, some of the slides are actively moving, particularly in areas of ground-water seepage. Alluvial material in the area, except perhaps colluvium, is generally stable, but may be undermined by failure of the underlying bedrock. Landslide scars also may provide a starting place for erosion by runoff from precipitation.

Hypothetical Example of Contaminant Movement

The following example demonstrates how the movement of non-reactive chemical constituents might occur. Assume that an accidental release or leak occurs on or into the Rocky Flats Alluvium in the central plant area. If this release or leak is less than 1,000 gals (3,800 ℓ) of liquid and occurs on an area of moderate size during a period of little or no precipitation, most or all of the liquid may go to replenish soil moisture in the unsaturated zone. Most of the liquid would probably remain in the soil column until flushed downward during the next period of recharge. Contamination probably would be contained in the unsaturated zone until later recharge caused the contaminant to move into the saturated zone.

Larger accidental releases, 5,000 gals (19,000 ℓ) or greater, or smaller releases occurring during wet periods or smaller releases on an area of very small size might enter the ground-water system within 24 hours or less. Recharge responses observed in well DP 1-66 indicate the time might be as short as 2 to 4 hours.

The selection of 1,000 and 5,000 gals (3,800 and 19,000 ℓ) to categorize releases or leaks that would or would not directly affect the ground-water system is based on interpretation of field data. The larger release or leak is comparable to the volume of water applied to irrigate the plot of trees near observation well DP 1-66 which caused the resulting water-level changes in the observation well.

Once the contaminant is within the Rocky Flats Alluvium ground-water system, flow will be generally eastward at about 3 to 11 ft (0.9 to 3.4 m) per day. The velocities indicate a maximum travel time of about 3 years along the longest flow line to a point of discharge. However, due to different lengths of the flow paths and hydrodynamic dispersion, detectable concentrations of the contaminant might begin to appear in springs and seeps issuing from the base of the alluvium in less than 3 months, possibly as soon as a few days.

Ground water issuing from springs and seeps at the base of the alluvium flows down the sides of the valleys towards the streams. Travel time down the slopes depends on the rate of discharge, the type of material on the slope, and the angle and length of the slope. Estimates of travel time suggest that colluvial slope cover derived from clay will transmit flow from springs and seeps to the streams in several weeks or months; gravel-derived colluvium transmits flow in hours to days; and uncovered bedrock slopes transmit flow in a matter of hours.

If the streams are not flowing, the contaminant would probably remain in the ground-water system of the streambed alluvium under conditions similar to the initial accidental release or leak on the plant area. However, if the streams are flowing, transport in the surface-water system is many times faster than in the ground-water system.

The contaminant also could enter the surface-water system via runoff. The rate of movement of contaminant by runoff would depend on the nature of the event that produced the runoff; snowmelt, frontal storm, or thunderstorm. Once in the streams, runoff from low-intensity frontal storms or snowmelt might transport the contaminant at a rate of about 60 ft (18 m) per minute based on data listed in table 5 and other basin lag-time data under pool-and-riffle conditions in the stream channels. The rate of contaminant movement by runoff from intense thunderstorms might be approximately 420 ft (128 m) per minute assuming open-channel-flow conditions. This rate of movement is based on calculations using the travel-time coefficient of 0.0024 minute per foot. Both rates were computed assuming the contaminant would be dissolved and would move at the same rate as the water. Suspended contaminants would move at a slightly lower rate than that given above. The rates of contaminant movement for both types of flow condition ignore the possible effects of on-channel retention reservoirs.

SUMMARY OF CONCLUSIONS

Accidental releases or leaks of contaminants onto an area of moderate size and resulting from the operations of the Rocky Flats Plant might move slowly or rapidly through the hydrologic system, depending on the magnitude of the release or leak and the hydrologic conditions at the time. An accidental release or leak of 1,000 gals (3,800 ℓ) of a liquid contaminant during a period of little or no precipitation would result in most or all of the liquid contaminant replenishing soil moisture in the unsaturated zone. Most of the contaminant probably would remain in the soil column until flushed downward during the next period of recharge. Contamination, therefore, would be local until later recharge moved the contaminant into the saturated zone.

Larger accidental releases or leaks, 5,000 gals (19,000 ℓ) or greater, or smaller releases or leaks occurring during wet periods or onto an area of small size, probably would enter the ground-water system in 24 hours or less. Recharge responses observed in an observation well indicate the time might be as short as 2 to 4 hours. Ground-water movement within the Rocky Flats Alluvium might move the contaminant, if it remains dissolved, generally eastward at a rate of about 3 to 11 ft (0.9 to 3.4 m) per day. The ground-water velocities indicate the maximum travel time would be about 3 years along the longest flow line to a point of discharge. However, appearance of the contaminant in springs and seeps issuing from the base of the alluvium might occur in less than 3 months, possibly as soon as a few days.

Movement of the contaminant from the springs or seeps down the slopes to the streams could take as long as several weeks or be as short as a few hours, depending on the characteristics of the slopes. A contaminant might move through the surface-water system at a rate of about 60 ft (18 m) per minute under pool-and-riffle conditions in the streams. Under open-channel-flow conditions following intense thunderstorms, the contaminant might move at a rate of approximately 420 ft (128 m) per minute.

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SUPPLEMENTAL INFORMATION

Geologic Characteristics of the Pierre Shale and Younger Formations

Pierre Shale

The Pierre Shale composed of upper Cretaceous marine strata is about 7,300 ft (2,225 m) thick in the vicinity of Rocky Flats. The Pierre Shale consists of four units, the lower shale unit, the lower sandstone unit, the upper shale unit, and the upper transition unit (Scott and Cobban, 1965). The lower shale unit, approximately 1,600 ft (490 m) thick, is predominantly dark-gray shale containing ironstone concretions and interbedded bentonitic layers. The lower sandstone unit, consisting of the Hygiene Sandstone Member, is about 600 ft (180 m) thick, and consists of dark-brown, well-cemented, fine-grained sandstone, interbedded with dark-brown to dark-gray shale. The upper shale unit, about 3,900 ft (1,190 m) thick, consists of dark shale and claystone containing limestone and ironstone concretions and layers of silty, sandy shale. The upper transition unit, about 1,200 ft (365 m) thick, consists of dark to rust-brown, silty, sandy shale and interbedded shaly sandstone layers. The Pierre Shale is overlain by the Fox Hills Sandstone.

The Pierre Shale-Fox Hills Sandstone Contact

The Fox Hills Sandstone was originally described by Emmons, Cross, and Eldridge (1896, p. 71) as consisting of 800 to 1,000 ft (240 to 300 m) of soft, friable, sandy shale, with occasional interstratified bands of clay capped by a persistent and characteristic sandstone, usually about 50 ft (15 m) thick. Scott and Cobban (1965, p. 3) state, however, that this interval includes all of the upper transition member of the Pierre Shale. In 1920, Henderson (1920a, p. 22) suggested that had the Pierre Shale and the Fox Hills Sandstone been studied in eastern Colorado, before publication of the formations in the upper Missouri region, the formations would not have been divided at all, or would have been separated at a much higher horizon--at the base of a massive upper sandstone--which he later designated as the Milliken Sandstone Member of the Fox Hills Sandstone. This was the same sandstone described by Emmons, Cross, and Eldridge (1896).

In 1932, the Rocky Mountain Association of Petroleum Geologists (Lovering and others, 1932) agreed to define the base of the Fox Hills "* * * as the horizon below which the section is predominantly gray marine clay shales and sandy shales of Pierre age, and above which the section changes rapidly to a buff to brown sandstone containing numerous large gray to brown, hard, sandy concretions. This lower concretionary member is commonly overlain by a series of light-gray to brown sandstones and sandy shales." The report further describes the base of the Fox Hills as being approximately 250 ft (76 m) below the top of the Fox Hills at localities 45 mi (72 km) east of Denver and 40 mi (64 km) north of Denver. The base was reported as about 100 ft (30 m) below the top of the Fox Hills, 65 mi (104 km) northwest of Denver.

However, Scott and Cobban (1965, p. 3) contended that this recommended lower boundary of the Fox Hills was unmappable except in small areas of excellent outcrops, and chose to map the top of the Pierre Shale at the base of the Milliken Sandstone Member. Geophysical logs from wells in the Denver Basin support the contention of Scott and Cobban (1965). For the purposes of this report, the base of the Milliken Sandstone Member of the Fox Hills Sandstone is the contact between the Pierre Shale and the Fox Hills Sandstone.

Fox Hills Sandstone

The Fox Hills Sandstone--Milliken Sandstone Member--usually has a thickness of 40 to 90 ft (12 to 27 m) and consists of sandy shale grading stratigraphically upward into massive sandstone. Based on the interpretation of geophysical logs, the thickness in some areas may be as great as 150 to 200 ft (46 to 61 m), usually due to an increased thickness in the lower sandy shale part of the unit. Some logs show sandstone beds below the horizons usually considered to be the base of the Fox Hills; these beds are interpreted to be tongues of the Fox Hills interfingering with the underlying Pierre Shale.

Combining descriptions by Camacho (1969, p. 44-55) of two adjacent localities in the southern part of the study area, the Fox Hills Sandstone is a tan to buff, feldspathic sandstone. The lower one-half tends to be thinly bedded parallel laminae of silty, very fine-grained sandstone and some thin beds of siltstone and shale. The upper one-half is fine- to medium-grained, parallel, thick-bedded sandstone.

Laramie Formation

The Laramie Formation is a brackish-water, continental deposit conveniently divided into two units, the lower sandstone unit and the upper shale unit. The lower sandstone unit ranges from about 150 ft (46 m) to a little more than 320 ft (98 m) thick and consists of thin to massive beds of fine-grained, moderate- to well-cemented sandstone interbedded with buff to dark, carbonaceous claystone. Kaolinite-rich clay is mined from near the base of this unit. Coal, in the middle and near the top of this unit, has been mined between Leyden and Marshall, Colo. (fig. 1). The lower sandstone unit consists of two subunits, the A and the B sands. The A sand, usually 5 to 40 ft (1.5 to 12 m) above the top of the Fox Hills Sandstone, tends to be highly resistant to weathering and forms the hogback ridges that extend from south of Golden to Marshall, Colo. (fig. 1). The B sand ranges from a relatively thick, massive sandstone to a series of thin sandstone beds interbedded with organic-rich claystones. Hydrologically, the Fox Hills Sandstone and the lower Laramie Formation--the A and the B sands--are collectively referred to as the Laramie-Fox Hills aquifer.

The upper shale unit of the Laramie Formation is about 450 to 630 ft (137 to 192 m) thick and consists of buff to dark-gray, organic-rich claystone. In many localities there are interbedded sand layers. Locally, about 100 to 200 ft (30 to 61 m) above the B sand, these sand layers are frequent and thick enough to be collectively designated as the C sand.

Arapahoe Formation

The Arapahoe Formation is a Late Cretaceous, continental deposit of lenticular sand bodies interbedded with clay. Ironstone nodules and layers are common, associated both with the sand bodies and the clay. Imprints of leaves and woody material as well as carbonaceous remains of plant material are commonly found where sand and clay are thinly interbedded. The lower one-half of the formation contains more sand beds than the upper one-half. Sand beds, as interpreted from geophysical logs, occurring at a stratigraphic horizon about 750 to 800 feet (260 to 280 m) above the top of the Fox Hills Sandstone, are used in this report as the base of the Arapahoe Formation. The maximum thickness of the Arapahoe Formation observed in the study area was about 270 ft (82 m) (test well 22-74). South and east of the study area, interpretation of geophysical logs indicates that the thickness of the formation, where overlain by the Denver Formation of Late Cretaceous and Paleocene age, ranges from 270 to 445 ft (82 to 136 m).

The sand bodies rarely exceed 5 to 8 ft (1.5 to 2.4 m) thick. The lateral extent of these sand bodies may be hundreds of feet, but tens of feet are more common. In many localities the same stratigraphic horizon contains several sand bodies which are not laterally connected. Individual beds within the sand bodies range in thickness from 0.063 in (1.6 mm) to about 2 ft (0.6 m) and usually show crossbedding. Ripple undulations of alternating sand and clay lamellae have been observed. Hard ironstone lenses may be interbedded with the sand and show little color banding. In the outcrop, the color ranges from light buff to dark brown and cementation ranges from none to moderate. Usually the darker colors are associated with the higher degree of cementation. The cementing material is carbonate and iron. At one locality, calcite ($CaCO_3$) and minor amounts of barite ($BaSO_4$) were observed filling joints in the sandstone.

An uncommon sedimentary feature was observed northeast of the study area, along the Community Ditch, in NW¼ sec. 32, T. 1 S., R. 69 W., where nearly horizontal sandstone beds are underlain by other sandstone beds that are almost vertical. This uncommon feature probably resulted from slump faulting contemporaneous with deposition as described by Weimer (1973).

The sand particles are fine to medium, subrounded to rounded grains of quartz. In some localities minor amounts of feldspar, mica, mafic minerals, and clay particles are present. Locally, the size of clastic particles are quite coarse. In the study area, the coarsest material ranges from very fine to fine gravel. In the vicinity of Golden, however, small cobble-sized clasts are not uncommon. Gravel-sized or coarser clasts occur at all stratigraphic horizons in the lower one-half of the formation.

The clay in the Arapahoe Formation ranges in color from light to dark gray, commonly with an olive-green cast. Oxidation or deposition of iron along joints and fractures creates a mottled orange appearance. The clay composition is montmorillonite with minor amounts of kaolinite and illite. Ironstone layers, lenses, and concretions are common. Color banding in the thinner layers of the ironstone locally is quite picturesque. In outcrops, the clay weathers into irregular, equidimensional fragments that quickly disintegrate into smaller particles. Earth slumps involving 500 to 1,000 tons (455 to 907 t) of material are common when the clay and weathering products become wet or when a potential slip surface becomes saturated.

Geologic Characteristics of Surficial Deposits

Within the study area, surficial deposits are Pleistocene and Holocene in age, and consist primarily of alluvium and colluvium. Older alluvium forms many of the higher topographic surfaces between present-day streams east of the mountain front. Younger alluvium occurs along the valleys of the present-day streams. Colluvium, the product of mass wasting, covers the sides of the valleys and slopes of the hills in some areas.

Pre-Rocky Flats Alluvium

The pre-Rocky Flats Alluvium, the oldest surficial deposit in the study area, extends east of the mountain front only about 1 mi (1.6 km). Topographically it is about 40 to 100 ft (12 to 30 m) above the general plane of the Rocky Flats Alluvium. Wells (1967, p. 45) described it as a pediment deposit about 10 to 30 ft (3.0 to 9.1 m) thick, consisting of bouldery gravel in a sand matrix. Van Horn (1972) adds that in places the top 1 to 6 ft (0.3 to 1.8 m) is clayey to pebbly silt. Scott (1972) suggests that it is perhaps correlative with the Nussbaum Formation of early Pleistocene age.

Rocky Flats Alluvium

The Rocky Flats Alluvium is a series of laterally coalescing alluvial fans deposited by streams, probably during floodflow. Where the streams emerged from the mountains, the loss of gradient and presumably wider channel width caused the streams to lose their carrying capacity and deposit their particle load. This clogging of the channels caused lateral migration of the streams during successive episodes of deposition, enlarging and thickening the fans. The minimal fan development in the vicinities of the present-day Clear Creek and Boulder Creek suggests that the antecedents of these streams were of sufficient strength and durability to convey particle loads downstream and not contribute to fan development.

The Rocky Flats Alluvium unconformably overlies all of the older bedrock formations. The erosional surface on which it is deposited has a general slope to the east. This surface, however, is quite irregular and has a local relief of about 50 ft (15 m). The resistant sandstone beds in the lower unit of the Laramie Formation formed a hogback ridge trending north that stood above the level of the surrounding erosional surface. Streams cutting through the hogbacks carved broad shallow valleys trending generally east. The thickness of Rocky Flats Alluvium on the north-trending hogbacks is small, in some places the alluvium is absent. The thickness of alluvium above some of the east-trending bedrock channels is 100 to 120 ft (30 to 37 m) (Ackerman, 1974; Oliveira, 1975). The average thickness of the alluvium in the study area is about 20 to 30 ft (6 to 9 m).

The Rocky Flats Alluvium consists of beds of clayey, sandy silt, some of which contain distinct horizons of subrounded gravel and cobbles. Locally, there are lenses of clean, moderately sorted medium to very coarse sand. Closer to the mountains, the alluvium tends to contain coarser material and boulders 2 to 3 ft (0.6 to 0.9 m) in diameter are not uncommon. The gravel and cobbles are light- to dark-gray, sometimes pinkish to light-tan, metaquartzite, and occasional pieces of gneiss, schist, granite, pegmatite, sandstone, and siltstone. Malde (1955, p. 225) reported that the gravel was 60 percent quartzite. Scott (1963, p. 13) states that, in the top 1 to 3.4 ft (0.3 to 1.0 m) at the type locality, the fragments are mostly schist and gneiss with some quartzite. Although pebble counts were not made during this study, repeated examination of the lithology, both on the surface and in fresh excavations several feet deep, indicated that at least 80 percent, and probably closer to 90 percent, of the gravel-size or larger fragments were quartzite. The clayey, sandy silt is yellowish to light-reddish brown which gives the formation its characteristic color. The sand particles are predominantly light-colored quartz and quartzite which give the silt a somewhat speckled appearance.

Malde (1955, p. 223) and Wells (1967, p. 47) both referred to the Rocky Flats Alluvium as a pediment gravel. Scott (1963, p. 52) in his work in the Kassler quadrangle calls the erosional surface beneath the gravel a pediment, but did not call the gravel part of the pediment. In his description of the Rocky Flats Alluvium in the Morrison Quadrangle (Scott, 1972) a height of the pediment above modern streams is included, presumably meaning the height of the upper surface of the deposit. Gary, McAfee, and Wolf (1972, p. 522) describe a pediment as an erosional feature, allowing, however, for a thin discontinuous veneer of alluvium. Under the definition of a pediplane (Gary and others, 1974, p. 523), the thickness of the veneer is limited to the effective depth of flood scour. The stratification and limited thickness of individual beds and total thickness of the formation indicate that the Rocky Flats Alluvium is depositional and, as such, it should not be called a pediment gravel.

Soil development on the Rocky Flats Alluvium may belong either to the Nederland soil series or the Valmont soil series (Moreland and Moreland, 1975, sheet No. 30). A comparison of these soils is shown in table 6.

Table 6.--*Comparison of Nederland and Valmont series soils*
[After Moreland and Moreland, 1975]

<table>
<tr><th colspan="2" rowspan="2">Property</th><th colspan="2">Soil Series</th></tr>
<tr><th>Nederland</th><th>Valmont</th></tr>
<tr><td colspan="2">Parent material</td><td>Old high terraces and alluvial fans.</td><td>Old high terraces and benches in gravelly and cobbly, loamy alluvium.</td></tr>
<tr><td colspan="2">Drainage</td><td>Deep, well-drained soils.</td><td>Deep, well-drained soils.</td></tr>
<tr><td colspan="2">Surface layer</td><td>Four inches (100 mm) of brown, very cobbly, sandy loam.</td><td>Four inches (100 mm) of grayish-brown, light clay loam containing varying amounts of cobbles and gravel.</td></tr>
<tr><td rowspan="3">Subsoil</td><td>Upper</td><td rowspan="4">Brown and reddish-brown, heavy, coarse, sandy loam and very cobbly, sandy, clay loam, 16 in (405 mm) thick. Underlying these materials to a depth of 60 in (1,520 mm) or more is reddish-brown, very cobbly, coarse sandy loam.</td><td>Brown clay loam, 3 in (75 mm) thick.</td></tr>
<tr><td>Middle</td><td>Brown light clay, 13 in (330 mm) thick.</td></tr>
<tr><td>Lower</td><td>Calcareous, light-brown, gravelly, clay loam, 4 in (100 mm) thick.</td></tr>
<tr><td colspan="2">Underlying material</td><td>Calcareous, pinkish-white and light-brown, very gravelly loam.</td></tr>
</table>

Locally, particularly in the eastern part of the study area, calcium carbonate enrichment mottles the soil texture between 1 to 5 ft (0.3 to 1.5 m) below land surface. In the SW¼NW¼ sec. 12, T. 2 S., R. 70 W., calcium carbonate development in the upper 5 ft (1.5 m) of the Rocky Flats Alluvium has produced dense, hard, thinly bedded layers of carbonate which become progressively less defined and grade vertically downward into noncalcareous alluvium. Individual layers of the carbonate material show wavy, concentric banding similar in appearance to the algal limestone at the top of the Ogallala Formation of Tertiary age in eastern Colorado and western Kansas (Elias, 1931). A layer 0.25- to 0.5-in (6- to 13-mm) thick associated with the concentric banding is made up of öolitic-like grains ranging from 0.005 to 0.035 in (0.13 to 0.89 mm) in diameter. John L. Wray, Marathon Oil Co. (oral commun., 1975), examined these carbonates in both hand specimens and thin sections, and reported that they contained no evidence of algal organisms. The alternative then is that they are primary sedimentary, presumably inorganic, accumulations of carbonate, or secondary accumulations associated with soil development. Detailed field and petrographic investigation would be required to determine which method is responsible.

Verdos Alluvium

The Verdos Alluvium occupies a topographic position about 50 to 100 ft (15 to 30 m) below the Rocky Flats Alluvium, and within the study area was deposited in alluvial fans and channels. The large deposit south of Leyden Gulch appears to have been deposited as an alluvial fan by the antecedent of Ralston Creek emanating from the mountains. The maximum thickness is about 40 ft (12 m). The rock fragments in this deposit are granite, pegmatite, and gneiss with lesser amounts of older sedimentary rock and minor amounts of gray quartzite and amphibolite. Around the periphery of the present extent of the Rocky Flats Alluvium, the Verdos Alluvium was deposited as fans and channel filling derived by erosion of the older alluvium. Coarseness of these deposits retarded subsequent erosion, in some cases inverting their former topographic position so that they now occupy knobs and ridges between the present drainage. In some areas where the Rocky Flats Alluvium has controlled erosion, the Verdos Alluvium is found as terraces on the sides of the present-day valleys. The appearance and lithology is similar to the Rocky Flats Alluvium except that it tends to be whitish gray in color, rather than reddish brown, and does not contain the numerous large boulders. The second generation of weathering and transport has further disintegrated the gneiss and schist, reducing their percentage in the total composition. A well-developed soil profile with calcium-carbonate enrichment commonly extends into the underlying bedrock. The maximum observed thickness of the soil profile is about 5 to 7 ft (1.5 to 2.1 m).

Slocum Alluvium

The Slocum Alluvium is a gravel deposit containing much sand and silt derived from erosion of bedrock and the older gravel deposits. Malde (1955, p. 233) describes it as a diversity of alluvial, colluvial, and eolian deposits preserved in a large number of discontinuous outcrops on bedrock hills and as low mounds surrounded by finer grained material that is locally mixed and interbedded with the gravel. The formation has a maximum thickness in the study area of about 20 ft (6.1 m), but is more commonly 5 to 10 ft (1.5 to 3.0 m) thick and occupies a topographic position of about 300 ft (90 m) below the Rocky Flats Alluvium.

Terrace alluvium

Locally two Wisconsin-age terraces are associated with the present drainage. These terraces consist of cobbles and pebble gravel containing scattered boulders. Along Coal Creek this alluvium has a maximum thickness of 12 ft (3.7 m) and consists of 65 to 70 percent quartzite, 30 to 35 percent granite and gneiss, and 1 to 3 percent sandstone (Malde, 1955, p. 238). Along Rock, Walnut, and Woman Creeks, the alluvium was derived from the bedrock and reworking of the older alluvial deposits, so the alluvium contains more fine material and less granite and gneiss. The thickness is seldom more than about 5 ft (1.5 m).

Valley fill

Valley fill occupies the bottom of the present valleys. Along Rock Creek in the NW¼ sec. 31, T. 1 S., R. 69 W., a thickness of 15 ft (4.6 m) was observed. Malde (1955, p. 243) reports that a thickness in excess of 10 ft (3.0 m) is common. The valley fill ranges from dark-brown sandy clayey silt to moderately sorted cobbles and small boulders. The valley fill, along streams which head on the Rocky Flats Alluvium and have not yet cut through to bedrock, tends to be coarse and have little or no fine material. Where the valley fill is deposited on bedrock, however, 0.5 to 2 ft (0.2 to 0.6 m) of cobbly sand and gravel commonly is overlain by several feet of sandy clayey silt. Subsequent erosion and deposition locally may have added more sand, gravel, and cobbles on top of the silt, or cut through the valley fill to expose bedrock along the channel bottom. The composition of the particles, sand-size or larger, is quartzite and occasional ironstone fragments.

Colluvium

Colluvium is the product of mass wasting which collects on the sides and at the base of hills and slopes. These deposits tend to be poorly sorted mixtures of soil and debris from bedrock clay and sand, mixed with gravel and cobbles derived from the older alluvium which caps the hills and ridges. Although the thickness of these deposits rarely exceeds 2 to 3 ft (0.6 to 0.9 m), their widespread occurrence tends to mask much of the underlying geology.

Structure

The general geologic structure of the area is north-striking beds with dips to the east or southeast. Major faulting is well documented in areas to the north, west, and south.

Folding

The study area is located along the western edge of the Denver Basin where monoclinal folding has resulted in steeply dipping north-trending beds. In the western part of the area, the beds are nearly vertical to overturned. The dip of the beds in the Laramie Formation 2 mi (3.2 km) east of the mountain front, is 45-50° to the east. In the eastern part of the study area the strike of the beds swings to the northeast and the dip is less than 1° to the southeast.

Faulting

Several types of faulting are found in and adjacent to the study area, all of which are related to the Laramide Orogeny of Late Cretaceous-early Tertiary age. Extending into the study area from the south is the Golden fault, which is a north-trending, medium- to high-angle, west-dipping, reverse fault. This fault consists of several subparallel fault branches which rarely affect any beds younger than the Fox Hills Sandstone. North of Golden, in the vicinity of Leyden Gulch, a branch of the Golden fault trends to the northwest to join at the mouth of Coal Creek Canyon with the northwest-trending Livingston shear zone. A branch of the Golden fault continues north of Leyden Gulch to become lost in the Pierre Shale, particularly when covered by the Rocky Flats Alluvium.

In the northern and northwestern part of the study area, high-angle normal faulting trending in a northeastern direction has been mapped by Spencer (1961). Colton and Lowrie (1973) indicate, however, that this is only a fraction of the faulting in the area. Weimer (1973, fig. 22) shows faulting in the Golden area which parallels these northeast-trending faults in Boulder County. He also shows what he calls "basin-margin faulting" trending north a few hundred feet east of and paralleling the hogback ridges of the lower unit of the Laramie. The northern limit of Weimer's basin-margin fault is at the border between the Golden and Louisville 7½-minute quadrangle maps. Projection of this fault to the north coincides with the eastern limit of mining in the now destroyed Caprock Mine near the center of sec. 16, T. 2 S., R. 70 W. This mine had an inclined shaft which followed down the dip of the beds for several hundred feet. Coal was mined by the room-and-pillar method along the strike of the beds. Examination of mine records and maps of the Rocky Mountain Energy Co., owners of the mine, did not indicate whether or not the eastern limit of mining was fault controlled (John Brown, oral commun., 1975).

Additional faulting in the study area, as shown on plate 1, was observed during the current study. The extension of the Eggleston fault is inferred from the alignment of minor displacements along a northwest-trending line. The youngest faulting, that which shows displacement in the Verdos Alluvium, occurs in the southern part of the area in the SW¼ sec. 23, T. 2 S., R. 70 W.

DAILY RAINFALL RECORDS

Table 7.--*Daily rainfall values for stations on Walnut and Woman Creeks and at the Rocky Flats Plant, 1972-74*

Day	Apr.	May	June	July	Aug.	Sept.	Oct.	Apr.	May	June	July	Aug.	Sept.	Oct.	Apr.	May	June	July	Aug.	Sept.	Oct.
	[Units are in inches from midnight to midnight]														[Units are in inches from 8 a.m. to 8 a.m.]						
	WALNUT CREEK, 1972							WOMAN CREEK, 1972							ROCKY FLATS PLANT, 1972						
1	----	----	----	----	----	0.52	----	----	----	----	----	----	0.49	----	----	----	----	----	----	0.57	----
2	----	----	----	----	0.25	.07	----	----	----	0.02	----	0.11	.06	----	----	----	0.05	----	----	.05	----
3	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	0.25	----	----
4	----	----	0.71	0.32	----	----	----	----	----	.48	0.29	----	----	----	----	----	.10	0.50	.03	----	----
5	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	.55	.05	----	----	----
6	----	----	1.19	.23	----	----	----	----	----	1.07	.14	----	----	----	----	----	.20	----	----	----	----
7	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	.15	----	----	----
8	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
9	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	.05	----
10	----	----	----	.11	----	----	----	----	----	----	.03	----	.08	----	----	----	----	.05	----	.10	----
11	----	----	----	----	----	.33	----	----	----	----	----	----	.23	----	----	----	----	----	----	.40	----
12	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
13	----	----	----	----	----	.09	----	----	----	----	----	----	.16	----	----	----	----	----	----	.25	----
14	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
15	----	----	----	.03	.34	----	----	----	----	----	.02	.21	----	----	----	----	----	.07	.28	----	----
16	----	----	.09	----	.26	----	----	----	----	----	.02	.27	----	----	----	----	----	.03	.31	----	----
17	----	----	.09	----	.03	----	----	----	----	----	----	.05	----	----	----	----	----	----	.10	----	----
18	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
19	----	----	----	----	.22	----	----	----	----	----	----	.24	----	----	----	----	----	----	.40	----	----
20	----	----	----	.06	----	----	----	----	----	----	.05	----	----	----	----	----	----	.25	----	----	----
21	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
22	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	.05	----	----	----	----
23	----	----	----	----	.83	----	----	----	----	----	----	.71	----	----	----	----	----	----	----	----	----
24	----	----	----	.32	.15	----	----	----	----	----	.19	.12	----	----	----	----	----	.10	.85	----	----
25	----	----	----	----	.02	----	----	----	----	----	.08	.21	----	----	----	----	----	.10	----	----	----
26	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	.04	----	----	----
27	----	----	----	----	----	----	----	----	----	----	.02	----	----	----	----	----	----	----	----	----	----
28	----	----	----	----	----	----	----	----	----	----	.04	----	----	----	----	----	----	----	----	----	----
29	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
30	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----	----
31		----		.24	.21		----		----		.22	----		----		----		.25	.25		----
TOTAL	----	----	2.08	1.31	2.31	1.01	----	----	----	1.57	1.10	1.92	1.02	----	----	----	0.95	1.59	2.47	1.42	----

Table 7.--*Daily rainfall values for stations on Walnut and Woman Creeks and at the Rocky Flats Plant, 1972-74*--Continued

[Units are in inches from midnight to midnight] (Walnut Creek and Woman Creek); [Units are in inches from 8 a.m. to 8 a.m.] (Rocky Flats Plant)

Day	WALNUT CREEK, 1973 Apr.	May	June	July	Aug.	Sept.	Oct.	WOMAN CREEK, 1973 Apr.	May	June	July	Aug.	Sept.	Oct.	ROCKY FLATS PLANT, 1973 Apr.	May	June	July	Aug.	Sept.	Oct.
1	NR	0.31	----	NR	----	----	----	NR	0.19	NR	----	----	----	----	----	0.30	----	----	----	0.05	----
2	NR	.10	----	NR	----	----	----	NR	.02	NR	----	----	----	----	0.60	.05	----	----	----	----	----
3	NR	----	----	NR	----	----	----	NR	----	NR	----	----	----	----	.15	----	----	----	0.04	----	----
4	NR	----	0.28	NR	----	----	----	NR	----	NR	----	----	----	----	----	----	0.55	----	----	----	----
5	NR	----	----	NR	----	----	----	NR	.93	NR	----	----	----	----	----	.26	----	----	----	----	----
6	NR	2.52	----	NR	----	----	----	NR	NR	NR	----	----	----	----	.25	2.43	----	----	----	----	----
7	NR	----	----	NR	0.06	----	----	NR	NR	NR	----	0.06	----	----	.30	.05	----	----	.10	----	----
8	NR	----	----	NR	----	----	----	NR	NR	NR	----	----	0.10	----	.50	----	----	----	----	.05	----
9	NR	----	----	NR	----	----	----	NR	NR	NR	----	----	.59	----	.15	----	----	0.05	----	.40	----
10	NR	----	----	NR	----	0.50	----	NR	NR	NR	----	----	----	----	----	----	----	----	.04	.05	----
11	NR	----	----	NR	.06	----	----	NR	NR	NR	----	.06	.58	----	----	----	----	----	.06	.75	----
12	NR	----	.07	NR	----	.31	----	NR	NR	NR	0.40	----	----	----	----	----	.05	.35	----	----	----
13	NR	----	----	NR	----	----	----	NR	NR	NR	.05	----	----	----	----	.02	----	.10	----	----	----
14	NR	----	----	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	.05	----	----	----	----
15	NR	----	----	NR	----	----	----	NR	NR	NR	.33	----	.06	----	.30	----	----	.40	----	.14	----
16	NR	----	----	NR	----	----	----	NR	NR	NR	----	----	.03	----	----	----	----	----	----	.05	----
17	----	----	----	NR	.19	----	----	----	NR	NR	----	.19	----	----	----	----	----	----	.25	----	----
18	0.12	----	----	NR	----	----	----	0.10	NR	NR	----	----	----	----	----	----	----	.07	----	----	----
19	.23	----	----	NR	----	----	----	.15	NR	NR	.13	----	----	----	.45	----	----	.09	----	----	----
20	----	----	----	NR	----	----	----	----	NR	NR	.18	----	----	----	----	----	----	.16	----	----	----
21	----	----	----	NR	----	----	----	----	NR	NR	----	----	----	----	----	.40	----	.02	.05	----	----
22	----	.24	----	NR	----	----	----	----	NR	NR	.10	----	----	----	----	.10	----	.10	----	----	----
23	----	----	----	NR	----	----	----	----	NR	NR	----	----	----	----	----	----	----	----	----	----	----
24	.65	.12	----	NR	----	----	----	----	NR	NR	.12	----	----	----	.55	.15	----	.10	----	----	----
25	.43	----	----	NR	----	.11	----	.88	NR	NR	----	----	----	----	.50	----	----	.04	----	.05	----
26	.28	----	----	NR	----	----	----	.21	NR	NR	----	----	.09	----	.15	----	----	----	----	.05	----
27	----	----	----	NR	----	----	----	----	NR	NR	----	----	----	----	----	----	----	----	----	----	----
28	----	----	----	NR	----	.10	----	----	NR	NR	----	----	----	----	----	----	.01	----	----	.80	----
29	----	----	----	NR	----	----	----	.03	NR	NR	----	----	1.03	----	----	.30	----	----	----	.35	----
30	.34	.95	----	NR	----	.63	----	.22	NR	NR	----	----	----	----	.50	.70	----	.05	----	----	----
31		----		NR	----		----		NR		----	----		----		----		----	----		----
TOTAL	----	4.24	0.35	----	0.31	1.65	----	----	----	----	1.32	0.31	2.48	----	4.40	4.76	0.66	1.53	0.54	2.74	----

Table 7.--*Daily rainfall values for stations on Walnut and Woman Creeks and at the Rocky Flats Plant, 1972-74*--Continued

Day	Apr.	May	June	July	Aug.	Sept.	Oct.	Apr.	May	June	July	Aug.	Sept.	Oct.	Apr.	May	June	July	Aug.	Sept.	Oct.
	[Units are in inches from midnight to midnight]														[Units are in inches from 8 a.m. to 8 a.m.]						
	WALNUT CREEK, 1974							WOMAN CREEK, 1974							ROCKY FLATS PLANT, 1974						
1	----	----	NR	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	0.01	----	0.10	----
2	0.19	----	NR	NR	NR	0.56	----	0.16	NR	NR	NR	----	0.48	----	0.44	0.01	0.05	----	----	.30	----
3	.23	----	NR	NR	NR	----	----	.17	NR	NR	NR	----	----	----	.08	----	----	----	----	----	----
4	.11	----	NR	NR	NR	----	----	.13	NR	NR	NR	----	----	----	----	----	----	----	----	----	----
5	----	----	NR	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	----	----	----	----
6	----	----	NR	NR	NR	----	----	NR	NR	NR	NR	----	----	----	----	----	.11	----	----	----	----
7	----	----	NR	NR	NR	----	----	NR	NR	NR	NR	----	----	----	----	----	.15	.02	0.04	----	----
8	.05	----	NR	NR	NR	----	----	NR	NR	NR	NR	----	----	----	----	----	1.69	----	----	----	----
9	----	----	NR	NR	0.17	----	----	NR	NR	NR	NR	0.12	----	----	----	----	----	----	.18	----	----
10	----	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	----	.02	----	----	----
11	----	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	----	----	----	.60	0.79
12	.11	----	NR	NR	----	.70	1.13	NR	NR	NR	----	----	.69	1.29	.05	----	----	----	----	.15	.22
13	.10	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	1.28	----	----	----	----	----	----
14	.15	----	NR	NR	----	----	.22	NR	NR	NR	----	----	----	.27	----	.07	----	----	----	----	.30
15	.03	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	----	.04	----	----	----
16	.05	----	NR	NR	----	----	----	NR	NR	NR	0.04	----	----	----	----	----	----	----	----	----	----
17	----	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	----	----	----	----	----
18	----	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	----	----	----	----	----
19	----	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	----	----	----	----	----
20	----	----	NR	NR	----	.08	----	NR	NR	NR	----	----	.06	----	----	----	----	----	----	.08	----
21	----	----	NR	NR	----	----	----	NR	NR	NR	.05	----	----	----	----	----	----	.05	----	----	----
22	----	----	NR	NR	----	----	.04	NR	NR	NR	.02	----	----	.07	----	----	----	.01	----	----	.07
23	----	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	----	----	----	----	----
24	----	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	.25	----	----	----	.02	----	----	.20
25	----	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	----	----	----	----	----
26	----	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	----	----	.01	----	----	----	----
27	----	----	NR	NR	----	.19	----	NR	NR	NR	----	----	.20	----	----	----	.03	----	----	.18	----
28	.27	----	NR	NR	----	----	----	NR	NR	NR	----	----	----	----	.50	----	----	.03	----	----	----
29	.72	----	NR	NR	----	----	.03	NR	NR	NR	.37	----	----	.14	.52	----	----	.27	----	----	----
30	----	----	NR	NR	----	----	.15	NR	NR	NR	----	----	----	.23	----	----	----	----	----	----	----
31		----		NR	----		----		NR		.05	----		----		----		.08	----		----
TOTAL	2.01	0.00	----	----	----	1.53	1.63	----	----	----	----	0.12	1.43	2.25	2.87	0.08	2.03	0.55	0.22	1.41	1.58

DAILY STREAMFLOW RECORDS

Table 8.--*Daily streamflow records for selected stations near the Rocky Flats Plant, 1972-75*

STATION NUMBER 06720690 WOMAN CREEK NEAR PLAINVIEW, CO. STREAM SOURCE AGENCY USGS
LATITUDE 395307 LONGITUDE 1051152 DRAINAGE AREA DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1									---	.08	.07	.05
2									---	.08	.06	.05
3									---	.07	.22	.05
4									---	.08	.08	.05
5									---	.06	.05	.05
6									---	.04	.18	.05
7									---	.05	.07	.05
8									---	.08	.07	.10
9									---	.07	.08	.10
10									---	.06	.18	.10
11									---	.03	.10	.20
12									---	.03	.30	.20
13									---	.08	.38	.20
14									---	.10	.33	.10
15									---	.18	.23	.10
16									---	.19	.20	.22
17									---	.22	.20	.25
18									---	.28	.20	.13
19									---	.25	.20	.06
20									---	.28	.20	.10
21									---	.28	.20	.04
22									---	.19	.06	.09
23									---	.10	.04	.09
24									---	.39	.05	.07
25									---	.49	.05	.09
26									---	.42	.05	.11
27									.22	.36	.05	.09
28									.16	.13	.05	.24
29									.19	.08	.05	.47
30									.19	.36	.05	.24
31									---	.13	.05	---
TOTAL										5.24	4.10	3.74
MEAN										.17	.13	.12
MAX										.49	.38	.47
MIN										.03	.04	.04
AC-FT										10	8.1	7.4

le 8.--*Daily streamflow records for selected st ons near the Rocky Flats Plant, 1972-75*--Continu

STATION NUMBER 06720690 WOMAN CREEK NEAR PLAINVIEW, CO. STREAM SOURCE AGENCY USGS
LATITUDE 395307 LONGITUDE 1051152 DRAINAGE AREA DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.10	.13	.24	.20	.48	.68	.19	.77	.56	.29	.24	.32
2	.08	.19	.19	.20	.41	.64	.24	.68	.38	.44	.35	.48
3	.10	.19	.24	.20	.32	.46	.68	.60	.32	.38	.32	.34
4	.10	.22	.26	.20	.32	.35	.73	.56	.32	.38	.29	.24
5	.08	.28	.26	.20	.32	.42	.82	.60	.32	.29	.24	.60
6	.06	.36	.19	.20	.26	.29	.60	2.0	.38	.29	.29	.24
7	.05	.32	.29	.20	.30	.29	.38	1.7	.41	.29	.29	.19
8	.05	.28	.52	.20	.30	.32	.35	1.4	2.5	.35	.38	.24
9	.06	.22	.41	.20	.40	.29	.32	1.4	.82	.48	.35	.24
10	.13	.19	.26	.20	.44	.38	.29	1.4	.44	.48	.39	.24
11	.13	.16	.29	.20	.67	.44	.29	1.0	.44	.44	.19	.38
12	.10	.20	.35	.20	.52	.32	.35	.73	.41	.48	.19	.64
13	.07	.20	.24	.20	.41	.29	.41	.60	.38	.48	.26	.35
14	.07	.20	.27	.20	.41	.26	.82	.52	.38	.35	.26	.35
15	.08	.20	.19	.50	.35	.26	3.0	.41	.48	.35	.40	.26
16	.08	.20	.22	1.2	.38	.29	3.8	.41	.41	.35	.29	.24
17	.08	.20	.38	1.4	.44	.22	2.6	.41	.44	.29	.29	.26
18	.08	.20	.29	2.0	.46	.26	1.4	.41	.38	.22	.24	.32
19	.10	.20	.24	1.4	.62	.38	.87	.73	.38	.19	.35	.32
20	.07	.26	.32	.87	.56	.32	.64	.60	.41	.19	.29	.32
21	.06	.24	.44	.73	.41	.29	.48	.64	.35	.19	.38	.32
22	.06	.17	.44	.68	.44	.24	.48	.68	.41	.22	.35	.26
23	.05	.17	.32	.50	.41	.24	.52	.64	.32	.22	.29	.24
24	.06	.19	.32	.50	.38	.29	.52	.64	.32	.15	.24	.24
25	.06	.17	.32	.50	.52	1.2	.52	.64	.26	.14	.24	.22
26	.07	.17	.29	.52	.52	.73	.48	.60	.26	.12	.24	.19
27	.07	.17	.20	.48	.50	.41	.38	.52	.24	.14	.29	.29
28	.07	.24	.24	.32	.59	.32	.41	.52	.24	.19	.32	.24
29	.13	.35	.20	.32	---	.22	2.9	.44	.14	.24	.35	.15
30	.28	.22	.20	.32	---	.24	1.4	.41	.17	.19	.35	.24
31	.16	---	.20	.41	---	.24	---	.44	---	.22	.29	---
TOTAL	2.74	6.49	8.82	15.45	12.14	11.53	26.87	23.10	13.27	9.03	9.24	8.96
MEAN	.088	.22	.28	.50	.43	.37	.90	.75	.44	.29	.30	.30
MAX	.28	.36	.52	2.0	.67	1.2	3.8	2.0	2.5	.48	.40	.64
MIN	.05	.13	.19	.20	.26	.22	.19	.41	.14	.12	.19	.15
AC-FT	5.4	13	17	31	24	23	53	46	26	18	18	18

WTR YR 1974 TOTAL 147.69 MEAN .40 MAX 3.8 MIN .05 AC-FT 293

Table 8.--*Daily streamflow records for selected stations near the Rocky Flats Plant, 1972-75*--Continued

STATION NUMBER 06720690 WOMAN CREEK NEAR PLAINVIEW, CO. STREAM SOURCE AGENCY USGS
LATITUDE 395307 LONGITUDE 1051152 DRAINAGE AREA DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.24											
2	.24											
3	.22											
4	.24											
5	.22											
6	.24											
7	.24											
8	.24											
9	.19											
10	.14											
11	.38											
12	.73											
13	.38											
14	.52											
15	.35											
16	.32											
17	.29											
18	.29											
19	.26											
20	.32											
21	.26											
22	.29											
23	.29											
24	.35											
25	.35											
26	.32											
27	.29											
28	.29											
29	.35											
30	.44											
31	.35											
TOTAL	9.63											
MEAN	.31											
MAX	.73											
MIN	.14											
AC-FT	19											

Table 8.--*Daily streamflow records for selected stations near the Rocky Flats Plant, 1972-75*--Continued

STATION NUMBER 06720700 WOMAN CREEK AT ROCKY FLATS PLANT, CO. STREAM SOURCE AGENCY USGS
LATITUDE 395308 LONGITUDE 1051105 DRAINAGE AREA 2.10 DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1										---	.02	.06
2										---	.09	.40
3										---	.06	.19
4										---	.04	.15
5										---	.06	.12
6										---	.03	.09
7										---	.01	.09
8										---	.01	.09
9										---	0	.09
10										---	.01	.06
11										---	.01	.05
12										---	.01	.28
13										---	0	.19
14										---	0	.23
15										---	.02	.98
16										---	.19	.19
17										---	.03	.12
18										---	.02	.09
19										---	.03	.09
20										---	.02	.23
21										---	.03	.19
22										---	.03	.09
23										---	.09	.04
24										---	.04	.03
25										---	.04	.03
26										0	.04	.15
27										.03	.04	.54
28										.03	.04	.12
29										.02	.04	.09
30										0	.04	.12
31										0	.04	---
TOTAL											1.13	5.20
MEAN											.037	.17
MAX											.19	.98
MIN											0	.03
AC-FT											2.2	10

le 8.--*Daily streamflow records for selected st ons near the Rocky Flats Plant, 1972-75*--Continu

STATION NUMBER 06720700 WOMAN CREEK AT ROCKY FLATS PLANT, CO. STREAM SOURCE AGENCY USGS
LATITUDE 395308 LONGITUDE 1051105 DRAINAGE AREA 2.10 DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.06	.47	.47	.50	.54	.54	1.5	47	.50			
2	.06	.61	.61	.50	.61	.54	1.9	60	.50			
3	.19	.69	.61	.50	.98	.88	3.4	42	.50			
4	.47	.69	.54	.50	1.2	.88	4.0	34	.50			
5	.23	.69	.50	.50	1.5	.88	9.8	37	.50			
6	.04	.69	.50	.50	1.3	.88	1.9	50	.50			
7	.03	.47	.50	.50	.88	1.1	1.5	30	.50			
8	.03	.69	.50	.50	.88	1.1	2.4	15	.50			
9	.09	.78	.50	.50	.88	1.6	3.4	10	.40			
10	.54	.40	.50	.50	.78	1.7	13	8.0	.40			
11	.23	.34	.50	.50	.98	1.2	9.8	4.0	.40			
12	.06	.40	.50	.60	1.7	.88	10	4.0	.40			
13	.03	.40	.50	.60	.98	.98	10	2.0	.30			
14	.03	.34	.50	.90	.78	.61	10	2.0	.30			
15	.02	.40	.50	.90	.78	.78	12	1.0	.30			
16	.02	.40	.50	.90	.98	.69	12	.50	.30			
17	.03	.40	.50	.98	1.1	.61	14	.50	.30			
18	.34	.47	.50	.78	.98	.54	16	.50	.30			
19	.09	.40	.50	.88	.88	1.2	25	.50	.30			
20	.09	.40	.50	.69	.78	2.3	31	.50	.30			
21	.19	.34	.40	.61	.88	1.6	20	.50	.30			
22	.19	.40	.40	.15	.88	.78	20	.50	.20			
23	.61	.40	.30	.19	.88	.78	21	.50	.20			
24	.54	.40	.30	.23	.69	.69	32	.50	.20			
25	.34	.34	.30	.50	.69	1.3	29	.50	.20			
26	.03	.40	.20	.60	.69	1.5	50	.50	.20			
27	.09	.40	.15	.54	.61	.88	31	.50	---			
28	.12	.54	.15	.47	.54	.88	36	.50	---			
29	.23	.61	.12	.98	---	1.2	41	3.0	---			
30	.28	.61	.23	.98	---	1.7	44	1.0	---			
31	.40	---	.30	.78	---	2.6	---	1.0	---			
TOTAL	5.70	14.57	13.08	18.76	25.35	33.80	516.6	357.50				
MEAN	.18	.49	.42	.61	.91	1.09	17.2	11.5				
MAX	.61	.78	.61	.98	1.7	2.6	50	60				
MIN	.02	.34	.12	.15	.54	.54	1.5	.50				
AC-FT	11	29	26	37	50	67	1020	709				

Table 8.--*Daily streamflow records for selected stations near the Rocky Flats Plant, 1972-75*--Continued

STATION NUMBER 06720780 WALNUT CREEK AT ROCKY FLATS PLANT, CO STREAM SOURCE AGENCY USGS
LATITUDE 395357 LONGITUDE 1051103 DRAINAGE AREA 1.09 DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1								---	.52		0	.15
2								---	.58		0	.15
3								---	.58		0	.15
4								---	.58		0	.15
5								---	.17		0	.15
6								---	2.0		0	.15
7								---	.58		0	.15
8								---	.21		0	.15
9								---	.08		0	.15
10								---	.08		0	.15
11								---	.05		0	.20
12								---	.05		0	.40
13								---	.03		0	.72
14								---	.03		0	.40
15								---	.01		0	.11
16								---	0		0	.03
17								---	.01		0	.01
18								---	.03		0	0
19								---	.01		.10	.05
20								---	0		.30	0
21								---	0		.15	0
22								.21	0		.15	0
23								.25	0		.15	0
24								.30	.01		1.5	0
25								.35	0		1.0	0
26								.35	0		.50	0
27								.40	0		.50	0
28								.30	0		.25	.98
29								.35	0		.15	.01
30								.40	0		.15	0
31								.46	---		.15	---
TOTAL									5.61	0	5.05	4.41
MEAN									.19	0	.16	.15
MAX									2.0	0	1.5	.98
MIN									0	0	0	0
AC-FT									11	0	10	8.7

Table 8.--*Daily streamflow records for selected stations near the Rocky Flats Plant, 1972-75*--Continued

STATION NUMBER 06720780 WALNUT CREEK AT ROCKY FLATS PLANT, CO STREAM SOURCE AGENCY USGS
LATITUDE 395357 LONGITUDE 1051103 DRAINAGE AREA 1.09 DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	0	.05	.11	.05	.30	.25	.87	7.8	.14	.01		0
2	0	.14	.11	.05	.30	.25	2.0	13	.05	.01		0
3	0	.14	.08	.05	.30	.65	3.2	9.5	.03	.01		0
4	0	.17	.11	.05	.30	.65	3.2	9.0	.14	.01		0
5	0	.11	.05	.05	.30	.79	2.0	8.3	.11	.01		0
6	0	.05	.05	.05	.30	.46	1.4	21	.05	.01		0
7	.01	.05	.05	.05	.30	.58	2.9	7.8	.05	.01		0
8	.03	.03	.05	.05	.20	.52	5.0	1.8	.03	.01		0
9	.05	.03	.05	.05	.20	.72	6.6	1.3	.03	.01		0
10	0	.03	.05	.05	.25	.72	6.6	.87	.01	.01		0
11	0	0	.05	.05	.30	.52	6.6	.65	.01	.01		.40
12	0	0	.05	.15	.30	.46	8.0	.52	.03	.01		.14
13	.03	0	.05	.30	.30	.52	3.9	.46	.05	.01		.01
14	0	0	.05	.30	.25	.17	1.5	.40	.05	.01		0
15	.05	0	.05	.30	.25	.30	2.4	.35	0	.01		0
16	0	0	.05	.30	.25	.30	2.2	.30	.01	.01		0
17	0	0	.05	.30	.25	.30	.95	.21	0	.01		0
18	0	0	.05	.30	.25	.30	1.3	.25	0	.01		0
19	0	0	.05	.30	.25	.95	.95	.25	.01	.01		0
20	0	0	.03	.30	.25	.87	4.2	.17	.01	.03		0
21	0	0	.01	.30	.25	.95	2.1	.40	.01	.21		0
22	0	0	.01	.30	.25	.58	1.7	.58	.01	.08		0
23	0	0	0	.30	.25	.35	4.1	.25	.01	.03		0
24	0	0	0	.30	.30	.30	6.0	.21	.01	.02		0
25	.01	0	0	.30	.30	.95	6.6	.30	.01	.03		0
26	.01	0	0	.30	.30	.87	7.6	.11	.01	0		0
27	0	.01	.05	.30	.30	.52	6.2	.03	.01	0		0
28	0	0	.05	.30	.30	.79	5.3	.01	.01	0		0
29	0	0	.05	.30	---	1.4	5.3	.14	.01	0		.25
30	.03	.11	.05	.30	---	1.9	6.2	1.8	.01	0		.30
31	.05	---	.05	.30	---	1.6	---	.35	---	0		---
TOTAL	.27	.92	1.46	6.40	7.65	20.49	116.87	88.11	.91	.59	0	1.10
MEAN	.009	.031	.047	.21	.27	.66	3.90	2.84	.030	.019	0	.037
MAX	.05	.17	.11	.30	.30	1.9	8.0	21	.14	.21	0	.40
MIN	0	0	0	.05	.20	.17	.87	.01	0	0	0	0
AC-FT	.5	1.8	2.9	13	15	41	232	175	1.8	1.2	0	2.2

WTR YR 1973 TOTAL 244.77 MEAN .67 MAX 21 MIN 0 AC-FT 486

Table 8.--*Daily streamflow records for selected stations near the Rocky Flats Plant, 1972-75*--Continued

STATION NUMBER 06720780 WALNUT CREEK AT ROCKY FLATS PLANT, CO STREAM SOURCE AGENCY USGS
LATITUDE 395357 LONGITUDE 1051103 DRAINAGE AREA 1.09 DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.92	.11	.26	.50	.84	1.1	2.2				---	
2	.21	0	.01	.50	.42	1.2	2.2				---	
3	0	0	.01	.50	.38	1.1	2.2				---	
4	0	0	.01	.50	.52	.87	1.9				---	
5	0	0	.01	.50	.33	.80	1.8				---	
6	0	.05	.01	.50	.19	.97	2.2				---	
7	0	.52	.01	.50	.35	.95	2.3				---	
8	0	0	.01	.50	.48	1.0	2.3				0	
9	0	0	.03	.50	.51	.96	2.3				0	
10	0	0	.68	.50	.52	1.2	2.3				0	
11	0	0	1.4	.50	.70	1.1	---				0	
12	0	0	.03	.50	.61	1.1	---				0	
13	0	0	.01	.50	.65	1.1	---				0	
14	0	0	.01	.55	.73	1.1	---				0	
15	0	0	.01	.66	1.2	1.2	---				0	
16	0	0	.01	1.3	.78	1.2	---				0	
17	.35	0	.01	1.9	.74	1.3	---				0	
18	.10	0	.01	2.1	.90	1.8	---				0	
19	0	0	.02	2.0	.75	1.9	---				0	
20	0	0	.09	1.6	.67	2.0	---				0	
21	0	.08	.24	1.2	.46	1.5	---				0	
22	0	.02	.58	.58	.72	1.5	---				0	
23	0	0	.67	.59	.70	1.5	---				0	
24	0	0	.44	1.0	.59	1.9	---				0	
25	0	0	.41	1.3	1.0	2.5	---				0	
26	0	0	.47	1.1	.89	2.2	---				0	
27	0	.01	.56	.88	1.1	2.2	---				0	
28	0	.01	.65	.90	1.0	2.2	---				0	
29	0	.01	.50	.81	---	2.2	---				0	
30	0	.33	.50	.81	---	2.2	---				0	
31	.40	---	.50	.81	---	2.5	---				0	---
TOTAL	1.98	1.14	8.16	26.59	18.73	46.35						0
MEAN	.064	.038	.26	.86	.67	1.50						0
MAX	.92	.52	1.4	2.1	1.2	2.5						0
MIN	0	0	.01	.50	.19	.80						0
AC-FT	3.9	2.3	16	53	37	92						0

CAL YR 1973 TOTAL 253.40 MEAN .69 MAX 21 MIN 0 AC-FT 503

Table 8.--*Daily streamflow records for selected stations near the Rocky Flats Plant, 1972-75*--Continued

STATION NUMBER 06720780 WALNUT CREEK AT ROCKY FLATS PLANT, CO STREAM SOURCE AGENCY USGS
LATITUDE 395357 LONGITUDE 1051103 DRAINAGE AREA 1.09 DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	0											
2	0											
3	0											
4	0											
5	0											
6	0											
7	0											
8	0											
9	0											
10	0											
11	0											
12	0											
13	0											
14	0											
15	0											
16	0											
17	0											
18	0											
19	0											
20	0											
21	0											
22	0											
23	0											
24	0											
25	0											
26	0											
27	0											
28	---											
29	---											
30	---											
31	---											
TOTAL												
MEAN												
MAX												
MIN												
AC-FT												

Table 8.--*Daily streamflow records for selected stations near the Rocky Flats Plant, 1972-75*--Continued

STATION NUMBER 06720770 SOUTH WALNUT CREEK AT ROCKY FLATS PLANT, CO STREAM SOURCE AGENCY USGS
LATITUDE 395414 LONGITUDE 1051103 DRAINAGE AREA DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1971 TO SEPTEMBER 1972
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1									---	.42	.10	1.0
2									---	.37	.10	.75
3									---	.42	.10	.28
4									---	.47	.10	.28
5									---	.28	.10	.37
6									---	.47	.10	.32
7									---	.47	.15	.16
8									---	.37	.15	.32
9									---	.24	.12	.42
10									---	.28	.16	.32
11									---	.47	.16	.58
12									---	.42	.16	.88
13									---	.37	.09	.20
14									---	.37	.12	.47
15									---	.37	.28	.58
16									---	.28	.58	.52
17									---	.24	.42	.20
18									---	.37	.24	.32
19									---	.37	.52	.47
20									---	.37	.42	.47
21									---	.42	.20	.63
22									---	.28	.28	.24
23									---	.20	.28	.07
24									---	.32	1.6	.04
25									---	.47	.58	.02
26									.28	.52	.42	.16
27									.37	.40	.32	.63
28									.37	.35	.28	.63
29									.42	.30	.37	.52
30									.42	.20	.32	.37
31									---	.15	.32	---
TOTAL										11.03	9.14	12.22
MEAN										.36	.29	.41
MAX										.52	1.6	1.0
MIN										.15	.09	.02
AC-FT										22	18	24

T[illegible]e 8.--*Daily streamflow records for selected sta*[illegible]*us near the Rocky Flats Plant, 1972-75*--Continu[illegible]

STATION NUMBER 067207[illegible]0 SOUTH WALNUT CREEK AT ROCKY FLATS PLANT, CO STREAM SOURCE AGENCY USGS
LATITUDE 395414 LONGITUDE 1051103 DRAINAGE AREA DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1972 TO SEPTEMBER 1973
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.20	.32	.25	.30	.35	.28	.28	1.6	.50	.12	.20	.28
2	.69	.47	.25	.30	.35	.37	1.4	1.3	.50	.16	.20	.16
3	.12	.75	.25	.30	.35	.47	2.2	.12	.50	.20	.20	.12
4	.09	.75	.25	.30	.35	.47	.88	.16	.50	.16	.20	.16
5	.07	.58	.25	.30	.32	.42	.69	.12	.50	.16	.20	.28
6	.04	.42	.25	.30	.37	.42	.75	40	.50	.20	.20	.16
7	.04	.37	.25	.30	.32	.42	.81	20	.50	.16	.20	.28
8	.04	.37	.25	.30	.32	.37	.81	10	.50	.12	.10	.28
9	.04	.37	.25	.30	.32	.32	1.1	5.0	.50	.12	.10	.20
10	.02	.32	.25	.32	.24	.32	1.4	4.0	.50	.20	.10	.30
11	.02	.28	.30	.32	.20	.24	1.6	3.0	.50	.20	.10	1.0
12	.01	.28	.30	.32	.32	.20	1.6	2.0	.50	.20	.10	.50
13	.01	.42	.30	.35	.28	.24	1.2	1.0	.50	.32	.10	.30
14	0	.42	.30	.35	.28	.20	1.2	.50	.50	.20	.10	.30
15	0	.42	.30	.35	.28	.20	1.0	.50	.50	.28	.05	.30
16	0	.42	.30	.35	.28	.20	.52	.50	.50	.58	.05	.30
17	0	.42	.30	.35	.28	.28	.52	.50	.50	.47	.05	.30
18	0	.32	.30	.35	.20	.63	.52	.50	.50	.37	.05	.30
19	.07	.16	.30	.35	.20	.58	1.4	.50	.50	.42	.05	.30
20	.16	.16	.30	.35	.32	.47	.69	.50	.40	.42	.05	.28
21	.52	.32	.30	.35	.32	.42	.52	.50	.40	.75	.05	.28
22	.28	.28	.30	.35	.32	.37	.31	.50	.24	.16	.10	.28
23	.20	.28	.30	.35	.28	.32	.42	.50	.24	.20	.10	.20
24	.58	.16	.30	.35	.24	.32	.42	.50	.16	.28	.07	.12
25	.88	.09	.30	.35	.16	.52	1.0	.50	.16	.32	.16	.04
26	.75	.25	.30	.35	.16	.28	.69	.50	.16	.24	.09	.04
27	.52	.25	.30	.35	.28	.28	.09	.50	.16	.32	.12	.20
28	.37	.25	.30	.35	.28	.37	.09	.50	.16	.24	.24	.60
29	.28	.25	.30	.35	---	.42	.09	.50	.16	.16	.28	1.0
30	.24	.25	.30	.35	---	.37	.20	.50	.20	.16	.24	.52
31	.28	---	.30	.35	---	.32	---	.50	---	.20	.28	---
TOTAL	6.52	10.40	8.80	10.31	7.97	11.09	24.40	97.30	11.94	8.09	4.13	9.38
MEAN	.21	.35	.28	.33	.28	.36	.81	3.14	.40	.26	.13	.31
MAX	.88	.75	.30	.35	.37	.63	2.2	40	.50	.75	.28	1.0
MIN	0	.09	.25	.30	.16	.20	.09	.12	.16	.12	.05	.04
AC-FT	13	21	17	20	16	22	48	193	24	16	8.2	19

WTR YR 1973 TOTAL 210.33 MEAN .58 MAX 40 MIN 0 AC-FT 417

T e 8.--*Daily streamflow records for selected sta ns near the Rocky Flats Plant, 1972-75*--Continue

STATION NUMBER 06720790 SOUTH WALNUT CREEK AT ROCKY FLATS PLANT, CO STREAM SOURCE AGENCY USGS
LATITUDE 395414 LONGITUDE 1051103 DRAINAGE AREA DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	1.0	.52	.52	.10	.29	.20	.53	.47	.06	.01	.01	.01
2	.20	.64	.02	.10	.14	.20	.19	.37	.06	.01	.02	.14
3	.20	.48	.04	.10	.03	.20	1.0	.10	.02	.06	.01	.06
4	.20	.54	.37	.10	.28	.20	.17	.09	.24	.02	.01	.08
5	.20	.02	.58	.10	.17	.20	.56	.44	.21	.01	.03	.01
6	.10	.35	.02	.10	.29	.20	.10	.06	.13	.01	.01	.01
7	.10	.45	.44	.10	.30	.20	.10	.36	.44	.03	.01	.02
8	.10	.01	.44	.10	.35	.20	.50	.10	2.4	.01	.05	.06
9	.20	.01	.02	.10	.30	.20	.33	.28	1.0	.01	.04	.01
10	.05	.01	.02	.10	.22	.20	.79	.12	.10	.01	.01	.01
11	.40	.01	.07	.10	.24	.20	.10	.06	.01	.01	.04	.03
12	.50	.01	.71	.10	.16	.20	.37	.13	.01	.02	.10	.13
13	.05	.01	.05	.10	.32	.20	.31	.32	.01	.01	.07	.08
14	.05	.01	.16	.42	.19	.20	.83	.04	.01	.01	.05	.01
15	.05	.01	.92	.51	.20	.20	1.1	.23	.01	.02	.02	.05
16	.04	.01	.07	.60	.20	.20	.63	.03	.01	.01	.03	.05
17	.50	.01	.02	.37	.20	.20	.49	.33	.01	.02	.01	.03
18	.32	.01	.39	1.7	.20	.20	.24	.03	.01	.01	.03	.03
19	.57	.01	.43	.59	.20	.20	.41	.03	.01	.05	.06	.01
20	.81	.01	.63	.16	.20	.20	.17	.30	.01	.01	.02	.02
21	.09	.50	.74	.33	.20	.50	.16	.02	.01	.01	.04	.02
22	.07	.50	.36	.39	.20	2.0	.43	.26	.01	.20	.02	.01
23	.46	.01	.06	.34	.20	.50	.33	.06	.01	.01	.04	.01
24	.24	.01	.23	.56	.20	.20	.38	.31	.01	.02	.01	.03
25	.09	.01	.35	.60	.20	.20	.18	.04	.01	.01	.01	.04
26	.68	.50	.21	.43	.20	.20	.44	.03	.01	.03	.05	.01
27	.57	.01	.33	.22	.20	.58	.11	.02	.01	.01	.08	.03
28	.04	.01	.30	.26	.20	.10	.10	.02	.01	.01	.05	.03
29	.02	.01	.46	.12	---	.69	1.0	.20	.01	.02	.12	.01
30	.35	.50	.11	.55	---	.10	.61	.03	.01	.01	.06	.03
31	.05	---	.10	.29	---	.14	---	.01	---	.02	.01	---
TOTAL	8.30	5.19	9.17	9.74	6.08	9.21	12.66	4.89	4.86	.70	1.12	1.07
MEAN	.27	.17	.30	.31	.22	.30	.42	.16	.16	.023	.036	.036
MAX	1.0	.64	.92	1.7	.35	2.0	1.1	.47	2.4	.20	.12	.14
MIN	.02	.01	.02	.10	.03	.10	.10	.01	.01	.01	.01	.01
AC-FT	16	10	18	19	12	18	25	9.7	9.6	1.4	2.2	2.1

CAL YR 1973 TOTAL 207.27 MEAN .57 MAX 40 MIN .01 AC-FT 411
WTR YR 1974 TOTAL 72.99 MEAN .20 MAX 2.4 MIN .01 AC-FT 145

e 8.--*Daily streamflow records for selected st ons near the Rocky Flats Plant, 1972-75*--Continu

STATION NUMBER 06720770 SOUTH WALNUT CREEK AT ROCKY FLATS PLANT, CO STREAM SOURCE AGENCY USGS
LATITUDE 395414 LONGITUDE 1051103 DRAINAGE AREA DATUM STATE 08 COUNTY 059

DISCHARGE, IN CUBIC FEET PER SECOND, WATER YEAR OCTOBER 1974 TO SEPTEMBER 1975
MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	.36											
2	.06											
3	.36											
4	.06											
5	.01											
6	.35											
7	.09											
8	.47											
9	.61											
10	.17											
11	.26											
12	.57											
13	.19											
14	.34											
15	.19											
16	.08											
17	.20											
18	.06											
19	.01											
20	.13											
21	.10											
22	.19											
23	.05											
24	.15											
25	.06											
26	.01											
27	.10											
28	.06											
29	.16											
30	.17											
31	.18											
TOTAL	5.80											
MEAN	.19											
MAX	.61											
MIN	.01											
AC-FT	12											